

CLIMATE CHANGE AND INDIA: Towards Preparation of a Comprehensive Climate Change Assessment



सत्यमेव जयते

**MINISTRY OF ENVIRONMENT AND FORESTS
GOVERNMENT OF INDIA**

October 2009

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Foreword

I am pleased to introduce the Report “**Climate Change and India: Towards Preparation of a Comprehensive Climate Change Assessment.**” This Report provides an overview of a major ongoing scientific programme being coordinated by our government to assess climate change and its impact on India. This has been an ambitious endeavour, bringing together over 120 institutions and over 220 scientists from across the country. The results of the various studies being done under this programme seek to enhance our understanding of the phenomenon of climate change and its impact on various sectors of the Indian economy and society.

This publication comes at a particularly opportune time. **We are now ready to take the next big step in our scientific programme on climate change assessment. I am pleased to announce the launch of the Indian Network of Climate Change Assessment (INCCA)**, a network-based programme to be coordinated by our Ministry, which will undertake an even more ambitious programme of climate change assessment.

This enhanced programme will be significant in many ways. First, the programme will be more broad-based, covering every significant aspect related to climate change, including, for example, the study of black carbon and the impact of climate change on glaciers and on rainfall patterns. It will also comprehensively cover every major sector of the Indian economy. Second, it will involve a larger set of institutions and scientists, including those in the private sector and those situated outside India, so that the best available expertise can be brought under a unified knowledge network. Third, it will be an ongoing programme, not a one-off, the results of which will be made available in the public domain for peer review, discussion and debate. Fourth, the programme will provide capacity building to create and nurture the next generation of climate change scientists and experts. For this, we plan to initiate a programme of climate change fellowships for young researchers in premier institutions across India.

We must make the “3 M’s” – Measure, Model and Monitor -the essence of sound policy making and we must build indigenous capacity for this. This is at the heart of the enhanced programme. I recall here the example of methane emissions from rice paddy cultivation that was pegged at around 38 million tonnes per year by US experts in the early 1990s but that was ultimately accepted at between 2 to 6 million tonnes per year after meticulous field research by Dr. A.P. Mitra and his colleagues. The current controversy surrounding the impact of black carbon on Himalayan glaciers and the Indian monsoon is another example of the urgency to build our own independent and credible research capacity.

I know that our Prime Minister gives this programme the utmost importance. I am particularly excited by the prospect, and will personally engage with and monitor this programme over the next few years. I wish to take this opportunity to congratulate all the researchers and other stakeholders involved in this critical scientific programme for their work so far. I am sure that this programme, in its enhanced avatar, will play a major role in ensuring that science-based policy choices get made in the domain of climate change.


Jairam Ramesh
7/10/09

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Context and Relevance

Climate has played significant role in the economic development of India. Many sectors of the economy are climate sensitive. Since the emergence of the threat of climate change, which has origins in anthropogenic activities, the implementation and impacts of the projected change is engaging the attention of planners, governments, and politicians worldwide. The Fourth Assessment Report (AR4) of the Intergovernmental Panel on Climate change (IPCC), has reported that the impact of human activities on climate and climate systems is unequivocal. It is no longer a scientific enquiry but the concern now rather is the timing and magnitude of the abrupt changes in the climate anticipated in the future over and above the continuous climate change occurring due to the continuous warming of the atmosphere. The AR4 projects wide ranging implications and adverse impacts on developing countries for reasons of their lack of capacity to respond to rapid change. Alarmed by the findings, the government of the countries across the world are engaged in working out the impacts and associated vulnerabilities of their economies to impending projected climate change.

Assessments of impacts of climate change to various sectors of the economy directly or indirectly are very essential for devising approaches, strategies and action plans to respond to the changes. Thus there is a need to have a comprehensive climate change assessment both at the national and state level. Such an assessment is necessary for timely preparedness and response to minimize impacts and cope up with the adversities due to climate change.

Considering the physiographic settings of India and the unique climatological features, the comprehensive assessment of impacts of climate change on India needs to cover almost every aspect of climate change, right



from the causes to the impacts & associated vulnerabilities; the institutional mechanisms that address climate at national and state level; the adaptation and mitigation actions taken or envisaged to be taken, within the context of its current national circumstances, its developmental goals, financial and technical capacities. Generating and gathering such information necessitates mobilization of a large number of institutions working in diverse knowledge domains.

The Ministry of Environment and Forests is currently engaged in the implementation of a work programme which aims at the development of a comprehensive climate change assessment with the involvement of a wide ranging institutes country wide.

In Retrospect

Before 1992 isolated studies, in project mode, were undertaken on selected aspects of climate change. For example, in 1992 a country wide methane campaign was undertaken to quantify the amount of methane released from rice cultivation in India which is one of the sources contributing towards climate change. In 1994, an assessment was undertaken by the Ministry of Environment and Forests (MoEF), the impacts of climate variability on Indian agriculture and the likely impacts of 1m sea level rise along the Indian coast. In 1998, under the Asia Least Cost Abatement Strategy (ALGAS) project, an assessment was made of the GHG emissions for 1990 for energy and transformation industries, agriculture, some key industrial process, changes in forest land use, and solid waste management.

A country wide elaborate programme was launched by the MoEF in 2001 for preparation of India's Initial National Communication to United Nations Framework Convention on Climate change (UNFCCC). Wherein an assessment of the drivers of climate change i.e. the greenhouse gases emissions of anthropogenic origin from various sources were made for the year 1994. Besides, it also developed climate change projections for 2050s and 2080s, and assessed the impacts of climate change on water resources, agriculture, forests, natural ecosystems, coastal zones, human health and energy and infrastructure. Further, the various programmes, projects, and observation systems that are conducive towards understanding and addressing climate change concerns in the country were documented.

A broad based participatory approach was adopted involving nationally recognized universities, premier research institutions, technical and technology institutions, non Governmental organizations, Industry associations, and relevant line ministries.

Institutions with knowledge of developing greenhouse gas inventory, undertaking measurements for developing emission factors for greenhouse gas, climate modeling, and doing biophysical modeling in the areas of water resources, agriculture, forests etc. were inducted in the process.

Our current understanding on the impacts and implications is based on the various studies undertaken under the aegis of work programme devised for reporting towards fulfillment of obligations under Climate Change Convention. The entire national assessment was completed within 2 years time. The details are well documented in India's Initial National Communication and related publications (see bibliography).

All the assessments made so far have been preliminary in nature. The greenhouse gas inventory prepared under the aegis of the previous efforts were not comprehensive enough. New pools of emissions identified recently could not be included, very few country specific emission factors were used in the estimates due to the non-availability of emission factors that capture the national circumstances. Further, the good practice guidance's brought out by the IPCC could not be implemented in their totality due to paucity of funds as well as time for carrying out the activities.

The climate projection scenario was developed on the basis of a single socio-economic scenario (IS92a). However, new generation socio-economic scenarios have been developed since then which represent different types of economic growth, hence emission scenarios for the future which force the climate system. Also the impact assessments carried out earlier were mostly sectoral in dimension and did not explicitly explore the inter-sectoral linkages and adaptation concerns arising due to climate change.

Towards a Comprehensive Climate Change Assessment

Considering the inadequacies of the studies, the MoEF has launched a more comprehensive initiative that aims to update current knowledge and generate new knowledge on issues on climate change relevant to India, by building upon the experiences gained in its previous efforts, by bridging the gaps encountered and by adding new elements of assessments, such as the adaptation concerns due to climate change, new pools of emission that were not taken into account in the previous assessments etc.

The work programme in present effort is designed to ensure that adaptation assessments are in the national context. Currently, the MoEF is in the process of generating multiple climate and socio-economic scenarios at the national scale, improving the national impact assessments of water resources, agriculture, forestry, natural ecosystems, coastal zones, human health and energy. Studies have also been launched to address adaptation issues associated with climate change of key sectors through an integrated assessment method at selected climate hotspots. The approach

is depicted in Figure 1.

Similarly in the GHG inventory component of the work programme, efforts are being made to build up a time series of emissions for all sectors, country specific emission factors for key categories and bridging activity data gaps, implementing QA/QC measures and estimating uncertainties as identified in the previous process.

To undertake the various studies, the Ministry has involved so far 127 institutions directly or indirectly working in various knowledge domain areas of climate change which belong to different umbrella organizations, such as the Council of Scientific and Industrial Research, the Ministry of Earth Sciences, the Indian Space Research Organisation and may others, including state universities, IITs, IIMs, NGOs, private sector, the line ministries, concerned state departments and the local authorities.

The following sections detail the various elements of the climate change assessments being carried out by the MoEF.

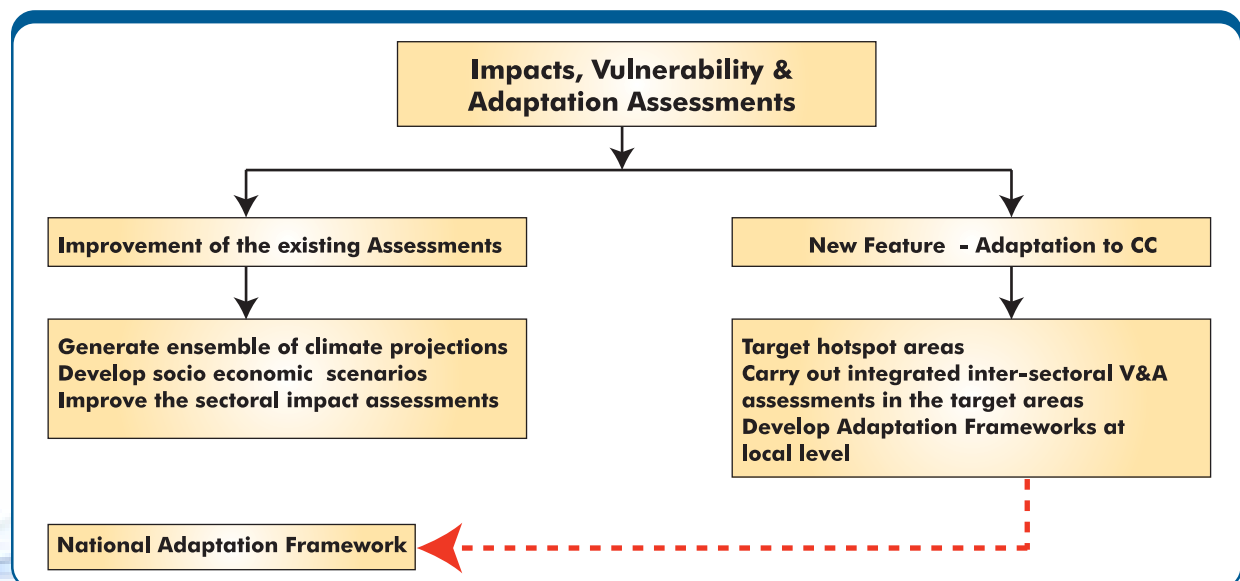


Figure 1: Schematic representation of the approach towards a comprehensive integrated V&A assessment

Elements of the Programme

CLIMATE CHANGE SCENARIOS

The PRECIS, a regional model, with 40 km by 40 km spatial resolution, developed by the Hadley Centre of the UK Met office, is being used to simulate the climate for the period 1961-1990 and make projections of climate change with respect to this base line for 2020s to 2100 using emission scenarios published in the IPCC special report using various story lines describing growth paths of different types of economies as forcing scenarios. The model output consists of various surface as well as upper air parameters such as temperature, precipitation, extreme events on daily and monthly time scales. Further an extraction tool has been developed that enables users to extract the parameters along different spatial scales and time line such daily, monthly and annual scales.

SOCIO-ECONOMIC SCENARIOS

Alternative socio-economic scenarios taking into account the sustainable development objectives of India are being developed specifically incorporating the concerns of climate change and inclusive development. Three scenarios are being developed through the study, reflecting alternative socio-economic developmental pathways. These include a business as usual scenario, a scenario impacted by possible climate change and a scenario with adaptation strategies for climate change. A mix of quantitative and qualitative techniques and tools of analysis will be used in gaining insights, collecting relevant data and information for the study.

IMPACT ASSESSMENTS AT NATIONAL LEVEL

Water Resources

Five studies are being undertaken under this category to assess the water resource availability in the future that include assessment of river run off at future time scales in the various river basins of India, an assessment of ground water potential, a review of the status of himalayan glaciers, and an assessment of the changes in water demand in the future with respect to current situation.

Agriculture

The earlier assessment focussed on impacts of climate change on irrigated rice and wheat crops in India. Eight studies are being carried out under this category which include rainfed crops as well. Besides, efforts have been made to also include studies that cover the impacts of climate change on cereals, vegetables, and fruits and crops having high economic value such as cotton, coconut, arcanut and cocoa etc.



Natural Ecosystems & Forestry

Biophysical models in association with regional climate change scenarios are being used to assess the impact of climate change on forest ecosystems at national and regional levels in terms of the shifts in boundary of forest systems, forest ecosystem change matrix, changes in species mix and species vulnerability to identify the vulnerable forest ecosystems, regions and hotspots. Implications of climate change on biodiversity, biomass production and net primary productivity are also being studied. Additionally a project has been launched to assess the status of Mangroves and Coral reefs in India, the changes in these ecosystems due to various natural (e.g., cyclones, tsunami etc.) and anthropogenic (e.g., habitation, exploitation, pollution, tourism, sea surface temperature etc.).



Sea Level Rise and Coastal Zones

The east coast of India is highly vulnerable, since it is low-lying and prone to the onslaught of storm surges. Observations in the past century indicate a slight increasing trend of occurrence of the number of severe storms in the Bay of Bengal. Simulations of the Regional climate model (PRECIS) are being made to determine the frequency distribution of tropical cyclones in the Bay of Bengal. Additionally, Storm surge model simulations for the Bay of Bengal, forced by wind fields from regional climate model, are

being used to estimate return periods of extreme sea level for the baseline scenario (1961-1990) and future A2 scenario (2071-2100).

Human Health

In the earlier assessment the focus was limited only to the vector borne malaria besides identification of hotspots. In the current programme, efforts are being made to assess the impacts of climate change on malaria in these hotspots by incorporating the socio-economic and land use change considerations along with climate parameters based on the outputs of the regional climate model in the assessment at national scale. Further, efforts are being made to study the impacts of climate change on dengue as well which is another mosquito driven disease but more devastating in city areas where the water from rains get accumulated and do not have passage of flow. Also efforts are on to assess extent of spatial spread of extreme heat and hence its impacts on health in India.

Energy

Climate change could affect energy production and supply in its various manifestations, namely, when extreme weather events become more intense, in regions dependent on water supplies for hydropower and/or thermal power plant cooling face reductions in water supplies, and in conditions where availability of biomass, wind power or solar energy might be affected. Over and above the impacts of changes in climate, the study is integrating the energy and environment policies to analyze the impacts on the energy systems in India in totality. Therefore sectoral studies of energy demand and supply projections, environmental implications of various technologies, detailed assessment of technological progress and energy transitions in future are being undertaken. Such an analysis, with explicit inclusion of developing country dynamics in scenario constructions

and modeling frameworks, would further add to the qualitative and quantitative understanding of emissions pathways and mitigation strategies.

INTEGRATED IMPACTS AND VULNERABILITY ASSESSMENTS

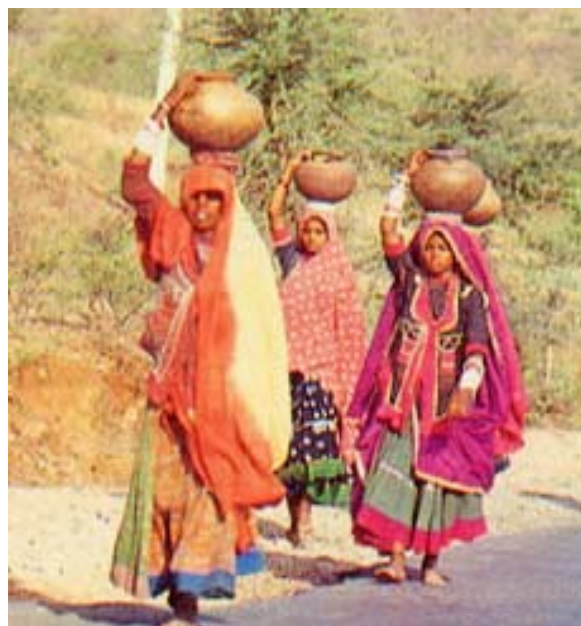
This component of the assessment is aimed at examining the cross cutting nature of the impacts. Given below are the various themes for integrated assessments being taken up as case studies.

Water Resources, Agriculture Productivity, Food Security and Livelihoods

Five studies have been launched under this theme. The first study is assessing vulnerability and impact of climate change on food security and hence livelihoods in seven agro climatic zones of Tamil Nadu. The second study is focussed in the Cauvery delta of Tamil Nadu which encompasses the whole of Nagapattinam and parts of Cuddalore District. The region has a low elevation coastal zone and 56% of the land lies below sea-level. The third study is simulating the impacts of current climate variability on crops in an Arid region through a case study in Rajasthan. A study in this region has also been launched to assess the impacts of climate change on the livelihoods of small scale farmers dependent on livestock.

Water Resources, Gender and Poverty

Rural and semi-urban women spend considerable time procuring, transporting and storing water from different water bodies such as rivers, lakes wells or community taps. They carry water in different containers on their head or in their arms. They often have to travel long distances and pay heavy physical (time, energy), temporal (time), affective (negative feelings and attitudes), and cognitive (opportunities for formal education, training and intellectual development) costs. In times of sickness of



family members, disasters and environmental stress, such as droughts or floods the burdens of women magnify several times, since they are the primary caregivers for the family. Climate change is likely to enhance the burden of women in arid area where further scarcity in water availability with respect to the current situation is projected. This present study aims to examine the linkages among gender, water and poverty, and quality of life and overall human development in different states of India at present as well as how this will be impacted by climate change in future.

Water, Human Health, Livelihoods and Adaptation

The study focuses on urban areas in India that will be susceptible to frequent extreme heat events due to climate change. The study is being carried out through a case study in the city of Kolkata, West Bengal. It includes quantification of the direct impacts of extreme temperature events on morbidity & mortality rates along with the indirect impacts of such events through deterioration of water quality and quantity. The study is also attempting to make an economic valuation of direct and indirect impacts. The study identifies the current adaptation strategies

in terms of individual adaptation mechanisms and the policies and programmes of the government that are helping to adapt to such conditions. Taking this as the base line scenario the study will evaluate the changes in extreme events, morbidity and mortality rates and associated economic loss for the future in a Business As Usual Scenario and for two climate scenarios.

Forest, Forest Products, Livelihood and Adaptation

Three mega biodiversity rich forest areas have been targeted in this theme. A study has been initiated in the western ghats region to assess the current status of the forests and associated livelihoods for the communities living around the forests. Since such a strong dependence of the communities exists on the forest products, a model based projection is being carried out to assess the changes in forest species that might occur due to climate change. The second study is in the north eastern region. The unique geo environment of the region vis a vis the Himalaya's in the east, characterised by heavy rain fall, accelerated rates of erosion and deforestation, weak geological formation. Intense land use pressure makes the region vulnerable to any changes including climate change that is likely to lead towards an increase in extreme rainfall activity in this region. The third study is being carried out in Madhya Pradesh that tracks the trends related to key climatic variables (precipitation and temperature), and possible impact on forests, forest products and hence the livelihoods of the tribals dependent on these forests.

Natural Ecosystems & Livelihoods

The livelihoods of a significantly large population in India is dependent on the ecosystem products of the Himalayas such as agriculture & forests. Climate Change projections indicate that the water resources

dependent on glaciers in this region, will enhance in the short term but will rapidly deplete. As a result agriculture thriving in this region is likely to face huge adverse impacts. Similarly die back and shifting of certain forest species have been projected in this region. Keeping in view the typical vulnerabilities of the region, the study area has been chosen in the Almora district of Uttarakhand, which has a population that thrives on agriculture as well as forest products. The study is tracking the trends of socio-economic development and degradation of mountain ecosystem and its vulnerability to climate variability and change. It is identifying the government policies and programmes that are conducive to adaptation in the context of climate variability in the region and the adaptation options embraced by the people. It is also developing an adaptation matrix vis a vis the projected changes in climate.



Energy Systems & Infrastructure

In India hydropower constitutes 23% of the total power capacity. In the present study an attempt is being made to soft-link outputs of climate and hydrology models with economic-energy-environment models to integrate water-energy and climate change in the context of a large multi-purpose dam. The second study aims to provide an overview of the practical implications of the

climate change impacts for India, with special emphasis on the challenges confronting the built environment.

Climate, Coastal Zones and Livelihoods

In earlier study it was observed that the districts of Kendra Para in Orissa, Nellore in Andhra Pradesh and Nagapattinam in Tamil Nadu are most vulnerable to cyclones and storm surges. The present assessment attempts to analyze the relative vulnerability pattern across the villages of the three study areas, the extent of vulnerability due to climate change due to the changing patterns of the climate in the future. The second study is being carried out in the Coastal region of Orissa as this region's food security as well as livelihood is majorly dependent on agriculture crops and marine fisheries that are susceptible to changes in frequency and intensity of cyclones and storm surges due to climate change.

DEVELOPING ADAPTATION FRAMEWORKS

Adaptation is imperative to combat the adverse impacts of climate change. Keeping this in view, the present effort aims to build adaptation frameworks for the studies being carried out in the above mentioned 7 thematic areas of integrated assessments that decipher the impacts of climate change and associated vulnerability and prioritize the same. The adaptation frameworks will be built on the current adaptation strategies of the concerned communities that have traditional knowledge of adaptation to combat climate variability and also will look into the additional strategies required to upgrade technological or technical impetus required to adapt to climate change. The adaptation frameworks will look into the augmentation policies, and assess the current institutional mechanisms identify the barriers and solutions for operationilising a smooth delivery system. Avenues for various risk sharing measures in the context of climate change will also be investigated.

INSTITUTIONAL ARRANGEMENT FOR IMPACTS, VULNERABILITY AND ADAPTATION ASSESSMENTS

In order to carry out the various activities of this component, expertise from a large number of institutions in India involved in climate, socio economic and impact modeling and undertaking policy research in the various sectoral and inter-sectoral studies have been pooled in. The institutional arrangements have been designed to address (a) climate and socio-economic scenarios, (b) national impact assessments on water resources, agriculture, forests, energy, coastal zones and human health, and (c) inter-sectoral studies in seven key thematic areas that sectorally integrate the assessments and develop adaptation frameworks through case study approach in climate hotspots. The seven thematic areas being (i) water resources- agriculture-food security-livelihoods and adaptation; (ii) water resources, gender and poverty, (iii) water-human health-livelihoods and adaptation, (iv) Forests-forest products-livelihoods, (v) natural ecosystems-livelihoods, (vi) Sea level rise- extreme events-coastal zones-livelihoods and (vii) Energy Infrastructure-Habitats-Adaptation The network diagram for preparation of V&A component is shown in figure 2.



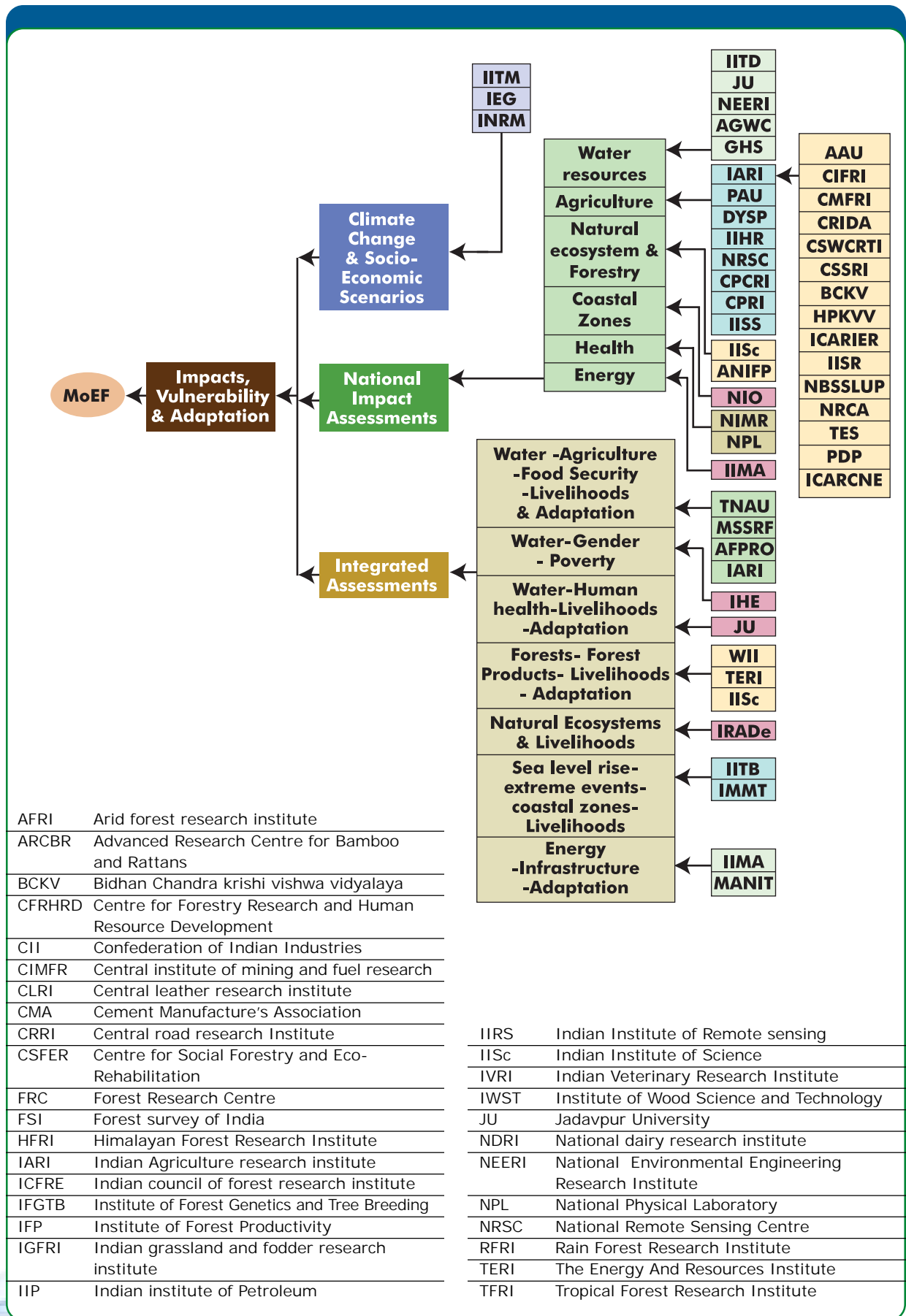


Figure 2: Knowledge institutions in the preparation of Impacts, Vulnerability & Adaptation Component

DEVELOPING GREENHOUSE GAS EMISSION PROFILE

The programme envisages preparing a comprehensive GHG emission inventory profile by sources and removals by sinks for India. It is being developed using comparable methodologies (IPCC 1996/ 2006). The scope of improvement with reference to the inventories presented in previous assessments include (i) estimation methodologies for some key categories made using higher tiers of estimations; (ii) GHG emission factors developed in the earlier efforts are being refined to keep up with the changing trends of the economy; (iii) New measurements are being carried out to develop country-specific emission factors for some key categories; (iv) Additional gases such as CO, NO_x, NMVOC, SO₂, HFC, PFC and SF₆ are being included to the extent capacities permit; (v) Additional GHG pools identified in IPCC



2006 guidelines are being included such as land use change from forests to other lands and vice versa; (vi) A strong emphasis is on QA/QC procedures as identified in IPCC Good Practices Guidance (GPG) 2000 and 2003 and on determining the uncertainties of estimates.

INSTITUTIONAL ARRANGEMENT FOR DEVELOPING GREENHOUSE GAS EMISSION PROFILES

Estimation of greenhouse gas emission inventories by sources and removal by sinks constitute one of the core elements of the assessment. A large number of institutions in India involved in scientific and policy research and industry associations collating data on various aspects of industries have been involved by the Ministry of Environment and Forests to develop the emission profiles. Efforts have been made to widen this base by encouraging formal or informal collaborations of the network institutions with other knowledge institutions that are either generators of activity data or are providing technical support on estimation or measurements of GHGs.

The knowledge institutions are grouped according to their respective expertise and capabilities to estimate GHG emissions and develop emission factors from energy sector, industrial processes, agriculture activities, land use land use change and forestry and from waste management. Figure 3 depicts the grouping of the institutions according to their tasks.

The institutions are drawn from a diverse mix of premier national agencies working under the aegis of the Council of Scientific and Industrial Research, the Indian Council of Agriculture Research, Indian Space Research Organisation, Indian Council of Forest Research. Additionally, industry associations, leading universities, Non-Governmental organisations, private consulting agencies are also part of the team. The government or autonomous institution of the Government interface with their nodal ministries and participate in the meetings of the national steering committees.

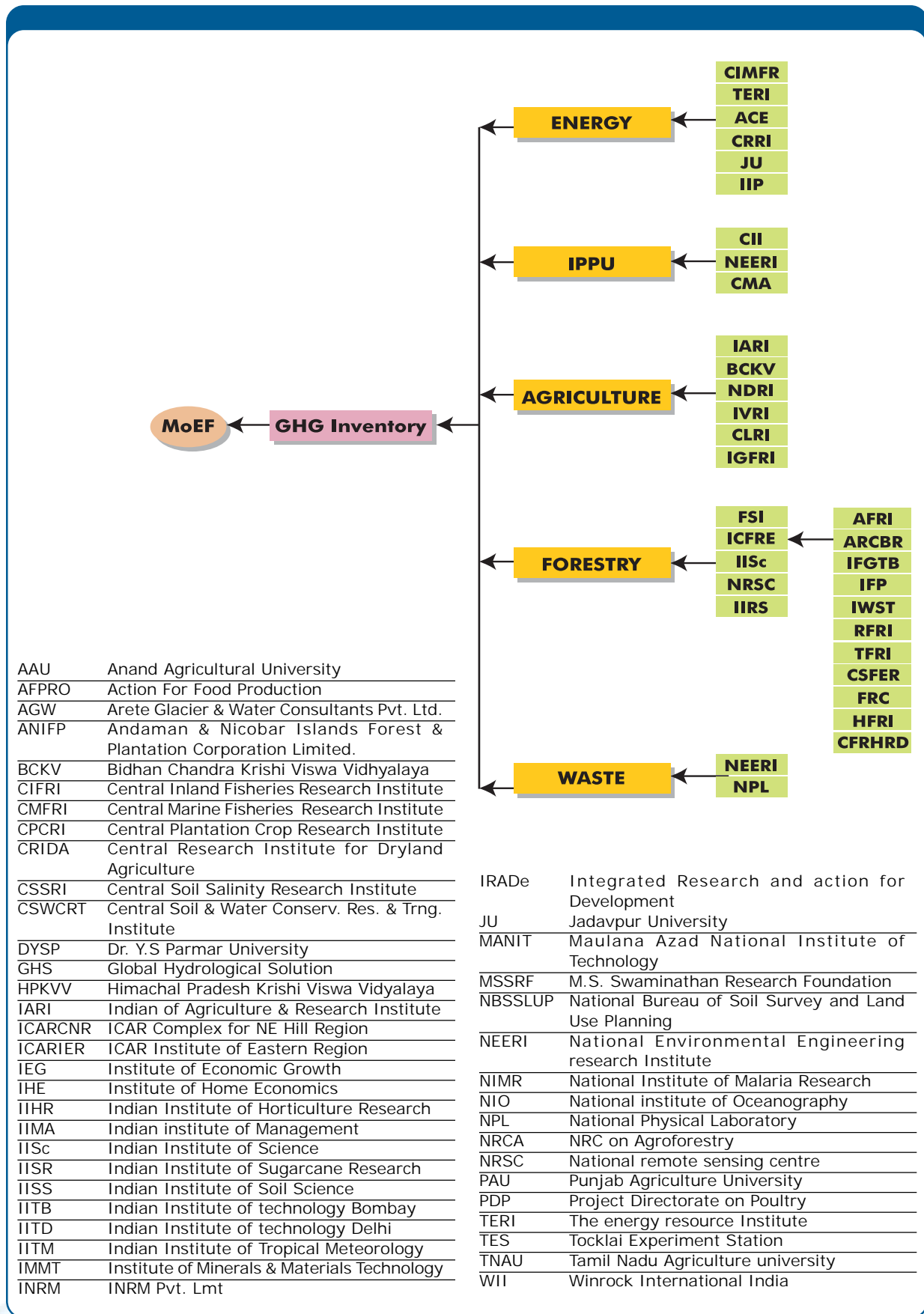


Figure 3: Knowledge institutions in the preparation of National Greenhouse gas emission inventory by sources and removal by sink.

STUDIES UNDER WAY

Wide ranging studies in the various components of the work programme constitute the core of the climate change assessment. About 57 independent studies have been commissioned so far. Provided in the Annexure 1 is a list of various studies being pursued under each element of the work programme. It also lists the institutions that are directly or indirectly involved in these studies.



OUTCOMES

The key outcomes of this programme are envisaged to (i) generate a comprehensive knowledge base on scientific issues related to climate change for informed decision making, (ii) Enable integration of climate change concerns towards the preparation of Action Plan on Climate Change and the related initiatives, (iii) Provide scientific for negotiations and (iv) build capacity of institutions by training new researchers in various aspects of climate change in the projects awarded to different institutions.

Some of the additional activities that can be derived from this programme are as follows:

National Communications to United Nations Framework Convention on Climate Change

India is a Party to the United Nations Framework Convention on Climate Change. The Articles 4.1 and 12, of the UNFCCC enjoins upon all parties to furnish national communication to the UNFCCC secretariat. The content, scope and periodicity of reporting of the same is guided by decisions of the Conference of Parties (COP) to the Convention. The initial national communication from India was reported as per decision 10 of COP2 (10/CP.2) and NATCOM 2 is being prepared as per the revised decision 17 of COP8 (17/CP.8), which is more in depth and extensive in nature with respect to 10/CP.2. The outline of the information to be provided in the NATCOM 2 as per 17/CP.8 include chapters on National Circumstances, National inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol, a General description of steps taken or envisaged to implement the Convention for a given base year, any other information conducive towards addressing concerns of climate change, and Constraints and gaps, and related financial technical and capacity needs.

National Inventory Management System

Building on the base of knowledge institutions already engaged in the preparation of a national assessment a National Inventory Management System (NIMS) under the MoEF can be developed. The NIMS may address the requirements of documentation, archiving and continuous updating of the databases as well as the QA/QC and uncertainty management issues of the GHG inventories being developed across the years. The NIMS will develop Systemic tools and procedures for documenting methodologies, Create databases of emission factors and activity data for each

point source and the various disaggregated sources that add up to generate the national GHG emission profiles across each year; Will undertake data management and collection on an annual basis; Devise strategies for data generation and improvement; Will put in place systems for data archiving and record keeping; Ensure mechanisms for synchronization and cross-feeding between emission inventories, national energy balances and relevant sector surveys; Provide guidance for technical peer reviews, procedures for QA/QC and uncertainty management. A web based data base management system will further help in wider accessibility of data to concerned stakeholders and also towards visualisation of GHG data thus generated.

Assessment of Climate Change, its Impacts and Associated Vulnerabilities at State Level, Agro-ecological or Agro-climatic Zones

The climate scenarios being developed at can be the basis for extracting climate change scenarios at state level, agro-ecological zones or at a agro climatic zones as per the requirement. The state level projections may enable the state level administrators to identify the economic sectors that are most vulnerable to climate change that adversely affect the state domestic product and social well being. The climate change scenarios extracted at the agro-ecological zones, could identify vulnerabilities of ecosystems such as forests, how they will respond to increasing concentrations of CO₂, increasing temperatures, the highly variable precipitation across the zone and frequent extreme precipitation events. The climate change scenarios extracted at the agro-climatic zones may help in the assessment of impacts of climate change on agricultural crops, their grain potential; and its impact on ensuring food security for the country.

Adaptation Frameworks

Identification of vulnerabilities and hence risks associated with climate change at state level, agro-ecological zones and agro-climatic zones enable the development of adaptation frameworks at these levels for a target sector or for the associated vulnerabilities. For example, at the state level, to ensure water security, for a given projection of scarce water availability in the state, these assessments will help in precisely developing adaptation strategies towards water security. Similarly advance planning based on the climate impact scenarios at agro-climatic zones, may assist in devising initiatives for ensuring food security as well as associated livelihoods at these spatial scale.

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Annexure

STUDIES UNDERWAY

CLIMATE SCENARIOS

- Indian Institute of Tropical Meteorology, Pune
- India Meteorological Department, New Delhi
- INRM Consultants Pvt. Ltd, New Delhi

SOCIO ECONOMIC SCENARIOS

- Indian Institute of Economic Growth, Delhi
- Planning Commission, New Delhi
- Indian Council of Agriculture Research, New Delhi
- Ministry of Finance, New Delhi

IMPACT ASSESSMENTS

Water resources

Improved river runoff Assessments for major river basins

- Indian Institute of Technology, Delhi
- Jadavpur University, Kolkata
- Central Water Commission, New Delhi
- West Bengal Irrigation and Water Works Department, Kolkata
- Damodar Valley Corporation (DVC), Durgapur

Water availability and Demand

- National Environmental Engineering Research Institute, Nagpur

Groundwater Resources and Future Scenarios

- Global Hydrological Solutions
- Central Ground Water Board

A review of status of Himalayan Glaciers and future projections

- Arete Glaciers, New Delhi
- University of Kashmir, Sri Nagar
- Department of Science and Technology, Government of Sikkim
- Indian Mountaineering Foundation, New Delhi



- Himalayan Institute of Mountaineering, Darjeeling
- Jawahar Institute of Mountaineering and Winter Sports, Pahalgam, Kashmir

Agriculture

Rainfed crops across India

- Indian Agricultural Research Institute, New Delhi

Rice/wheat and other crops in Punjab

- Punjab Agriculture University, Ludhiana

Apple & horticulture

- Dr Y S Parmar U H F, Nauni, Solan, Himachal Pradesh
- Regional Horticulture Fruit Station, Moshobra, Shimla
- Regional Horticulture Research Station, Sharbo, Kinaur

Vegetables and fruits

- Indian Institute of Horticultural Research, Bangalore
- National Horticultural Research and Development District, Maharashtra
- Foundation Chitegaon Phata, Nashik-Aurangabad

Major legume crops

- National Research Centre for Soybean, Indore

Coconut and arcanut plantations

- Central Plantation Crop Research Institute, Kasaragod

Potato

- Central Potato Research Institute, Jalandhar, Punjab

Cotton

- Indian Institute of Soil Science, Bhopal
- Central Institute for Cotton Research, Nagpur
- University of Agricultural Sciences, Dharwad
- Navsari Agricultural University, Surat

Castor and oilseeds

- Central Research Institute for Dryland Agriculture, Hyderabad

Fisheries

- Central Marine Fisheries Research Institute, Chennai

Natural Ecosystems including Forests**Indian forests**

- Indian Institute of Science
- National Remote Sensing Agency, Hyderabad
- National Bureau of Soil Science & Land Use Planning, Nagpur
- National Bureau of Soil Science & Land Use Planning, Bangalore

Mangroves and Coral reefs

- Andaman & Nicobar Islands Forest & Plantation Corporation Ltd., Andaman and Nicobar island
- Zoological Survey of India, Port Blair unit
- Reef Watch Marine Conservation, Mumbai
- Forest Survey of India

Coastal Zones**Sea Level rise, cyclones, and storm surges**

- National Institute of Oceanography

Health**Malaria and Dengue**

- National Institute of Malaria Research, Delhi
- National Physical Laboratory
- Patel Chest Institute

INTEGRATED V&A ASSESSMENTS**Water, Agriculture, Food Security, Livelihoods & Adaptation**

- Tamil Nadu Agricultural University, Coimbatore
- M.S. Swaminathan Research Foundation, Chennai
- Action for Food Production, Field Unit-III, Udaipur
- Indian Agriculture Research Institute, New Delhi

Water- Gender- Poverty

- Indian Institute of Home Economics, New Delhi

Water- Human Health –Livelihoods- Adaptation

- Jadavpur University, Kolkata, West Bengal

Forests-Forest products –Livelihoods

- Indian Institute of Science
- The Energy Resources Institute
- Winrock International India

Natural Ecosystems & livelihoods

- Integrated Research and Action for Development

Sea level rise-extreme events-coastal zones & livelihoods

- Indian Institute of Technology, Mumbai
- Indian Institute of Minerals and Metal Technology, Bhubaneswar
- Central Rice Research Institute, Bhubaneswar
- National Institute of Oceanography, Goa
- Water Technology Centre for East Region, Bhubaneswar

- Orissa Space Application Centre, Bhubaneswar
- Indian Institute of Technology, New Delhi

Energy Infrastructure & habitats

- Indian Institute of Ahmedabad, Ahmedabad
- Maulanazad National Institute of Technology, Bhopal

GHG EMISSION PROFILE

Energy

NCVs of Coal

- Central Mining and Fuel Research Institute, Dhanbad

Measuring GHG emissions factors from power plants

- Central Mining and Fuel Research Institute, Dhanbad
- Jadavpur university, Kolkata
- Damodar Valley Corporation, Jharkhand
- Naively Lignite Corporation Ltd., Tamilnadu

Measuring GHG emission factors from steel plants

- Central Mining and Fuel research Institute, Dhanbad
- Steel Authority of India

Estimating GHG emissions from Energy Industries and Manufacturing Industries

- Central Mining and Fuel research Institute, Dhanbad

Estimating GHG emission from the transport sector

- Central Road Research Institute, New Delhi
- Indian Institute of Petroleum, Dehradun

Developing Country Specific Emission Factors from Venting and Flaring

Central Mining and Fuel Research Institute

Estimating GHG emissions from fugitive emissions

Central Mining and Fuel research Institute, Dhanbad

Estimating GHG emissions from energy industries, manufacturing & construction and other sectors and from biomass combustion

- The Energy Resources Institute, New Delhi

Industrial Process and Product Use (IPPU)

Estimating GHG emissions from IPPU

- Confederation of Indian Industries
- Central Glass and Ceramic Research Institute, Kolkata
- Indian Lead Zinc Development Association, New Delhi
- Alkali Manufacturers' Association of India, New Delhi
- Indian Chemical Council, Mumbai, Maharashtra
- India Semiconductors Association, Bangalore, Karnataka
- Fertiliser Association of India, New Delhi
- Electronics Industries Association Of India, New Delhi

Estimating Country specific CO2 emission factor and emission from Cement production and Fuel Use

- Cement Manufacturing Association, New Delhi
- Central Mines Planning & Design Institute, Dhanbad
- Indian Bureau of Mines, Nagpur
- Coal India Ltd, Kolkata
- Holtec Consulting Engineers Ltd; Gurgaon
- Department of Mines, Ministry of Mines, GoI
- Deptt. of Coal, Ministry of Coal, GoI
- Deptt. Of Power, Ministry of Power, GOI, New Delhi
- Petroleum Conservation Research Association, New Delhi
- Ministry of Petroleum & Natural Gas, GoI, New Delhi
- Ministry of New & Renewable Energy, GoI, New Delhi
- Central Statistical Organization, New Delhi

Estimating N₂O emission factor from ammonia production

- National Environment Engineering Institute, Nagpur

Agriculture

Estimating GHG emission profile from crop & soils

Indian Agriculture Research Institute

Estimating CH₄ emission factor from rice cultivation

- Indian Agriculture Research Institute
- Bdhhan Chandra Krishi Vidyalaya, Kalyani

Measuring & estimating CH₄ emission factor from Livestock

- Central Leather Research Institute, Chennai
- Indian Grass Land & Fodder Research Institute, Jahnsi
- Indian Veterinary Research Institute, Izatnagar
- National Dairy Research Institute, Karnal

Estimating CH₄ and N₂O emissions from livestock & manure

- National Dairy Research Institute

Land Use Land Use Change and Forestry

GHG emissions from forest remaining forest

- Indian Institute of Science
- National Remote Sensing Agency, Hyderabad
- National Bureau of Soil Survey and Land Use Planning, Bangalore
- University of Agricultural Sciences, Bangalore

GHG emission from other land changing to forest

- Forest Survey of India

Estimating soil carbon stocks and dynamics in forest

- Indian Council of Forest Research
- Centre for Forestry Research and Human
- Institute of Wood Science and Technology, Bangalore

- Institute of Forest Resource Development, Chhindwara
- Tropical Forest Research Institute, Jabalpur
- Advance Research Centre for Bamboo and Rattans, Aizwal
- Arid Forest Research Institute, Jodhpur
- Institute of Forest Genetics and tree breeding, Coimbatore
- Centre for Social Forestry and Eco-Rehabilitation. Allahabad

Waste

Measuring & Estimating GHG emissions from Municipal Solid waste

- National Environment Engineering Institute, Nagpur
- National Physical Laboratory, New Delhi

Estimating GHG emissions from waste water

- National Environment Engineering Institute

Quality Assurance & Quality Control Providing QA/QC support for intercalibration of samples of CO₂, CH₄ and N₂O

- National Physical Laboratory, New Delhi





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