Constraints and Gaps, and Related Financial, Technical and Capacity Needs

Chapter 7

This chapter, in accordance with national circumstances and development priorities, describes constraints and gaps, and related financial, technical and capacity needs, as well as proposed activities for overcoming the gaps and constraints associated with the implementation of activities and programmes envisaged under the UNFCCC . This chapter also includes some climate change projects. The coverage is not an exhaustive elucidation of India's financial and technological needs and constraints, and these have been identified during the implementation of the enabling activity for the Initial National Communication. With more scientific understanding and increasing awareness, further areas of work could also be identified, including the continuing need for improving the quality of national GHG inventories, regional and sectoral assessment of vulnerabilities and adaptation responses, and communication of information on a continuous basis.

The broad participatory approach adopted for preparing India's Initial National Communication has contributed to understanding the challenges for addressing climate change concerns in India, while simultaneously building capacity in diverse disciplines, such as inventory estimation, emission coefficient measurements, quantitative vulnerability assessment, and inventory data management.

NEED FOR CONTINUOUS REPORTING

Present efforts in inventory estimation

The GHG emissions inventory for non-annex I countries is to be reported to the UNFCCC Secretariat as per 10/CP.2 guidelines for the Initial National Communications. These guidelines have been improved and were adopted during the COP-8 at New Delhi in October 2002. GHG inventory reporting requires detailed activity data collection and estimation of country-specific emission coefficients. The level of inventory reporting depends on the data quality and methodology employed and is indicated as Tier I, II or III, as per the Revised 1996 IPCC Guidelines for Greenhouse Gas Inventories. Despite the comprehensive initiation of activities under the Initial National Communication project, there is considerable scope for further improvement. The inventory estimation has to be made at a more disaggregated level, preferably at a Tier II or III levels for most of the sectors, resolving the differences between top-down and bottom-up estimates. Finer sub-sectoral level estimates for activity data and EF have to be developed. Similar and consistent formats have to be adopted for data reporting and consistency by organizations generating activity data. The major constraints and gaps in Indian GHG inventory estimation are now presented.

Non-availability of relevant data

This is a prominent concern, especially in developing countries where time series data required for GHG inventory estimation is not available for some specific inventory sub-categories. For example, in the waste sector, details about annual municipal solid waste generation, collection, dumping and dumpsite characteristics are not available beyond five to 10 years for even the large metropolitan cities; while for smaller cities, the data availability is poor . This data is required for methane emission estimation. In absence of this data, the available time series information is extrapolated for a city, or that from a few cities extrapolated for the entire country, based on homogeneous city classifications.

Another constraint is the non-availability of data for informal and less organized sectors of the economy. These include agriculture, forestry and many small-

scale industries (SSI) like brick, sugar, glass and ceramics, dyes, rubber, plastic, chemical and engineering products. The SSI sector in India comprises modern and traditional industries encompassing the continuum of the artisans and handicrafts units at one end and modern production units producing a wide range of around 7,500 products. Many of these industries, along with domestic and commercial sectors, are informal as far as energy accounting is concerned.

Similarly, improvements in activity data for various sub-categories of agriculture-related GHG emissions are critical. The key activity data include livestock population, synthetic fertilizer application, areas under different water regimes for rice paddy cultivation, and agriculture crop residue generation for various crops. Under the LULUCF sector; the area under different land-use categories, above-ground biomass and mean annual increment, soil carbon density, fuelwood and

Energy consumption data in unorganised sectors and small scale industries, such as sugar, ceramics and brick, require refinement.

commercial timber consumption, have considerable uncertainty.

The National GHG inventory preparation is a continuous process of improving the reliability and consistency of inventory assessments. The Indian GHG inventory for the Initial National Communication has been mostly reported using Tier 1 and 2 approaches . As India plans to move to higher tier and more detailed inventory assessments in subsequent communications, the data gaps have to be identified and corrective action taken. Since the GHG inventory-reporting year lags behind the year of assessment by about four to five years for developing countries, the above data has to be generated now for use in subsequent national communications. This requires sustained commitment of resources and setting up of appropriate institutional frameworks.

Data non-accessibility

This is yet another peculiar data problem in developing countries. Since data collection requires considerable effort and resources, it is often treated as proprietary. Moreover, some of the data required for refining inventories to the Tier III level is considered confidential by the respective firms and not easily accessible. These firms have to be therefore sensitized about data needs for inventory reporting and refinement. Systems have to be devised for the regular publication of relevant information in desired formats for national GHG inventory estimation.

Another issue is the non-availability of data in electronic form. However, due to the increased penetration of computers and information technology, more data is becoming electronically available.

Data organization constraints

The different levels of GHG inventory reporting, called Tiers, require different data quality . Although data required for initial levels is already in the public domain through the annual reports and data statistics of various ministries and departments of the Government of India, it is not organized in desired formats. This requires considerable data organization, consistency checks and data management.

There is also inconsistency in some data sets released by the central and state governments for some activity data . Coal consumption by power plants is one such example, where the top-down data on gross national coal consumption and plant-level bottom-up coal consumption data from separate reports of different ministries do not converge to the same number. The reasons may be due to aggregation errors, and/or inaccuracies in supply side reporting of coal off-take by the power sector versus the demand side reporting of coal consumption by individual power plants.

Another gap area is that the sectoral data for various fuels do not match across different ministry reports in a few instances. Although many of the industries are reasonably well organized, however, accounting of all their energy resources is not widely available. For example, the Ministry of Petroleum and Natural Gas reports the consumption of major petroleum products like diesel, furnace oil, and low sulphur heavy stock (LSHS) for engineering, aluminium, ceramic and glass, chemical industries, mining and quarrying (MoPNG, 1994-1995). However, the Coal Directory of India does not indicate coal consumed by these industries separately (MoC, 1996). Therefore, energy consumption for these industries cannot be provided for all the energy resources. Thus, for consistent energy consumption accounting and reporting purposes, many industries have to be combined together as 'Other Industries'. The final inventory reporting is determined by the least common factors of reporting and therefore, limits detailed representation.

The sectoral definitions for different fuels may not be consistent even in the same ministry document. For example, the national consumption of LSHS is combined and reported together for the entire transport sector, while for diesel consumption, separate data for road, aviation, shipping, railways and other transport is provided (MoPNG, 1999-2000). Therefore, for inventory estimation and reporting purposes, either the LSHS data is to be distributed exogenously among various transport sub-sectors based on some indicators, or inventory reporting is to be done at the gross transport sector level only.

Development of representative emission coefficients

To capture Indian national circumstances, a beginning has been made to generate India-specific emission coefficients by undertaking in-situ measurements in some key source categories to try and define the range in uncertainties in the estimates through statistical methods. However, time and budgetary resources available under the project constrained the coverage under this activity. For uncertainty reduction in GHG emissions, India needs to undertake in-situ measurements for many more activities to capture the Indian realities. The sample size has to be statistically determined for all the categories covered under the National Communication , for instance, GHG emissions from power plants. Some critical gap areas covering the key source categories for Indian GHG emissions are as follows :

- Measurement of GHG emission coefficients from power plants.
- Measurement of GHG emission coefficients from steel plants.
- Measurement of GHG emission coefficients from cement plants.
- Measurement of GHG emission coefficients from petroleum refineries.
- Measurement of GHG emission coefficients for the road transport sector.
- Methane emission coefficient measurements from coalmines.
- Methane emission coefficient measurement from oil and natural gas venting, flaring and transport.
- GHG emission coefficient measurements from fully/partially informal energy intensive sectors, such as brick manufacturing, sugar and ceramics .

- Methane emission coefficients from municipal solid waste (MSW) sites.
- Methane emission coefficients from waste water (industrial and domestic).
- GHG emission coefficient measurements from industrial processes like lime production and use, nitric acid production, aluminium production, soda ash use, pulp and paper production.
- Measurements for the LULUCF sector, including rate of above-ground biomass (AGB) growth for different forest types, woody biomass volume for different forest types , land-use change matrix, and soil carbon density in Indian forests on a fine gridded scale.
- GHG emission measurements and activity data assessment for biomass used for energy purposes.
- Measurement of methane emissions from enteric fermentation for different livestock categories and age groups.
- Measurement of methane and N_2O from manure management.
- Measurement of N_2O emission coefficients from different rice paddy systems.
- Measurement/ estimation of GHG emission coefficients (especially N_2O) for different types of soils in India.

These activities require significant additional scientific work requiring considerable resources. Technical capacity has to be built at more institutions to conduct these in-situ measurements. Instrumentation upgradation and process accrediting has to be done for many existing laboratories.

Needs for GHG inventory estimation on a continuous basis

The GHG inventory estimation needs may be estimated at three levels:

- Data needs.
- Capacity development and enhancement needs.
- Institutional networking and coordination needs.

The data needs are based on the data gaps and constraints (Table 7.1). These include designing consistent data reporting formats for continuous GHG inventory reporting, collecting data for formal and informal sectors of the economy, enhancing data quality to move to a higher tier of inventory reporting, and conducting detailed measurements for India-specific emission coefficients. Capacity development has to be at two levels: institutions and individual researchers. Institutional capacity development requires financial support, technological support, instrumentation, and networking. Individual researcher capacity development is required to sensitize and train data generating teams in various sectors and at different institutions about the GHG inventory estimation process, so that researchers would be better equipped to collect and report the desired data on a continuous basis. Institutional networking and coordination is a critical factor for establishing new data frameworks and reporting formats in various sectors. The Initial National Communication project has contributed to initiate this process in India at various levels. However, sustained and timely financial and technological support are critical to sustain and strengthen this process.

LULUCF sector constraints and needs

The LULUCF sector in India has the potential to be a major source or sink of CO_2 in the future. The uncertainty in the estimates of inventory in the LULUCF sector is shown to be higher than other sectors, such as energy transformation, transportation, industrial processes and agriculture. The availability and access to information on activity data, emission coefficients and even sequestration rates in the LULUCF sector in India is limited and the uncertainty of the data is high, as in most countries. Thus, there is a need for improvement in the information generation processes for the inventory, to reduce the uncertainty involved in the estimation of GHG inventory in the LULUCF sector.

Inventory in the LULUCF sector requires activity data on area under different forest types and the area subjected to land-use change as well as the changes in carbon stocks of different land-use categories or forest types. The data needs and features are given in Table 7.2.

Status of data and uncertainty involved: Reliable and consistent GHG inventory requires activity data and emission or sequestration factors for various land-use categories in the country. However, uncertainty in the reliability and quality of activity data and emission factors in the LULUCF sector is high in all countries,

Table 7.1: Constraints and gaps in GHG inventory estimation

Gaps and constraints	Description	Potential measures (examples)
Data organization	Published data not available in IPCC-friendly formats for inventory reporting	Design consistent reporting formats
	Inconsistency in top-down and bottom-up data sets for same activities	Data collection consistency required
	Mismatch in sectoral details across different published documents	Design consistent reporting formats
Non-availability of relevant data	Time series data for some specific inventory sub-categories, e.g., municipal solid waste sites	Generate relevant data sets
	Data for informal sectors of economy	Conduct data surveys
	Data for refining inventory to higher tier levels	Data depths to be improved
Non-accessibility of data	Proprietary data for inventory reporting at Tier III level	Involve industry and monitoring institutions
	Data not in electronic formats	Identify critical datasets and digitize
	Lack of institutional arrangements for data sharing	Establish protocols
	Time delays in data access	Awareness generation
Technical and institutional capacity needs	Training the activity data generating institutions in GHG inventory methodologies and data formats	Arrange extensive training programmes
	Institutionalize linkages of inventory estimation with broader perspectives of climate change research	Wider dissemination activities
Non-representative emission coefficients	Inadequate sample size for representative emission coefficient measurements in many sub-sectors	Conduct more measurements
Limited resources to sustain national communication efforts	Sustain and enhance research networks established under Initial National Communication	Global Environment Facility (GEF)/ international funding
	India-specific emission coefficients	Conduct adequate sample measurements for key source categories
	Vulnerability assessment and adaptation	Sectoral and sub-regional impact scenario generation, layered data generation and organization, modelling efforts, case studies for most vulnerable regions
	Data centre and website	National centre to be established

particularly in developing countries.

i) Area under different land-use categories and area subjected to change:

Source: The FSI provides area under forest, and under different tree crown density classes at a frequency of two years. Area under agriculture and other land-use categories is provided by MOA.

Status of data: Availability of activity data according to forest and plantation types is limited. Currently, only the aggregate area under different tree crown densities is published, which is inadequate for inventory purposes. Changes or conversion of different forest and plantation types and grassland categories is not available.

Uncertainty: Uncertainty is high due to lack of data

Table 7.2: Data needs for GHG inventory in the LULUCF sector.

Activity Data		Emission Factor/Sequestration Rate	
Data needs	**Details**	**Data needs**	**Details**
Area under different land categories	Forest types Plantation types Trees outside forests Agricultural land	Above ground biomass (AGB)	Forest types Plantation types
Land-use change; Area under different forest types, subjected to change	Land converted to forest Conversion of forest and grassland to other categories	Mean annual AGB growth rate	Plantation types Regenerating abandoned land
Managed area abandoned	Subjected to regeneration Traditional and commercial	Soil carbon density	Native land types (forests, etc.) Agricultural land Pasture land Other land categories At different periods, for instance, over 20 years
Fuelwood consumption	fuelwood consumption Source of fuelwood		
Commercial timber consumption	Proportion coming from forest conversion and extraction from existing factors		

on area under different forest and plantation types as well as the area subjected to conversion according to these categories.

Limitations and barriers: The area under forests, according to tree crown densities is currently monitored at a frequency of two years. Expanding this to forest or plantation types requires large ground truthing. Lack of technical manpower and financial support is the key barrier to monitoring area as well as changes or conversion according to forest or plantation types.

ii) AGB and mean annual increment: This data is required for different forest or plantation types and managed land, both abandoned and regenerating.

Source: Forest inventory, silvicultural studies, field ecological research studies and plantation companies.

Status of data: The FSI has estimated the AGB for 22 forest strata, based on forest inventory. This data is available only for one-period. The estimates of Mean Annual Increment (MAI), which are based on the measurement of AGB at two periods is lacking. The MAI is available only for some forest types in published field research studies.

Uncertainty: Uncertainty of estimates of AGB is high due to:

- absence of periodic forest inventories
- absence of measurements of AGB according to different forest or plantation types at a disaggregated level
- absence of AGB measurements from the same plot at two time periods, close to the inventory year
- absence of permanent plots for frequent and periodic measurements and monitoring.

Limitations and barriers: Monitoring of AGB, for instance a frequency of five years, requires establishment of a large number of permanent inventory plots in each forest or plantation. India does not have periodic forest inventory plots and measurements due to financial and institutional barriers.

iii) Soil carbon density: is required for different native land-use categories before they are subjected to conversion as well as after conversion to a new land use category.

Source: Soil carbon density data is being estimated by the National Bureau of Soil Survey and Land Use

Planning (NBSSLUP), largely for non-forest land use categories. The only source of data on soil carbon density is the large number of research studies carried out in some forest types in India.

Status of data: Soil carbon density data is not available for all the forest and non-forest land use categories for the top 30 cm. Further, its availability is limited to only one time period.

Uncertainty: Uncertainty in soil carbon density data is high due to:

- absence of data for all forest and non-forest land-use categories
- absence of data at two time periods and over 20 year period in land categories subjected to land-use change.

Limitations and barriers: The forest inventory studies do not incorporate the measurement of soil carbon density. There is no specialized agency for monitoring soil carbon density in forest land-use categories. Forest departments are inadequately equipped to conduct soil carbon studies.

iv) Fuelwood and commercial timber consumption: GHG inventory in the LULUCF sector requires data on the quantity of traditional and commercial fuelwood and timber consumption, and the proportion of wood coming from forest clearing and from extraction in the existing forests.

Source: The sources of data on consumption include forest department statistics as well as the national-level fuelwood consumption studies, carried out in the past. The source of timber consumption is the forest department as well as the FSI.

Status of data and uncertainty: Fuelwood and commercial roundwood consumption data is not available for the inventory year, particularly the proportion coming from forest clearing and extraction from existing forests and non-forest trees. Thus, the uncertainty is high.

Limitations and barriers: India does not have any programme to monitor the consumption of fuelwood and commercial roundwood periodically. There is no dedicated institution to monitor the extraction of fuelwood and commercial roundwood from forest and non-forest sources.

Existing institutions and capacity for generating data in the forest sector: The main sources of data for inventory in the forest sector are the forest departments, FSI and research institutions.

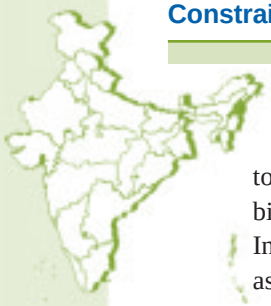
i) Forest area monitoring: The FSI is a dedicated institution under the MoEF for periodically monitoring the changing situation of land and forest resources and presents the data for national planning, conservation and management of environmental preservation and implementation of forestry projects at the national and state level. The FSI has regional offices in different parts of India, and has monitored the area under forests using remote-sensing techniques at a scale of 1:250,000 since 1987 to 1999. During 2000, a 1: 50,000 scale has been adopted for interpretation. The FSI does not have adequate resources and technical manpower to conduct periodic forest inventories.

ii) AGB and mean annual increment: The FSI has instituted a programme to conduct, periodic forest inventories in a limited number of locations. Currently, the main source of data on MAI as well as AGB is from studies conducted by universities and research institutions. There is no dedicated institution to periodically monitor the AGB and MAI.

iii) Soil carbon density: The NBSSLUP is a large national institution with regional centres for preparing soil maps and for estimating soil organic carbon in a large number of grids. The focus of the preparation of soil maps and estimates of different soil characteristics is largely limited to non-forest land use categories. A national level digitized soil carbon map has been prepared by NBSSLUP, but not accessible for research.

iv) Fuelwood and commercial roundwood consumption: India does not have any dedicated institution to estimate the consumption of fuelwood and commercial wood or their source.

Technology, capacity development and financial needs: India is a large developing country with a large forest-dependent population and thus, there is a need



to monitor the status of forests, area, biodiversity, biomass stock, soil carbon and biomass extraction. India will have to initiate a dedicated forest inventory as well as GHG inventory programme to generate information and data needed. However, there are technical, institutional and financial barriers in establishing a dedicated forest and GHG inventory programme. This involves identifying existing or establishing new institutions, infrastructure and capacity development, and provision of adequate financial resources.

- *Technology needs:* India has to adopt advanced forest inventory, soil carbon density change monitoring and biomass extraction and utilization monitoring programmes.
- *Enlarged and periodic inventory*: The forest inventory should include long-term inventory plots for the estimation of AGB, below-ground biomass (BGB), litter, soil carbon pools and dead organic matter. There is a need to use remote-sensing techniques to monitor AGB changes, in addition to traditional forest inventory techniques.
- *Monitoring of forest area and changes*: The existing programmes of the FSI need to be enlarged to monitor the area changes according to forest or plantation types. There is also a need to generate a land-use change matrix describing the flows or changes from one category to another. This requires the strengthening of satellite monitoring system, as well as computation and interpretation facilities at FSI and regional centres of FSI.
- *Fuelwood and commercial roundwood consumption studies*: India has to establish a national sample survey programme for periodically monitoring fuelwood, industrial wood and sawn wood consumption in households, establishments and industries. This requires scientific sampling methods, data collection formats, data entry frameworks and analysis techniques.
- *Modelling;* tools and techniques are required for the following studies:
  - Projecting AGB stock and MAI for the inventory year and for future projections based on data from two inventory periods
  - Projecting soil carbon changes with land-use change over different periods
  - Projecting fuelwood and commercial roundwood consumption at the national level, based on sample studies.

***v) Capacity and institutional needs*:** India has established institutions for undertaking the monitoring of forest area changes, forest inventory and soil organic carbon changes. India also has the Indian Council for Forestry Research and Education (ICFRE) and several other institutions, dedicated to training and research. However, all these institutions need additional capacity development to address the needs of GHG inventory estimation on a continuous basis.

- There is a need to undertake monitoring of forest area changes at aggregate and disaggregate levels, such as national or state forest types. This would require additional human resource for ground truthing periodically, computing and interpretational facilities.
- The GHG inventory in the LULUCF sector requires systematic and periodic forest inventory, incorporating additional parameter measurements such as: BGB, soil carbon and litter. Forest departments in different states will have to carry out the forest inventory for generating data required for GHG inventory at the national level. Thus, there is a need for enhancing the human capacity and training of field personnel, as well as staff for synthesis and periodic reporting.
- In India, the soil carbon status is being monitored by the NBSSLUP. However, since this institution does not focus on forest lands, there is a need for a dedicated institution to set up permanent plots for periodically monitoring soil carbon changes under different forest land-use systems as well as those that are subjected to change. Regional centres may also have to be set up to periodically monitor and report soil carbon changes.
- The National Sample Survey (NSS) is currently a large institutional system, aimed at monitoring social, financial, economic and other data. The NSS could be strengthened to incorporate the monitoring of fuelwood and commercial roundwood consumption in households, establishments and industry.

Vulnerability assessment and adaptation

The six critical priorities of the Indian planning process are:

- Economic security
- Energy security

- Environmental security
- Water security
- Food security, and
- Provision of shelter and health for all.

Climate change would impact all of these in varying degrees. Linking of these priority concerns with climate change policies is the key to harmonizing sustainable development and climate change actions. Research has been initiated under the Initial National Communication project to assess the potential impacts of climate change on some of these concerns, such as Indian agriculture, water resources, forestry, coastal zones, natural ecosystems, human health, industry and infrastructure, including the construction of consistent climate change scenarios for India and the assessment of extreme events using existing models and expertize. The work involves assimilation of existing research work, identification of vulnerable sectors and areas, and a few specific case studies for each sector. Time and budgetary resources available under the project constrained the coverage and in-depth sectoral impact assessment studies under this activity. The lack of data and national databases, resource scarcity, sub-regional and sectoral impact assessment scenarios, lack of modelling efforts and trained manpower, and limited national and regional networking of institutes and researchers, constitute some of the constraints.

The key tasks to address vulnerability and adaptation may be viewed in the matrix of strategies and geographic hierarchy (Table 7.3). Climate change is a long-term issue, i.e., the change in climatic parameters and their impacts would continue to exacerbate over decades and centuries. Therefore, the type and intensity of interventions would enhance with the expiry of time.

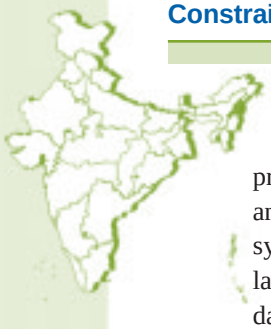
Research and systematic observation

Weather, climate and oceanographic research

The main thrust for Indian atmospheric and oceanographic research is committed to enhance the knowledge of the Asian summer monsoon under various objectives viz. the climate modelling, monsoon studies, climatic tele-connections,

Table 7.3: Key tasks for addressing vulnerability and adaptation needs.

Geographic Hierarchy	Local	National	Regional/ Global
Strategies			
Capacity Building	Monitoring, observation Awareness/assessment at state/ district/ community levels	Scientific assessment, measurement, models, national research agenda	Participation in global/ regional modelling and assessments
Knowledge/ Information	Locale-specific databases, scenarios and assessment, local monitoring networks	Research networks, National databases (e.g., NATCOM), scientific and policy models, national scenarios, technology inventory	Interface with IPCC assessments, interfacing with regional/global databases, scenarios and assessments, technology inventory database
Institutions/ Partnerships	Community initiatives, Early warning networks	Stakeholders networks, public/ private programs	UNFCCC processes, trans-boundary impact assessments
Policy/ Instruments	Locale specific adaptation plans, community-based adaptation programmes	Science-policy linkage, economic instruments (e.g., insurance, R&D funds), integration with national development/ planning process	Adaptation funds, trans-boundary regulations
Technology	Locale-specific technology adaptation	Targeted R&D, technology transfer protocols, demonstration/ pilot projects	Scientific exchange, technology transfer



predictability of weather and climate, climate change and related socioeconomic impacts, severe weather systems, middle and upper atmosphere, boundary layer and land surface processes, observation system, data archive and dissemination.

The main thrust of research in the atmospheric sciences in India is to improve the capabilities of the existing GCMs and paleao-climatological models, to simulate the past, present and future of the Asian summer monsoon under the projected biogeophysiological changes. The parameterization of sub-grid scale physical processes, including convection and land surface processes to improve the skill of models and inclusion of orography, are another thrust area. Improving the model resolution for better understanding of the monsoon is also considered as the main objective in modeling research. Other objectives are to resolve several important monsoon phases, like active and break phases, interannual variability, monsoon trough, intertropical convergence, southern hemispheric equatorial trough, easterly jet and low level jet. The interaction between the tropics and extra tropics in the monsoon region is yet to be understood, which include the role of blocking, shifts of the westerly jet and other major anomalies in the circulations of both the hemispheres. The development of physical and mathematical models of energy and mass exchange in the boundary layer of agro ecosystems and other land surface processes are also projected for the near future.

A detailed analysis of the ENSO-Monsoon relationship using Tropical-Ocean-Global-Atmosphere (TOGA) and other support from the World Climate Research Program (WCRP) is projected. Understanding the synoptic scale and mesoscale phenomena in the monsoon region using satellite cloud imagery/ Ocean-Land-Remote sensing data, radar and other conventional data, etc., is proposed. Kinematics and the dynamical study of different phases, such as onset, progression, withdrawal, break and active phases, is also considered as a thrust area. The interrelationship between the monsoon and other global circulations is to be explored using a statistical approach. A detailed study of the winter monsoon in India, which is the least studied part in Indian meteorology, is proposed as an important task to enhance our knowledge base and to improve the winter agriculture system.

Instrumental capabilities are to be improved by developing various ground-based remote-sensing systems, such as lidars, sodars, spectrometers, photometers and radiometers. These are supposed to enhance the capability of studying minor species and trace gases, including aerosols, ozone, CO_2 etc. The role of CO_2 and other such constituents in the evolution of atmospheric processes leading to the climate of the given region is to be studied for understanding the atmosphere-biosphere reactions.

Extreme events

Under the theme of extreme events, studies on the pre-monsoon thunderstorm activities in the north-eastern region of India, intense vortices within the monsoon system, such as lows, depressions, mid tropospheric cyclones and offshore vortices are important.

To lower the impact of loss due to cyclonic activities, Doppler radars are being installed along the Indian coast with the use of multi-sensor instrumented aircraft flights. Further, three-dimensional models are also being developed for the simulation and prediction of cyclones. Support is being taken from physical factors or synoptic features for studying the cyclones favourable for the development and movement of cyclones over the Indian seas, with particular interest like re-curvature and looping, formation and maintenance of the cyclone eye. Associated phenomenon, such as storm surges, are also being modelled.

Agriculture sector research

The future pathway for agriculture research includes: inventorization, characterization and monitoring of natural resources using modern tools and techniques. The development of sustainable land-use plans for each agro-ecological sub-region in the country is underway. Another agenda is to develop a system, which regulated the fertilizers usage by increasing the fertilizer-use efficiency by 8-10 per cent from the current level and its integrated use with organics and by enhancing the contribution of organics including bio-fertilizers. The management and monitoring of soils for sustainability, on-farm irrigation water management to enhance water-use efficiency,

refinement of technology for economical utilization of poor and marginal quality water for agriculture, development of location-specific model watersheds in various agro-ecological zones of the rain-fed areas to enhance the productivity, are decided for the future.

Weather-based expert systems for enhanced prediction and improvement in agriculture meteorology advisory services are planned for the near future. Increasing the overall cropping intensity with an emphasis on energy efficiency and alternate agriculture, especially with low water requiring crops is proposed to be investigated. The Development of agro-forestry systems to enhance tree cover in agricultural lands to support the supply of fodder, fuel, industrial wood and small timber requirements on a sustainable basis, monitoring of climate change and mitigation of its adverse effects on agricultural production systems, is also planned.

Space sciences

The ISRO has initiated the development of many future satellites with particular emphasis on meteorological and oceanographic objectives (Table 7.4). In the next five years, it has a mandate to launch satellites with advanced payloads.

Sustenance and enhancement of established capacities

Capacity building, networking and resource commitment form the core of institutionalizing Indian climate change research initiatives. This involves a shared vision for policy relevant climate change research, scientific knowledge and institutional capacity strengthening (enhanced instrumentation, modelling tools, data synthesis and data management), technical skill enhancements of climate change researchers, inter-agency collaboration and networking improvement, and medium- to long-term resource commitment.

Several anchors have to be developed for the sustenance and enhancement of established capacities in India, based on policy needs and disciplines. Policy research includes diverse needs such as international climate change negotiation-related research, contribution to the IPCC process, sub-regional sectoral and integrated impact assessment, adaptation/ response strategy formulation, mechanisms for mitigation and adaptation project selection and financing, and climate-friendly technology identification and diffusion in multiple sectors.

Sporadic research efforts are continuing in India since the last decade, such as the Asia Least cost Greenhouse Gas Abatement Strategy (ALGAS) initiative; independent climate change-related research initiatives by government ministries such as the MoEF, Ministry of Water Resources, Ministry of Health and Family Welfare, MoA and MST among others; and the National Communication project; apart from a few initiatives at the individual expert and institution level. Many Indian scientists and researchers have contributed and continue contributing significantly to the IPCC process. India's Initial National Communication project has, for the first time, brought these together in a formal network to cover diverse research areas such as preliminary sub-regional sectoral impact assessments, GHG emission coefficient development for a few key source categories, and institutional networking.

Table 7.4: Future directions (Meteorological and Oceanographic Satellites).

Name	To be launched during	Usage
CARTOSAT-2	2004-2005	Remote-sensing satellite
INSAT 3 series	2004-2005	Meteorology, telecommunications, extension programmes
RISAT-1	2005-2006	Remote-sensing satellite
OCEANSAT-2	2006-2007	Remote-sensing satellite
ASTROSAT	2005-2006	Astrophysics, environment, meteorology
KALPANA 2	2005-2006	Meteorology, environment
MEGHA-TROPIQUES	2006-2007	Meteorology, oceanography, environment

However, the procedures, methodologies, and data requirements for GHG inventory preparation are not known to most of the institutions generating activity data in various sectors. On the other hand, a few research teams in the country have the latest international expertize in preparing GHG inventories. The NATCOM project had attempted to network the two. However, the capacity-building initiatives have to be continued, widened and strengthened. The existing capacity gaps have to be identified, prioritized and then strengthened gradually. The focus has to be to institutionalize the process. Climate change research has to catch the attention and imagination of the younger Indian research community, especially in the universities and premier academic institutions, and then to keep these researchers engaged in their pursuit. There have to be sustained capacity-building efforts for a reasonable time, so that the process then becomes self-sustaining and institutionalized. Timely and sustained international funding is critical to realize this effort.

Initial institutional networks have been established and are operational under the NATCOM project. There are 19 institutions involved with GHG inventory estimation, while 17 research teams have contributed to measurement of emission coefficients in various sectors. Over 40 institutions contributed to the research initiatives on climate change vulnerability assessment and adaptation, and steps to implement the Convention (refer Annexures). These efforts have to be sustained. However, there are many more institutions in India that have individual researchers working on climate change-related aspects. Industrial associations and the private sector have also to be brought in for activity data reporting, along with government ministries and departments for consistent reporting formats. Private accredited laboratories have to be brought in to strengthen the government institutions-based GHG emission coefficient measurement activities. There are therefore, many potential partners and future centres of climate change research. Thus, it is necessary to broaden the existing networks to include all these research initiatives. This is important for creating a critical mass of researchers that would sustain climate change research in India. Networking mechanisms, particularly like data and information sharing, will require to be established and institutionalized. This would avoid duplication of effort, especially in data collection, and ensure effective resource utilization.

The networking efforts may have to be simultaneously extended to interface the research community with industry and policy-makers. Industry would benefit from the latest scientific research and GHG accounting practices. On the other hand, industry concerns and capabilities would also be reflected in research.

CLIMATE CHANGE PROJECTS

Improvements for future national communications

India would like to immediately launch the activities for preparing the Second National Communication, reflecting its commitment to the UNFCCC. India seeks further funding from the GEF for this purpose. Some of the proposed projects are indicated in Table 7.5. These include projects on improving inventory estimation, vulnerability assessment and adaptation research, and capacity building. However, this is only an indicative and not an exhaustive list.

Thematic project proposals

Some thematic potential project concepts that are over and above the specific projects presented in earlier sections are presented. These include projects for assessment of vulnerability of various socioeconomic sectors and natural ecosystems to climate change, enhancing adaptation to climate change impacts, GHG emission abatement projects, and capacity-building initiatives (Table 7.6). These however, are indicative and not an exhaustive listing of concepts. New understanding, knowledge development, resources and technology transfers will enhance India's capacity to augment this list in subsequent national communications. India needs financial assistance to convert these project concepts into specific projects for funding.

It is envisaged that activities to enable continuous reporting to the UNFCCC will involve more detailed development of local emission factors, thus reducing uncertainties in inventory estimates, focus on methodological issues, help develop regular monitoring networks, maintain and enhance national capacity through establishment

Table 7.5: Project proposals for improvements of future National Communications.

S.No	Type/ Sector	Title	Description
A	National Communication	Preparation of Second National Communication proposal document	The project will assist India in preparing a detailed proposal for 'Enabling Activities for the preparation of India's Second National Communication to the UNFCCC'
B	National Communication	Enabling activities for the preparation of India's Second National Communication to the UNFCCC	The project will assist India in undertaking the enabling activities to prepare the Second National Communication to the UNFCCC and to build capacity to fulfil its commitments to the Convention on a continuing basis.
Activity data for GHG inventory			
1	All sectors	Data format preparation for GHG inventory reporting	Presently the data being reported by the various ministries and departments at resources and sectors level shows some mismatch and the consistency cannot be easily verified. It is imperative that the available data formats be reorganized for reporting data at intra and inter ministerial levels in appropriate GHG inventory reporting formats.
2	Energy	Strengthen the activity data for GHG emission estimates from India's transport sector	Analysis of the current vehicle types and their distribution in various cities of the country and fuel use. The railways, aviation and the waterways sectors will also be covered.
3	Energy	GHG emission measurements and activity data assessment for biomass used for energy purpose	GHG emission measurements and activity data assessment for biomass used for energy purpose
4	Energy and Industrial processes	GHG inventory estimation	Data collection and GHG inventory estimation to climb the tier ladder to 2/3 tiers from the current Tier 1 for the various sub-sectors
5	Agriculture	Inventory Estimation	Evaluation of sources and sinks of GHG related to agricultural activities at disaggregated level, including data collection and validation of age-wise livestock, water regime-wise rice paddy cultivation, sub-regional crop production, sub-regional synthetic fertilizer use.
6	LULUCF	Land-use pattern assessment for India for GHG inventory estimation	Periodically monitoring and estimating the area under different forest types as well as to prepare a land-use change matrix, describing the extent of land-use change from one category to another, preferably at $1/2^0 \times 1/2^0$
7	LULUCF	Assessment of wood consumption in India for GHG inventory estimation	Estimating the fuelwood and commercial roundwood consumption, dung cake production and consumption, and agriculture crop residue consumption in India
8	LULUCF	Assessment of carbon pools in India for GHG inventory estimation	Estimating different terrestrial carbon pools, namely vegetation biomass, soil and litter carbon stocks under various land use categories and assess changes in C-pools
9	Waste	Activity data improvement for the waste sector.	Data collection and GHG inventory estimation to climb the tier ladder to 2/3 tiers from the current Tier 1 for the various sub-sectors
B.2 Uncertainty reduction in inventory estimation			
10	Energy	Development of CO_2 emission factors, linking coal beds with power plants, and impacts on their immediate environment, dispersion and transportation of emitted pollutants	(a) Power sector is one of the major contributors to the Indian CO_2 emissions. This project envisages GHG emission measurements from 40 power plants (coal and gas based). (b) Evaluation of the changing sectors of coal use,including small-scale sectors. Investigation of characteristics of coal in the country, linking them to the various coalfields. Comparative evaluation of the reliability of emission measurements by direct measurement, traditional mass balance approach and the Continuous Monitoring System. (c) Carry out dispersal modelling and ascertain the levels of emissions in and around the plants. Explore the sequestration potential of planned forest cover around the plants.
11	Energy	Development of mass emission measurement system for GHG from the automotive vehicles.	This will involve development and integration of techniques and systems for measurement of GHGs (CO_2 CH_4 N_2O) along with direct toxic emissions (CO, HC, NO_X and PM) for conventional and

S.No	Type/ Sector	Title	Description
			alternative fuels. Measurements and data generation for emission factors in gm/km of about 60 vehicle technologies and vintage combinations. Procurement and commissioning of measurement and sampling systems for GHGs.
12	Energy and industrial process	GHG emission measurement from large point sources—steel plants and cement plants	Due to high requirement of coking coal for steel production, the steel sector has a very high emissions per unit of production and contributes substantially to Indian CO_2 emissions. Similarly cement production contributes significantly to energy and process based CO_2 emissions. This project envisages GHG emission measurements from 10 steel plants and 30 cement plants. The process-based emissions will be distinguished and will be measured separately.
13	Energy	GHG emission measurement from large point sources—Petroleum Refineries	GHG emission measurements from five petroleum refineries.
14	Energy	Methane emission measurements from the coal mines	Cover a 100 coal mines, including opencast mining for methane emission coefficient measurements.
15	Energy	Methane emission measurement from oil and natural gas venting, flaring and transport	Cover all the major oil exploration sites in India
16	Energy	GHG emission measurement from informal/partially informal energy intensive sectors	GHG emission measurements from fully/partially informal energy-intensive sectors like brick manufacturing, sugar and ceramics etc. About 10 sectors are proposed to be covered here. The major ones being brick (sample about a 100 kilns), sugar (sample about 50 units), soda ash (sample about five units), textile (sample about 20 units), ceramics (sample about 30 units), and chemical and dyes (sample about 30 units).
17	Industrial Processes	Reduction of uncertainties in GHG emissions factor in lime and cement sectors in India	This project will help to reduce the uncertainties in CO_2 emission coefficients derived for the first phase of NATCOM. The work programme will entail systematic collection of CO_2 fluxes, samples of raw materials, intermediate and final products for analysis. About 50 cement plants representing prevalent technologies for producing cement in India will be covered.
18	Industrial Processes	GHG emission coefficient measurements from industrial processes	GHG emission coefficient measurements from industrial processes like nitric acid production, aluminium production, soda ash use and pulp and paper production.
19	Agriculture	Nitrous oxide emission from selected agricultural fields of rice and paddy	Irrigated rice and dry land farming are major sources of CH_4 and N_2O in selected agroecological zones consisting of irrigated as well as dry land farming. The project will measure CH_4 and N_2O emission coefficients from these.
20	Agriculture	(a) Measurement of CH_4 and N_2O emission coefficients for rice cultivation (b) Development of emission coefficient of non-CO_2 gas emissions from major agriculture crop residue	This will involve setting up a network of stations for continuous and more refined measurement of these emissions for the entire season of rice growth and year, assessment of fertilizer used, types of cultivars planted, soil carbon etc., to ascertain the dependence of CH_4 and N_2O emissions on these parameters. Also individual measurements of changes in CH_4 emission under increased CO_2 environment using the FACE facility will be carried out.
21	Agriculture	Measurement of CH_4 and N_2O emission coefficient from enteric fermentation in animals and manure management.	This will involve establishment of CH_4 emission coefficients from different types of animal categories in India, with the focus on the major emitters and N_2O emission coefficients measured from different types of manure management.
22	Agriculture	Measurement of N_2O emission coefficients from major soil types in India	This will involve establishment of network of stations for taking year long measurements of N_2O for representative soil types in India.
23	Agriculture	Soil carbon content assessment	To assess the organic carbon contents of Indian agricultural soils at $1/2^0$ x $1/2^0$ grid.
24	LULUCF	CO_2 emission and uptake measurements in specific forest types/areas to ascertain their net sink capacity	(a) This will involve the establishment of towers inside and outside forests fitted with on-line CO_2 measuring equipments and weather parameters, including temperature, humidity and wind direction. (b) Determination of the rate of photosynthesis, transpiration, leaf area and canopy cover of different native and planted species vis-à-vis reduction in GHGs especially, CO_2.

S.No	Type/ Sector	Title	Description
25	LULUCF	Soil carbon measurements, Soil carbon cycle modelling, remote sensing and generation of GIS based-mapping of land use for Indian forest	(a) Setting up of a network of stations for measuring soil carbon for different soil types in India. The measurements will be carried out according to the IPCC specification of soil depths. (b) Carbon cycle modelling will be developed. (c) To get a perspective of the land use and forestry of the Indo-Gangetic region of India, GIS-based maps will be developed by decoding remote-sensed data for use in emission inventory from this source in the future.
26	LULUCF	Uncertainty Reduction	Generating Emission Factor/Sequestration Factors for GHG inventory in the LULUCF sector of India.
27	Waste	Measurement of emission coefficients from domestic and commercial waste water	(a) Measurement of CH_4 emission coefficient from domestic waste water with distinctive composition (b) Measurement of CH_4 emission coefficients from representative major affluent producing industries.
28	Waste	Methane emission from selected landfill sites	Methane measurements will be carried out in identified major landfill sites in cities with population greater than one million. The likely cities to be selected for this study will be: Mumbai, Delhi, Chennai, Kolkata, Bangalore, Hyderabad and Ahmedabad in India, where systematic collection and dumping of solid waste takes place.
29	All	Undertake climate change related environmental studies (background measurements)	Continuous in-situ monitoring of concentrations of GHGs (CO_2, N_2O and CH_4) from base line stations at Kodaikanal and Shillong using Gas Chromatographic Analysers. Regional grab sampling programme for GHGs using stainless steel sampling flasks and Gas Chromatographic analysis from a central laboratory.
B.3 Vulnerability assessment and adaptationn			
30	Climate Change Modelling	Generation of high resolution regional climate change scenarios and investigating its impact on the Indian monsoon and on extreme climate events	(a) This will involve detailed diagnostic analysis of climate model control runs to assess the skill in simulation of present day climate and its variability over India; (b) Analysis of perturbed simulations with IS92a/SRES emission scenarios to quantify the climate change pattern over India with reasonable high resolution during the 21st century; (c) Application of regionalization techniques to improve the assessment of climate change on regional scale; (d) Study of the sensitivity of monsoon climate to natural/ anthropogenic perturbations by model output diagnostics and numerical experiments; (e) Perform climate change experiments with global AOGCMs as well as regional climate models, with special emphasis on the development of realistic scenarios for the Indian region; (f) Examination of the nature of possible changes in the frequency and intensity of severe weather and climate events (e.g., droughts/ floods, cyclonic storms). (g) Interaction with various impact assessment groups and design specific climate change data products for use in their models through workshops and meetings; (h) Wearhouse for storage of all validated and downscaled AOGCM data products for South Asia, designed for regional climate change impact assessment, high-resolution scenario data for different administrative units of India (e.g., states) and provide regular up gradation to keep pace with developments in the area.
31	Indian Emission Scenarios	Generation of future GHG emission scenarios for India	Articulation of alternate development pathways for India and quantification of key driving forces. These alternate scenarios will be congruent to IPCC-SRES scenarios and Indian climate change scenarios.
32	Various relevant sectors	Development of vulnerability and adaptation scenarios for India	Develop sub-regional vulnerability and adaptation scenarios for India which integrate the cross linkages between different sectors of the economy. These scenarios will be congruent to the Indian climate change and emission scenarios.
33	Agriculture	Assessment of vulnerability of the Indian agriculture sector	(a) Studying the impacts of enhanced level of CO_2 using Mid-FACE facility in the country on grain yield of cereals important to the

S.No	Type/ Sector	Title	Description
		due to impacts of climate change and formulation of adaptation strategies.	economy (rice and wheat). The cereals under each category should be of different types of cultivars. (b) Incorporating these results into modelling (c) Case study to understand the impacts of climate change on important crops in the country using the modelling approach and formulating a matrix of alternate cultivar/cropping pattern/farming practices etc., to adapt to climate change.
34	Water Resources	To study the impact of climate change on the water resources and to develop adaptation strategies	(a) A national assessment of water resources taking into account the climate change. (b) To identify future water scarce zones in the country. (c) To undertake case studies in some of the anticipated water scarce zones in the country and devise adaptation strategies for availing water.
35	Water Resources	Reducing uncertainties in assessing climate change variability and extreme events such as droughts and floods in India	Enhancing the temporal and spatial resolutions of GCM/ RCMs models to be more specific to India and using the precipitation and temperature series thus generated, as input to hydrologic models for forecasting droughts/ floods' variability and extremes in: select water stressed river basins (Sabarmati in Gujarat and Palar in Tamil Nadu), and select flood prone basins—Ganges and Meghna.
36	LULUCF	To study the impact of climate change on forestry and formulate adaptation strategies	Develop current (and past) climate and vegetation type linkages, correlation's and geographic maps of distribution. Evaluate, adapt and develop vegetation response models suitable for the complex, diverse vegetation types in India. Assess the vulnerability of different ecosystems to different scenarios of climate change. Assess the impacts of different climate change scenarios on vegetation ecosystems in terms of shifts in boundary, changes in area, biodiversity, regeneration and growth rates, and carbon sink capacity. Evaluate different adaptation options and implementation barriers to reduce adverse impacts of climate change. Develop policy, institutional and financial measures to implement adaptation measures.
37	Natural Ecosystems	To study the impacts of climate change on natural ecosystems, such as the Sunderbans	This will involve study and modelling of impacts of climate change including sea-level rise on the dominant forest species in Sundarbans. Modelling the impacts of sea-level rise on appearance and disappearance of islands in the Sundarban area.
38	Human Health	To study the impacts of climate change on human health Impacts of climate change and extreme events on coastal zones	This will involve identification of areas where malaria and diseases related to extreme heat or cold events will be prevalent in the future climate scenarios. Identification of communities most susceptible to climate change. Undertaking case studies integrating climate change and socioeconomic scenarios. Development of adaptation matrix to combat the impacts of climate change.
39	Extreme Events and Coastal Zones	Integrated model development for assessment of impacts on energy sector	(a) This study will include development of a sea-level rise scenario due to climate change along the coastline of India. Study on impacts of sea-level rise on specifically densely populated and area with important infrastructure. (b) Impacts of sea-level rise on fisheries.
40	Energy	Impacts of climate change on energy and infrastructure in the country	Developing software modules for impact assessment of climate change on energy sector and 'soft linking' the same with models of inventory estimation to obtain an integrated view.
41	Energy and Infrastructure		(a) This study will involve specific case studies to evaluate the impacts of climate change on the energy availability and urban infrastructure in India. (b) Evaluation of adaptation strategies including insurance to combat the impacts.
42	Energy and Infrastructure	Development of urban policy response for integrating climate change and sustainable development	This will involve identification of issues in urban areas relevant to climate change and a development of methodology for linking them to sustainable development.

S.No	Type/ Sector	Title	Description
B.4 Capacity building/ enhancement			
43	Inventory Estimation	To establish a GHG reference laboratory for generating and disseminating certified reference materials	(a) This will involve the preparation and dissemination of gas-CRMs of CO_2, CH_4, and N_2O. Calibration of Gas Chromatographs (GCs) used for baseline monitoring for above gases. (b) Preparation of uncertainty budget for baseline monitoring for above gases for homogenization of uncertainty of measurements. Validation of test methods and organization of proficiency tests for measurement of the above gases.
44	Inventory Estimation	Nodal centre for synthesis and coordination of uncertainty reduction in GHG emissions	This centre will essentially validate, synthesize and ensure the application of good practices for uncertainty management and quality assurance and quality control. Periodic training will be conducted to update researchers on the latest good practice guidance techniques for undertaking measurements and also train personnel for undertaking measurements in various sectors. Following the guidance specified by the IPCC Good practices report, this agency will act as a third party for implementing the QA measures.
45	Vulnerability Assessment and Adaptation	Integrated impact assessment for India, including long-term emission scenarios, GHG abatement policies and adaptation measures.	Develop an integral impact assessment modelling framework for India using sectoral models, consistent scenarios and databases. It is proposed to deploy modular integration, i.e., integrating modules consisting of individual sectoral models, run using similar climate, emission and socioeconomic scenarios. The basic thrust will be on generating common and finely gridded databases for use in models.
46	Energy	Setting up of an Indian energy systems model for medium- and long-term energy and environmental policy	Economy-energy-environment modelling using Indian emission scenarios and shared databases developed under other projects. Major outputs will include the projection of alternate GHG emission pathways, energy intensities, technology and fuel mix, and energy sector investment requirements for India in medium to long term.
47	All sectors	Organizational and institutional issues for climate change	Creating awareness at all levels (grassroot to policy) on climate change, vulnerability and adaptation issues for industry and infrastructure, energy, agriculture, LULUCF sectors, through sectoral workshops in various (vulnerable) regions of the country; dissemination; publication, etc.
48	All Sectors	Educating and informing the corporate sector about the emission abatement technologies and projects.	(a)Create awareness about climate change in the business sector, especially on impacts on industry, cleaner production, CDM, etc. b)Role of insurance as a tool of adaptation for long-life assets.
49	LULUCF	Modelling efforts	Develop technical and institutional capacity for modelling, monitoring and verification of C-stock changes in LULUCF projects involving: developing models for predicting changes in stocks of different pools in different types of forestry projects; build capacities of institutions to undertake these activities; assisting project developers and project promoters; and, developing information packages.

of nodal centres for climate change research, impact assessment and adaptation-related activities, and increase public awareness through information dissemination and education. The following thematic activity areas may be covered to strengthen the scientific capacity in India to respond to climate change challenges and lay the foundation for further national communications and implementation of the Convention.

- Establishment of systematic observation networks for monitoring emissions of GHGs, other trace gases and pollutants
- Improvement in GHG emission estimates in key sectors for improved future national communication by regular monitoring and measurement of emission coefficients in the energy, transport, industry, agriculture, forestry and waste sectors.
- Development of high-resolution regional climate scenarios for India.
- Development of socioeconomic scenarios for India
- Institutional and human capacity building for undertaking research on Integrated Impact

Table 7.6: Research and demonstration project proposals for adaptation, vulnerability assessment and abatement.

S.No	Sector	Title	Description
A	**Adaptation**		
1	Agriculture	Crop insurance and climate change	Research to understand performance of various insurance models to develop comprehensive crop insurance packages for Indian farmers.
2	LULUCF	Vegetation modelling	Develop, validate and disseminate dynamic vegetation models for assessing impact of climate change on the forest ecosystem at the regional level, including: the evaluation of existing dynamic vegetation models; adaptation/ modification/ development of dynamic vegetation models for application at regional scales; validation for current climate and vegetation; and, dissemination of information package on the dynamic vegetation model.
3	LULUCF	Ecosystem modelling	Long-term monitoring of vegetation response in Himalayan Ecosystem/Western Ghats with wide altitudinal gradient to changing climate, along the latitudinal and altitudinal gradient, specifically including: monitoring climate changes and monitor vegetation changes; establishing linkages between climate change variables and forest vegetation characteristics.
4	LULUCF	Adaptation policies for forest ecosystems	To assess the impact of forest policies, programmes and silvicultural practices, to enhance resilience or reduce the vulnerability of Himalayan Ecosystems/ Western Ghats with wide altitudinal gradient forest ecosystem to projected climate change. Specifically it will include: review of forest policies, programmes and silvicultural practices in selected regions; suggesting policies, programmes and silvicultural practices to reduce vulnerability of forest ecosystems; assessing the implications of biodiversity, silvicultural practices and dominant species to determine the vulnerability of forest ecosystems.
5	LULUCF	Assisting adaptation for vulnerable plant species	Anticipatory planting of vulnerable plant species in Himalayan Ecosystems/ Western Ghats to adapt to projected climate change involving: identifying vulnerable species which are likely to migrate; planting along altitudinal gradient; monitoring performance of species; and making recommendations on anticipatory planting practices.
6	Coastal Zones	Integrated adaptation policies for coastal zones	Identifying points of integrating the adaptation policy, having elements of both coastal zone management and sustainable development, into national, regional and local developmental planning and policies. Specifically, it will include: review of other policies—disaster abatement plans, land-use plans, watershed resource plans; understanding 'local livelihood stresses', induced due to environmental factors such as groundwater degradation due to sea water intrusion, coastal flooding and erosion; understanding and documenting the local traditional knowledge systems used in combating these non-climatic stresses and climate change induced enhanced variability and extremes in flooding.
7	Agriculture	Small and marginal farmers	Develop suitable adaptation policy and implementation of a few pilot schemes to enhance the adaptive capacities of small and marginal farmers in India.
8	Water Resources	Arid and semi-arid regions	Developing check-dams and water harvesting demonstration projects in each of the arid and semi-arid districts in India.
9	Agriculture, Forestry and Water Resources	Conventional adaptation practices	Develop a compendium of rational indigenous and traditional practices on adaptation in selected sectors like agriculture, forestry, water resources (floods and droughts) in various agro-ecological regions of India.
10	Industry	Research on innovations	Research on adaptation innovations in Indian industry for adaptation to climate change impacts.
11	Agriculture	Agronomic management	To evaluate alternate agronomic management options to sustain the agricultural production in relation to changed soil moisture availability in flood and drought prone regions.
12	All	Integrated impact assessment modeling for India	Developing integrated assessment models for India to assess the impacts of climate change and corresponding adaptation requirement, in addition to understanding possible abatement and adaptation measures, in various sectors —water resources, agriculture, terrestrial and marine ecosystems, human health, human settlements, energy, and industry.
B	**Vulnerability**		
13	All	Extreme events and identification of	Impact assessment to address a range of possible increase in temperature scenarios in floods, cyclones and droughts prone regions, as these different geographical regions

S.No	Sector	Title	Description
		vulnerable regions in India	are expected to experience variability in temperature changes due to climate change.
14	All	Economic scenarios and vulnerability to Climate Change	Conducting scenario based studies for various possibilities of extent of climate change impacts, e.g., for a range of increase in temperatures, rise in sea water level, deforestation, economic growth and emissions, and abatement efforts etc
15	Infrastructure, Industry	Climate change impact on coastal infrastructure and Industries	Coastal infrastructure is most vulnerable to the sea-level rise and extreme events. India has many industrial complexes close to the coastal areas. The infrastructure such as roads, railway lines, and ports will be adversely affected by the changing rainfall pattern and extreme events.
16	Energy	Impact of Climate Change on energy demand and resultant change in emission pattern	Increase in temperature and changing climate is likely to affect the energy demand. Almost all the sectors will experience change in the demand based on the location. The increased demand for energy will also affect the resultant emissions, as most of the increased demand will be fulfilled by the power sector, which depends primarily on coal.
17	Agriculture	Soil and crop productivity	Evaluating the impact of climate change and its variability on soil and crops' productivity (five years).
18	Water	Impacts of climate change on water resources on transportation sector of agriculture goods	Mapping the existing inter-state flow volume of agriculture goods and assessing impact of 'drought' conditions on reduction in transportation and assessing opportunities for adapting to shortfalls in agriculture production relative to food security.
19	Agriculture	Developing genetic modified species	Will involve developing species and conducting trials of the same, and disseminating the findings through bio-technological advances for improving crop yields in drought prone states
20	Water resources	Assessing the effect of global warming on major Indian rivers and aquifers	This study will assess aquifers and their behaviour in Indian peninsula vis-à-vis their exploitation for water and hence GHG emissions.
21	Water resources	Impact of climate change on water availability in Himalayan glaciers and rivers	Himalayan glaciers and rivers have an important role in the Indian water supply system. Temperature increase due to climate change may bring about changes in the Himalayan ecosystem, which will alter the water availability for India in the short, medium and long term.
22	Water resources	Developing hot-spot (extreme scarcity) areas in water resources sector and developing micro-level (household and community level) assessments of vulnerability and impacts of droughts	(a) This will involve preparing overlays of maps—such as drought hazard maps, groundwater development and degradation maps, surface water development, road network, state domestic product, state human development indices, and superimposing the same to assess hot-spots for detail assessment of micro level vulnerability assessment (b) Based on the identification of hot-spot states as above, conducting field surveys in a 100 randomly proportionate stratified sampled villages in each state for a total of 400 villages.
23	Water resources	Mapping vulnerable population due to climate change impacts on water resources	Mapping national level temporal (at five year intervals) and spatial (at state level) distribution of vulnerable population at risk at state level due to climate change impacts on water resources. This will involve mapping the current demographic trends in urban and rural population growths, overlaying the same with state developmental plans on infrastructure in water supply sector and water sector reforms parameters.
24	Industry and infrastructure	Assessment of Impacts on industry and infrastructure	Assessing impacts on industry and infrastructure through preparation of a catalogue of historic extreme events, assessing the damages and providing the loss estimates in coastal and inland areas, showing the spatial distribution; developing detail GIS map covers with topographic, vegetation and geological details showing the major industries and infrastructure systems and their components; and assessing sensitivities of different components with respect to various climate parameters.
25	Agriculture	Gridded database generation	To characterize the extent of rainfall variability, surface and ground water availability in various agro-ecological regions of the country at $1/2^0$ x $1/2^0$ grid (or finer).
26	Agriculture, Forestry and Water Resources (livelihoods)	Asset vulnerability assessment	Research to understand vulnerability by assessing type and extent of various livelihood assets—social, physical, financial, institutional and natural—of communities from various potential impact geographical regions.

S.No	Sector	Title	Description
27	Coastal zones	Vulnerability assessment at coastal village level	Assessing vulnerabilities of communities from a 100 villages along the coast to climate change impacts by use of sustainable livelihood framework. Analyzing social dynamics and institutional landscape to identify points of leverage for short-term and long-term adaptation interventions.
28	Health	Vulnerability assessment of areas where malaria has been predicted to shift in the climate change	Assessment of vulnerability of communities to be affected by malaria in areas above 1800 m and in coastal areas will be the focus of this study. The accessibility to health facilities, and assessment of current adaptation practices and the policies of the government will be reviewed to understand the adaptation needs of the afflicted communities in the climate change regime.
29	Health	Assessing vulnerability of communities exposed to extreme heat	Extremely high temperatures have been recorded in recent times in northern , central and south eastern parts of the country, which have caused mortality. A study will be carried out to identify areas which will experience recurrent intense heat due to climate change and assessment will be made of adaptation needs of communities in the climate change regime. For this, the current adaptation practices including the government policies will be analyzed.
C	**Abatement/ Capacity development**		
30	Energy	To study the level of non-coking coal beneficiation and its impact on efficiency improvement/ abatement of GHG emission in thermal power stations.	This will involve a detailed study of non-coking coals for identification of quality parameter/s including combustion behaviour. Estimation of the impact of coal quality on the boiler efficiency. Quantitative assessment of the effects of the variations of fuel quality on the performance of the critical sub-processes involved in power generation and GHG emission.
31	Energy	Validation of the Multi Stage Hydrogenation (MSH) technology for converting coal to oil	(a) The aim is to confirm the results of the batch reactor studies. (b) Establish viability of the process through generation of technical data required upscaling the process to higher scale. (c) Research for increasing the present yield of distillates from 60% higher yields between 85% - 90 %; commercial viability of this project.
32	Energy	Utilization of GHG (CO_2 and Methane) for production of fuels and chemicals.	This will involve conversion of CH_4 and CO_2, producing syngas with low H_2 / CO ratio, (nearer to one) which is highly desirable in gas to liquid fuels conversion technology using iron-based catalysts. Conversion of methane gas by development of solid acid catalysts based on heteropoly acids and other catalysts to value added chemicals like methanol, formaldehyde and ethylene.
33	Energy	Abatement of GHG via *in situ* infusion of fly ash with CO_2 in thermal power plant: upscaling of the process vis- a- vis associated carbon sequestration and adoption.	(a) This will involve characterization of fly ash samples from 2-3 representative thermal power plants of the country in respect of various physico-chemical parameters including minerals and trace and heavy metals content. Carry out experiments, under laboratory conditions, on CO_2 infusion of these fly ashes at varying pressure. (b) Assessment of extent of infusion of fly ash and consumption of CO_2 therein. Experiments on leaching characteristics of fly ashes (treated and untreated) with CO_2 infusion following shake and column tests.
34	Energy	Minimization of CO_2 and other polluting gaseous levels by suitably developing soft coke technology as the source of rural/ semi-urban domestic energy	This will involve development of more energy efficient soft coke technology utilizing inferior coal. Development of suitable provisions for less emitting/arresting the GHG. Improvement of the present technology for making it more suitable for rural use. Generation of data /techno-economic as well as socioeconomic evaluation. Improvement in design/development of the fixed/movable domestic soft coke cook-stove in view of energy efficiency as well as emission of GHG
35	Energy	Cleaner electricity production through fuel cell technology	The present project will develop a 200 KW SOFC system operating at 800^0 C. The performance of this system will be evaluated with reformed natural gas fuel as well as with coal gas.
36	Energy	CO_2 Sequestration in geologic formations with enhanced coal bed Methane Recovery.	This will involve examination of the potential for CO_2 sequestration in geologic formations/un-mineable coal seams. Identification of un-mineable coal seams/ geologic formations in India suitable for CO_2 sequestration. Develop mathematical models for reservoir simulation of CO_2-CBM and a mathematical model for gas-water flow in coal beds.

S.No	Sector	Title	Description
37	Energy	Improvement in solar cell efficiency	R&D studies to improve the efficiency of solar cells to 15% at commercial level and 20% at research level. This will be built on the ongoing programme of the Ministry of Non-Conventional Energy Sources.
38	Energy	Energy Penetration of energy efficient technologies	Demonstration projects for increased penetration of efficient technologies (supply and demand management based) such as, heat rate reduction, electric arc furnaces, energy efficient processes, efficient lighting and agriculture pump-sets, in order to enhance scale and acceptance of efficiency interventions for GHG emission abatement.
39	Energy/ petroleum	Energy/petroleum geological storage of CO_2 in exploration/ recovery of petroleum gas.	This will involve injection of CO_2 in the petrioleum wells for recovery of petroleum gas and other products.
40	Energy	Energy Removal/ absorption of CO_2 through absorptive media	This will involve the identification, characterization of different absorptive media for CO_2 removal and its absorption in thermal power plants.
41	Energy	Energy CO_2 decomposition through plasma technology	This will involve the use of an arc discharge device where CO_2 will be dissociated with ionized to give rise to carbon and oxygen ions. A directionally aligned magnetic field can be used to separate the carbon and oxygen ions. The carbon ions so deflected with the help of magnetic field can be separately collected.
42	Energy and Agriculture	Energy and Agriculture recovery of methane from landfills and paddy fields	This will involve the study of methane efflux in different seasons at various sites. The components of the measurements will include investigation on CH_4 production potential of different methanogenic bacteria under different conditions, the process of augmentation of CH_4 formation through biological and non-biological means, the suppression of CH_4 oxidation through manipulation of edaphic factors and the use of inhibitors. The study will also investigate and demonstrate the options for maximum recovery of CH_4 gas from landfills and paddy fields for heat and electricity production.
43	Industrial Processes	Ecologically-friendly and value added steel making process based on VRDR-SAF-ESR route	The proposed process attempts use hot charging of DRI into submerged arc furnace (SAF)/ Electro-slag Crucible Melting Furnace (ESCF), from which the hot liquid steel enters the electro-slag casting equipment to produce high quality alloyed steel product of near-net shapes. The process is expected to be environment friendly and techno-economically attractive even on a medium scale of operation. The process has the flexibility to treat various feed materials and produce a range of different steel products based on the local demand. Since the DRI-based route by-passes the conventional components such as coke and sinter making, the process would require much less energy and would lead to substantial reduction in emission of CO_2 to the atmosphere.
44	Industrial Processes	Non CO_2 GHG emission abatement from process industries.	Abatement demonstration projects in industries such as nitric acid, paper, adipic acid.
45	Agriculture	Cost-effective abatement strategies for the Indian agriculture sector	Developing abatement strategies for GHG reduction; socioeconomic evaluation of the abatement strategies; possible consequences of the suggested abatement options on agro-ecological system (short- and long-term consequences).
46	LULUCF	Enhancing agroforestry in India	Implementing agroforestry in dry land farms to increase the tree resources on farms, increase the economic returns and to increase C-stocks in any rain fed region/ states such as Karnataka, Andhra Pradesh, Tamil Nadu, Madhya Pradesh and Haryana. The scale of the project would be 20,000 ha, covering about 20,000 to 40,000 farms.
47	LULUCF	Energy plantation in India for GHG emission abatement	Provide biomass sustainably for generation of biomass power, substituting fossil-fuel energy in any of the states facing power shortage such as Karnataka, Tamil Nadu and Andhra Pradesh and where power generation is mainly from coal-based power plants. The activities will involve: raising mixed species energy plantations in about 6000 ha in a phased manner, using high yielding package utilities; developing and implementing sustainable biomass harvesting practices to supply feedstock to biomass power utilities; and, installing biomass power plant of 20 MW and supplying electricity to meet the decentralized power needs.

S.No	Sector	Title	Description
48	LULUCF	Carbon sink enhancement and sustainable development in villages	Developing, implementing and disseminating an integrated and participatory approach to revegetation of village ecosystems for enhancing carbon sinks, conserving biodiversity and enhancing sustained flow of benefits to the local communities in the Western Ghats region in about 10,000 ha, extending over a 100 villages.
49	LULUCF	LULUCF degraded forest regeneration	To sequester carbon by regenerating degraded *sal* forests of Orissa, West Bengal or Bihar involving: regenerating degraded *sal* forests for timber and non-timber forest products; involving local communities in protection and management of regenerating forests; and, promoting biodiversity.
50	LULUCF	Mangrove ecosystem rehabilitation	Rehabilitating about 20,000 ha degraded mangrove ecosystem in Orissa to protect the coastal lands and sequester carbon involving: identifying degraded mangrove; protecting and regenerating mangroves; monitoring the biodiversity, growth rate and C-stock changes
51	Energy, Industry and Infrastructure, and Waste	Issues in technology transfer for abatement of GHG emissions in India	Facilitating transfer of technology from developed to developing countries. through joint research and development, and adoption.
52	Industry	Fiscal instruments for emission abatement from Indian industry	Research and pilot projects.
53	Energy	Role of technology in abatement and adaptation of climate change impacts on energy sector	Conduct intensive studies for abatement and adaptation of energy efficient technology and methods and identify points of leverage in market chains and institutional regimes for demand side management measures for abatement.
54	Agriculture	Carbon sequestration in agriculture soils	Research and demonstration projects to sequester carbon in agricultural soils by adopting appropriate land use options.
55	Energy	Fuel switching	Research and demonstration projects for penetration of low and no carbon fuels in transport sector.
56	Industry	Industry energy efficiency improvement	Research and demonstration of energy efficient technologies in energy intensive SSI in India.
57	Agriculture Energy	Agriculture enteric fermentation Energy CO_2 capture and storage	Research, development and demonstration of low-methane emitting feeds Demonstration project for CO_2 capture and storage at one high concentration CO_2 stream plant in India.
58	LULUCF	Ecosystem development and conservation	Integrated and participatory approach to revegetate village ecosystems in Karnataka for carbon sink enhancement and biodiversity conservation through sustained livelihood development.
59	LULUCF	Carbon sequestration	Carbon sequestration and biodiversity conservation in the Uttaranchal hills by holistic initiatives in village agro-ecosystem.
60	LULUCF	Rehabilitate arid lands	Integrated ecosystem approach to rehabilitate degraded arid and semi-arid lands of western India for combating desertification.
61	Energy	Renewable technologies	Rural electrification using solar photovoltaic technology-based mini-grids in ecologically fragile and geographically inaccessible areas.
62	Energy	Renewable technologies	Cleaner and efficient technology interventions in small and medium scale industries in India, using biomass gasifier system.
63	Energy	Renewable technologies	Increased market penetration of solar thermal technologies for low/medium grade heating applications in India
64	Waste/Energy	Waste to energy	Efficient utilization of organic solid wastes for energy and resource recovery and GHG abatement.
65	Energy	Renewable technologies	Sustainable bagasse based cogenerated power distribution in the command Area of Shri Tatyasaheb Kore Warana Sahakari Sarhar Karkhana (STKWSSK) Ltd in Taluka Panhala, District Kolhapur, Maharashtra.
66	Energy	T&D losses	Reduction in transmission and distribution losses
67	Energy	Waste to energy	Power generation from refinery residues using IGCC technology.
68	Energy	Carbon abatement	Reduction of carbon emission by renovation and modernisation of old coal-fired thermal power plants.
69	Energy	Carbon abatement	Efficiency improvements in the Indian brick industry.
70	Energy	Carbon abatement	Demonstration of coal gasification and supply of coal gas to tunnel kilns in pottery.
71	Energy	Waste to energy	492 MW IGCC power plant, based on refinery residue-vistar

S.No	Sector	Title	Description
72	Energy	CO_2 capture and storage	Identification and carrying out geological mapping of potential areas for CO_2 capture from large point sources and subsequent storage in India like in sedimentary rocks, unmineable coal seams, depleted oil wells, etc to evaluate total CO_2 storage capacity available in the country and its long term implications.
73	Energy	Fuel Switching	Design and development of zero emissions coal fired thermal power stations wherein coal will be gasified and CO will be converted in CO_2 by shift reaction and hydrogen will be used for power generation employing fujel cell / turbine to get zero emission power.

Assessment and adaptation policy formulation for various sectors in India.

- Consolidation of indigenous efforts for climate change abatement, including energy efficiency improvement efforts in various sectors, transfer of cleaner technology, promoting the use of renewable technologies, etc.
- Clearing house for climate change related database management and processing
- Strengthening and building of human and institutional capacity in India for energy and environment sector modelling.

There is a need to form a network of stations, which will monitor the background GHG concentrations in pristine areas and also concentrations in polluted areas. For this, measurement facilities need to be set up at pristine areas such as at high altitude Hanle in Ladakh (the Himalayas), at Sundarbans in West Bengal, at Kodaikanal in Tamil Nadu, and the Andaman and Nicobar Islands in the Bay of Bengal. These stations need to run like the Global Atmospheric Watch (GAW) stations to measure the GHG concentrations continuously.

India has enormous potential for implementing climate change projects. This is primarily because the power sector in India is still predominantly coal based and the vintage technology status in the power and transport sector have considerable potential for efficiency improvements. Abatement projects are mainly in the areas of energy efficiency, renewable energy and sustainable transports. The capacity to develop bankable detailed project proposals can be enhanced in India. It is critical to ensure minimum performance standards, codes and certification for energy auditors. Energy managers in industries need training. Commercial banks also need to gradually build their own technical capacity. A project-financing approach to lending has to be promoted rather than collateral-based loan financing for energy efficiency.

Additionally, the forest sector provides large potential for the removal of carbon. Though the deforestation rate in India has reduced in the recent years, the vast degraded lands can be used for afforestation and hence for the sequestration of carbon. For example, lands in and around mines and the abandoned agricultural lands can be the initial targets for afforestation.

The Asia Least Cost Greenhouse Gas Abatement Strategy (ALGAS) study conducted by the Asian Development Bank (ADB) had identified technological improvement in Indian power plants, fuel switching in Indian power plants, using less polluting fuels in the transportation sector and the use of renewable energy technologies as the possibilities for abating GHG in the Indian energy sector. In the forestry sector, the activities are: forest conservation and expansion of sinks by reforestation of degraded forest areas and afforestation in private land. In the agriculture sector, the activities are: change in feedstock to contain methane emissions from livestock, changing paddy cultivation practices to reduce methane emission from continuously submerged paddy fields and the appropriate reduction of nitrous oxide emission from fertilizers.

Some other thematic areas of research that require support and further development, as appropriate are: international and intergovernmental programmes and networks or organizations aimed at defining, conducting, assessing and financing research, data collection and systematic observation. This may include:

- Forecasting energy requirements.
- Energy usage efficiency studies from producers

to user groups.

- Socioeconomic costs related to climate change i.e., increased vulnerability to climate change.
- Effect of climate change on marine infrastructure, business and marine ecosystem.
- Conservation studies.
- Assessment of carbon abatement potential.
- Design of the Indian economic modelling in conjugation with global economic modelling based on carbon and energy intensities, and the cost reductions from trading, including the compatibility of domestic and international mechanisms, constraints on emissions trading, transaction costs, and marginal cost estimates.
- Analyses of 'spillover' effects on non-Annex I countries.
- Technology development and diffusion for cost-effective stabilization studies.
- Studies on emission pathways.
- Studies to assess incentive needed for promotion of energy efficient technologies .
- Promotion of research on energy efficient building technologies and development of codes and standards for the sector.
- To conduct environment policy research for economic development and environmental changes

NEEDS FOR ADAPTATION TO CLIMATE CHANGE

Reduction of GHG emissions, leading to stabilization of their concentrations in the atmosphere in the long run, will neither altogether prevent climate change, sea-level rise, nor reduce their impacts in the short to medium run. Adaptation is a necessary strategy at all scales, from national to local, to complement climate change abatement efforts; thus, together they can contribute to sustainable development objectives and reduce inequities.

In addition, the development of planned adaptation strategies to address risks and utilize opportunities can complement abatement actions to reduce climate change impacts. However, adaptation would entail costs and cannot prevent all damages. There are many constraints faced by the developing countries such as India while deploying the scarce resources for adaptation measures.

Afforestation on degraded land.

Need for awareness at all levels

There is a need for enhancement of awareness at all levels on adaptation needs. The nature of adaptation needs would differ from location to location and sector to sector in an economy and even at the micro level, across different economic activities in a locality. These also need to consider the stakeholder's perspective and their difference in endowment of resources and capacity.

Need for research on formulating specific adaptation measures for various sectors

Sectoral adaptation measures would depend to a large extent on the awareness and understanding of the climate change impacts. Various sectors like water resources, agriculture, terrestrial and marine ecosystems, human health, human settlements, energy, and industry, have their unique adaptation requirements and there is a need for research to understand the extent of climate change impacts and the possible sectoral adaptation measures.

Need for inter-linkages in adaptation policy and market responses

Adaptation to climate change presents complex challenges, as well as opportunities in many sectors. Policy formulation on adaptation measures has to relate to the complex sectoral interdependence and

inter-relationships in climate change impacts. This area has been scarcely researched in the Indian context and information necessary at the local level for adaptation policy planning is generally not available. This in turn also affects coordination with the market responses in adaptation. Market responses would not be forthcoming if there is no clarity in cause-effect. Further in the absence of proper information, the policies do not reflect such clarity and free riding prevails. Developed countries have experienced cases of complacency and maladaptation fostered by public insurance and relief programmes. The developing countries, which may experience adverse effects of climate change, have to deal with equity issues and development constraints in market responses. Market responses must be matched with extensive access to insurance and more widespread introduction of micro-financing schemes and development banking.

Need of resources to implement adaptation measures

The costs of adverse events have risen rapidly despite significant and increasing efforts at fortifying infrastructure and enhancing disaster preparedness in the recent decades. Part of the observed upward trend in disaster losses over the past 50 years is linked to socioeconomic factors, such as population growth and urbanization in vulnerable areas. Moreover, climate change impacts occur in the long term and for a sustained level research to enhance preparedness requires enormous resources in developing capabilities in knowledge and infrastructure.

TECHNOLOGICAL NEEDS

The Government of India has been promoting low CO_2 emission technologies for sustainable development through programmes such as the Integrated Renewable Energy Programme. India has one of the largest programmes for promoting renewable energy in the world, covering all major renewable energy technologies, such as, biogas, biomass, solar energy, wind energy, small hydropower and other emerging technologies. The Ministry of Non-conventional Energy Sources (MNES) is involved in the promotion for development, demonstration and utilization of these technologies, such as, solar thermal; solar photovoltaic; wind power generation and water pumping; biomass gasification/combustion/co-generation; small, mini, and micro hydro power; solar power; utilization of biomass, biogas, improved cook-stove; geothermal for heat applications and power generation/energy recovery from urban, municipal and industrial wastes; and tidal power generation. The commercialization of several renewable energy systems and products are currently underway. The MNES also deals with other emerging areas and new technologies, such as, chemical sources of energy, fuel cells, alternative fuel for surface transportation and hydrogen energy.

The global thrust on climate-friendly technologies is presently focused on climate change mitigation, such as fuel cell cars, biotechnologies, nano technologies to reduce electricity demand and CO_2 capture and storage. There is a growing need to develop technologies that reduce the vulnerabilities of developing and least developed country populations to adverse impacts of climate change. These technologies have to be low cost and be compatible with local environment and socioeconomic situations for faster adaptation . The revival of and building upon conventional wisdom, such as water management in arid and desert areas, weatherproof low-cost housing, and less water intensive night soil disposal, is also required. Modern technologies should augment the conventional wisdom for adapting to climate change. Various ministries and departments of the Government of India are engaged in technology development on diverse fronts that have been synthesized through the Technology Information, Forecasting and Assessment Council (TIFAC). The continuing work of scientists will remain crucial, generating the knowledge needed to develop effective responses to the challenges of climate change. North-South and South-South cooperation on climate change is a necessity, especially from the developing country perspective, as they need support for adaptation activities, and technology transfer.

CAPACITY NEEDS

Beyond the sectoral and scientific or technological capacity needs on climate change, the critical need in India is to integrate the diverse scientific assessments and link them with policy-making. Science has to provide objective scientific and technical advice to the policy-makers, especially for a complex process

like climate change. While some experience of using integrated assessment models does exist in India, the capacity building in this area remains a double priority - first, to provide policy orientation to the scientific assessments and second, to provide robust scientific foundation to policy making. The development of assessment tools by interdisciplinary teams within developing countries is crucial. This would need commitment of sustained resources and institutionalization of multidisciplinary and networking efforts, within the scientific and policy-making establishments.

Climate change concerns, assessment challenges and response strategies, for diverse sectors and regions in India require an integrated assessment approach. Integrated assessment is an interdisciplinary process that combines, interprets, and communicates knowledge from diverse scientific disciplines from the natural and social sciences to investigate and understand causal relationships within and between complex systems. Integrated assessment attempts to present the full range of consequences of a given policy—economic or environmental, intended or unintended, prompt or delayed—in order to determine whether the action will make the society better or worse off, and by how much. It must be noted here that, integrated assessment is also not a monolithic, uniform, unique and universal model that can be applied to any context. It indicates an approach to policy-making that has to consider contextual issues and specific nuances of the sector under scrutiny to arrive at integrated policy assessment. For example, in deciding policy for water quality management in a particular place, integrated scientific advice should include the direct and indirect effects of urban development, agricultural run-offs, industrial pollution, and climate change-induced increase in heavy precipitation events on water resources, along with many other factors.

Networking is a critical requirement for integrated climate change assessments. The Initial National Communication project has made a beginning where more than a 100 inter-disciplinary research teams spread across the country have been networked together for a shared vision on climate change-related research. Such initiatives have to be strengthened. The participation of state and UT government departments is to be encouraged in climate change activities. This will build capacities at the state level for implementing policy measures such as those for reducing vulnerability of various sectors and communities , disseminating and promoting climate-friendly technologies and initiatives, adaptation, and energy efficiency improvements.

Finally, technology R&D, technology transfer and technology diffusion in India must be promoted. Since there are diverse disciplines involved in climate change, having a unified command and control regime may not be appropriate for these.

FINANCIAL NEEDS

The financial needs arise from the constraints detailed in the previous sections. They are necessary for research and actual projects for implementing climate change related policies and programmes. These cover diverse sectors and require considerable technology transfers and financial resources in terms of Article 4.3 of UNFCCC. Given the magnitude of the tasks, complexities of technological solutions and diversity of actions needed, the resources made available at present are wholly inadequate to address and respond to the requirements of the Convention.

The systems and policies in developing countries are not tuned to handle even the present climate-related stress and climate variability. Income disparities and population growth further constrain the opportunities and equitable access to the existing social infrastructure. The projected climate change could further accentuate these conditions. The challenge then is to identify opportunities that facilitate the sustainable use of existing resources. It entails considerations that make climate-sensitive systems, sectors and communities more resilient to current climate variability. This will pave the way to enhance their adaptive capacity to future climate change. Faster economic development with more equitable income distribution, improved disaster management, sustainable sectoral policies, careful planning of capital intensive and climate-sensitive long-life infrastructure assets are some measures that assist in ameliorating India's vulnerability to climate change.