Low Carbon Strategies for Inclusive Growth

An Interim Report

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सत्यमेव जयते

Planning Commission
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Preface

On a per-capita basis, India is one of the lowest Greenhouse Gas (GHG) emitters in the world. Its emission of 1.18 tonnes of CO_2 equivalent per capita in 2008 was nearly one-fourth of the corresponding global average of 4.38 tonnes. However, India is highly vulnerable to climate change, and has a strong interest in having a fair and equitable global agreement for minimizing the risk of climate change. Although India has not created the problem of climate change, which is largely due to the historical emissions of the developed countries, India stands ready to be a part of the solution. India has already announced that it will reduce the emissions intensity of its GDP by 20-25 percent over the 2005 levels by the year 2020, through pursuit of proactive policies. India's Twelfth Five Year Plan, to be launched on 1st April, 2012 will have, as one of its key pillars, a low carbon inclusive growth. This Expert Group has been set up to develop a strategy for the same.

The TOR of the group and the list of its members are given as Annexure to this report. The group was required to give an interim report as soon as possible. Given the short time period it was decided that the interim report will provide a menu of options to reduce GHG emission intensity in critical sectors of the Indian economy. We set up a number of working groups to report on different sectors of the economy. The sectoral reports had to be made consistent to avoid double counting which did take some time.

This interim report provides a menu of options that can reduce India's emission intensity over the time frame. Some policy measures implied by various options have also been indicated. The main sectors examined in this report are power, transport, industry, buildings and forestry.

In the power sector, reducing electricity demand by use of more efficient appliances, introduction of more fuel efficient power plants and changes in the mix of power plants are considered. In the transport sector, promoting goods transport by railways, mass transport for passenger movement, facilitating non-motorized transport and increasing fuel efficiency of vehicles are explored. Among industries, the possibilities of reducing emissions through change in technology in the steel, cement, oil and gas sectors are considered. The scope for reducing energy needs of commercial buildings is assessed. In the forestry sector, the Green India Mission is briefly outlined.

The options considered suggest that, with Determined Efforts, we can bring down emission intensity of India's GDP by 23 to 25 percent over the 2005 levels, and with Aggressive Efforts, we can bring it down by as much as 33 to 35 percent over the 2005 levels.

I would, however, like to emphasize that we have not yet worked out the costs associated with these measures, nor the feedback effect these measures would have in a macro-framework. In the next report, we will examine these effects, suggest a set of options to meet these targets and also provide an estimate of the associated costs.

We also intend to identify barriers, if any, to the adoption of these measures and the policies needed to overcome them. Our emphasis would be on measures that create incentives to self-motivate the economic agents to adopt a low carbon growth path. The concern for inclusive growth is embedded in the scenarios at this stage. It will become more explicit when the policies are articulated

I would like to thank my colleagues on the Expert Group for their contribution, and their patience in responding to my queries and carrying out the needed revisions several times. I would particularly like to acknowledge the contributions of Arunish Chawla and Varad Pande for their help in putting together the different chapters and in drafting the report.

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1 Climate Change: Background and Approach

The threat of climate change is a serious global concern. There is near consensus among scientists that the threat is due to man- made emissions of Greenhouse Gases and probabilities of different degrees of temperature change have already been estimated by the Inter-governmental Panel for Climate Change (IPCC).

1.1 Background

Increase in anthropogenic activities since the advent of industrialisation in the mid-18th century has led to cumulative accumulation of Greenhouse Gases (GHGs) in the earth's atmosphere (IPCC, AR4, 2007; see Box 1.1). Increased concentrations of GHGs and the overall warming of the atmosphere has resulted in changing rainfall patterns, disruption in hydrological cycles, melting of ice caps and glaciers, rise in sea levels, and increase in frequency and intensity of extreme events such as heavy precipitation and cyclonic activities. These have in turn had serious impact on sustainability of water resources, agriculture, forests and ecosystems, affecting the well being of billions of people on earth.

BOX 1.1: Greenhouse Gases, Radiative Forcing and Global Warming

Greenhouse Gases are gases in the atmosphere that absorb and emit radiation within the thermal infrared range. This process is the fundamental cause of the greenhouse effect. Greenhouse Gases greatly affect the temperature of the Earth; without them, the Earth's surface would be about 33°C (59 °F) colder than at present. The natural greenhouse gases in the Earth's atmosphere are water vapor, carbon dioxide, methane, nitrous oxide and ozone. Some amounts of GHGs are absorbed by the natural systems such as oceans and plant biomass, which are also referred to as sinks of GHGs. However, when plants are cut down and allowed to decay or are burnt; the GHGs absorbed by them from the atmosphere are released back into the atmosphere. The build up of GHGs in the atmosphere is therefore the net emission from sources and removal by sinks. Since the time of Industrial revolution in the mid-18th century large scale burning of fossil fuels, land use change and forestry activities have considerably enhanced the concentration of greenhouses gases in the atmosphere, for example, the concentration of carbon dioxide had gone up from 275 to 285 ppm in the pre-industrial era (AD 1000–1750) to 379 ppm in 2005. Additionally synthetic greenhouse gases like CFCs, HCFCs and SF6 are also accumulating in the atmosphere.

Table 1.1 shows the increase in main GHGs in the atmosphere from 1750 till 2005. It also indicates radiative forcing, i.e., the amount of energy reflected back by the particular GHG per square metre of upper atmosphere. Though the concentration of CO_2 is 220 times that of Methane, the radiative forcing of CO_2 is only three times as much as a molecule of the same.

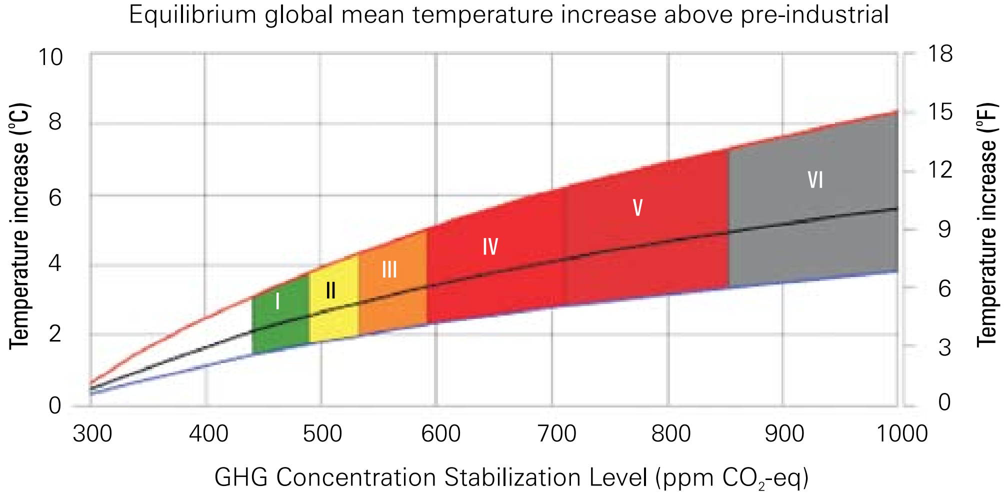
Table 1.1: GHG Concentration in Atmosphere (1750-2005)

Gas	Pre-industrial Level	Current Level	Increase Since 1750	Radiative Forcing (W/m^2)
Carbon Dioxide	280 ppm	379±0.65 ppm	38.2%	1.66
Methane	700 ppb	1774±1.8 ppb	149.3%	0.48
Nitrous Oxide	270 ppb	319±0.12ppb	16.3%	0.16
CFC-12	0	538±0.18 ppt	–	0.17

Source: IPCC, AR4 (Table 2.1, AR4, Working Group1)

The 2007 Fourth Assessment Report compiled by the IPCC (AR4) noted that "changes in atmospheric concentrations of greenhouse gases and aerosols, land cover and solar radiation alter the energy balance of the climate system" and concluded that "most of the observed increase in globally averaged temperatures since the mid-20th century are very likely (greater than 90 percent probability) due to observed increase in anthropogenic greenhouse gas concentrations". IPCC projections (Fig.1.1) indicate the likely temperature increase with corresponding levels of stabilisation of GHGs. If emissions continue to rise at their current pace and are allowed to double from their pre-industrial level, the world will face an average temperature rise of around 3°C this century. Serious impact is associated with this scenario, including rise in sea-levels, shifts in growing seasons, and an increasing frequency and intensity of extreme weather events such as storms, floods and droughts.

Figure 1.1: Global Temperature Rise – Effect of Increase in GHG Concentration



Source: IPCC AR4, (Working Group III: Mitigation of Climate Change)

The first step, to limit temperature rise to 2 degrees celsius, would therefore be to reduce the level of GHG emissions. This would require collective and cooperative global action. No country can solve the problem by itself. It would be of no use for one country to reduce GHG emissions and another to increase it by the same amount.

According to the IEA, by 2030, in the Reference Scenario, which assumes no change in government policies, world primary energy demand is expected to be 40 percent higher than in 2007 (WEO, 2009). The capital required to meet projected energy demand through to 2030 is huge, amounting to a cumulative $26 trillion (in 2008 prices) — equal to $1.1 trillion (or 1.4 percent of global GDP) per year on an average basis. Over half of the entire energy investment worldwide is needed in non-OECD countries, where demand and production are projected to increase the fastest. If these investments are not directed into climate-friendly technologies, by 2050 emissions will go up by 50 percent over the current level. Bringing down the level of emissions by 50 percent is considered desirable, if we are to restrict global warming to 2 degrees celsius.

A shared vision for a climate-resilient and low-emission future can be built upon a long-term global goal for emission reductions. It should factor in people's aspirations for development, and yet provide a yardstick for concrete and measurable action. Scientific information from the IPCC suggests that to avoid the most catastrophic impacts of climate change, greenhouse gas emissions need to reduce to 50-80 percent below 1990 levels by 2050.

Some of the impacts of climate change highlighted by the IPCC include:

- By 2020, in some parts of Africa, yields from rain-fed agriculture (the dominant method) could reduce by up to 50 percent;
- Approximately 20-30 percent of plant and animal species are likely to be at increased risk of extinction, if increase in global average temperature exceeds 1.5-2.5°C;
- Widespread melting of glaciers and snow cover will reduce melt water from major mountain ranges (e.g. Hindu Kush, Himalaya, Andes) where more than one billion people currently live;
- More than 20 million people were displaced by sudden climate-related disasters in 2008 alone. An estimated 200 million people could be displaced as a result of climate impacts by 2050.

Impacts of climate change disproportionately affect the poor, those who do not have the means to deal with them. Thus, a strong adaptation and mitigation framework is required, and substantial resources in terms of finance, technology and capacity building will be needed to implement it.

1.2 A Brief History of Global Action

Recognition and beginnings of a concerted global response to the deterioration of the environment and its implications can be traced to the United Nations Conference on Human Development held in Stockholm in 1972, where India's Prime Minister Indira Gandhi, was the only attending Head of State apart from the host Prime Minister Olof Palme of Sweden. Concern on climate change increased through the 1980s, and an Intergovernmental Panel on Climate Change (IPCC) was established by the World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) as a scientific intergovernmental body to provide an assessment of the latest scientific research and its policy implications for mitigation and adaptation.

The 1990s witnessed the growing consolidation of the global response at the international level. At the Rio Summit in 1992, the United Nations Framework Convention on Climate Change (UNFCCC) was adopted. The UNFCCC is the primary vehicle of Global Cooperation and Action for Climate Change with the objective of stabilising Greenhouse Gas (GHG) concentration at a level that would prevent dangerous anthropogenic interference with the climate system. The UNFCCC places the primary responsibility of mitigation on industrialised countries. It recognises that the economic and social development and poverty eradication are the first and overriding priorities of the developing countries and that in the course of meeting the developmental needs, GHG emissions of developing countries are bound to rise. Any mitigation action by the developing countries is to be taken in the context of sustainable development and had to be consistent with national priorities. The Convention entered into force on March 21st, 1994 after receiving the requisite number of ratifications.

The first Conference of Parties (COP) to the Convention (UNFCCC), which was held in April 1995, adopted the Berlin Mandate which led to the formulation of Kyoto Protocol in 1997. As per the Kyoto Protocol, industrialised countries (US has not ratified the Kyoto Protocol) have to undertake quantified emission reductions over specified commitment periods. As per the principle of 'common but differentiated responsibilities and respective capabilities' of the UNFCCC, industrialised countries listed in "Annex I" of the Protocol have binding commitments to reduce their emissions. Annex I Parties committed themselves to reducing their overall emissions of six greenhouse gases by at least 5.2 percent below 1990 levels in the period between 2008 and 2012, with specific targets varying from country to country. The Protocol also provided the basis for three mechanisms to assist Annex I Parties in meeting their national targets cost-effectively – an emissions trading system, Joint Implementation (JI) of emissions-reduction projects between Annex I Parties, and a Clean Development Mechanism (CDM) to encourage joint projects between Annex I and Non-Annex I (developing country) Parties.

Since progress towards meeting the objectives of the UNFCCC was not satisfactory and the evidence on climate change became the subject matter of intense debate following the publication of the 4th Report (2007) of IPCC, the Parties adopted, at the 13th Conference of Parties (CoP 13) in Bali, an Action Plan to enhance the implementation of the UNFCCC. The Bali Action Plan (BAP) seeks to ensure full, effective and sustained implementation of the UNFCCC through long-term cooperative action of the Parties, up to and beyond 2012. It is a comprehensive document to address the four major building blocks of climate change, i.e. GHG mitigation; adaptation to climate change impacts; technology development and cooperation;

and finance, on the basis of the principles of the UNFCCC. The BAP also called for articulating a "shared vision for long-term cooperative action," including a long-term global goal for emission reductions. As per the BAP, developed countries have to take nationally appropriate mitigation actions in form of commitments to reduce emissions, while the developing countries have to take mitigation actions supported and enabled by finance and technology provided by developed countries.

Parties were expected to reach an agreement on issues under negotiations as per the BAP at the CoP 15, held at Copenhagen in December 2009. However, negotiations could not be concluded and no agreed outcomes could be reached because of continuing differences amongst parties over several contentious issues. The two "Ad-hoc Working Groups" (AWGs) were given an extended period of one more year with a mandate to reach an agreement at CoP 16 to be held at Cancun (Mexico) from November 29 to December 10, 2010.

The Copenhagen conference did lead to the emergence of the "Copenhagen Accord" on climate change, negotiated by a group of countries. The Accord, which could not achieve consensus, was noted by the COP, and later supported by several countries under specific conditions. The Accord reflects a broad political consensus on some of the issues that are relevant to negotiations:

There is an agreement on the broad scientific view that the world must not exceed a 2 degrees celsius increase in warming on the basis of equity, and in the context of sustainable development.

All participating countries have agreed to communicate their mitigation commitments and actions. Developed countries (Annex I parties) have agreed to report measured, reported and verified (MRV) mitigation actions as per COP guidelines. Developing countries (Non-Annex I Parties) have agreed to communicate information on the implementation of their mitigation actions through national communications, with provisions for international consultations and analysis under clearly defined guidelines that will ensure that national sovereignty is respected.

- For the first time, the participants in the discussions on Accord have agreed to establish mechanisms for forestry (REDD plus), financing and technology in order to enable the flow of resources.

- Developed countries have committed to jointly mobilising short-term finance of USD 30 billion from 2010 – 2012. The Accord agrees to a goal for the world to raise USD 100 billion annually by 2020 to address the mitigation needs of developing countries. A significant part of the fund will flow through a "Copenhagen Green Climate Fund". A High Level Panel has also been established to study the contribution of the potential sources of revenue towards meeting this ambitious funding goal.
- There is also a provision for a review of the implementation of the Accord by 2015 in order to assess whether the long-term stabilisation goal needs to be revised from 2 degrees to 1.5 degrees.

There are many areas under multilateral negotiations. These include, for example the level of Annex I parties' ambition and emission reduction commitments, establishment of financial mechanism, issue of prohibiting trade actions on the ground of competitiveness etc. that are not fully covered by the Accord. While these will remain a subject matter for further discussions, India has now agreed to list itself in the Chapeau of Accord with some conditions. India has clarified that, in its understanding the Accord is a political document; it is not legally binding. The Accord is meant to facilitate the ongoing negotiations in the two tracks in accordance with the principles and provisions of the UNFCCC, the Kyoto Protocol and the Bali Action Plan. The Accord could have value if the areas of convergence reflected in the Accord are used to help the Parties reach agreed outcomes under the UN multilateral negotiations in the two tracks, i.e., the Ad-hoc Working Group on Long Term Cooperative Action and the Ad-hoc Working -Group on Kyoto Protocol. The Accord is only an input into the two-track negotiations and is not a new track of negotiations or a template for outcomes.

The developed countries account for two-third of energy consumption and a similar level of CO_2 emissions. The energy consumption of developing countries is estimated to rise by 4 to 5 percent over the next 20 years, and emissions would also increase to sustain such a growth in energy consumption. China has seen rapid growth over the last 15 years, and its CO_2 emissions have also grown significantly.

CO_2 emissions for India are also growing due to accelerated pace of growth and energy consumption. However, the per capita energy consumption and emission in India are still in the mid range for the least developed countries (LDCs). The per capita energy consumption and emission parameters for some of the major energy consuming nations are given in Table 1.2.

1.3 Carbon Footprint of Countries

The GHG emissions of a country depend on many things -- its level of income, life style, need for heating or cooling, population, level of economic activity, trade patterns, urbanisation, population density, size of the country, transport infrastructure, its natural resources, etc. Thus, not only the total emissions, but also per capita emissions vary widely across countries. So do the emission intensities of economic activities as measured in tonnes of carbon dioxide emitted per dollar worth of Gross Domestic Product (GDP).

Table 1.2: 2008 Emissions Data for Selected Countries

Region / Country	Population (million)	GDP (billion 2000 US$)	GDP ppp (billion 2000 US$)	Energy Cons. (MTOE)	CO_2 Emissions MT CO_2	Per-capita Energy Cons. (kgOE)	Energy Intensity KgOE/ $GDPppp	Kg CO_2/ $GDP ppp	Per-capita Electricity Cons. (kwh)	Per-Capita CO_2 Emission (tonnes)
World	6609	39493	61428	12029	28962	1.82	0.20	0.47	2752	4.38
China	1327	2623	10156	1970	6071	1.48	0.19	0.60	2346	4.58
Brazil	192	808.95	1561	235.56	347	1.23	0.15	0.22	2154	1.80
India	1123	771	4025	421	1146	0.53	0.10	0.28	543	1.18
Japan	128	5205	3620	513.5	1236	4.02	0.14	0.34	8475	9.68
S. Africa	48	178	517	134.3	346	2.82	0.26	0.67	5013	7.27
Thailand	64	173	548	104	226	1.63	0.19	0.41	2157	3.54
Turkey	74	372	821	100	265	1.35	0.12	0.32	2210	3.59
UK	61	1766	1833	211	523	3.48	0.12	0.29	6142	8.60
USA	302	11468	11468	2340	5769	7.75	0.20	0.50	13616	19.10
France	64	1506	1738	264	369	4.15	0.15	0.21	7573	5.81
Germany	82	2065	2315	331	798	4.03	0.14	0.34	7185	9.71
Russia	141.79	429.55	1651.17	786	1593.83	5.54	0.48	0.97	6443	11.24

Source: International Energy Agency 2009

It is seen that India's CO_2 emissions are less than one fifth that of USA and China. In per capita terms India emits 1.18 tonnes of CO_2, China emits four time as much and US 16 times as much. Our emission intensity is 0.28 kg of CO_2/$ of GDP in Purchasing Power Parity (PPP) terms, China's is more than twice as high, and USA's is higher than the world average and 1.8 times of India. In fact, developed countries account for two-third of global energy consumption and similar levels of CO_2 emissions. On the other hand, per capita energy consumption and emissions for India are amongst the lowest in the world.

Since GHGs are estimated to stay in the atmosphere for 100 years or so, a country's responsibility is related to its emissions over a long period of time. Table 1.3 shows GHG emissions of various countries since 1850 when the pace of industrial revolution accelerated, and then again from 1990 when preparations for the Rio conference began and all countries became aware of the threat of climate change.

Table 1.3: Energy-related Cumulative CO_2 Emissions

Country / Region	MT CO_2	MT CO_2	Percent	Percent
	1990 - 2006	1850 - 2006	1990 - 2006	1850 - 2006
World	400834	1150702	100.0	100.0
India	15977	27433	4.0	2.4
China	61360	99204	15.3	8.6
Brazil	4925	9457	1.2	0.8
USA	92641	333747	23.1	29.0
Europe15	55377	252148	13.8	21.9
Annex I	237534	856115	59.3	74.4
Non-Annex I	157582	281497	39.3	24.5

Source: WAI, CAIT Database Accessed on May 4, 2010.

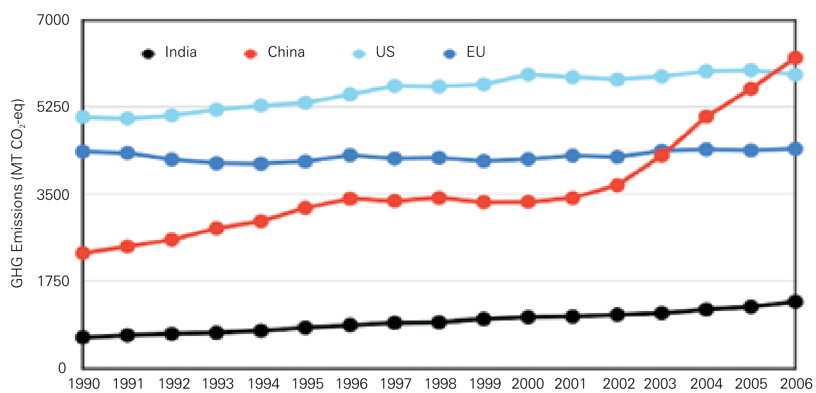
It is seen that India's contribution since 1850 to global emissions was only 2.4 percent while that of USA was 29 percent. Annex I (developed) countries account for nearly 75 percent and Non-Annex I (developing) countries around 25 percent of cumulative global emissions. List of Annex I countries is given in the Box below. When looking at cumulative emissions since 1990, the share of Non-Annex I countries is nearly 40 percent, as emissions of Non-Annex 1 countries have grown faster than emissions of Annex I countries over this period. However, India's share of emissions since 1990 has only been 4 percent, while China's has been 15 percent and USA's 23 percent.

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.

Total energy-related CO_2 emissions at the global level increased from 22.0 $BtCO_2$ in 1990 to 29.9 $BtCO_2$ in 2007, and that of USA increased from 4.8 $BtCO_2$ to 6.1 $BtCO_2$, an increase almost as much as India's total emissions of 1.5 $BtCO_2$ in 2007. While total emissions of most countries have grown, the intensities have been gradually declining. Figure 1.2 shows how emissions for selected countries have changed since 1990's. The only country that showed significant reduction was Germany. Emissions of USA have grown despite the UNFCCC and Kyoto protocol[1]. The most dramatic increase is shown by China which tripled its emissions over these years and now emits more than USA.

Figure 1.2:Growth of Total CO_2 Emissions of Select Countries



1.4 India's Energy Needs for Inclusive Growth

India needs to sustain an economic growth of 9 percent over the next 20 years to eradicate poverty and meet its human development goals. Meeting the energy requirements for growth of this magnitude in a sustainable manner presents a major challenge.

In December 2008, Government of India approved an Integrated Energy Policy

[1] *US has refused to ratify the Kyoto Protocol.*

(IEP) for the country. The IEP estimates that the 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 9 percent through 2031-32 with primary energy supply growth of around 5.8 percent per year. Commercial energy supply would need to grow faster at about 6.8 percent per annum as it will incrementally replace non-commercial energy over this period.

Table 1.4 indicates the range of projected future energy requirement scenarios under 11 alternative policy regimes, implying different degrees of energy intensity. An important aspect of India's energy future is that even with the most optimistic assumptions the country will be heavily dependent on imported energy at the end of this period. Dependence on imported oil will be over 90 percent (by the year 2030-31) and dependence on imported coal is also likely to increase significantly.

Table 1.4: Range of Commercial Energy Requirement
(Estimates for 9 percent Growth by 2031-32)

Fuel	Energy use in 2003-04	Range of Requirement in Scenarios	Assumed Domestic Production	Range for Imports#	Import (Percent)#
		(R)	(P)	(I)	(I/R)
Oil (Mt)	119	397-555	35	362-520	91-94
Natural Gas (Mtoe)	29	125-235	100	25-135	20-57
Coal (Mtoe)#	167	860-1296	560	300-736	35-57
TCPES (Mtoe)*	329	1667-2077	-	972-1382	58-67

Source: Integrated Energy Policy

*# Mtoe- Million tones of oil equivalent. 1 toe equals 2.5 tonnes of coal or 900 cubic metres of natural gas / coal bed methane (CBM). * TCPES – Total Commercial Primary Energy supply including hydro, nuclear and renewables*

If 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 that all have access to clean cooking fuels such as natural gas or LPG. In other words, a secular shift from traditional biomass (which is mostly carbon neutral) to modern commercial energy has to be consciously built into our strategy. Towards this end, the IEP scenarios project 100 percent electrification of all households by 2020. It also estimates the cooking fuel requirement of LPG for 1.5 billion persons at around 55 Mtoe by 2020.

Increasing energy use efficiency, ensuring a competitive energy sector, expanding domestic resource base, acquiring energy assets abroad, developing alternate fuels, laying pipelines for importing gas, building LNG terminals, improving and augmenting port facilities, building strategic reservoirs for crude storage, enhanced diplomacy for continuance of energy import for bridging the gap between demand and indigenous supply, are some of the measures necessary for energy security in the country. Our compulsions require we develop the available options and in particular, the low carbon ones.

1.5 India's Actions on Climate Change

India is determined to see that her 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 towards energy consumption and places a self-imposed restraint. It is a voluntary commitment made by India towards the international community.

In December 2009, India announced that it would aim to reduce the emissions intensity of its GDP by 20-25 percent from 2005 levels by 2020. This is a further articulation of India's voluntary domestic commitment, even though it does not see itself a part of any internationally legally binding agreement on emission intensity targets and emission reduction outcomes. This announcement shows India's resolve to ensure that its growth process is sustainable and based on low carbon principles. This goal will require necessary sector specific actions to reduce emissions intensities over India's 12^{th}, 13^{th} and 14^{th} Five Year Plan periods. This is what the present Expert Group is helping develop.

1.6 Conceptualising Low Carbon Inclusive Growth

India's approach to low-carbon inclusive growth recognises that policies for climate change mitigation differentially affect the objectives of development. These objectives include poverty alleviation, improvement in quality of life, distributional justice, job creation, competitiveness, industrial growth and improving the quality of local environment. Improvement in quality of life goes beyond simple poverty alleviation.

Low-carbon policies that are inclusive need to be differentiated across sectors based on national priorities and transaction costs of implementing the policy. In sectors such as land, water and forests; livelihood considerations such as income generation and poverty alleviation must dominate our policy choice, even if it requires overriding carbon emission concerns. Who bears the burden and whether it is equitably distributed, need to be examined and considered explicitly during the formulation and implementation of low-carbon strategies.

This requires two sets of actions. The first is the need to quantify the extent of additional burden imposed on, and the benefits that accrue to different consumers and sectors of the economy. This will allow for rational policy choices. The second is the need to embed in the policy an effective internal burden-sharing mechanism, to make the burden and benefits more equitable. For example, due to affordability constraints large groups of consumers like agriculture workers, poor households, small commercial establishments etc. may not be able to bear the costs, and additional burden may have to be imposed on the affording consumer class. Differentiated responsibilities should be clearly stated before a policy choice is made.

Burden-sharing issues are also important with regard to the debate on comparability of effort in multilateral fora – given that there needs to be equitable burden-sharing of the mitigation effort across countries, and not only within the countries. Approaching low carbon growth to meet multiple objectives of inclusive growth is a complex task. It highlights the importance of credible information to support such analysis, as well as the need to internalise multiple objectives into policy making at all levels.

A low carbon strategy for inclusive growth should suggest options that meet the objective of inclusive growth in low carbon ways. Many low-carbon options have attractive payback period for individuals and firms; yet these are not adopted for a variety of reasons. The low carbon strategy should identify the barriers to adoption of these options, as also the policy measures that will help overcome them.

1.7 Approach of the Expert Group

Given the wide range of expertise available among the members of the group, working groups were set up to evaluate low-carbon options in different areas and sectors. Given the limited time available for the interim report, we decided that a menu of these options identified by the working groups, vetted for some measure of consistency, will constitute the interim report.

Through its interim report, the group intends to get feedback from public by means of the internet and public hearings at selected places in the country. Subsequently, these options will be analysed for macro-economic consistency to define a country wide strategy for low carbon inclusive growth. This will be followed by design of policies for implementation.

The present interim report is organised as follows: Chapters 2 looks at the structure of India's emissions to identify the sectors and areas that need attention and offer scope for reduction in emission intensity. Chapter 3 summarises the low carbon options identified in the power, transport, industry, building and forestry sectors.

2 India's Emission Structure

In order to explore strategic options for reducing emission intensity of the economy, an analysis of the quantities and trends of GHG emissions from different sectors is essential. This helps to prioritise sectors, industries and gases where efforts can be made for an effective action. Emissions take place both during, production and consumption processes. 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 emission-efficient. For example, need for air conditioning can be reduced by better insulation and further reduce the energy and emissions by increasing the efficiency of the air conditioner.

Estimating anthropogenic GHG emissions (CO_2, CH_4 and N_2O) and making inventories began on a limited scale in India, in 1991. These were enlarged and revised, and the first definitive report for the base year 1990 was published in 1998 (ALGAS, 1998) using the IPCC guidelines for preparation of national GHG inventories by sources and removal by sinks. Since then, several papers have been published on GHG emissions for 1990 at national level (Mitra et al. 2002), as well as district level (Garg et al. 2001) have been published. These papers have included country-specific emission factors and activity data, accounted for additional sources of emissions and additional gases or pollutants. Also in 2000 and 2003, the IPCC brought out good practice guidances that were aimed towards improving the comprehensive coverage, comparability, transparency, and accuracy of the national GHG inventory (IPCC GPG 2000, 2003).

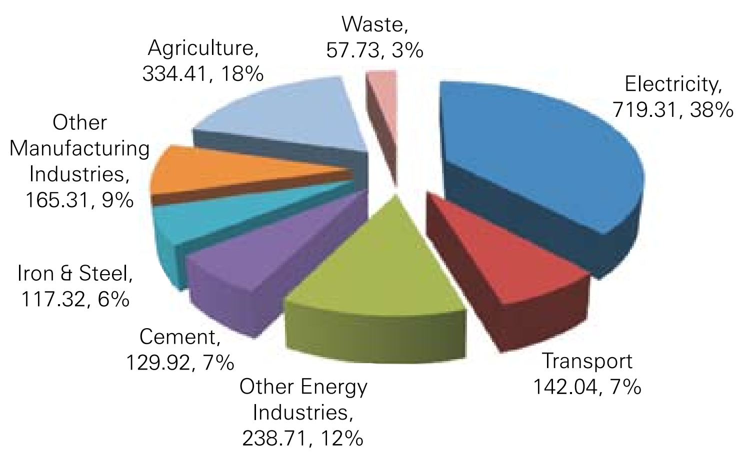
Taking stock of all such developments, and further fine tuning them, a comprehensive inventory of emissions of CO_2, CH_4 and N_2O for the year 1994 from energy related activities, industrial processes, agriculture, land use, land use change and forestry and waste management practices of the country was reported in India's Initial National Communication to the UNFCCC in 2004 (NATCOM, 2004). Subsequent research papers, examine the trends of GHG emissions and make a comprehensive comparison and analysis of emissions with respect to global and other country emissions (Sharma et al. 2006; Garg et al 2006). Recently, the Ministry of Environment and Forests, under its Indian Network for Climate Change Assessment – INCCA programme has made a rapid assessment of GHG emissions by sources and removal by sinks for the year 2007 (INCCA, 2010). These together allow us to examine the trends in emissions, and energy and emissions intensity over the last decade of post-liberalisation economic growth.

This chapter briefly describes the greenhouse gas emissions structure by sectors in 2007 and the trends of emissions by sector since 1994. Based on this trend, the chapter deduces the emissions for 2005.

2.1 GHG Emissions in 2007

In 2007, India's greenhouse gas (GHG) emissions by sources and removal by sinks was 1727.71 million tons of CO_2 equivalents. This includes emissions from the energy sector, industries, agriculture and waste and removals by the Land Use Land Use change and Forestry (LULUCF) sector. Without LULUCF, the GHG emissions were 1904.73 million tons of CO_2 equivalents. The GHGs covered include CO_2, CH_4 and N_2O. The distribution of CO_2 equivalent (CO_2-eq) emissions across sectors is shown in figure 2.1.

Figure 2.1: GHG Emissions Distribution (MT CO_2-eq) Across Sectors (2007)[2]



[2] ***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:*** *comprise of other minerals such as glass and ceramic, soda ash use; chemicals such as ammonia, nitric acid, carbides. titanium dioxide, methanol, ethylene, EDC and VCM*

...Contined on Page 17

Energy sector: The energy sector emissions comprise of emissions due to fuel combustion in electricity generation, solid fuel manufacturing, petroleum refining, transport, residential & commercial activities, agriculture & fisheries. It also includes the fugitive emissions due to coal mining, and handling of oil and natural gas. The energy sector emitted 1100.06 million tons of CO_2-eq in 2007, which is 58 percent of the total CO_2-eq emissions in that year. In 2007, 992.84 million tons was emitted as CO_2, 4.24 million tons as CH_4 and 0.06 million tons as N_2O.

The largest chunk of emissions was from electricity generation amounting to 719.31 million tons of CO_2-eq which represented 65 percent of the total CO_2 equivalent emissions from the energy sector. The transport sector emitted 14 percent of the emissions (142.04 million tons of CO_2-eq). 13 percent of the emissions were from residential and commercial sectors (149.51 million tons of CO_2-eq). Fossil fuel combustion in Petroleum refining and solid fuel manufacturing sector, in the Agriculture and Fisheries sector and fugitive emissions from coal mining and handling of oil and natural gas, each resulted around 3 percent of the total emissions from the energy sector, which were 33.85, 33.66, and 31.70 million tins respectively. The residential sector emissions are due to fossil fuel and biomass combustion in rural and urban residential households. About half of the residential CO_2-eq emissions reported were in the form of non-CO_2 emissions from combustion of fuel wood, wood waste, cow- dung and crop residue in rural households.

Transport: Fuel combustion in transport sector including road transport, aviation, navigation and railways resulted 142.04 million tons of CO_2-eq emissions accounting for 7 percent of the total GHG emissions from the country in 2007. Amongst all modes of transport, the road transport alone emitted 87 percent of the total GHG emissions or 123.55 million tons of CO_2-eq. Civil aviation emitted 7 percent of the total transport emissions and in absolute terms, 10.21 million tons of CO_2-eq. Railways emitted 6.84 million tons of CO_2-eq (or 5 percent of the total transport emissions). The GHG

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production, acrylonitrile, carbon blck, caprolactam and other chemicals; metals other than iron and steel such as ferro alloys, aluminium, lead, zinc etc.; other industries such as pulp and paper, leather/ textile, food processing, mining and quarrying and non specific industries (components described in the text); and non energy products such as paraffin and wax.

emissions from railways only account for emissions due to fuel combustion for locomotive purposes, and for purposes other than locomotive use at manufacturing units of railways. The emissions due to electricity consumption in the railways are included in the emissions from electricity generation in the energy sector.

Industries: Accounted for 22 percent of the total GHG emissions or 412.55 million tons of CO_2-eq in 2007. The GHG emissions from industries are both due to fossil fuel combustion as well as due to processes that chemically or physically transform materials. Industries covered are the mineral industries, chemical industries, metals, mining and quarrying, food processing, pulp and paper, textile and leather, and many non specific industries such as rubber, plastic, watches, clocks, transport equipment, furniture etc. are included. Also covered are emissions due to non energy product use such as lubricants and paraffin waxes derived from fossil fuel.

In 2007, the top 2 GHG emitting industries, cement and iron and steel together accounted for about 60 percent of the total GHG emissions from the Industry sector. Around 31.5 percent or 129.92 million tons of CO_2-eq emissions from the industries sector was from cement industries. The Iron and steel industries emitted 117.32 million tons of CO_2-eq. and accounted for 28.4 percent of the total emissions from the industries sector. The non-specific industries together were the 3rd highest emitter in this sector contributing 21.4 percent of the total GHG emissions from this sector or 88.23 million tons of CO_2-eq emissions. Food processing industries emitted 27.72million tons of CO_2-eq and the emissions from this source were 6.7 percent of the total GHG emissions from the industries. Rest of the industries comprising of other minerals, metals, all chemicals, pulp and paper, textile and leather, and use of non energy products contributed 12.0 percent of the total CO_2-eq from this sector and the emissions equalled 49.36 million tons of CO_2-eq.

Agriculture: Enteric fermentation in livestock, manure management, rice cultivation, agricultural soils and onsite burning of agricultural crop residue are the sources of emissions in the agriculture sector. Together all these activities released 334.41 million tons of CO_2-eq in 2007 contributing 18 percent of the total national GHG emissions in that year. 63 percent of the emissions in the agriculture sector were due to enteric fermentation of feed in the rumen of livestock and was in the form of CH_4 (10.09 million tons of CH_4 or 212.09 million tons of CO_2-eq). CH_4 emissions from rice cultivation in 2007 was 3.33 million tons which is 69.87 million tons of CO_2-eq and accounted for 21 percent of the total GHG emissions from the agriculture sector. CH_4 emission from rice cultivation is the net result of opposing bacterial processes - production in anaerobic microenvironments and consumption and oxidation in aerobic microenvironments, both of which can be found side by side in flooded rice. Direct and indirect emissions of N_2O from soils contributed 13 percent of the total GHG emissions amounting to 0.14 million tons of N_2O or 43.40 million tons of CO_2-eq. Rest 2 percent of the emissions in the agriculture sector were from onsite burning of crop residue, which was 6.60 million tons of CO_2-eq.

Waste: With increase in population, there has been an increase in solid waste and waste water output. Systematic collection of solid waste, it's recycling and incineration for recovering energy has a large potential for reducing emissions from this sector. However, in India, systematic collection and dumping of waste is only carried out in urban areas leading to CH_4 emissions. Incineration of waste for energy has started in one or two sites only on a pilot basis. The domestic waste water is managed in most of the cities and industrial waste water treatment plants regularly treat the waste in industries. These two are also a large source of CH_4 emissions. In 2007, the waste sector released 57.73 million tons of CO_2-eq, of which 19.8 percent was from municipal solid waste, 36.8 percent from domestic waste water and 34.4 percent was from industrial waste water.

Table 2.1 summarises the emissions of CO_2, CH_4 and N_2O and the resulting CO_2 equivalent (CO_2-eq) emissions in 2007 from the different sectors of the economy mentioned above, revealing the overall carbon inventory the economy. For an explanation on conversion to CO_2-eq, see box 2.1. CO_2 equivalence of these GHGs has been derived using the Global Warming Potentials (GWP) provided by the IPCC in its Second Assessment Report "1996 IPCC GWP Values" based on the effects of GHGs over a 100-year time horizon (See Box 2.1).

Gas	Global Warming Potential
CO_2	1
CH_4	21
N_2O	310

Source: IPCC (1996)

Box 2.1: Global Warming Potential (100-year Time Horizon)

The IPCC developed the Global Warming Potential (GWP) concept to compare the ability of each greenhouse gas to trap heat in the atmosphere relative to another gas. The GWP of a greenhouse gas is defined as the ratio of the time-integrated radiative forcing from the instantaneous release of 1 kilogram (kg) of a trace substance relative to that of 1 kg of a reference gas (IPCC 2001). Direct radiative effects occur when the gas itself is a greenhouse gas. The reference gas used is CO_2, and therefore GWP-weighted emissions are measured in CO_2-equivalents (CO_2-eq.). All gases in this chapter have also been presented in units of Gg CO_2-eq. See box 2.1 for the GWPs used in this report

Table 2.1 GHG Emissions by Sector (2007)

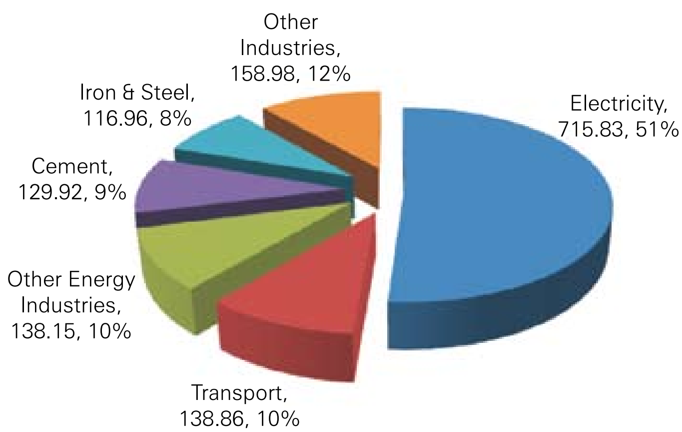
Sector	CO_2 (million tons)	CH_4 (million tons)	N_2O (million tons)	CO_2 -eq (million tons)
Electricity	715.83	0.08	0.011	719.31
Transport	138.86	0.23	0.009	142.04
Other energy activities	138.15	4.23	0.038	238.71
Cement	129.92	—	—	129.92
Iron and steel	116.96	0.009	0.001	117.32
Other manufacturing industries	158.98	0.14	0.019	165.31
Agriculture	—	13.78	0.146	334.41
Waste	—	2.52	0.015	57.73
TOTAL	1398.70	20.56	0.24	1904.75

2.1.1 Carbon Dioxide Emissions

In 2007, the total amount of CO_2 emitted without LULUCF was 1398.70 million tons, which accounted for 73.4 percent of the total CO_2 emissions. The electricity sector accounted for 51 percent of the total CO_2 emissions emitting 715.38 million tons of CO_2. About 10 percent of the CO_2 emission was from the transport sector (138.86 million tons of CO_2). Another 10 percent was from other energy industries

(138.15 million tons of CO_2). Amongst the other energy industries, 80 percent of the CO_2 emissions (or 104.36 million tons of CO_2) were from residential, commercial/ institutional, and agriculture/fisheries sectors, indicating the use of fossil fuel for space lighting, cooling, heating, pumping and for engines to run trawlers etc. All the manufacturing industries together accounted for 29 percent of the total CO_2 emissions (405.86 million tons). of this 58 percent of the CO_2 emissions were together from iron and steel industry and the cement industries (246.88 million tons of CO_2). See figure 2.2 for details of CO_2 emissions distribution across sectors in 2007.

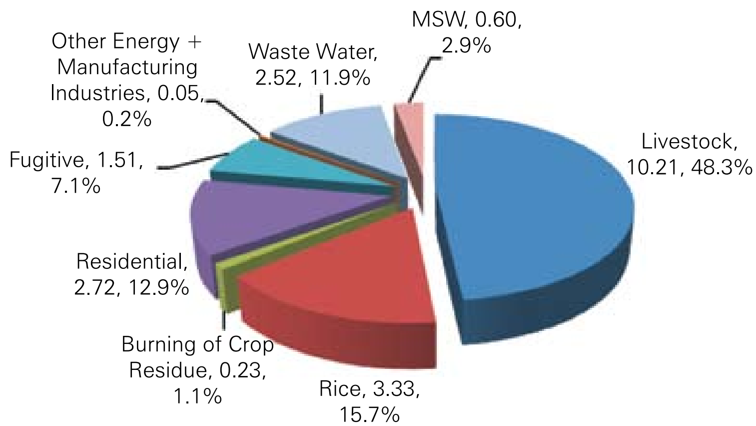
Figure 2.2: CO_2 Emissions Distribution (million tons) Across Sectors (2007)



2.1.2 Methane Emissions

In 2007, 20.56 million tons of methane (CH_4) was emitted from anthropogenic activities, which accounted for 22.7 percent of the total CO_2 equivalent emissions without LULUCF. Agriculture sector is the largest source of CH, it accounted for 66.1 percent of the total CH_4 emissions. Livestock, Rice cultivation, and onsite burning of crop residue respectively emitted 48.3, 15.7 and 1.1 percent of the total CH_4 emissions from India in 2007. The residential sector contributed 12.9 percent of the total CH_4 mainly due to combustion of fossil fuel as well as biomass in rural and urban households. Fugitive emissions from the energy sector are substantial as well, as they account for 7 percent of the total CH_4 emitted in 2007. In the waste sector, CH_4 from waste water i.e domestic and industrial waste water together account for 11.9 percent of the total CH_4 emissions. Compared to that the methane emitted from municipal solid waste is only 2.9 percent of the total CH_4 emission in 2007. See figure 2.3 for detailed CH_4 emission distribution by sector.

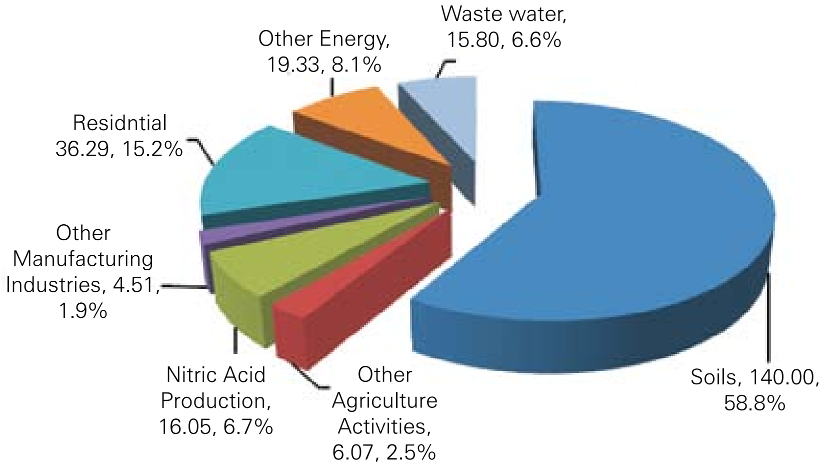
Figure 2.3: CH_4 Emission Distribution (million tons) Across Sectors (2007)



2.1.3 Nitrous Oxide Emissions

N_2O emissions constitute a rather small portion of CO_2 equivalent emissions in India (only 3.9 percent of the total CO_2-eq without LULUCF in 2007). The maximum N_2O emissions is due to agricultural activities which accounted for 64.9 percent of the total N_2O emissions. Direct and indirect N_2O emissions due to use of nitrogenous fertilisers is the main reason for nitrous oxide emissions in agriculture sector. In 2007 about 140 thousand tons of N_2O was emitted from agricultural soils. Within the energy sector, the residential sector is the largest emitter of N_2O. It emitted 36.29 thousand tons of N_2O, accounting for 15.2 percent of the total N_2O emissions in 2007. Amongst the manufacturing industries, nitric acid production lead to the maximum N_2O emissions of around 16.05 thousand tons accounting for 6.7 percent of the total N_2O emissions in 2007. For details of emissions of N_2O by sector, see figure 2.4.

Figure 2.4: N_20 Emissions Distribution (thousand tons) Across Sectors (2007)



2.2 Trends of GHG Emissions and Carbon Intensity

A comparison of GHG emissions trends between 1994 and 2007 (table 2.2) reveals that the total CO_2 equivalent emissions excluding LULUCF has increased by 690.58 million tons over this period, growing at a compounded annual growth rate (CAGR) of 3.5 percent. Further, if the agriculture sector is subtracted from the this total, then the GHG emissions in this period is seen to be growing from 869.76 million tons to 1570.34 million tons, an increase of 700.58 million tons. The compounded annual growth rate being 4.6 percent.

All sectors show an increase in emissions, except for agriculture. The emissions from sectors that are growing at a very fast rate are cement, electricity and waste with a CAGR of 6 percent, 5.6 percent and 7.3 percent respectively. Growth in these sectors can be attributed to tremendous increase in capacity of production during 1994 to 2007. Further, the emission intensity as expressed in grams of CO_2-eq per Rs. of GDP has fallen from 66.8 in 1994 to 56.21 in 2007, indicating the impact of government policies that encourage energy efficiency in various sectors of the economy.

Table 2.2: Trends of CO_2-eq Emissions and Emission Intensities

Sector	1994	2007	Change	CAGR
Electricity	355.04	719.31	364.27	5.6
Transport	80.29	142.04	61.75	4.5
Residential	78.9	137.84	58.94	4.4
Other Energy	78.92	100.87	21.96	1.9
Cement	60.87	129.92	69.05	6.0
Iron & steel	90.53	117.32	26.79	2.0
Other manufacturing Industries	101.98	165.31	63.33	3.8
Agriculture	344.49	334.41	-10.08	-0.2
Waste	23.23	57.73	34.50	7.3
Total CO_2-eq emissions excluding LULUCF	1214.25	1904.75	690.50	3.52
Total excluding LULUCF and Agriculture	869.76	1570.34	700.58	4.65
GDP (Rs. Billion)*	12,825	30,619	17,794	6.92
Emission intensity**	66.8	56.2	10.2	-1.34

**@1999-00 prices (Central Statistical Commission, India)*

***in grams of CO_2 equivalents per Rs. of GDP*

2.3 GHG Emissions in 2005

Since India envisages reduction in the emissions intensity of its GDP by 2020, by 20-25 percent over the 2005 levels, it is important to assess the baseline GHG emissions for 2005, and use the knowledge to design low carbon strategies that also allow for inclusive growth. In order to do so, a detailed bottom up assessment of activities leading to GHG emissions, duly validated by national communication, is desirable. However, in the absence of the same, growth rate of emissions is also a fairly reliable indicator. In table 2.2, it can be seen that CO_2 equivalent emissions excluding LULUCF and Agriculture are rising at a compounded annual rate of 4.65 percent. Using this growth rate, it is estimated that India emitted 1433 million tons of CO_2-eq in 2005.

2.4 GHG Inventory - Data and Measurement

Accurate and timely availability of national GHG emissions data is critical for good policymaking and for tracking the progress we are making towards the goal of reducing the emission 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 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) requires GHG inventories to be reported for the year 2000 by the year 2011. In view of the time-lag, Ministry of Environment and Forests has carried out a rapid assessment and has arrived at GHG inventories by 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 earlier gap years as well as for the years ahead, and for continuously reviewing these.

Annual GHG inventories will provide an opportunity to measure the impact of the steps taken to reduce carbon intensities. Also, reporting with large lags does not provide timely information for policy-making. Thus the need to create a mechanism that can estimate the GHG emissions on a regular basis, particularly in the light of the goals that India has set for itself on reducing its emissions intensity. This is a daunting task as uncertainty exists in terms of gap in activity data, quality of the activity data and non-availability of emission factors etc. These over a period of time can be bridged by collating activity data from various Ministries, their Departments, the Industry etc., performing QA/QC checks on routine basis, commissioning surveys to ascertain data gaps, developing emission factors for key emission sources, analysis to ascertain level of uncertainties, and last but not the least, a regular review of the estimates by a third party for reliable inventory estimate of greenhouse gases at all levels on an annual basis.

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 emitting 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 national/state/city level, emitted from all activities by sector.
- The bottom-up approach would track GHG inventories of companies/PSUs that would take into account the impact of the various energy efficiency or fuel switching measures implemented at the utilities/installations (can be referred to as point sources). 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, and regulations and standards on energy efficiency and emissions that may be brought about in the future.

The key initiatives that need to be undertaken for India to have a comprehensive data base of GHG emissions from the country for all sectors at various levels of disaggregation would entail:

1. Setting up of a National Greenhouse Gas Inventory Management Authority (NGIMA) to track the trends of greenhouse gas emissions from all sectors of the economy at national state district 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, that will produce the trends of emissions or removals by sector at national/ state/ district/ or at point source level
3. Designing mechanisms for voluntary disclosure of GHGs from installations managed by PSUs/Corporates, and from Medium Scale Enterprises to track the impact of energy efficiency measures or GHG mitigating measures undertaken by them on their annual GHG emissions.

2.5 Summary

GHG emissions from India without LULUCF have increased during the period 1994-2007 from 1214.25 to 1904.75 million tons of CO_2-eq., registering an increase of 690.5 million tons. The compounded annual growth rate of emissions was 3.52 percent. Further, excluding agriculture, the change in emission between the two periods was 700.58 million tons and the emissions increased at a compounded annual growth rate of 4.65 percent. All sectors of the economy except agriculture, showed an increase in emission between 1994 and 2007. Using the rate of growth for overall CO_2-eq emissions, excluding LULUCF and agriculture sectors, it is estimated that India emitted 1433 million tons of CO_2-eq in 2005.

CO_2-eq emission intensity per unit of GDP is observed to be decreasing, though both CO_2-eq emissions and GDP are increasing annually. It is pertinent to mention that over this period (1994-2007) GDP from services on an average grew faster than the overall GDP. With the growth accelerating further and manufacturing taking its due place in the overall economy, emissions are expected to increase further up to 2020. Many low C technological options are currently being used to decrease the energy intensity of the economy. More such options could be explored to achieve the desired target of reducing the emission intensity of India's GDP by 20-25 percent over the 2005 levels by 2020.

Further, to assist national level decision-making, it is necessary to have year-on-year GHG inventory assessment conducted through point sources, both by sectors and categories. This annual process will enable improvement in the GHG numbers by reducing uncertainties through increase in data coverage, ensuring comparability of numbers, transparency and accuracy. Continuous bridging of data gaps, updating existing country specific emission factors and proper implementation of the QA/QC procedures can all be done by establishing a National Inventory Management System under the umbrella of a National GHG Management Authority.

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3 Sectoral Strategies

We have seen in Chapter 2 that major GHG emitting sectors are power, transport, industries and households (including buildings both residential and commercial). Options to reduce emissions by improving energy efficiency on the demand side and by reducing GHG emissions on supply side are important, and offer a significant scope for mitigation. In this chapter, we examine the options for each sector.

For each sector we make projections for two growth outcomes, namely average real GDP growth rates of 8 and 9 percent up to 2020. And for each growth outcomes, we give an expected range of emissions. The lower end of the emission reduction range would henceforth be called Determined Effort Scenario; and the higher end of this range would henceforth be called Aggressive Effort Scenario. Both of these are defined below.

1. **Determined Effort [Lower End of the Emission Reduction Range]**

   Determined Mitigation Effort implies policies that are already in place or contemplated are pursued vigorously and implemented effectively up to 2020. This is by no means automatic as it requires continuous up-gradation of technology as well as finance from both public and private sources. This also assumes the private sector sustains its current efficiency enhancing efforts.

2. **Aggressive Effort [Higher End of the Emission Reduction Range]**

   Aggressive Mitigation requires, in addition to the above, introduction as well as implementation of new policies. This requires new technology as well as additional finance. The private sector needs to scale up its efforts significantly from the present levels. This is essentially what the Expert Group feels is the upper limit of feasibility up to 2020. The details of policies, technology and finance required to achieve this would be spelt out in the Final Report.

3.1 Power Sector

India's gross generation in 2007-08 was 813[3] billion kWh. This includes generation by captive power plants above 1 MW. It does not include generation by millions of small diesel generators. India's GDP in 2007 (constant 1999-00 prices) was Rs. 30,619 billion. This provides an electricity intensity of 0.028kWh/1 Rs of GDP. The GDP for 2020 (in constant 1999-00 prices) using GDP growth rate of 8 percent and 9 percent per year is given in Table 3.1 below.

Table 3.1: Projected GDP in 2020

Year	2007	2020	2020
GDP Growth Rate	-	8 percent	9 percent
GDP (Rs. billion)	30,619	83,273	93,873

The Integrated Energy Policy report estimated the elasticity of electricity generated with GDP at 1.30 for the period 1980 – 81 to 2003 – 04, 1.06 during 1990 – 91 to 2003 – 04 and 0.95 for 2004 – 05 to 2011 – 12[4] . Future projections of elasticity trends require a detailed assessment of the macroeconomic growth trends and the impact of several of the factors like "the relative prices of fuels, changes in technology, changes in end-use efficiency of equipment, the level of the energy infrastructure and development priorities that affect the structure of the economy. However, there is also a feeling that, for India, the energy elasticity of GDP growth will not fall any further as rising income levels will foster life style changes that are more energy intensive".

It is known that the Indian grid operates at an energy shortage of 10-15 percent. One way to project the future requirement would be to add this shortfall to the actual generation before projecting. However, the approach taken here is that the projected GDP growth already takes into account the energy shortfall. In other words, the GDP growth rate would be higher in the event of no shortage.

The total current electricity generation that includes the captive and utility based generation has been taken into account to project the total future requirements – captive and utility. It has to be noted that the growth rates of utility and captive

[3] *Utilities, 722.6 billion kWh + Non-utilities, 90.4 billion kWh (All India Statistics, General Review 2009, Central Electricity Authority, May 2009)*
[4] *Integrated Energy Policy Report, Planning Commission, Government of India, 2006.*

generation would be different; this has been discussed in the subsequent section on supply options.

For the sake of simplicity, we have assumed a constant elasticity of 0.95 from 2007 - 08 to 2020 - 21 to project the required electric power generation in 2020 in the baseline scenario. Subsequently we have considered the impact of demand side management and energy efficiency measures on the reduction of electricity demand. This is explained in the following sections.

Using the total gross generation of 813 Billion kWh in 2007-08 as a base and an elasticity of 0.95, the corresponding gross generation numbers for 2020 - 21 are 2,104 and 2,359 billion kWh respectively (Table 3.2). The corresponding net generation required is 1,970 and 2,208 billion kWh respectively (assuming an auxiliary power consumption of 6.5 percent).

Table 3.2: Electricity Generation Required in 2020 (with base year 2007 - 08 generation)

GDP Growth Rate	8 percent	9 percent
Gross Generation Required in 2020 (Billion kWh)	2,104	2,359
Net Generation Required in 2020 (Billion kWh)	1,970	2,208

3.1.1 Energy Efficiency and Demand Side Options

Energy Efficiency (EE) can play a key role as India struggles to meet its development goals under severe environment and resource constraints. Several EE options are less expensive than coal or gas-based generation, and therefore, should be the "first resource" considered for fulfilling demand. However, despite the apparent attractiveness of several EE options, their diffusion and adoption is sluggish. Clearly, there are barriers to adoption that need to be overcome by appropriate policies and institutional arrangements. We will deal with these in the final report.

In this section, we have estimated the energy saving potential in all sectors (domestic, commercial, industrial and agricultural) that can be realized through:(a) Determined Effort and (b) Aggressive Effort. The two energy efficiency scenarios are defined below.

In case of domestic and commercial appliances, the two energy efficiency scenarios can be specifically defined as:

Efficiency Gains through Determined Effort:

Here we not only assume that policies that are already in place are implemented, but also that there is a progressive adoption of highly efficient[5] appliances. We assume that 70 percent of all appliances sold in 2020 are highly efficient and the remaining use current technologies.

Efficiency Gains through Aggressive Effort:

Here, in addition to the determined effort energy efficiency scenario, we assume that super efficient appliances constitute a reasonable fraction of the sales in 2020. We assume that 65 percent of all appliances sold in 2020 are super efficient[6], 25 percent are highly efficient and the remaining use current technologies.

The procedure for estimation of energy savings from improved appliance efficiency is summarized as below.

1. Estimates of sales of new appliances up to 2020,
2. Estimates of stock in 2020 based on appliance life times,
3. Expected trends for efficiency improvements in the determined effort and the aggressive effort scenarios as defined above. We assume a linear interpolation between the present annual energy consumption of average appliance and that expected in 2020,
4. Estimates of total energy consumption in 2020 based on current technologies and in the two scenarios,
5. Estimates of energy savings in the two scenarios.

We have considered several leading energy consuming appliances such as refrigerator, fan, television, air conditioner, and lighting equipment (Table 3.3). The saving potential for commercial AC is calculated separately, because it is mainly based on centralized system, which is often customized. Together these end-uses account for about 90 percent of the residential and commercial sectors consumption[7].

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[5] 5 star appliances as per Bureau of Energy Efficiency (BEE) labeling

[6] Based on energy efficient appliances available in international markets.

[7] The energy consumption for the other appliances such as washing machines, radio, tape-recorders and CD players, computers, set-top boxes, DVD players and VCR/VCP form less than 10% of the total consumption.

Table 3.3: Present and Future Energy Consumption of Various Appliances

Appliance Electricity Usage (kWh per year)	Average Appliance Sold in 2005	Highly efficient Appliance	Super Efficient Appliance
Refrigerator	418	314	104
Fan	71	55	38
TV	175	134	79
Air Conditioner	1370	1072	831
Lighting Bulb (Watts)	60	15	13
Lighting Tube (Watts)	51	40	32

Table 3.3 shows the annual energy consumption of an average appliance sold in 2005, and the energy consumption of highly efficient and super efficient appliances. Clearly, there is a large potential for reduction of energy consumption by appliances. However, the diffusion of efficient appliance technologies is often impeded by barriers such as economics, environmental compatibility, public acceptance and appropriate policies. As pointed out earlier, it is beyond the scope of this interim report to go into a detailed assessment of these issues. We will instead focus on assessing the energy savings potential from the adoption of above technologies. With the economy growing at 8 – 9 percent, the sales of appliances is expected to show robust growth in the coming years. The increasing purchasing power of people is expected to drive this growth. Table 3.4 gives the stock, growth in sales and average life of various appliances as in 2008.

Table 3.4: Stock & Sales in 2008, Sales Growth Rate and Average Life of Individual Appliances[8]

Appliance	Stock in 2008 (millions)	Sales in 2008 (millions)	Sales Growth Rate	Average Life (years)
Refrigerator	37	7.3	6%	15
Fan	246	30	6%	12
TV	99	13.7	10%	12
Air conditioner	5	2.3	15%	8
Lighting-Bulb	374	734	2%	0.6
Lighting-Tube	280	186	186	3

[8] *Prayas Energy Group*

Table 3.5 summarizes the results of the analysis. The total energy savings in the determined effort and aggressive effort scenarios are 80 billion kWh and 147 billion kWh respectively. Lighting accounts for a significant fraction of the total energy consumption and consequently provides a large potential for energy savings.

Table 3.5: Estimates of Energy Consumption and Savings by Appliances under Alternate Energy Efficiency Scenarios (billion kWh)

Appliances	Energy Consumption with Present Technologies (1)	Determined Effort for Energy Efficiency		Aggressive Effort for Energy Efficiency	
		Energy Consumption (2)	Energy Savings (1) – (2)	Energy Consumption (3)	Energy Savings (1) – (3)
Refrigerator	63	58	6	45	18
Fan	38	34	4	30	8
TV	56	51	6	42	15
Air conditioner	92	82	10	71	21
Lighting-Bulb	56	27	29	19	37
Lighting-Tube	107	92	15	79	28
Others	50	40	10	30	20
Total	463	383	80	316	147

In the agriculture sector there are opportunities for energy savings by replacing the present irrigation pumps with more efficient motors. Better load management and reducing the water consumption also result in electricity savings. However, these are complex issues and involve modification in agricultural tariffs. A few experiments in agricultural DSM have met with limited success and therefore, it is not clear how much savings can be actually achieved. In this report, we assume potential savings of 5 and 10 billion kWh in the determined and aggressive effort scenarios.

In the industry sector, there is a large energy savings potential in energy intensive manufacturing industries, particularly iron and steel, and cement. These are discussed separately in another chapter. Most industries consume thermal and electrical energy and the specific energy consumption shows a wide range in the country. Some industries are very efficient and achieve the global standards, while older units are typically less efficient. The Government has recently announced the Perform Achieve and Trade (PAT) scheme for improving the efficiency of manufacturing industries.

This is a market based mechanism and allows for trading of energy efficiency certificates. There are estimates that this scheme if implemented fully will result in an overall energy savings of ~ 24 million tons oil equivalent by 2020[9]. Thermal energy savings account for roughly 75 percent of this and the balance is electricity. Therefore, industrial energy efficiency improvement could result in electricity savings of about 20 billion kWh in the determined and 60 billion kWh in the aggressive effort scenarios[10].

Table 3.6 summarizes the total energy savings potential including appliances, agriculture and industry sectors. The total electricity savings under determined and aggressive effort scenarios at the consumer end are 105 and 217 billion kWh respectively. Assuming transmission and distribution losses of 15 percent, these translate to avoiding a net electricity generation of 124 and 255 billion kWh at bus bar[11]. The table also provides the net electricity generation required to sustain a GDP growth rate of 8 percent and 9 percent after accounting for the energy savings from the DSM options as discussed above.

Table 3.6: Net Electricity Generation Required in 2020 under Determined Effort and Aggressive Effort Scenarios (billion kWh)

Sector	Determined Effort for Efficiency Improvement		Aggressive Effort for Efficiency Improvement	
Appliances	80		147	
Agriculture	5		10	
Industry	20		60	
Total Savings (Billion kWh)	105		217	
Savings in Net Electricity Generation (Billion kWh)	124		255	
Growth Scenarios	**GDP 8%**	**GDP 9%**	**GDP 8%**	**GDP 9%**
Net electricity generation without DSM (Billion kWh)	1,970	2,208	1,970	2,208
Net electricity generation required after DSM savings (Billion kWh)	1,846	2,084	1,715	1,953

[9] Estimates by Center for Study of Science, Technology and Policy (C-STEP)
[10] 1 Million tons oil equivalent = 11.67 billion kWh
[11] Assuming transmission and distribution losses of 15%

3.1.2 Supply Options and Emissions (2007)

The net electricity generation from utilities for the year 2007 – 08 was 653 Billion kWh and corresponding CO_2 emissions were 520 Million Tons[12]. The generation from non-utilities for 2007 - 08 was 90.4 billion kWh[13] (53.5 of coal, 10.7 of diesel, and 25.5 of gas and a small component of renewable). This results in 76 million tons of CO_2 emissions from the net generation from the non-utilities[14]. Thus, the total power sector CO_2 emissions for 2007 - 08 are estimated to be 598 million tons leading to overall power sector specific CO_2 emissions of 0.81 kg/kWh. In fact, the specific CO_2 emissions have been relatively stable during the period 2005 – 09 at an average of 0.82 kg per kWh.

It should be noted that the CO_2 emissions quoted by NATCOM 2007 report[15] for the period 2007 - 08 is 719 million tons different than the number estimated above (598 million tons). This is due to difference methodology adopted by the two agencies – CEA and NATCOM. This could partly be attributed to the inefficiencies in the coal transportation and distribution network and likely diversion to the other sectors.

Thermal Generation

On the supply side, coal is presently the least cost option and will continue to be the main power generation source in 2020 as well. To ensure energy security the present coal based capacity needs to be expanded to 230 GW by 2020.[16] This will require an annual coal supply of at least 1000 million tons, two and a half times the present. Domestic mining will have to increase considerably otherwise imports will have to meet a large fraction of coal demand.

As of May 2010, all the coal based plants are based on sub-critical technology. The total generation from coal and lignite power plants was 461 billion kWh (at bus-bar) leading to CO_2 emissions of 508 million tons during 2008 – 09. Thus, the specific CO_2 emission of all existing coal and lignite power plants is 1.1 kg per net kWh for this period[9]. Some of the old and less efficient coal power plants emit as high as 2

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[12] Central Electricity Authority, CO_2 Baseline Database, Version 5, November 2009
[13] All India Electricity Statistics, General Review 2009, CEA
[14] The emissions from coal based generation is assumed to be 1.1 kg/kWh and the assumptions for the rest are the same as given later in the box 3.1
[15] NATCOM 2007 Report
[16] The requirement of coal based power may actually be greater if we fail to take the required DSM Measures.

kg per kWh. However, the new 500 MW sub-critical power plants have net heat rates of 2450 kCal/kWh leading to specific emission of 0.93 kg per net kWh[17],[18].

There are several technology options to improve the combustion efficiency and lower CO_2 emissions. Super critical plants operate at higher temperatures leading to net heat rate of 2235 kCal per kWh and specific emission of 0.83 kg per net kWh11. The technology is available globally and the cost is almost the same as sub-critical plants. As per recent guidelines and projections, super-critical power plants would account for 60 percent of thermal capacity to be built in 12th Plan and 100 percent in 13th Plan[19]. Super critical units could thus contribute up to 50 GW by 2020[20].

Ultra super critical power plants operate at still higher temperatures leading to net heat rate of 1986 kCal per kWh and specific CO_2 emissions of 0.74 kg per kWh. However, the technology is still not ready for large scale adoption. The high temperatures impose stringent materials challenges. It is unlikely that such plants would be installed before 2020. Integrated Coal Gasification Combined Cycle (IGCC) is another promising technology, which can attain higher efficiencies and lower CO_2 emissions and also produce synthetic chemical fuels such as diesel and hydrogen. However, initial estimates under Indian conditions of high ash coal show very high auxiliary power consumption and hence the overall efficiency is comparable with sub critical units at almost double the cost. While we should pursue research in IGCC, commercial deployment of IGCC is unlikely before 2020.

Carbon Capture and Sequestration (CCS) is being considered in several countries with large coal based power. However, there are several technical, economic and regulatory challenges in its role as a commercially viable low carbon option. The government should watch the development of this technology in USA and EU, where a number of commercial plants are under implementation/consideration and also undertake a few studies to examine the issues of potential and feasibility both technical and economic.

Gas based power is an attractive power generation option as the capital cost is low and the CO_2 emissions are only 0.4 kg per kWh. However, the cost of gas is

[17] *Discussions with NTPC*
[18] *"Future of Coal", Massachusetts Institute of Technology, 2007*
[19] *CEA Advisory from Ministry of Power, February 2, 2010*
[20] *Subject to availability of equipment and supplies*

usually much more than the cost of coal to generate one unit of electricity. Also there is considerable uncertainty about availability of gas for power given the limited reserves and also its alternate use in fertilizer production and other sectors. It is therefore unlikely that gas can contribute a large share of electricity generation. We have assumed that gas capacity could grow to 25,000 MW by 2020.

Hydro and Renewable Sources

Hydro power's share in power generation has been gradually declining because of increasing difficulty in exploiting the remaining potential, which is mainly in the north eastern regions. The present installed capacity of 36,885 MW could grow to 50,000 – 65,000 MW based on the ongoing and sanctioned projects[21].

India has done well in wind power, which is a commercially mature technology. The momentum should continue and wind capacity could increase to 30,000 MW by 2020. Even though the load factor of wind plants is low, it is attractive as it could be set up quickly.

Biomass based power, though a promising option for rural decentralized generation has several issues in biomass availability, pricing and institutional factors. Biomass cogeneration in rice and sugar mills is more attractive and biomass could contribute at least 4,000 MW.

The National Solar Mission has provided solar power the much needed thrust to make it a major contributor of India's future energy mix. It has considerable advantages for both centralized and decentralized power generation, and also for powering the rural areas for education, health and employment. Solar is presently expensive, almost 3 – 4 times the coal based power. However, industry is optimistic that with growing manufacturing capacity in the country, short term viability gap support from government, aggressive research and development, large scale deployment, the cost could come down to grid parity within the coming decade. Solar installed capacity if pursued with seriousness could grow to 20,000 MW by 2020. It is one of the critical technology options for India's long term energy security. Several parts of India are endowed with good solar radiation and deploying solar even on 1 percent of the land area could result in over 500,000 MW of solar power. The coming decade is vital to

[21] *Viability of large hydro projects needs to be examined given the high cost of resettlement and emissions from land clearing.*

validating the techno-economic viability of solar as a major contributor to the nation's future energy supply.

Nuclear Power

India's present nuclear installed capacity is 4,780 MW, consisting mainly of domestic Pressurized Heavy Water Reactors (PHWRs), which require natural uranium as the fuel. There are plans to build eight more PHWRs of 700 MW each. It is also pursuing the building of Light Water Reactors (LWR) with imported enriched uranium. Two Light Water reactors of 1000 MW each are under construction at Kudamkulam and there are plans to build four more such reactors. India is also building 500 MW Fast Breeder Reactors (FBR).

Indian nuclear power received an impetus with the international agreement with the nuclear suppliers' group. This enables India to import nuclear technology, fuel and equipment. Recently, the Jaitapur site has received environmental clearance for building six LWRs of 1,650 MW each. However, future capacity addition depends on economics, availability of suitable sites and public acceptance. Further, the recent nuclear accident in Japan has raised public concerns about the safety of nuclear power as an energy source. The government has announced plans to revisit the safety of existing and future planned reactors.

Considering all the above, we estimate that the nuclear power capacity could reach up to 17,500 MW by 2020.

3.1.2.1 Projections of Future Fuel Mix and Emissions (2020)

The previous discussion on energy efficiency suggests that a GDP growth of 8 percent requires a net generation of 1,970 billion kWh in 2020, which reduces to 1,846 and 1,715 billion kWh under adoption of determined and aggressive effort for energy efficiency measures. Similarly, GDP growth of 9 percent requires a net generation of 2,208 billion kWh, which correspondingly reduces to 2,084 and 1,953 billion kWh.

Given that our current net generation is about 760 billion kWh, the above implies adding new generation capacity for 1000 – 1200 billion kWh over the next ten years after considering energy savings from DSM options. In other words, it translates to adding about 20,000 MW of new generation capacity per annum. As against this, in the recent years, India has added only about 10,000 MW per annum, which makes these scenarios challenging. Of course past performance is no indication of the future performance; however, this does point to the challenge that lies ahead. If this challenge is not met availability of power could act as a constraint on growth.

We now attempt to construct a fuel generation mix to achieve the desired electricity generation as outlined above. Strictly speaking, the procedure should consist of starting with options with lowest economic and environmental cost, and progressively moving to other options. However, we have not considered this approach because of the constraints of time and data availability. These could be the subject for further work.

Therefore we have followed the following procedure:

- We have considered current installed capacity, committed plans of future capacity addition for various sources such as coal, hydro, gas and nuclear.
- In emerging areas such as solar, the government has announced major initiatives with a target of 22,000 MW by 2020. Developing low cost and indigenous solar technologies is crucial for the country's long term energy security. The cost of solar PV has shown considerable reduction in recent times and the trend is continuing.
- The total installed captive capacity as of March, 2009 was around 27,000 MW[22]. The trend of increase in the captive generation will continue because of shortfall in grid supply and the tariff differentials. Here a 45,000 MW of captive installation is assumed for 2020[23].

Evaluating the potential and constraints of each of the supply option, it is clear that most of these scenarios pose challenges, however, the demand for a 9 percent GDP growth without DSM measures poses even more of a challenge. This is primarily because of the difficulty in creating by 2020, the Coal and Nuclear power installed capacity of the magnitude that will be required. It is clear that in the absence of implementing DSM measures, India will continue to face power shortage in 2020, which itself could place an energy constraint on growth. The Emission and Generation options are summarized in the Box 3.1 and Table 3.7.

22 All India Electricity Statistics, General Review 2009, CEA

[23] It is assumed that around 80% of the generation will be coal based and the rest will be based on natural gas and diesel.

Box 3.1 : Assumptions

1. Plant Load Factors (PLF) for 2020: Coal 80%, gas and diesel 55%, nuclear 80%, hydro 35%, wind 17%, solar 20%, biomass and others 40%, Non Utility (40%)
2. Auxiliary power consumption: Coal 8%, nuclear 10.5%, gas and diesel 3.1%, hydro 0.5%, wind 2%, solar photovoltaic 1%, concentrated solar thermal power 7%, biomass and others 7%, Non Utility (3%)
3. Specific emission of the total current fleet of coal and lignite power plants is 1.1 kg of CO_2 per net kWh. Based on CEA data (Central Electricity Authority, CO_2 Baseline Database, Version 5, and November 2009).
4. For the new 500 MW sub critical power plants, net heat rate is 2450 kCal/kWh leading to a specific emission of 0.93 kg of CO_2 per net kWh (Discussions with NTPC and Future of Coal, MIT report). For the super critical plants we have assumed a net heat rate of 2235 kCal per kWh leading to a specific emission of 0.83 kg of CO_2 per net kWh (Discussions with NTPC and Future of Coal, MIT report)
5. CO_2 emissions from captive generation are mainly based on coal. Close to 60% of the current captive generation is coal based and about 26% is gas based. Going forward it is assumed that all new plants will be coal based. Blended specific CO_2 emissions of 0.9 kg per Net kWh is assumed.

Table 3.7: Installed Capacity (MW) in 2020

MW Installed	8 Percent GDP Growth			9 Percent GDP Growth		
Generation Source	Baseline Scenario	Determined Effort for Efficiency	Aggressive Effort for Efficiency	Baseline Scenario	Determined Effort for Efficiency	Aggressive Effort for Efficiency
Coal-Subcritical	2,00,000	1,62,000	1,30,000	2,28,000	1,94,000	1,57,000
Coal-Supercritical	25,000	35,000	40,000	25,000	35,000	45,000
Gas and Diesel	25,000	25,000	25,000	25,000	25,000	25,000
Nuclear – PHWR	4,780	7,580	7,580	7,580	7,580	7,580

MW Installed	8 Percent GDP Growth			9 Percent GDP Growth		
Generation Source	Baseline Scenario	Determined Effort for Efficiency	Aggressive Effort for Efficiency	Baseline Scenario	Determined Effort for Efficiency	Aggressive Effort for Efficiency
Nuclear – LWR	2,000	5,000	8,000	4,000	6,000	9,300
Nuclear – FBR	500	500	500	500	500	500
Hydro & SHP	50,000	55,000	60,000	60,000	60,000	65,000
Wind	25,000	30,000	30,000	25,000	30,000	30,000
Biomass and Others	4,000	4,000	4,000	4,000	4,000	4,000
Solar PV	5,000	6,000	10,000	5,000	10,000	10,000
Solar Thermal	1,000	2,000	5,000	1,000	5,000	10,000
Total Utility	3,42,280	3,32,080	3,20,080	3,85,080	3,77,080	3,63,380
Captive generation	45,000	45,000	45,000	45,000	45,000	45,000
Total Utility + Nonutility	3,87,280	3,77,080	3,65,080	4,30,080	4,22,080	4,08,380
Net Generation (Billion kWh)	1,962	1,846	1,717	2,203	2,085	1,955
CO_2 Emissions (Million tons)	1,609	1,428	1,263	1,770	1,620	1,452

Discussions and Analysis

The above analysis provides interesting insights into the mitigation prospects for the power sector. The gross and net generation in 2007-08 is estimated at 813 billion kWh and 760 billion kWh respectively. The total CO2 emissions in 2007-08 were 598 million tons, leading to a specific CO2 emissions intensity of 0.81 kg CO2 per kWh (net). Further, the average CO2 emissions intensity over the last 5 years has been almost constant at 0.82 kg per kWh. If the same fuel mix24 was continued, then for the baseline scenario in 2020, the CO2 emissions would be 1,609 million tons for a GDP growth rate of 8 percent (Table 3.7). Assuming the same fuel mix in the determined effort scenario, the CO2 emissions in 2020 would be 1,513 million tons, meaning thereby that CO2 savings due to energy efficiency are likely to be 96 million tons. As per Table 3.6 above, actual CO2 emissions from the supply side are estimated to be 1,428 million tons. This is because of the addition of low carbon technologies such

[24] Same Fuel Mix means the carbon intensity remains 0.82 kg CO_2 per kWh (net).

as super critical coal combustion, nuclear and solar power plants. The supply side CO_2 savings are therefore estimated to be 85 million tons. In the determined effort scenario, this leads to a total CO_2 savings of 181 million tons from the baseline case. In the aggressive efficiency scenario, the total CO_2 savings are estimated to be 346 million tons, out of which 201 million tons are expected to be from energy efficiency and 145 million tons from the supply side. Table 3.8 shows these calculations for GDP growth rate of 8 percent. The CO_2 emissions under 2007 energy mix would have been 1,609 million tons.

Table 3.8: CO_2 Emissions Projections and Energy Savings for GDP Growth Rate of 8 Percent

Scenarios	Determined Effort for Efficiency	Aggressive Effort for Efficiency
Net Generation (Billion kWh)	1,846	1,717
CO_2 emissions under Fuel mix of 2007 (Million Tons)	1513	1,408
CO_2 savings from Energy Efficiency from Demand side (Million Tons)	96	201
Actual CO_2 Emissions from Supply side (Million Tons)	1,428	1,263
Savings from Supply side change in generation efficiency and mix (Million Tons)	85	145
Total savings from Demand and Supply (Million Tons)	181	346

Table 3.9 similarly shows CO_2 emissions projections and savings for a GDP growth rate of 9 percent. The CO_2 emissions under 2007 energy mix would have been 1806 million tons.

Table 3.9: CO_2 Emissions Projections and Energy Savings for GDP Growth Rate of 9 Percent

Scenarios	Determined Effort for Efficiency	Aggressive Effort for Efficiency
Net Generation (Billion kWh)	2085	1955
CO_2 emissions under Fuel mix of 2007 (Million Tons)	1,710	1,603
CO_2 savings from Energy Efficiency from Demand side (Million Tons)	96	203
Actual CO_2 Emissions from Supply side (Million Tons)	1,620	1,452
Savings from Supply side change in generation efficiency and mix (Million Tons)	90	151
Total savings from Demand and Supply (Million Tons)	186	354

This information is pictorially presented in Figures 3.1 and 3.2. It shows the savings in emissions due to demand side measures to improve energy efficiency in appliances, agriculture and industry, and also savings from supply side due to increase in efficiency of generation and fuel mix of plants.

Figure 3.1: Projection of CO_2 Emissions and Saving from Power Sector for 8 Percent GDP Growth

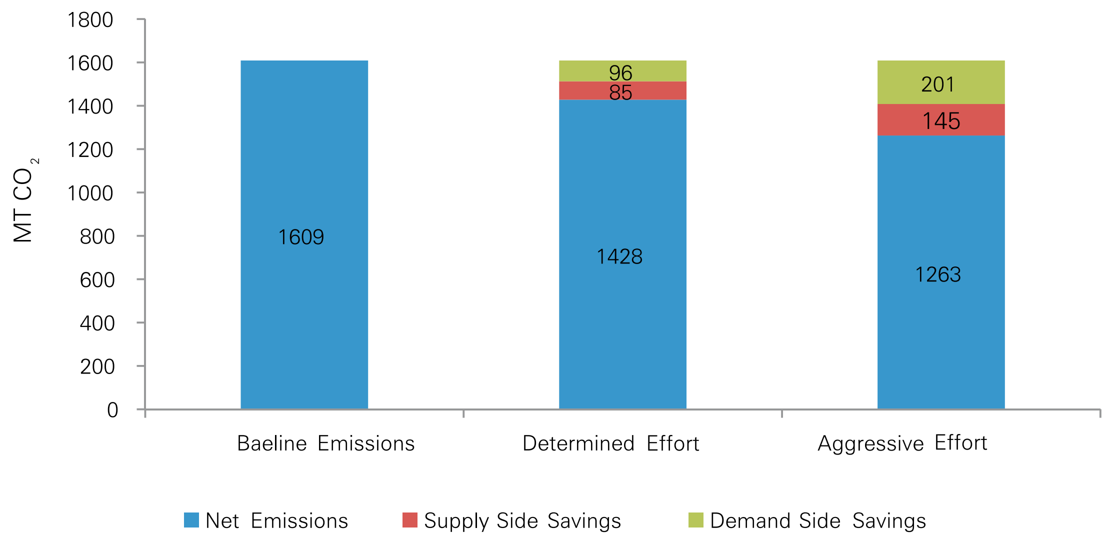
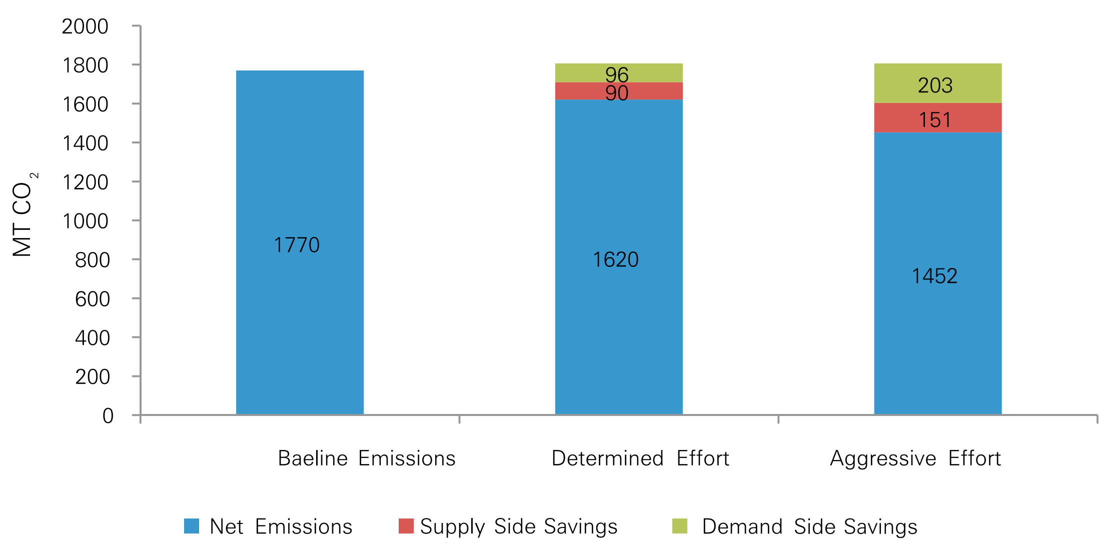


Figure 3.2: Projection of CO_2 Emissions and Saving from Power Sector for 9 Percent GDP Growth



3.2 Transport Sector

3.2.1 The Scene in 2007

The transport sector is the second largest contributor to energy related GHG emissions in India, and its share in national GHG emissions has increased from 6.4 percent to 7.5 percent between 1994 and 2007 [NATCOM 2007]. Moreover, India imports about 80 percent of its petroleum requirements, a significant part of which is used for transport. The quantity of oil imported, the unit cost of oil and the share of transport fuels (gasoline, diesel and aviation turbine fuel or ATF) in the petroleum basket are all steadily increasing. Given the likely oil-constrained future, there is need to lower transport's dependence on petroleum to enhance India's energy security and lower its carbon footprint. This section provides an overview of the emissions from the transport sector and suggests options to reduce GHG emissions from some sub-sectors of the transport sector.

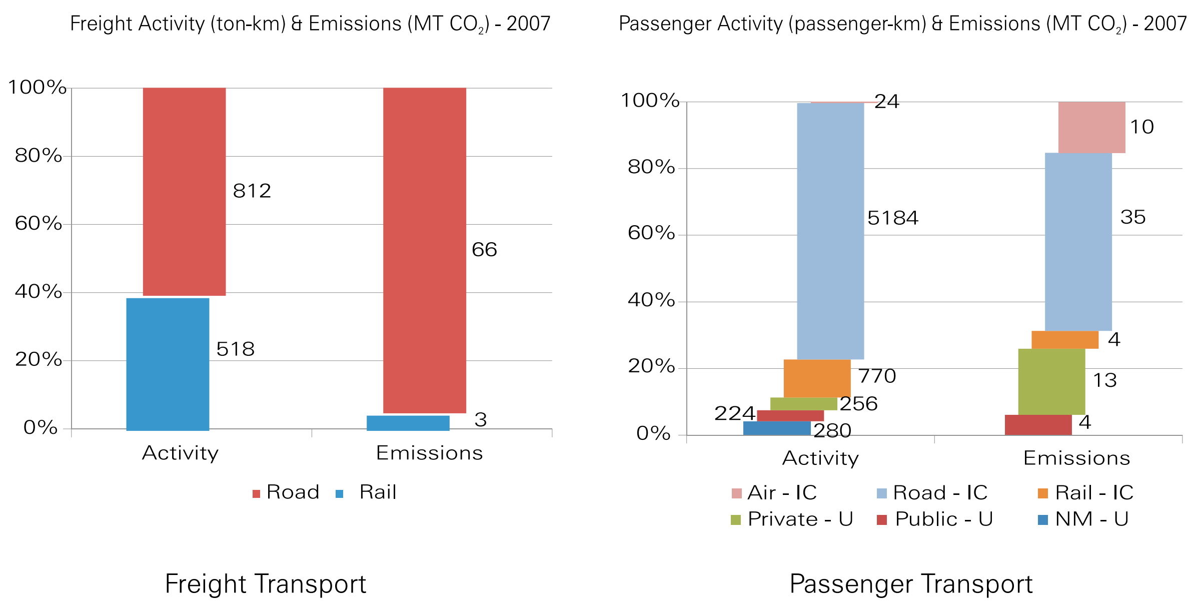
Figure 3.3 depicts the transport activity and emissions from different modes for freight and passenger transport in the country in 2007, with passenger transport further disassembled into urban (U) and non-urban or inter-city (IC) transport. It can be seen that road transport activity is the most significant contributor (about 88 percent) to emissions from the transport sector, while supporting about 60 percent of freight activity (ton-km) and 83 percent of passenger activity (passenger-km). The aviation sector is also important from a GHG emissions perspective since it contributes 15 percent of emissions from passenger transport (and 7 percent of the transport sector) while supporting only 1 percent of passenger activity. In contrast, rail contributes only 5 percent of transport sector emissions[25] while supporting about 40 percent of freight activity and 12 percent of passenger activity. Therefore, reducing GHG emissions from transport sector would broadly require a shift away from road and air towards rail and water (which is even more energy efficient than rail), in addition to improving efficiencies of individual modes. Moreover, within the road passenger sector, there is scope for improvement by increasing the shares of efficient modes such as public and non-motorized transport.

[25] *See NATCOM 2007. This is based on accounting for emissions from electricity generation and use in railways to the power sector.*

3.2.2 Other Studies

[McKinsey 2009, TERI 2006] are two other reports that project India's transport sector activities, energy consumption and emissions, and also suggest options and potential for GHG emission mitigation. We briefly summarize these reports here.

Figure 3.3: Transport Activity and CO_2 Emissions in 2007[26]



Source: NATCOM 2007, MORTH 2007, MOPNG 2009, WSA 2008, DGCA and Indian Railways

3.2.2.1 McKinsey Report

[McKinsey 2009] analyzes different GHG mitigation options and estimates their costs and benefits. In the reference scenario (with GDP growth rate 7.5 percent), it shows an emission elasticity of 0.8 for freight emissions and 0.93 for passenger emissions up to 2030. The mitigation options suggested in this report are:

1. Improving vehicle efficiency.
2. Shifting freight transport from road to railways and waterways.
3. Shifting passenger transport to public transport.

[26] NM-U: Non-motorized (Urban transport), Public-U: Public Transport (Urban transport), Private-U: Private motorized transport (Urban transport), Rail-IC: Railway (inter-city), Road-IC: Road (inter-city), Air-IC: Air (inter-city). Please see the appendix for details about the numbers in this graph.

4. Shifting vehicles to electric and hybrid varieties.
5. Greater penetration of biodiesel.

The report predicts a possible 24 percent reduction of transport sector emissions by 2030 based on these options.

3.2.2.2 TERI Report

This report is not focused so much on GHG mitigation as to map energy requirements and suggest options to minimize energy consumption for various sectors including transport. It predicts transport activity in future under different GDP growth scenarios of 8 percent and 10 percent, based on parameters such as urbanization rate, industrial and agricultural GDP growth, and vehicle stock increase rates. This report predicts elasticity between 1.11 and 1.18 for freight and 0.68 to 0.77 for passenger transport. This again varies significantly from available official data. The energy saving (and hence GHG mitigation) options suggested by the study include:

1. Increasing the share of public transport to 60 percent and share of rail in passenger transport to 35 percent
2. Increasing the share rail in freight movement to 50 percent
3. Increasing efficiency of vehicles
4. Introducing cleaner fuels
5. Increasing electrification of railway tracks

These two reports, as well as reports by IEA and Chella Rajan, predict that the bulk of the increase in energy consumption and GHG emissions is going to be from trucks, cars and motorized two wheelers or MTWs [IEA 2007, Chella Rajan 2010]. The two reports are also in broad agreement over the policy recommendations to mitigate the situation.

3.2.3 Methodology

The long-term (1990 - 2005) elasticity of freight activity to national GDP was around 1.2, while the recent (2000 - 05) elasticity has been about 0.92. On the other hand, the long-term elasticity of passenger transport activity to national GDP was around

1.76, though the recent elasticity has been around 2.0. This increase in passenger transport activity is driven by rising incomes (and hence more motorized trips per-capita) and a huge increase in air passenger traffic. We believe this explosive rate of growth of passenger transport activity will reduce because oil prices are likely to remain high, and because the recent demand spurt has perhaps captured most latent travel demand that was awaiting improved road and air connectivity. Therefore, going forward, we assume freight transport activity elasticity to be 1.0 and passenger transport activity elasticity to be 1.5.

Under these assumptions, the CO_2 emissions from transport in 2020 would be about 476 million tons under 8 percent GDP growth scenario 555 million tons under 9 percent GDP growth in the reference scenario (under which efficiencies and modal shares are unchanged).

3.2.4 Strategy to Reduce Energy Consumption and Emissions

The strategy adopted to reduce emissions from the transport sector is best described as the avoid-shift-improve paradigm[27] which is also described pictorially in Figure 3.4. The elements of this paradigm can broadly be described as follows:

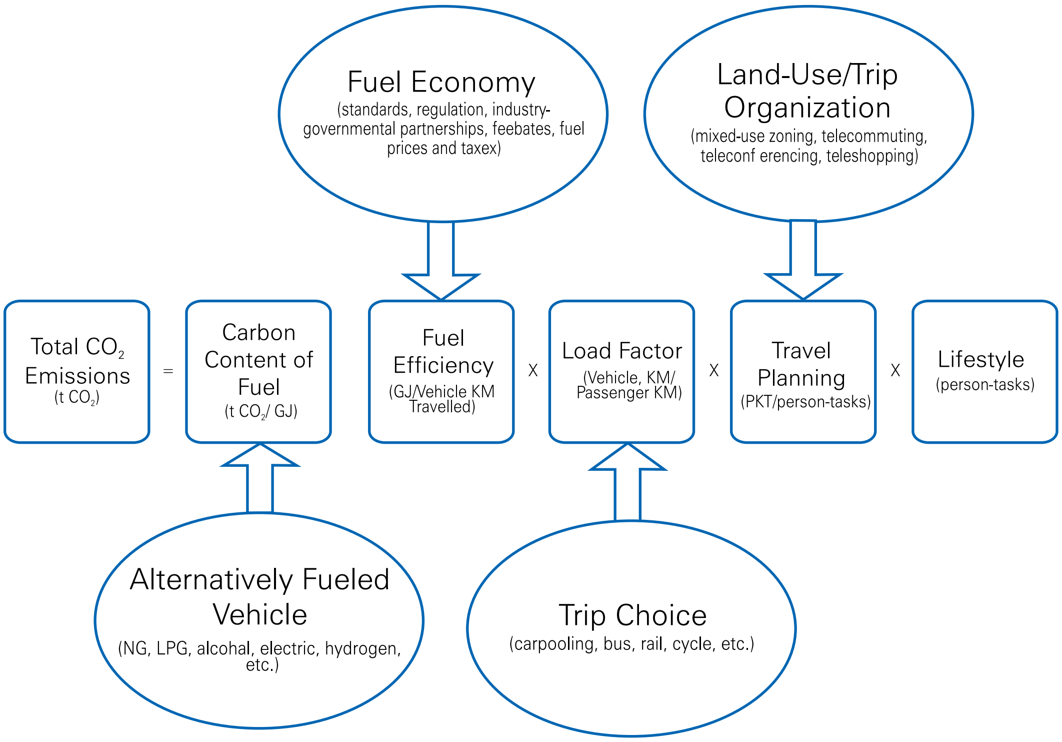
a) Avoid: This element involves designing systems to reduce the need for transport through policies to locate industries so as to minimize movement of raw materials and finished products, and urban planning to minimize commuting needs. These interventions typically impact the right of Figure 3.4.

b) Shift: This element emphasizes the usage of more (carbon) efficient modes of transport. These interventions would typically impact the middle of Figure 3.4.

c) Improve: The focus of this element is to use the most carbon efficient technologies given a mode of transport. These interventions would typically impact the left of Figure 3.4.

27 See for example, Changing course: A new paradigm for sustainable urban transport, Asian Development Bank 2009; and [Sundar 2008].

Figure 3.4: Emissions from Transport Sector



Source: Tellus Institute, 2002

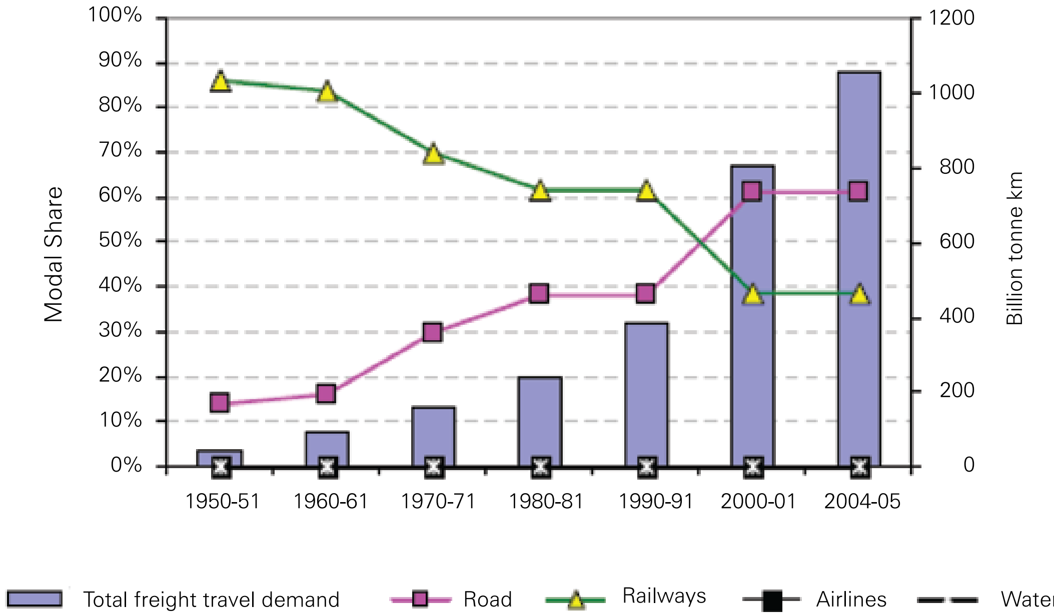
To lower the emission trend and emission intensity, the Expert Group suggests interventions that support efficient modes and technologies, and discourage inefficient ones through policy instruments. The subsequent sections suggest specific interventions broadly aimed at three goals that follow from the strategy discussed above:

1. Increasing the share of rail in freight transport by making rail freight more attractive (SHIFT interventions).
2. Increasing or retaining the current modal shares of public and non-motorized transport in urban passenger transport (AVOID and SHIFT interventions).
3. Improving the efficiency of the current vehicle fleet and its operation (IMPROVE interventions).

3.2.5 Increasing the Share of Rail in Freight Transport

Indian Railways had about 88 percent share of the freight market (in ton-km) in 1950-51, which has fallen to about 40 percent now. The bulk of this lost share of the freight market has been captured by road freight (though the shares seem to have stabilized since the early part of the century) as shown in Figure 3.5.

Figure 3.5: Share of Road and Rail Freight in India



Source: Sundar, 2008

Rail freight is considerably more energy efficient than road. The average energy intensity of rail freight in India (diesel and electric) is about 0.18 MJ/ton-km as against 1.6 MJ/ton-km for road freight[28], i.e. rail freight is about 9 times as efficient as road freight.

Given the distinct possibility of an oil-constrained future and India's rising import dependence, there is an urgent need to arrest and reverse the falling trend of rail share in freight transport. Currently, the highest share of rail freight among the major countries is only around 40 percent - roughly similar to the share in India, though many are actively trying to increase the share of rail in freight. However, given that the share of rail in India is decreasing, and for the reasons of energy security mentioned above, it is advisable to look at interventions that will reverse this trend and set ambitious targets for share of rail freight.

[28] The energy intensity of rail freight is based on official data from Indian Railways and considers total energy input, i.e. including the conversion inefficiencies and transmission losses for electric haulage. The energy intensity of road freight is computed assuming 3.5 kmpl mileage and 6-ton loading of trucks.

As a principle, the idea is that rail should be the major freight mode along key corridors while road, with its much greater reach and flexibility, should be the preferred mode to take the freight from this 'spine' to the interior parts of the country not served by rail.

If railways are to succeed in attracting larger share of freight traffic, as pointed out in the Integrated Energy Policy report, they will have to significantly increase investment in rail infrastructure (including dedicated freight corridors), cut down the cross subsidy from freight to passenger traffic or be compensated for it by the government directly, introduce competition, provide time-tabled freight services, develop multi-modal logistics parks to facilitate door-to-door service, increase containerized cargo movement by rail, adapt to businesses other than bulk cargo business and improve its operational efficiency as reflected in measures such as net ton km per wagon per day and net ton km per employee. It is recommended that a level playing field is provided between rail and road, by providing similar financial and other incentives to rail.

Table 3.10: Annual Savings from Freight Modal Shift[29]

GDP Growth	Determined Effort		Aggressive Effort	
	MT CO_2 Savings	Import Savings (Rs. '000 Cr.)	MT CO_2 Savings	Import Savings (Rs. '000 Cr.)
8%	14	9	22	14
9%	15	10	25	15

With a determined effort, it is expected that there would be a 5 percent modal shift from road to rail by 2020 (i.e. rail would have a share of 45 percent), with the shift assumed to begin in 2012. In the aggressive effort scenario, it is expected that the modal shift would be 8 percent by 2020, i.e. rail would have a 48 percent share of the freight activity. Such a shift would result not only in CO_2 emissions reduction but also a reduction in diesel consumption, thus also resulting in import savings. Table 3.10 summarizes these savings.

[29] Savings calculations assume the modal shift begins in 2012. Energy intensities are based on Indian Railways data and mileage assumptions for trucks. Import savings are calculated using a petroleum import cost of Rs. 19,985/ton (US $63/barrel at Rs 45/$), which is the average net import cost over the last 4 years.

3.2.5.1 Improving the Efficiency of Road Freight

In addition to enabling railways to carry more freight, there is also a need to investigate how road freight efficiency can be improved. India offers highly competitive, low-cost road freight services. However, there is considerable room for improvement in its operational efficiencies. Possible reasons for this include sub-optimal utilization rates of trucks, inefficient border crossing and toll regimes, lack of hub-and-spoke like arrangements for efficient dispersal of heavy loads onto smaller trucks for last mile connectivity, and excess trucking capacity. The industry also needs to move towards more multi-axle and tractor-trailer trucks.

These issues need to be further investigated to identify the key bottlenecks to improvement of road freight efficiency and suggest solutions to overcome them.

3.2.6 Urban Transport: Promoting Public and Non-Motorized Transport

In the reference scenario, we apply the passenger transport elasticity of 1.5 to project urban passenger transport activity[30] and use predicted modal shares as given in [WSA 2008] (see Table 3.11). As can be seen, the shares of non-motorized and public transport decrease gradually while the shares of cars and MTWs increase in the reference scenario. Apart from resulting in increasing energy consumption and emissions per passenger-km travelled, this also leaves out the disadvantaged who cannot afford vehicles and increases the possibility of accidents on the road. This is a consequence of the neglect of non-motorized transport and the inability of public transport to keep up with rising urbanization, and higher incomes facilitating increased motorization.

WSA [2008] states that between 60 to 90 percent of CO_2 emissions in India's urban areas come from cars and MTWs. This is corroborated by Sperling [2004] (which is quoted in the IPCC 2007 report), according to which the emissions per passenger-km of buses are lower than those for cars and MTWs. It must also be kept in mind that non-motorized transport (walking, cycling, cycle-rickshaws etc.) has no direct GHG emissions at all, while these modes currently support about 39 percent of trips in urban India.

[30] *Note that urban passenger activity as projected by [WSA 2008] increases at roughly 5% a year until 2030. This is surprisingly low considering national passenger transport activity data from MORTH indicates that passenger activity has been growing at about 15% p.a, and urban transport activity is likely to increase at least as fast as national passenger activity. Hence, we use the elasticity of 1.5 for urban passenger transport also.*

Therefore, though Indian cities currently have reasonably good shares of public and non-motorized transport, the challenge is to retain and improve their modal shares in the face of current trends. Many cities in Europe (e.g. Amsterdam and Copenhagen) with high car ownership took specific steps to prioritize bicycling as a mode, which has resulted in bicycling now contributing to over 30 percent of trips. This shows that policies and actions promoting such modes can induce a modal shift.

Table 3.11: Decreasing Shares (percent) of Public and Non-motorized Transport

City Category	No. of Cities	Population (lakhs)	2007			2011			2021			2031		
			PT[13]	PV+ IPT	NMT	PT	PV+ IPT	NMT	PT	PV+ IPT	NMT	PT	PV+ IPT	NMT
Category 1-a	4305	1385.3	5	57	38	4	59	36	3	66	31	2	72	26
Category 1-b			8	34	58	7	37	56	5	47	48	3	57	40
Category 2	35	247.9	9	39	53	8	42	50	6	51	43	5	58	36
Category 3	25	323.8	13	43	44	12	46	43	10	52	38	9	57	34
Category 4	5	128.5	10	47	43	9	49	42	8	51	41	8	52	40
Category 5	4	235.3	22	42	36	21	45	35	15	51	34	12	54	34
Category 6	4	549.2	46	24	30	42	28	30	31	40	29	26	46	28

Source: WSA 2008

The interventions suggested in this regard are[32]:

1. Use policies such as National Urban Housing and Habitat Policy to ensure that cities remain dense and of mixed land-use with adequate provisions for housing for the poor to ensure that their travel distances remain small.
2. Develop urban planning guidelines to encourage transit-oriented development, discourage sprawl, rationalize parking policies and charges, and mandate public transport accessibility indicators for large developments, institute intelligent transport systems to enable schemes such as congestion charging.

[31] PT: Public transport; PV: Private motorized vehicles; IPT: Intermediate public transport; NMT: Non-motorized transport

[32] These are largely adapted from [Tiwari 2010]

3. Improve the National Urban Transport Policy (NUTP) by introducing elements such as demand management, rational transport pricing and clear definition of the role for Urban Mass Transport Authority.

4. Improve the JNNURM scheme by improving its Monitoring & Verification mechanisms to ensure that projects are NUTP-compliant, modal shares of public and non-motorized transport are actually improving in cities and infrastructure is friendly for non-motorized transport.

5. Incentivize bus operations in cities by providing capital subsidy and reimbursing taxes and duties paid on fuel.

These interventions will have to be implemented at the central, state and city levels given that various agencies are involved in governing the transport sector. The National Mission on Sustainable Habitat, one of the missions under the National Action Plan on Climate Change, also addresses the issue of de-carbonizing urban transport.

We estimate the range of CO_2 emission savings[33] in 2020 that can result from the above interventions in the determined and aggressive effort scenarios. In the determined effort scenario, we assume that, compared to the expected modal shares in 2020, public transport share increases by 5.5 percent (3 percent from MTWs and 2.5 percent from cars) and non-motorized transport share increases by 3 percent (1.5 percent each from MTWs and cars). In the aggressive effort scenario, we assume that public transport share in 2020 increases by 8 percent (4 percent each from MTWs and cars) and non-motorized transport share increases by 4 percent (2 percent each from MTWs and cars)[34]. The resultant savings in CO_2 emissions and oil imports are given in table 3.12.

Table 3.12: Annual Savings from Passenger Transport Modal Shift

GDP Growth	Determined Effort		Aggressive Effort	
	MT CO_2 Savings	Import (Rs. '000 Cr.) Savings	MT CO_2 Savings	Import (Rs. '000 Cr.) Savings
8%	17	10	24	15
9%	20	12	29	18

[33] Modal share data for 2020 is used from WSA [2008]. Further, for the reference scenario, we assume no technology change in this period and compute emissions using the values given in table 3.16.

[34] The shifts are assumed to begin in 2012. Note that in spite of these shifts, the share of MTW in 2020 is 18% and 17% in the determined and aggressive scenarios respectively compared to its current share of 20%. The modal share of cars increases from a current share of 6% to 11% and 9% respectively.

3.2.7 Improving Fuel Efficiency of Vehicles

Introducing fuel efficiency norms for automobiles is another approach to address the twin problems of energy security and increasing emissions from transport. This can be achieved by the following:

1. Label individual vehicles on a kmpl basis to enable consumers to make a rational choice. This could be accompanied by either a star rating or a mention of the worst and best fuel efficiencies in that vehicle class.
2. Begin with labelling that is based on a continuous function of weight and fuel efficiency.
3. Define a minimum efficiency standard for the country's vehicle fleet.
4. Fuel efficiency can be improved by imposing periodically tightened corporate fleet efficiency standards, with mechanisms to penalize non-conformance. These norms can be GHG based, and efficiency achievements may be traded.
5. Given differential fuel efficiencies and fuel taxation, if the Government desires, it could consider imposing an up-front tax on personal vehicles to absorb the benefits accruing from differential taxation while passing on fuel efficiency benefits to the consumers. However, some members of the group felt such an up-front tax would be unfair to the manufacturers as up-front costs are an important determinant in vehicle choice. It may be better to simply get rid of the relative distortions in fuel pricing by letting petrol and diesel be priced on the same footing, and let fuel efficiency and technology govern the choice of vehicle for the consumers.
6. The norms can initially be defined by BEE or MORTH and implemented by MORTH for cars, and can then be extended to other vehicles such as trucks, buses and two-wheelers.

Each percentage improvement in specific fuel consumption of new cars by 2020 (with no difference in car ownership or usage) will induce a saving of about 0.7 MT CO_2 in 2020 under 8 percent GDP growth and 1 MT CO_2 under 9 percent GDP growth (due to greater car ownership). Therefore, defining the correct norms and quickly implementing them is critical. If we assume a 2 percent improvement in specific fuel consumption per year (beginning 2012) in the determined effort scenario and 3 percent improvement in specific fuel consumption per year in the aggressive effort scenario[35], this translates to CO_2 savings as given in table 3.13.

Table 3.13: Annual CO_2 Savings from Introducing Fuel Efficiency Norms

GDP growth	Savings (MT CO_2)	
	Determined Effort	Aggressive Effort
8%	11	17
9%	16	24

Additionally, some options to modernize the vehicle fleet in the country by replacing older vehicles with newer ones (with better technology and lower emissions) were considered. These included incentives to owners of commercial vehicles older than 15 years to modernize their fleet, encourage owners of private vehicles older than 15 years to replace their vehicles through a suitable tax regime, a vehicle recycling policy and drastic improvement in the inspection and certification regime. However, these were expected to only yield a one-time saving of about 1 MT CO_2 (by 2015) after replacing about 3 million vehicles. Hence this is not being considered further in the report.

3.2.8 Co-Benefits

The interventions suggested above for the transport sector have many other socio-economic impacts whose benefits are likely to be greater than any directly climate-related benefits.

1. Inclusive Growth: The interventions for improvement of public and non-motorized transport will make them more attractive and accessible to the poorer sections of society who are the major users of these modes [Badami 2004]. It will also improve productivity (due to reduced congestion) and safety on the road.
2. Air Pollution: Increased use of rail freight, non-motorized and public transport modes and introduction of cleaner vehicles and fuels will also contribute greatly to reduced air pollution in our cities.
3. Energy Security: The suggested interventions will lead to reduced fuel consumption, in turn, improving India's energy security since most of the

[35] This is roughly in line with international fuel consumption or emission standards [ICCT 2011]

transport fuels are imported. This could translate into a reduction in the annual fuel import bill of up to Rs. 20,500 cr in the 8 percent GDP growth scenario and Rs. 24,500 cr in the 9 percent GDP growth scenario in 2020.

4. Safety: The road safety of India is quite poor, and the suggested interventions in urban passenger transport are likely to greatly improve this.
5. Technical Leapfrogging: Technological innovations and advancements by Indian industry in low carbon technologies will give it a competitive advantage in the global market. The Government can facilitate this through suitable R&D and other incentives for the industry.

3.2.9 Data Issues

Comprehensive and cohesive data on the transport sector is hard to come by, which makes planning harder. A central agency with responsibility to collect and collate all relevant data needs to be created. Such data will help in policy analysis and research, which may be done in-house by the agency or commissioned.

3.2.10 Potential to Reduce GHGs from the Transport Sector

Table 3.14 summarizes the key interventions suggested in this report and the possible CO_2 benefits emanating from them. For 8 percent average GDP growth, total CO_2 savings from the transport sector are estimated to be 41 MT CO_2 in the Determined Effort scenario and 63 MT CO_2 in the Aggressive Effort Scenario. For 9 percent average GDP growth, total CO_2 savings from the transport sector are likely to be 51 MT CO_2 and 77 MT CO_2 in the two scenarios respectively. Thus, if these interventions are implemented, the total emissions from the transport sector in 2020 are likely to be 413 to 435 MT CO_2 under 8 percent GDP growth and 477 to 504 MT CO_2 under 9 percent GDP growth.

The working group on transport discussed the suggestions in this report over a series of meetings and discussions with the stakeholders. Discussions covered not only potential CO_2 benefits of interventions, but also touched upon their inclusiveness and cost. However, not all possible options have been explored in detail in this report. For example, options such as better usage of inland and coastal waterways, highspeed rail as an alternative to air travel and ways of improving non-urban passenger transport have not been explored. These will be taken up in the final report. We also hope to work out detailed costs, barriers for adoption, time for adoption etc. for all suggested interventions.

Table 3.14: Summary of Suggested Interventions and Benefits

Head	Interventions	Saving by 2020 (MT CO_2)	
		Determined Effort	Aggressive Effort
Improving the share of rail in freight transport	▪ Increase investment in infrastructure such as DFCs ▪ Offer terms for private participation that are as attractive as that offered for highway construction ▪ Reduce cross-subsidization of rail passenger transport by rail freight by identifying other revenue sources ▪ Expedite institutional reforms and capacity building in Indian Railways to enable greater market share for railways in fast changing scenario.	8% GDP: 14 9% GDP: 15	8% GDP: 22 9% GDP: 25
Improving the share of non-motorized and public transport in urban passenger transport	▪ Urban planning norms to decrease the need for mobility and enable better walking, cycling conditions ▪ Improve NUTP to include rationalized taxes, demand management etc. ▪ Target oriented JNNURM with better M&V ▪ Capital and operational subsidy for bus operations in cities	8% GDP: 17 9% GDP: 20	8% GDP: 24 9% GDP: 29
Fuel efficiency norms for vehicles	▪ Introduce vehicle labelling/rating systems ▪ Introduce minimum efficiency standards ▪ Introduce corporate fleet efficiency standards	8% GDP: 11 9% GDP: 16	8% GDP: 17 9% GDP: 24
TOTAL		8% GDP: 41 9% GDP: 51	8% GDP: 63 9% GDP: 77

Emission reductions from various options in the transport sector are summarized in Table 3.15 and Figure 3.6 below.

Table 3.15: Summary of Emissions Reduction from Transport Sector by 2020

Growth Rate	Emissions at 8% GDP Growth ($MT\ CO_2$)		Emissions at 9% GDP Growth ($MT\ CO_2$)	
Scenarios	Determined Effort	Aggressive Effort	Determined Effort	Aggressive Effort
CO_2 Emissions at 2007 norms	476	476	555	555
Reductions Due to				
- Increased Freight Share of Railways	14	22	15	25
- Non-motorised & Public Transport	17	24	20	29
- Fuel Efficiency of Vehicles	11	17	16	24
Total Reduction	42	63	51	78
Net Emissions (by 2020)	434	413	504	477

Figure 3.6: Potential Emission Reductions from Transport Sector

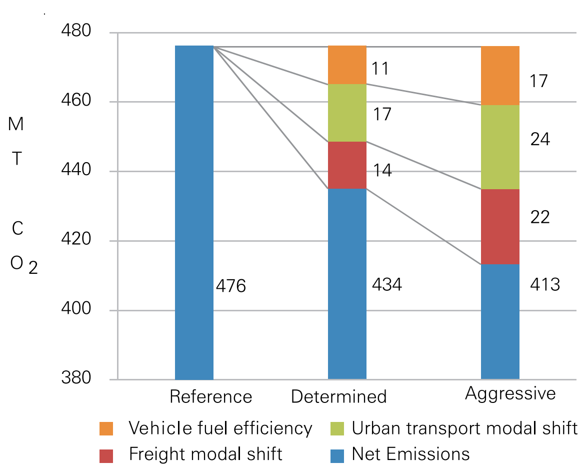


Figure 3.6a: Emissions Reduction by 2020: 8 Percent Growth

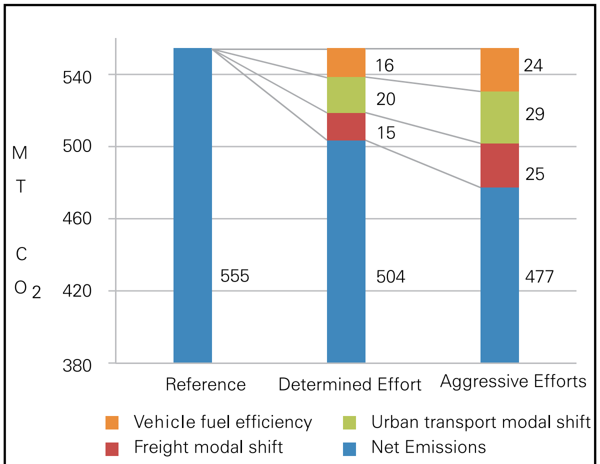


Figure 3.6b: Emissions Reduction by 2020: 9 Percent Growth

Appendix

This appendix explains the numbers shown in Figure 3.3. Transport activity data is taken from [MORTH 2007] while fuel consumption data is taken from [MOPNG 2009, NATCOM 2007]. Urban transport activity is taken from [WSA 2008] and emissions from urban transport are calculated using the assumptions for the vehicle stock in 2007 as given in Table 3.16. We have also classified all rail passenger transport as inter-city though some rail travel is also intra-city. Emissions from electricity used in railways are not accounted here, as [NATCOM 2007] accounts for this under the electricity sector.

Table 3.16: Vehicle Efficiency Assumptions

Parameter	Buses	Two-wheelers	Cars	Three-wheelers
Mileage (kmpl)	3.5	50	10	25
Occupancy	42	1.5	2	1.8

Reconciling official transport activity data with official fuel consumption data indicates vehicle fuel efficiencies that are perhaps on the higher side. However, Figure 3.3 uses official numbers as given, which results in inter-city road transport's emission share being shown as being smaller than its activity share since the activity and emissions for this category is calculated as the difference between overall road-based activity/emissions and sum of the other road passenger activity/emissions. In reality, its share of emissions is likely to be higher than its share of activity.

3.3 Industry

3.3.1 Introduction

Industry accounts for nearly one-third of global energy usage while contributing almost 40 percent to global GHG emissions. With over 35 percent of total energy consumption in the country, the Indian industry is particularly energy & emissions intensive consuming about 6300 PJ energy in 2007 including electricity used by it (LBNL 2009). This represents the second-largest share in the final energy usage after the residential sector. With this energy share the industry sector contributed 29 percent towards the GDP in 2009 (MOSPI, 2011). The Indian industry energy mix is dominated by coal and oil with these two energy sources contributing over half of the energy consumption in industry, the rest coming mainly from electricity and biomass (IEA 2010). And while selected modern Indian units display efficiencies paralleling global best available technology (BAT) levels, the average energy usage in industry lags the world's best levels. The presence of nearly 3 million Small and Medium Enterprises (SMEs) which constitute over 80 percent of the total number of industrial enterprises in the country is partially responsible for this situation. With their limited technological and financial capabilities it is difficult for the SMEs to adopt BATs and become more energy efficient.

Despite the energy intensive nature of the sector, Industry has seen greater energy efficiency improvement since the late 1980s than any other sector in India (World Bank, 2010). Greater competitions following liberalization, high energy prices and government policies since the introduction of the Energy Conservation Act in 2001 have contributed to this trend. Most of the sectors have shown a decline in the energy as well as emissions intensity of production in the recent decades. In 2007, industry as a sector contributed 412.55 MT CO_2 in the form of direct emissions (INCCA, 2010). Of these, Cement and Iron & Steel together contributed about 60 percent of industrial GHG emissions in India in 2007 (MoEF 2010).

This section presents estimates of future emissions scenario of the Indian industry in these two key sectors. A comparison of the 2020 projections of production, emissions & energy intensities of these sectors juxtaposed with the 2007 benchmarks show a potential for significant reduction in the intensities, although, as expected, deeper reductions will entail targeted programs and significant up-front investments.

It should be noted that detailed quantification of emission-intensity-reduction potential takes us into a somewhat grey zone, given the lack of availability of uniform and comprehensive data for the current situation as well as for the future projections. This likely is also the reason for the differences between the estimates that are developed here and those reported by other sources such as CSE (2010), IRADe (2009), McKinsey (2009), and World Bank (2010).

Furthermore, lack of extensive cost data has made impossible the cost estimation of different mitigation measures. Nevertheless, adoption of improved technologies and processes in the industrial sector (including improved generation efficiency and feedstock modification) promises to provide meaningful emissions & energy intensity reduction in the future. If anything, this exercise demonstrates the need for better – comprehensive and uniform – data collection to serve as a foundation for more detailed and robust analyses for informed policy-making.

3.3.2 Iron and Steel

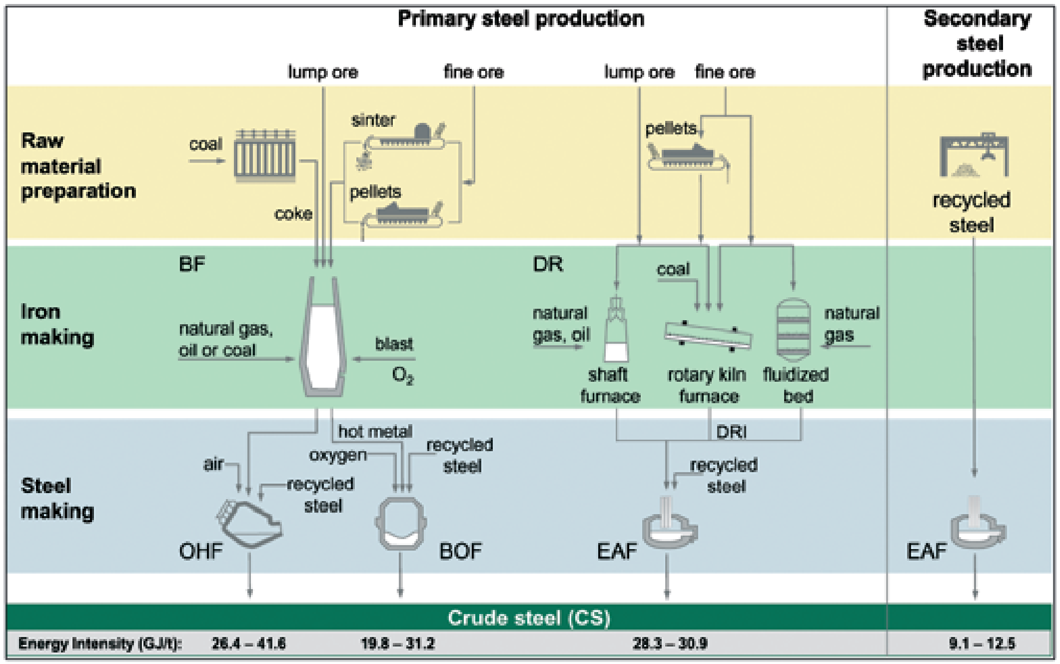
3.3.2.1 Background & Current Status

While steel production in India has a long history – the first plant was set up in 1907 – there was a period of growth in the decades after independence. The plants set up during this period still exist, although they now account only a minority of India's steel production due to the large amount of capacity established in the post-1991 economic liberalization period.

The Indian steel industry has witnessed strong growth in the past decade with the production in 2008-09 at 58.4 million tons of crude steel (mtcs), an increase of over 300 percent since 1994-95 (JPC, 2010). In fact, India now is among the top five steel producers in the world, although it still accounted for only about 5 percent of the global production. The per-capita consumption of the country remains low – 45 kg of finished steel in 2008, which was about a quarter of the global average (World Steel Association, 2010). Most major industrialized countries still use significant steel – the US per-capita consumption was about 7 times, Germany 11 times, and Japan almost 14 times that of India in 2008; even industrializing countries such as China and Korea use about 7 and 26 times more steel than India on a per-capita basis (World Steel Association: World Steel Facts 2010). Not surprisingly, as the country builds up its infrastructure & the economy expands, a burgeoning demand is expected.

Beyond the impressive growth in steel production in recent years, the Indian steel industry has also undergone a shift in terms of the process, and concomitantly, energy and carbon intensity. As Figure 3.7 illustrates, there are multiple routes for producing steel with substantial differences in the underlying energy and emissions intensities. Primarily, two process routes dominate worldwide steel production: Blast Furnace-Basic Oxygen Furnace (BF-BOF) and Electric Arc Furnace (EAF, using scrap steel or the Direct-Reduced Iron (DRI) inputs). Both of these are in use in India, in addition to a third route -- Induction Furnace (IF), which relies on electrical induction heating to melt the iron. The high share of inefficient technologies and the dominance of the coal-based-DRI process for providing input into the steel production all contributed to the relative inefficiency of Indian steel production until the 1990s.

Figure 3.7: Steel Production Routes & Energy Intensity Per Route (GJ/tonnes of crude steel produced)



Source: World Steel Energy Fact Sheet

This figure is for illustrative purposes only; the actual steelmaking process can vary with facilities.

In the last decade or so, though, the process paradigm of the steel sector in India has changed with the highly-inefficient open-hearth furnace (OHF) process route almost disappearing, production through the BOF & EAF routes growing and Induction Furnaces (IFs) emerging. Within the BOF route, many of the older plants have been upgraded (but there still remain some very inefficient units such as modified open hearths). At the same time, there has been significant addition of capacity both by existing as well as new players in the post-liberalization era with many of the new plants being world-class in their energy and GHG performance, Within the EAF route, scrap now forms a not-insignificant fraction of the input (~20 percent), which contributes to improvement in efficiency of production. The IF route, though theoretically much cleaner than the BOF route, has not been particularly low on energy and emissions intensity (partly because they use sponge iron (i.e., DRI) as an input rather than costlier scrap and because these are smaller units are not focused on improving energy efficiency). Moreover, the disappearance of emissions-intensive OHF route has also improved the overall emission intensity of steel production in the country. Further, there has been a secular decline in the energy and emission intensities of the BOF and EAF routes through retrofitting of old plants and adoption of efficient technology in the Greenfield plants.

By 2008, the process mix in the Indian steel industry comprised 40 percent production through the BF-BOF route and 60 percent using the electrical routes. The corresponding global average figures were 67 percent production from BF-BOF process and 31 percent from the electrical processes (World Steel Statistical Yearbook 2009). IFs accounted for about 18 mtcs of production[36] (i.e., over half of the electrical-based production in India). Interestingly, in 1994, the electrical route accounted for only 26 percent of the crude steel production in India (Steel Statistical Yearbook 1995); thus there has been a significant growth in electrical-based production capacity in India in the past decade and half.

Beyond these variations in the production of crude steel, in 2008 only 65.9 percent of the steel was processed using continuous casting technique, which is more efficient than ingot casting. This fraction is far lower than the global average of 90.7 percent (but it should be noted that in 1994, only about 22 percent of the crude steel production in India was cast continuously)

As a result, the past years have seen a decrease in Specific Energy Consumption (SEC) and emissions intensity of steel production in India with convergence in the values reported by different plants, albeit some old plants still have quite higher SEC values. Even though the SEC values in Indian plants have declined from 42 GJ/MT in 1990 and 36.4 GJ/MT in 1995 to 28.9 GJ/MT in 2007 (LBNL 2009) and are still decreasing (27.3 GJ/MT in 2009), they compare rather poorly against the SEC values in countries like Japan (23.3 GJ/MT - 2004), US (20.1 GJ/MT - 2001) & China (25.6 GJ/MT - 2001) (CSE 2010). This is partly due to higher recycling rate that these countries (except China) have in comparison to India. The emissions intensity of steel production in India was estimated at 2.21 MT CO_2-eq. /tcs in 2007[37].

[36] Based on data obtained from the Ministry of Steel and discussion with industry experts
[37] Computed based on the 2007 INCCA numbers

3.3.2.2 Options to improve Carbon Efficiency

The following interventions have significant potential to lower energy and emissions intensity in Indian steel plants: a) adoption of more efficient technologies for the principal process systems, also called “mother technologies”; b) adoption of technologies for energy recovery and conservation; and c) adoption of technologies for raw material enhancement.

Technology adoption for improving the principal process systems would improve the efficiency of steel production significantly. The BF-BOF plants can reduce their emissions through an all encompassing adoption of continuous casting, and integrated casting & rolling operations (IEA, 2010). A shift towards DC arc technology for the electric furnace steel production is estimated to improve the process efficiency by over 5 percent with other advantages like improved melting efficiency and increased hearth life (NEDO, 2008). Technologies like LD convertor, cold rolling and slab casting have been adopted by several plants in the Indian steel sector, while a more encompassing adoption of these technologies in existing plants would provide a further scope for intensity reduction (CSE, 2010). Further, newer smelt reduction technologies like COREX & FINEX obviate the need for coking and sintering plants by using non-coking coal with lump ore and pellets as inputs. This is particularly attractive in India, where coking coal availability is a major issue for the steel industry.

For energy recovery and conservation an emerging technique in the steel industry that promises energy savings of over 1 GJ/tcs is the Coke Dry Quenching (CDQ) technique. CDQ is a process that quenches carbonized coke using an inert gas; the heated gas is then used to generate electricity, thus affording energy benefits over the conventional wet quenching. With about 90 percent Indian plants yet to adopt CDQ (IEA, 2009), a potential for energy savings is being underutilized. The adoption of Top Pressure Turbine (TPT), a power generation system for converting the physical energy of the high pressure blast furnace top gas, also promises an energy saving of up to 0.6 GJ/tcs (NEDO, 2008). Further, several waste heat recovery technologies are available to tap into the process waste heat and convert it into useful energy. The adoption of an automated monitoring system for ensuring process optimization in the plants would also reduce the energy and emissions intensity of steel production. This intervention would however require availability of modern control systems and trained personnel to operate them.

A major source of energy use and ensuing emissions in the steel industry is the process of raw material processing, with coke making and sintering processes representing over 15 percent of the total energy consumed in steel making (CSE, 2010). The use of Pulverized Coal Injection (PCI) over the conventional coke usage also results in energy and emissions saving by obviating the energy intensive coke making process, and should be adopted more widely by the plants (NEDO, 2008). Further, waste heat recovery from the cooler used to cool heated sintered ore could provide medium heated steam that could be put to use for power generation. This technology in the form of a Sintering Machine cooler waste heat recovery device can lead to savings of about 0.25 GJ/t-SI (Sintered steel) (NEDO, 2008). Next generation coke making technologies (SCOPE21) offer more flexibility in terms of coal resource quality and provide reductions in energy & emissions intensity of the coke making process (NEDO, 2008). The SCOPE21 technologies are thus ideal candidates for adoption by the Indian industry. The BF-BOF production route provides for molten steel manufacture through a convertor; this process entails the generation of a large amount of heated gas which could be used for heat recovery. The heat recovery could be done either by combustion method or a non-combustion method (OG method) resulting in savings of up to 0.8 GJ/t PI (Pig Iron) (NEDO, 2008).

Intervention in the form of raw material enhancement could also help in lowering the overall energy consumption in the sector. With the quality of both feedstock (iron ore) and the fuel (coal) available in India being below the world average norms, it becomes necessary that beneficiation processes for iron ore and coal are adopted by plants using domestic supplies. Other efficiency improvement measures that could be widely adopted by the industry include use of tar in blast furnaces; carbon monoxide firing in vertical shaft kilns; and adoption of multi-slit burners. Further, general energy saving practices viz. installation of variable frequency drives; use of high-efficiency motors, pumps, and blowers; improved insulation of furnaces; and replacing electric heaters with fuel-fired heaters could incrementally reduce energy usage in the plants (World Bank, 2010).

3.3.2.3 Future Projections

To assess future emission intensity we need to project future steel production, the technologies that may be adopted by new greenfield plants and the improvements that may be retrofitted by brownfield plants.

There is wide variation in the projections for the growth of the Indian steel industry. The National Steel Committee had estimated in 2005 that by the year 2020, the production of steel in the country would reach 110 MT. Subsequent projections by the Ministry of Steel, based on an assessment of ongoing projects and the MOUs executed, suggested that India's steel capacity would be nearly 293 million tons by 2020. The 2005-2020 growth in steel production estimated by the World Bank yields production of 117 MT, IRADe model projects 144 MT, and CSE projects (CSE 2010) 137 MT by 2020.

Steel consumption over the 2001-2007 period indicates an elasticity of 1.33 with respect to GDP growth. Assuming an 8 percent growth rate for the Indian GDP till 2020, the annual growth rate for steel sector would be 10.67 percent[38]. Projections based on this growth rate yield a production figure of approx. 200 MT for 2020. Given the strong demand in recent years and future growth expected in the Indian economy, this figure of 200 MT seems achievable, and also reasonable.[39] With 9 percent growth, the corresponding production figure would be 240 MT.

Policies over the last decade have been able to induce large steel plants to opt for energy saving technologies, albeit slowly, while they has had a limited impact on the smaller producers. The efficiency of greenfield plants has been better with a reasonable penetration of newer technology. Since a large fraction of greenfield capacity is expected to be large plants based on blast furnace, one can expect gradual improvements in the overall emissions intensity of Indian steel sector under the existing policy.

With limited emphasis on ensuring appropriate raw material mix by the IF plants, the mitigation potential of such plants is not likely to be realized. Then again, the increasing cost of power is expected to increase the adoption of waste heat recovery interventions by the plants, even though, with limited adoption in smaller plants owing to the capital intensive nature of such interventions. Although some Indian steel producers have demonstrated an ability to indigenise & improvise upon imported

[38] Computed using the elasticity of consumption growth in the steel sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 8%. Consumption growth is assumed to be a close metric to assess the manufacturing sector growth. Steel consumption data are from World Steel, 2010.

[39] In our discussion with industry experts, there is concurrence that the projected number of 293 MT is too high and that 200 MT is more realistic estimate.

technology (e.g. COREX improvisation by JSW), there has been limited policy support for formalization of R&D in this sector. Under these circumstances, the development, adaptation and adoption of newer technologies would be slower and sporadic across the sector. Under the present policy scenario, much of the future production growth is expected to occur via the BF-BOF route, subject to the availability of coking quality coal in the country (with sizeable imports). Moreover, smelt reduction technologies such as COREX & FINEX, which are better suited for Indian coal properties, would also be expected to increase their contribution. The DRI-EAF route is expected to have a stagnant production, with scrap availability constraints & little interest from the large steel makers who are now foraying or expanding into the Indian steel sector. Similarly the IF route for production is expected to grow, albeit slowly as compared to the overall sector.

The Determined Effort Scenario played out till 2020, would impact the efficiencies of plants employing alternate process routes differently. Existing plants, employing the BOF route have been able to decrease their emission intensity at a rate of approximately 1 percent per year in the recent years primarily through technology interventions. These improvements are expected to continue in the future, with several technology options available for the BOF plants. The existing EAF plants, plagued with 'higher than world average' intensities, are also expected to improve efficiencies at a rate of about 1 percent per annum, partly due to better availability of scrap in the future. However, the IF plants, which represent almost 30 percent of the 2007 steel production, are expected to continue their operations with the present emission intensities. Lack of strong policies for intensity reduction and quality checks in steel production would allow these plants to continue operating with their present intensities.

New capacity addition via the BOF route is expected to get more efficient in the future, albeit with more encompassing adoption of all available technology interventions. A typical greenfield plant in 2020 is expected to be over 10 percent more efficient than a greenfield plant setup in 2006 (by our estimates). The capacity addition through the EAF route is expected to be quite small, with limited scope for efficiency improvement over the existing Brownfield plants. The capacity addition through the IF route is expected to maintain its 2007 emission intensities till 2020, much due to the lack of policy push for improvements. With such technology and process mix, implementing the existing policy regime in future is expected to reduce the emissions intensity of steel production in India to 2.03 MT CO_2-eq/tcs, thus, entailing overall emissions of approx. 406 MT CO_2-eq.[40]

The emissions intensity of the sector potentially can however be brought as low as 1.8 MT CO_2-eq/tcs[5] under the Aggressive Mitigation Regime. Policy regulations and incentives that ensure an appropriate raw material mix for the IF plants and closure of unsustainable capacity, could help in mitigating the 'above average' emissions from these plants. Consequently, under the aggressive policy push, production through the IF route could decline by around 50 percent over its 2009-10. The future production capacity addition under such a scenario would be expected to occur largely through the blast furnace route: the BF-BOF accounting for nearly 60 percent and the smelt reduction route (COREX/FINEX) accounting for another 25 percent. As a result of the stunted growth through the IF route, under an aggressive policy regime, the DRI-EAF route is expected to experience a secular growth, contributing around 10 percent of the total steel production in 2020. To achieve the aggressive emissions reduction objective, technology transfer support, including financial support for technology interventions for the smaller plants needs to be ensured through government intervention. The industry could also formalize collaborative R&D to facilitate both technology development & adaptation. Several emerging technologies like COREX are better suited for Indian feedstock and coal quality; further exploration into these technologies needs to be done by the industry along with timely adoption of suitable technologies. The industry also needs to adopt energy recovery and conservation technologies in an encompassing manner so as to further decrease energy consumption in these plants.

Under the aggressive policy regime, the Brownfield plants employing the BOF route are expected to reduce their emissions intensity by over 1.5 percent per annum. Similarly, the existing EAF plants are expected to improve their efficiencies due to better scrap availability and employment of available technology interventions. The existing IF plants on the other hand would have limited efficiency improvement due to better scrap availability, as not much technology intervention is expected in this process

[40] *Based on technology & other intervention mitigation potential estimates from literature with inputs from experts under the corresponding policy scenario, with the intervention regime outlined in the text.*

route (and no new IF plants are expected under the aggressive policy scenario). If a majority of plants in India adopt an appropriate intervention mix in the form of above mentioned technologies and the process-mix of Indian industry excludes the less efficient processes (IF): the overall emissions from the steel sector are expected to be about 362 MT CO_2-eq in 2020. Table 3.17 summarizes the projected penetration of technologies and resulting emissions intensities from steel production.

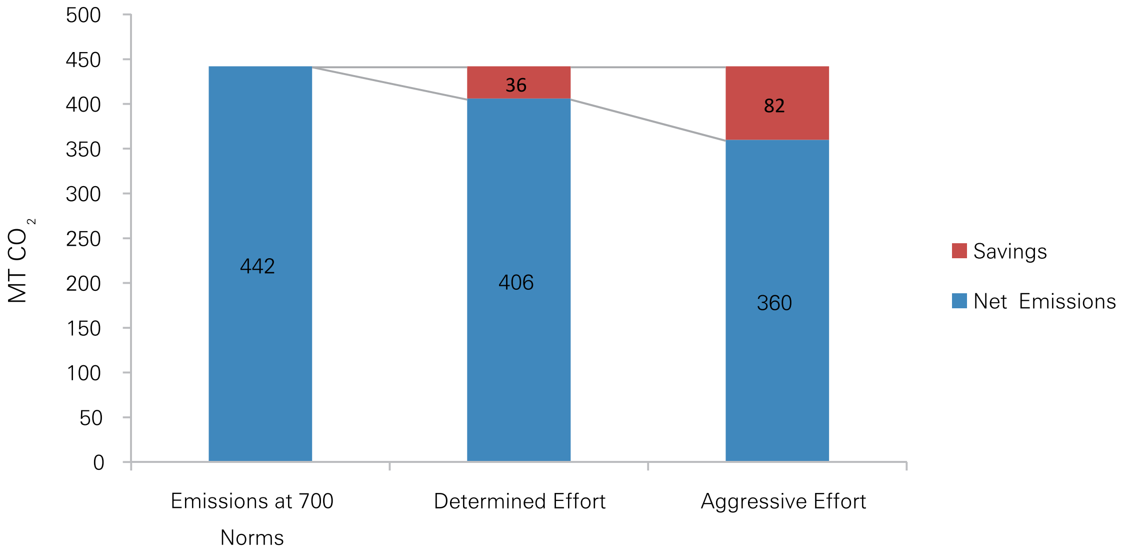
Table 3.17: Projected Penetration of Technologies & Resulting Emissions under Different Scenarios

Process	Production by Process (MT)			Emission Intensities (T CO_2 / T of Steel)				
	2007	2020		2007	2020 (Determined Effort)		2020 (Aggressive Effort)	
		Determined Effort	Aggressive Effort		Old Plants	New Plants	Old Plants	New Plants
BF-BOF	25	115	120	2.3	2.1	2	1.95	1.8
COREX/FINEX-BOF	3	40	50	2.21	2.1	2	1.95	1.8
DRI-EAF	10.5	15	20	1.75	1.75	1.7	1.7	1.6
IF	14.5	30	10	2.5	2.5	2.4	2	N/A

To conclude, the steel sector, due to its scale of production and energy intensive nature, represents a sizeable opportunity to reduce CO_2 emissions from the Indian industry. At 8 percent GDP growth rate, production is expected to reach 200 MT in 2020. At 2007 energy and emission intensities, this production would entail 442 MT CO_2-eq as emissions in 2020. The reduction potential for the Indian steel plants through technology interventions and process-mix changes is estimated to be in the range of 8.3-18.7 percent by 2020 over the 2007 levels, depending on whether one continues with the Determined Effort Regime or implements an Aggressive Mitigation Regime. This would imply the GHG intensity of steel production in India coming down from present levels to 1.8-2.03 MT CO_2/tcs, resulting in overall emissions in the range of 360-406 MT CO_2-eq by 2020.

The corresponding production, emission intensity and emission-intensity reduction estimates for 9 percent GDP growth are 240 MT, 1.8-2.03 MT CO_2/tcs and 8.3-18.7 percent by 2020. As a result, under the 9 percent growth paradigm, the overall emissions from the Steel sector are expected to lie in the range of 432-488 MT CO_2-eq by 2020.

Figure 3.8: Emissions Reduction from Steel Sector



3.3.3 Cement

3.3.3.1 Background & Current Status

The cement industry in India has been growing at a strong pace with an average annual growth rate exceeding 8 percent for the past three decades. The total production in 2007 was 165 million tons, up from 63 million tons on 1995 (CMA estimates). India is now the second largest cement producing country in the world, albeit its per-capita consumption in 2008 of approx. 150 kg is almost a third of the world average, half that of the US, one-third that of Japan, and one-seventh that of rapidly-industrializing countries such as China and South Korea (Report of the Working Group on Cement for the 11th Five Year Plan, Planning Commission of India, 2007). With strong demand impetus fuelled by the construction boom and infrastructure development in India, this sector is also poised for high growth.

The Indian cement industry comprised, as of March 2009, of 148 large cement plants and 365 mini-cement plants, with installed capacities of 219 MT and 11 MT respectively.[41] Indian cement industry, the largest consumer of power among the industry, has managed to attain high efficiencies comparable to the best in the world. The rapid expansion in the sector has been leveraged by the manufacturers to upgrade

[41] *http://www.cmaindia.org/industry.html*

their production methods and employ the best-available technologies in production. The more energy intensive wet-process technology has seen its share in the process mix decline from 97 percent in 1950 to just 3 percent in 2007 with an almost blanket adoption of the more-efficient dry-process technique (CMA 2009). The production mix in the Indian cement industry is characterized by a large proportion of blended cement (which consumes less energy and is less emissions intensive than ordinary Portland cement). Although the market share of blended cement in India at 60 percent was much higher than US (4 percent), China (40 percent), Japan (25 percent) (2005 data), the percentage of blending material in blended cement needs to increase further (CMA 2009). This low percentage of blending material in Indian cement has lead to a clinker/cement ratio of over 0.86; compared to China's average of less than 0.74 and the world average at around 0.79 in 2007 (IEA, 2009). Clinker production is quite energy and emission intensive compared to primary blending materials (like fly ash & slag), with a result that a higher clinker/cement ratio indicates more energy and emission intensive production.

The SEC (Electrical) values for cement manufacturing in India have been decreasing over the past few years: the 2005-06 SEC (Electrical) value of 77.6 KWh/ton has decreased to 75 KWh/ton in 2007-08 (NECA, BEE 2010) and these values compare quite favorably with the world average. The same is the case with fuel usage in cement manufacturing, where the Indian figure of 3.3 GJ/MT is better than the world average of 3.6 GJ/MT and close to the BAT figure of 3 GJ/MT (LBNL, 2009).

The cement industry has decreased its emissions intensity from 1.04 MT CO_2/MT cement in 1995 to about 0.79 MT CO_2/MT cement in 2007. Decrease in the share of inefficient wet process from 12 percent in 1999 to around 2 percent in 2007 has also contributed to this emissions decrease. The share of blended cement has also increased from less than 30 percent in 1994 to over 70 percent in 2007 (CMA, 2009). Since blended cement has a lower clinker percentage and consequently lower emissions intensity, this shift towards blended cement has reduced the overall emissions intensity of cement production in India. Further, the use of multi-stage pre-heaters and pre-calciner kilns indicated in the BAT by most Indian plants has contributed to decreasing the energy and emissions intensity of clinker production in India (CSE 2010).

The contribution of the cement industry towards CO_2 emissions was 129.9 MT in 2007,[42] with an emissions intensity of around 0.79 MT CO_2-e /MT cement. This figure may be compared to the US cement industry that emitted 0.97 MT CO_2 / MT cement in 2002.

3.3.3.2 Options to Improve Carbon Efficiency

The Indian cement industry has managed to adopt five to six stage preheated dry kiln process in majority of plants thereby improving their energy efficiency considerably (IEA, 2009). However, there is scope for further penetration of the BATs in the sector through retrofitting of the existing plants (which is limited to some extent by the capital investment requirements).

Increase in the blending percentage would directly offer options for emission reduction. Usage of waste materials (less carbon intensive than coal) for fuel substitution offers scope for substantial efficiency improvements in this sector. With some European Union countries already having an average substitution rate of over 50 percent, the fuel substitution rate is expected to increase in India with its extent dependent upon the provident policy push (Cement Technology Roadmap 2009).

Waste heat recovery and cogeneration can reduce emissions. Japanese plants have reported a potential emission saving of up to 0.06 MT CO_2/MT cement through co-generation (NEDO 2008). However, Indian plants utilize part of the process waste heat in drying of the feedstock materials and coal (which have higher moisture content than the global average), thus resulting in a reduction in the cogeneration potential. In spite of this characteristic the absolute amount of waste heat generated in Indian plants is enough to provide for meaningful co-generation, more so with the increasing captive power costs.

Other technology interventions like vertical roller mill technology, fluidized bed cement fired kiln system, and use of mineralisers could further reduce the carbon intensity of Indian cement production (CSI/ECRA, 2009). However, a caveat goes with the emissions reduction potential of the above mentioned interventions when seen together- these improvements are not additive, with the interventions having an impact on each other's reduction potential. For example, increase in the use of

[42] *Computed based on the 2007 INCCA numbers*

alternative fuels (which could have higher moisture content) can increase specific energy consumption in clinker production. The actual reduction achievable by a plant would depend on the feedstock quality and the 'mix' of technology & other interventions adopted.

3.3.3.3 Future Projections

Strong growth in the cement sector is expected to emanate from the growing emphasis on infrastructure development in the country. As in the steel sector, future growth projections for the sector by previous reports shows a wide range of estimates: 440 MT (CSE, 2010), 427 MT (projections by IRADe model (IRADe, 2009) with potential to grow up to 600 MT (CSE, 2010; IEA, 2009). Projections from the Planning Commission also suggest high growth, reaching around 600 MT cement production in 2020. Cement consumption during the 2001-2007 period suggests a growth elasticity of 1.1 with the GDP. Assuming an 8 percent growth rate for the Indian GDP till 2020, the annual growth rate projection for steel sector stands at 8.78 percent.[43] Projections based on this growth rate yield a production figure of approx. 500 MT for 2020. With a 9 percent GDP growth, the production would be expected to be 570 MT.

Previous efforts for the domestic cement manufacturing sector have been well directed and have resulted in improvements in the efficiencies of clinker production processes through an efficient transfer of secular improvements in the BATs to the plants. Withal, policy efforts for getting down the barriers associated with increased blending and fuel substitution in the sector have been limited. Playing out the Determined Effort regime over the next decade would result in an efficiency improvement characterized by a highly efficient clinker production albeit with lower blending (compared to the world average) and low fuel substitution in the plants. The clinker/cement ratio for Indian cement is expected to decrease to 0.8 by 2020 driven primarily by financial incentives of using lesser amounts of costly power. However, fuel substitution faces several logistic hurdles in become more widely prevalent under the current regime – only a fuel substitution of around 5 percent in expected by 2020. Moreover, the penetration of BATs for smaller cement producers would remain below

[43] Computed using the elasticity of consumption growth in the cement sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 8%. Consumption growth is assumed to be a close metric to assess the sector growth. Cement consumption data provided by the Planning Commission

its potential owing to the institutional and financial barriers for these plants to adopt the BATs including cogeneration.

Effective implementation of the Determined Effort regime over the next decade with the clinker/cement ratio decreasing to 0.8 by 20202 and a fuel substitution of around 5 percent would lower the emission intensity to 0.67 MT CO_2/MT cement by 2020[44]. Overall emissions from this sector under such a scenario are projected to lie in the range 336 - 383 MT CO_2 range for 2020.

A more aggressive policy push towards lower emissions would incorporate new policy interventions to increase blending in cement, and increase fuel substitution for the cement plants. Regulatory policies to ensure quality control for blending materials would be needed for a more encompassing adoption of increased blending by the cement plants and for such cement to fulfil the standards set by the Bureau of Indian Standards (BIS).[45] This would require that blending norms and standards for the cement varieties be modified after requisite testing and availability of high quality slag & fly-ash, at reasonable price with a stringent quality control enforced by the BIS. Moreover, provision of requisite pre-blending processing technology is a must before adopting this intervention comprehensively. Under such a policy regime, the clinker/cement ratio for Indian cement could go down to 0.75 by 2020.

A similar push is required to ensure operational waste collection and processing, with a standardization and simplification of the waste handling & treatment procedures to facilitate fuel substitution by the Indian cement plants. Provision of incentives for consumption of hazardous waste materials (e.g., as in Japan) by the cement plants could further the penetration of the fuel substitution interventions increasing the adoption rate to over 10 percent by 2020. Technology adoption in terms of secular efficiency improvement for BATs could be turned aggressive through better tracking of technology improvements and by facilitating the transfer of identified suitable technologies to the entire cement industry. Increasing energy costs and incentives for improving energy efficiencies (e.g. the Bureau of Energy Efficiency's Perform, Achieve, and Trade (PAT) program) would also incentivize adoption of BAT technologies by the Indian cement industry.

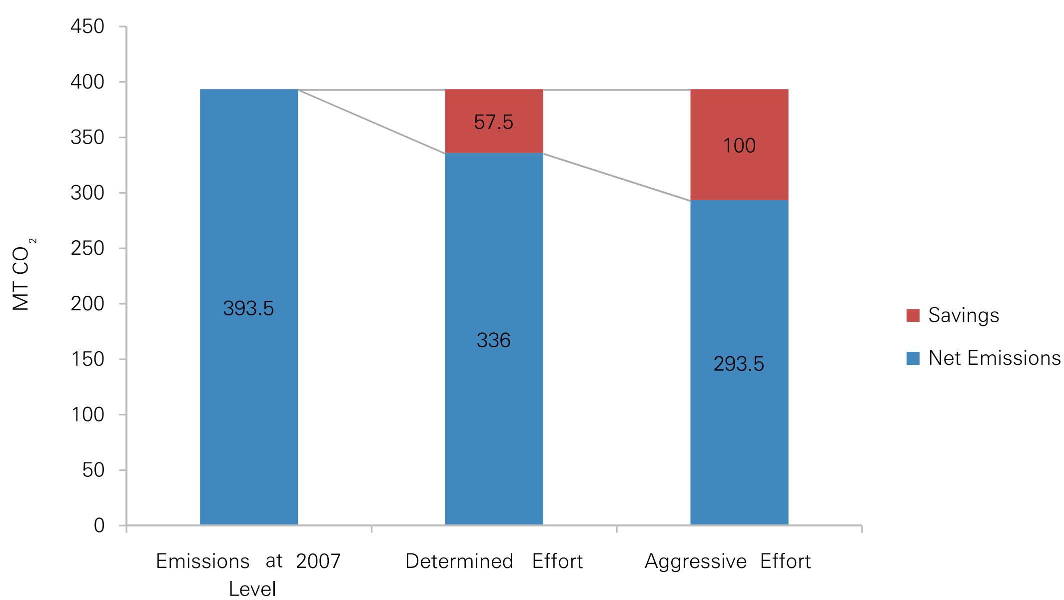
[44] *Based on technology & other intervention mitigation potential estimates from literature with inputs from experts under the corresponding policy scenario, with the intervention regime outlined in the text.*
[45] *Based on discussion with industry experts.*

In general, companies operating a small number of cement plants (one or two) have not been able to adopt the BATs due to limited financial resources. With the evolution of newer technologies such firms may require greater assistance for their use under Indian conditions (raw material and coal quality milieu). This would entail financial support for the smaller cement plants as well as a more comprehensive technology support arrangement than at present. Smaller plants would also need support for adoption of expensive interventions like cogeneration. However, financial attractiveness of cogeneration could improve with increase in the cost of captive power cost.

Another emerging area that may require policy interventions is that of low carbon cements. With an active ongoing research in the area, the developments are expected to be protected by IPR, and such technologies may require policy efforts for transfer to smaller firms.

Under the Aggressive Effort Regime the clinker/cement ratio could come down to 0.75 by 2020, fuel substitution with the adoption of newer technologies could increase to 10 percent, and adoption of BAT by smaller units could lead to 1.8 percent per annum decrease in emissions intensities. This could see the emissions intensity of Indian cement industry coming down to 0.59 MT CO_2/MT cement, resulting in around 293.5-335 MT GHG emissions in 2020.[46]

Figure 3.9: Emission Reduction from Cement Sector



[46] *The range of emissions corresponds to the range of production projected for 2020; the lower overall emission corresponds to a lower production projection.*

Table 3.18 summarizes the projected emissions intensities from cement production under the 8 percent GDP growth regime.

Table 3.18: Projected Emissions from Indian Cement Sector in 2020

Production Estimate	Production by Process (MT)			Emission Intensities (T CO_2/ T of Cement)				
	2007	2020		2007	2020 (Determined Effort)		2020 (Aggressive Effort)	
		Determined Effort	Aggressive Effort		Old Plants	New	Old Plants	New Plants
8 % GDP growth (approx. 500 MT)	165	361.8	361.8	0.8	0.68	0.669	0.63	0.57

In conclusion, if cement plants in India maintained their 2007 energy and emissions intensities, the cement production in 2020 would emit around 393.5 - 448.5 MT CO_2 compared to 129.9 MT in 2007. Under the 8 percent GDP growth regime, the reduction potential for the Indian cement plants through technology interventions, fuel substitution and increased blending has been estimated to be in the range of 14.6-25.4 percent by 2020 over 2007 levels (under the determined effort and aggressive effort mitigation regimes); and this would mean the GHG intensity of cement production in India coming down from present levels to 0.59-0.67 MT CO_2/MT. These intensities and production figures would result in the overall CO_2 emissions from the cement sector in 2020 to be in the range 293.5-336 MT.

The corresponding production, emission intensity and emission-intensity reduction estimates for 9 percent GDP growth are 570 MT, 0.59-0.67 MT CO_2/tcs and 14.6-25.4 percent respectively (under the two regimes). As a result, under the 9 percent growth paradigm, the overall emissions from the Cement sector are expected to lie in the range of 334.5-383 MT CO_2-eq by 2020.

Table 3.19 presents emission-related data for 2007 and estimates for 2020 under the determined and aggressive policy push for these two sectors.

Table 3.19: Emission-related Data (2007 baseline and 2020 estimates) for Major Industry Sectors

		Cement	Iron & Steel	Cement	Iron & Steel
		8% GDP Growth (2007-2020)		9% GDP Growth (2007-2020)	
2007	Total Emissions (MT CO_2-eq.)	129.9[1]	117.3[2]	129.9[1]	117.3[2]
	Production (MT)	165[3]	53.1[4]	165[3]	53.1[4]
	SEC (GJ/MT)	3.3[5]	28.9[6]	3.3[5]	28.9[6]
	Emissions Intensity (MT CO_2-eq./MT)	0.79	2.21	0.79	2.21
2020 Estimates	Reduction in Emissions Intensity	14.6-25.4 % [7, 8]	8.2-18.6 % [9,10]	14.6-25.7 % [7, 8]	8.3-18.7 % [9, 10]
	Emissions Intensity (MT CO_2-eq./MT)	0.59[11] - 0.67[12]	1.8[11] - 2.03[12]	0.59[11] - 0.67[12]	1.8[11] - 2.03[12]
	Production (MT)	500[13,14]	200[15]	570[16]	240[17]
	Total Emissions (MT CO_2-eq.)[18]	293.5 - 336	360 - 406	334.5 - 383	432 - 488
Total emissions with 2007 intensity (MT CO_2-eq.)		393.5	442	448.5	530.5

Explanations:

1 Computed using the 2007 GHG emissions from INCCA

2 Computed using the 2007 GHG emissions from INCCA

3 Data received from the Planning Commission.

4 Data received from the Joint Plant Committee, Kolkata (2010).

5 From LBNL 2009

6 BEE estimates the SEC value as 28.96 GJ/MT for 2007-08.

7 A computation based on 2007-2020 emissions-intensity-reductions projected by the World Bank (2010), Scenario 1 projects a 9.5 percent reduction till 2020.

8 Employing the reduction rate projected by CSE 2010 (BAU scenario), a reduction of about 15.5 percent is projected by 2020 over 2007 (assuming the reduction rate is valid for 2007-2020); however the 2020 emissions intensity suggested by CSE 2010 seems rather low; a possible reason could be the sample characteristics of the plants that CSE 2010 surveyed.

9 A computation based on 2007-2020 emissions-intensity-reductions projected by the World Bank (2010), Scenario 1 projects about 15 percent reduction till 2020.

10 Employing the reduction rate projected by CSE 2010 (BAU scenario), a reduction of about 9 percent is projected by 2020 over 2007 (assuming the reduction rate is valid for 2007-2020). A possible reason for the low reduction potential could be the production mix assumed by the study in 2020, with DRI-EAF route (with a lower efficiency improvement potential in the Indian context, over the BOF route) as the major production route.

11 Based on technology & other intervention mitigation potential estimates with inputs from experts under an existing policy scenario with the corresponding intervention regime and respective GDP growth assumptions outlined in the text.

12 Based on technology & other intervention mitigation potential estimates with inputs from experts under an aggressive policy scenario with the corresponding intervention regime and respective GDP growth assumptions outlined in the text.

13 Computed using the elasticity of consumption growth in cement sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 8 percent. Consumption growth is assumed to be a close metric to assess the sector growth. Cement consumption data based on Planning Commission estimates.

14 Production estimates using World Bank (2010) projected 2005-2020 increase: 412 MT: using CSE (2010) growth rate applied over 2005-2020: 434 MT; and using LBNL (2009) projected increase, adjusted for 8 percent growth rate: 479 MT.

15 Computed using the elasticity of consumption growth in the steel sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 8 percent. Consumption growth is assumed to be a close metric to assess the sector growth. Steel consumption data from World Steel, 2010.

16 Computed using the elasticity of consumption growth in cement sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 9 percent. Consumption

growth is assumed to be a close metric to assess the sector growth. Cement consumption data based on Planning Commission estimates.

17 Computed using the elasticity of consumption growth in the steel sector with the GDP growth; Annual GDP growth for 2007-2020 assumed to be 9 percent. Consumption growth is assumed to be a close metric to assess the sector growth. Steel consumption data from World Steel, 2010.

18 Computed from estimated 2020 emission intensities and production figures above.

3.3.4 Oil and Gas

3.3.4.1 Demand Projections for Oil and Gas

The demand of petroleum products in 2005 - 06 was 113.19 million tonnes and for the year 2009 -10 it is estimated to be 136.61 MMT, growing at an annual rate of 4.85 percent over the period 2005 - 2010. It is expected that the demand of petroleum products is likely to grow by about 4 percent during the next 10 -15 years to meet largely the demand of transport and domestic fuel (LPG) sector. As kerosene will be replaced by LPG/Natural Gas for domestic fuel consumption and Furnace oil & Naphtha will be replaced by natural gas, the demand growth would largely be for the transport sector.

The supply of natural gas has increased over the period 2005 - 2010 due to large increase in domestic gas production and import of LNG. The supply during this period has increased from 37.89 BCM to 61.81 BCM in 2009 - 10, thus giving a growth rate of 13 percent during this period. The growth rate of natural gas including LNG supply is likely to be about 8 to 9 percent during the year 2005 to 2020. However, as large gas fields would reach peak production by the end of 11th plan, the growth rate may slow to 5 percent during 2013 - 2021. Currently, the share of natural gas in the energy basket is only 12 percent, which is quite low compared with the global average of 24 percent, and efforts needs to be made increase this share progressively to 20 percent. However, the share of oil in energy basket is 34 percent and is comparatively higher.

Efforts are being made to shift towards natural gas usage in many sectors due to the increased availability of domestic gas and also creation of LNG import capacity in the country. The increased availability of natural gas has facilitated replacement of liquid fuels by natural gas in transport, power sector, fertilizer, petrochemicals, refineries, households and many other fuel intensive sectors. The city gas distribution system is functioning in 25 cities at present and is likely to be extended to 200 cities by 2015. The table 3.20 below gives a possible scenario for oil & gas demand up to 2020.

Table 3.20: Oil and Gas Demand Projection

Sl.	Items	2005-06	2009-10	2011-12	2017-18	2020-21
1	Crude Oil Production (MMT)	32.19	35.95	42.88	40.40	42.88
2	Gas Prod. + LNG (BCM)	39.86	58.00	84.4	103.00	131.9
3	LNG Imports (BCM)	6.57	11.57	19.5	25.46	30.94
4	Refining Capacity (MMT)	118.75	182.00	240.00	302.00	342.00
5	Demand Petroleum Products (MMT)	113.19	136.61**	150.61*	185.14*	212.45*

**Provisional. ** Assumed 5 percent growth for 2010-11 and 2011-12 over the consumption levels of 2009-10.*

3.3.4.2 Emissions from Oil & Gas

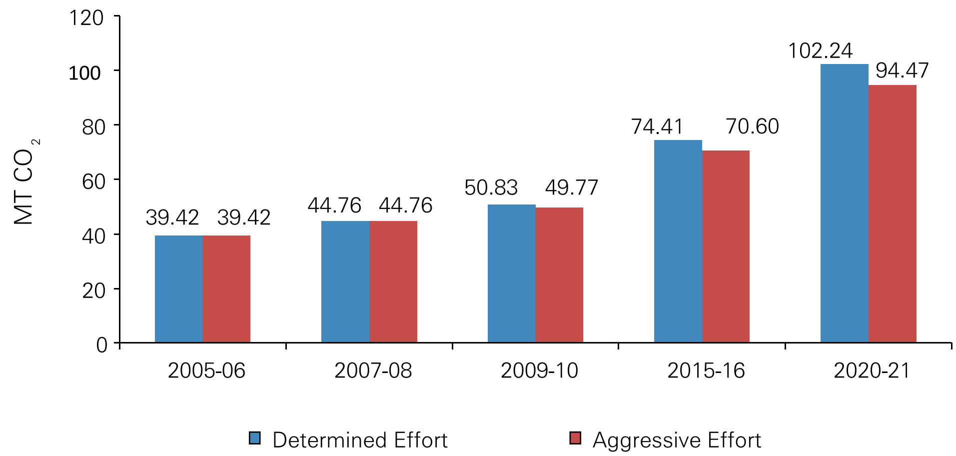
Majority of emissions in oil & gas industry are due to the refining activity, gas flaring, pipeline transportation of oil & gas, oil exploration, storage and its flow to the consumers. Some amount of natural gas is being flared by ONGC and OIL for technical reasons.

3.3.4.2.1 Petroleum Refining

As the refining capacity is likely to grow by about 4 percent beyond 12th plan period, there is a necessity to develop the energy efficient refineries. As around 80 percent of oil and gas sector emissions come from the refining activity every refinery has taken up a program to reduce fuel use per tonne of oil processed. The refineries and refinery technologists have to play greater role in improving the refining efficiencies of their processes and fuels. Based on the assumption that the new refineries would be 20 - 25 percent more efficient, the Figure 3.11 below shows the emission from refining activity in Determined and Aggressive Effort scenarios.

The Indian refining capacity is set to increase from a capacity of 118.75 MMTPA in 2005 to 240 MMTPA in 2012 and 342 MMTPA by 2021. Indian refineries are continuously improving the efficiencies of fuel utilization and reducing losses. In future, Oil companies which are able to improve energy efficiencies of existing processes and adopt technologies, which are energy efficient and environment friendly, will only be able to sustain their businesses

Figure 3.10: Emissions from Petroleum Refining (at 8% GDP Growth)

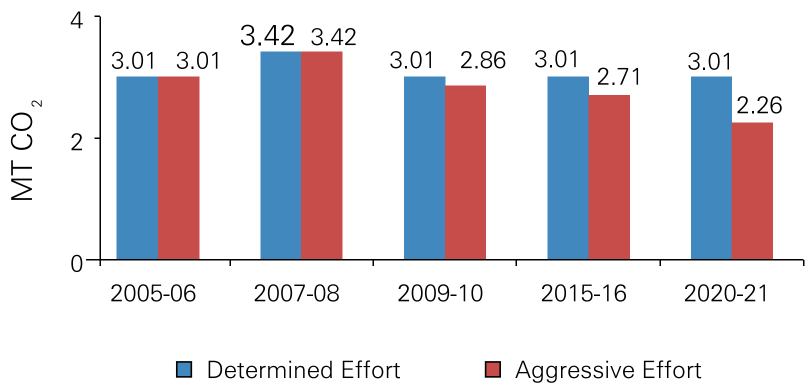


3.3.4.2.2 Gas Processing, etc.

The other component of emissions in the Oil and Gas sector is the Gas Processing. This report includes Gas Processing and Gas Flaring & Transportation in this category.

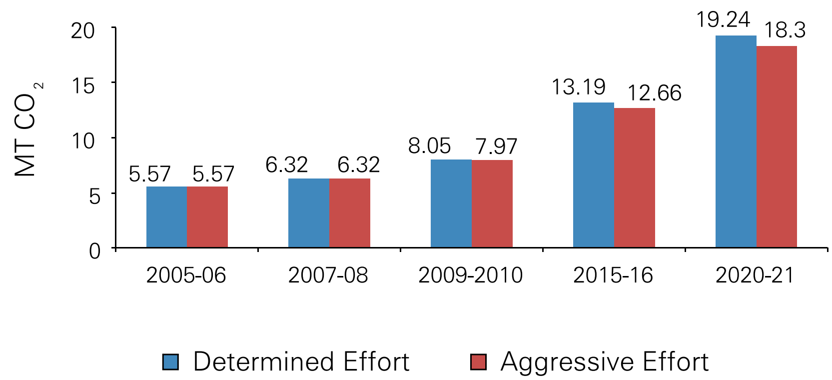
i. **Gas Flaring:** Various efforts have been made by the oil companies to reduce the flaring by directly using the gas & the flaring has come down from 6 percent in 2001 - 02 to 3 percent in 2008-09. Still about 1.09 BCM of gas is flared in the country. The value of this gas in oil equivalent energy terms at 80 $/bbl price is about 500 million US$ per year. Further efforts are being made by the oil companies to reduce the flaring from various oil fields. Action is being taken by ONGC and OIL to eliminate flaring to minimum level and to monetize the gas for various fuel uses. The ONGC and OIL are planning to monetize the onshore and offshore flared gas through liquefaction, compression mode and transport the flared gas to locations near pipeline for pipeline injections or use it as a fuel for industrial or domestic use. In case of Determined Effort scenario, the Gas Flaring Emissions are expected to remain stagnant at the current levels of 3.01 MMT CO_2-eq. If the measures are taken by ONGC and OIL to reduce flaring to minimum level (except some technical flaring), in case of Aggressive Effort, the emissions could be reduced from current levels of 3.01 MMT CO_2 to 1.51 MMT CO_2 by 2020 - 21. Figure below shows reduction in emission from gas flaring.

Figure 3.11: Emissions From Gas Flaring (at 8% GDP Growth)



ii. **Gas Processing & Transportation:** Currently about 174 MMSCMD of gas is being utilized in the country. Given the demand of more than 390 MMSCMD by 2025, the use of gas for processing, extraction and its transportation would increase gradually. However, the impact would be smaller due to the large volumes being handled in the trunk line. Though gas transportation companies are taking measures to improve efficiencies at various gas processing plants, its measurement is however is not done. However, about 5 percent energy consumption efficiencies can possibly be achieved for the gas transportation, extraction and processing activities which would facilitate in emission reduction of about 0.95 MMT CO_2 between Determined and Aggressive Effort scenarios by 2020 - 21. The figure below gives estimates of emissions from gas transportation, extraction and processing activities.

Figure 3.12: Emissions from Gas Processing & Transportation (at 8% GDP Growth)



3.3.4.2.3 Status of Future Perspective on Growth of Consumption of Oil & Gas And Related Emissions

The overall compounded average growth for the oil and natural gas sector considering 8 percent growth rate is estimated at 5.42 percent (4.28 percent for the petroleum products and 8.25 percent for the natural gas). The growth of oil and gas consumption would depend upon the gas based power capacity addition and the growth of transport fuels. Last 5 years major growth has been observed in transport fuels (MS and HSD) and domestic fuels like LPG. As all the three fuels are highly subsidized w.r.t. international prices, it affects the optimal level of consumption in household and transport sector. Bringing the fuel prices to market price parity level would improve the efficiencies of utilization of these fuels and could further bring down the consumption by 5 - 7 percent, which is also the difference for consumption in achieving the 8 and 9 percent growth rates. However, the actual consumption levels for the oil and gas for achieving 8 and 9 percent growth rates would depend upon the price liberalization of petroleum products.

The major impact could be from the household sector using biomass for cooking. If entire biomass for cooking is replaced by LPG and gas, both in urban and rural areas, it substantially reduces the emission levels coming from the household sector. However, large numbers of households currently use biomass for cooking and the overall CO_2 emissions are estimated at 138 million tonnes of CO_2-eq in 2007. In case all the households are provided with natural gas (in urban areas) & LPG (in rural areas) instead of biomass, the emission intensity of the household sector can be brought down substantially.

3.3.4.2.4 Overall Emissions From Oil & Gas Sector

Emission from the oil and gas sector under different mitigation and growth scenarios are summarized in the table below.

Table 3.21: CO_2-eq Emissions (million tonnes) in Oil & Gas Sector

Emissions 2007	Mitigation Scenarios	2020 (with 8% GDP Growth)	2020 (with 9% GDP Growth)
44.76	Refinery Emissions		
	Determined Effort	102	115
	Aggressive Effort	95	105
9.75	Emissions from Gas Processing, etc.		
	Determined Effort	23	25
	Aggressive Effort	20	23
54.5	Total Emissions		
	Determined Effort	125	140
	Aggressive Effort	115	128

3.4 Buildings

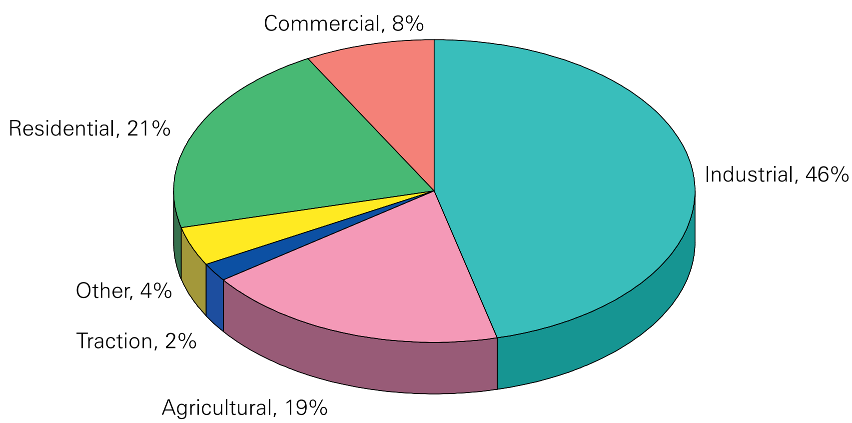
3.4.1. Introduction

Energy consumption in buildings offers a large scope for improving efficiency. We define the building sector to include residential and non-industrial buildings. The latter are called commercial buildings and 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 here.

The potential to reduce energy consumption through improvement in efficiency of appliances and equipment is already accounted for in the power section. However, apart from this, buildings can be made more energy efficient by designs that reduce the need for lighting, heating, ventilation and air conditioning. We concentrate on savings in energy intensity that can be realized over and above what is possible through improvement in appliances and equipment.

The sector-wise electricity consumption in India is shown in Figure 3.13.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). Significant part of this goes into heating, cooling and lighting. In order to work out the likely opportunities to reduce emission intensity we need to first project the likely growth in buildings of different categories. The energy demand by buildings will continue to grow with the growth of IT, ITES and the hospitality sectors.

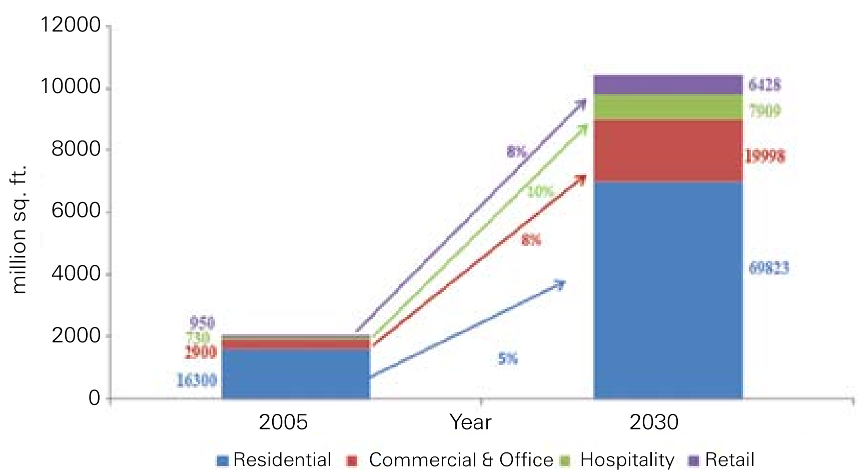
Figure 3.13: Primary Electricity Consumption in India (sector-wise)



Source: International Energy Association, 2008

Figure 3.14 below highlights the projected growth in the residential, commercial, hospitality and retail sectors.

Figure 3.14: Future Trend of Building Sector in India



Source: CWF, 2010

The major growth in constructed area will be seen by residential and commercial sectors, as much as 4 to 5 times the constructed area in 2005 (CWF, 2010). The growth rates in hospitality and retail sectors are even higher, through their total areas are relatively small.

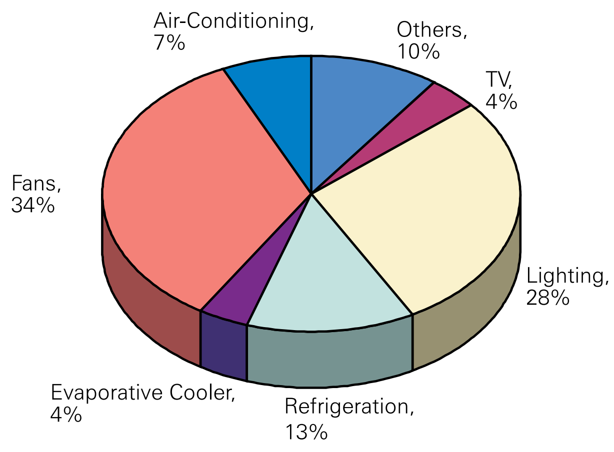
3.4.2 Residential Sector

Amongst the building sector, the residential sector is growing at a rapid pace. The Indian residential sector has witnessed phenomenal growth over the last 15 years, primarily due to population increase, higher GDP, growing urbanization, rise in income levels & the change in lifestyles and favorable public policies.

In 1961, the urban population of India was 78.9 million i.e. 18 percent of the total population. By 2001 it reached 285.5 million i.e. 27.8 percent of the total population. The urban populations are predicted to rise to 550 million by 2030 or 42.0 percent of the total population (Roberts, Brian and Trevor Kanaley, 2005). This urban growth, combined with rapid growth in the economy, has resulted in putting enormous pressure on housing requirements, urban infrastructure and other services.

The residential sector accounts for 21 percent of the total energy consumption[47] in India (Figure 3.13). The share of various energy consuming equipments in the residential sector is indicated below in Figure 3.15.

Figure 3.15: Energy Consumption Distribution in Residential Buildings



Source: Bureau of Energy Efficiency

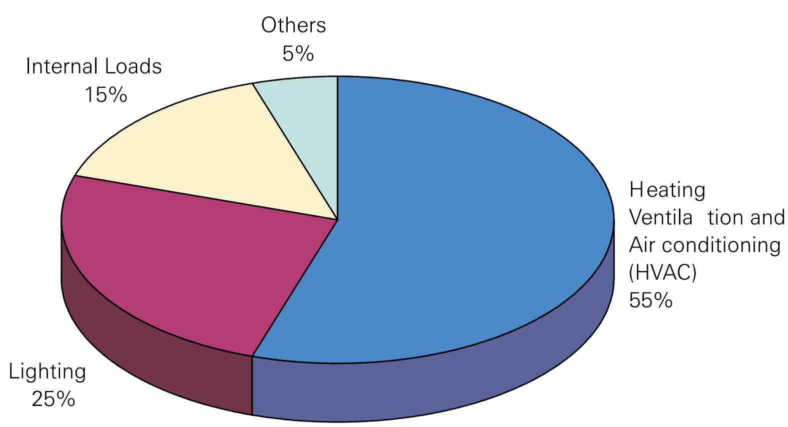
[47] *Cooking is not included. This includes only electricity consumption in households.*

Ceiling fans and lighting constitute major energy use (62 percent) in the residential buildings. The efficiency gains from the launch of the BEE energy labelling program for domestic appliances to enhance energy efficiency of these appliances has already been accounted for in the power chapter. The gains from redesigning buildings to reduce the load for heating and air conditioning are not accounted for. However, these would be small for residential buildings and we do not estimate them here at this stage.

3.4.3 Commercial Sector

The major energy consuming equipments in commercial sector are lighting (60 percent), heating, ventilation and air conditioning (HVAC) (32 percent), and other office related equipment (8 percent), as illustrated in Figure 3.16.

Figure 3.16: Energy Consumption Distribution in Commercial Building



Source: Bureau of Energy Efficiency: Ministry of Power

Commercial buildings also use window air conditioners and the gains in efficiency of these have been accounted for in the power chapter. However, many of the commercial buildings have central air conditioning and chillers, whose efficiencies can be improved. In other words, designs that increase daylight and reduce need for daytime 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 of geo-thermal energy. The gains from Energy Conservation Building Codes (ECBC) are mainly of these types and we estimate the potential for gains on the basis of ECBC.

3.4.4 Present Codes and Standards

Codes and Standards as determined by policy can significantly enable the reduction of CO_2 emissions in the building sector. The country has done well in developing various standards like National Building Code (NBC), Energy Conservation Building Codes (ECBC), Bureau of Energy Efficiency rating programs for appliances and the more recent energy rating program for the existing buildings. The market-driven voluntary Green Building Rating Programs have significantly transformed the way buildings are designed. Green buildings have the potential to save 40 to 50 percent energy vis-à-vis the conventional practices.

Some of the widely used building codes in India are discussed below.

3.4.4.1 Energy Conservation Building Code

Energy Conservation Building Codes, 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 500 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.

3.4.4.2 Green Building Rating Systems

Green building rating systems have come to India in a big way. Major green building rating systems currently operating in India are:

- Indian Green Building Council (IGBC) programmes - LEED India New Construction, LEED India Core and Shell, IGBC Green Homes, IGBC Green Factory Building, IGBC Green SEZ *, IGBC Green Cities* [*under development]
- TERI – GRIHA
- Eco housing

47 Cooking is not included. This includes only electricity consumption in households.

3.4.5 CO_2 Mitigation Opportunities in Building Sector

There are tremendous opportunities to maximise the energy efficiency and there by reducing the GHG emissions in the building sector. These opportunities are available in both existing and new stock, covering both commercial and residential sector. It is estimated that there is a potential to abate 142 Million Tonnes of CO_2 per year by 2020 and 296 Million Tonnes of CO_2 per year by 2030 respectively (IGBC - Indian Green Building Council estimates).

Analysis of the Commercial Sector

The projected area of commercial buildings is shown below in Table 3.22.

Table 3.22 Projected Area of Commercial Buildings in 2020 and 2030

Building Type	Area (Million Sq.ft)	Growth Percent	Area (Million Sq.ft)	Area (Million Sq.ft)
	2005		2020	2030
Commercial Office Space	2900	8	9199	19861
Hospitality	730	10	3049	7909
Retail	950	8	3014	6506
Total	4580	–	15262	34276

The existing consumption pattern in conventional buildings (data from BEE) and the consumption trends in some of the recently constructed energy efficient buildings, which would be ECBC compliant, have been analyzed. The ECBC compliant buildings are estimated to be 20 to 30 percent more efficient than conventional buildings. These buildings have many energy conservation measures such as the use of flash blocks, wall and roof insulation, high performance glass, high SRI paints, vegetated roofs, LPD's (<1w/sq.ft), high performance chillers, economizers, variable frequency drives and cooling towers. The current baseline for CO_2 emissions for conventional buildings is estimated at 40,000 tonnes of CO_2 per million Sq.ft or 430,570 tonnes of $C0_2$ per million Sq.m of building area. At this rate, the expected emissions from the commercial building sector will be 610 Mt of CO_2 in 2020 and 1,370 Mt of CO_2 in 2030.

During the current voluntary phase of the ECBC, motivated early adopters are designing compliant commercial buildings which achieve savings that are much higher than what can be achieved by minimum ECBC compliance. Post the notification of ECBC, it is expected that the vast section of new commercial buildings shall meet only the minimum code compliance requirements with relatively few achieving higher levels of savings than what is currently being achieved. In assessing the CO_2 abatement in the commercial buildings due to implementation of the ECBC, the following scenarios are considered:

Determined Effort Scenario till 2020

- 10 percent of the new buildings (i.e. the buildings built between year 2007 and 2020) will surpass the ECBC requirements and their CO_2 and energy use will be 50 percent of the existing baseline.
- A further 10 percent of the new buildings (i.e. built between 2007 &2020) will meet the ECBC requirements, and the CO_2 emissions will be 70 percent of the existing baseline (i.e. reduction of 30 percent).
- 10 percent of the existing buildings and 30 percent of new buildings may not meet the full ECBC requirements, but will at least have an energy performance comparable to that of a retrofitted building and save 18 percent of the existing baseline.

Aggressive Effort Scenario till 2020

- 15 percent of the new buildings (i.e. the buildings built between year 2007 and 2020) will surpass the ECBC requirements and their CO_2 and energy use will be 50 percent of the existing baseline.
- A further 35 percent of the new buildings (i.e. built between 2007 &2020) will meet ECBC requirements, and the CO_2 emissions will be 70 percent of the existing baseline (i.e. reduction of 30 percent).
- 20 percent of the existing buildings and 50 percent of new buildings may not meet the full ECBC requirements, but will at least have an energy performance comparable to that of a retrofitted building and save 18 percent of the existing baseline.

The potential CO_2 mitigation by the years 2020 is worked out and is summarized below in Table 3.23.

The following assumptions are made to work out the additional emission savings between 2020 and 2030:

- 100 percent of additional area added between 2020-2030 is ECBC compliant
- 50 percent of existing Buildings are Retrofitted
- 20 percent of new Buildings surpass the Requirements of ECBC

It is pertinent to mention that enforcement of buildings code is not entirely in the hands of the Central Government, and it will take time before the systems are put into place at the level of the State and Local Governments.

Table 3.23: Emission Savings from the Commercial Building Sector in 2020

Sl.	Determined Effort Scenario	Million Tonnes of CO_2 Abated
1	10 % new buildings respond to market penetration of rating systems and save 50% of emissions	22
2	10% of new buildings ECBC compliant save 30% of emission	12
3	10% of the existing buildings are retrofitted and 30 % of new buildings save 18% of emissions	26
	Total Emissions Abated	60

Sl.	Aggressive Effort Scenario	Million Tonnes of CO_2 Abated
1	15% buildings respond to market penetration of rating systems and save 50% of emissions	32
2	35% of new buildings ECBC compliant save 30% of emissions	45
3	20% of the existing buildings are retrofitted and 50% of new buildings save 18% of emissions	45
	Total Emissions Abated	122

3.4.6 Energy Performance Index (EPI)

Energy consumption in commercial buildings can also be defined in terms of Energy performance Index (EPI). EPI serves as a tool to indicate the specific power consumption in a building. EPI in these building depends on various factors such as, i) Orientation; ii) Climate; iii) Functionality; iv) Hours of operation (daylight, 24hrs); v) Number of occupants; vi) Schedules- Lighting, occupancy; vii) Equipment loads; viii) Ratio of conditioned and unconditioned areas; ix) Parking area vis-à-vis the total area.

The EPI are only indicative and there could be significant variance depending upon the above mentioned factors. It is recommended that BEE initiates a study to arrive at EPI values for various climatic zones and types of buildings addressing the above mentioned factors.

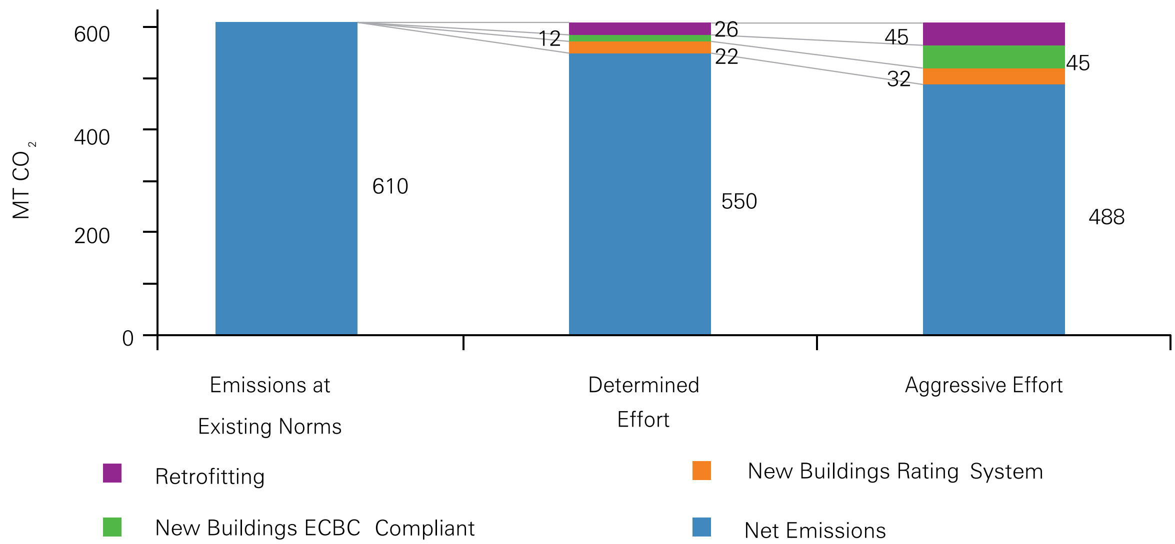
3.4.7 Conclusion

The Indian construction sector, which is one of the major contributors to the National GDP, is poised to grow fast in the coming years. While on one hand this is a welcome opportunity, and on the other it poses some challenges. One major challenge is the increase in energy demand and the consequent CO_2 emissions. The launch of the ECBC code, BEE rating for appliances and the application of rating systems has pushed the efficiency bar higher and higher.

To translate energy saving opportunities to tangible benefits, there is a need for several interventions – encouraging public policies, enhancing awareness, capacity building, absorption of new trends and technologies. Besides these, there is a need to develop indigenous standards & codes and facilities for testing & verification.

By adopting the strategies and recommendations made above, it is possible to abate approximately 60 Mt and 122 Mt of CO_2 per year by 2020 in the determined and aggressive scenarios respectively. The savings by 2030, from the commercial buildings sector, can be 400 Mt to 440 Mt of CO_2 per year. The contribution of the residential sector has not been factored in, as no reliable estimates of energy savings through interventions pertaining to building envelope and its components are available. The expected reductions in emissions from the commercial building sector in 2020 are summarized in Figure 3.17.

Figure 3.17: Emission Reduction Potential from Commercial Buildings



3.5 Forestry

3.5.1 Introduction

Forests and tree vegetation play an important role in the mitigation of climate change by absorbing CO_2 from atmosphere and turning it into biomass comprising 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.

Forestry assumes added significance as investment in this sector doubly effects the reduction in Emission Intensity (EI) - one by increasing the forest carbon sink, and two by increasing the GDP. In a nutshell, forestry sector positively influences the numerator as well as the denominator of the EI.

India is in the process of finalizing a National Mission for a Green India, as one of the eight Missions under its National Action Plan on Climate Change (NAPCC). This Mission is going to provide an overarching framework for forestry activities in order to address climate change. This summary provides highlights of the new strategy. The next report of the Working Group will build upon the work of the GIM and provide additional recommendations, undertake a quantification of benefits in terms of carbon sequestration and provide the link to the broader cross-Sectoral strategy for low carbon inclusive growth.

3.5.2 Background

The GIM acknowledges the influence that the forestry sector has on environmental amelioration and inclusive development. It helps climate mitigation through sequestration. It increases water retention and percolation, and reduces surface runoff leading to improved water and food security. It facilitates biodiversity conservation and provides livelihood to forest dependent communities. The mission puts "greening" in the context of climate change adaptation and mitigation, meant to enhance ecosystem services like carbon sequestration and storage, hydrological services and biodiversity along with provisioning services like fuel, fodder, small timber and NNTP's etc.

The Mission aims at addressing climate change by:

- enhancing carbon sinks in sustainable managed forests and other ecosystems;
- enhancing the resilience and ability of vulnerable species/ecosystems to adapt to the changing climate; and
- enabling adaptation of forest dependant local communities in the face of climatic variability

3.5.3 Mission Objectives

The objectives of the mission are three-fold:

- Double the area to be taken up for afforestation and eco-restoration in India in the next 10 years, taking the total area to be afforested and eco-restored to 20 million ha. (i.e., 10 million ha of additional forest/non forest area to be treated by the Mission, in addition to the 10 million ha which is likely to be treated by Forest Department and other agencies through other interventions).
- Increase the GHG removals by India's forests to 6.35 percent of India's annual total GHG emissions by the year 2020 (an increase of 1.5 percent over what it would be in the absence of the Mission). This would require an increase in above

[48] *Source: India's Forests and Tree Cover: Contribution as a carbon sink, Technical paper, ICFRE, 2009; pp.10*

and below ground biomass in 10 million ha of forests/ecosystems, resulting in increased carbon sequestration of 43 million tons CO_2-e annually.[48]

- Enhance the resilience of forests/ecosystems being treated under the Mission – enhance infiltration, groundwater recharge, stream and spring flows, biodiversity value, pr ovisioning of services (fuel wood, fodder, timber, NNTP's, etc.) to help local communities adapt to climatic variability.

3.5.4 Mission Targets (Outputs)

The Mission will have clear targets for different forest types and ecosystems which will enable achieving the overall objectives of the Mission. The Mission targets can be classified into the following:

- 2.0 m ha of moderately dense forests show increased cover and density
- 4.0 m ha of degraded forests are regenerated/afforested and sustainable managed
- 2.0 m ha of degraded scrub/grasslands are restored and put under sustainable uses
- 0.10 m ha of mangroves restored/established
- 0.10 m ha of wetlands show enhanced conservation status
- 0.20 m ha of urban/peri urban forest lands and institutional lands are under tree cover
- 1.50 m ha of degraded agricultural lands and fallows are brought under agro-forestry
- 0.10 m ha of corridor areas, critical to wildlife migration are secured
- Improved fuel wood use efficiency devices adopted in about 10 million households (along with alternative energy devices)
- Biomass/NTFP based community livelihoods are enhanced that lead to reduced vulnerability

3.5.5 Key Elements of Mission Strategy

Some key highlights of the Mission strategy are listed below.

- Holistic view to "greening" (broader than plantations):

The scope of greening will not be limited to just trees and plantations. Emphasis will be placed on restoration of ecosystems and habitat diversity e.g. grassland and pastures (more so in arid/semi-arid regions), mangroves, wetlands and other critical ecosystems. It will not only strive to restore degraded forests, but would also contribute in protection/enhancement of forests with relatively dense forest cover.

- Integrated cross-sectoral approach to implementation:

  The Mission would foster an integrated approach that treats forests and non forest public lands as well as private lands simultaneously, in project units/ sub-landscapes/sub-watersheds. Drivers of degradation e.g. firewood needs and livestock grazing will be addressed using inter Sectoral convergence (e.g. livestock, forest, agriculture, rural development, energy etc.)

- Key role for local communities and decentralized governance:

  Local communities will be required to play a key role in project governance and implementation. Gram Sabha and its various committees/groups including JFMCs, CFM groups, Van Panchayats, etc. would be strengthened as institutions of decentralized forest governance. Likewise, the Mission would support revamping/strengthening of the Forest Development Agencies. The Mission would support secured community tenure, capacity building for adaptive forest management and livelihood support activities e.g. community based NTFP enterprises.

- 'Vulnerability' and 'Potential' as criteria for intervention:

  An overarching criterion for selection of project areas/sub-landscapes/sub-watersheds under the Mission would include vulnerability to climatic change projections and potential of areas for enhancing carbon sinks.

- Robust and effective monitoring framework:

  A comprehensive monitoring framework at four different levels is proposed. In addition to on-ground self- monitoring by multiple agencies, the Mission would support use of modern technology like Remote Sensing with GPS mapping of plot boundaries for monitoring at output/ outcome level. A few identified sites within the project area will be selected for intensive monitoring using additional parameters like ground cover, soil condition, erosion and infiltration, run-off, ground water levels to develop water budgets as well as biomass monitoring indicators. The Mission would also commission a comprehensive research needs assessment in support of Mission aim and objectives. The Mission would set up a cell within Mission Directorate to coordinate REDD Plus activities in the country.

The Mission will implement its strategy through a set of 9 sub-missions and cross-cutting initiatives.

3.5.6 Mission Organisation

An Advisory Council chaired by the Minister for Environment and Forests, Government of India, will provide overall guidance to the Mission. A National Steering Committee will provide necessary direction and support to the Mission activities. The Mission will be serviced by a Mission Directorate at MoEF to be housed in the National Afforestation and Eco-development Board (NAEB). At State level, the Mission will be housed within the State Forest Development Agency in the Forest Department and will have a State Steering Committee and an Executive Committee to help the Mission achieve its aims and objectives. At District level, the Mission activities will be coordinated through the existing mechanism of District Planning Committees and FDAs. The Gram Sabhas and the various Committees set up by them, including JFMCs, CFM groups, Van Panchayats, Village Council etc., will be the key vehicle for planning and implementation at the village level.

3.5.7 Timeframe and Costs

The implementation period of the Mission would be 10 years, i.e., from FY 2010-2011 to FY 2019-2020. The first year of the Mission would be utilized in institution building, sensitization, capacity building and baseline research etc. Actual field operations will commence from the second year of the Mission.

The initial estimate of the total mission cost is Rs. 44,000 crore.

3.5.8 Sequestration and Emission Neutralization

The Mission would increase above and below ground biomass in 10 million ha of forests and other ecosystems resulting in increased carbon sequestration of 43 million tons CO_2 equivalents annually in the year 2020. This will neutralize an additional 1.5 percent of India's annual GHG emissions in 2020, taking GHG removal by India's forests in 2020 to 6.35 percent.

Most of carbon sequestration takes place during the period of growth of trees and mature forests sequester small amounts if any. Thus for sequestration through forests an optimal strategy should examine the [possibilities of fast growing trees, periodically harvested and locking up the captured carbon in furniture and buildings or burnt to generate power replacing coal.

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4 Summary and Conclusions

4.1 Putting It All Together

The interim report of the Expert Group on 'Low Carbon Strategies for Inclusive Growth' starts with an overview of the challenge posed by climate change, giving a brief description of the Greenhouse Gas emissions across the world. A comparative account of the Greenhouse Gas emissions across major economies and an overview of the global action on climate change are presented in Chapter 1.This chapter also outlines India's commitment to reducing intensity of its carbon emissions and the voluntary measures it has promised to undertake before the international community.

In **Chapter 2**, we look at the structure of India's emissions, and particularly, its distribution across sectors. It is pertinent to mention that India has done particularly well on the mitigation front and its per-capita emissions are among the lowest in the world. This chapter gives an overview of the *GHG inventory data and measurement system* that India has put into place. India became conscious of the climate challenge fairly early, and starting in the early 1990's, a significant emission intensity reduction had already been achieved when the emissions data was published for 2007. Clearly, any attempt to interpret 'business-as-usual' for India must start with the early 1990's, and take into account the conscious policy choices India has made since then and the documented emission intensity reduction it has achieved over this period. Moreover, as developing economies go through different phases of development, past intensity trends cannot be treated as 'business-as-usual' for their national emission trends. An increase in emissions intensity during industrialization was seen in many industrialized and recently industrializing countries, and the same could happen for India if its growth mix changes over the next decade. Chapter 2 also highlights a number of issues associated with data availability, and the need for an integrated and facilitative approach towards compilation of information. Institutional issues relating to collection, availability and use of information also need to be addressed to measure the effectiveness of mitigation policies.

Chapter 3 summarises the low carbon strategies for power, transport, industry, buildings and forestry sectors. We project a range for GHG emission intensity reduction in 2020 for both 8 and 9 percent real GDP growth. Two scenarios have been presented:

The first scenario, at the lower end of emissions intensity reduction range, is called the **Determined Effort Scenario**, which essentially means vigorous and effective implementation of mitigation policies that have either been put into place or are presently contemplated by the Government. This is by no means automatic, and requires continuous up-gradation of technology as well as finance from both public and private sources, in addition to an effective policy coordination between different agencies.

The second scenario, which aims at a higher level of reduction in emissions is called the **Aggressive Effort Scenario**. This scenario will require, in addition to vigorous implementation of policies already put into place, design and implementation of new policies. It will need significant deployment of new technologies, large amounts of additional finance and considerable innovation effort. It is pertinent to mention here that India alone may not be able to mobilise resources of this scale and magnitude, and international help will be necessary to bring in new technology as well as additional finance.

Power: According to the CEA data the power sector generated 598 million tons of CO_2 equivalent emissions in 2007[49]. Future projections for the sector takes into account changed scenarios in both demand and supply of power. Implementing the principle of 'waste not; want not' in the use of power, improvements in efficiency should considerably lower the demand for power. With respect to supply of power, reduced emissions can be achieved by altering the mix of generation plants. To achieve 8 percent growth, the country needs an installed utility capacity of 320,000 to 332,000 MW by 2020. For 9 percent growth, the installed utility capacity required in

[49] The Central Electricity Authority data is based on sampling at the receiving end of the power plants, while the NATCOM data is based on coal dispatches to power plants in accordance with the coal linkage at the pit head. According to the latter, emissions form the power sector were 719 MT of CO_2-eq in 2007. There is admittedly a leakage between the two, and in spite of our best efforts we found it impossible to reconcile the difference. We have therefore treated this gap as 'Miscellaneous Emissions' and made reasonable assumptions in projecting it forward upto 2020.

2020 should be between 3,63,000 to 3,77,000 MW. When the supply side possibilities are matched with the demand side scenarios, CO_2 emissions in 2020 are expected to be in the range 1263 to 1428 million tonnes of CO_2 equivalents for the 8 percent growth scenario, and in the range 1452 to 1620 million tonnes of CO_2 equivalents for the 9 percent GDP growth scenario.

Buildings: In this section, the Expert Group has suggested implementation of Energy Conservation Building Code and Green Buildings Rating System for both new and existing buildings in the country. These will 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 2020. It is still important to make a beginning, ensure that a suitable code is evolved and integrated with statutory regulations at all levels of Government. If action is initiated on this front, CO_2 equivalents emitted from the building and power sectors are expected to come down by 2020 to 1,141 to 1368 million tonnes for the 8 percent growth scenario and 1,330 to 1,560 million tonnes for the 9 percent growth scenario.

Transport: The transport section gives an overview of the scenario in 2007 and makes demand projections for 2020. Early completion of the dedicated freight corridor, investment in urban public transport and improvement in fuel use efficiency of vehicles are critical for emission reduction over the next decade. The Chapter highlights an avoid-shift-improve paradigm for emission intensity reduction according to which the emissions can be limited to between 413 to 435 MT of CO_2 equivalents for the 8 percent and between 477 to 504 MT of CO_2 equivalents for the 9 percent GDP 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 2007. Iron and steel, cement, and oil & gas industries constitute around 60 percent of the industrial emissions in the country. The iron and steel industry emitted 117 million tons of CO_2 equivalents in 2007 against a production of 53 million tons. The Cement sector emitted 130 million tons of CO_2 equivalents against a production of 165 MT in 2007. Going by the trend, iron and steel output is expected to grow to 200 to 240 million tons by 2020, while the production of cement is expected to rise to 500 to 570 million tons by 2020. 'Other industries', include industries with smaller GHG emissions, with no particular industry being a large and dominant contributor. For many of these, it is difficult to make precise projections for 2020. For these sectors, the emission-output elasticity over the period 1994-2007 has been used for projection forward up to 2020. Other industries are expected to emit 270 to 300 million tons of CO_2 equivalents in the 8 percent GDP growth scenario, and between 288 to 319 MT of CO_2 equivalents in the 9 percent GDP growth scenario. Emissions from oil and gas industry were 55 million tons in 2007. This includes fugitive emissions (like gas flaring) as well as emissions from petroleum refining. Emissions from this sector are expected to rise to 115 to 125 million tons of CO_2 equivalents in the 8 percent GDP growth scenario and between 128 to 140 MT of CO_2 equivalents in the 9 percent GDP growth scenario.

Other Energy Emissions: Refers to the use of biomass and fossil fuels (LPG, kerosene, diesel, coal etc.) to meet the cooking and lighting requirements of households, institutions and commercial establishments, as also their use as energy in agriculture and fisheries. 'Other' excludes the use of electricity as a source of energy. In the Determined Effort Scenario, emissions from this sector are expected to be grow at the same slow rate as that between 1994 and 2007, leading to an emission of 261 to 276 million tons of CO_2 equivalents by 2020. 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 further 20 percent to about 221 to 235 million tons CO_2 equivalents by 2020.

Waste: The emissions through waste increased at a compounded annual growth rate of 7.3 percent between 1994 and 2007. Projecting the same emission-GDP elasticity forward up to 2020, emissions from the waste sector are expected to rise to 146 to 163 million tons of CO_2 equivalents in 2020 under the 8 percent GDP growth scenario and 165 to 183 million tons of CO_2 equivalents in 2020 under the 9 percent GDP growth scenario.

Miscellaneous Emissions: As explained above, in spite of our best efforts, the discrepancy between the power emissions from the two sources, namely CEA and NATCOM, could not be reconciled. This gap was 121 MT of CO_2-eq in 2007 (nearly 20 percent above the CEA data). Only heuristics can project leakages and gaps of this kind. Making a reasonable assumption that improved governance will bring down this gap down to 10 percent by 2020, we have projected miscellaneous emissions for each scenario in table 4.1 below.

Agriculture Processes: The agricultural processes emitted 334 million tons of CO_2 equivalents in 2007. No recommendations have been made for reduction in agriculture process emissions given the needs of inclusive growth, and given the understanding of the Expert Group that much reduction may not be practically possible in this area up to 2020.

Forestry: The Expert Group recommends implementation of a comprehensive Green India Mission for the country, whereby emphasis is placed not just on increasing the forest and tree cover, but also on increasing the stock, volume and density of existing forests. This will increase carbon sequestration by 43 million tons of CO_2 equivalents annually, increasing the GHG removals by India's forest cover to 6 percent of annual GHG emissions by the year 2020. From a long term point of view, we need to develop an optimal strategy for carbon sequestration from wood plantations that are periodically harvested for use as timber in furniture and construction industry.

Scenario Summary: India has already achieved commendable emission intensity reduction since the early 1990's, when global action started in the right earnest. Recent official data has made a comparison between the 1994 and the 2007 emissions inventory as compiled bottom-up in the country. In terms of CO_2 equivalents, the total non-agriculture GHG emissions increased from 870 MT in 1994 to 1,570 MT in 2007 implying an emission-GDP intensity reduction of 24.9 percent over this period.

Table 4.1 summarises the projected GHG emissions for India in 2020. A range of emission possibilities have been provided for 2020, if the real GDP grows at an average 8 percent and at an average 9 percent over the next decade. Table 4.2 then computes the emissions intensity reduction over the 2005 levels for each growth and efficiency scenario. The lower end of emissions reduction range is the **Determined Effort Scenario**, under which the country could achieve **23 to 25 percent** emission intensity reduction over the 2005 levels, while sustaining an average real GDP growth rate of 8 to 9 percent over the next decade. The higher end of emissions reduction range is the **Aggressive Effort Scenario** under which as much as **33 to 35 percent** emission intensity reduction could be achieved over the 2005 levels, provided adequate international help was forthcoming, both in terms of technology and finance.

It should, however, be noted that while some of these reductions look large, the cost effectiveness of these measures may need to be re-assessed. While some of these measures may not finally prove to be cost effective, others may face institutional barriers limiting our ability implement them. The feasible technology options, policy actions and finance requirements would be spelt out in greater detail in our final report.

Table 4.1: Projected Green House Gas Emissions for India in 2020

Sl.	Growth Scenarios	2007 Emissions	2020 with 8% GDP Growth		2020 with 9% GDP Growth	
	Higher and Lower Ends of the Range		Determined Effort	Aggressive Effort	Determined Effort	Aggressive Effort
1	GDP (1999-00 prices) Rs. Billion	30,619	83,273	83,273	93,873	93,873
2	GHG Emissions (MT CO_2-eq)#	1,570	3,537	3,071	4,016	3,521
	a. Power	598	1,428	1,263	1,620	1,452
	Plus Building Code		1,368	1,141	1,560	1,330
	b. Transport	142	435	413	504	477
	c. Industry	478	1,167	1,009	1,330	1,183
	i) Iron and Steel	117	406	360	488	432
	ii) Cement	130	336	294	383	335
	iii) Oil and Gas	55	125	115	140	128
	iv) Other Industries	176	300	240	319	288
	d. Other Household Energy	173	261	235	276	221
	e. Waste Management	58	163	146	183	165
	f. Miscellaneous	121	143	126	162	145
3	Emission at 2007 Levels	1,570	4,270	4,270	4,813	4,813
4	Emission Intensity (grams CO_2-eq/ Rs. GDP)	51.28	42.47	36.87	42.79	37.51
5	Emissions per capita (TCO_2-eq/person)	1.43	2.67	2.32	3.03	2.66

#Excludes Agriculture Process and LULUCF Emissions. #With LULUCF and Agriculture Processes Emissions 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 4.2: Projected Emission Intensity Reduction over 2005 levels

Sl.	Growth Scenarios	2005 Emissions	2020 with 8% GDP Growth		2020 with 9% GDP Growth	
	Higher and Lower Ends of the Range		Determined Effort	Aggressive Effort	Determined Effort	Aggressive Effort
1	Emissions at 2005 Levels (MT CO_2-eq)	1,433	4,571	4,571	5,248	5,248
2	Actual and Projected Emissions (MT CO_2-eq.)	1,433	3,537	3,071	4,016	3,521
3	Emission Intensity (grams CO_2-eq/Rs. GDP)	56.21	42.47	36.87	42.79	37.51
4	Percentage Reduction in Emission Intensity	–	24.44%	34.40%	23.88%	33.27%

4.2 Tasks Ahead

The interim report provides a menu of several options that can help reduce emission intensity of our economy. The cost and co-benefits of these measures will be spelt out in the next report. This will enable selection of measures that would help the country reach the desired target of reduction in the carbon intensity of its economy.

It should, however, be kept in mind that some of these options may have macro-economic feedback effects. For example, if fuel efficiency of vehicles goes up, people might drive more. Such possibilities need to be accounted for by studying them in relation to each other, so that we fully understand the manner in which they affect each other. To do it consistently, macro-economic modelling would be necessary. This would require cost benefit analysis of critical options, sectoral modelling to solve for optimal programmes and macro-economic modelling to identify the desirable low carbon strategies for inclusive growth.

Besides suggesting measures, a low carbon strategy for inclusive growth needs to identify policy interventions that will help in attain the mitigation targets. Several measures may look attractive on paper, but they may not be adopted by people or firms. We also need to identify measures that could possibly help overcome such barriers. Therefore, among the tasks ahead are not only assessment of costs, co-benefits, and feedback effects, but also identification of strategies that help overcome the adoption barriers.

In implementing low-carbon strategies for inclusive growth, a supportive institutional set up is necessary. A broad consensus is also necessary, if the strategy is to be implemented smoothly. It is therefore important to have stakeholder consultations before the final report is submitted.

Policies and institutional designs need to be based on the following principles:

1. Policies need to be incentive compatible, such that they create incentives for people to self-regulate themselves.
2. They must promote technological and institutional innovation such that efficiency continuously improves over time. The development and introduction of green technology is an essential element of any low-carbon strategy. There is an urgent need to scale up and expand investment in the research and development of such technologies. This will not only require supportive policy framework for research and development, but also interventions that facilitate adoption and absorption of new technology. Venture capital funds that take equity risk could contribute to successful commercialisation of innovations.
3. Policies and implementation strategy must recognise that actions will have to come from multiple levels in Government, including the sub-national governments such as the States, the Municipalities, the Sectoral Regulators and the Panchayats, as well as Industry, Institutions and Individuals. Since many actions take place at the State and Local Government levels, not only the analysis and formulation of action plans, but also capacity building will have to be tailored to these levels.
4. Implementation should also harness the creative potential of non-governmental actors, particularly business, professional associations and the civil society at large.
5. Policies should facilitate coordination so to reduce transaction costs in the implementation of mitigation strategies. While setting priorities, both 'co-benefits' and 'consequential losses' need to be considered, as also cross-cutting effects across sectors of the economy.
6. Policies must factor in uncertainties. In the context of climate change, such uncertainties could be – uncertainty about current and cumulative greenhouse gas emissions, uncertainty about the time patterns of global warming, uncertainty about collective action at the global level, uncertainty about technology

development, uncertainty about behavioral responses of the emitters, and uncertainty about the impact of global warming on local ecosystems. In order to reach consensus on mitigation policies, we need institutions that are participatory in nature, that help resolve inter-regional and inter-sectoral conflicts. Such institutions must be knowledge based, with built-in flexibility to respond to the unexpected changes.

7. Mitigation policies also have to deal with the difficult issue of the pricing of fossil fuels. Carbon emissions are essentially a negative externality. While it may not be possible to impose externality tax on fossil fuels for the time being; we could at least consider pricing them at economic costs and removing the relative distortions as we simultaneously make efforts (including adoption of electronic benefit transfer systems) to better target subsidies to the poor. We also need to debate whether fossil fuels should be universalised, or whether traditional biomass which is self-replenishing and cheaper, should be used more efficiently.

A contentious issue is that some of the options described in this report could lead to competition for limited land and water resources in the country, particularly for bio-fuels, biomass and forestry initiatives that enhance carbon sequestration. It is essential that we plan in such a way that excessive pressure on land, including rain-fed farming land, is avoided, so as to avoid an adverse impact on food security and livelihood of the poor. This is not just an institutional issue, but also a techno-economic issue in terms of evaluation of the trade-offs. Pursuing a low carbon approach not only requires that trade-offs between development and low carbon objectives are explicitly understood, but also that amongst them, optimal policy choices are made.

To conclude, if India is to sustain an 8-9 percent real GDP growth rate over the next decade, despite its efforts at improving emission intensities, the total GHG emissions in 2020 are expected to be at least double of the absolute levels in 2007; and this carbon space must be made available to it to achieve inclusive growth and eliminate poverty.

Appendix

Expert Group on Low Carbon Strategies for Inclusive Growth

I. Composition of the Expert Group

1	Kirit Parikh, former Member, Planning Commission and Director, Integrated Research and Action for Development	Chairman
2	Nitin Desai, former Under Secretary General, Economic & Social Affairs, United Nations	Member
3	Ajay Mathur, Bureau of Energy Efficiency	Member
4	Chairman, Central Electricity Authority	Member
5	R.S. Paroda, former DG, ICAR	Member
6	Amit Mitra, FICCI	Member
7	Chandrajit Banerjee, CII	Member
8	Jamshed Irani, Tata Sons	Member
9	Jamshed Godrej, CII, Climate Change Council	Member
10	Pavan Goenka, SIAM	Member
11	Tulsi Tanti, Suzlon Energy	Member
12	Deepak Puri, Moser Baer	Member
13	Prem C Jain, Green Building Council	Member
14	Anand Patwardhan, IIT Mumbai	Member
15	Ambuj Sagar, IIT, Delhi	Member
16	Navroz Dubash, Centre for Policy Research	Member
17	D. Raghunandan, Delhi Science Forum	Member
18	Anshu Bharadwaj, C-STEP	Member
19	Girish Sant, Prayas	Member
20	Ritu Mathur, TERI	Member
21	S.C. Sharma, Planning Commission	Member
22	Sumona Bhattacharya, NATCOM Secretariat	Member

23	Jagdish Kishwan, Principal Chief Conservator of Forests	Member
24	U. Sankar, Madras School of Economics	Member
25	Varad Pande, Ministry of Environment & Forests	Member
26	Basudev Mohanty, Director, PPAC, Ministry of Petroleum	Member
27	Sharad Anand, Executive Director & CEO, NETRA, NTPC	Member
28	Indrani Chandrasekhran, Adviser (Environment & Forests), Planning Commission	Member
29	Representative of Ministry of Power	Member
30	Representative of Ministry of New and Renewable Energy	Member
31	Representative of Ministry of Road, Transport and Highways	Member
32	Representative of Ministry of Railways	Member
33	Representative of Ministry of Urban Development	Member
34	Arunish Chawla, Planning Commission	Convener

II. 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 and policies as required to operationalize the low carbon roadmap.
4. The Expert Group shall submit its Report to the Planning Commission.