

NATIONAL ACTION PLAN ON CLIMATE CHANGE

GOVERNMENT OF INDIA

PRIME MINISTER'S COUNCIL ON CLIMATE CHANGE



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National Action Plan on Climate Change

1. Overview

India is faced with the challenge of sustaining its rapid economic growth while dealing with the global threat of climate change. This threat emanates from accumulated greenhouse gas emissions in the atmosphere, anthropogenically generated through long-term and intensive industrial growth and high consumption lifestyles in developed countries. While engaged with the international community to collectively and cooperatively deal with this threat, India needs a national strategy to firstly, adapt to climate change and secondly, to further enhance the ecological sustainability of India's development path.

Climate change may alter the distribution and quality of India's natural resources and adversely affect the livelihood of its people. With an economy closely tied to its natural resource base and climate-sensitive sectors such as agriculture, water and forestry, India may face a major threat because of the projected changes in climate.

India's development path is based on its unique resource endowments, the overriding priority of economic and social development and poverty eradication, and its adherence to its civilizational legacy that places a high value on the environment and the maintenance of ecological balance.

In charting out a developmental pathway which is ecologically sustainable, India has a wider spectrum of choices precisely because it is at an early

stage of development. Our vision is to create a prosperous, but not wasteful society, an economy that is self-sustaining in terms of its ability to unleash the creative energies of our people and is mindful of our responsibilities to both present and future generations.

Recognizing that climate change is a global challenge, India will engage actively in multilateral negotiations in the UN Framework Convention on Climate Change, in a positive, constructive and forward-looking manner. Our objective will be to establish an effective, cooperative and equitable global approach based on the principle of common but differentiated responsibilities and respective capabilities, enshrined in the United Nations Framework Convention on Climate Change (UNFCCC). Such an approach must be based on a global vision inspired by Mahatma Gandhi's wise dictum—The earth has enough resources to meet people's needs, but will never have enough to satisfy people's greed. Thus we must not only promote sustainable production processes, but equally, sustainable lifestyles across the globe.

Finally, our approach must also be compatible with our role as a responsible and enlightened member of the international community, ready to make our contribution to the solution of a global challenge, which impacts on humanity as a whole. The success of our national efforts would be significantly enhanced provided the developed countries

affirm their responsibility for accumulated greenhouse gas emissions and fulfill their commitments under the UNFCCC, to transfer new and additional financial resources and climate friendly technologies to support both adaptation and mitigation in developing countries.

We are convinced that the principle of equity that must underlie the global approach must allow each inhabitant of the earth an equal entitlement to the global atmospheric resource.

In this connection, India is determined that its per capita greenhouse gas emissions will at no point exceed that of developed countries even as we pursue our development objectives.

2. Principles

Maintaining a high growth rate is essential for increasing living standards of the vast majority of our people and reducing their vulnerability to the impacts of climate change. In order to achieve a sustainable development path that simultaneously advances economic and environmental objectives, the National Action Plan for Climate Change (NAPCC) will be guided by the following principles:

- Protecting the poor and vulnerable sections of society through an inclusive and sustainable development strategy, sensitive to climate change.
- Achieving national growth objectives through a qualitative change in direction that enhances ecological sustainability, leading to further mitigation of greenhouse gas emissions.
- Devising efficient and cost-effective strategies for end use Demand Side Management.
- Deploying appropriate technologies for both adaptation and mitigation of greenhouse gases emissions extensively as well as at an accelerated pace.
- Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote

sustainable development.

- Effecting implementation of programmes through unique linkages, including with civil society and local government institutions and through public-private-partnership.
- Welcoming international cooperation for research, development, sharing and transfer of technologies enabled by additional funding and a global IPR regime that facilitates technology transfer to developing countries under the UNFCCC.

3. Approach

The NAPCC addresses the urgent and critical concerns of the country through a directional shift in the development pathway, including through the enhancement of the current and planned programmes presented in the Technical Document.

The National Action Plan on Climate Change identifies measures that promote our development objectives while also yielding co-benefits for addressing climate change effectively. It outlines a number of steps to simultaneously advance India's development and climate change-related objectives of adaptation and mitigation.

4. The Way Forward: Eight National Missions

In dealing with the challenge of climate change we must act on several fronts in a focused manner simultaneously. The National Action Plan hinges on the development and use of new technologies. The implementation of the Plan would be through appropriate institutional mechanisms suited for effective delivery of each individual Mission's objectives and include public private partnerships and civil society action. The focus will be on promoting understanding of climate change, adaptation and mitigation, energy efficiency and natural resource conservation.

There are Eight National Missions which form the core of the National Action Plan, representing multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change. While several of these programmes are already part of our current actions, they may need a change in direction, enhancement of scope and effectiveness and accelerated implementation of time-bound plans.

4.1. National Solar Mission

A National Solar Mission will be launched to significantly increase the share of solar energy in the total energy mix while recognizing the need to expand the scope of other renewable and non-fossil options such as nuclear energy, wind energy and biomass.

India is a tropical country, where sunshine is available for longer hours per day and in great intensity. Solar energy, therefore, has great potential as future energy source. It also has the advantage of permitting a decentralized distribution of energy, thereby empowering people at the grassroots level. Photovoltaic cells are becoming cheaper with new technology. There are newer, reflector-based technologies that could enable setting up megawatt scale solar power plants across the country. Another aspect of the Solar Mission would be to launch a major R&D programme, which could draw upon international cooperation as well, to enable the creation of more affordable, more convenient solar power systems, and to promote innovations that enable the storage of solar power for sustained, long-term use.

4.2. National Mission for Enhanced Energy Efficiency

The Energy Conservation Act of 2001 provides a legal mandate for the implementation of the energy efficiency measures through the institutional mechanism of the Bureau of Energy Efficiency (BEE) in the Central Government and designated agencies in each state. A number of schemes and programmes have been initiated and it is anticipated that these

would result in a saving of 10,000 MW by the end of 11th Five Year Plan in 2012.

To enhance energy efficiency, four new initiatives will be put in place. These are:

- A market based mechanism to enhance cost effectiveness of improvements in energy efficiency in energy-intensive large industries and facilities, through certification of energy savings that could be traded.
- Accelerating the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable.
- Creation of mechanisms that would help finance demand side management programmes in all sectors by capturing future energy savings.
- Developing fiscal instruments to promote energy efficiency

4.3. National Mission on Sustainable Habitat

A National Mission on Sustainable Habitat will be launched to make habitat sustainable through improvements in energy efficiency in buildings, management of solid waste and modal shift to public transport. The Mission will promote energy efficiency as an integral component of urban planning and urban renewal through three initiatives.

- i. The Energy Conservation Building Code, which addresses the design of new and large commercial buildings to optimize their energy demand, will be extended in its application and incentives provided for retooling existing building stock.
- ii. Recycling of material and Urban Waste Management will be a major component of ecologically sustainable economic development. India already has a significantly higher rate of recycling of waste compared to developed countries. A special area of focus will be the development of technology for producing power from waste. The National Mission will include a major R&D programme, focusing on bio chemical conversion, waste water use, sewage utilization and recycling options wherever possible.

iii. Better urban planning and modal shift to public transport. Making long term transport plans will facilitate the growth of medium and small cities in ways that ensure efficient and convenient public transport.

In addition, the Mission will address the need to adapt to future climate change by improving the resilience of infrastructure, community based disaster management, and measures for improving the warning system for extreme weather events. Capacity building would be an important component of this Mission.

4.4. National Water Mission

A National Water Mission will be mounted to ensure integrated water resource management helping to conserve water, minimize wastage and ensure more equitable distribution both across and within states. The Mission will take into account the provisions of the National Water Policy and develop a framework to optimize water use by increasing water use efficiency by 20% through regulatory mechanisms with differential entitlements and pricing. It will seek to ensure that a considerable share of the water needs of urban areas are met through recycling of waste water, and ensuring that the water requirements of coastal cities with inadequate alternative sources of water are met through adoption of new and appropriate technologies such as low temperature desalination technologies that allow for the use of ocean water.

The National Water Policy would be revisited in consultation with states to ensure basin level management strategies to deal with variability in rainfall and river flows due to climate change. This will include enhanced storage both above and below ground, rainwater harvesting, coupled with equitable and efficient management structures.

The Mission will seek to develop new regulatory structures, combined with appropriate entitlements and pricing. It will seek to optimize the efficiency of existing irrigation systems, including rehabilitation of systems that have been run down and

also expand irrigation, where feasible, with a special effort to increase storage capacity. Incentive structures will be designed to promote water-neutral or water-positive technologies, recharging of underground water sources and adoption of large scale irrigation programmes which rely on sprinklers, drip irrigation and ridge and furrow irrigation.

4.5. National Mission for Sustaining the Himalayan Ecosystem

A Mission for sustaining the Himalayan Ecosystem will be launched to evolve management measures for sustaining and safeguarding the Himalayan glacier and mountain eco-system. Himalayas, being the source of key perennial rivers, the Mission would, *inter-alia*, seek to understand, whether and the extent to which, the Himalayan glaciers are in recession and how the problem could be addressed. This will require the joint effort of climatologists, glaciologists and other experts. We will need to exchange information with the South Asian countries and countries sharing the Himalayan ecology.

An observational and monitoring network for the Himalayan environment will also be established to assess freshwater resources and health of the ecosystem. Cooperation with neighbouring countries will be sought to make the network comprehensive in its coverage.

The Himalayan ecosystem has 51 million people who practice hill agriculture and whose vulnerability is expected to increase on account of climate change. Community-based management of these ecosystems will be promoted with incentives to community organizations and panchayats for protection and enhancement of forested lands. In mountainous regions, the aim will be to maintain two-thirds of the area under forest cover in order to prevent erosion and land degradation and ensure the stability of the fragile eco-system.

4.6. National Mission for a Green India

A National Mission will be launched to enhance ecosystem services including carbon sinks to be called Green India. Forests play an indispensable role in the

preservation of ecological balance and maintenance of bio-diversity. Forests also constitute one of the most effective carbon-sinks.

The Prime Minister has already announced a Green India campaign for the afforestation of 6 million hectares. The national target of area under forest and tree cover is 33% while the current area under forests is 23%.

The Mission on Green India will be taken up on degraded forest land through direct action by communities, organized through Joint Forest Management Committees and guided by the Departments of Forest in state governments. An initial corpus of over Rs 6000 crore has been earmarked for the programme through the Compensatory Afforestation Management and Planning Authority (CAMPA) to commence work. The programme will be scaled up to cover all remaining degraded forest land. The institutional arrangement provides for using the corpus to leverage more funds to scale up activity.

4.7. National Mission for Sustainable Agriculture

The Mission would devise strategies to make Indian agriculture more resilient to climate change. It would identify and develop new varieties of crops and especially thermal resistant crops and alternative cropping patterns, capable of withstanding extremes of weather, long dry spells, flooding, and variable moisture availability.

Agriculture will need to be progressively adapted to projected climate change and our agricultural research systems must be oriented to monitor and evaluate climate change and recommend changes in agricultural practices accordingly.

This will be supported by the convergence and integration of traditional knowledge and practice systems, information technology, geospatial technologies and biotechnology. New credit and insurance mechanisms will be devised to facilitate adoption of desired practices.

Focus would be on improving productivity of rainfed agriculture. India will spearhead efforts at the international level to work towards an ecologi-

cally sustainable green revolution.

4.8. National Mission on Strategic Knowledge for Climate Change

To enlist the global community in research and technology development and collaboration through mechanisms including open source platforms, a Strategic Knowledge Mission will be set up to identify the challenges of, and the responses to, climate change. It would ensure funding of high quality and focused research into various aspects of climate change.

The Mission will also have, on its research agenda, socio-economic impacts of climate change including impact on health, demography, migration patterns and livelihoods of coastal communities. It would also support the establishment of dedicated climate change related academic units in Universities and other academic and scientific research institutions in the country which would be networked. A Climate Science Research Fund would be created under the Mission to support research. Private sector initiatives for development of innovative technologies for adaptation and mitigation would be encouraged through venture capital funds. Research to support policy and implementation would be undertaken through identified centres. The Mission will also focus on dissemination of new knowledge based on research findings.

5. Implementation of Missions

These National Missions will be institutionalized by respective ministries and will be organized through inter-sectoral groups which include in addition to related Ministries, Ministry of Finance and the Planning Commission, experts from industry, academia and civil society. The institutional structure would vary depending on the task to be addressed by the Mission and will include providing the opportunity to compete on the best management model.

Each Mission will be tasked to evolve specific objectives spanning the remaining years of the

11th Plan and the 12th Plan period 2012-13 to 2016-17. Where the resource requirements of the Mission call for an enhancement of the allocation in the 11th Plan, this will be suitably considered, keeping in mind the overall resources position and the scope for re-prioritisation.

Comprehensive Mission documents detailing objectives, strategies, plan of action, timelines and monitoring and evaluation criteria would be developed and submitted to the Prime Minister's Council on Climate Change by December 2008. The Council will also periodically review the progress of these Missions. Each Mission will report publicly on its annual performance.

Building public awareness will be vital in supporting implementation of the NAPCC. This will be achieved through national portals, media engagement, civil society involvement, curricula reform and recognition/ awards, details of which will be worked out by an empowered group. The Group will also consider methods of capacity building to support the goals of the National Missions.

We will develop appropriate technologies to measure progress in actions being taken in terms of avoided emissions, wherever applicable, with reference to business as usual scenarios. Appropriate indicators will be evolved for assessing adaptation benefits of the actions.

These Eight National Missions, taken together, with enhancements in current and ongoing programmes included in the Technical Document, would not only

assist the country to adapt to climate change, but also, importantly, launch the economy on a path that would progressively and substantially result in mitigation through avoided emissions.

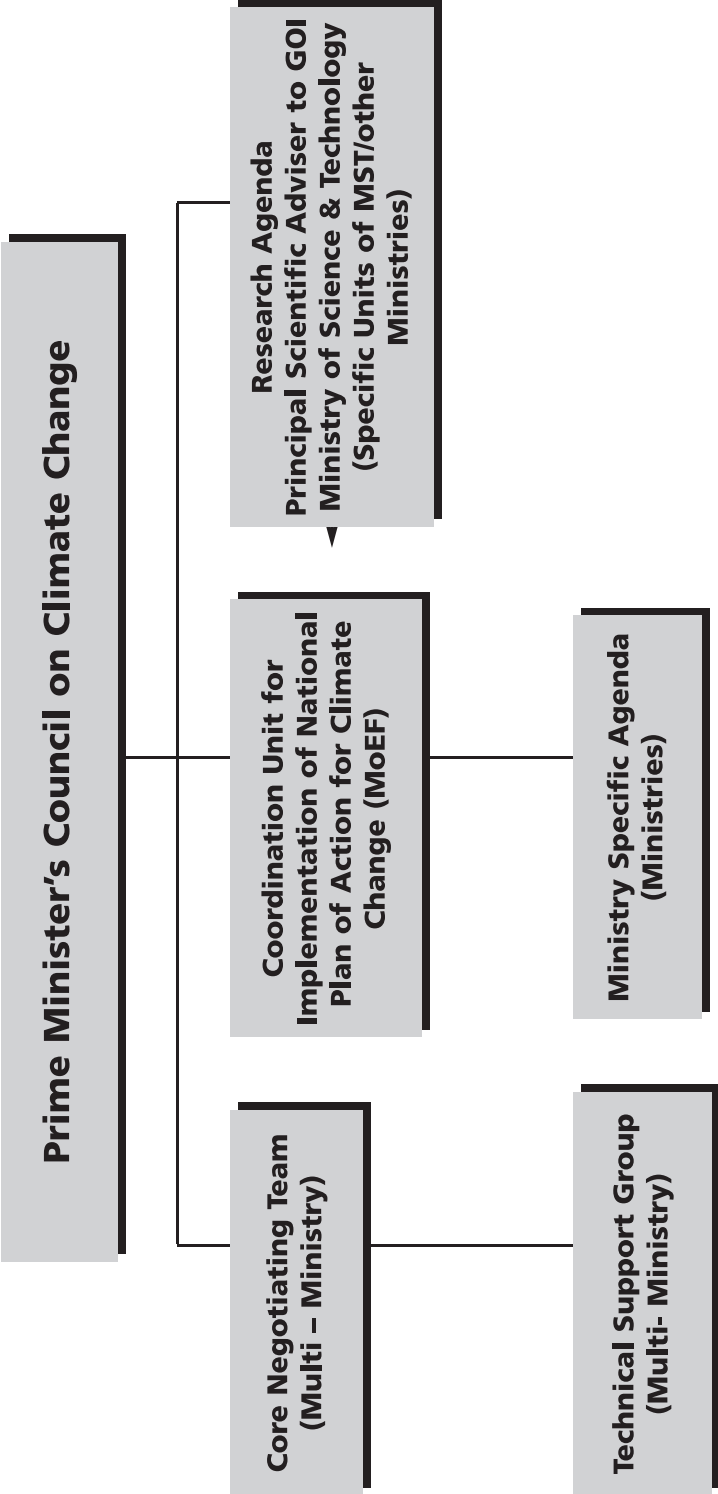
5.1. Institutional Arrangements for Managing Climate Change Agenda

In order to respond effectively to the challenge of climate change, the Government has created an Advisory Council on Climate Change, chaired by the Prime Minister. The Council has broad based representation from key stake-holders, including Government, Industry and Civil Society and sets out broad directions for National Actions in respect of Climate Change. The Council will also provide guidance on matters relating to coordinated national action on the domestic agenda and review of the implementation of the National Action Plan on Climate Change including its R&D agenda.

The Council chaired by the Prime Minister would also provide guidance on matters relating to international negotiations including bilateral, multi-lateral programmes for collaboration, research and development. Details of the institutional arrangement are at Annexure 1.

The NAPCC will continue to evolve, based on new scientific and technical knowledge as they emerge and in response to the evolution of the multilateral climate change regime including arrangements for international cooperation.

Annexure - I



TECHNICAL DOCUMENT

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1. Background to India's National Action Plan on Climate Change

The Fourth Assessment report of the Intergovernmental Panel on Climate Change (IPCC-AR4)¹ concluded from direct observations of changes in temperature, sea level, and snow cover in the northern hemisphere during 1850 to the present, that the warming of the earth's climate system is unequivocal. The global atmospheric concentration of carbon dioxide has increased from a pre-industrial value of about 280 ppm to 379 ppm in 2005. Multi-model averages show that the temperature increases during 2090-2099 relative to 1980-1999 may range from 1.1 to 6.4°C and sea level rise from 0.18 to 0.59 meters. These could lead to impacts on freshwater availability, oceanic acidification, food production, flooding of coastal areas and increased burden of vector borne and water borne diseases associated with extreme weather events..

The Prime Minister's Council on Climate Change, in its first meeting on 13th July, 2007, had decided that "A *National Document compiling action taken by India for addressing the challenge of Climate Change, and the action it proposes to take*" be prepared.

The National Action Plan for Climate Change responds to the decision of the PM's Council, as well as updates India's national programmes relevant to addressing climate change. It identifies measures that promote our development objectives, while also yielding co-benefits for addressing climate change effectively. It lists specific opportunities to simultaneously advance India's development and climate related objectives of both adaptation as well as greenhouse gas (GHG) mitigation.

India's development agenda focuses on the need for rapid economic growth as an essential precondition to poverty eradication and improved standards of living. Meeting this agenda, which will also reduce climate-related vulnerability, requires large-scale investment of resources in infrastructure, technology and access to energy. Developing countries may lack the necessary financial and technological resources needed for this and thus have very low coping capacity to meet threats from climate changes. Only rapid and sustained development can

generate the required financial, technological and human resources. In view of the large uncertainties concerning the spatial and temporal magnitude of climate change impacts, it is not desirable to design strategies exclusively for responding to climate change. Rather, the need is to identify and prioritize strategies that promote development goals while also serving specific climate change objectives.

It is imperative to identify measures that promote our development objectives, while also yielding co-benefits for addressing climate change effects. Cost-effective energy efficiency and energy conservation measures are of particular importance in this connection. Similarly, development of clean energy technologies, though primarily designed to promote energy security, can also generate large benefits in terms of reducing carbon emissions. Many health-related local pollution controls can also generate significant co-benefits in terms of reduced greenhouse gas emissions. This document identifies specific opportunities to simultaneously advance India's development and climate related objectives of adaptation and GHG mitigation.

It also describes India's willingness and desire, as a responsible member of the global community, to do all that is possible for pragmatic and practical solutions for all, in accordance with the principle of common but differentiated responsibilities and respective capabilities. The purpose of this document is also to create awareness among representatives of the public at large, different agencies of the government, scientists, industry – in short, the community as a whole – on the threat posed by climate change and the proposed steps to counter it.

1.1. The Imperative of Poverty Alleviation

Economic reforms, implemented since 1991, have resulted in faster growth of the Indian economy. GDP growth rates have averaged roughly 8% during 2004-2008. However, 27.5% of the population still lived below the poverty line in 2004-05 and 44% are still without access to electricity. The Approach Paper to the Eleventh Plan emphasizes that rapid economic growth is an essential prerequisite to reduce poverty. The poor are the most vulnerable to climate

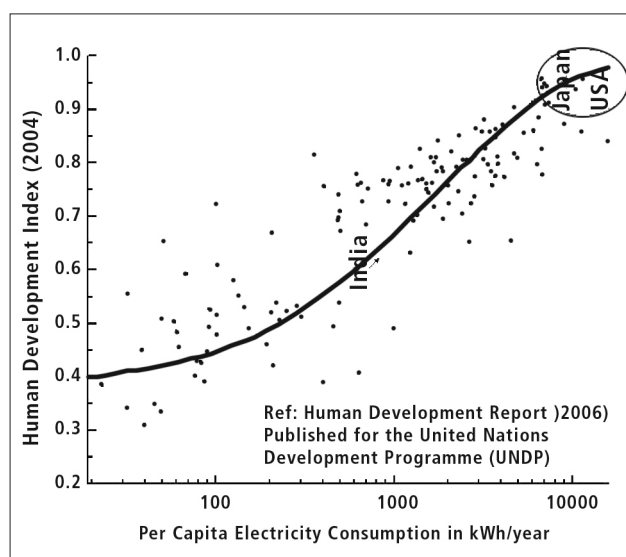
change. The former Prime Minister, late Smt. Indira Gandhi, had stated: 'poverty is the worst polluter'. Therefore, development and poverty eradication will be the best form of adaptation to climate change.

The impacts of climate change could prove particularly severe for women. With climate change, there would be increasing scarcity of water, reduction in yields of forest biomass, and increased risks to human health with children, women and the elderly in a household becoming the most vulnerable. With the possibility of decline in availability of foodgrains, the threat of malnutrition may also increase. All these would add to deprivations that women already encounter and so in each of the Adaptation programmes, special attention should be paid to the aspects of gender.

1.2 Relationship between Human Development Index and Energy Consumption

The strong positive correlation between energy use and human development is well recognized (Figure 1.2.1). It is obvious that India needs to substantially increase its per capita energy consumption to provide a minimally acceptable level of well being to its people.

Figure 1.2.1: Human Development Index versus per capita electricity consumption



1.3 Current Carbon Dioxide Emissions in India

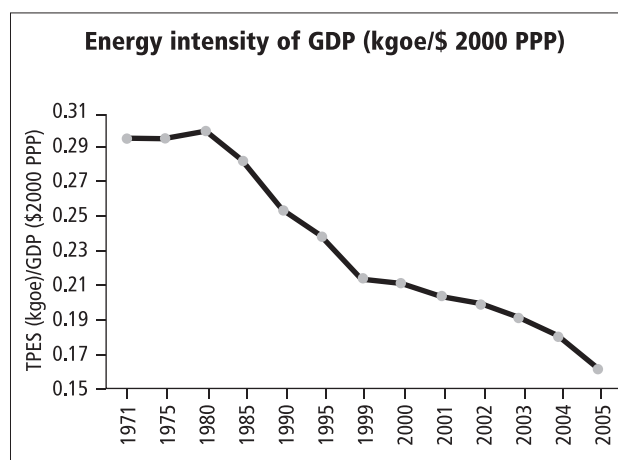
India's CO₂ emissions per capita are well below the world's average². Per capita carbon dioxide emissions of some regions in the world in 2004 are as follows:

Table 1.3.1: A comparison of India's per capita GHG emissions with some other countries

Country	Per-Capita Carbon-dioxide emissions (metric tons)
USA	20.01
EU	9.40
Japan	9.87
China	3.60
Russia	11.71
India	1.02
World Average	4.25

India has a well-developed policy, legislative, regulatory, and programmatic regime for promotion of energy efficiency, renewable energy, nuclear power, fuel switching, energy pricing reform, and addressing GHG emissions in the energy sector. As a consequence of these measures, India's energy intensity of the economy has come down sharply since the 1980s and compares favourably with the least energy intensive developed countries³.

Figure 1.3.2: India's Energy intensity of GDP based on International Energy Agency data⁴



1.4. Observed Changes in Climate and Weather Events in India

There are some observed changes in climate parameters in India. India's Initial National Communication, 2004 (NATCOM 1)⁵ to UNFCCC has consolidated some of these. Some highlights from NATCOM I and others are listed here. No firm link between the documented changes described below and warming due to anthropogenic climate change has yet been established.

• Surface Temperature

At the national level, increase of ~ 0.4° C has been observed in surface air temperatures over the past century. A warming trend has been observed along the west coast, in central India, the interior peninsula, and north-eastern India. However, cooling trends have been observed in north-west India and parts of south India.

• Rainfall

While the observed monsoon rainfall at the all-India level does not show any significant trend, regional monsoon variations have been recorded. A trend of increasing monsoon seasonal rainfall has been found along the west coast, northern Andhra Pradesh, and north-western India (+10% to +12% of the normal over the last 100 years) while a trend of decreasing monsoon seasonal rainfall has been observed over eastern Madhya Pradesh, north-eastern India, and some parts of Gujarat and Kerala (–6% to –8% of the normal over the last 100 years).

• Extreme Weather Events

Instrument records over the past 130 years do not indicate any marked long-term trend in the frequencies of large-scale droughts and floods. Trends are however observed in multi-decadal periods of more frequent droughts, followed by less severe droughts. There has been an overall increasing trend in severe storm incidence along the coast at the rate of 0.011 events per year. While the states of West Bengal and Gujarat have reported increasing trends, a decline has been observed in Orissa. Goswami⁶ et al, by analysing a daily rainfall data set, have shown (i) a rising trend in the frequency of heavy rain events,

and (ii) a significant decrease in the frequency of moderate events over central India from 1951 to 2000.

• Rise in Sea Level

Using the records of coastal tide gauges in the north Indian Ocean for more than 40 years, Unnikrishnan and Shankar⁷ have estimated, that sea level rise was between 1.06-1.75 mm per year. These rates are consistent with 1-2 mm per year global sea level rise estimates of IPCC.

• Impacts on Himalayan Glaciers

The Himalayas possess one of the largest resources of snow and ice and its glaciers form a source of water for the perennial rivers such as the Indus, the Ganga, and the Brahmaputra. Glacial melt may impact their long-term lean-season flows, with adverse impacts on the economy in terms of water availability and hydropower generation.

The available monitoring data on Himalayan glaciers indicates that while recession of some glaciers has occurred in some Himalayan regions in recent years, the trend is not consistent across the entire mountain chain. It is accordingly, too early to establish long-term trends, or their causation, in respect of which there are several hypotheses.

Under the National Action Plan, these data will be updated and refined continuously and additional reliable data will be collected.

1.5. Some Projections of Climate Change over India for the 21st Century

Some modelling and other studies have projected the following changes due to increase in atmospheric GHG concentrations arising from increased global anthropogenic emissions:

- Annual mean surface temperature rise by the end of century, ranging from 3 to 5° C under A2 scenario and 2.5 to 4° C under B2 scenario of IPCC, with warming more pronounced in the northern parts of India, from simulations by Indian Institute of Tropical Meteorology (IITM), Pune.

- Indian summer monsoon (ISM) is a manifestation of complex interactions between land, ocean and atmosphere. The simulation of ISM's mean pattern as well as variability on interannual and intraseasonal scales has been a challenging ongoing problem. Some simulations by IITM, Pune, have indicated that summer monsoon intensity may increase beginning from 2040 and by 10% by 2100 under A2 scenario of IPCC.

- Changes in frequency and/ or magnitude of extreme temperature and precipitation events. Some results show that fine-scale snow albedo influence the response of both hot and cold events and that peak increase in extreme hot events are amplified by surface moisture feedbacks.

1.6. Possible Impacts of Projected Climate Change

1.6.1. IMPACTS ON WATER RESOURCES

Changes in key climate variables, namely temperature, precipitation, and humidity, may have significant long-term implications for the quality and quantity of water. River systems of the Brahmaputra, the Ganga, and the Indus, which benefit from melting snow in the lean season, are likely to be particularly affected by the decrease in snow cover. A decline in total run-off for all river basins, except Narmada and Tapi, is projected in India's NATCOM I. A decline in run-off by more than two-thirds is also anticipated for the Sabarmati and Luni basins. Due to sea level rise, the fresh water sources near the coastal regions will suffer salt intrusion.

1.6.2. IMPACTS ON AGRICULTURE AND FOOD PRODUCTION

Food production in India is sensitive to climate changes such as variability in monsoon rainfall and temperature changes within a season. Studies by Indian Agricultural Research Institute (IARI) and others indicate greater expected loss in the Rabi crop. Every 1 °C rise in temperature reduces wheat production by 4-5 Million Tonnes. Small changes in temperature and rainfall have significant effects on the qual-

ity of fruits, vegetables, tea, coffee, aromatic and medicinal plants, and basmati rice. Pathogens and insect populations are strongly dependent upon temperature and humidity, and changes in these parameters may change their population dynamics. Other impacts on agricultural and related sectors include lower yields from dairy cattle and decline in fish breeding, migration, and harvests. Global reports indicate a loss of 10-40% in crop production by 2100.

1.6.3. IMPACTS ON HEALTH

Changes in climate may alter the distribution of important vector species (for example, malarial mosquitoes) and may increase the spread of such diseases to new areas. If there is an increase of 3.8 °C in temperature and a 7% increase in relative humidity the transmission windows i.e., months during which mosquitoes are active, will be open for all 12 months in 9 states in India. The transmission windows in Jammu and Kashmir and in Rajasthan may increase by 3-5 months. However, in Orissa and some southern states, a further increase in temperature is likely to shorten the transmission window by 2-3 months.

1.6.4. IMPACTS ON FORESTS

Based on future climate projections of Regional Climate Model of the Hadley Centre (HadRM3) using A2 and B2 scenarios and the BIOME4 vegetation response model, Ravindranath et. al.⁸ show that 77% and 68% of the forest areas in the country are likely to experience shift in forest types, respectively under the two scenarios, by the end of the century, with consequent changes in forests produce, and, in turn, livelihoods based on those products. Correspondingly, the associated biodiversity is likely to be adversely impacted. India's NATCOM I projects an increase in the area under xeric scrublands and xeric woodlands in central India at the cost of dry savannah in these regions.

1.6.5. VULNERABILITY TO EXTREME EVENTS

Heavily populated regions such as coastal areas are exposed to climatic events, such as cyclones, floods, and drought, and large declines in sown areas in arid

and semi-arid zones occur during climate extremes. Large areas in Rajasthan, Andhra Pradesh, Gujarat, and Maharashtra and comparatively small areas in Karnataka, Orissa, Madhya Pradesh, Tamil Nadu, Bihar, West Bengal, and Uttar Pradesh are frequented by drought. About 40 million hectares of land is flood-prone, including most of the river basins in the north and the north-eastern belt, affecting about 30 million people on an average each year. Such vulnerable regions may be particularly impacted by climate change

1.6.6. IMPACTS ON COASTAL AREAS

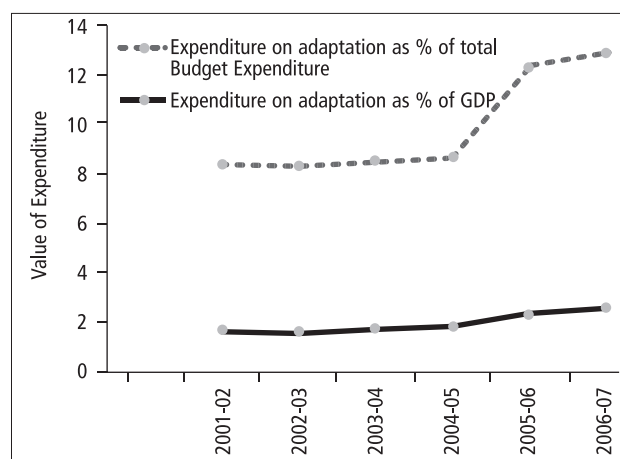
A mean Sea Level Rise (SLR) of 15–38 cm is projected along India’s coast by the mid 21st century and of 46–59 cm by 2100. India’s NATCOM I assessed the vulnerability of coastal districts based on physical exposure to SLR, social exposure based on population affected, and economic impacts. In addition, a projected increase in the intensity of tropical cyclones poses a threat to the heavily populated coastal zones in the country (NATCOM, 2004).

2. Some Current Actions for Adaptation and Mitigation

Adaptation, in the context of climate change, comprises the measures taken to minimize the adverse impacts of climate change, e.g. relocating the communities living close to the sea shore, for instance, to cope with the rising sea level or switching to crops that can withstand higher temperatures. Mitigation comprises measures to reduce the emissions of greenhouse gases that cause climate change in the first place, e.g. by switching to renewable sources of energy such as solar energy or wind energy, or nuclear energy instead of burning fossil fuel in thermal power stations.

Current government expenditure in India on adaptation to climate variability, as shown in Figure 2.1, exceeds 2.6% of the GDP, with agriculture, water resources, health and sanitation, forests, coastal-zone infrastructure and extreme weather events, being specific areas of concern.

Figure 2.1: Expenditure on Adaptation Programmes in India



2.1 Some Existing Adaptation related Programmes

2.1.1. CROP IMPROVEMENT

The present programmes address measures such as development of arid-land crops and pest management, as well as capacity building of extension workers and NGOs to support better vulnerability reducing practices.

2.1.2. DROUGHT PROOFING

The current programmes seek to minimize the adverse effects of drought on production of crops and livestock, and on productivity of land, water and human resources, so as to ultimately lead to drought proofing of the affected areas. They also aim to promote overall economic development and improve the socio-economic conditions of the resource poor and disadvantaged sections inhabiting the programme areas.

2.1.3. FORESTRY

India has a strong and rapidly growing afforestation programme. The afforestation process was accelerated by the enactment of the Forest Conservation Act of 1980, which aimed at stopping the clearing and degradation of forests through a strict, centralized control of the rights to use forest land and

mandatory requirements of compensatory afforestation in case of any diversion of forest land for any non-forestry purpose. In addition an aggressive afforestation and sustainable forest management programme resulted in annual reforestation of 1.78 mha during 1985-1997, and is currently 1.1 mha annually. Due to this, the carbon stocks in Indian forests have increased over the last 20 years to 9 -10 gigatons of carbon (GtC) during 1986 to 2005.

2.1.4. WATER

The National Water Policy (2002) stresses that non-conventional methods for utilization of water, including inter-basin transfers, artificial recharge of groundwater, and desalination of brackish or sea water, as well as traditional water conservation practices like rainwater harvesting, including roof-top rainwater harvesting, should be practised to increase the utilizable water resources. Many states now have mandatory water harvesting programmes in several cities.

2.1.5. COASTAL REGIONS

In coastal regions, restrictions have been imposed in the area between 200m and 500m of the HTL (high tide line) while special restrictions have been imposed in the area up to 200m to protect the sensitive coastal ecosystems and prevent their exploitation. This, simultaneously, addresses the concerns of the coastal population and their livelihood. Some specific measures taken in this regard include construction of coastal protection infrastructure and cyclone shelters, as well as plantation of coastal forests and mangroves.

2.1.6. HEALTH

The prime objective of these programmes is the surveillance and control of vector borne diseases such as Malaria, Kala-azar, Japanese Encephalitis, Filaria and Dengue. Programmes also provide for emergency medical relief in the case of natural calamities, and to train and develop human resources for these tasks.

2.1.7. RISK FINANCING

Two risk-financing programmes support adaptation to climate impacts. The Crop Insurance Scheme supports the insurance of farmers against climate risks, and the Credit Support Mechanism facilitates the extension of credit to farmers, especially for crop failure due to climate variability.

2.1.8. DISASTER MANAGEMENT

The National Disaster Management programme provides grants-in-aid to victims of weather related disasters, and manages disaster relief operations. It also supports proactive disaster prevention programmes, including dissemination of information and training of disaster-management staff.

2.2. Some of India's Actions Relating to GHG Mitigation

2.2.1. INDIA'S POLICY STRUCTURE RELEVANT TO GHG MITIGATION

India has in place a detailed policy, regulatory, and legislative structure that relates strongly to GHG mitigation: The Integrated Energy Policy was adopted in 2006. Some of its key provisions are:

- Promotion of energy efficiency in all sectors
- Emphasis on mass transport
- Emphasis on renewables including biofuels plantations
- Accelerated development of nuclear and hydropower for clean energy
- Focused R&D on several clean energy related technologies

Several other provisions relate to reforming energy markets to ensure that energy markets are competitive, and energy prices reflect true resource costs. These include: Electricity Act 2005, Tariff Policy 2003, Petroleum & Natural Gas Regulatory Board Act, 2006, etc. The provisions taken together are designed to:

- Remove entry barriers and raise competition in

exploration, extraction, conversion, transmission and distribution of primary and secondary energy

- Accomplish price reform, through full competition at point of sale
- Promote tax reform to promote optimal fuel choices
- Augment and diversify energy options, sources and energy infrastructure
- Provide feed-in tariffs for renewables (solar, wind, biomass cogeneration)
- Strengthen, and where applicable, introduce independent regulation

The Rural Electrification Policy, 2006, promotes renewable energy technologies where grid connectivity is not possible or cost-effective. The New and Renewable Energy Policy, 2005, promotes utilization of sustainable, renewable energy sources, and accelerated deployment of renewables through indigenous design, development and manufacture.

The National Environment Policy, 2006, and the Notification on Environment Impact Assessment (EIA), 2006, reform India's environmental assessment regime. A number of economic activities are required to prepare environment impact assessments, and environment management plans, which are appraised by regulatory authorities prior to start of construction. The EIA provisions strongly promote environmental sustainability.

2.2.2. INTRODUCTION OF LABELLING PROGRAMME FOR APPLIANCES

An energy labelling programme for appliances was launched in 2006, and comparative star-based labelling has been introduced for fluorescent tube-lights, air conditioners, refrigerators, and distribution transformers. The labels provide information about the energy consumption of an appliance, and thus enable consumers to make informed decisions. The Bureau of Energy Efficiency has made it mandatory for refrigerators to display energy efficiency label and is expected to do so for air conditioners as well. The standards and labelling programme for manufacturers of electrical appliances is expected to lead to significant savings in electricity annually.

2.2.3. ENERGY CONSERVATION BUILDING CODE

An Energy Conservation Building Code (ECBC) was launched in May, 2007, which addresses the design of new, large commercial buildings to optimize the buildings' energy demand based on their location in different climatic zones. Commercial buildings are one of the fastest growing sectors of the Indian economy, reflecting the increasing share of the services sector in the economy. Nearly one hundred buildings are already following the Code, and compliance with the Code has been incorporated into the mandatory Environmental Impact Assessment requirements for large buildings. It has been estimated that if all the commercial space in India every year conform to ECBC norms, energy consumption in this sector can be reduced by 30-40%. Compliance with ECBC norms is voluntary at present but is expected to soon become mandatory.

2.2.4. ENERGY AUDITS OF LARGE INDUSTRIAL CONSUMERS

In March 2007 the conduct of energy audits was made mandatory in large energy-consuming units in nine industrial sectors. These units, notified as "designated consumers" are also required to employ "certified energy managers", and report energy consumption and energy conservation data annually.

2.2.5. MASS TRANSPORT

The National Urban Transport Policy emphasizes extensive public transport facilities and non-motorized modes over personal vehicles. The expansion of the Metro Rail Transportation System in Delhi and other cities and other mass transit systems, such as the Metro Bus project in Bangalore, are steps in its implementation. The state government of Maharashtra recently announced that it will impose a congestion tax to discourage the use of private cars in cities where it has created "sufficient public transport capacity".

2.2.6. CLEAN AIR INITIATIVES

In urban areas, one of the major sources of air pollution is emissions from transport vehicles. Steps taken

to reduce such pollution include (i) introduction of compressed natural gas (CNG) in Delhi and other cities; (ii) retiring old, polluting vehicles; and (iii) strengthening of mass transportation as mentioned above. Some state governments provide subsidies for purchase and use of electric vehicles. For thermal power plants, the installation of electrostatic precipitators is mandatory. In many cities, polluting industrial units have either been closed or shifted from residential areas.

2.2.7 PROMOTION OF ENERGY SAVING DEVICES

The Bureau of Energy efficiency has introduced “The Bachat Lamp Yojana”, a programme under which households may exchange incandescent lamps for CFLs (compact fluorescent lamps) using clean development mechanism (CDM) credits to equate purchase price. Some states have made mandatory the installation of solar water heaters in hospitals, hotels and large government and commercial buildings. Subsidy is provided for installation of solar water heaters in residential buildings.

2.2.8. PROMOTION OF BIOFUELS

The Biodiesel Purchase Policy mandates biodiesel procurement by the petroleum industry. A mandate on Ethanol Blending of Gasolene requires 5% blending of ethanol with gasolene from 1st January, 2003, in 9 States and 4 Union Territories.

3. The Way Forward: Eight National Missions

The experience gained so far enables India to embark on an even more proactive approach. The following subsections describe the various programmes that may be taken up under the National Action Plan.

3.1. National Solar Mission

The National Solar Mission would promote the use of solar energy for power generation and other applications. Where necessary for purposes of system bal-

ance or ensuring cost-effectiveness and reliability, it would also promote the integration of other renewable energy technologies, for example, biomass and wind, with solar energy options.

India is largely located in the equatorial sun belt of the earth, thereby receiving abundant radiant energy from the sun. The country receives about 5,000 trillion kWh/year equivalent energy through solar radiation. In most parts of India, clear sunny weather is experienced 250 to 300 days a year. The annual global radiation varies from 1600 to 2200 kWh/m², which is typical of the tropical and subtropical regions. The average solar insolation incident over India is about 5.5 kWh/m² per day. Just 1% of India's land area can meet India's entire electricity requirements till 2030.

Solar based power technologies are an extremely clean form of generation with practically no form of emissions at the point of generation. They would lead to energy security through displacement of coal and petroleum. T&D losses are very low in decentralized systems. Deployment can be done independently of the national grid and integrated with the national grid when needed.

3.1.1. SOLAR THERMAL POWER GENERATION

Solar Thermal Power Generating Systems (STPG) or Concentrating Solar Power (CSP) use concentrated solar radiation as high temperature energy source (> 500⁰C) to produce electricity.

The working mechanism for solar heat to electricity is fundamentally similar to that of traditional thermal power plants. STPG technologies are now on the verge of significant scale commercialization. Major technologies include parabolic trough or dish, dish-engine system, central tower receiver system, and solar chimney (which drives an air draft turbine, and does not raise steam).

Solar power is, obviously available only during sunlight hours. There are also significant seasonal variations. Moreover, the need to track the movement of the sun during the day, as also the seasonal variations in orientation, although fully predictable, may add significantly to cost in respect of dish collector systems. However, design variants are available that require movement of only the heat collector at

the focus, or only of individual mirrors in an array, thus reducing costs.

The cyclical (diurnal, annual) and episodic (cloud cover) variations of solar insolation, and the impossibility of regulating the solar flux means that in order to ensure steady power supply, meet peaking requirements, as well as to ensure optimal utilization of steam turbines and generators, it is necessary to either hybridize solar thermal systems with alternative means of raising steam, or provide for high temperature thermal energy storage. The former may be accomplished by hybridization with conventional fuels, or by biomass combustion systems. The latter may be accomplished by insulated storage of molten salts; however, in their case the rate of heat loss may be significant, and storage for more than 10-12 hours is uneconomic.

The investment cost of stand-alone (i.e. without hybridization) solar thermal power plants are in the range of Rs 20-22 cr/MW. It usually includes the cost of the solar concentrators, balance of system (BOS), receiver (turbine) with generator and control equipments, etc. The estimated unit cost of generation is currently in the range of 20-25 Rs/KWh. (Source Scientific American, January 2008)

Proposed R&D activities in respect of Solar Thermal power generation would cover design and development of concentrating solar thermal power systems, including parabolic troughs, central receiver systems, and dish/engine systems. The R&D effort should be directed mainly at reducing costs of production and maintenance, and include both production design and fabrication/assembly techniques. In addition, R&D should cover balance of systems issues involved in hybridization with biomass combustion based systems and/or molten salts thermal storage.

3.1.2. SOLAR PHOTOVOLTAIC GENERATION

In photovoltaic generation, solar energy is directly converted to electricity using a semi-conductor, usually a silicon diode. However, while there are other semi-conductors (e.g. cadmium telluride) that may be used for power generation, most of them are at various stages of R&D.

The investment costs of solar PV based

power systems are in the range of Rs. 30-35cr/MW. This includes the cost of the solar panels and balance of system (BOS). The unit cost of generation is still in the range of Rs. 15-20 KWh, but may fall significantly for thin-film based systems.

Proposed R&D activities in respect of Solar Photovoltaic generation, for the near and medium term would include improvement in solar cell efficiency to 15% at commercial level; improvements in PV module technology with higher packing density and suitability for solar roofs; and development of lightweight modules for use in solar lanterns and similar applications.

3.1.3. R&D COLLABORATION, TECHNOLOGY TRANSFER, AND CAPACITY BUILDING

In specific areas of both solar thermal and solar PV systems, it would be useful to enter into collaboration with institutions working elsewhere, with sharing of the resulting IPRs.

Technology transfer in both Solar Thermal technologies and the PV technologies will be required in respect of cost-effective and efficient technologies suitable for use in India. Support to commercial demonstration by entrepreneurs of Solar Thermal and Solar PV, both stand-alone and distributed generation systems, in particular in remote locations, and using these as training facilities for local entrepreneurs and O&M personnel would also help develop this sector.

The National Solar Mission would be responsible for: (a) the deployment of commercial and near commercial solar technologies in the country; (b) establishing a solar research facility at an existing establishment to coordinate the various research, development and demonstration activities being carried out in India, both in the public and private sector; (c) realizing integrated private sector manufacturing capacity for solar material, equipment, cells and modules (d) networking of Indian research efforts with international initiatives with a view to promoting collaborative research and acquiring technology where necessary, and adapting the technology acquired to Indian conditions; (e) providing funding support for the activities foreseen under (a) to (d) through government grants duly leveraged by

funding available under global climate mechanisms, and earnings from deployment of research sponsored by the Mission. Policy and Regulatory measures for promotion of solar technologies would also be enhanced as common to all renewables based technologies.

Over the 11th and 12th Plan periods (till 2017) the Mission would aim to deliver at least 80% coverage for all low temperature (<150° C), and at least 60% coverage for medium temperature (150° to 250° C) applications of solar energy in all urban areas, industries, and commercial establishments. Rural solar thermal applications would also be pursued under public-private partnerships where feasible. Commensurate local manufacturing capacity to meet this level of deployment, with necessary technology tie-ups, where desirable, would be established. Further, the Mission would aim for local Photovoltaic (PV) production from integrated facilities at a level of 1000 MW/annum within this time frame. It would also aim to establish at least 1000 MW of Concentrating Solar Power (CSP) generation capacity, again, with such technical tie-ups as essential within the stated time frame.

The untapped energy potential of each of the three generic solar based energy approaches (i.e. solar PV, solar thermal, and biomass) is well beyond current usage levels. In the long term the Mission would aim to network Indian research efforts in solar technology with global initiatives in these three areas, so as to enable delivery of solar solutions to India's energy needs in tandem with developments worldwide.

In the long-term, the Mission would direct Indian solar research initiatives to deliver truly disruptive innovations that cut across more than one approach or technology. These include: (a) getting the same electrical, optical, chemical and physical performance from cheap materials as that delivered by expensive materials; (b) developing new paradigms for solar cell design that surpass current efficiency limits; (c) finding catalysts that enable inexpensive, efficient conversion of solar energy into chemical fuel; (d) identify novel methods of self-assembly of molecular components into functionally integrated systems; and (e) developing new materi-

als for solar energy conversion infrastructure, such as robust, and inexpensive, thermal management materials.

The ultimate objective of the Mission would be to develop a solar industry in India that is capable of delivering solar energy competitively against fossil options from the Kilowatt range of distributed solar thermal and solar PV to the Gigawatt scale of base load priced and dispatchable CSP within the next 20-25 years.

3.2. National Mission for Enhanced Energy Efficiency in Industry

The industry sector is the largest user of commercial energy in India, accounting for 42% of the country's total commercial energy use during 2004–05. The Indian industry sector, comprising large, medium, and small enterprises registered a growth of 10.6% in April–December 2006 (MoF, 2007). Since the industry sector is viewed as central for economic growth, it would continue to play a major role in the overall development of India.

The industrialization policies of the country have helped in setting up of several energy-intensive primary manufacturing facilities such as iron and steel, cement, fertilizer, refineries, with investment targets fixed in successive Five-year Plans of the Government of India. The planners also encouraged various small scale industries, providing huge employment. The small scale sector produces close to 7500 items in which 326 items are reserved by the Government of India (MoSSI, 2007) to be exclusively produced by small units.

As per the national greenhouse inventory, the direct CO₂ emissions from industrial sources accounted for nearly 31% of the total CO₂ emissions from the country (data for base year 1994) (NATCOM, I). The CO₂ emissions from the industrial sector can be broadly categorized into two heads, i.e. process related emissions, and emissions due to fuel combustion in industries. Of the total estimated 250 million tonnes of direct CO₂ emissions from the industry in 1994, nearly 60% were accounted for by energy use (NATCOM, I).

3.2.1. GHG MITIGATION OPTIONS IN THE INDUSTRY SECTOR

GHG Mitigation options in the industry sector can be broadly grouped under three heads as given below:

- Sector specific technological options
- Cross-cutting technologies options
- Fuel switch options

3.2.2. SECTOR SPECIFIC TECHNOLOGICAL OPTIONS

Various GHG mitigation technology options in respect of the Chlor-Alkali, Cement, Aluminum, Fertilizer, Iron and Steel, Pulp and Paper, and Textile sectors are currently being investigated.

3.2.3. CROSS-CUTTING TECHNOLOGICAL OPTIONS

Apart from sector-specific options, there are certain cross-cutting energy efficient technological options that could be adopted in a wide range of industries. In general, in the industries sector, approximately 50% of the industrial energy use is accounted for by cross-cutting technologies.

The estimated energy saving potential for a large number of plants is of the order of 5% to 15%.

3.2.4. FUEL SWITCH

With the increasing availability of natural gas in the country (both as imported LNG [liquefied natural gas] and likely increased domestic natural gas supply), industries may have the option to switch over from coal to the use of natural gas. Fuel-switch to natural gas generally leads to increase in energy use efficiency.

Another option is switching over from fossil fuels to producer gas from biomass fuels for various thermal applications. Industries with low temperature requirements (upto 100°C) (for example, textiles and pharmaceuticals) may also use solar thermal systems for water heating.

3.2.5 POTENTIAL FOR EMISSIONS REDUCTION

Although the efficiency of most large industrial sec-

tors has been improving over time, and the specific energy consumption of many of the large plants compares well with the world's best, it is estimated that CO₂ emissions from fuel and electricity use in the industry sector could be further reduced by about 605 million tonnes (approximately 16% reduction from the BAU scenario) in the year 2031. However, this will involve major incremental investment costs, as well as, overall, large economic costs, besides technology transfer.

3.2.6. CO-BENEFITS

Energy-efficiency measures in the industrial sector also have some co-benefits due to reduction in fuel and material use leading to reduced emission of air-pollutants, solid waste, and waste water. In addition, some options also lead to improvement in the quality of product.

3.2.7 TECHNOLOGY TRANSFER

Relevant technologies under development that would reduce specific energy consumption need to be transferred to India when commercially viable.

3.2.8. FINANCING

The move to efficient technologies in the industry sector generally involves significant incremental investment, and in many cases, economic costs. These would have to be provided by multilateral funding arrangements. In particular, special financing mechanisms would need to be put in place for the SMEs. Bundling and/or programmatic CDM could be a possible financing route for these units.

3.2.9. CAPACITY-BUILDING NEEDS

Cooperative approaches by the government and industry are needed to enhance awareness of energy-efficient options, and upgrade relevant technical knowledge. The financial sector also needs capacity building in appraisal of specific energy efficiency improvement investments in existing industries.

3.2.10. POLICY AND REGULATORY OPTIONS

Under the Energy Conservation Act (2001), 9 energy intensive industrial sectors, i.e. thermal power stations, fertilizer, cement, iron and steel, chlor-alkali, aluminum, railways, textile and pulp and paper, are required to employ a certified energy manager, conduct energy audits periodically, and adhere to specific energy-consumption norms that may be prescribed.

Currently, almost every industrial sector is characterized by a wide band of energy efficiencies in different units. Several of them are at global frontier levels, but some others have relatively poor performance. As an approach to enhancement of overall energy efficiency in each sector, the efficiency band-width of the sector is divided into 4 bands. The energy efficiency improvement target, in percentage, from current levels for each unit varies with its band, being highest for the least energy efficient, and the least for the most efficient. These targets would have to be achieved within a period of 3 to 5 years within each group.

Given the fact of fertilizer subsidies, individual fertilizer units have little incentive to undertake energy-efficiency investments. It is, therefore, imperative that fertilizer subsidies be restructured to eliminate such absence of incentive.

To promote technology upgradation in the SME (small and medium enterprise) sector, it would be essential to evolve sector-specific integrated programmes for technology development. This would require external support for significantly longer durations to address various technological barriers and promote energy efficiencies at the unit level. The information or knowledge gap is more pronounced in case of small industries and “hand-holding” to help industries install energy efficient technologies as well as to ensure their optimum performance through best operating practices will be required.

Most of the energy-efficient equipment require higher upfront investment. An accelerated depreciation up to 80% in the first year on energy-efficient equipment would help their deployment. Further, reduced rate VAT (value added tax) on energy-efficient equipment would also help in reducing

the required upfront investment.

To further enhance energy efficiency, four new initiatives may be considered. These are:

- Mandated specific energy consumption decreases in large energy consuming industries and facilities that have been notified as Designated Consumers under the Energy Conservation Act, and provide a framework to certify energy savings in excess of the mandated savings. The certified excess savings may be traded amongst companies to meet their mandated compliance requirements, or banked for the next cycle of energy savings requirements.
- Tax incentives for promotion of energy efficiency, including differential taxation on appliances that have been certified as energy efficient through energy labeling programme.
- Creation of energy efficiency financing platforms for enabling public-private-partnerships to capture energy savings through demand side management programmes in the municipal, buildings, and agricultural sectors.
- Fiscal Incentives

3.2.11. DELIVERY OPTIONS

The key delivery options for energy efficiency in industry are:

- Projects, including retrofits, by the corporate sector, with institutional finance
- Activities related to cluster development, particularly in SMEs
- Promotion of ESCOs (Energy Service Companies) for providing energy efficiency solutions across industry sectors

The Energy Efficiency Financing Platform initiated by the Bureau of Energy Efficiency, in conjunction with a robust ESCO industry could provide the necessary impetus to energy efficiency. In respect of each delivery mode, carbon finance through the CDM would also be relevant.

3.3 National Mission on Sustainable Habitat

The Mission comprises three components, i.e. promoting energy efficiency in the residential and commercial sector, management of municipal solid waste, and promotion of urban public transport. These are presented below:

3.3.1. PROMOTING ENERGY EFFICIENCY IN THE RESIDENTIAL AND COMMERCIAL SECTOR

The residential sector accounts for around 13.3% of total commercial energy use in India. While several households, especially in the rural areas, continue to use biomass for cooking in traditional cookstoves, which leads to high levels of indoor air pollution and poses a major health risk especially to women and children, the use of modern fuels such as LPG (liquefied petroleum gas) and kerosene is increasing rapidly. During 1990–2003, consumption of LPG increased at an annual rate of 11.26%, while electricity use increased at 8.25% annually in the residential sector.

Electricity consumption in the residential sector is primarily for lighting, space conditioning, refrigeration, and other appliances. According to a study on energy consumption in the residential sector in the city of Delhi, while lighting accounted for around 8%–14% of total electricity consumption, space-conditioning accounted for nearly 52%, and refrigerators accounted for around 28% (in the summer months). Accordingly, energy saving measures related with space conditioning (heating and cooling), refrigeration, and lighting have great significance in moving towards sustainable residential energy use.

The commercial sector comprises various institutional establishments such as banks, hotels, restaurants, shopping complexes, offices, and public buildings. Electricity consumption has increased at the rate of 7.4% annually between 1990–2003 in the commercial sector. It is estimated that on average, in a typical commercial building in India around 60% of the total electricity is consumed for lighting, 32% for space conditioning, and 8% for refrigeration. However, the end-use consumption varies significantly with space conditioning needs. While a fully airconditioned office building could have about 60% of the total electricity consumption accounted for by

air conditioning, followed by 20% for lighting, in a non-airconditioned building the consumption patterns would be significantly different.

Energy use in residential and commercial buildings also varies significantly across income groups, building construction typology, climate, and several other factors. There exists significant scope to reduce energy use, while also providing the requisite energy services in case of both existing as well as new constructions. Although the saving potential of each option may vary with typology, climate, space conditioning needs, and the initial base design proposed by the client/designer, on an average it is estimated that the implementation of energy efficient options would help in achieving around 30% electricity savings in new residential buildings and 40% electricity savings in new commercial buildings. In case of existing buildings, the energy saving potential for residential buildings is estimated to be around 20%, and that for commercial buildings around 30%.

Various studies have established that substantial energy savings can be achieved in the residential and commercial sectors. Implementing carbon mitigation options in buildings is associated with a wide range of co-benefits, including improved energy security and system reliability. Other co-benefits of energy efficiency investments include the creation of jobs and business opportunities, while the energy savings may lead to greater access to energy for the poor, leading to their improvement and well-being. Other co-benefits include improved indoor and outdoor air quality, and thereby improved health and quality of life.

3.3.1.1. COSTS AND FINANCING

The incremental cost of implementation of energy-efficient measures is estimated to vary between 3%–5% for residential buildings and 10%–15% for commercial buildings on a case-to-case basis. Economic savings over the lifetime of the appliances would depend upon the specific-usage patterns. Also, it is expected that in general, private home-owners would seek shorter pay-back periods than owners of commercial property.

While the use of more efficient appliances can play a key role in reducing final energy demands,

energy-efficient appliances typically have higher up-front costs than their non-labeled counterparts. Given that significant incremental investment costs are associated with the efficient technologies, appropriate financing mechanisms need to be adopted in order to promote these technologies.

Adoption of energy-efficient lighting and space-conditioning technologies should be integrated into housing finance schemes of financial institutions, appliance financing schemes need to incentivize purchase of energy-efficient equipment, and utility-based programmes should be put in place to pay for the higher upfront capital costs of lighting systems in the utility bills.

Carbon-market financing would enable access to these technologies where there are higher investment costs, or higher economic costs of the required energy service, or both. This may be especially useful in view of the “split incentive” problem in such cases, that is, the persons who incur the additional investment costs are different from those that might realize the energy savings.

3.3.1.2. RESEARCH & DEVELOPMENT

The R&D needs for the residential and commercial sectors is mainly related to energy efficient technologies. It needs to focus on the development of energy-efficient products for the following applications:

- Energy-efficient buildings and building components
- Development of energy efficient windows
- Development of low-cost insulation material
- Development of simulation software to predict the energy used in buildings
- Energy efficient appliances
- Development of energy-efficient ceiling fans
- Development of very-low-energy-consuming circuits for stand-by power
- Development of low-cost light-emitting diode (LED)-based lamps for space lighting

The SAC-C (Scientific Advisory Committee of the Cabinet) has recommended the launch of a National Networked Initiative for R&D on the development of the next generation of LEDs, particularly white LEDs.

3.3.1.3. TECHNOLOGY TRANSFER AND CAPACITY BUILDING

The energy efficient lighting and space conditioning technologies developed internationally are generally superior as compared to those available within the country. There is therefore a need for technology transfer from the developed countries. However adopting these internationally developed technologies is associated with payment of additional costs due to the IPR component associated with these technologies. Mechanisms need to be put in place so that these costs do not impose an additional burden on the consumers.

Solar evacuated tubular panel technology is available internationally for solar water heating systems, but needs to be transferred for diffusion in the Indian market.

Lack of awareness of energy-saving options and potential among architects, engineers, interior designers, and professionals in the building industry including plumbers and electricians is a major barrier to the construction of low-energy buildings. Realizing the potential of energy saving requires an integrated design process involving all the stakeholders, with full consideration of opportunities for passively reducing building energy demands.

Builders and developers need to be trained and made aware of the options to save energy in new constructions. There is a need to create comprehensive integrated programmes at universities and other professional establishments to impart such training for designing and constructing low-energy buildings.

3.3.1.4. POLICY AND REGULATORY ENHANCEMENTS

A diverse portfolio of policy instruments would be required to address the barriers to efficient energy use in the residential and commercial sectors.

There is a need to continuously update appliance energy norms and building energy codes and labeling, move towards rational energy pricing based on long-term average economic cost, and provide fiscal benefits for efficiency improvements.

The ECBC (Energy Conservation Building Code) was developed after the adoption of the Energy Conservation Act (2001). The ECBC aims to reduce the baseline energy consumption by supporting adoption and implementation of efficiency sav-

ings and savings in GHG emissions, besides other benefits. ECBC intervention has encouraged design innovation in the building envelope and system design and specification, which have resulted in 50% energy savings (as measured in ECBC compliant buildings) when compared to conventional constructions.

Given the scale of energy savings that can be achieved by the implementation of ECBC, it is important to direct policy towards encouraging/mandating energy savings. As an example, it would be pertinent to address the cost of CFL (Compact Fluorescent Lamp) and T5 (Efficient Tube Light) which is a barrier to their wide spread use, and implement measures to increase the demand in order to reduce prices through scale effects. Large-scale availability of appropriate materials and equipment to meet the requirement of ECBC is also urgently needed. The energy codes are still new in India and the products (insulation, efficient glass, efficient HVAC systems, and so on) and services required by buildings to comply with the code requirements are not readily and abundantly available, or competitively priced. Market power monopoly of a handful of manufacturers of energy efficient products has resulted in a non-competitive market for products like insulations, chillers, and so on.

In addition to the above, the MoEF (Ministry of Environment and Forests) has developed a manual on norms and standards for environmental clearance for large construction projects after wide consultation with experts from different disciplines. The manual would be used as a technical guideline to assist the project proponents/ stakeholders/ consultants for the preparation environmental impact assessments of projects and obtain environmental clearance. Both the EACs (Expert Appraisal Committee) at MoEF and SEACs (State Expert Appraisal Committee) at the state/ UT level appraise and grade all new construction projects requiring environmental clearances on the basis of the manual. The state pollution control boards are required to verify the compliance of the Environmental Management Plan and the observance of the criteria of gradation by the project proponents.

Successful implementation of performance-based codes requires education and training of building officials and inspectors and demonstration projects. Setting flexible performance-based codes

rather than technology/options prescriptions can help keep compliance costs low and may provide incentives for innovation.

3.3.1.5. DELIVERY OPTIONS

The BLY (Bachat Lamp Yojana) model needs to be pursued to promote energy efficient and high quality CFLs as replacement for incandescent bulbs in households. Comprehensive implementation of the BLY can lead to a reduction of 10,000 MW (Megawatt) of electricity demand. The BLY depends upon CDM (clean development mechanism) revenues to meet the incremental investment cost as well as the incremental economic cost that would be the case in many participating households.

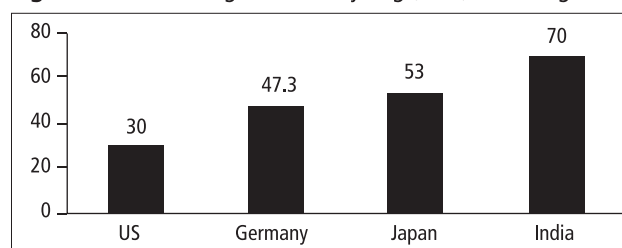
ESCOs (Energy Service Companies) need to be promoted as vehicles to deliver energy-efficiency improvements, in particular because of the “split incentives” problem, and facilitate access to carbon finance through bundled CDM projects.

The energy efficient options in the residential and commercial sectors should be promoted as bundles of programmatic CDM options.

3.3.2 MANAGEMENT OF MUNICIPAL SOLID WASTE (MSW)

Municipal solid waste (MSW) generation reflects not just income levels, but also lifestyle choices. Recycling of materials is an important option for reducing environmental pressures. Figure 3.3.2.1 below indicates that India has a significantly higher rate of recycling of materials in MSW than developed countries.

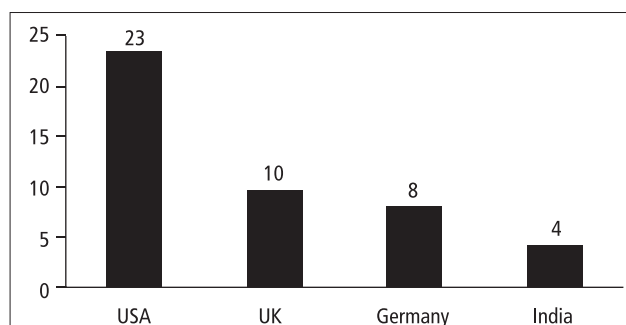
Figure 3.3.2.1: Average rate of recycling (in %), excluding re-use



Source: TERI (2006)

GHG emissions from MSW in India are also much lower than in developed countries, reckoned per unit of consumption (in \$ 1000 at PPP), Figure 3.3.2.2 below:

Figure 3.3.2.2: GHG emissions intensity from waste generation (in gm/\$1000 at PPP GDP)



Source: TERI (2006)

MSW generation in Indian cities (around 5100 ULBs) is estimated to have increased from 6 million tonnes in 1947 to 48 million tonnes in 1997, and to 69 million tonnes in 2006 (Central Pollution Control Board 2000, TERI 2001). In addition, Indian consumption of plastics is around 4 MTPA (million tonnes per annum). About 60% of this comprises polyolefins, which are primarily used as packaging material. About 2.0 MTPA of total consumption is generated as plastic waste of which around 70% is recycled, mostly by the informal sector. The decadal growth in consumption of plastics during the period 1991-2001 was around 14% (Indian Centre for Plastics in the Environment and Central Institute of Plastic Engineering Technology 2003). Although the quantity of plastic waste reaching disposal sites is fairly low (0.62% on a dry weight basis), testifying to the high rate of recycling/reuse, the management of thin plastic bags remains a matter of concern due to low collection efficiency in their case. The plastic waste-recycling sector therefore needs to be strengthened.

Table 3.3.2.1: Characteristics of MSW in 59 cities

Parameter	Unit	Range
Compostable	%	30 – 73
Recyclable (Plastics, Paper, Metal, Glass etc)	%	10 – 37
Moisture	%	17 – 65
Carbon/Nitrogen (C/N)	Ratio	14 – 53
HCV	kcal/kg	520 - 3766

Source: CPCB, 2005

There is a trend of increase in the percentage of recyclables, accompanied by decreases in the percentage of biodegradable matter in the waste stream.

Table 3.3.2.2: Change in waste composition in selected cities

City	Compostables (%)		Recyclables (%)	
	1982-1990	2005	1982-1990	2005
Lucknow	60.31	47.41	6.72	15.53
Kolkata	46.58	50.56	2.58	11.48
Kanpur	53.34	47.52	2.57	11.93
Mumbai	59.37	62.44	3.85	16.66
Delhi	57.71	54.42	8.24	15.52
Chennai	56.24	41.34	6.60	16.34
Bangalore	75.00	51.84	2.70	22.43
Ahemdabad	48.95	40.81	7.57	11.65

Source: 1982-90: Planning Commission; 1995, 2005: CPCB

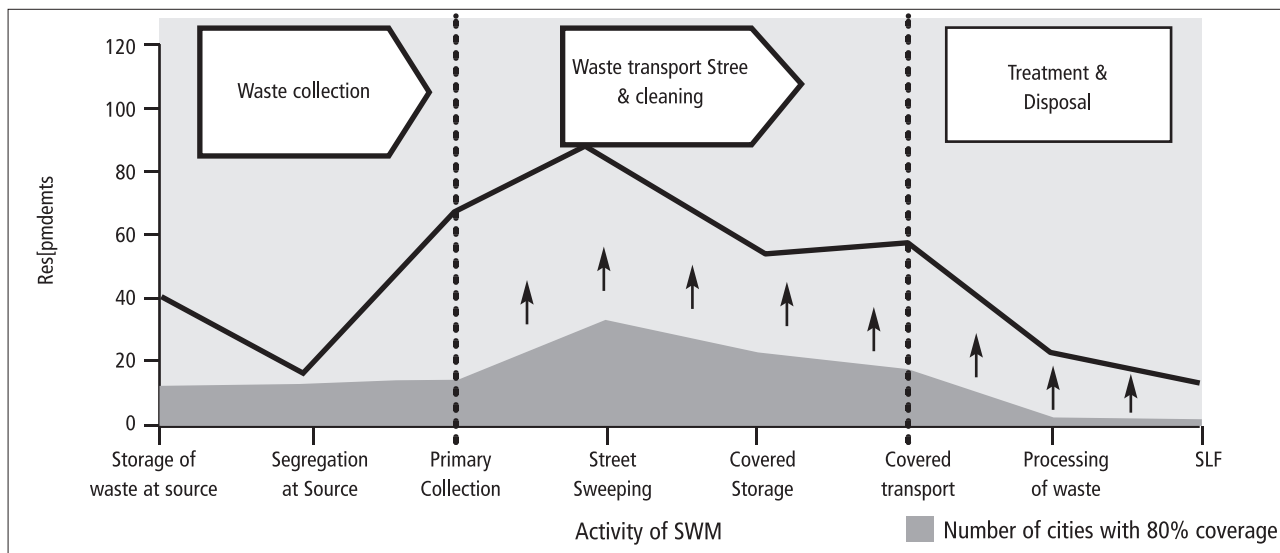
3.3.2.1 POLICIES AND REGULATIONS

The 74th Constitutional Amendment (1992) transferred the responsibility for collection, treatment and disposal of MSW from State Governments to the Urban Local Bodies (ULBs). The outbreak of plague at Surat (1994) focused policy attention on the importance of proper systems for MSW in the ULBs. In response to direction by the Supreme Court in a PIL (WP No. 888/1996) MSW Rules 2000 were promulgated, MSW service from generation to disposal was mandated, and Local Governments made responsible for compliance. Since then ULBs have gradually improved the systems of collection and transport of MSW. However, major gaps exist in respect of treatment and disposal. In particular, in respect of disposal, the compliance is poor (<5%), and while there are an increasing number of projects incorporating safe disposal, most have inadequate capacity.

Efforts at composting, and generating energy from waste have generally not been successful for a variety of systemic, technology, and pricing issues, including variable quality of waste, insufficient segregation of MSW, opposition to siting the facilities from local residents, and accordingly, the practice of open dumping continues. The dominant technology choice remains composting.

In addition, experience has made clear that

Figure 3.3.2.1: Compliance Status of MSW Rules (Survey: 2004)



Source: World Bank WSP, 2007

MSW operations cannot overall be profitable, and while cost-effectiveness and revenue streams should be pursued, MSW operations as a whole should be recognized as entailing the provision of a public good (or environmental service), generally requiring net fiscal expenditures by the concerned local bodies.

The MSW Rules under the Environment Protection Act are currently somewhat focused on specific treatment options, including the chain of collection, transport and disposal. This focus is unduly prescriptive, and prevents innovation in systems and procedures, as well as update on new technologies and techniques. The MSW Rules should be revised to focus instead on performance or outcome norms that are to be met, irrespective of particular systems and procedures, or technologies. This would provide benchmarks for monitoring and enforcement, as well as give space for innovation in systems, procedures, and technologies.

There is an emerging consensus that MSW Rules should enable (but not require) the sharing of infrastructure, including transport and treatment facilities, across a given region, including towns and villages. This would help realize scale economies, besides access to better and more cost-effective systems and treatment options for the smaller urban centres and habitations.

Broad guidelines for policy reform in the MSW sector include:

- **Common Regional Facilities:** In respect of smaller towns and villages located in a region, say a district, disposal facilities should be developed as a common regional facility.
- **Integrated Systems for collection, transport, transfer, treatment, and disposal facilities:** even if different organizations implement different components, as opposed to stand-alone facilities and open dumping.

MSW operations cannot be financially viable: ULBs should not expect to realize net royalties for treatment and disposal of MSW, and a tipping fee would be necessary (reckoned on tonnage of MSW or number of sources of different kinds) to be met from ULB revenues.

While there are several potential benefits in implementing MSW operations through public-private partnerships, including cost-effectiveness, as compared to operations carried out by the local bodies on their own, it is imperative that municipal finances are placed on a sound footing prior to outsourcing this function. While the issue of municipal finance reform is complex with many dimensions, and needs to be pursued independent of MSW issues, a pre-requisite is separation of the accounts of the local bodies in respect of their different responsibilities, such as MSW, water supply, sewage disposal and roads. This separation would firstly, provide

guidance to setting user charges (however collected), and a benchmark against which bids for provision of MSW services may be judged.

The National Environment Policy, 2006, provides for:

- Removal of barriers (incentives, regulation) for beneficial utilization of non-hazardous materials
- Implementing viable PPPs for operation of hazardous and non-hazardous waste disposal facilities on payment of user fees, taking into account concerns of local communities
- Survey and preparation of national inventory of toxic and hazardous waste sites and online monitoring of their movement
- Giving legal recognition to and strengthening informal sector systems of, collection and recycling and enhancing their access to finance and technology

The significance of the last is that while the informal recycling sector is the backbone of India's highly effective recycling system, unfortunately, a number of municipal regulations impede the operation of the recyclers, owing to which they remain at a tiny scale without access to finance or improved recycling technologies.

3.3.2.2. R&D NEEDS

Technological requirements are listed as follows:

- Biomethanation technology for waste to energy including its decentralised application for segregated waste streams like vegetable market waste, slaughterhouse waste and dairy waste.
- Development of indigenous gas engines for waste to energy applications to reduce the overall cost of the package.
- Upgrading plastic waste recycling technologies to reduce occupational and environmental hazards.
- Recycling technologies for construction and demolition wastes and e-waste streams.

3.3.2.3. FINANCING

The 10th Plan emphasized provision of important infrastructure facilities and 100% coverage of urban

population with water supply facilities, and 75% of urban population with sewerage and sanitation by the end of the plan period. Under the JNURM, till January 2008, funds amounting to Rs 900 crores were released to ULBs. The required funding for upgrading MSW facilities in all cities and towns would be much greater.

3.3.3. PROMOTION OF URBAN PUBLIC TRANSPORT

An increase in the demand for transportation services for both passengers and freight is inevitable, given economic growth and increase of population. The total number of registered motor vehicles in India has increased from 21.4 million in 1991 to 72.7 million in 2004 at a CAGR of 9.9%, with the two wheeler segment comprising of motorcycles, scooters, and mopeds growing most rapidly amongst personalized modes of transportation. Road based transportation is the main source of GHG emissions in the transportation sector.

Various studies have estimated that policy and technological measures can lead to significant energy and thereby emission savings in the transport sector. Estimates of the Planning Commission indicate an energy saving potential of 115 mtoe (million tonnes of oil equivalent) in the year 2031/32 by increasing the share of railways and improving efficiencies of different modes of transport (Planning Commission, 2006). Similarly, TERI estimates indicate an energy saving of 144 mtoe in 2031 by including efficiency improvement across modes as well as considering enhanced use of public transportation and rail based movement, use of bio-diesel as compared to business-as-usual trends. The corresponding CO₂ emissions reduction is estimated at 433 million tonnes in 2031.

3.3.3.1. TRANSPORT OPTIONS

Mass transport options including buses, railways and mass rapid transit systems, etc. are the principal option for reducing energy use in the urban transport sector, and mitigating associated GHG emissions and air pollution. The use of CNG has helped reduce air pollution due to diesel use in some cities because of its lower particulates emissions. Regarding biofuels, ethanol blending of gasoline upto 5% is required in 9 states, and is expected that this limit would be increased to 10%. R&D has to be carried out on the

combustion characteristics of motor engines for blending of higher content of ethanol in petrol. Bio-diesel production from *Jatropha curcas* and *Pongamia* shrubs is also increasing. The National Mission on Bio-diesel aims in the first (demonstration) phase to establish biodiesel plantations in 26 states, while the second phase will lead to the production of sufficient bio-diesel to enable a 20% blend in vehicle diesel in 2011/12. However, the oil content of bio-diesel crops from different parts of India is highly variable. R&D has to be carried to identify superior genotypes and collect seeds, which need to be inventorised, documented and stored under different agro-climatic zones. Introduction of bio-fuels should not divert land marked for food production and thus decrease the availability of food-grains to population. There is also some controversy about the net GHG emission of some biofuels.

Hydrogen has the potential to replace fossil fuels in the future. In recent years, significant progress has been reported by several countries for overcoming problems in its storage and production. In India, a National Hydrogen Energy Road Map has been prepared. Some organisations have already developed prototypes of two-and three-wheelers and buses to run on hydrogen fuel. However, large scale penetration of the market by hydrogen propelled vehicles is not expected till a few decades from now.

3.3.3.2. COSTS AND FINANCING

Most of the energy-efficiency measures require huge investments in the creation of new infrastructure. Efforts to reduce CO₂ emissions by the way of introduction of MRTS (mass-rapid transit system) would involve diverting resources from other priority claims on fiscal resources.

Moreover, the possibility of substantially reducing the dependence on petroleum products is constrained by the significantly higher costs of most alternative fuel options as of now. The main barrier to the use of hydrogen based fuel cell vehicles (FCVs) is that of high FCV drive-train costs.

3.3.3.3. CO-BENEFITS

Mitigation options such as enhanced shares of public

transport or rail-based movement, efficiency improvements, and increased adoption of bio-diesel or CNG have important co-benefits at the regional and local levels.

Pricing, taxes, and charges, apart from raising revenue for governments, are expected to influence travel demand and choice of transportation modes, thereby decreasing fuel demand and GHG emissions. Transport pricing can offer important gains in social welfare by simultaneously reducing local pollution and GHG emissions, accidents, noise and congestion, as well as generating state revenue for enhancing social well-being and/or infrastructure construction and maintenance.

FCVs fuelled by hydrogen have zero CO₂ emission and high efficiency, address air quality (zero tailpipe emissions), and may promote energy security since hydrogen can be produced from a wide range of sources.

With an expanding automobile sector, recycling of recoverable materials at end-of-life of automobiles would lead to considerable energy savings⁹. It is estimated that by 2020, recoverable materials annually will be of the order of 1.5 million tons of steel, 180,000 tons of aluminium and 75,000 tons each of rubber and plastics. Recycling of these materials will also reduce mining, depletion of natural resources, and degradation of environment. India has no formal regulations regarding recyclability and disposal of end-of-life vehicles.

The following actions are proposed for the transport sector:

- Promoting the use of coastal shipping and inland waterways, apart from encouraging the attractiveness of rail-based movement relative to long-distance road based movement
- Encouraging energy R&D in the Indian Railways
- Introducing appropriate transport pricing measures to influence purchase and use of vehicles in respect of fuel efficiency and fuel choice
- Tightening of regulatory standards such as enforcing fuel-economy standards for automobile manufacturers
- Establishing mechanisms to promote investments in development of high capacity public transport systems (e.g. offer equity participation and/or via

bility gap funding to cover capital cost of public transport systems)

- Abandoning of old vehicles to be made illegal with suitable legislation and fixing the responsibility of handing over the end-of-life vehicle to collection centers on the last owner of the vehicle
- Setting up of a demonstration unit to take up recycling of vehicles, especially two wheelers, which require new techniques
- Setting up a Combustion Research Institute to facilitate R&D in advanced engine design
- Providing tax benefits and investment support for recovery of materials from scrap vehicles

3.4. National Water Mission

India gets on an average 1197 mm of rainfall every year. This amounts to a total precipitation of 4000 billion m³. However, 3000 billion m³ of this is lost due to run off, and only 1000 billion m³ is available as surface and ground water sources, amounting to c.1000 m³ per year per capita water availability. This is about 1/5th – 1/10th of that of many industrialised countries. Many parts of India are water stressed today and India is likely to be water scarce by 2050. The problem may worsen due to climate change impacts. It is therefore important to increase the efficiency of water use, explore options to augment water supply in critical areas, and ensure more effective management of water resources. New regulatory structures with appropriate entitlements and pricing and incentives to adopt water-neutral and water positive technologies may be required. Integrated water policies will help to cope with variability in rainfall and river flows at the basin level. Some specific aspects related to water resources are discussed in more detail below.

3.4.1 STUDIES ON MANAGEMENT OF SURFACE WATER RESOURCES

Rivers and lakes, the most visible sources of surface water, often indicate the state of the environment more clearly than many other indicators. Such resources also have economic significance in the form of waterways for transport, sources of clean

energy in the form of hydropower, and vital inputs to agriculture in the form of irrigation. Key elements on surface water studies include the following:

- Estimating river flows in mountainous areas
- Customizing climate change models for regional water basins
- Extending isotopic-tracer-based techniques of monitoring river water discharge to all major river monitoring stations
- Developing digital elevation models of flood-prone areas for forecasting floods
- Mapping areas likely to experience floods and developing schemes to manage floods
- Strengthening the monitoring of glacial and seasonal snow covers to assess the contribution of snowmelt to water flows of Indian rivers that originate in the Himalayas
- Establishment of a wider network of automatic weather status and automated rain gauge stations
- Planning of watershed management in mountain ecosystems

3.4.2. MANAGEMENT AND REGULATION OF GROUNDWATER RESOURCES

Groundwater accounts for nearly 40% of the total available water resources in the country and meets nearly 55% of irrigation requirements, 85% of rural requirements and 50% of urban and industrial requirements. However, overexploitation of the resource has sharply lowered the water table in many parts of the country, making them increasingly vulnerable to adverse impacts of climate change. Key areas in this programme may include the following:

- Mandating water harvesting and artificial recharge in relevant urban areas
- Enhancing recharge of the sources and recharge zones of deeper groundwater aquifers
- Mandatory water assessments and audits; ensuring proper industrial waste disposal
- Regulation of power tariffs for irrigation

3.4.3. UPGRADING STORAGE STRUCTURES FOR FRESH WATER AND DRAINAGE SYSTEMS FOR WASTEWATER

To address the problems of droughts and floods triggered by extreme weather events, it is essential to

both augment storage capacity and improve drainage systems. Effective drainage is also essential to reclaim waterlogged and saline-alkali lands and to prevent the degradation of fertile lands. Key areas are listed below:

- Prioritizing watersheds vulnerable to flow changes and developing decision support systems to facilitate quick and appropriate responses
- Restoration of old water tanks
- Developing models of urban storm water flows and estimating drainage capacities for storm-water and for sewers based on the simulations
- Strengthen links with afforestation programmes and wetland conservation
- Enhancing storage capacities in multipurpose hydro projects, and integration of drainage with irrigation infrastructure

3.4.4. CONSERVATION OF WETLANDS

Wetlands provide a range of ecological services, including water conservation, recharge of ground-water, and preservation of flora and fauna, including species and varieties at risk and are a source of livelihood to many. Wetlands face the threat of conversion to other uses, which means a loss of their ecological services, making those who depend on them vulnerable. Actions identified for conserving wetlands are listed below:

- Environmental appraisal and impact assessment of developmental projects on wetlands
- Developing an inventory of wetlands, especially those with unique features
- Mapping of catchments and surveying and assessing land use patterns with emphasis on drainage, vegetation cover, silting, encroachment, conversion of mangrove areas, human settlements, and human activities and their impact on catchments and water bodies.
- Creating awareness among people on importance of wetland ecosystems
- Formulating and implementing a regulatory regime to ensure wise use of wetlands at the national, the state, and district levels

3.4.5. DEVELOPMENT OF DESALINATION TECHNOLOGIES

In India, desalination has been recognized as a possible means to augment the water supply through natural resources for meeting the growing needs of water due to population and industrial growth. Since desalination is an energy intensive process (the energy required may vary from about 3 kWh to 16 kWh for separating 1000 litres depending on the type of process used), the application of desalination technology for increasing regional water supplies strongly links to energy issues and thus GHG emissions. Development activities have been initiated in various laboratories in the country. Desalination has been recognized as an important cross disciplinary technology area for R&D in the 11th Plan. Technologies are being developed for the following:

- Seawater desalination using Reverse Osmosis and multistage flash distillation to take advantage of low-grade heat energy e.g. from power plants located in the coastal regions or by using renewable energy such as solar
- Brackish water desalination
- Water recycle and reuse
- Water purification technologies

3.5. National Mission for Sustaining the Himalayan Ecosystem

The Himalayan ecosystem is vital to the ecological security of the Indian landmass, through providing forest cover, feeding perennial rivers that are the source of drinking water, irrigation, and hydropower, conserving biodiversity, providing a rich base for high value agriculture, and spectacular landscapes for sustainable tourism. At the same time, climate change may adversely impact the Himalayan ecosystem through increased temperature, altered precipitation patterns, and episodes of drought.

Concern has also been expressed that the Himalayan glaciers, in common with other entities in the global cryosphere, may lose significant ice-mass, and thereby endanger river flows, especially in the lean season, when the North Indian rivers are largely fed by melting snow and ice. Studies by

several scientific institutions in India have been inconclusive on the extent of change in glacier mass, and whether climate change is a significant causative factor.

It is accordingly, necessary to continue and enhance monitoring of the Himalayan ecosystem, in particular the state of its glaciers, and the impacts of change in glacial mass on river flows. Since several other countries in the South Asian region share the Himalayan ecosystem, appropriate forms of scientific collaboration and exchange of information may be considered with them to enhance understanding of ecosystem changes and their effects.

It is also necessary, with a view to enhancing conservation of Himalayan ecosystems, to empower local communities, in particular through the Panchayats, to assume greater responsibility for management of ecological resources.

The National Environment Policy, 2006, inter-alia provides for the following relevant measures for conservation of mountain ecosystems:

- Adopt appropriate land-use planning and watershed management practices for sustainable development of mountain ecosystems
- Adopt “best practice” norms for infrastructure construction in mountain regions to avoid or minimize damage to sensitive ecosystems and despoiling of landscapes
- Encourage cultivation of traditional varieties of crops and horticulture by promotion of organic farming enabling farmers to realize a price premium
- Promote sustainable tourism through adoption of “best practice” norms for tourism facilities and access to ecological resources, and multistakeholder partnerships to enable local communities to gain better livelihoods, while leveraging financial, technical, and managerial capacities of investors
- Take measures to regulate tourist inflows into mountain regions to ensure that these remain within the carrying capacity of the mountain ecology

- Consider particular unique mountain scapes as entities with “Incomparable Values”, in developing strategies for their protection

3.6. National Mission for a “Green India”

Forests are repositories of genetic diversity, and supply a wide range of ecosystem services thus helping maintain ecological balance. Forests meet nearly 40% of the energy needs of the country overall, and over 80% of those in rural areas, and are the backbone of forest-based communities in terms of livelihood and sustenance. Forests sequester billions of tons of carbon dioxide in the form of biomass and soil carbon. The proposed national programme will focus on two objectives, namely increasing the forest cover and density as a whole of the country and conserving biodiversity.

3.6.1. INCREASE IN FOREST COVER AND DENSITY

The report of the Working Group on Forests for the 11th Five-Year Plan puts the annual rate of planting during 2001/02 to 2005/06 at 1.6 million hectares and proposes to increase it to 3.3 million hectares during the 11th Plan. The final target is to bring one-third of the geographic area of India under forest cover.

The Greening India Programme has already been announced. Under the programme, 6 million hectares of degraded forest land would be afforested with the participation of Joint Forest Management Committees (JFMCs), with funds to the extent of Rs 6000 crores provided from the accumulated additional funds for compensatory afforestation under a decision of the Supreme Court in respect of forest lands diverted to non-forest use.

The elements of this Programme may include the following:

- Training on silvicultural practices for fast-growing and climate-hardy tree species
- Reducing fragmentation of forests by provision of corridors for species migration, both fauna and flora
- Enhancing public and private investments for raising plantations for enhancing the cover and the density of forests
- Revitalizing and upscaling community-based initia-

tives such as Joint Forest Management (JFM) and Van Panchayat committees for forest management

- Implementation of the Greening India Plan
- Formulation of forest fire management strategies

3.6.2. CONSERVING BIODIVERSITY

Conservation of wildlife and biodiversity in natural heritage sites including sacred groves, protected areas, and other biodiversity 'hotspots' is crucial for maintaining the resilience of ecosystems. Specific actions in this programme will include:

- In-situ and ex-situ conservation of genetic resources, especially of threatened flora and fauna
- Creation of biodiversity registers (at national, district, and local levels) for documenting genetic diversity and the associated traditional knowledge
- Effective implementation of the Protected Area System under the Wildlife Conservation Act
- Effective implementation of the National Biodiversity Conservation Act, 2001

3.7. National Mission for Sustainable Agriculture

Contributing 21% to the country's GDP, accounting for 11% of total exports, employing 56.4% of the total workforce, and supporting 600 million people directly or indirectly, agriculture is vital to India's economy and the livelihood of its people. The proposed national mission will focus on four areas crucial to agriculture in adapting to climate change, namely dryland agriculture, risk management, access to information, and use of biotechnology.

3.7.1. Dryland Agriculture

Out of the net cultivated area of approximately 141 million hectares, about 85 million hectares (60%) falls under the dryland/rain-fed zone. Accordingly, to realise the enormous agricultural growth potential of the drylands in the country and secure farm-based livelihoods, there is a need to prevent declines in agricultural yields during climatic stress. Priority actions on dryland agriculture with particular rele-

vance to adaptation will be as follows:

- Development of drought- and pest-resistant crop varieties
- Improving methods to conserve soil and water
- Stakeholder consultations, training workshops and demonstration exercises for farming communities, for agro-climatic information sharing and dissemination
- Financial support to enable farmers to invest in and adopt relevant technologies to overcome climate related stresses

3.7.2. RISK MANAGEMENT

The agricultural sector may face risks due to extreme climatic events. Priority areas are as follows:

- Strengthening of current agricultural and weather insurance mechanisms
- Development and validation of weather derivative models (by insurance providers ensuring their access to archival and current weather data)
- Creation of web-enabled, regional language based services for facilitation of weather-based insurance
- Development of GIS and remote-sensing methodologies for detailed soil resource mapping and land use planning at the level of a watershed or a river basin
- Mapping vulnerable eco-regions and pest and disease hotspots
- Developing and implementing region-specific contingency plans based on vulnerability and risk scenarios

3.7.3. ACCESS TO INFORMATION

Although many information channels are available to farmers, none of them offers need-based information in an interactive mode. Supplying customized information can boost farm productivity and farm incomes, and the following areas deserve priority:

- Development of regional databases of soil, weather, genotypes, land-use patterns and water resources.
- Monitoring of glacier and ice-mass, impacts on

water resources, soil erosion, and associated impacts on agricultural production in mountainous regions

- Providing information on off-season crops, aromatic and medicinal plants, greenhouse crops, pasture development, agro-forestry, livestock and agro-processing.
- Collation and dissemination of block-level data on agro-climatic variables, land-use, and socio-economic features and preparation of state-level agro-climatic atlases

3.7.4 USE OF BIOTECHNOLOGY

Biotechnology applications in agriculture relate to several themes, including drought proofing, taking advantage of elevated CO₂ concentrations, increased yields and increased resistance to disease and pests. Priority areas include:

- Use of genetic engineering to convert C-3 crops to the more carbon responsive C-4 crops to achieve greater photosynthetic efficiency for obtaining increased productivity at higher levels of carbon dioxide in the atmosphere or to sustain thermal stresses
- Development of crops with better water and nitrogen use efficiency which may result in reduced emissions of greenhouse gases or greater tolerance to drought or submergence or salinity
- Development of nutritional strategies for managing heat stress in dairy animals to prevent nutrient deficiencies leading to low milk yield and productivity

3.8. National Mission on Strategic Knowledge for Climate Change

This national mission envisages a broad-based effort that would include the following key themes:

- Research in key substantive domains of climate science where there is an urgent need to improve the understanding of key phenomena and processes, including, for example, monsoon dynamics, aerosol science and ecosystem responses

- Global and regional climate modelling to improve the quality and specificity of climate change projections over the Indian sub-continent, including changes in hydrological cycles
- Strengthening of observational networks and data gathering and assimilation, including measures to enhance the access to and availability of relevant data
- Creation of essential research infrastructure, such as high performance computing and very large bandwidth networks to enable scientists to access and share computational and data resources

These broad themes are elaborated in the sub-sections below:

3.8.1. CLIMATE MODELLING AND ACCESS TO DATA

Although the IPCC-AR4 has addressed the general global trends on climate change, spatially detailed assessments are not available for India. This is because of inadequate computing power available, difficulties in getting climate related data, and dearth of trained human resources amongst climate modelling research groups in India. The following actions will be taken:

3.8.2. ENHANCED RESEARCH ON CLIMATE MODELLING IN INDIA

There is a need to develop high resolution Air Ocean General Circulation Models (AOGCM) and nested Regional Climate Models (RCM) that simulate regional climate change, in particular monsoon behaviour, by pooling institutional capabilities and computational resources.

In respect of General Circulation Models (GCM), there is a need to build national level core climate modelling groups to develop high resolution coupled AOGCM that effectively simulate monsoon behaviour. These would be employed for multi-ensemble and multi-year simulations of the present and future climate. Indigenous Regional Climate Models (RCM) are necessary to generate accurate future climate projections upto (at least) district level. Regional data re-analysis projects should be encouraged. A Regional Model Inter-comparison

Project (RMIP) for climate is required to minimize uncertainty in future climate projections.

3.8.3. PROMOTING DATA ACCESS

There are several databases that are relevant for climate research, along with the respective agencies that are responsible for collecting and supplying that data. It is suggested that each of these Ministries and Departments may appoint a ‘facilitator’, who will

provide access to the data. A concept of ‘registered users’ has been proposed, who will have easier access to climate related data held by the various scientific Ministries and Departments of the Government. There is a need to review the restrictions on data access. The Ministries and their agencies should also take action to digitize the data, maintain databases of global quality, and streamline the procedures governing access. Existing databases that will need to be expanded and improved are listed below.

Table 3.8.3 Some Databases for Climate Research

S. No.	Database	Data Collecting and Supplying Agency	Facilitator reporting to
1	Oceans Sea surface temperature Salinity Sea level rise	Ministry of Earth Sciences	Secretary, Ministry of Earth Sciences
2	Cryosphere Snow cover Glacial data	a) National Remote Sensing Agency (NRSA) b) Geological Survey of India c) Snow and Avalanche Studies Establishment (SASE), Defence Research and Development Organization	a) Secretary, Department of Space b) Secretary, Ministry of Mines c) Secretary, Department of Defence Research and Development
3	Meteorology Precipitation Humidity Surface temperature Air temperature Evaporation data	India Meteorological Department, Ministry of Earth Sciences.	Secretary, Ministry of Earth Sciences
4	Land Surface Topography Erosion Imagery (vegetation map) Forest cover	a) Survey of India b) National Remote Sensing Agency (NRSA)	a) Secretary, Department of Science and Technology b) Secretary, Department of Space
5	Hydrological Ground water Water quality River water Water utilization	a) Central Water Commission b) State Water Resource Organizations	a) Secretary, Ministry of Water Resources b) Chief Secretaries of the respective States
6	Agriculture Soil profile Area under cultivation Production and yield Cost of cultivation	Ministry of Agriculture	a) Secretary, Department of Agriculture and Co-operation b) Secretary, Department of Agricultural Research and Education
7	Socio-Economic Demography Economic status	Census of India	Registrar General India, Ministry of Home Affairs
8	Forests Forest resources Plant and animal species distribution	a) Forest Survey of India b) State Forest Department c) Botanical Survey of India d) Zoological Survey of India e) Department of Space	a) Secretary, Ministry of Environment and Forests b) Chief Secretaries of the respective States c) Secretary, Ministry of Environment and Forests d) Secretary, Ministry of Environment and Forests e) Secretary, Department of Space
9	Health Related Data	Department of Health Research	Secretary, Department of Health Research

3.8.4. STRENGTHENING NETWORKS

The creation of an integrated National Knowledge Network (scalable and ultimately of multi-10 Gbps capacity) as suggested by the National Knowledge Commission and the Principal Scientific Adviser's Office would obviously benefit climate modellers. The upcoming Grid Computing stands out as a unique technology for handling terabytes of experimental data requiring hundreds of teraflops of computing power. Various Ministries of the Government are also taking steps to augment their super-computing resources in the Eleventh Plan.

3.8.5. HUMAN RESOURCE DEVELOPMENT

In order to meet the new challenges related to climate change, human resources would require to be enhanced through changes in curricula at the school and college levels, introduction of new programmes at the university level, and training of professionals and executives in relevant fields. An overall assessment of additional skills required will have to be carried out at the national, state and local levels, so that necessary measures can be undertaken for enhancing the quality and quantum of human resource required in the coming years and decades. The latter would have to be viewed also in the context of the current difficulties faced in attracting young people to careers in science in general, to overcome which steps are being taken during the 11th Plan.

4. Other Initiatives

4.1. GHG Mitigation in Power Generation

The present energy mix in India for electricity generation is shown in Table 4.1 below:

Table 4.1: Present Energy Mix in Electricity Generation in India

Source	Percentage
Coal	55
Hydropower	26
Oil and gas	10
Wind and solar power	6
Nuclear power	3

At present, fossil fuels account for 66% of the total, and are responsible for most of the GHG emissions from the energy sector. During the 11th Five-Year Plan, utility-based generation capacity is expected to increase by 78,000 MW. A significant proportion of this increase will be thermal-coal based. While the new investments in the thermal power sector, which are substantial, have high efficiencies, the aggregate efficiency of the older plants is low. In addition, high ATCL (aggregate technical and commercial loss) in power transmission and distribution is a key concern.

There are three ways of lowering the emissions from coal based plants: increasing efficiency of existing power plants; using clean coal technologies (relative emissions are c.78% of conventional coal-thermal), and switching to fuels other than coal, where possible. These measures are complementary and not mutually exclusive. Another option that has been suggested is carbon capture and sequestration (CCS). However, feasible technologies for this have not yet been developed and there are serious questions about the cost as well permanence of the CO₂ storage repositories.

Approximately 5000 MW out of total of 73,500 MW of present installed capacity (at the end of November, 2007) of coal thermal plants have low capacity utilization of less than 5%, as well as low conversion efficiency. During the 11th Plan, these units would be retired, and during the 12th Plan, an additional 10,000 MW of the least efficient operating plants would be retired, or reconditioned to improve their operating efficiency.

4.1.1. SUPERCRITICAL TECHNOLOGIES

Supercritical and ultra-supercritical plants can achieve efficiencies of ~ 40 and ~ 45% respectively, compared to about 35% achieved by subcritical plants. Since coal-based power generation will continue to play a major role in the next 30–50 years, it would be useful, wherever cost-effective and otherwise suitable, to adopt supercritical boilers, which is a proven technology, in the immediate future, and ultra-supercritical boilers when their commercial viability under Indian conditions is established. At present, construction of several supercritical coal based power projects is in progress.

Research and development with regard to ultra-supercritical technology needs to focus on the following areas:

- Development of materials for use in steam generator tubes, main steam piping, and high-pressure turbines that can withstand high pressure and high temperatures of more than 600°C, and are resistant to oxidation, erosion, and corrosion
- Development of know-how related to heat transfer, pressure drop, and flow stability at ultra-supercritical conditions

4.1.2. INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) TECHNOLOGY

Integrated gasification combined cycle technology can make coal-based power generation ~ 10% more efficient. For every 1% rise in efficiency, there is a 2% decrease in CO₂ release. Besides, there is a substantial reduction in NO_x emissions. Demonstration of plants using high-ash, low-sulphur Indian coal needs to be pursued, while recognizing constraints such as high costs and availability of superior imported coal. Recent research has shown that these plants should be based on the Pressurized Fluidized Bed (PFB) approach.

Bharat Heavy Electricals Ltd. (BHEL) already has 3 R&D plants based on PFB, which have provided design information to scale up this technology¹⁰. BHEL and APGENCO have signed an agreement recently to set up a 125 MW plant at Vijayawada using indigenous IGCC technology.

4.1.3. NATURAL GAS BASED POWER PLANTS

Natural gas based power generation is cleaner than coal-based generation as CO₂ emissions are only ~ 50% compared to coal. Besides, natural gas can be used for electricity generation by adopting advanced gas turbines in a combined cycle mode. Introduction of advance class turbines with inlet temperature in the range 1250 °C – 1350° C has led to combined cycle power plant efficiency of about 55% under Indian conditions. Many such plants are in operation in India. With the discovery of significant reserves of natural gas in the Godavari basin, setting up more

combined cycle natural gas plants is an attractive GHG mitigation option in India.

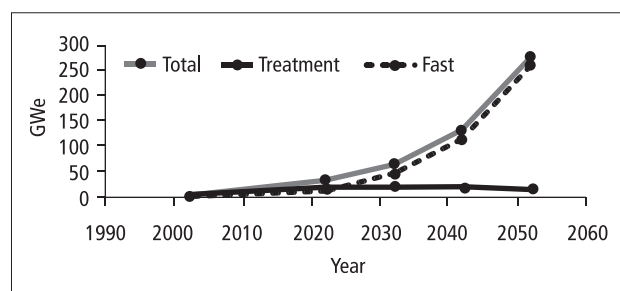
4.1.4. CLOSED CYCLE THREE STAGE NUCLEAR POWER PROGRAMME

Promotion of nuclear energy through enhancing nuclear capacity and adoption of fast breeder and thorium-based thermal reactor technology in nuclear power generation would bring significant benefits in terms of energy security and environmental benefits, including GHG mitigation.

India's uranium resources are limited but the country has one of the largest resources of thorium in the world. Therefore, right from inception, India has adopted a programme that will maximize the energy yield from these materials. This is the three-stage nuclear power programme. The first stage of nuclear power generation is based on PHWR (Pressurized Heavy Water Reactor) technology using indigenous natural uranium. The second stage is based on FBR (Fast Breeder Reactor) technology using plutonium extracted by reprocessing of the spent fuel obtained from the first stage. The third stage consists of using thorium resources.

The current installed capacity of nuclear power plants is 4200 MW, accounting for nearly 3% of total installed capacity. A 500 MW fast breeder reactor is under construction and is expected to go on stream in about three years. A 300 MW Advanced Heavy Water Reactor (AHWR) has been designed. Its construction is due to begin in the 11th Plan. The projected installed nuclear power by Department of Atomic Energy (DAE) is shown in Figure 4.1 below.

Figure 4.1.4: Nuclear Power Generation Projections upto 2050 by DAE



For sustainability of nuclear energy as a mitigation option in the long term, it is important to close the nuclear fuel cycle¹¹. In this way one can produce several tens of times more energy from the existing uranium resources if the plutonium from the spent fuel is recycled in fast breeder reactors and this potential can be increased by another order of magnitude by closing the nuclear fuel cycle with thorium. Therefore, the three stage nuclear programme of India based on the closed fuel cycle philosophy assumes greater significance in the context of climate change mitigation. The closed fuel cycle, in comparison to the once-through cycle, also reduces the volumes of radioactive waste requiring treatment and disposal.

4.1.5. EFFICIENT TRANSMISSION AND DISTRIBUTION

India's current technical losses during transmission and distribution are as high as 16%–19%. By adopting HVAC (high voltage AC) and HVDC (high voltage DC) transmission, the figure can be brought down to 6%–8% by using amorphous core transformers and up-grading the distribution system (avoiding congestion etc.). Distribution losses can also be reduced by adopting energy-efficient transformers, which use high-grade steel in the transformer core.

4.1.6. HYDROPOWER

The CEA (Central Electricity Authority) has estimated India's hydropower potential at 148,700 MW. The hydroelectric capacity currently under operation is about 28,000 MW, while 14,000 MW capacity is under various stages of development. The CEA has also identified 56 sites for pumped storage schemes with an estimated aggregate installed capacity of 94,000 MW. In addition, a potential of 15,000 MW in terms of installed capacity is estimated from small, mini, and micro-hydel projects. Of this only about 2000 MW has been exploited at present. These projects are important, in particular, for electrification of remote hilly areas, where it may not be feasible for the grid electricity to reach. Large-scale hydropower with reservoir storage is the cheapest conventional power source in India. However, resettlement of displaced population due to submergence of large

areas of habitation lands has to be attended to with care.

4.2. Other Renewable Energy Technologies Programmes

Renewable energy sources, i.e. based on primary energy sources that are regenerated naturally in time-spans that are meaningful in terms of policy and planning horizons, represent genuine supply side sustainability of global energy systems.

Renewable energy technologies (RETs) have several well-recognized advantages in relation to conventional, largely fossil fuels based, energy systems. First, by displacing use of fossil fuels, in particular, petroleum based fuels, they promote energy security. Second, they are amenable to adoption at different scales – from hundreds of megawatts capacity to a few kilowatts. In many cases they may be deployed in modular, standardized designs. This enables RETs to be matched closely with end-use scales, enabling decentralized deployment, and thus avoiding the risk of failures, and unauthorized access to large networks, which leads to non-commercial losses. The feasibility of location close to the load or consuming centres enables reduction of technical transmission and distribution losses. However, where centralized grids (networks) exist, they may be inserted as individual modules in the grid (network) supply. Third, they can help promote sustainable development, broadly defined, through increased opportunities for local employment, especially the rural poor, and environmental improvement through reducing GHG emissions, local air pollutants, solid waste and waste-water generation, and (in case of forestry-based sources), soil and water conservation, and maintaining habitats of wild species.

On the other hand, several RETs also have disadvantages. First, some primary energy flows (e.g. solar, wind) are intermittent, and insufficiently predictable, requiring hybridization with systems more under human control. For another, some RETs forms, such as biofuels compete with arable land and irrigation water with food crops. If not implemented with great care, they may have adverse social and economic consequences,

RETs easily have the potential to replace all current and foreseeable use of fossil fuels, for power generation, transportation, and industrial use, for all time to come. RETs represent a range of specific conversion pathways and technologies. These are at different stages of deployment, innovation, and basic research. Some that are fully established commercially, e.g. biomass combustion and gasification based power generation need up-scaling through policies and regulations that would permit some unique deployment models to be operationalized. In other cases, where commercial scale operation has been demonstrated, but costs are still high, with the possibility that increased scale and further innovation in both technology and deployment models will reduce costs, tariff and regulatory support for a limited period may be needed. Where technologies have been demonstrated at laboratory scale, further R&D to enable pilot and commercial scale demonstration may involve facilitation of industry and research laboratory partnerships, and may also involve public fiscal (investment) support.

4.2.1. RETs FOR POWER GENERATION

Power generation technologies based on renewable energy flows comprise the following major primary sources: Biomass, Hydropower, Solar, and Wind. Technologies in each of these primary sources have already been deployed in India at commercial scale, but there remain several challenges in respect of policies and regulations, R&D and transfer of technologies, costs and financing, and deployment models, that need to be addressed in order to ensure their mainstreaming in the commercial power sector.

4.2.1.1. BIOMASS BASED POWER GENERATION TECHNOLOGIES

Biomass based technologies include those involving primary biomass combustion, and those that do not involve direct biomass combustion, but may involve conversion to a secondary energy form.

Historically, primary biomass combustion has been the main source of energy for India. The Integrated Energy Policy (Planning Commission, 2006) has estimated that around 80 mtoe is currently used in the rural household sector. In addition, the

Ministry of New and Renewable Energy has estimated state-wise gross and net availability of agro-residues for power generation.

There are two basic technology pathways for biomass for power options currently being implemented. These technologies are *Straight Biomass Combustion* and *Biomass Gasification*.

4.2.1.1.1. COSTS AND FINANCING

Plant capacities for straight primary biomass combustion are not very large due to limited radius of economic biomass collection. Investment cost for biomass combustion based power projects or co-generation projects varies between Rs. 4 to Rs. 5 crores per MW, depending upon project site, design and operation related factors. The cost of electricity generation is around Rs. 3/kWh depending upon specific fuel consumption, which in turn depends on type of fuel and operating pressure of the boiler and steam turbine. This technology is, thus, generally cost-competitive with conventional power delivered by the grid to rural areas.

In respect of biomass gasification technologies, the investment cost, with IC engines as source of power generation, comes between Rs. 25,000 – 60,000 / kW, depending on the type of gasification system and type of fuel, including costs of gasifier and IC engine. The cost of electricity generation cost varies between Rs.3 kWh to Rs. 5/kWh for the currently available technologies in India.

In both cases, the costs of biomass collection and transportation are key issues, which limit scale of operation of individual units.

4.2.1.1.2. CO-BENEFITS

Biomass based power technologies avoid problems associated with ash disposal from coal based plants. The ash from the biomass combustion may be returned to the fields to enhance agricultural productivity. If the biomass is grown in energy plantations on wastelands or common/panchayat lands, there would be increase in rural employment, besides water, and soil conservation. T&D losses would be very low especially in decentralized systems, and deployment can be done independently of

the national grid and integrated with the national grid when extended.

4.2.1.1.3 RESEARCH & DEVELOPMENT

The technology for power generation through straight primary biomass combustion is mature, with significant commercial deployment. R&D is required for compacting different types of biomass for transportation, and improved boiler design to enable the use of multiple biomass feedstocks.

One significant area of R&D is development of hot gas cleaning systems and optimum integration with the gasifiers. Another is the development of gasifier systems based on charcoal and pyrolyzed biomass, since volatile distillates of biomass feedstock may have significant economic value, which would be lost if the biomass is directly burned.

4.2.1.1.4. TECHNOLOGY TRANSFER AND CAPACITY BUILDING

Biomass gasifiers available in the country are of very low capacity compared to European and American gasifiers, where the capacities vary from 1 MW to 100 MW. Biomass gasifiers with capacities upto 100 MW based on Circulating Fluidised Bed (CFB), Bubbling Fluidised Bed (BFB) and Pressurised Fluidised bed (PFB) are available in the USA, Finland and UK. Transfer of these technologies, and where necessary adaptive R&D, would enable deployment models involving energy plantations on wastelands or common/panchayat lands which would not compete with food crops.

Capacity building needs include support to commercial demonstration by entrepreneurs of biomass based distributed generation systems and using these as training facilities for local entrepreneurs and O&M personnel. Such demonstration and skills development would enable accelerated deployment of these technologies.

4.2.1.2. SMALL-SCALE HYDROPOWER

Hydropower, both large (reservoir storage) and small scale, accounts for 18% of the total electricity generated in India. Of the total estimated large hydropower potential of 148,700 MW (storage and run-of-

river), so far only 35,000 MW has been utilized. In addition, there are 56 assessed sites for pumped storage hydropower, totaling 94,000 MW. The total small hydropower (upto 25 MW) potential is 15,000 MW, of which only 1905 MW has been utilized. Large-scale hydropower with reservoir storage is the cheapest conventional power source in India. Small-scale hydropower is cost competitive with conventional generation options, in particular for rural electrification. In remote rural locations far away from the grid, it may be the only feasible and economic power option.

The technology options for hydropower at all scales are commercially well established, except in the pico-turbine ranges i.e. < 1 kW.

4.2.1.2.1. COSTS AND FINANCING

The cost of generation ranges from Rs. 2 to 4 per kWh. The capital costs are higher than for conventional power, and usually in the range of Rs. 7 crore per MW.

4.2.1.2.2. CO-BENEFITS

Small hydropower displaces diesel gensets, thereby avoiding local pollution. By thus avoiding consumption of petroleum products, it also promotes energy security. Small hydropower is generally more predictable than solar or wind based sources, with variations occurring over the year, rather than on an hourly or daily basis.

4.2.1.2.3. RESEARCH & DEVELOPMENT AND CAPACITY BUILDING

The following are priorities for R& D:

- Design of pico turbines (< 500W range): This would enable very small scale generation at the household level, based on local hydro resources
- Electronic Load Controller for micro hydro: This would enable supply of power from micro-hydel sources to village level grids
- Cost reductions in E&M
- Standardizing the modules and optimizing the usage of materials is critical for reducing equipment, and hence generation, costs
- Support to commercial demonstration by entrepre-

neurs of small/micro-hydel based distributed generation systems, in particular in remote locations, and using these as training facilities for local entrepreneurs and O&M personnel would help develop this sector.

4.2.1.3. WIND ENERGY

The installed capacity for using wind energy has gone up rapidly during the last few years (presently about 8000 MW). However, the capacity utilization factors are low due to the variations in the wind flow. Action is required to design, develop and manufacture small wind energy generators (WEGs) upto 10 kW capacity, that can generate power at very low speeds (~ 2 to 2.5 m/sec). Effort is also required for the development of low weight carbon fiber and other new generation composites, etc. for use in wind turbines.

An encouraging sign is the strong interest of the private sector in the wind area. Some Indian private companies are involved in setting up wind turbines in other countries in a big way.

4.2.2 GRID CONNECTED SYSTEMS

The Electricity Act, 2003 and the National Tariff Policy, 2006, provide for both the Central Electricity Regulatory Commission (CERC) and the State Electricity Regulatory Commissions (SERC) to prescribe a certain percentage of total power purchased by the grid from renewable based sources. It also prescribes that a preferential tariff may be followed for renewables based power.

The following enhancements in the regulatory/tariffs regime may be considered to help mainstream renewables based sources in the national power system:

- (i) A dynamic minimum renewables purchase standard (DMRPS) may be set, with escalation each year till a pre-defined level is reached, at which time the requirements may be revisited. It is suggested that starting 2009-10, the national renewables standard (excluding hydropower with storage capacity in excess of daily peaking capacity, or based on agriculture based renewables

sources that are used for human food) may be set at 5% of total grids purchase, to increase by 1% each year for 10 years. SERCs may set higher percentages than this minimum at each point in time.

- (ii) Central and state governments may set up a verification mechanism to ensure that the renewables based power is actually procured as per the applicable standard (DMRPS or SERC specified). Appropriate authorities may also issue certificates that procure renewables based power in excess of the national standard. Such certificates may be tradeable, to enable utilities falling short to meet their renewables standard obligations. In the event of some utilities still falling short, penalties as may be allowed under the Electricity Act 2003 and rules thereunder may be considered.
- (iii) Procurement of renewables based power by the SEBs/other power utilities should, in so far as the applicable renewables standard (DMRPS or SERC specified) is concerned, be based on competitive bidding, without regard to scheduling, or the tariffs of conventional power (however determined). Further, renewables based power may, over and above the applicable renewables standard, be enabled to compete with conventional generation on equal basis (whether bid tariffs or cost-plus tariffs), without regard to scheduling (i.e. renewables based power supply above the renewables standard should be considered as displacing the marginal conventional peaking capacity). All else being equal, in such cases, the renewables based power should be preferred to the competing conventional power.

4.2.3. RETs FOR TRANSPORTATION AND INDUSTRIAL FUELS

Internal combustion engine based power plants for transportation modes require liquid or gaseous fuels. In addition, rail (inc. LRT) modes, and some niche personal transportation modes are based on storage battery power, which may be recharged from mains outlets. The focus in this section is on liquid fuels of biological origin for transportation, and industrial applications (prime-movers, heating fuels).

4.2.3.1. TECHNOLOGY PATHWAYS

There are several possible pathways for deriving transportation and industrial fuels (not being feedstocks where the chemical composition rather than energy content is the main consideration).

At present, only biodiesel sourced from *Jatropha* or *Pongamia* plantations, and bioethanol using spoilt foodgrains are cost-effective in relation to petroleum based fuels. While significant R&D is being carried out in several countries, including in India, in respect of technologies based on several of the above pathways, at present, the costs are not competitive with petroleum. However, it is probable that several biofuels technologies would eventually become competitive with petroleum, and the policy/regulatory regime must enable them to be commercially deployed when that happens.

4.3. Disaster Management Response to Extreme Climate Events

With projected increases in the frequency and intensity of extreme events including cyclones, droughts, and floods attributable to climate change, disaster management needs greater attention. In the 11th Plan, the approach towards disaster management has moved from relief to prevention, mitigation, and preparedness. Two main planks of the new approach are mainstreaming disaster risk reduction into infrastructural project design and strengthening communication networks and disaster management facilities at all levels.

4.3.1. REDUCING RISK TO INFRASTRUCTURE THROUGH BETTER DESIGN

As a planned adaptation strategy, reducing risks from natural disasters needs to be a part of infrastructure project design, especially in areas vulnerable to extreme events. It is generally much cheaper to incorporate appropriate features in the initial design and construction of infrastructure projects, including siting, than to undertake retrofits later. The various elements of this Programme may include:

- Disaster-specific vulnerability assessments and sectoral impacts assessments at the state and district level for preparing contingency plans
- Maintenance of critical facilities such as health care services and water supplies
- Collaboration with insurance providers to insure infrastructure, mainstreaming disaster risk reduction into Sarva Shiksha Abhiyan, Jawaharlal Nehru National Urban Renewal Mission and Indira Awas Yojana
- Capacity building among design engineers, project planners and financial institutions on incorporating elements of disaster management
- Development of prefabricated structures instead of cast-in-place construction in vulnerable areas
- Enforcement of building codes; better urban planning and zoning of vulnerable areas

4.3.2. STRENGTHENING COMMUNICATION NETWORKS AND DISASTER MANAGEMENT FACILITIES

Ensuring that communication channels are not severed during disasters can protect lives and expedite relief and rehabilitation operations. Furthermore, it is essential to have a regular monitoring programme in place to provide early warning of imminent disasters to facilitate a planned response, including evacuation from vulnerable areas to minimize the impact of disasters. Specific action areas will include:

- Upgrading forecasting, tracking and early warning system for cyclones, floods, storms and tsunami
- Monitoring river flows and mapping flood zones
- Generation of regional scenarios based on single or multi-hazard mapping
- Disaster response training at the community level to build infrastructure and human resources for medical preparedness and emergency medical response to manage mass casualties during extreme events

4.4. Protection of Coastal Areas

The coastal areas are an important and critical region for India not only because of the vast 7500-km coast-

line but also because of the density of population and livelihoods dependant on coastal resources. Coastal zones are particularly vulnerable and sensitive to such impacts of climate change as rise in the sea level, rise in the high-tide level, and cyclones and storms, which are projected to become more frequent and intense. The programme will focus on two elements, namely (1) coastal protection and (2) early warning systems. Priority areas on coastal zones include:

- Development of a regional ocean modelling system especially in the Bay of Bengal and the Arabian Sea
- High-resolution coupled ocean–atmosphere variability studies in tropical oceans, in particular the Indian Ocean
- Development of a high-resolution storm surge model for coastal regions
- Development of salinity-tolerant crop cultivars
- Community awareness on coastal disasters and necessary action; plantation and regeneration of mangroves
- Timely forecasting, cyclone and flood warning systems
- Enhanced plantation and regeneration of mangroves and coastal forests

4.5 Health Sector

The proposed programme comprises two main components, namely provision of enhanced public health care services and assessment of increased burden of disease due to climate change. Areas that can contribute to enhanced health care services include the following:

- Providing high-resolution weather and climate data to study the regional pattern of disease
- Development of a high-resolution health impact model at the state level
- GIS mapping of access routes to health facilities in areas prone to climatic extremes
- Prioritization of geographic areas based on epidemiological data and the extent of vulnerability to adverse impacts of climate change

- Ecological study of air pollutants and pollen (as the triggers of asthma and respiratory diseases) and how they are affected by climate change
- Studies on the response of disease vectors to climate change
- Enhanced provision of primary, secondary, and tertiary health care facilities and implementation of public health measures, including vector control, sanitation, and clean drinking water supply

4.6. Creating Appropriate Capacity at Different Levels of Government

In view of several new initiatives that would be required, both in respect of adaptation and mitigation, creation of knowledge and suitable capacity at each level of Government to facilitate implementation of appropriate measures assumes great importance.

At the level of the central government, there would be a need to carry out the following:

There should be support to relevant policy research to ensure that adaptation and mitigation takes place in a manner that enhances human well-being, while at the same time minimizing societal costs. This should lead to the design of suitable legal, fiscal and regulatory measures.

Appropriate capacity for implementing R&D activities and promoting large-scale public awareness and information dissemination on various aspects of climate change is required. For adequate R&D activities a proactive approach favouring partnerships between research organizations and industry would be efficient and productive.

At the level of state governments, several agencies would need to enlarge and redefine their goals and areas of operation. For instance, State Electricity Regulatory Commissions would need to concern themselves with regulatory decisions that ensure higher energy efficiency, greater use of renewable energy, and other low carbon activities that would ensure energy security, reduced local pollution, and increased access to energy in areas where distributed and decentralized forms of energy production would be economically superior to conventional methods. State governments may also employ

fiscal instruments to promote appropriate options and measures.

Local bodies would need to create capacity on regulatory measures, particularly for ensuring energy efficiency in new buildings as well as through a programme of retrofits. In respect of adaptation measures, local capacity and the involvement of communities in actions to adapt to the impacts of climate change would be crucial.

Public awareness on climate change would have to be spearheaded and driven by government at all levels. Emphasis on schools and colleges is essential.

In some cases legislation may be required at the central and state levels to arrive at appropriate delegation of responsibility and authority for meeting some of the goals mentioned above.

5. International Cooperation: the Multilateral Regime on Climate Change

As a party to the UN Framework Convention on Climate Change and its Kyoto Protocol, India plays an active role in multilateral cooperation to address climate change. These agreements are based on the principle of *"common but differentiated responsibilities and respective capabilities"* of Parties. Thus, they incorporate certain common commitments for all Parties, including an obligation to *"formulate and implement programmes containing measures to mitigate climate change"*. Additionally, the Convention requires the developed countries (listed in its Annex I) to stabilize and reduce their greenhouse gas emissions and the Kyoto Protocol establishes quantified, time-bound targets in this regard. Countries with the most advanced economies (listed in Annex II of the convention) are also required to transfer financial resources and technology to developing countries for purposes of mitigation and adaptation.

The Convention specifically notes that *"per capita emissions in developing countries are still relatively low and...the share of global emissions originating in developing countries will rise to meet their social and development needs."* The Convention also recognizes that *"economic and social development*

and poverty eradication are the first and overriding priorities of the developing country parties." Thus, developing countries are not required to divert resources from development priorities by implementing projects involving incremental costs – unless these incremental costs are borne by developed countries and the needed technologies are transferred.

The Global Environmental Facility (GEF) finances implementation of projects in developing countries under the Convention. Additionally, the Kyoto Protocol created the Clean Development Mechanism (CDM), which allows developed countries to meet part of their emission reduction commitments by purchasing credits from emission reduction projects in developing countries, thus serving the dual objective of facilitating compliance by developed countries of their emission reduction commitments and of assisting developing countries to achieve sustainable development.

5.1. Some Technology Development and Transfer Issues

In the move towards a low-carbon economy, technology has a vital role to play. Technology solutions are also very important for enhancing adaptive capacity and reducing vulnerability to climate change and its impacts. In this respect, international cooperation in science and technology assumes great significance.

It is important to ensure that within the multilateral process under the UNFCCC, the menu of cooperation mechanisms is not constrained, and indeed, proactive measures are taken for these mechanisms to be used. The stage of the technology in terms of its progression from research to widespread market adoption will play an important role in determining the mechanisms that are appropriate and relevant.

For example, when the technology solutions are at a very early stage of development, the primary focus is usually on cooperation in basic scientific research. India has always been very actively engaged in, and is making key contributions to international scientific programmes that may have significant implications for the transition to a sustainable

energy future, such as the International Thermonuclear Experimental Reactor (ITER). At the individual and institutional level, Indian participation in scientific networks is also very strong. From a long-term perspective, this scientific cooperation will remain very important.

As ideas progress from the laboratory closer towards the market, the focus shifts towards technology design and development. Mechanisms that enable joint technology development involving public and private sector entities and with suitable norms for financing and IPR-sharing would be important for ensuring that the process of technology development and commercialization happens more rapidly and effectively.

For the final stage of deployment and market adoption of technologies in developing countries, two different contexts may be identified. For technologies that are already mature and deployed in the developed countries, appropriate financing models are essential, which may become operational through multilateral institutions, carbon markets and mechanisms like the CDM. However, as was noted earlier, given the somewhat limited role that the CDM appears to have played with regard to technology transfer, this issue will merit detailed examination.

However, the transition to a more sustainable energy future will require a much more rapid progression towards a variety of newer, low-carbon and energy efficient technologies in different areas. The usual mechanism considered for this purpose is that of technology transfer from the developed to the developing countries. The conventional model of technology transfer, considers that technology developed in the North is first established there, before it is supplied to the South. The rapid changes in the global economic and technology environment are making this model less applicable. As the experience so far also suggests, this model may be inadequate in terms of satisfying the scale and scope of the technology response required. New models and mechanisms for technology transfer will need to incorporate at least three key elements: appropriate funding modalities and approaches; a facilitative IPR environment, and enhancing the absorptive capacity within developing countries.

New multilateral technology cooperation funds may be required that would finance the development, deployment, diffusion and transfer of technologies for both mitigation and adaptation to developing countries.

One of the main barriers to technology adoption lies in the low absorptive capacities of developing countries. It is vital that mechanisms for technology transfer include measures that will enable the enhancement of absorptive capacities, keeping in mind the targets of such technology interventions.

5.2. Clean Development Mechanism

India has given host-country approval for 969 CDM projects as of June 2008. Renewable energy, including renewable biomass, accounted for the largest number of projects (533), followed by energy efficiency (303). Very few projects in the forestry (6) and municipal solid waste (18) sectors were included, despite their large potential. The expected investments in these 753 projects (if all go on stream) is about Rs. 106,900 crores.

Of the 969 projects, 340 projects have been registered by the multilateral Executive Board (CDM EB). India accounts for about 32% of the world total of 1081 projects registered with the CDM EB, followed by China (20%), Brazil (13%), and Mexico (10%) (Source: UNFCCC). About 493 million certified emission reductions (CERs) are expected to be generated until 2012 if all these host-country approved projects in India go on stream (National CDM Authority, November 2007). As of June 2008, 152.4 million CERs had been issued to projects worldwide, of which India accounted for 28.16%, China (29.25%), Korea (17.87%), and Brazil (14.13%).

Some cross-cutting challenges in CDM implementation in India are listed below:

- The projects from India are generally small. Of the 283 projects registered with the CDM EB till October 2007, 63% are small-scale projects (in terms of the Protocol definition)
- The portfolio is dominated by unilateral projects,

i.e. the investors are Indian parties, employ locally available technologies, and use domestic financial resources. While this has provided a significant impetus to local innovation, CDM has not led to the technology transfer from industrialized to developing countries envisaged by the Protocol

- Industrialized countries have not participated significantly in project financing and the project risks are mostly taken up by the host industries
- Insurance companies in general have shown little interest in CDM, which is unfortunate since they can catalyse carbon trading by providing risk and financial analysis skills
- There is much subjectivity in the multilateral CDM process, and divergent interpretations are given by different designated operating entities (DOEs) accredited by the CDM EB
- High transactions costs prevent the small-scale sector (in the Indian definition) from participating in CDM
- In the absence of an international transactions log (ITL), there is lack of reliable information in the carbon market on CDM transactions

Despite the above, there is encouraging response from Indian entrepreneurs to the CDM across different sectors. Besides, several recent enhancements of CDM such as bundling and programmatic CDM need to be mainstreamed. Alongside the carbon market under the Kyoto Protocol, a voluntary (non-compli-

ance) carbon market is emerging involving trades in VERs (verified emission reductions). This market may grow substantially in the future.

5.3. Enhanced Implementation of the UNFCCC

India looks forward to enhanced international cooperation under the UNFCCC. Overall, future international cooperation on climate change should address the following objectives:

- Minimizing the negative impacts of climate change through suitable adaptation measures in the countries and communities affected and mitigation at the global level
- Provide fairness and equity in the actions and measures
- Uphold the principle of common but differentiated responsibilities in actions to be taken, such as concessional financial flows from the developed countries, and access to technology on affordable terms

India as a large democracy, with the major challenge of achieving economic and social development and eradicating poverty, will engage in negotiations and other actions at the international level in the coming months that would lead to efficient and equitable solutions at the global level.

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