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List of Abbreviations

AKRSP: Aga Khan Rural Support Programme
AOSIS: Association of Small Island States
ATF: Aviation Turbine Fuel
BEE: Bureau of Energy Efficiency
BRTS: Bus Rapid Transit System
CBDR: Common but differentiated responsibilities
CDM: Clean Development Mechanism
CED: Centre for Education and Documentation
CEEESA: Center for Energy, Environmental, and Economic Systems Analysis
CER: Certified Emission Reduction
CERES: Centre for Education and Research in Environmental Strategies
CETP: Common Effluent Treatment Plant
CH₄: Methane
CMA: Cement Manufacturers Association
CMIE: Centre for Monitoring Indian Economy
CMIP3: Coupled Model Inter-comparison Project 3
CNG: Compressed natural gas
CO₂: Carbon Dioxide
COP: Conference of Parties
CP: Cleaner Production
CRED: Center for Research on Environmental Decisions
CSE: Centre for Science and Environment
CSR: Corporate Social Responsibility
CSTEP: Centre for Study of Science, Technology and Policy
DEPR: Depression cyclones
DPSIR: Driving Forces-Pressures-State-Impacts-Responses
EIA: Environmental Impact Assessments
ETP: Evapo-Transpiration Potential
FFS: Farmer's Field Schools
GCPC: Gujarat Cleaner Production Centre
GDP: Gross Domestic Product
GEC: Gujarat Ecology Commission
GEDA: Gujarat Energy Development Agency
GERC: Gujarat Electricity Regulatory Commission
GERMI: Gujarat Energy Research and Management Institute
GETCO: Gujarat Energy Transmission Company
GETCO: Gujarat Energy Transmission Corporation Limited
GHG: Greenhouse Gas
GIDB: Gujarat Infrastructure Development Board
GIDC: Gujarat Industrial Development Corporation
GIPCL: Gujarat Industries Power Company Ltd.
GoG: Government of Gujarat
GoI: Government of India
GPCB: Gujarat Pollution Control Board
GRIHA: Green Rating for Integrated Habitat Assessment
GUDC: Gujarat Urban Development Company
GUVNL: Gujarat Utrja Vikas Nigam Limited
GWP: Global warming potential
HADCM2: Hadley Centre coupled model
HFCs: Hydro fluorocarbons
HVDC: High voltage direct current
IATA: International Air Transport Association
ICRISAT: International Crops Research Institute for Semi-Arid Tropics
IFAD: International Fund for Agricultural Development
IGES: Institute for Global Environmental Strategies
IIED: International Institute for Environment and Development
IINC: India's Initial National Communication
INCAA: Indian Network for Climate change Assessment
INDEXTb: Industrial Extension Bureau
International Fund for Agricultural Development
IOCL: Indian Oil Corporation Limited
IOD: Indian Ocean Dipole
ISO: International organization for standardization
IPCC: Intergovernmental Panel on Climate Change
IPPs: Independent Power Producers
IPPU: Industrial processes and product use
ISWM: Institute of Solid Waste Management
JFM: Joint Forest Management
LDC: Least developed countries
LED: Light Emitting Diodes
LEED: Leadership in Energy and Environmental Design
MECC: Management Education Centre on Climate Change
MoEF: Ministry of Environment and Forest
MoNRE: Ministry of New and Renewable Energy Sources
MoPNG: Ministry of Petroleum and Natural Gas
MSW: Municipal solid waste
MTCO2e: Metric tons CO2 equivalent
N2O: Nitrous Oxide
NAPCC: National Action Plan on Climate Change
NATCOM: National Communication
NCSCM: National Centre for Sustainable Coastal Management
NCPC: National Cleaner Production Centre
NIOH: National Institute of Occupational Health
NTFP: Non-timber forest products
OECD: Organization for Economic Co-operation and Development
OFDA/CRED International Disaster Database:
OFDA: Office of U.S. Foreign Disaster Assistance
PACS: Poorest Areas Civil Society
PAT: Perform Achieve and Trade
PCN: Project Conceptual Note
PDD: Project Design Document
PFCs: Perfluorocarbons
PRECIS: Providing Regional Climates for Impacts Studies
PSIR: Pressures-State-Impacts-Responses
RCM: Regional Climate Model
SANDRP: South Asia Network on Dams, Rivers and People
SCCI: Swinomish Climate Change Initiative
SDA: State Designated Agency
SF6: Sulphur Hexafluoride
SNA: State Nodal Agency
SPGs: Solar power generators
SPPWCP: Sardar Patel Participatory Conservation Project
SRI: System of Rice Intensification
SST: Sea Surface Temperature
SSTR: Severe Strong Cyclone
SWAT: Soil and Water Assessment Tool
Tg: Tera gram
TOI: Times of India
U.S.CCSP: United States Climate Change Science Program
ULBs: Urban Local Bodies
UN: United Nations
UNDP: United Nations Development Programme
UNEP: United Nations Environment Programme
UNFCCC: United Nations Framework Convention on Climate Change
UNIDO: United Nations Industrial Development Organization
USAID: United States Agency for International Development
WHO: World Health Organization
WMO: World Meteorological Organization
WRI: World Resources Institute
XGN: extended green node
Introduction
1 INTRODUCTION

Our existence on earth came into being millions of years after the Big Bang. During this time the level of greenhouse gases (GHGs) in the atmosphere served as a blanket to keep the planet warm, rather than turn it into a cold ball, enabling the existence and sustenance of life. The factors that contributed to the changes in climate and enabled the evolution of life and ecosystems are ascribed to natural forcing such as volcanic activity, solar irradiance, and earth’s orbit around the sun.

Climate change concerns us because of the potential impacts on the humans. Climate variability and greenhouse gas concentrations in the atmosphere are of no concern to humans unless there are human implications and risks. Greenhouse gas concentration is at the highest today than ever before including pre-industrial (before 1750) ages (World Meteorological Organization (WMO) 2011). Studies have shown high correlation between climate variability and greenhouse gas concentration. Climate change today is at a pace that has exceeded paleo-climatological changes. Human societies today have to adapt to the rapidly changing climates and the risks posed are not to the earth but to humans. There is a need to build the resilience against the impacts of climate change.

The Brundtland Commission Report of 1987, referred to as “Our Common Future”, opened the eyes of the world to the impending doom on the environment due to rapid industrial development. The World Meteorological Organization (WMO) and the United Nations Environment Programme (UNEP) to provide governments of the world with reliable, scientific evidence on the climate system and pressures and the potential impacts on humans created the Intergovernmental Panel on Climate Change (IPCC) in 1988. The first assessment report by the IPCC brought out in 1990 gave scientific evidence of anthropogenic emissions and its effects on the climate system and the importance of dealing with climate change at a political platform. The Brundtland Commission report and the first assessment report of the IPCC was the highlight of the United Nations World Commission on Environment and Development at Rio de Janeiro (Earth Summit); the deliberations led to the formation of the international environment convention, the United Nations Framework Convention on Climate Change (UNFCCC) in 1992.

Climate system is a global common and climate change is a global phenomenon as it manifests across land, air, ocean and life thereby the climate systems becomes entwined with our relations with one and other. There is a great deal of certainty of climate-induced changes, although predictions about the precise nature of their changes are uncertain. The UNFCCC recognized the climate system as a global common whose stability can be affected by the industrial and other greenhouse gas emissions. As a common property resource, the climate systems would also be subject to the principle of the ‘tragedy of the commons. There is a need for global solution and the enforcement of common but differentiated responsibilities (CBDR) to sustain this global common. The convention set a framework for intergovernmental efforts to tackle the problem of climate change and today the convention enjoys membership with 192 countries to combat climate change.

In 1997, a second and far more reaching treaty was signed on climate change and adopted in Kyoto, where it enforced mandatory targets on greenhouse-gas emissions for the world's leading
economies, commitments of greenhouse gas reductions under the protocol vary from nation to nation. It put into place flexible mechanisms for meeting these targets through, international emissions trading, intergovernmental emissions trading, clean development mechanism and joint implementation. The protocol intended to be effective against a complicated problem and was also politically accepted, except for the United States that stayed out of the protocol.

In February 2007 the IPCC in its summary for the policy makers concluded, “warming of the climate system is unequivocal, as is now evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice, and rising global average sea level.” The Convention defines climate change in Article 1(2) as “a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods” (UNFCCC n.d.). The definition has accentuated the role of anthropogenic factors that influence climate change. However to understand the gravity of climate change, attention has to be paid to climate variability and its impacts.

The IPCC Fourth Assessment Report (IPCC 2007) has highlighted the climate change impacts as an increased risk of animal and plant species extinction, melting of glaciers and snow cover, displacement due to sudden climate change related disasters, and adverse health impacts. At this juncture it is pertinent to differentiate between the impact on developed and developing countries. Developing and least developed countries do not have the means to address climate change related challenges making them the most vulnerable to the impacts of climate change. It has also been identified by the UNFCCC and the IPCC that it is the vulnerable communities that are urgently required to increase their adaptive capacity. The Third Assessment Report of the IPCC has suggested that despite full implementation of the Kyoto protocol, the impacts of global climate change will start being felt within the next few decades especially by the most vulnerable countries and communities.

The global community has to follow the UNFCCC and Kyoto Protocol in dealing with the impacts of climate change. The UNFCCC has two policy frameworks on tackling climate change. One is through “mitigation” where there is a prevention of a dangerous interference with the climate system and the second is through the process of “Adaptation” where there is reduction of vulnerability to climate change. Adaptation relates to development and related policy questions (UNFCCC n.d.). These actions reduce the forcing on the climate system as well as increase the coping capacity of humans to the impacts of climate change.

1.1 Important Negotiations and the Climate Deal

Climate change debate and negotiations have been volatile; the United Nations Conference on Climate Change in Bali in 2007 was to create a successor for the Kyoto Protocol. The main objective of the new protocol had to be the same as before; to stabilize greenhouse gas emission so as to avoid uncontrollable climate change. There were various alliances that went into the conference. The European Union sought binding comments from the industrialized nations that went beyond the Kyoto’s 20-40 percent reduction from 1990 levels by 2020. The developing countries with the BASIC countries (Brazil, South Africa, India and China) as leaders however objected to binding emission targets in the interest of development and proposed common but
differentiated responsibilities (CBDR). United States backed by Canada, Japan and Australia opposed the emission reduction targets set by the EU. While the least developed countries (LDC) and Association of Small Island States (AOSIS) faced the brunt of the climate vagaries and where in need financial assistance from developed nations. The question that arose next was who would take the financial burden of reducing greenhouse gas, follow a sustainable approach to development and help poor countries adopt a path of sustainable development with rapid economic growth. Finally at the end of the Bali conference there was some hope for a new protocol emerging beyond the Kyoto when the US reversed its stand on staying out of the climate deal. Developing countries like India and China plan on sitting out of the climate negotiations were also ending as US decided to be party to the climate agenda. This was the first step taken by the developed nations through collective action to protect the global common property resource.

On March 28th 2008, the United Nation Human Rights Commission adopted a resolution on human rights and climate change. It was for the first time in a UN resolution explicitly recognized that climate change “has implications for the full enjoyment of human rights”. The application of human rights principles and norms can bring about a range of benefits to international and national efforts to respond to global warming, and that the obstacles to doing so are mainly practical difficulties, related in particular to the entrenched “path dependence” of the two policy areas (Limon 2009). Following this another change had taken place in the developing nations; India had brought out in June 2008 its National Action Plan on Climate Change (NAPCC) stating India’s contribution in combating climate change. There are eight missions under the NAPCC namely

1. National Solar Mission
3. National Mission on Sustainable Agriculture
4. National Water Mission
5. National Mission for Sustaining Himalayan Ecosystem
6. National Mission on Sustainable Habitat
7. Green Indian Mission
8. Nation Mission for Strategic Knowledge for Climate Change

and the concerned ministries would be responsible for developing objectives, implementation strategies, timelines, and monitoring and evaluation criteria.

Post 2008, India’s stand on the climate change debate became convincing at the next Conference of Parties (COP) 15 in Copenhagen in 2009, where India signed the Copenhagen accord with China and accepted legally binding carbon reduction of 20-25 percent and with a low carbon growth strategy. In a landmark decision at COP 17 in Durban (2011) for the first time commitment from all countries were to work out a global legally binding framework to cut emissions. Though the three largest emitters of the world, US, India and China have committed to sign a legal framework to cut emissions, India showed strong resistance. The contribution of this deal will be felt in the long term as it will increase food and water security, provide clean air and would improve livelihood of individuals in the country rather than write their livelihood away. At Durban it was also decided that the Kyoto was to exist until 2017 and during this period, a new legal binding commitment is to be decided to supersede the Kyoto Protocol. India
demand of equitable access to sustainable development for developing countries without being hindered by emission cuts at local level. At the local level there has been much action in the energy sector to mitigate climate change by the government through clean energy projects, there has been a little done to facilitate adaptation and increase resilience of poor and vulnerable communities. Although Gujarat’s image is of high economic growth, it cannot do away with the livelihood needs of the poor, and discharging welfare functions for its citizens. There is a critical need for Gujarat to implement adaptation projects in the agricultural, water resources and coastal zone to increase resilience.

There is scientific evidence that climate change impacts humans across various sectors affecting human health, economy, increasing food and water security and the livelihoods of the poor and vulnerable. There is a need to communicate the causes and the impacts of climate change to increase resilience. The world continues to negotiate a comprehensive international climate agreement and countries begin to implement their national greenhouse gas emission reduction targets as actions under the precautionary principal. Skepticism still remains mainly among those who deny taking responsibility for the climate system, and want to befoul it without looking at implication of their actions. Today there is peer reviewed scientific evidence and new findings are connecting the dots between anthropogenic greenhouse gas emissions and its effects on the natural climate system and the consequence impacts on humans.

1.2 New Scientific Findings

The World Resources Institute (WRI) has put its efforts to understand the functioning of the climate system and its impacts. Since 2005, the WRI has taken up a daunting task of identifying astounding contributions to support climate change science and reduce skepticism. This section will give a few insights on new scientific, peer-reviewed evidence on climate change.

**Physical climate**

New scientific findings have shown that cumulative total anthropogenic carbon emissions need to be limited to one trillion tones if global average temperatures are to remain below the 2°C (range of 1.3–3.9 °C) limit as per temperature increase agreed to in the Copenhagen Accord. Estimates of future warming are more dependent on total anthropogenic carbon emissions than on the realization of a specific stabilization scenario (Allen et al. 2009). It is suggested by Lean & Rind (2009) that short-term climate (2009-2014) trends will show an increase in temperature of 0.150C (+/- 0.03°C), a rate that is 50 percent higher than IPCC projections. However, because of declines in solar activity resulting from the Sun’s natural cycle, the increase from 2014 to 2019 would be 0.03°C (+/- 0.01°C).

**Intensification of hydrological cycle**

According to Allen & Soden (2008) based on a study conducted using models forecast that a warmer atmosphere will hold more moisture and rainfall events will become more common in the tropics. Precipitation events will be more extreme than previously thought. The researchers compared model predictions (using multiple Coupled Model Inter-comparison Project 3 (CMIP3) models) of daily precipitation over tropical oceans with data collected from satellite observations. They found that the observations and model simulations do not match perfectly, with the simulated rate of extreme rainfall events being lower than the observations. The Indian
Ocean Dipole (IOD) is an important driver of tropical weather patterns in the Indian Ocean. The authors suggest that human-induced climate change will lead to a strong interdependency between the IOD and Asian monsoon precipitation variability. IOD events can result in heavy rainfall events in western India (Abram et al. 2008).

**Ecosystem and ecosystem services**

According to a recent study by Carpenter et al. (2008), the resilience of corals will depend upon its ability to adapt, future atmospheric concentrations of carbon dioxide, and the reduction of non-climate stressors, such as eutrophication, sewage discharge, and coastal development. Bleaching events may become so common that the species will be unable to recover and will be pushed to extinction. The loss of coral species will have concomitant impacts on reef-dependent species and, thus, on marine ecosystems and global biodiversity at large. The authors point out that the loss of reef-building corals will have cascading impacts on food security, given that human populations on the order of hundreds of millions depend on reef fish for food sources. In a study it is pointed out that higher temperatures alone will have significant negative effects on crop yields, even without the projected impacts of associated drought. Experimental models of most major grains suggest that the temperature increases that are projected will reduce yields by 2.5–16 percent for every 1 degree C in seasonal temperatures, simultaneously stressing already vulnerable populations in India, China and Indonesia (Battisti & Naylor 2009).

### 1.3 Sine Qua Non

The question in consideration here is *whether the weather is propitious to take action?*

Action to reduce the impending impacts must be taken now. Despite the international scientific community’s consensus on climate change, critics continue to deny that climate change exists or that humans are causing it. There has been agreement in terms of reducing the build-up of greenhouse gases in the atmosphere but limited real action and bitter arguments around negotiations show that the achievements of lasting reduction in greenhouse gas emission will involve more than setting targets. This attitude has been taken to the international negotiations where negotiators use the uncertainty among the risks to avoid making planned responses to adapt and mitigate. Cautious observations about challenges facing governments in reaching decisions on actions to minimize the threat of climate change looks like a cop out.

There is scientific evidence that climate change will affect humans and ecosystems, it is therefore, imperative to mitigate climate change or to adapt to it. Where there is risk with uncertainty of harm being caused to the society and environment, preemptive action needs to be taken. Here the precautionary principle must be enforced so as to reduce these impacts. The Rio declaration of 1992, defines the precautionary principle “in order to protect the environment, the precautionary approach shall be widely applied by States according to their capabilities. Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation (UN General Assembly 1992).

According to the UNFCCC 1992, the ultimate objective of this Convention and any related legal instruments that the Conference of the Parties may adopt is to achieve, in accordance with the
relevant provisions of the Convention, stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system. Such a level should be achieved within a time frame, sufficient to allow ecosystems to adapt naturally to climate change, to ensure that food production is not threatened and to enable economic development to proceed in a sustainable manner. Depending on what is done and how quickly it is implemented, the rate of growth will be slowed, but consequences will become appreciable in the long term.

Action can be taken in two broad forms of mitigation and adaptation. The UNFCCC (n.d.) defines mitigation as “an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases.” Climate adaptation is the, “Adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.” Types of adaptation can be distinguished, as autonomous and planned adaptation. Climate change mitigation is action to decrease the intensity of radiative forcing in order to reduce the potential effects of increased temperature due to increase in greenhouse gases. Adaptation to global warming and climate change seeks to reduce the vulnerability of natural and human systems to climate change effects.

However, if action against climate change is not taken up, and if the climate system warms up more rapidly or reaches a critical level which precipitates a flip, then it could be too late. Actions taken now are bound to concentrate on making economic sense, which may delay global warming and could have additional benefits of reducing risks of extreme events.

Gujarat has taken cognizance of climate change and related impacts it may have on livelihoods, vulnerable population and industry. Under the common but differentiated responsibility, the state has done commendable work to mitigate climate change and has the maximum number of registered projects under the clean development mechanism in India. The state is also gearing up to adapt against climate related impacts through various programmes such as *Krushi Mahotsav*, crop and soil management, integrated coastal zone management, etc.
METHODODOLOGY
2 METHODOLOGY

2.1 PSIR Framework

Society is becoming more concerned with environmental issues. This increased awareness means that there is a willingness to protect the environment and limit the damage caused by human activities. PSIR is a general framework for organizing information about state of the environment. The idea of the framework was however originally derived from social studies and only then widely applied internationally, in particular for organizing systems of indicators in the context of environment and, later, sustainable development (Niemeijer & Groot 2008). Environmental Impact Assessments (EIA) has been made mandatory for planning and decision making from private enterprises to governments and international organizations.

Environmental indicators have come to play a vital role in environmental reporting as they provide signs to communicate complex messages. In recent years, environmental indicators have become a prerequisite component of assessing environmental impacts and reporting the state of the environment in India and various other countries. This has increased the influence of environmental indicators on environmental management and policy making at all scales of decision making as well as monitoring and evaluation (OECD 1999; Niemeijer & Groot 2008).

According to Kristensen (2004), the DPSIR framework is a chain of causal links starting with ‘driving forces’ (economic sectors, human activities) through ‘pressures’ (emissions, waste) to ‘states’ (physical, chemical and biological) and ‘impacts’ on ecosystems, human health and functions, eventually leading to political ‘responses’ (prioritization, target setting, indicators). It obvious that not all issues or themes of a state-of-the-environment report need a full DPSIR presentation, in many cases some aggregation of DPSIR elements will only make them easier to work with and understand. Here for “The State of Climate Change Report” we use a PSIR framework, which is more adapted to the state of environment reporting in India.

The framework assumes cause-effect relationships between interacting components of social, economic, and environmental systems, which are

1. Cause of the problem: **Pressure** (P)
   - Economic, social, institutional or other pressures on the environment that may contribute to or cause particular environmental states

2. Status of the issue: **State** (S)
   - Condition or quality of the environment and trends in that condition brought about by human or other pressures

3. Impact of the issue: **Impact** (I)
   - Effects of the issue on people, environment and economy

4. Response to the issue: **Response** (R)
   - Measures taken by different stakeholders to improve the situation
2.2 Methods, Data Collection and Issues

2.2.1 Climate trend analysis

Methods: Data on mean, minimum and maximum temperatures and annual rainfall were analyzed. For temperature analysis, average of all the seasons was calculated region wise. Seasons considered are spring (March), summer (April, May), monsoon (June, July, August, September), autumn (October, Number) and winter (December, January, February) for the analysis. The trend line has to show the change in climate has been tested for significance. To understand trends 30 years moving point averages have been calculated. These calculations were based on data from 20 stations located at district level and were up-scaled to show five regions. The regions are North Gujarat (Ahmadabad, Banaskantha, Gandhinagar, Mahesana, Patan, Sabarkantha), Central Gujarat (Anand, Dhaod, Kheda, Panchmahal, Vadodara), South Gujarat (Baruch, Dang, Narmada, Surat), Saurashtra (Amreli, Bhavnagar, Rajkot, Surendarnagar). For rainfall annual mean precipitation for the different regions were calculated.

Data Collection: Data on mean, minimum, maximum temperatures for the period of 1901-2001 was collected from India water portal. Similarly rainfall data for 1901-2008 was collected from India water portal and IMD.

2.2.2 Greenhouse gas accounting

Climate change happens due to the increased concentration of greenhouse gases in the atmosphere contributed by natural and anthropogenic activities. Today the level of greenhouse gases in the atmosphere is highest at any given point in time (World Meteorological Organisation.
therefore, the increase in anthropogenic greenhouse gas concentration has affected the climate system through the greenhouse gas effect. For the State of Climate Change Report of Gujarat 2012, efforts were made to inventorise greenhouse gases (CO₂, CH₄ and NOₓ). To estimate the total amount of greenhouse gases emitted from Gujarat the IPCC 2006 guidelines and the Inter Government Panel on Climate Change (IPCC) 2003 guidelines were used for making inventories of greenhouse gases.

The general procedure for calculating GHG emissions from each emission source is as follows:

1. Determine the needed activity data for each emission source
2. Collect the activity data.
3. Select appropriate emission factors based on the activity data
4. Calculate GHGs emissions by gas (i.e., CO₂, CH₄, N₂O, HFCs, PFCs, and SF₆) by multiplying activity data by the appropriate emission factors
5. Convert emissions to metric tons CO₂-equivalent (CO₂e) using each GHG’s global warming potential (GWP) and sum to obtain total emissions

Three methods provided in the IPCC 2006 Guidelines for estimating greenhouse gases. **The Tier 1 Reference Approach** aggregate estimates of emissions by fuel type; whereas the Sectoral Approach allocates these emissions by source category, these values are aggregated. **The Tier 2 and Tier 3** methods provide more detailed results for those countries whose consumption data are collected at a detailed level. Tier 2 and tier 3 give more accurate values.

The procedures for greenhouse gases inventories of the following sectors are given below in detail include data collection, issues and limitations.

**Power Sector**

**Methods:** IPCC 2006 guidelines, calculation done till tier 2.

Tier 2

Emission \( GHG = \text{Fuel consumed}_{\text{fuel}} \times \text{Country specific Emission Factor}_{GHG_{,fuel}} \)

**Data Collection:** Fuel consumption, time of commissions, technology used and efficiency data was acquired from 15 out of the 18 power stations in Gujarat.

**Issues:** Time series data is available only from 2005-2006 onwards. To show emissions form Gujarat’s power sector from 1990 (baseline) default values for coal, lignite and natural gas were acquired from consultations with experts.

**Transport Sector**

**Methods:** IPCC 2006 guidelines for tier 1 for road, rail, water-borne and airways to inventories emissions. For road transportation tier 2 another methodology was used developed on the basis of the IPCC 2006 guidelines, approach of Ramachandra et al. (2009) was used to make the inventory stronger by reaching more accurate values.
Tier 1: Emissions = Fuel consumed \( \text{type of fuel} \) * Default emission factor \( \text{type of fuel} \) (Road, rail, water and air transportation)

Tier 2: Emissions = (Number of vehicles * distance travelled in a year per different vehicle type) * Country specific emission factor (For road transportation)

**Data Collection:** Data was collected from Indian Oil Corporation Limited (IOCL) on fuel consumed by each of the following sectors. Average kilometer travelled by vehicle type was understood by various authors (Mittal & Sharma 2003, CPCB 2007; EEA 2001). Total number of vehicles data was collected from the Directorate of Economics and Statistics, Government of Gujarat.

**Issues:** As far as the waterways are concerned the International bunkers are not considered. Even for the airways and railways, only the emissions are based on the fuelling within the state. Emissions by planes / locomotives, which operate in Gujarat but are fuelled elsewhere, have not been accounted for.

**Industry Sector**

**Methods:** The Intergovernmental Panel on Climate change (IPCC) has come out with a methodology for estimating the emissions from the industry sector under the industrial processes and product use (IPPU) in 1996 and again in 2006 and the Good Practice Guidance 2000. The 2006 IPCC guidelines for National Greenhouse Gas Inventories also provide methods of estimating GHGs from industry sector. According to this the Greenhouse gas emissions are categorized into two types

- non energy emissions
- energy emissions

The non energy emissions are basically due to industrial processes and use of products and the non energy use of fossil fuel carbons, whereas the energy emissions are due to the use of fossil fuels for energy and heat generation during the processes.

Here we consider only those industry types that have a high share in contributing to greenhouses gas emissions in the State. Considering the importance and GHG emission potential, we considered following industries for our study.

- Ammonia production
- Cement
- Textile Manufacturing
- Paper and pulp
- Food Processing

Tier 1 level of emission estimates were achieved for all the industry types and Tier 2 was achieved for the Cement manufacturing industries.

For the textile and food processing industry the emissions based on the fossil fuel consumption for their activities were used to calculate the emissions. All others are based on the non-energy emissions, and were calculated based on their industrial processes.
The Formulae used for calculation of the Greenhouse Gas emissions are as provided by the IPCC 2006 guidelines and the IPCC good practice guidelines of 2003.

**Ammonia Production**

Tier 1

\[ \text{ECO}_2 = \text{AP} \times \text{FR} \times \text{CCF} \times \text{COF} \times (44/12) - R \]

Where,
- \( \text{ECO}_2 \) = Emissions of \( \text{CO}_2 \), Kg
- \( \text{AP} \) = ammonia production, tonnes
- \( \text{FR} \) = fuel requirement per unit of output, GJ/tone of ammonia produced (38.141748GJ as used in the INCCA report 2007)
- \( \text{CCF} \) = carbon content factor of the fuel, kg c/GJ (14.4, INCCA report 2007)
- \( \text{COF} \) = carbon oxidation factor of the fuel, fraction (0.995, INCCA report 2007)
- \( R \) = \( \text{CO}_2 \) recovered for downstream use (urea production), kg

**Cement Manufacturing**: Tier 1 and Tier 2

Tier 1

\[ \text{CO}_2 \text{emissions} = \left[ \sum (\text{Mc}_i \times \text{Cc}_i) - \text{Im} + \text{Ex} \right] \times \text{EFclc} \]

Where:
- \( \text{Mc}_i \) = weight (mass) of cement produced of type \( i \), tonnes
- \( \text{Cc}_i \) = clinker fraction of cement of type \( i \), fraction
- \( \text{Im} \) = imports for consumption of clinker, tonnes
- \( \text{Ex} \) = exports of clinker, tonnes
- \( \text{EFclc} \) = emission factor for clinker in the particular cement, tonnes \( \text{CO}_2 \)/tonne clinker (0.537 tonnes \( \text{CO}_2 \)/tonne of clinker produced, INCCA report 2007)

Tier 2

\[ \text{CO}_2 \text{emissions} = \text{Mc}_1 \times \text{EFcl} \times \text{CFckd} \]

Where:
- \( \text{Mc}_1 \) = Weight (mass) of clinker produced, tonnes
- \( \text{EFcl} \) = emission factor for clinker produced, tonnes
- \( \text{EFcl} \) = emission factor for clinker, tones \( \text{CO}_2 \)/tonne clinker
- \( \text{CFckd} \) = emissions correction factor for CKD, dimensionless
Paper and Pulp:
Pollutant Emitted = Amount of paper produced * Emission Factor

Food Processing:
Pollutant Emitted = Quantity of food produced * Emission Factor

Based on the Fuel consumed
Emissions = Quantity of fuel consumed * Emission Factor for that particular fuel

Textile Manufacturing:
The emissions were calculated based on the fuel consumed
Emissions = Quantity of fuel consumed * Emissions Factor of that particular fuel

Data collection: Data to calculate greenhouse gas emissions from the industry sector was largely collected from Industrial Extension Bureau (iNDEXTb) for large and medium scale industries. The data for various industrial products were also obtained from relevant publications such as that of the Ministry of Chemicals and Fertilizers, Ministry of Petroleum and Natural Gas (MoPNG) etc. The emission factors that are required to estimate the emissions were obtained based on the Indian Network for Climate change Assessment (INCCA) and values which are countries (India) specific. The IPCC default values were used when country specific values were not available. For the Cement industry, data was collected from the Cement Manufacturers Association (CMA), the fuel consumed by the textile and food-processing industry was collected from the Prowess 4 (CMIE database).

Issues: For tier 1 production detail of every industry is required, but is not available. Greenhouse gas emissions calculated using the assumption that every industry can produce to its installed capacity thereby the potential greenhouse gas emission as per installed capacity is calculated. In India, some industries produce above their installed capacity while others produce less. There is no detailed data available for calculation at tier 2 let alone tier 3 levels for the industry mentioned above. The data obtained from Prowess 4 were found to be inadequate and erratic and does not account for all the industries in Gujarat. This is due to the fact that a number of industries were not covered under this database. Another limitation of using this database is industries with their head/registered office in Gujarat were also considered to have their manufacturing units in the State, which is not the case. Hence such industries have also been omitted from greenhouse gas calculations.

Agriculture and Livestock

Rice cultivation

Methods: IPCC 2006 Guidelines are used to estimate the methane emission from rice cultivation. Tier 1 is used by using the default values from 2006 IPCC Guidelines for National Greenhouse Gas Inventories. IPCC, 2003 Good Practice Guidance for Land Use, Land Use Change and Forestry.
Tier 1
Calculation of Daily Emission Factor
EF_i = EF_c • SF_w • SF_p • SF_o • SF_s,r

Where,
EF_i = adjusted daily emission factor for a particular harvested area
EF_c = baseline emission factor for continuously flooded fields without organic amendments
SF_w = scaling factor to account for the differences in water regime during the cultivation period
SF_p = scaling factor to account for the differences in water regime in the pre-season before the cultivation period
SF_o = scaling factor should vary for both type and amount of organic amendment applied
SF_s,r = scaling factor for soil type, rice cultivar, etc.

Calculation of CH\textsubscript{4} from Rice Cultivation

\[ \text{CH}_4\text{rice} = \sum (EF_{i,j,k} \cdot t_{i,j,k} \cdot A_{i,j,k} \cdot 10^{-6}) \]

Where,
CH\textsubscript{4}\text{Rice} = annual methane emissions from rice cultivation, Gg CH\textsubscript{4} yr\textsuperscript{-1}
EF_{i,j,k} = a daily emission factor for i, j, and k conditions, kg CH\textsubscript{4} ha\textsuperscript{-1} day\textsuperscript{-1}; t_{i,j,k} = cultivation period of rice for i, j, and k conditions, day
A_{i,j,k} = annual harvested area of rice for i, j, and k conditions, ha yr\textsuperscript{-1}; i, j, and k = represent different ecosystems, water regimes, type and amount of organic amendments, and other conditions under which CH\textsubscript{4} emissions from rice may vary

Data Collection: Data was collected from Directorate of Agriculture, and reports like Gujarat Agriculture statistics at a glance 2010-11, Irrigation in Gujarat 1997, Irrigation in Gujarat 1999, and Irrigation in Gujarat 2008-09.

Issues: Only irrigated data is used for study as the further classification of Rain-fed/ deep-water area couldn’t be retrieved as detailed level of classification is unavailable.

Burning of Crops

Methods: The 2-step method as laid down by Revised 1996 IPCC Guidelines for National Greenhouse Gas Inventories: Reference Manual was used. Also INCAA (2007) was referred for India specific analysis.

Tier 1
Step 1: Total Carbon release from burning of agricultural residues

\[ \text{Total Carbon released (tones of carbon)} = \sum A \times B \times C \times D \times E \times F \]

Where,
A= Annual production of crop
B= the ratio of residue to crop product
C= the average dry matter fraction of residue
D= the fraction actually burnt in the field
E= the fraction oxidized
F= the carbon fraction
Step 2: Gas Emissions
The amount of carbon released is multiplied by Emission ratios (as given by IPCC, 1996) so as to get the full molecular weights of these gases.

\[
\text{CH}_4 \text{ Emissions} = (\text{carbon released}) \times (\text{emission ratio}) \times \frac{16}{12}
\]

\[
\text{CO Emissions} = (\text{carbon released}) \times (\text{emission ratio}) \times \frac{28}{12}
\]

\[
\text{N}_2\text{O} \text{ Emissions} = (\text{carbon released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times \frac{44}{28}
\]

\[
\text{NO}_x \text{ Emissions} = (\text{carbon released}) \times (\text{N/C ratio}) \times (\text{emission ratio}) \times \frac{46}{14}
\]

**Data Collection:** District wise crop production figures were collected from Directorate of Agriculture, Government of Gujarat. The ratios of residue to crop were taken from IPCC 1996. The dry matter fraction of crop residue is taken from Bhattacharya & Mitral (1998). Fraction oxidized, fraction burnt and carbon fraction value is taken from IPCC 1997.

**Enteric fermentation**

**Methods:** The production of \( \text{CH}_4 \) is mainly calculated under this category. Ruminant livestock (e.g. cattle, buffalo and sheep) and non-ruminant livestock (pigs, horses, ponies etc.) are considered for analysis.

Tier 2: This level of analysis is followed due to availability of country specific emission factors which have been derived from extensive research taking into account gross energy intake, methane conversion factor for specific livestock category.

Formula for Enteric Fermentation emission from livestock category

\[
\text{Emission} = \text{EF}(T) \cdot N(T) \cdot 10^6
\]

Where,

- Emissions = methane emissions from Enteric Fermentation, Gg \( \text{CH}_4 \) \( \text{yr}^{-1} \)
- \( \text{EF}(T) = \) emission factor for the defined livestock population, kg \( \text{CH}_4 \text{head}^{-1} \text{yr}^{-1} \)
- \( N(T) = \) the number of head of livestock species / category \( T \) in the country
- \( T = \) species/category of livestock

Country specific emission factors for the subcategories of livestock population considered for study are taken from India’s Initial National Communication to the United Nations Framework Convention on Climate Change (IINC-UNFCCC 2003)


**Manure Management**

**Methods:** The greenhouse gases emitted from this sector mainly include \( \text{CH}_4 \) and \( \text{N}_2\text{O} \). For \( \text{CH}_4 \) Tier 2 is followed, the \( \text{CH}_4 \) emission factors are obtained from India’s Initial National Communication to the United Nations Framework Convention on Climate Change (IINC-UNFFCCC), 2003. For \( \text{N}_2\text{O} \) Tier 1 is followed. Due to non-availability of country specific emission factors, we relied on factors provided from 2006 IPCC Guidelines for National
Greenhouse Gas Inventories.

Tier 2 (CH₄ Emission Calculation): Country specific emission factors have been derived considering detailed information on animal characteristics and manure management practices which are based on the conditions prevalent in the country.

\[
\text{CH}_4\text{Manure}= \sum (\text{EF}(T) \cdot N(T) \cdot 10^{-6})
\]

Where,

\(\text{CH}_4\text{Manure} = \) Methane emissions from manure management, for a defined population, Gg CH₄ yr⁻¹  
\(\text{EF}(T) = \) emission factor for the defined livestock population, kg CH₄ head⁻¹ yr⁻¹  
\(N(T) = \) the number of head of livestock species/category T in the country  
\(T = \) species/category of livestock

Tier 1 (N₂O Emission Calculation): It is done by taking into account different types of manure management systems.

\[
\text{N}_2\text{O}_{D(mm)} = \left[\sum(\sum(N(T) \cdot N_{ex}(T) \cdot MS(T,S)) \cdot \text{EF}_{3(S)}\right] \cdot 44/28
\]

Where,  
\(\text{N}_2\text{O}_{D(mm)} = \) direct N₂O emissions from Manure Management in the country, kg N₂O yr⁻¹  
\(N(T) = \) number of head of livestock species/category T in the country  
\(N_{ex}(T) = \) annual average N excretion per head of species/category T in the country, kg N animal⁻¹ yr⁻¹  
\(MS(T,S) = \) fraction of total annual nitrogen excretion for each livestock species/category T that is managed in manure management system S in the country, dimensionless  
\(\text{EF}_{3(S)} = \) emission factor for direct N₂O emissions from manure management system S in the country, kg N₂O-N/kg N in manure management system S  
\(S = \) manure management system  
\(T = \) species/category of livestock; 44/28 = conversion of (N₂O-N)(mm) emissions to N₂O (mm) emissions


Landuse Change and Forestry

Forestland remaining forestland

Methods: 2006 IPCC Guidelines are used to estimate the potential annual increase in carbon stocks in biomass (includes above-ground and below-ground biomass) and loss of carbon from wood removal is estimated in the forests of Gujarat. The three main forest types in Gujarat out of the 11 forest types have been re-categorized as per the IPCC types of forest. The calculations were based on the default values provided by IPCC. Both the factors, annual increase in biomass and less of carbon, from wood removal is included in the study.
Step 1: Annual increase in biomass carbon stocks due to biomass increment in land remaining in the same land-use category

\[ \Delta C_G = \sum (A_{i,j}.G_{TOTAL_{i,j}}. CF_{i,j}) \]

Where,
\( \Delta C_G \) = annual increase in biomass carbon stocks due to biomass growth in land remaining in the same land-use category by vegetation type and climatic zone, tonnes C yr\(^{-1}\)
\( A \) = area of land remaining in the same land-use category, ha
\( G_{TOTAL} \) = mean annual biomass growth, tonnes d. m. ha\(^{-1}\) yr\(^{-1}\)
\( i \) = ecological zone (i = 1 to n)
\( j \) = climate domain (j = 1 to m)
\( CF \) = carbon fraction of dry matter, tonne C (tonne d.m.)\(^{-1}\)

Step 2: Loss of carbon from wood removal

\[ L_{wood-removals} = \{H . BCEF_R . (1+R) . CF\} \]

Where,
\( L_{wood-removals} \) = annual carbon loss due to biomass removals, tonnes C yr\(^{-1}\)
\( H \) = annual wood removals, round wood, m\(^3\) yr\(^{-1}\)
\( R \) = ratio of belowground biomass to aboveground biomass, in tonne d.m. below-ground biomass (tonne d.m. above-ground biomass)\(^{-1}\)
\( CF \) = carbon fraction of dry matter, tonne C (tonne d.m.)\(^{-1}\)
\( BCEF_R \) = biomass conversion and expansion factor for conversion of removals


Issues: Further analysis on loss of carbon due to fuel wood removal and loss of carbon from disturbances such as forest fires etc. could not be done to unavailability of data.

Cropland remaining cropland

Methods: 2006 IPCC Guidelines for national greenhouse gas inventories have been used the calculations are undertaken by using the default values from the same. The analysis has been conducted by using data on the woody crops like cotton, sugarcane, castor, mango, chiku, citrus, ber bean, guava and pomegranate. This is done to analyze the loss of carbon/ minerals due to the growth of perennial woody crops grown in the state. The study covers annual charge in carbon stocks in biomass as well as annual change in carbon stocks in mineral soils.

Step I: Annual change in carbon stocks in biomass

\[ \Delta C_B = A \ast (\Delta C_G - \Delta C_L) \]

Where,
\( \Delta C_B \) = annual change in carbon stocks in biomass for each land sub-category, considering the total area, tonnes C yr\(^{-1}\)
\( \Delta C_G \) = annual increase in carbon stocks due to biomass growth for each land sub-category, considering the total area, tonnes C yr\(^{-1}\)
\( \Delta C_L \) = annual decrease in carbon stocks due to biomass loss for each land sub-category, considering the total area, tonnes C yr\(^{-1}\)

Step II: Annual change in carbon stocks in mineral soils

\[
SOC = \sum (SOC_{REF,c,s,i} \cdot F_{LU,c,s,i} \cdot F_{MG,c,s,i} \cdot F_{Ic,s,I} \cdot A_{c,s,i})
\]

Where,
\( \Delta C_{\text{Mineral}} \) = annual change in carbon stocks in mineral soils, tonnes C yr\(^{-1}\)
\( SOC_0 \) = soil organic carbon stock in the last year of an inventory time period, tonnes C
\( SOC_{(0-T)} \) = soil organic carbon stock at the beginning of the inventory time period, tonnes C
\( T \) = number of years over a single inventory time period, yr
\( D \) = Time dependence of stock change factors
\( c \) = represents the climate zones, \( s \) the soil types, and \( i \) the set of management systems that are present in a country.
\( SOC_{REF} \) = the reference carbon stock, tonnes C ha\(^{-1}\)
\( F_{LU} \) = stock change factor for land-use systems or sub-system for a particular land-use
\( F_{MG} \) = stock change factor for management regime
\( F_{I} \) = stock change factor for input of organic matter
\( A \) = land area of the stratum being estimated, ha

**Data Collection:** Department of agriculture, Department of Horticulture, and Statistical Reports for Gujarat state, were the major source of data.

**Issues:** Annual change in carbon stocks in organic soils analysis could not be done due to non-availability of data.

**Waste sector**

**Methods:** The waste sector is covered under the Volume 5 of the 2006 IPCC Guidelines. The major gases that can be estimated in this sector are methane (CH\(_4\)) and nitrous oxide (N\(_2\)O). The following classes are considered for the estimation of greenhouse gases
- Solid waste disposal
- Incineration and open burning of waste
- Domestic wastewater treatment and discharge

The IPCC provides a default method, which gives a reasonable annual estimate of actual emissions. The Formulae used for calculation of the greenhouse gas emissions are as provided by the IPCC 2006 guidelines and the IPCC good practice guidelines of 2000
Domestic Wastewater:
Tier 1

\[ \text{CH}_4 \text{ emissions} = [\sum (U_i T_{ij} E_{Fj})](\text{TOW} - \text{S}) - \text{R} \]

Where,
Methane (CH4) Emissions = Methane (CH4) emissions in the inventory year, Kg CH4/yr
TOW = total organics in wastewater in inventory year, Kg BOD/yr
S = organic component removed as sludge in inventory year, Kg BOD/yr
U_i = fraction of population in income group I in the inventory year
T_{ij} = degree of utilization of the treatment/ discharge pathway or system j, for each income
    group fraction I in inventory year
I= income group: rural, urban high income and urban low income
J = each treatment/discharge pathway or system
E_{Fj} = emission factor, Kg CH4/Kg BOD
R = amount of CH4 recovered in inventory year, Kg CH4/yr

**Data collection:** Solid waste and domestic waste water data has been collected from Gujarat
Urban Development Company (GUDC).

**Issues:** Data pertaining to industrial waste water and incinerated waste is unavailable in the
format required for greenhouse gas inventory from the pollution control boards. Moreover time
series data is unavailable thereby calculation of greenhouse gases over a period is limited.

**Residential sector**

**Methods:** IPCC 2006 methodology is used for tier 1 level of emission inventory. For this sector
basically emissions due to energy use have been considered. Though residential sector uses
electricity intensively, it has been included in the calculations to avoid double counting. This is
so because emissions from electricity have been taken care of in the power sector. Here, mainly
consumption of kerosene, LPG, and biomass is taken into account.

Tier 1

\[ \text{Emission}_{\text{GHG}} = \text{Fuel consumed}_{\text{fuel}} \times \text{Country specific Emission Factor}_{\text{GHG, fuel}} \]

**Data Collection:** Data on LPG and Kerosene has been collected from IOCL and consumption of
biomass per person is a national default value of 27.75 kg per person per year, which is provided
by a study by Centre for Study of Science, Technology and Policy (CSTEP 2011).

**Issues:** No certain or fixed methodology provided
2.2.3 Impact analysis

**Methods:** Documentation of observed impacts in Gujarat is done through literature review. Future trend in climate change is established from literature of regional climate models. Exhaustive literature review has been conducted to understand potential climate impacts.

**Data collection:** Exhaustive literature review

2.2.4 Response analysis

**Methods:** Responses are analysed under the broad headings of ‘Mitigation’ and ‘Adaptation’. Documentation of responses made by state, private and civil society organizations is done under three domains of (i) institutional changes (ii) technological changes, and (iii) capacity building. Potential responses for future trends in climate will are also identified.

**Data collection:** Exhaustive literature review

The data sources and the type of data used to measure GHGs emissions are given in table 1.

<table>
<thead>
<tr>
<th>Sector</th>
<th>Data Type</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Agriculture and Livestock</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice Cultivation</td>
<td>Annual harvested area, Cultivation period of the rice</td>
<td>1989-90, 1994-95, 2004-05</td>
<td>Directorate of Agriculture, Government of Gujarat</td>
</tr>
<tr>
<td>Land Use and Forestry</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cropland remaining cropland: Annual change in carbon stock</td>
<td>Area under crop</td>
<td>1990-2010</td>
<td>Directorate of Agriculture</td>
</tr>
</tbody>
</table>
| Forestland remaining forestland       | Area of forest land remaining forest land      | 1990-2010                   | Monitoring and Evaluation Cell, Forest Department, Gujarat}
<table>
<thead>
<tr>
<th>Category</th>
<th>Description</th>
<th>Year</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Waste</strong></td>
<td>(Domestic waste water)</td>
<td></td>
<td>Gujarati Urban Development Company (GUDC)</td>
</tr>
<tr>
<td></td>
<td>Income group, Discharge pathway or system, Degree of utilization of the treatment/discharge pathway or system for each income group.</td>
<td>2010</td>
<td></td>
</tr>
<tr>
<td><strong>Residential</strong></td>
<td>Fuel Consumption in terms of Liquefied Petroleum Gas, Kerosene</td>
<td>2005-2010</td>
<td>Indian Oil Corporation Limited</td>
</tr>
<tr>
<td></td>
<td>Biomass Consumption (National default value)</td>
<td>2005-2010</td>
<td>Center for study of Science, Technology and Policy</td>
</tr>
<tr>
<td><strong>Industry</strong></td>
<td><strong>Cement</strong></td>
<td>1992-2009</td>
<td>indextb, Cement Manufacturers Association</td>
</tr>
<tr>
<td></td>
<td>Installed Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Paper and Pulp</strong></td>
<td>1990-2007</td>
<td>indextb</td>
</tr>
<tr>
<td></td>
<td>Installed Capacity</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Food Processing</strong></td>
<td>1989-2011</td>
<td>Center for Monitoring Indian Economy</td>
</tr>
<tr>
<td></td>
<td>Fuel Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Textile Manufacturing</strong></td>
<td>2009</td>
<td>Center for Monitoring Indian Economy</td>
</tr>
<tr>
<td></td>
<td>Fuel Consumption</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Ammonia Production</strong></td>
<td>2005</td>
<td>Department of Fertilizers, Government of India</td>
</tr>
<tr>
<td></td>
<td>Production</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Power</strong></td>
<td>Coal &amp; Gas based power generation</td>
<td>2006-2009</td>
<td>15 power stations</td>
</tr>
<tr>
<td></td>
<td>Fuel Consumption, Time of consumption, Technology used and Efficiency</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td>Fuel consumption</td>
<td>2006-2009</td>
<td>Indian Oil Corporation Limited</td>
</tr>
</tbody>
</table>

Director of Economics and Statistics, Government of Gujarat
PRESSURES
3 PRESSURES

Climate change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. The industrial revolution in the 19th century saw the large-scale use of fossil fuels for industrial activities. This also prompted extensive use of natural resources for construction, industries, transport, and consumption. Consumerism (our increasing want for material things) has increased by leaps and bounds, creating mountains of waste. All this has contributed to a rise in greenhouse gases in the atmosphere. Human activities contribute to climate change by causing changes in Earth’s atmosphere in the amounts of greenhouse gases, aerosols (small particles), and cloudiness. The largest known contribution comes from the burning of fossil fuels, which releases carbon dioxide gas to the atmosphere. It has been stated by the IPCC (2007), that global atmospheric concentrations of carbon dioxide, methane and nitrous oxide have increased remarkably as a result of human activities since 1750 and now far exceeded pre-industrial values determined from ice cores spanning many thousands of years.

Scientific consensus has identified carbon dioxide (CO$_2$) as the dominant greenhouse gas forcing. Methane and nitrous oxide are also major forcing contributing to the greenhouse effect. The global increases in carbon dioxide concentration are due primarily to fossil fuel use and land-use change, while those of methane and nitrous oxide are primarily due to agriculture that acts as pressures on the climate system. Greenhouse gases and aerosols affect climate by altering incoming solar radiation and out-going infrared (thermal) radiation that are part of Earth’s energy balance. Anthropogenic emissions are changing the atmospheric abundance, or properties of these gases and particles can lead to a warming or cooling of the climate system. It is now evident that the warming of the climate system is unequivocal, evident from observations of increases in global average air and ocean temperatures, widespread melting of snow and ice and rising global average sea level (IPCC 2007). Gujarat’s rapid economic growth is serving the purpose of being a climate forcing. There is a need to reduce the pressure on the climate system and hence mitigate adverse impacts. India needs to reduce its carbon intensity by 20-25 percent below 2005 levels by 2025; therefore it is essential that Gujarat reduce its carbon intensity by 20-25 percent under the principle of common but differentiated responsibilities. To understand the level of emission reduction there is a need to identify the total amount of emission from the state. This section tries to quantify the total greenhouse gases emitted from Gujarat. The sectors that contribute to major anthropogenic emissions are considered for such quantification. These emissions that act as pressure on the climate system are discussed below.

The sectors for which GHG emissions are calculated are maintained in the following sections. Data used for the calculation of GHGs are given in the table along with the sources.

3.1 Power Generation

The energy systems of most economies are majorly driven by combustion of fossil fuels, namely: coal; oil, natural gases, etc. the burning of fossil fuels oxidises the carbon in it thus producing carbon dioxide. The carbon gets converted to CO, CH$_4$ etc. which gradually get oxidised to
CO₂ over the years. In 2007, the energy sector in India emitted about 1100.06 million tonnes of CO₂ equivalent. Approximately 65.4 percent of the emissions of the energy sector were from the electricity produced (INCAA 2009). Gujarat is self sufficient in energy production. The emission from 15 power plants spread over Gujarat in the last half decade is also analysed. This is based on the actual coal/lignite/ oil consumption by the individual power plants (see Figure 2-3). A point worth noting is that the power sector in Gujarat initially heavily depended on coal. But there has been a shift from coal to gas based power generation due to dynamic policies encouraging use of cleaner fossil fuels. Other sources like solar, wind and nuclear power plants are also growing appreciably in Gujarat. It was inferred from the analysis of 15 power generation units, that the total generation from the coal-based power plants is 3770 MW whereas that from gas-based units is 2398 MW. Data of about 1800 MW of generation form coal based power plants has not been taken into account, due to unavailability of data. This also indicates that the Government of Gujarat has been proactive in advancement in gas-based power generation. Fuel switching to gas, enables to reduce the forcing applied on the climate system due to coal fired power plants.

Figure 2: Emissions from Gas based Power plants, based on actual fuel consumption
3.2 Transportation

Transportation sector emissions include all greenhouse gas emissions from road transport, railways, aviation and navigation. It is estimated in the last INCAA report for the year 2007, that the transport sector in India emitted 142.04 Tg of CO$_2$ equivalents (INCAA 2009). Of this approximately 87 percent contribution was by the road sector. Analysis of greenhouse gas emissions from the transport sector show that the state’s industrially and economically advanced status contributed maximum compared to the other states. The average emission for the country is 6.9 Tg of CO$_2$ in the year 2003-04. The total CO$_2$ emission for the Indian transport was 258.10 Tg in 2003-04, of which 94.5 percent is contributed by the road sector alone. Talking of road transport among all the states Gujarat stood just the third with 23.31 Tg after Maharashtra (28.85 Tg) and Tamil Nadu (26.41 Tg) (Ramachandran 2009).

The share of emission from the transportation sector is shown in 5 for Gujarat. Railways, roadways, waterways and airways contribution to the total emissions from this sector can be understood herein. Road transport has the major share and is the most significant one covering approximately 92.5 percent. This is because large number of masses is dependent on the roadways for their passenger as well for goods movement over the years.
The total emission from the entire transportation sector in Gujarat comes to ~32.30703Tg when the cumulative emissions from the year 2006 to 2008 are calculated. The trend of emissions is seen to be increasing over the time (Figure 5).

Figure 5: Total emissions from the transport sector from the years 2005-2008
Roadways
The roadways continue to be the significant contributor in these emissions. The decadal emission trend from roadways has been analysed. Figure 6 shows how the emissions from the transport sector have grown exponentially over the years due to rapid economic growth.

Figure 6: Decadal growth of Carbon dioxide emissions from road transport sector in Gujarat

The contribution of various vehicles to this emission can be shown in Figure 7. It is seen that over the years the share of two wheelers has increased substantially, and so have their emissions.

Figure 7: Contribution of each vehicle type to the Carbon dioxide emissions in roadways
Next, consumer preference of vehicle use was analyzed; it is found that the pattern has changed over the last 46 years. As shown in the Figure 8, there has been a significant shift in the mode of travelling. The share of two wheelers dominates road transport. This shift indicates a growing preference for private conveyance over public transportation. One of the major mitigation potentials for climate change in this sector is a modal shift to public transportation, with an intention to burn less fuel as population increases. Figure 8 shows that for Gujarat, the share of two wheelers has increased over the years, while the proportion of buses shows a substantial decline. On comparison of the number of buses on road, with their emissions a similar trend is seen, i.e. the rate of decrease of buses on road and the rate of decrease in contribution of buses to emissions is the same.

Figure 8: Vehicle population in Gujarat 1960-2006

District-wise analysis of emissions was done to understand the spatial pattern. For 2006, Ahmadabad overshot the emissions as compared to all the other districts; so much so that district Surat registered only half of Ahmadabad. It can be assumed that this trend is due to the fact that these districts comprise the economic engines of the state.
Figure 9: District-wise GHG emissions (tera grams) from road and off-road transport, 2006

**Railways:**
There is increasing trend seen in the emissions by the railways. The total emissions amount to 0.507889 Tg CO$_2$ equivalent over the entire time frame under consideration.
**Waterways:**

It has been suggested by the Committee on Climate Change (n.d.) that emissions from shipping currently account for 3 percent of total global emissions, (1.1 Gt CO$_2$). They have increased rapidly in recent years, driven by growth in international trade, and are projected to grow by 3 percent per annum till 2050. Around 80 percent of shipping emissions are due to international shipping, and are therefore not included in country-level emissions inventories and associated emission reduction targets. For Gujarat, we take into account the fuel consumed by water-borne transport sector. International bunkers are not taken into account for greenhouse gas emissions. The emissions sum up to a total of 0.393586 Tg, and show a rising trend over the years (Figure 11)

Figure 11: Emissions from the waterways sector from 2005-2008
Airways:
Aviation is responsible for 2 percent of global man-made CO$_2$ emissions – but it is a small part of a major problem of climate change (IATA 2009). The emission estimates are based on the ATF sold in the state alone for the years 2005 to 2007-08, the emissions add up to 0.921069Tg during 2005-06 to 2007-2008 shown in figure 12.

Figure 12: Emissions from the Airways sector from 2006-2008

3.3 Industry Sector
The International Energy Agency (2007) has suggested that industries account for nearly a third of the world’s energy consumption and 36 percent of the CO$_2$ emissions. Chemicals, petrochemicals, iron and steel, cement and paper and pulp account for more than two-thirds of this amount. In the developing countries the use of energy has grown by 61 percent between 1971 and 2004. The major gases emitted by the industry sector are CO$_2$, CH$_4$, and N$_2$O. The INCCA (2007) report has indicated that the CO$_2$ equivalent emissions from the industrial sector (cement, ammonia production, paper and pulp, food processing and textiles) of India to be 174.80997 Tg out of which the individual contribution of these industrial sectors is as given below

- Cement: 129.92 Tg
- Ammonia production: 10.05643 Tg
- Paper and pulp: 5.24835 Tg
- Food processing: 27.71725 Tg
- Textiles: 1.86794 Tg
Industrial development in Gujarat
At the time of its inception, the State’s industrial development was majorly confined to four major cities, namely, Ahmadabad, Vadodara, Surat and Rajkot and some isolated locations. Today almost every district of the state has witnessed industrial development in varying degrees. Gujarat has shown impressive industrial development since its formation in 1960. This was possible only by the judicious exploitation of the natural resources such as minerals, oil and gas, marine, agriculture and animal wealth. Gujarat has diversified its industrial base from textiles and auxiliaries in 1960-61 to 12 major industry groups. This comprises over 1200 large and 345000 micro, small and medium industries. Gujarat accounts for 19.69 percent of India’s fixed capital investment and added 15.35 percent of the net value in the industrial sector. The discovery of oil and gas in the 60s played an important role in setting up of petroleum refineries, fertilizer and petrochemical complexes. In the recent years, the refined petroleum products have emerged as one of the largest industrial groups having 33 percent followed by chemicals having 21 percent of the total share. This is followed by the food products (8.5 percent), textiles and apparel (6.9 percent) and paper and pulp products (1.1 percent) (Industries Commissionerate n.d.). The products considered for the study include those, which have a substantial contribution in terms of production to the industrial sector of India. The State’s contribution in terms of production in India is ammonia fertilizers (19.5 percent), textiles (34 percent), refined petroleum (33 percent) and cement (10 percent) (Industries Commissionerate n.d.)

The following section deals with the calculation of the GHG estimates from ammonia production, cement manufacturing, paper and pulp industry, food processing and textile industry

Ammonia Production
The major greenhouse gas emitted from ammonia fertilizer production is CO₂. The state has seven large-scale plants that contribute to significant emissions from this sector. The total emission for the year 2005 is found to be 5.16 Tg; the value is after subtracting the CO₂ removed during urea production. The 13 show a secular increase in the emissions from ammonia production.

Figure 13: Carbon dioxide emissions from ammonia production in Tera grams

![Figure 13: Carbon dioxide emissions from ammonia production in Tera grams](chart)
The emissions from the individual plants considered for calculating the emissions from ammonia production based on the data provided by the reports of the Department of Fertilizers (GoI) are as shown in Figure 14. It is seen that the plant in Kandla emits the highest with 41.9Tg for the past 10 years.

Figure 14: Plant wise Carbon dioxide emissions from ammonia production in Tera grams for the period 2000-2010

Cement Industry
The State’s cement production accounts for 10 percent of the total production of India. The major greenhouse gas emitted from manufacturing of cement is CO₂. The emissions are calculated from two data sources (the installed capacity from indextb (Tier 1) and based on the Cement Manufacturers Association (CMA) (Tier2). The emissions are calculated for those cement industries that are registered with the CMA during the year 2008-2009 and are estimated to be 8.55 Tg. The emission based on the installed capacity of the state for the year 2009 is found to be 8.74 Tg. The Figure 15 shows a comparison with the increasing emissions with the number of industries. A secular trend is seen with the increase in the emissions and the number of industries.
Figure 15: A comparison of the emissions in tera grams and the number of cement industries

The Figure 16 shows the emissions from the cement industry from 1992 to 2009 shows that there is an increase in the emissions of CO₂ from the cement industries with a coefficient of regression of 0.568.

Figure 16: Figure showing the emissions from the cement industry in Tera grams

The district wise emissions based on the installed capacity from the cement industry are as shown in the Figure17. Kutch has the highest percentage of emissions of 39.06 percent followed by Amreli 33.78 percent and Junagadh 11.90 percent.
Textile Industry
The textile industry accounts for 34 percent of the total production of the country. The emissions are based on energy consumption by the textile industries of the state. The major greenhouse gases that are emitted from this sector are CO₂, CH₄ and N₂O. The total emission from this sector is based on the fuel consumption data from Prowess 4 (CMIE database). The major fuel types used are gas, natural gas, furnace oil and diesel. Apart from this, the emissions from coal (0.12 percent) and gas (0.06 percent) whose contributions are negligible. The emissions based on the Prowess 4 database are found to be 11.89 Tg of CO₂ equivalents, of which gas has the highest share of 62 percent (7.36 Tg) followed by furnace oil, 24 percent (2.80 Tg), diesel, 14 percent (1.70 Tg).
Ahmadabad contributes to 29.72 percent (3.531Tg) followed by Bharuch 24.56 percent (2.91Tg) and Surat 20.98 percent (2.49Tg).

Figure 19: District wise Carbon dioxide equivalent emissions from the textile industries
Paper and Pulp
The emissions from the paper and pulp industry are CO$_2$ and N$_2$O. These are calculated based on the **installed capacity** in the State. The total emission from the year 1990-2007 is calculated to be 0.45Tg. The Figure 20 shows that there is an increase in the emissions with the increase in the number of industries. The coefficient of regression is given to be 0.955.

Figure 20: Figure showing rise in emissions corresponding to rise in the number of industries

![Graph showing emissions from 1990 to 2007 with a coefficient of regression of 0.955.]

It can be seen from the Figure 21 the increase in the emissions during the period 1990 to 2007 with a coefficient of regression of 0.878.

Figure 21: Carbon dioxide equivalent emissions in Tera grams from the paper and pulp industries

![Graph showing emissions from 1990 to 2007 with a coefficient of regression of 0.878.]

The district wise contribution from the paper and pulp industry is as shown in Figure 22; with Valsad having the highest share of 81.9 percent followed by Bharuch 6.32 percent.
Figure 22: Percentage contribution from the paper and pulp industry to the emissions for the years 1990-2007

**Food Processing**
The emission from the food processing industry on the basis of installed capacity for the year 2011 is calculated to be 0.00033Tg. The Figure 23 shows an increase in the emissions with the year with a coefficient of regression of 0.645.
The emission from the food processing industry is calculated based on the fuel consumption. Calculations done on the data obtained from Prowess 4 (CMIE database) shows that the furnace oil contributes to 97 percent (20.95 Tg) of the CO$_2$ equivalent contributed by the sector, followed by firewood (1.34 percent, 0.29 Tg), coal (1.04 percent, 0.222 Tg), and diesel (0.64 percent, 0.136 Tg). The emissions from gas and lignite are meager.

Figure 24: Contribution of individual fuels to emissions from the food processing industry
3.4 Agriculture and Animal Husbandry

Rice Cultivation
The contribution of agriculture to anthropogenic greenhouse gas emissions is about one-fifth of the annual increase in emissions and rice cultivation is accredited as one of the most important contributors of anthropogenic methane. Methane emissions from rice cultivation are not only majorly determined by water regime and organic inputs, but are also influenced by soil type, weather, tillage management, residues, fertilizers, and rice cultivar. Recent assessments of methane emissions from irrigated rice cultivation in Gujarat estimate global emissions for the year 2000 at a level corresponding to 625 million metric tons of carbon dioxide equivalent (CO\textsubscript{2}e). Rice environments with an insecure supply of water, namely rain-fed rice have a lower emission potential than irrigated rice.

Organic inputs stimulate methane emissions as long as fields remain flooded. Therefore, organic inputs should be applied to aerobic soil to reduce methane emission. In addition to management factors, methane emissions are also affected by soil parameters and climate. Rice soils that are flooded for long periods of the year tend to accumulate soil organic carbon, even with complete removal of above-the-ground plant biomass. Significant input of carbon and nitrogen is derived from biological activity in the soil–floodwater system, and conditions are generally more favorable for the formation of conserved soil organic matter (Wassmann, Hosen & Sumfleth 2009). Analysis of three points of time has been done to estimate the emission of rice cultivation in Gujarat state for the years being 1989-90 (baseline), 1994-95 and 2003-04. The state wide yearly emission graph shows that there has been marginal rise in emission from 1989-90 to 2003-04 with total emission of the state ranging from 0.000364758 Tg CH\textsubscript{4} yr\textsuperscript{-1} to 0.000502529 Tg CH\textsubscript{4} yr\textsuperscript{-1}, which is negligible, compared to India statistics.

Figure 25: Yearly emissions from rice cultivation
The district wise analysis shows that Kheda contributes maximum to CH₄ emissions from irrigated rice cultivation. The highest was calculated for the year 1994-95 i.e. 0.0001456 TgCH₄/yr followed by Ahmadabad 0.000084867443 TgCH₄/yr.

Figure 26: District wise emissions of year 1994-95 to 2003-04 identify the district contributing the most to methane emission

The calculated emissions have shown a considerable increase from 1994-95 to 2003-04. Mainly attributed to the fact that policy interventions and increase irrigation system have been put into place in the state due to which the production has gained with more usage of water. Kheda contributes to maximum emission of 0.00000960954 Tg CH₄ yr⁻¹ in 2003-2004 followed by Ahmadabad with 0.00008264208 TgCH₄/Yr.

**Burning of Crop Residue**

Crop residues are generally left in the field after the crops are harvested and threshed. Though most of the crop residues are fed to the animals, burning of crops residue is also in practice mainly in areas with high yield potential. As the crop residues may interfere with tillage and seeding operations for the next crop, many farmers prefer to burn the residues left in the field. India produces about 500 million tons (Mt) of crop residues annually. Processing of agricultural produce through milling and packaging also produces substantial amount of residues. Many Indian states like Uttar Pradesh, Punjab, West Bengal, Haryana, Bihar, Madhya Pradesh, Himachal Pradesh, Maharashtra, Gujarat, Chhattisgarh, Jharkhand, Tamil Nadu, Uttaranchal and Karnataka are reported of burning agricultural crop residues which is responsible for producing gases like CO, CH₄, N₂O, NOₓ, NMHCs, SO₂ and many others.

According to INCAA (2010), 0.23 million tons of CH₄ and 0.006 million tons of N₂O were emitted from burning of crop residue in India in 2007. It has been reported that 40 to 80 percent of the nitrogen in wheat crop residue is lost as ammonia when it is burnt in the field. The ash left on the soil surface after burning crop residues causes an increase in urea activity and may cause
nitrogen losses from soil while applied fertilizer residue burning can have a beneficial short-term effect on the nitrogen supply to subsequent crops, but has negative long-term effects on overall nitrogen supply and soil carbon levels.

GHGs emissions were calculated for crops like rice, wheat, millet, maize, sugarcane, cotton and mustard crops (the crops rice, wheat, millet, maize are considered from revised 1996 IPCC Guidelines, whereas sugarcane, cotton and mustard are taken due to their high production and also referring to literature). An increasing trend in emission of CH$_4$and N$_2$O was observed in the 4 years time interval for analysis. In 1991-92 the estimated CH$_4$ release was 0.001248 million tones and 0.0000934 million tonnes of N$_2$O which increased to 0.004651 million tonnes of CH$_4$and 0.000348212 million tonnes of N$_2$O by the year 2005-06. This increase is mainly due the fact that the production of crops considered for analysis have increased leading to increase in crop residues and followed by traditional on field burning practiced in several parts of the state.

District level emission of 2009-10 show that Rajkot contributes to maximum emission of 708.8434 tonnes of CH$_4$ and 53.068 tonnes of N$_2$O followed by Surendranagar with 573.65 tonnes of CH$_4$ and 42.94 tonnes of N$_2$O.
Enteric Fermentation
Gujarat livestock population is the 11th largest in India as suggested by the 2003 livestock census and the total population according to 2007 census being 23793513; therefore an analysis on this area stands crucial. Livestock is also an important source of methane emission. Livestock’s impact on climate change is mainly due to the process called ‘Enteric Fermentation’. Ruminant like cattle, buffalo, sheep, goat and camels produce significant amount of methane under anaerobic conditions as part of their normal digestive process. The microbial fermentation process referred to as enteric fermentation produces methane, which is generally released by eructation, normal respiration and small quantity as flatus. At India level 9.65 million tons of methane was estimated emission in the year 2004 (NATCOM 2007), which is 96 percent of the total emissions from the agricultural sector. Buffaloes are the highest producers of methane emissions in the livestock sector accounting to nearly 60 percent of the total emissions.

Analyzing the data of past three livestock census (1997, 2003 and 2007) it has been observed that in 1997 the total emission calculated is 0.023906868 TgCH₄/yr. The emissions in the subsequent years have increased from 0.022591 TgCH₄ yr⁻¹ as calculated in 2003 to 0.057192 Tg CH₄ yr⁻¹ in 2007. The high emission is mainly due the reason that the state is highly dependent on its milk production that contributes to the economic and agriculture progress.

Figure 28: Methane emissions from Enteric Fermentation

![Methane emission from Enteric Fermentation](image)

The following Figure shows that the contribution of buffaloes in Gujarat is half compared to other species.
Figure 29: The contribution of various species of livestock towards Enteric Fermentation (Figure prepared by taking into account the statistics of year 2007)

Figure 30: District wise emissions form Enteric Fermentation 2007
Mehsana buffaloes are one of the best milk breeds of buffaloes in India (Pundir & Sahana et al. 2000). An analysis of the livestock census of three consecutive years has shown a remarkable increase in this species in Gujarat. Looking at the district wise emissions of 2003 Sabarkantha with 0.001819 TgCH₄/yr and Banaskantha with 0.001749 Tg CH₄/yr are the leading emitters, mainly due to the dependence on livestock for agriculture and dairy purposes. Another reason for the livestock species increase in the past years particularly in Sabarkantha and Banaskantha is attributed to better management practices, utility of breed, animal housing, calf management, feeding and genetic characterization.

**Manure Management**
Manure from livestock is a huge contributor of greenhouse gas mainly methane and nitrous oxide. Methane is generally emitted during the anaerobic decomposition of organic matter mainly during storage whereas nitrous oxide is emitted during storage and soil application. Temperature, oxygen level (aeration), moisture and sources of nutrients are other factors that affect GHG emission from manure. The estimation of emission from manure management takes into account manure type, diet, storage, handling of manure (pile, anaerobic lagoon, etc.) and manure application (injected, incorporated, etc.). Methane emission from manure management tends to be generally lesser than that of enteric fermentation, also confined animal management operations contribute towards more substantial emissions where manure is mainly handled with liquid based systems. Nitrous oxide emissions is much more complex and may vary significantly between types of manure system used and can also result in indirect emissions due to nitrogen loss of the system (IPCC 2006).

According to INCAA Report (2010) manure management is not systematically followed in India. Manure is mainly used for energy purposes by preparing dung cakes. It is estimated that about 0.0115 million tonnes of CH₄ and 0.07 thousand tones of N₂O are emitted from manure management. An analysis for CH₄ emissions from manure management was done for Gujarat state. Emissions have tend to show an increase from 1997 to 2007 due to both increase in livestock population and also due to preferable breeding of buffaloes and crossbred cattle species to gain more economic benefit through them. The CH₄ emissions are accounted as 0.002020 TgCH₄/yr⁻¹ in 1997, 0.002103382 TgCH₄ yr⁻¹ in 2003 and 0.005476 Tg CH₄ yr⁻¹ in 2007 respectively.
Figure 31: CH$_4$ emissions from manure management

![Bar chart showing CH$_4$ emissions from manure management in Tg from 1997 to 2007.]
Figure 32: CH₄ emission from Manure management district wise in Gujarat 2007 where the highest emissions observed in Dahod

Also a state specific estimation of N₂O was calculated using the IPCC 2006, Tier 1 approach by taking into account management of manure practices prevalent in India and specifically in Gujarat state. The N₂O emissions are comparatively very less as compared to CH₄ emissions mainly due to the fact that proper management systems are still not prevalent in the state, which makes it possible to account emissions completely. The emissions are estimated for the three years considered for analysis are 6256817.228 Kg N₂Oyr⁻¹ in 1997, 16149562.2 Kg N₂Oyr⁻¹ in 2003 and 16871733.235 Kg N₂Oyr⁻¹ in 2007.
Figure 33: Emission of N$_2$O through manure management in Gujarat (for years 1997, 2003 and 2007)

![Emission of N$_2$O in Gujarat through Manure Management](image1)

Figure 34: Emissions of N$_2$O district wise with the highest being reported in Banaskantha

![Nitrous Oxide Emission through Manure Management (2007)](image2)
3.5 Land-use and Forestry

Cropland Remaining Cropland
The main purpose of this analysis is to estimate the annual greenhouse gas emission and removal estimation by calculating annual change in carbon stocks in biomass and annual change in carbon stocks in mineral soils. The biomass change helps us to estimate the carbon storage done by perennial woody biomass and change in carbon stocks in mineral soils help us estimate how different management practices impact the carbon storage potential of different soil types.

The annual change in carbon stocks in biomass in Gujarat for 2010, considering a 20-year period for main crops and 10 year for fruit crops, is 111451.32 tonnes C yr\(^{-1}\). Also taking into account the same timeframe for annual change in carbon stocks in mineral soils is estimated as 5428076.161 tonnes C yr\(^{-1}\), which is mainly governed by different management practices applicable in the state.

Figure 35: Annual Change in Carbon stock in biomass in Gujarat state
Forestland remaining Forestland
Analysis on the forests of Gujarat was done district wise for the year 2008-09. Forests have both negative and positive climate feedbacks, positive contribution is mainly due to the sequestration of carbon in biomass and negative impact is mainly due to anthropogenic/natural activities like wood removal/cutting or forest-fires. For this the annual increase in carbon stocks in biomass (including aboveground and belowground biomass) was calculated.

Figure 37: Forest distribution in Gujarat according to IPCC classification of forest types
Annual increase in biomass carbon stocks due to biomass growth was estimated to be highest for Tropical Moist Deciduous with 91276544 tonnes C/yr. This value shows the potential of this forest type to sequester maximum carbon [division: Dangs (North & South), Navsari, Valsad (South), Jamnagar and Narmada]. Followed by Tropical Dry Forests which has the potential to store 79974765 tonnes C/yr [division: Dahod, Vadodara (Chota Udepur), Panchmahal (Godhra), Panchmahal (Jambugoda Sanctuary), Surat, Gandhinagar, Kheda (Nadiad), Sabarkantha and Banaskantha].

Figure 38: Increase in biomass stock in the year 2008-09 in the categories defined by IPCC 2006

The overall potential of biomass carbon stock from all the forest types of Gujarat (which are moist deciduous, slightly moist teak, dry teak, very dry teak, dry deciduous shrub, tropical dry deciduous, dry deciduous, dry mixed deciduous, and tropical, desert thorn scrub forest and mangrove forest) is estimated to be 172061755 tonnes C yr⁻¹. Also the loss of carbon from the forest was analyzed based on the annual district wise wood removal for various purposes.
Maximum carbon is lost from humid tropical forest (tropical moist deciduous), which is 2573.4040 tonnes C yr\(^{-1}\) [division: Surat, Valsad and Baruch] followed by dry tropical, subtropical forest (tropical dry forest), which is 279.8199 tonnes C yr\(^{-1}\) [division: Vadodara, Gandhinagar, Vadodara (W.L.), Ahmadabad and Mehsana extension].

### 3.6 Wastes

Waste has a major role in the emissions in the form of methane and nitrous oxide. These gases are due to the aerobic and anaerobic decomposition of the waste. With growing population and industrialization there is bound to be an increase in the quantity of waste. Urbanization, the level of income and the consumption pattern plays an important role in waste disposal and treatment. The quantity and quality of waste depend on these factors including the purchasing power of the population.

The main greenhouse gas emitted from the waste sector is CH\(_4\) released as the byproduct of anaerobic decomposition of solid waste and wastewater. N\(_2\)O emissions take place when there is protein content. This is majorly seen in the domestic wastewater. At the India level the amount of emissions from the waste sector was found to be 57.72 Tg (INCCA 2007), Of which, the solid waste sector accounts for 12.69 Tg, domestic wastewater 22.98Tg and Industrial wastewater accounts for 22.05 Tg.

#### Emission from Domestic wastewater in Gujarat

Domestic wastewater is the dominant source of CH\(_4\) emissions in India. The emission from Gujarat’s domestic wastewater for the year 2010 is calculated to be 1.423121161Tg CH\(_4\) equivalent. The percentage of CH\(_4\) emissions from the wastewater for both the urban and the rural areas district wise are as shown in Figure 41. Ahmadabad has the highest emission both in the urban and the rural areas as compared to any other district, with 42.39 percent (0.35 Gg) from
the urban areas and 20.96 percent (0.17 Gg) from the rural areas followed by Surat at 3.03 percent (0.0252 Gg) from the urban areas and 2.79 percent (0.023 Gg) from the rural areas.

Figure 40: District wise Methane emissions in Percentage for the year 2010

The N₂O emissions from the districts are as shown in Figure 41. The total N₂O emission of the state for the year 2010 is calculated to be 0.004534 Tg. The emissions are highest in Ahmadabad 0.000521 Tg (11.47 percent) followed by Surat 0.000383 (8.43 percent) and Vadodara 0.000326 (7.18 percent).
3.7 Residential Sector

The emissions from this sector are based on that from of energy use. Residential sector is one of the most intensive electricity use- sectors. However electricity usage is not included in the computation of emissions so as to avoid double counting. Hence here energy consumption in the form of Liquid Petroleum Gas (LPG), Kerosene and biomass use is considered. There is a steady rise in the fuel consumption by this sector. For LPG and Kerosene the fuel sold estimates and the country specific emission factors have been used. However for biomass, as per the national statistic, it is assumed that 27.7 kg of biomass is used per person per month.

It is observed that that the kerosene consumption is gradually declining in the state. This can be attributed to various factors like improved technology, increasing purchasing power, easy and cheaper access to alternative energy sources like LPG. The emissions from Superior Kerosene Oil (SKO) use show the following trend, it contributes 14.28 Tg of CO₂ equivalents.
Figure 42: Emissions from the Superior Kerosene Oil use in the residential sector from 2005-2010

There is seen a gradual decline in Superior Kerosene Oil from 2005, the total emission from the LPG usage comes to 12.18 Tg of CO\textsubscript{2}equivalents.

Figure 43: Emissions from the Liquefied Petroleum Gas use in the residential sector from 2005-2010
The average biomass used has been calculated based on the population of the state. Since there is a growth in the population there is a corresponding rise in the emissions from biomass the total emission being 0.000582973 Tg of CO₂ equivalents. The graphical representation is as following:

Figure 44: Emissions from the biomass use in the residential sector from 2005-2010

Now that all the factors contributing to residential emissions have been accounted for, the total emission trend from this sector has been discussed. There is a clear rise in the emissions from this sector as well; the emissions total up to 26.46 Tg.

Figure 45: Emissions from the residential sector from 2005-2010
### 3.8 Summary of Emissions

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STATUS
4 STATUS

4.1 Introduction

This section will discuss in detail climate change occurrence in Gujarat. Climate trends have been analysed to understand if temperatures are rising and if there are observed changes in precipitation. Extreme events such as cyclone, flood, drought, heat and precipitation intensities are discussed in this section.

Administrative Divisions and Regionalisation in Gujarat

The state of Gujarat comprises 27 districts and 225 talukas (sub-district) comprising 18,618 villages and 242 towns. Kutch is the largest district of the state holding 23 percent of its total geographical area. For the purpose of this study the state is broadly classified into five geographical regions as depicted in Figure 46, namely South, Central, North, Saurashtra and Kutch regions. Large parts of the state comprise the plains concentrated more or less in central and northern Gujarat.

South Gujarat: The southern region includes the districts of Surat, Bharuch, Valsad, Dangs, Tapi, Narmada and Navsari. Its total geographic area is 23.22 lakh hectares. The region has the highest forested area in the state. Annual rainfall averages between 1,000 and 1,500 mm and the climate varies from semi-arid to dry sub humid.

Central Gujarat: The Central Gujarat region includes the districts of Kheda, Anand, Vadodara, Ahmedabad, Gandhinagar, Panchmahals and Dahod. The total geographic area of the region comprises 34.13 lakh hectares. The forested area is not extensive in the region and this region leads in agricultural development. Annual rainfall averages from 800 to 1000 mm and the climate is semi-arid.

North Gujarat: The North Gujarat region includes the districts of Sabarkantha, Mehsana, Banaskantha, and Patan. Its total geographic area comprises 28.91 lakh hectares. This region has a very small area under forests. It receives 500 to 800 mm of annual average rainfall and the climate varies from arid to semi-arid.

Saurashtra: The Saurashtra region includes the districts of Amreli, Bhavnagar, Rajkot, Bhavnagar, Jamnagar, Surendranagar, Junagadh, and Porbandar. The total geographic area of the region consists of 60.95 lakh hectares. The climate here is dry sub-humid with very low average rainfall at 500 to 800 mm annually.

Kutch: The North-west arid region encompasses the Kutch district. This region receives very little annual rainfall between 300 and 400 mm - rendering it totally arid. The total geographic area of the region is 40.89 lakh hectares. The Kutch region consists of the Ranns, which are salt-encrusted wastelands and rises only a few meters above sea level. Inundated during the monsoons they are divided into the great Rann to the north and the little Rann of Kutch to the east, the Banni Plains between the great Rann and the rocky mainland and the hilly region with the island belt of four rocky projections rising above the Rann, the Kutch mainland, and the southern coastal plains.
Climate Scenario of Gujarat
Climate is one of the most important factors that govern natural resources of a region and also the mode of human activity. Climate is the average weather usually taken over a 30-year time period for a particular region and time period. Climate is not the same as weather, but rather, it is the average pattern of weather for a particular region. Weather describes the short-term state of the atmosphere. Gujarat astride the Tropic of Cancer is located in the western part of the sub continent occupying the sub tropical high-pressure zone and experiences varied climate. South Gujarat witnesses sub-humid climate, while along the coastline the conditions are sultry and humid. Regions of Central Gujarat and Central Saurashtra face moderately humid and dry conditions respectively, while North Gujarat and Kutch face arid and semi-arid conditions. Out of total geographic area of the state, 58 percent falls under arid and semi-arid climatic zone. The seasons can be divided into: the winter season from December to February, spring season in March, summer season from to May, the south-west monsoon season from June to September and autumn season from October to November.

Climate change scenario in Gujarat
Climate change in Gujarat has tried to be established using data collected from 20 meteorological stations. Data has been collected from 1901-2001 for mean, minimum and maximum temperature and rainfall from 1901-2010. For our climate analysis, Gujarat has been divided into five regions as given in the figure below. In order to understand climatic trends better, seasonal variations have been analyzed. This chapter attempts to present regional variation in temperature and rainfall.
4.2 Temperature

Mean Temperature

North Gujarat
In North Gujarat there has been a gradual increase in summer temperature over the period of 1901-2002. Thirty year moving point averages of mean summer season (April, May) have been prepared for the various observation of North Gujarat. The normals have shown a significant increase of 0.41°C over North Gujarat. During the rainy season (June, July, August, September) there has been a gradual decrease observed in mean temperature. Thirty years moving averages show a decrease in temperature normals in North Gujarat, which is of the order of -0.08°C. This decrease in temperature during the monsoon season shows an insignificant change.

A gradual significant increase in mean autumn (October, November) temperature has been observed over North Gujarat. Thirty years moving average show an increase in normal mean temperature of 0.77°C by during autumn season. This shows that the greatest warming is seen in the autumn season over North Gujarat. It also shows a gradual increase in mean winter temperature (December, January and February) over North Gujarat. The normals that have been
observed show an increase of 0.67°C. Spring temperatures (March) have also shown a significant increase of 0.51°C. The overall trend in over North Gujarat for the period 1901-2002 shows an increase in mean temperature. Thirty years moving averages show an increase in trend of 0.46°C. The figures 47–52 show the changes in temperature, for North Gujarat every season and the change in mean temperature during all seasons.

Figure 47: Summer Mean Temperature in North Gujarat
Figure 48: Monsoon Mean Temperature in North Gujarat

Figure 49: Autumn Mean Temperature in North Gujarat

Figure 50: Winter Mean Temperature in North Gujarat
Figure 51: Spring Mean Temperature in North Gujarat

Figure 52: Annual Mean Temperature in North Gujarat
Central Gujarat
Summer temperature in Central Gujarat is also on the rise. Thirty years moving averages indicate a significant increase in summer temperature of 0.42°C. There is insignificant decrease in temperature during the rainy season of -0.007°C as shown by the Thirty-year moving point average. There has been a significant increase in mean autumn temperatures. Thirty year moving point averages show an increase of 0.877°C rise in mean autumn temperatures over Central Gujarat. Winter temperatures also follow the same trend in temperature increases as autumn, the Thirty year moving averages show an increase in winter temperature of 0.66°C as also increase in mean spring temperature for Central Gujarat is 0.59°C. The overall rise in mean temperature in Central Gujarat has been significant and is0.51°C. The figures 53–58 show the changes in temperature, for Central Gujarat every season and the change in mean temperature during all seasons.

Figure 53: Summer Mean Temperature in Central Gujarat
Figure 54: Monsoon Mean Temperature in Central Gujarat

Figure 55: Autumn Mean Temperature in Central Gujarat
Figure 56: Winter Mean Temperature in Central Gujarat

Autumn Mean Temperature in Central Gujarat

Winter Mean Temperature in Central Gujarat

Figure 57: Spring Mean Temperature in Central Gujarat
Figure 58: Annual Mean Temperature in Central Gujarat

South Gujarat
South Gujarat shows a significant increasing temperature trend for all the seasons as shown in the figures below. The 30 years moving averages show a significant increase in autumn (0.81°C) and winter temperatures (0.59°C). There is a gradual increase in summer (0.39°C), spring (0.57°C) and mean (0.48°C) temperature with an insignificant rise in temperature during the monsoon season (0.05°C). The figures 59–64 show the changes in temperature, for South Gujarat every season and the change in mean temperature during all seasons.

Figure 59: Summer Mean Temperature in South Gujarat

![Summer Mean Temperature in Southern Gujarat](image)

Figure 60: Monsoon Mean Temperature in South Gujarat
Figure 61: Autumn Mean Temperature in South Gujarat

Autumn Mean Temperature in Southern Gujarat

R² = 0.1981

Linear (Southern Gujarat Autumn Mean Temperature)

30 per. Mov. Avg. (Southern Gujarat Autumn Mean Temperature)
Figure 62: Winter Mean temperature in South Gujarat

Winter Mean Temperature in Southern Gujarat

Figure 63: Spring Mean Temperature in South Gujarat

Spring Mean Temperature in Southern Gujarat

$R^2 = 0.2264$  
Linear (Southern Gujarat Winter Mean Temperature)

$R^2 = 0.1111$  
Linear (Southern Gujarat Spring Mean Temperature)
Saurashtra

Saurashtra has witnessed an increase in temperature during the autumn and winter months. The thirty years moving point averages show an increase of 0.71°C and 0.67°C respectively. Whereas there is insignificant decrease in temperature during the rainy season (-0.09°C) while a gradual increase in spring (61°C) summer (0.50°C) and mean (0.46°C) temperature of Saurashtra is observed. The figures 65–70 show the changes in temperature, for South Gujarat every season and the change in mean temperature during all seasons.
Figure 66: Monsoon Mean Temperature in Saurashtra

Monsoon Mean Temperature in Saurashtra

\[ R^2 = 0.0118 \]

Years

Mean Temperature

Figure 67: Autumn Mean Temperature in Saurashtra

Autumn Mean Temperature in Saurashtra

\[ R^2 = 0.1601 \]

Years

Mean Temperature
Figure 68: Winter Mean Temperature in Saurashtra

Figure 69: Spring Mean Temperature in Saurashtra
**Kutch**

Kutch has been witnessing an insignificant decreasing trend in temperature during the monsoon season. There has been a significant increase in temperature during the winter, autumn, summer, spring and the mean temperature of Kutch. The 30-year moving point averages show temperature trends of 0.61°C, 0.51°C, 34°C, 0.47°C and 0.36°C in winter, autumn, summer, spring and mean respectively. The graphs show the trends in temperature of Kutch.
Figure 71: Summer Mean Temperature in Kutch

![Summer Mean Temperature in Kutch](image1)

R² = 0.06

- Linear (Kutch Summer Mean Temperature)
- 30 per. Mov. Avg. (Kutch Summer Mean Temperature)

Figure 72: Monsoon Mean Temperature in Kutch

![Monsoon Mean Temperature in Kutch](image2)

R² = 0.0323

- Linear (Kutch Monsoon Mean Temperature)
- 30 per. Mov. Avg. (Kutch Monsoon Mean Temperature)
Figure 73: Autumn Mean Temperature in Kutch

Autumn Mean Temperature in Kutch

![Autumn Mean Temperature graph with R² = 0.0985]

Figure 74: Winter Mean Temperature in Kutch

Winter Mean Temperature in Kutch

![Winter Mean Temperature graph with R² = 0.2029]
Figure 75: Spring Mean Temperature in Kutch

Spring Mean Temperature in Kutch

R² = 0.0868

Figure 76: Annual Mean Temperature in Kutch

Annual Mean Temperature in Kutch

R² = 0.1954
Observation of mean spring, summer, autumn and winter show an increasing trend with a significant increase in mean temperature during the autumn and winter months. This suggests that spring, summer, autumn and winter are going to get hotter during the future years as greenhouse gases concentration increases, causing global warming. Figure 77 shows the increase in mean summer temperature for the 4 time periods (1901–1930, 1931–1960, 1961–1990 and 1991–2002). Ray et al. (2009) has suggested that the gridded 30 years moving averages of **mean temperature** over Gujarat state indicate an increase by 0.07°C in past 40 years (1969-2005). The station wise analysis (1969-2008) further indicates that the increase is more over coastal Saurashtra region as compared to that of the remaining parts. Analysis conducted for this study takes into account data from the 1901 to 2001 for mean, minimum, maximum temperature and rainfall. Data collected has been analyzed corresponding to five different geographical regions, namely, North, Central and South Gujarat, Saurashtra and Kutch. The analysis is based on data collected from 20 meteorological stations. The analysis made by Ray et al. (2009) is found to be consistent with our analysis.

Figure 77: Average of the Summer Mean Temperature in North Gujarat
Mean Minimum Temperature

**North Gujarat**
North Gujarat experiences an increase in minimum temperature in all seasons except for the monsoon season where it experiences insignificant negative temperature trends of -0.08°C. For North Gujarat, the increase in temperature normals is calculated using 30-year moving point averages as shown in the following figure. Temperature trends for summer, spring, autumn, winter and mean are 0.41°C, 0.51°C, 0.76°C, 0.67°C and 0.45°C respectively. The figures 77–82 show the changes in mean minimum temperature over North Gujarat.

**Figure 78: Summer Minimum Temperature in North Gujarat**

![Graph showing summer minimum temperature in North Gujarat with trend line and data points.](image-url)

- Linear (Summer Minimum Temperature in North Gujarat)
- 30 per. Mov. Avg. (Summer Minimum Temperature in North Gujarat)

$R^2 = 0.0642$
Figure 79: Monsoon Minimum Temperature in North Gujarat

![Monsoon Minimum Temperature in North Gujarat](image1)

Figure 80: Autumn Minimum Temperature in North Gujarat

![Autumn Minimum Temperature in North Gujarat](image2)
Figure 81: Winter Minimum Temperature in North Gujarat

Winter Minimum Temperature in North Gujarat

R² = 0.177

Linear (North Gujarat Winter Minimum Temperature)

30 per. Mov. Avg. (North Gujarat Winter Minimum Temperature)

Figure 82: Spring Minimum Temperature in North Gujarat

Spring Minimum Temperature in North Gujarat

R² = 0.0745

Linear (North Gujarat Spring Minimum Temperature)

30 per. Mov. Avg. (North Gujarat Spring Minimum Temperature)
Central Gujarat

Central Gujarat experiences an increase in minimum temperature for all temperatures. The figures (83 to 88) show the increase in mean minimum temperature using 30 years moving point averages. The temperature increase has been significant in seasons as follows; summer (0.42°C), spring (0.59°C), autumn (0.86°C), winter (0.67°C) and the overall mean minimum increase in temperature for Central Gujarat is 0.51°C. An insignificant decrease has been observed in monsoon temperatures of -0.007°C.
Figure 84: Summer Minimum Temperature in Central Gujarat

Figure 85: Minimum Monsoon Temperature in Central Gujarat
Figure 86: Autumn Minimum Temperature in Central Gujarat

Autumn Minimum Temperature in Central Gujarat

R² = 0.1565

Figure 87: Winter Minimum Temperature in Central Gujarat

Winter Minimum Temperature in Central Gujarat

R² = 0.202
Figure 88: Spring Minimum Temperature in Central Gujarat

Figure 89: Annual Minimum Temperature in Central Gujarat
**South Gujarat**

South Gujarat also shows trends similar to Central Gujarat. Temperature normals are on a significant rise. The mean minimum temperature calculated using 30 year moving point averages show an increase in summer (0.39°C), spring (0.57), monsoon (0.06°C), autumn (0.81°C), winter (0.79°C) and the mean minimum temperature increase for South Gujarat is 0.52°C. Figure 90–95 show the change in mean minimum temperatures over South Gujarat.

Figure 90: Summer Minimum Temperature in South Gujarat

![Figure 90: Summer Minimum Temperature in South Gujarat](image)

**R² = 0.1024**

- **Linear (South Gujarat Minimum Temperature)**
- **30 per. Mov. Avg. (South Gujarat Minimum Temperature)**

Figure 91: Monsoon Minimum Temperature South Gujarat
Figure 92: Autumn Minimum Temperature in South Gujarat

Autumn Minimum Temperature in South Gujarat

R² = 0.1973

- Linear (South Gujarat Autumn Minimum Temperature)
- 30 per. Mov. Avg. (South Gujarat Autumn Minimum Temperature)
Figure 93: Winter Minimum Temperature in South Gujarat

Winter Minimum Temperature in South Gujarat

Figure 94: Spring Minimum Temperature in South Gujarat

Spring Minimum Temperature in South Gujarat
Saurashtra
Saurashtra experienced significant increase in mean minimum temperature of 0.45°C for the period of 1901–2002. The 30 year moving point averages show an increase in minimum temperatures for the following seasons, summer (0.38°C), spring (0.60°C), autumn (0.70°C) and winter (0.66°C). There is a slight insignificant dip in minimum temperature for the monsoon season of -0.08°C. Figures 96–101 show the changes in mean minimum temperature in Saurashtra over all seasons.
Figure 96: Summer Minimum Temperature in Saurashtra

![Graph showing Summer Minimum Temperature in Saurashtra]

- **R²**: 0.0998
- **Linear**: (north saurashtra_summers)
- **30 per. Mov. Avg.**: (north saurashtra_summers)

Figure 97: Monsoon Minimum Temperature in Saurashtra

![Graph showing Monsoon Minimum Temperature in Saurashtra]

- **R²**: 0.0119
- **Linear**: (North Saurashtra Monsoon Minimum temperature)
- **30 per. Mov. Avg.**: (North Saurashtra Monsoon Minimum temperature)
Figure 98: Autumn Minimum Temperatures in Saurashtra

R² = 0.1582

Figure 99: Winter Minimum Temperature in Saurashtra

R² = 0.2364
Figure 100: Spring Minimum Temperature in Saurashtra

Figure 101: Annual Minimum Temperature in Saurashtra

Kutch
Kutch shows similar trends of minimum temperatures as seen in Saurashtra. The 30-year moving averages a greater dip for the monsoon season, though insignificant (-0.11°C) and significant increase for the remaining seasons: summer (0.33°C), spring (0.46°C), autumn (0.50°C) and 0.60°C for the winter months. There is also a linear increase in the mean minimum temperature of 0.35°C for Kutch.
Figure 102: Summer Minimum Temperature in Kutch

Figure 103: Monsoon Minimum Temperature in Kutch
Figure 104: Autumn Minimum Temperature in Kutch

Autumn Minimum Temperature in Kutch

![Autumn Minimum Temperature Graph]

$R^2 = 0.0941$

Figure 105: Winter Minimum Temperature in Kutch

Winter Minimum Temperature in Kutch

![Winter Minimum Temperature Graph]

$R^2 = 0.2097$
Minimum temperature normal has increased by 0.107°C. The trend showed a steady increase over the years. In case of moving averages of 30 years the increase was 0.25°C. Analysis was performed for north and South Gujarat region separately but not much difference was observed in case of gridded data. In general the temperature rise was found to be the highest in Saurashtra and Kutch as compared to North and Central Gujarat region.
Mean Maximum Temperature

North Gujarat
Thirty years moving averages have shown that over North Gujarat the normal show a significant rise in temperature except for the monsoon season (-0.07°C). The mean maximum temperature for North Gujarat is 0.44°C and the remaining seasons following the same trend, 0.38°C (summer), 0.52°C (spring), 0.82°C (autumn) and 0.79°C (winter). Figure 109–114 show the changes in maximum temperature for all seasons over North Gujarat.
Figure 110: Monsoon Maximum Temperature in North Gujarat

Figure 111: Autumn Maximum Temperature in North Gujarat
Figure 112: Winter Maximum Temperature in North Gujarat

Winter Maximum Temperature in North Gujarat

R² = 0.1596

Figure 113: Spring Maximum Temperature in North Gujarat

Spring Maximum Temperature in North Gujarat

R² = 0.0708
Central Gujarat
There is a significant increase in normal temperature for Central Gujarat even but an insignificant change during the monsoon season (0.004°C). Autumn and winter months show a high increase in the normal of 0.85°C and 0.63°C respectively. There is an increase in mean maximum summer (0.39°C), spring (0.60°C) temperature, maximum along with the mean maximum temperature of Central Gujarat (0.49°C).
Figure 115: Summer Maximum Temperature in Central Gujarat

Summer Maximum Temperature in Central Gujarat

![Graph showing Summer Maximum Temperature in Central Gujarat]

R² = 0.0745

Figure 116: Monsoon Maximum Temperature in Central Gujarat

Monsoon Maximum Temperature in Central Gujarat

![Graph showing Monsoon Maximum Temperature in Central Gujarat]

R² = 0.0002
Figure 117: Autumn Maximum Temperature in Central Gujarat

R² = 0.1458

Figure 118: Winter Maximum Temperature in Central Gujarat

R² = 0.1882
Figure 119: Spring Maximum Temperature in Central Gujarat

Figure 120: Annual Maximum Temperature in Central Gujarat
**South Gujarat**

An overall increase in maximum temperature has been observed for all seasons based on the 30 year moving point average. The increase in normal for all the seasons are as follows: summer (0.36°C), spring (0.57°C), monsoon (0.07°C), autumn (0.77°C), winter (0.56°C) and mean maximum increase is 0.47°C. The increases for all seasons are significant except form the monsoon.

Figure 121: Summer Maximum Temperature in South Gujarat

![Summer Maximum Temperature in South Gujarat](image1)

Figure 122: Monsoon Maximum Temperature in South Gujarat

![Monsoon Maximum Temperature in South Gujarat](image2)
Figure 123: Autumn Maximum Temperature in South Gujarat

Figure 124: Winter Maximum Temperature in South Gujarat
Saurashtra
Saurashtra has experienced a significant increase in maximum temperature except for the monsoon season where there is an insignificant decrease in maximum temperature (-0.07°C). The
remaining seasons have experienced an increase in maximum temperatures; spring (0.57°C), summer (0.33°C), autumn (0.69°C) and winter (0.62°C). The total mean maximum temperature has shown a gradual increase for Saurashtra of 0.43°C. Figures 126–131 show the changes in the maximum temperatures of all seasons over Saurashtra region of Gujarat.

Figure 126: Summer Maximum Temperature in Saurashtra

![Summer Maximum Temperature in Saurashtra](image)

R² = 0.0862

- Linear (North Saurashtra Summer Maximum Temperature)
- 30 per. Mov. Avg. (North Saurashtra Summer Maximum Temperature)

Figure 127: Monsoon Maximum Temperature in Saurashtra

![Monsoon Maximum Temperature in Saurashtra](image)

R² = 0.0114

- Linear (North Saurashtra Monsoon Maximum Temperature)
- 30 per. Mov. Avg. (North Saurashtra Monsoon Maximum Temperature)
Figure 128: Autumn Maximum Temperature in Saurashtra

Autumn Maximum Temperature in Saurashtra

Figure 129: Winter Maximum Temperature in Saurashtra

Winter Maximum Temperature in Saurashtra

R² = 0.1493

Linear (North Saurashtra Autumn Maximum Temperature)

R² = 0.2173

Linear (North Saurashtra Winter Maximum Temperature)

30 per. Mov. Avg. (North Saurashtra Autumn Maximum Temperature)

30 per. Mov. Avg. (North Saurashtra Winter Maximum Temperature)
Figure 130: Spring Maximum Temperature in Saurashtra

\[ R^2 = 0.1048 \]

Figure 131: Annual Maximum Temperature in Saurashtra

\[ R^2 = 0.262 \]
Kutch

Kutch shows similar trends as Saurashtra but the increase in maximum temperature during the winter season shows a higher decrease of -0.11°C. For the remaining seasons Kutch show a gradual significant increase in maximum temperatures: spring (0.45°C), summer (0.30°C), autumn (0.50°C), winter (0.57°C) and the mean maximum temperature (0.34°C) for Kutch also follows an increasing trend.

Figure 132: Summer Maximum Temperature in Kutch

Figure 133: Monsoon Maximum Temperature in Kutch
Figure 134: Autumn Maximum Temperature in Kutch

Autumn Maximum Temperature in Kutch

R² = 0.0971

Figure 135: Winter Maximum Temperature in Kutch

Winter Maximum Temperature in Kutch

R² = 0.1847
The annual normal **mean maximum temperature** was found to have increased by 0.11°C. The rise is again very steady and highly linear. The 10 years moving averages showed an increase of 0.5°C in the past 40 years. The increase has been stable and significant for both maximum and
minimum temperature. The analysis was carried out for North Gujarat and South Gujarat region separately and same trend was observed, with higher increase in Saurashtra and South Gujarat region as compared to the other regions. The rise in normal of annual mean temperatures over Gujarat state was 0.07°C and 10years averages showed a rise of 0.3°C. The gridded 30 years moving averages of mean temperature over Gujarat state indicate an increase by 0.07°C in past 40 years (1969-2005) (Ray et al. 2009). The figure 139 shows the average summer maximum temperature for 4 time periods (1901–1930, 1931–1960, 1961–1990 and 1991–2002), to give an understanding of the spatial sprawl of temperature rise.

Figure 138: Annual Mean Maximum Temperature over Gujarat

![Moving averages of Annual mean temperature of Gujarat](image)

Source: (Ray, K. et al. 2009)

Table 2: Summary of the changes in mean temperature (in °C) in Gujarat (1901-2001)

<table>
<thead>
<tr>
<th>Mean temperature</th>
<th>North Gujarat</th>
<th>Central Gujarat</th>
<th>South Gujarat</th>
<th>Saurashtra</th>
<th>Kutch</th>
<th>Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>0.42</td>
<td>0.43</td>
<td>0.40</td>
<td>0.39</td>
<td>0.34</td>
<td>0.39</td>
</tr>
<tr>
<td>Monsoon</td>
<td>-0.08</td>
<td>-0.008</td>
<td>0.06</td>
<td>-0.09</td>
<td>-0.12</td>
<td>-0.05</td>
</tr>
<tr>
<td>Autumn</td>
<td>0.78</td>
<td>0.88</td>
<td>0.82</td>
<td>0.71</td>
<td>0.51</td>
<td>0.74</td>
</tr>
<tr>
<td>Winter</td>
<td>0.67</td>
<td>0.67</td>
<td>0.60</td>
<td>0.67</td>
<td>0.61</td>
<td>0.64</td>
</tr>
<tr>
<td>Spring</td>
<td>0.52</td>
<td>0.60</td>
<td>0.58</td>
<td>0.61</td>
<td>0.47</td>
<td>0.55</td>
</tr>
<tr>
<td>All seasons</td>
<td>0.46</td>
<td>0.51</td>
<td>0.49</td>
<td>0.46</td>
<td>0.36</td>
<td>0.46</td>
</tr>
</tbody>
</table>
Table 3: Summary of the changes in minimum temperature (in °C) in Gujarat (1901-2001)

<table>
<thead>
<tr>
<th>Minimum Temperature</th>
<th>North Gujarat</th>
<th>Central Gujarat</th>
<th>South Gujarat</th>
<th>Saurashtra</th>
<th>Kutch</th>
<th>Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>0.41</td>
<td>0.42</td>
<td>0.39</td>
<td>0.38</td>
<td>0.33</td>
<td>0.39</td>
</tr>
<tr>
<td>Winter</td>
<td>0.76</td>
<td>0.86</td>
<td>0.81</td>
<td>0.7</td>
<td>0.5</td>
<td>0.73</td>
</tr>
<tr>
<td>Spring</td>
<td>0.51</td>
<td>0.59</td>
<td>0.57</td>
<td>0.6</td>
<td>0.46</td>
<td>0.55</td>
</tr>
<tr>
<td>All seasons</td>
<td>0.45</td>
<td>0.51</td>
<td>0.52</td>
<td>0.45</td>
<td>0.35</td>
<td>0.46</td>
</tr>
</tbody>
</table>

Table 4: Summary of the changes in maximum temperature (in °C) in Gujarat (1901-2001)

<table>
<thead>
<tr>
<th>Minimum Temperature</th>
<th>North Gujarat</th>
<th>Central Gujarat</th>
<th>South Gujarat</th>
<th>Saurashtra</th>
<th>Kutch</th>
<th>Gujarat</th>
</tr>
</thead>
<tbody>
<tr>
<td>Summer</td>
<td>0.38</td>
<td>0.39</td>
<td>0.36</td>
<td>0.33</td>
<td>0.3</td>
<td>0.35</td>
</tr>
<tr>
<td>Monsoon</td>
<td>-0.07</td>
<td>0.004</td>
<td>0.07</td>
<td>-0.07</td>
<td>-0.11</td>
<td>-0.04</td>
</tr>
<tr>
<td>Autumn</td>
<td>0.75</td>
<td>0.85</td>
<td>0.77</td>
<td>0.69</td>
<td>0.5</td>
<td>0.71</td>
</tr>
<tr>
<td>Winter</td>
<td>0.62</td>
<td>0.63</td>
<td>0.56</td>
<td>0.62</td>
<td>0.57</td>
<td>0.60</td>
</tr>
<tr>
<td>Spring</td>
<td>0.52</td>
<td>0.6</td>
<td>0.57</td>
<td>0.57</td>
<td>0.45</td>
<td>0.54</td>
</tr>
<tr>
<td>All seasons</td>
<td>0.44</td>
<td>0.49</td>
<td>0.47</td>
<td>0.43</td>
<td>0.34</td>
<td>0.43</td>
</tr>
</tbody>
</table>
4.3 Rainfall

Analysis conducted has shown that the mean seasonal rainfall has increased over Saurashtra and South Gujarat region (along west coast) and has remained more or less same over North Gujarat region and adjoining Kutch. It cannot be said that there is a significant change. This can by far be related only to climate variability. Heavy precipitations events have also increased in most parts of Gujarat. There is an increase in heavy rainfall events in Surat, Veradale, Zadora and Rajkot (see table 4). The figures given below show the above-mentioned trends.
Figure 140: Annual Rainfall in Saurashtra

Average Annual Rainfall in Saurashtra

\[ R^2 = 0.0043 \]

Rainfall in mm

Year


Figure 141: Annual Rainfall in South Gujarat

Average rainfall in South Gujarat

\[ R^2 = 0.0138 \]

Rainfall in mm

Year

Figure 142: Annual Rainfall in Kutch

Figure 143: Annual Rainfall in North Gujarat
From figure 145 it can be observed that there has been an insignificant increase in rainfall patterns over Gujarat though there have been changes in precipitation patterns. Ray et al. (2009) analyzed seasonal rainfall for all observatories for the 40 years period (1969-2008). Thirty years moving averages of seasonal rainfall indicate an increase in rainfall normal for all the stations. Maximum rise of seasonal rainfall normal was found to be in Saurashtra (Bhavnagar, 60mm) and South Gujarat region (Surat, 100mm). Year to year variations of rainfall was found to be high for all stations. The standard deviations of seasonal rainfall over the past 40 years ranged from 250mm to 500mm. Therefore the analysis was done for 30 years moving averages only. The seasonal rainfall normal varied from 300mm in Buhl to 1100 mm in Seurat.
Gujarat faces the threat of sea level rise apart from the climate-induced events. Based on the observations at Kendal it is estimated that the sea level is rising at 3.37mm per year (Dived& Sharma 2005). The study conducted by National Institute of Oceanography shows an increase in sea level rise by 1.06-1.75 mm, which is in accordance with the IPCC value of 1-2 mm (Hindtoday2011). A preliminary research done by the MS University revealed that there has been a shift of 10-15 meters of seawater in the last one decade. The sea level has risen by 80 meters at some places (Path an 2008).

Sea level rise is likely to inundate high tidal flats and deltaic plains of Gujarat. The most vulnerable areas towards sea level rise as pointed out by Kayak included, the Little Rann of Kutch, the southern part of the (main) Ran of Kutch, OkraRan, Corals of Sitka, high tide mudflats near Porbandar, flood prone areas of Ghed in Junagadh district, the coastal areas of north Bhavnagar, the Gulf of Khabhant, Hajira and the Bhal region (Nayak 1994). A total of 1,81, 000 ha of coastal area is likely to be affected in case of one meter sea level rise (Diksha and
The maximum wetland losses due to sea level rise will be experienced in Gujarat. With a rate of 3.37 28mm per year, sea level rise at Kandla station can affect Gujarat coastal wetlands very adversely (Dwivedi el at. 2005).

4.5 Extreme Events

Cyclone

The rainfall pattern over the coast of India is mainly due to cyclone and its intensity. Table below shows the cyclones, which have originated in the past years mainly from Arabian Sea and moved towards Saurashtra/ Kutch coastline with different intensities.

Figure 146: Year-wise cyclone occurrence in Gujarat

In the period between 1920 and 1960 most of the cyclones that hit the state (covering regions like Kandla, Baruch, Bhavnagar, Porbandar) were DEPR (Depression cyclones) with intensity up to 60 km/hr. The analysis of data helps us interpret that the numbers of cyclones hitting the Kutch district has increased in the period between 1990 and 2010. Around 10 cyclones have been reported in the Kutch district during this time period of 20 years most of which are SSTR (Severe Strong Cyclone) with an intensity of 88-117 km/hr. Also prior to 1990s the maximum number of cyclones recorded within a span of 2 decades was only 5.

Therefore, it is logical to conclude that the cyclonic events in the coast of Gujarat (mainly Kandla, Rajkot, North Saurashtra, Kutch, Porbandar, and Jamnagar) have increased to a great extent as observed between the years 1890 and 1950.
Floods
Analysis of the data of floods from time period 1970 to 2005 it is seen that the most adverse floods were reported in the years 1995-1999 and from 2003 to 2005 impacting the districts of Vadodara, Surat, Bharuch, Anand, Kheda, Valsad and Navsari. The years 2000 to 2002 have observed comparatively slight floods having an impact on Vadodara. In early 1970-1997, it is observed that the intensity of flood in most districts of Gujarat had been normal with the main districts impacted being Gandhinagar, Banaskantha, Rajkot, Kutch and Vadodara. The intensity of floods has increased to adverse level in the years after 1995-97 and then returning during the years 2004-05 with similar level of intensity mainly in the districts of Vadodara, Surat, Kheda, Anand and Navsari.
Droughts
An analysis of 30 years of drought occurrence was done of which the highest frequency was observed in the arid west districts of Saurashtra and Kutch. Gujarat on the whole experiences high incidents of drought. Analysis of occurrence of drought in consecutive years showed that Gujarat experienced drought for 3 consecutive years from 1985 to 1987. Also Saurashtra and

The past droughts as analyzed through the year wise data available is estimated to be in the years 1985-87 more severely impacting the districts of Kutch and Bharuch. In 1998-99 the drought intensity was adverse severely impacting the districts of Bhavnagar, whereas drought with slight intensity has been experienced at large in the districts of Rajkot, Jamnagar and Amreli.

![Figure 151: Drought](image)

![Figure 152: District wise occurrence in Gujarat 1985-2005](image)

Droughts with slight intensity have been reported in two time periods, 1985-88 and later in 2000-03 mainly in the districts of Vadodara, Rajkot, Anand, Banaskantha, Amreli, Patan and Mehsana.
A span of normal drought was observed in 2001-03 mainly in the districts of Junagadh and Rajkot. Drought with very less intensity (normal) was observed in Vadodara in the years 1986-87 and 2000.

**Extreme Heat Events**

The extreme heat wave conditions use the definition as suggested by Ray et al. (2009), heat wave in summer: monthly average of maximum temperature (40 years) +5°C. Table 3 gives a glimpse of the trend in heat waves between 1969 and 2008. It is evident that there has been an increase in heat wave events in most stations observed.

**Table 5: Decadal Frequency of Heat Wave Conditions in Selected Stations**

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Ahmadabad</td>
<td>20</td>
<td>4</td>
<td>17</td>
<td>3</td>
</tr>
<tr>
<td>Baroda</td>
<td>16</td>
<td>12</td>
<td>9</td>
<td>28</td>
</tr>
<tr>
<td>Deesa</td>
<td>20</td>
<td>5</td>
<td>10</td>
<td>29</td>
</tr>
<tr>
<td>Bhuj</td>
<td>31</td>
<td>27</td>
<td>42</td>
<td>16</td>
</tr>
<tr>
<td>Rajkot</td>
<td>9</td>
<td>1</td>
<td>14</td>
<td>22</td>
</tr>
<tr>
<td>Veraval</td>
<td>53</td>
<td>52</td>
<td>34</td>
<td>72</td>
</tr>
<tr>
<td>Naliya</td>
<td>17</td>
<td>35</td>
<td>30</td>
<td>52</td>
</tr>
<tr>
<td>Okha</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>Surat</td>
<td>54</td>
<td>43</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>

Source: (Ray et al. 2009)
**Heavy Rainfall Events**
The heavy rainfall conditions use the definition as suggested by Ray et al. (2009), heavy rainfall: >70 mm. Table 4 gives a glimpse of the trend in heavy rainfall events between 1901 and 2010. It is evident that there has been an increase in heavy rainfall events in most stations observed.

Table 6: Decadal Frequency of Heavy Rainfall Events in Selected Stations Conditions in Selected Stations

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
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<td>VV Nagar</td>
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<td>30</td>
<td>11</td>
<td>21</td>
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</tbody>
</table>

Source: Based on data from Indian Meteorology Department

Note: *Missing data for 3 years in the decade 1981-1990; **Missing data for 2 years in the decade 1981-1990; @Missing data for 1 year in the decade 2001-2010; #Missing data for 1 year in the decade 1991-2000.
### 4.6 Current Status of Greenhouse Gas Emission

In this section the greenhouse gas emitted for by various sectors for the latest year available is presented.

Table 7: Greenhouse Gas emissions from various sectors

<table>
<thead>
<tr>
<th>Sector</th>
<th>Year</th>
<th>Emission</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td><strong>Power Sector</strong></td>
</tr>
<tr>
<td>Coal based power generation</td>
<td>2009</td>
<td>47.29 Tg</td>
</tr>
<tr>
<td>Gas based power generation</td>
<td>2009</td>
<td>4.11 Tg</td>
</tr>
<tr>
<td><strong>Transport</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roadways (Tier 2)</td>
<td>2006</td>
<td>26.90 Tg</td>
</tr>
<tr>
<td>Railways (Tier 1)</td>
<td>2006</td>
<td>0.182 Tg</td>
</tr>
<tr>
<td>Waterways (Tier 1)</td>
<td>2006</td>
<td>0.140 Tg</td>
</tr>
<tr>
<td>Airways (Tier 1)</td>
<td>2006</td>
<td>0.272 Tg</td>
</tr>
<tr>
<td><strong>Industry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cement – Installed capacity</td>
<td>2009</td>
<td>8.75 Tg</td>
</tr>
<tr>
<td>Cement – CMA</td>
<td>2008</td>
<td>8.55 Tg</td>
</tr>
<tr>
<td>Ammonia production</td>
<td>2005</td>
<td>5.16 Tg</td>
</tr>
<tr>
<td>Paper and Pulp</td>
<td>2007</td>
<td>4.44 Tg</td>
</tr>
<tr>
<td>Textiles – CMIE database</td>
<td>Latest</td>
<td>11.89 Tg</td>
</tr>
<tr>
<td>Food Processing</td>
<td>2011</td>
<td>0.00033 Tg</td>
</tr>
<tr>
<td><strong>Agriculture, Land Use and Forestry</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice Cultivation (Methane)</td>
<td>2003-04</td>
<td>0.00502529 Tg</td>
</tr>
<tr>
<td>Burning of Crop residues (Methane)</td>
<td>2005-06</td>
<td>0.004651 Tg</td>
</tr>
<tr>
<td>Burning of Crop residue (Nitrous oxide)</td>
<td>2005-06</td>
<td>0.000348 Tg</td>
</tr>
<tr>
<td>Enteric Fermentation (Methane Emission)</td>
<td>2007</td>
<td>0.057192 Tg</td>
</tr>
<tr>
<td>Manure Management (Methane emission)</td>
<td>2007</td>
<td>0.005476 Tg</td>
</tr>
<tr>
<td>Manure Management (Nitrous oxide)</td>
<td>2007</td>
<td>0.016871733 Tg</td>
</tr>
<tr>
<td>Forest land remaining forest land: Biomass carbon stock</td>
<td>2008-2009</td>
<td>172061755 tonnes C/yr (Sequestration)</td>
</tr>
<tr>
<td>Forest land remaining forest land: Carbon loss due to wood removals</td>
<td>2008-2009</td>
<td>2573.4040 tonnes C/yr</td>
</tr>
<tr>
<td>Cropland remaining cropland: annual change in carbon stock</td>
<td>2010</td>
<td>111451.32 Tonnes C/yr</td>
</tr>
<tr>
<td>Cropland remaining</td>
<td>1990-2010</td>
<td>5428076.161 Tonnes C/yr</td>
</tr>
</tbody>
</table>
### Table: Waste

<table>
<thead>
<tr>
<th>Source</th>
<th>Year</th>
<th>Amount (Tg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Domestic wastewater</td>
<td>2010</td>
<td>1.4231</td>
</tr>
<tr>
<td>Total</td>
<td>2011</td>
<td>4.53</td>
</tr>
<tr>
<td>SKO Consumption</td>
<td>2011</td>
<td>2.3</td>
</tr>
<tr>
<td>LPG consumption</td>
<td>2011</td>
<td>2.2357</td>
</tr>
<tr>
<td>Biomass consumption</td>
<td>2011</td>
<td>0.7650x10^-6</td>
</tr>
</tbody>
</table>

Gujarat has contributed to high levels of India’s greenhouse gas emission; alongside considerable work has been done to mitigate carbon more than just depending upon forests to sequester them. Gujarat has initiated several CDM projects to mitigate carbon though these Certified Emission Reduction credits are used to show national level emission reductions but it is essential to show mitigation efforts taken by the Gujarat state. As of 2010 Gujarat has 186 CDM projects (Register, under review and in pipeline). Estimated greenhouse gas displacement is 2,70,10,000 tonnage/year. The total CERs earned till 2010 is 32896 and has mitigated 32896 MT CO₂ equivalents.

India is a signatory to 2009 Copenhagen accord and is required to reduce carbon intensity by 20-25 percent by 2025. It is essential for Gujarat to reduce its carbon intensity by 20-25 percent by 2025 under the common but differentiated responsibility. Gujarat is the leading state in the country and accounts for 42 percent of total CER generated from India. It is essential that Gujarat continues the trend of investing in CDM projects but more efforts need to be made mainstream perform achieve and trade (PAT) into the industrial sector so as to reduce future emissions from the source rather than find other options to offset carbon. This would show that Gujarat recognizes that the climate system is a global common that needs to be protected rather than a few initiatives that do not pose a threat to the climate system.
IMPACTS
5 IMPACTS

5.1 Potential Impacts due to Climate Change in Gujarat

This chapter deals with potential and observed impacts of climate change in Gujarat. Climate change has been a hot topic of discussion since Rio summit in 1992. The Kyoto Protocol that came into force expressed concerns on impacts due to climate change on humans and natural systems. It has been two decades and there is still reluctance to accept scientific evidence on the impacts of climate change. Response to climate change according to UNFCCC must follow the precautionary principle; hence there is a need to understand future risks. This is achieved through modeling real world scenarios using various parameters. Models help in projecting the future using different variables of the real world scenario. Documentation of the observed impacts of climate change is low on a micro/regional scale as the climate agenda has taken its time to mainstream into the political system of various countries.

On the macro level, there are evidences of climate change impacts on communities and ecosystems. There is scientific backing that climate change is causing and will impact communities and ecosystems in the future as well. Hence there is a need to understand risks and adapt and mitigate to these risks under the precautionary principle. Modelling has tried to project future climate scenarios under different storylines to enable us understand risks and potential impacts of climate change. Modeling results have shown future changes in temperatures over India to range from 1°C to 4°C corresponding to a range of IPCC GHG emission scenarios. No significant change in monsoon rainfall is expected until about 2050s and an increase in the order of 8-10 percent towards the end of 21st Century – biases and larger spread across models in the projected changes leading to lesser confidence. Projected future increase in the monsoonal rainfall appears to be caused by an increase in the total moisture content in the atmosphere rather than an increase in the strength of monsoon circulation. A hint of ~10 percent increase in the future in the variability of monsoon rainfall from the current levels is observed with a possibility of stretching of the monsoon season with a substantial increase in the rainfall during May and October. An El Nino like response of sea surface temperatures in the Pacific associated with increased monsoon could have implications for the seasonal prediction of monsoon in the future (Intergovernmental Panel on Climate Change (IPCC) 2007).

Projections made by the PRECIS RCM Model show a decrease in number of rainy days and increase in the intensity of rainfall on a given rainy day in the future. Extremes in rainfall and temperature are showing an increase. There is no significant change in the date of onset of monsoon but the variability of onset date appears to be higher in the future and no significant change in the frequency of cyclonic storms/monsoon depressions but the intensity of storms seem to be higher by 10 percent in the future. With these future climate scenarios the predicted impacts due to climate change as reported by NATCOM show drop in wheat production by 4-5 million tones, with even a 1°C rise in temperature, rising sea levels causing displacement along one of the most densely populated coastlines in India, threatened freshwater sources and mangrove ecosystems, increase in frequency and intensity of floods over India, and increase in the vulnerability of people in coastal, arid and semi-arid zones of the country. Studies indicate that over 50 percent of India’s forests are likely to experience alteration in forest types adversely impacting associated biodiversity, regional climate dynamics as well as forest-based livelihoods.
This section of this chapter will deal with the potential impacts that Gujarat can face due to future climatic conditions.

### 5.1.1 Agriculture

The impact analysis of climate change on wheat and maize yield was assessed using CERES wheat and CERES-maize models, which were calibrated and validated using experimental data conducted at Anand (Anon 2007; Patel 2004; Patel et al. 2007). Fifty years (1958-2007) of rainfall and temperature data was analyzed to study the impacts on crops maize and wheat. The simulated grain yield of wheat by CERES-wheat model under incremental units of maximum temperature (1 to 3°C) showed gradual decrease in yield ranging from 3546 to 2646 kg/ha (8 to 31 percent) under irrigated condition. Under limited irrigation condition, yield reduction was recorded to the extent of 2841 to 2398 kg/ha (9 to 23 percent). In general, increase in maximum temperature from 1 to 3°C significantly reduced the wheat yield despite carbon fertilization (Aggarwal n.d.). The reduction in yield was mainly due to reduction in the duration of anthesis and grain filling with rise in ambient temperature. Similarly in case of gradual down scale of maximum temperature in the range of -1 to -3 °C, opposite trend was observed. Similar trend was also noticed in case of increase and decrease in minimum temperature. The magnitude of effect of minimum temperature was quite less (-14 to +19 percent) than those due to maximum temperature (-31 to +26 percent). This showed that wheat yield was found to be highly sensitive to change in temperature under irrigated as well as under limited irrigation conditions.

The increase in solar radiation from 1 to 3 MJm⁻² day⁻¹ resulted in increase in yield of wheat from 18 to 40 percent while reduction in solar radiation by −1 to −3 MJm⁻² day⁻¹ caused decrease in wheat yield to the tune of −18 to −50 percent. However, under limited irrigation conditions the yield was found to decrease both under elevated as well as reduced solar radiation. This showed that under limited irrigation condition the higher solar radiation receipt may have adverse effect through heating and thereby reduction in yield. It may be noted that under lower solar radiation regime, the yields under both conditions are the same. The overall response of varying radiation to grain yield of wheat showed that the model was more sensitive to radiation than it was to temperature. The effects of elevated carbon dioxide on simulated grain yield of wheat showed that due to gradual increase in CO₂ concentration from 440 to 660 ppm, the yield levels increased to the tune of 21 to 68 percent under irrigated condition(Pandey, Patel & Karande 2009). Under limited irrigated condition similar response was observed with slightly lower magnitude (19 to 57 percent). This showed that under climate change scenario, CO₂ enhancement proved beneficial to higher productivity. The increase in yield under increase in concentration in CO₂, may be due to most plants growing in experimental environments with increased levels of atmospheric CO₂, exhibit increased rates of net photosynthesis and reduced stomatal opening. Partial stomatal closure leads to reduced transpiration per unit leaf area and, combined with enhanced photosynthesis, often improves water-use efficiency.

**Effects of temperatures, solar radiation and CO₂ concentration:** Results on effects of minimum and maximum temperatures, solar radiation and CO₂ concentration on simulated grain yield of maize revealed that as the maximum temperature increases the yield decrease and vice versa (Pandey, Patel & Karande 2009). In case of increase or decrease of minimum temperature, yield was found to increase; however, there is a drastic decrease in yield if minimum temperature falls by more than 3°C. Thus the minimum and maximum temperature influences the maize crop.
differently: Higher CO$_2$ concentration was found to have favorable effect on maize yield. Doubling of CO$_2$ may increase its yield by 8-9 percent. A study by INCAA (2007) contests that the coast including Gujarat is projected to lose coconut yields up to 40 percent. This may be due to existing high summer temperatures, which are projected to increase further in the west coast region.

5.1.2 Livestock

Significantly longer heat wave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heat waves (Kawahara & Yamazaki 1999; Zhai et al. 1999; Lal 2003; Zhai & Pan 2003; Ryoo et al. 2004; Batima et al. 2005a; Cruz et al. 2006; Tran et al. 2005). Increased temperature in Gujarat has observed to induce heat stress in dairy animals affecting their productivity and reproductive ability as researched by Centre for Education and Documentation (CED)(2010). The anticipated rise in temperature between 2.3 and 4.8°C over the entire country together with increased precipitation as part of climate change is also aggravating the heat stress in dairy animals and the intensity is predicted to increase in the near future.

5.1.3 Ecosystems and biodiversity

Forests

According to the Third Assessment Report of IPCC, forest ecosystems will undergo change even with a global warming of 1-2°C, which will lead to shift in forest type. By 2085, country’s dominant forest cover, characterized by Moist Savanna (32.5 percent) and Dry Savanna (33 percent) is projected to change, such that Tropical Dry Forest (37.2 percent) and Tropical Seasonal Forest (28.4 percent) becomes dominant Savanna (32.5 percent) and Dry Savanna (33 percent). According to the various projections made, there will be less impact on the forests of Gujarat due to climate change as forest resources are lower in the state in comparison to India.

Wetland

As per the tide gauge records of more than 40 years of the north Indian Ocean by the National Institute of Oceanography, it is observed that the sea level rose by 1.06-1.75 millimeters per year during the past century (Unnikrishnan & Shankar 2007). This estimate is consistent with the estimated global sea-level rise of 1-2 millimeters per year made by the Inter Governmental Panel on Climate Change (IPCC 2007). Gujarat is richest in terms of the coastal wetlands and hosts approximately 60 percent of the total coastal wetland of the India. The maximum loss of coastal wetland due to sea level rise is projected as 8453 square km out of the total 25083 square km(Dwivendi & Sharma 2005).

Shallow-water marshes and swamps (Inland or Freshwater Wetlands) would be even more vulnerable to increased temperatures and lower precipitation as projected for central and northwestern India by the Hadley Centre’s HADCM2 (IINC 2004). The increased evaporation of water and reduced inflow from rainfall could desiccate the marshes, swamps and shallow lakes. The rising sea level can disrupt the wetlands; can cause flooding in the coastal areas, and saltwater intrusion may take place. Other findings are that sea level rise increases the frequency and/or duration of tidal flooding throughout a salt marsh. Following, which marshy grass drowns
and marsh soil erodes and hence portions of the high marsh become low marsh. Thus coastal wetlands are usually the worst hit.

**Mangroves**
The extent of high tidal mudflats constitutes major share of the tidal mudflats, especially in Gujarat State. This will provide great potential to the mangroves of the region for adjustment and adaptation against sea level rise. Climate unsuitability is another factor responsible for mangrove’s change and disappearance (Climate Talks 2009). Hardy species like *Avicennia sp* recolonised the area like the Gulf of Kutch fast, but this is not true in case of the species of genus *Rhizophora, Ceriops, Sonneratia* and *Aegiceras* in the Gulf of Kutch. Global warming and sea level rise would bring changes in the parameter of Evapo-Transpiration Potential (ETP) in most of the region, resulting in alternation in mangrove setting (Singh 2000).

**Coastline**
Sea level rise will cause submergence of around 502.04 sq. km area by 2025 and 1136.25-sq.km areas by 2050. Erosion of 10 to 40 km coastline is possible by 2025 and 2050 as predicted by Consortium of coastal Academic Institutions for the National Centre for Sustainable Coastal Management 2010 (DeshGujarat 2011).

**Grasslands**
During 2041-2060 the HADCM2 projections for Western India show a steep increase in temperature of 3°C in the south (except along the coast) to over 4°C in the north-west, and a decrease in precipitation of over 30 percent in the north-west though little change in parts of the south as predicted by India’s Initial National Communication (IINC 2004). This combination of temperature increase and rainfall decrease would cause major changes in the composition of present day vegetation in these regions, with an overall shift to a more arid type.

**Wildlife and birds**
The Rann of Kutch supports large Greater Flamingo colonies. With sea level rise, these salt marshes and mudflats will submerge, decreasing their habitat, and that of lesser floricans (DeshGujarat 2011). Also about 2000 Indian wild asses in the Rann of Kutch could lose their only habitat due to sea level rise.

5.1.4 **Water resources**
Climate change and climate variability are likely to affect irrigated agriculture, installed power capacity, environmental flows in the dry season and higher flows during the wet seasons, thereby causing severe droughts and floods in urban and rural areas of India (Kumar et al. 2006).

**Surface water**
Climate change projections show that there is an increase in the precipitation levels and water yields in the near term (2021-2050) and the long term (2071-2098) from the present baseline of 1960-1990. These projections do contain a lot of uncertainty, which are left unresolved due to the assumptions made and by the variations in the natural cycles, model parameters (PRECIS, SWAT A1B Model (Gosain et al. 2011) and in the A2 and B2 scenarios (Kumar et al. 2006)) orography and other associated factors. On an average, the model projections show that there
would be an increase in the extreme precipitations particularly over the west coast and west central India. Most of the models project enhanced precipitation during the monsoon season producing increased runoff and potentially more flooding. The major river systems of Gujarat show a 26.4 percent increase in precipitation on an average (Tapi-35 percent, Sabarmati- 30 percent, Narmada- 37 percent, Mahi- 25 percent and Luni-5 percent) the models also project an increase of 54.4 percent in the water yield of the major river systems in Gujarat (Tapi-55 percent, Sabarmati-70 percent, Narmada- 45 percent, Mahi-42 percent and Luni-60 percent). The change in evapo-transpiration also exhibits an increase of 10 percent in the Luni river basin and a decrease of 4.1 percent in the midterm and increases by the end term. The model also predicts that there would be moderate to extreme drought severity for the Sabarmati and Mahi River systems despite the overall increase in the precipitation, whereas floods are predicted in the Tapi and Narmada river systems. The model projects a decrease in the blue water under the present and future scenarios (near term and end term) conditions. Whereas green water storage will deteriorate in the Luni and Mahi systems in near and long term scenarios.

Sedimentation plays an important role in water resources projects as the projects are designed for a specific sediment load. In the event of an increase in the sediment load it is necessary to undertake steps to curtail erosion at the source. The models project an overall increase in sedimentation load in all the river basins under the near term scenario and the situation continues towards the long term (Gosain 2010).

**Groundwater**

The models project an increase in the precipitation and water yield in the river systems of Gujarat they also show an increase in the sedimentation of these river systems leading to an increased runoff and decreased percolation of water. Projections of increased temperature also lead to changes in the hydrological cycle by indirectly impacting the flux and storage of water in the surface and subsurface reservoirs (Singh & Kumar n.d.). The direct effect of climate change on ground water depends upon the change in volume and distribution of groundwater recharge.

Salinity in the groundwater increases due to excess pumping by reversing the gradient between the fresh water and salt water (Soni et al. 2010). Higher salinity impacts surface and groundwater supplies, damaging urban water supplies, ecosystems, and coastal farmland (IPCC 1998). Further, a reduced groundwater head caused by higher temperature and increased runoff will aggravate the impacts of sea level rise. Saline intrusion into alluvial aquifers may be moderate, but higher in limestone aquifers. Reduced rates of groundwater recharge, flow and discharge and higher aquifer temperatures may increase the levels of bacterial, pesticide, nutrient and metal contamination. Similarly, increased flooding could increase the flushing of urban and agricultural waste into groundwater systems, especially into unconfined aquifers, and further deteriorate groundwater quality (IGES white paper 2009). However, actual impacts of climate change on groundwater in Gujarat will also depend on the recharge measures, which have already initiated by the state.
5.1.5 Health

Food security
It is projected that the agricultural productivity will go down in Gujarat (IINCA 2004) for certain crops such as maize, wheat, rice, cotton etc. resulting in an alteration in food production. This points out towards insufficient yields from the farms, which may lead to hunger and malnutrition, especially in the poorer section (Chattopadhyay 2008).

Vector borne diseases
With climate change, geographical ranges and survival of species bearing diseases will vary. Warmer, wetter climates, particularly during breeding season, enable mosquitoes to spread their range and survive longer. Such climatic conditions also lead to increased rates of dengue fever and schistosomiasis (Battacharya et al. 2006). For arid to dry regions, as is the case with some parts of Gujarat, there is potential rise expected for malaria, with the persisting high temperatures and increased rainfall(IPCC 2007). Malaria is a very climate sensitive disease; at increased temperatures, the rate of digestion of blood meal increases, which in turn accelerates the ovarian development, egg laying, reduction in the duration of the gonotrophic cycle and more frequency of feeding on hosts, thus increasing the probability of transmission (Molineaux 1998). The increased incidences of malaria can be correlated to the heavy precipitation and increasing temperature in the past. Predictions of increase in intensity of precipitation rise over Gujarat can therefore lead to malaria becoming a major health hazard unless breeding conditions of mosquitoes are destroyed.

Heat waves
According to Intergovernmental Panel on Climate Change (IPCC 2001) an increase in the frequency or intensity of heat waves will increase the risk of mortality and morbidity, primarily in older age groups and the urban poor, particularly living in slums or squatter settlements (Akhtar n.d.). In Gujarat, the heat waves and associated mortality have shown an upward trend; the situation can worsen if precautionary steps are not taken based on the anticipated results of climate change (Kumar 1998).

5.1.6 Damage to Infrastructure
Gujarat has the longest coastline of 1600 km characterized by creeks and inland waters and can be classified as submergence type. The state is on the path of higher economic growth with high emphasis on development of coastal areas such as construction of 41 ports. Being one of the most industrialized states of India, Gujarat has been following a development strategy with clear focus on industrialization and urbanization. The saturation of the golden corridor has shifted attention to the coastal zone. It is emerging as the prime mover of economic growth, not just for the state but also for the Nation, given its role as a gateway for hydrocarbons. Oil terminals, storage and berthing facilities and refineries and ancillary units are being set up rapidly. Special economic zones, road networks and habitation facilities comprise the engines of economic growth. Most of these are located near the coast and serve as conduits for commerce between interior agricultural and industrial regions and the rest of the world. As it happens, these locations are at greater risk from current and projected climate hazards such as cyclones, high winds, flooding, coastal erosion and deposition, and sea-level rise(Khan 2010).
### Storm surges and cyclones

The degree of disaster potential depends on the storm surge amplitude associated with cyclone at the time of landfall, characteristics of coast, phases of tides and vulnerability of the area and the community. The frequency of cyclones in the Arabian Sea is lower than of the Bay of Bengal, in the ratio of 4:1. Even then the annual probability of a cyclonic event is 17.5 percent based on the frequency of disasters during the last 80 years as is given in the OFDA/CRED International Disaster Database. Junagadh is the most vulnerable district followed by Kutch, Jamnagar and Bhavnagar (Dubey 1997). The storm surges occur in the months of October and November, post monsoon season.

Figures 154 and 155 show zones that are under risk due to storm surges when there is a 50 percent (medium level surge) and 100 percent (very high level surge) of the possible maximum surge (PSM) respectively at the mean sea level. It is seen that for both the above scenarios, the Gulf of Khambhat is expected to be the most affected region, whereas the district of Bharuch followed by Bhavnagar is likely to be at a higher vulnerability. The most affected regions in the Gulf of Kutch are the districts of Kutch followed by Jamnagar. Also the districts of Navsari, Surat and Valsad are majorly affected due to storm surges both in the medium and very high level of surges.

Figure 154: Map showing zones affected by Medium Level Surge (50 percent of PMS)
The regions that face severe threat are the Gulf of Khambhat, the Gulf of Kutch and the western coast of southern Gujarat. A closer view of these regions provides details of areas that would be inundated due to very high PMS at mean sea levels. It is seen that a few of the major ports and industrial clusters like Dahej and Hazira, which are the major contributors to the state’s GDP, face higher risk of inundation due to very high level surges.

Gujarat has a total of 41 ports along its coastline, supporting industrial development. The state would face a 7 percent capital loss and 0.2 percent revenue loss to its ports in the event of a cyclone for a 50-year return period. The most vulnerable ones are located along the Gulf of Kutch (Kandla (89.50), Rozi (97.10), Bedi (11.70), Sikka (59.20) and Okha (52.50)) and coastal Saurashtra (Porbandar (375.60) and Jafrabad (52.20)). The port at Sikka (67.82) stands out significantly with its highest share in revenue generation.
Figure 156: Capital loss to ports due to cyclone for 50-year return period (Rs. In Million at 2002-2003 prices)
The cyclone damage to transmission networks is expected to be most pronounced along the west coast of Saurashtra. The 66KVA and the 220KVA transmission lines will be at highest risk. Though there exist no generation losses, losses due to transmission and distribution account for 2 percent and 4 percent respectively.
Figure 158: Cyclone damages to transmission networks (66 KVA Lines)

Source: (Gujarat State Disaster Management Authority (GSDMA) 2005)
Figure 159: Cyclone damages to transmission networks (220 KVA Lines)

Source: (Gujarat State Disaster Management Authority (GSDMA) 2005)
Sea level rise
Around 6 percent of Gujarat’s coastal population would be affected if there is a sea level rise of 1 meter, as around 181000 hectares of coastal area would be inundated (Lal & Aggrawal 2000). Increasing sea levels have the potential to inundate certain facilities and suitable development areas in low-lying areas. Hazira, Dahej industrial estates, ports like Mundra, Hazira and industrial cities like Surat, Jamnagar and Okha are the economic portals of the State and are located close to the coastline and are already facing the problems of sea level rise and floods due to their low elevation and poor management of urban infrastructure.

Coastal Erosion and Submergence
Coastal erosion is primarily associated with dynamic natural shoreline and Gujarat has a dynamic shoreline (Chauhan 2001). This is a universal problem; it has been estimated that 70 percent of all the beaches in the world are eroding. Most of the existing and potential coastal erosion hazards arise because of coastal development being undertaken too close to the sea. Erosion of banks in the vicinity of facilities may increase in certain areas from intense storm events. Increased soil saturation and undermined slope stability will destabilize banks, potentially decreasing structural stability and increasing structure maintenance and cost (Shetye 1990).

Floods
Gujarat has transformed itself from a drought prone state to one where floods are increasing in frequency. This is seen in conjunction with the increase in precipitation as predicted by the RCM models. Floods are increasingly recognized as the most frequent and damaging disasters in Gujarat as they have short term impacts due to destruction and water logging as well as long term adverse impacts from stagnant water, epidemics, etc. While floods have affected millions of people and their livelihoods in the state, expenditure on flood management is not so high. Warnings for timely evacuation are not always possible, transforming a natural hazard into a severe disaster, as recent experiences highlight. The annual probability of flood occurrence is around 25 percent (Ahmed et al. 2007); thus there is a high probability that it might cause damage to near shore development.

Figure 160 shows that almost all parts of Gujarat except for the northern and eastern boundaries are flood prone. The figure depicts settlements in north, central and South Gujarat as flood prone. South Gujarat region is flood prone due to the presence of hills which act as catchment areas. The map identifies flood prone areas in Saurashtra and Kutch for the first time. Saurashtra region is not as flood prone as compared to other areas but the flood prone areas in the Saurashtra region extend to the upper basins because of the presence of dams, which resort to emergency discharge during rainstorms. In this region even the small valleys are used for agriculture. Hence, flooding in these areas impact both residents and settlement.
The districts of Ahmadabad, Surat, Navsari, Junagadh and Valsad would be the most affected during floods. The estimated number of lives lost due to floods is 0.001 percent.
Damage to buildings due to floods in Gujarat would be 4 percent, with maximum damage in the southern coastal regions extending to parts of Central Gujarat. The total economic losses to buildings would account for 7 percent, with Ahmadabad being the most vulnerable.

The animal husbandry sector faces a capital stock vulnerability of 1 percent and the economic losses account for 2 percent due to floods. The districts, which are most vulnerable, will be Valsad, Surat, Ahmadabad, Bhavnagar and Jamnagar.

**Storm water control**

The PRECIS model results show an increase in precipitation in the western and central parts of India; with decreased rainy days, increase in rainfall intensity has been observed in the last 5-6 years, whether or not climate change significantly alters future weather patterns. Designers and operators of storm drainage systems must prepare for grater uncertainty in the design of storm drainage systems (Ashley et al. 2005). With respect to the operation and design of drainage infrastructure, changes in rainfall intensity have two consequences. First, the flow against which a structure is designed is no longer constant over time. Second, the level of service provided by
drainage infrastructure (once it is constructed) will gradually decrease over time (i.e. storm sewers will flood and culverts will surcharge more frequently) (Ariz, Hanz et al. 2006).

Regardless of this, there is a need for upgrading and improving the quality of storm water systems. This may be in the form of efficient management, and designing considering the future, accommodating for additional capacity and desilting requirements. Model predictions show that there is an increase in the levels of sedimentation in the river systems of Gujarat. This with increased precipitation and runoff would clog the storm water systems, and result in flooding. With sea level rise some storm water outfalls will be inundated and may need to be replaced at higher locations. This may also result in some systems being completely redesigned, as most of the storm water systems release their discharge into the sea.

**Hazardous sites**

It is important to protect sites that are potential sources of toxic contamination from inundation or surges. As with other flood events, this can serve as a major pathway for resource contamination by toxic or hazardous materials. Any building or facilities within inundation risk zones should be free from hazardous materials. New hazardous material collection and temporary storage sites should be located outside the inundation or surge risk zones.

The hazardous waste sites in the state are located at Alang and Surat along the coast thus facing the risk of sea level rise and coastal erosion. Sites at Surat and Ahmadabad are prone to flood due to increased precipitation and rapid urbanization of the cities and clogging of natural drains.

**Waste Management**

Climate change could imply changes in temperatures, cloud cover, rainfall patterns, wind speeds, and storms: all factors that could impact future waste management facilities’ development and operation. The time scales for climate change and waste management are similar in terms of being long. For instance, landfill sites can be operational for decades and still remain active for decades following their closure. There is, therefore, a need to consider potential changes in waste management over significant timescales and respond appropriately.
Table 8: Potential impacts on the waste sector

<table>
<thead>
<tr>
<th>Climate Variable</th>
<th>Potential Climate Change</th>
<th>Impacts on Waste Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Annual warming between 1°C and 5°C by 2080’s</td>
<td>Increased water demand for both workers and operations</td>
</tr>
<tr>
<td></td>
<td>Increase in number of hot days</td>
<td>Impacts of heat stress: Higher temperatures not only increase the rate of waste degradation but also increase the leachate chemical oxygen demand and ammonia concentration.</td>
</tr>
<tr>
<td></td>
<td>Number of cold days decreases</td>
<td>Impacts on the biological processes</td>
</tr>
<tr>
<td>Precipitation</td>
<td>Intensity increases for rainy seasons</td>
<td>Disruption of infrastructure, Increased risk of flooding, changes in the distribution of vermin and pests, can affect the slope stability of waste management sites (Jones, 1993)</td>
</tr>
<tr>
<td>Sea level Rise</td>
<td>Mean sea level may rise up to 30 cm. by the 2100</td>
<td>Inundation of the waste management sites and erosion of the coastal areas</td>
</tr>
</tbody>
</table>

Source: (Ahmed 2012)

5.1.7 Power

Energy sector forms the backbone of all activities in the present time. The climate change impacts on this sector can be broadly understood under the following two heads; firstly, energy production and distribution and secondly, energy consumption patterns (National Communication (NATCOM) 2004).

A thorough literature review emphasizes that the responsiveness of climate change of energy use to climate change is greater in the long run than in short run. In the residential and building sector, a major energy demand is expected to be for space cooling like in Gujarat. For instance, consumers may run their air conditioners more often in response to higher temperatures. The ambient temperature would alter significantly, thus affecting the future energy consumption pattern.

A major sector that impacts energy sectors both directly and indirectly is agriculture, which is very sensitive to any type of climate changes. With the predicted temperature rise, changing precipitation pattern, evaporation rate is also expected to rise because of the temperature increase; water requirement for agriculture is also expected to be greater, resulting in a higher demand of energy for irrigation. Other than irrigation agricultural energy use generally falls into five main categories: equipment operations, embodied energy in fertilizers and chemicals, product transport, and drying and processing. Gujarat has 8 hours/day of assured power supply for agricultural sector, with one day/week of staggered power for the industrial sector.
Impacts on energy production and distribution
Impacts on energy/power resources and supply will largely be in the form of disruption in services as a result of severe storm event. Backup energy sources are extremely limited, being largely confined to a few generators serving large facilities. Energy production in Gujarat is dominated by fossil fuels: coal, petroleum, and natural gas. Every existing source of energy in India has some potential impact to climate change.

Renewable energy sources tend to be more sensitive to climate variables; but fossil energy production can also be adversely affected by air and water temperatures, and the thermoelectric cooling process that is critical to maintaining high electrical generation efficiencies which also applies to nuclear energy (United States Climate Change Science Program (U.S.CCSP) 2007). In addition, extreme weather events have adverse effects on energy production, distribution, and fuel transportation.

Thermoelectric plants: The most direct climate impacts related to power plant are cooling and water availability (United States Climate Change Science Program (U.S.CCSP) 2007). As currently designed, power plants require significant amounts of water, which may be vulnerable to fluctuations in water supply. For Gujarat, as precipitation increases in the mid to long-term, there will be a positive feedback to climate change. In addition, low-lying coastal regions are being considered for the siting of new plants due to the obvious advantages in delivery of fuel and other necessary feed stocks. Significant percentages of other energy infrastructure assets are located in these areas, including a number of the nation’s oil refineries as well as most coal import/export facilities and liquefied natural gas terminals. Given that a large percentage of Gujarat’s energy infrastructure lies along the coast, rising sea levels could lead to direct losses such as equipment damage from storm surges and flooding or indirect effects such as the costs of raising vulnerable assets to higher levels or building future energy projects further inland, thus increasing transportation costs.

Impacts on Energy Transmission, Distribution, and System Infrastructure
In addition to the direct effects on operating facilities themselves, networks for transport, electric transmission, and delivery would be susceptible especially to changes due in stream flow, annual precipitation and seasonal patterns, storm severity, and even temperature increases (e.g., pipelines handling supercritical fluids may be impacted by greater heat loads if temperatures increase) (Ebinger & Vergara 2011).

Impacts on Energy Use
Possible effects in the context of Gujarat due to increased precipitation and temperature in the mid to long-term of the 21st century include:
(1) Increases in the amount of energy consumed in residential, commercial, and industrial buildings for space cooling;
(2) Changes in the balance of energy use among delivery forms and fuel types; and
(3) Changes in energy consumption in key climate-sensitive sectors of the economy, such as transportation, construction, agriculture, and others (U.S. CCSP 2007).
5.1.8 Transport

Climate change impact on transportation infrastructure and its operation can be divided into three categories: the effects of climate on operations; the effects of sea level rise on coastal facilities; and the effects of climate on infrastructure. Swinomish Climate Change Initiative (SCCI) defines the following as the potential impacts of climate change on road transportation that are applicable to Gujarat.

Access and circulation
Climate change can affect the operational capacity and accessibility for transportation routes and has the potential to directly affect the mobility of people and goods by the inundation of roads from sea-level rise, storm/tidal surges etc., road closure resulting from extreme flooding events and finally public transport disruption. Such impacts are reported by Renckien’s study of climate change and city synergies for Hyderabad city.

Road system integrity
RCM predictions for Gujarat indicate that there will be increase in temperature and precipitation for Gujarat leading to premature deterioration of concrete road surfaces as a result of weathering (Wooler 2004). Intensified flooding events can deteriorate pavement surfaces from loosening of aggregate due to water saturated road base, resulting in subsidence. Heavy precipitation from more frequent intense storms can overwhelm road drainage and create debris. Exposure to increased temperatures will amplify buckling, rutting, and bleeding of roads (National Research Council of the National Academics 2008). Pavement/soil erosion and landslides in erosion-prone areas may increase from more frequent intense storm events.

Table 9: Potential impacts in the transport

<table>
<thead>
<tr>
<th>SECTOR</th>
<th>CLIMATE CHANGE PARAMETERS</th>
<th>DIRECT IMPACTS</th>
<th>INDIRECT IMPACTS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aviation</td>
<td>Extreme events</td>
<td>Physical damage</td>
<td>Migratory traffic, tourism shifts, carbon constraints</td>
</tr>
<tr>
<td>Roads</td>
<td>Precipitation, extreme events</td>
<td>Land subsidence, soil erosion</td>
<td>Migration pressure, modal shift</td>
</tr>
<tr>
<td>Ports/ inland waterways &amp; transport</td>
<td>Storm surges, extreme events</td>
<td>Physical damages, excessive siltation</td>
<td>Modal shifts</td>
</tr>
<tr>
<td>Railways</td>
<td>Precipitation, extreme events</td>
<td>Land subsidence, soil erosion, vegetation cover</td>
<td>Carbon constraints, modal shifts</td>
</tr>
</tbody>
</table>
5.2 Observed Impacts of Climate Change in Gujarat

Gujarat has the longest coastline of 1600 km and seven agro-climatic zones making the environment dynamic. Over the past sixty years there has been a steady increase in temperature; this can be associated with climate change due to anthropogenic actions. Gujarat, which was considered drought prone zone, has not experienced any significant drought since the last decade. Rather, it experiences floods with a 25 percent probability of occurrence. Sea level rise is also another offset of climate change as it damages the coastline affecting coastal population, biodiversity and groundwater. Sea level rise along Gujarat coastline has been increasing at 3mm/year. It is of utmost importance that climate change impacts are documented so that there is a record of climate impacts on society and economy. The Government of Gujarat is favorably disposed to mitigating climate change, as there are economic opportunities for large industrialist and the private sector. It is the duty of the government to communicate the adverse effects of climate change to its citizens and take the lead in protecting the poor and vulnerable communities from the vagaries of climate change.

5.2.1 Impacts on Agriculture

According to Gujarat Agriculture Labour Union (GALU), International Union of Foodworkers (IUF) & Delhi Platform (2011) warmer winters in recent years have reduced the moisture availability for winter crops maize, wheat, tuar dal, etc. leading to reduction in yields of these crops, at times also forcing farmers to leave their land fallow. In the districts of Banaskantha and Sabarkantha the warmer winters in the state have resulted in increased incidence of pest attack forcing farmers to use higher inputs/ pesticides on farms. Also warmer winters over the past 10-12 years have resulted in reduced grain size. Winter periods have got shorter causing terminal heat stress during the period of grin growth thereby affecting grain size and overall yield. Irregular rainfall events in 2010-11 have led to the reduced production of important crops like cotton, groundnut and potato.

Coastal erosion, an indirect consequence of sea level rise and high intensity of precipitation also poses a major problem in South Gujarat. Erosion rates between the Mindhola and Varoli estuary is almost 10mm/year. Many farmers have lost their agricultural land due to erosion. Erosion also reduces water availability in coastal aquifers and increases salinity intrusion another indirect effect of sea level rise. Migration of coastal communities due to environmental degradation is a potential problem in South Gujarat. Hence Coastal Regulation Zones must be enacted to protect the habitat and livelihood of the coastal community. At a local level about 70 percent of people from Bilimora and Gandevi village have migrated due to coastal erosion as analysed by Consortium of coastal Academic Institutions for the National Centre for Sustainable Coastal Management (NCSCM 2010).

5.2.2 Impacts on Livestock

Significantly longer heat-wave duration has been observed in many countries of Asia, as indicated by pronounced warming trends and several cases of severe heat waves (De & Mukhopadhyay 1998; Kawahara & Yamazaki 1999; Zhai et al. 1999; Lal 2003; Zhai & Pan
2003; Ryoo et al. 2004; Batima et al. 2005a; Cruz et al. 2006; Tran et al. 2005). As suggested by the Gujarat Agriculture Labour Union (GALU), International Union of Foodworkers (IUF) & Delhi Platform (2011), local and hybrid cow breeds mostly in districts of Eastern Gujarat are hit by heat stress. This situation has been further aggravated by lesser availability of fodder. This has affected the fat content of the milk produced. A drought spell during 1987 affected over 168 million cattle in India, due to decline in feed and fodder availability and serious water shortages. During the same time, in Gujarat, one of the worst drought affected states, 18 million cattle out of 34 million were reported to have died before the next monsoon as researched by Poorest Areas Civil Society (PACS 2008).

5.2.3 Impacts on Corals

During 1985-2005, the minimum SST in Gulf of Kutch has increased by 0.116°C per decade. The reefs in the Gulf of Kutch in contrast were less severely affected. Only 2 percent of the coral was bleached severely and no bleaching related death was observed. The present analysis confirms that the warming was centered between 0.7°-12° N Latitudes and the intensity reduced toward the northern latitudes (2.3° N -5° N of Gulf of Kutch). In future, the entire belt of coral reefs along the South Gujarat coast is in danger of getting bleached. Nearly 30 percent of the coral reefs in the Gulf of Kutch are bleached due to the sea level rise and warming (Center for Science and Environment n.d.).

5.2.4 Impacts on Water resources

Water resources in Gujarat are vulnerable to climate change and are also aggravated by it. As per the study (Salinity Mapping in the Coastal Areas using GIS and Remote Sensing) based on the GALDT method of vulnerability to coastal aquifers using hydrological parameters, the areas which are vulnerable to salinity have increased considerably in the last two decades from 1983 onwards. The number of villages under the threat for drinking water containing chloride content more than 250 mg/lit has increased and so has the chloride content for the decades from 1983 to 1993. As sea level rises salinity ingress also increases hence the study by Agarwadkar (2005) considered distance from the shore and depth of the aquifer below sea level.

5.2.5 Health Impacts

The world's climate system is fundamental to life. A changing climate is likely to affect all these conditions and hence have a powerful impact on human health and well-being. In its Third Assessment Report, the United Nation's IPCC concluded that “climate change is projected to increase threats to human health.”

Studies have been conducted to understand the relation between climate variability and malaria in India. It has been seen that rainfall is an important indicator for early warning of malaria in the drier parts like Rajasthan and Gujarat. Gujarat state lies in the eco-epidemiological setting of semi-arid plains. In the semi-arid plains of western India, malaria is unstable and comes in 5–8 year ‘troughs and crests’ associated with rainfall variations. Analysis of the trend of malaria in Gujarat state over 1961–2005 shows that two major epidemic waves have occurred in the state with the first major peak incidence in 1976 and the second one in 1989 (National Institute of Malaria Research (NIMR) n.d.). Focal outbreaks of malaria have also occurred in certain high rainfall years.
Figure 162: Trends in Malarial cases in India

Also studies reveal that the proportion of incidences caused by the *Plasmodium falciparum* increases from 20 percent during normal rainfall years, to 35 percent in the years of the epidemic correlated with the high rainfall years. Similarly, it is also known that the *Plasmodium falciparum* parasite in the female anopheles mosquitoes requires a higher temperature for their development in the initial stage. Hence higher precipitation and temperatures have a bearing on the multiplication of the *Plasmodium falciparum* parasite. Increase in *Plasmodium falciparum* cases is likely to increase the proportion of severe and complicated cases and deaths due to malaria (National Malaria Research Institute (NMRI) n.d.).

Malarial Transmission Windows (TWs) are determined based on the minimum required temperature and relative humidity conditions. As inferred from our analysis, a minimum, mean rise in temperature of 0.41 is observed in 8 months of the year, as well as a steady increase in the precipitation trends for the state of Gujarat. This is indicative of a clear widening of the TWs here. However, a close analysis of the malarial cases reported in the state indicates that there has been a decrease in the number, as a result of better sanitation and government policies and initiatives but increase in mortality due to malaria.

Another significant aspect of this issue is the underreporting of malaria cases in Gujarat. There have been reports which said that re-examination of blood smears in nine PHCs revealed changes in the climatic variables that 6.7 percent of them had been misdiagnosed (Dash 2007). As a result, 1,262 malaria cases went undetected and unreported. Consequently, the annual parasite incidence of malaria should have been 9.0 instead of the 5.9 reported. The annual parasite incidence is a malariometric index to express malaria cases per thousand populations. As per the National Vector Born Disease Control Programme incidence records, in most of India, the API
was < 2, whereas 2–5 API was in scattered regions, and regions with > 5 API were scattered in the states of Rajasthan, Gujarat, Karnataka, Goa, Southern Madhya Pradesh, Chhattisgarh, Jharkhand, Odisha and in north-eastern states (ibid).

Heat index (HI) is assessed to determine the heat stress that is caused to humans due to combined effect of excessive levels of atmospheric temperature and moisture. Based on climate projections of the Regional Climate Model of the Hadley Centre’s ‘PRECIS’ (Providing Regional Climates for Impacts Studies) for A1B scenario, heat index (HI) has been derived for different districts of Gujarat (India) for baseline (1961–1990), middle line (2021–2050) and future line (2071-2098) periods. The results showed a rising trend of heat index in almost all the districts of Gujarat (Sharma 2012).

The highest increase in HI value under future scenario has been observed in the districts of Bharuch, Jamnagar, Junagadh, Narmada, Porbandar and Valsad as compared to other districts of the state. The highest HI is observed in Kutch (35.70°C), Little Rann of Kutch (35.76°C) and Rann of Kutch (36.59°C) even in the base line period where thermal regime is already a challenge to human tolerance. Heat stress may cause occupational health risks as well as reductions of work productivity that can have a negative impact on family income and the community economy. Several studies have identified heat stress as an important health risk in agricultural and industrial sectors in India. The major industries studied so far include automotive, coal mines, ceramics and pottery, iron works, stone quarry and textiles (Dash 2001). The average increase in HI from the base line values are 2.75°C and 6.93°C in middle line and future line periods respectively. This figure indicates an increasing nature of environmental warmth from April to June, the peak summer months. The most vulnerable zones in terms of potential warming zones are Rajkot, Surendrenagar and Patan (National Institute of Occupational Health (NIOH) 2009).

This is not a new phenomenon, as per a CSE1998 report, a surprisingly high number of heat wave days were experienced in the country. During this Gujarat, along with 7 other states namely Uttar Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Orissa, Punjab, and south Tamil Nadu saw 1300 deaths in total. Heat stress mortality in Gujarat has been reported to show an escalating trend over the years. The figure below shows the temperature profile of Gujarat for the year 2009.

5.2.6 Infrastructure

Energy
In this sector, the energy use patterns now seen in Gujarat can be analysed. Some instances of a more climate proofed energy consumption patterns are discussed below:

Air conditioner sales have increased at 20 percent per year during the last 5 years in Gujarat and at 30 percent per annum in Ahmadabad. Refrigerator sales have increased at 9 percent per annum for Gujarat and at 30 percent per annum in Ahmadabad during the last 5 years (United States Agency for International Development (USAID) Report 2009). A rise in the use of these technologies used for cooling purposes is indicative of the people’s response to the rising maximum temperatures in all the seasons.
Shoreline
As per the study of the tide gauge records of the north Indian Ocean for more than 40 years, conducted by the National Institute of Oceanography, it is observed that the sea-level rose by 1.06-1.75 millimeters per year in the past century. This estimate is consistent with the estimated global sea-level rise of 1-2 millimeters per year made by the IPCC. Coastal erosion is a universal problem and it has been estimated that 70 percent of all the beaches in the world are eroding. Most of the existing and potential coastal erosion hazard problems arise because of coastal development having been undertaken too close to the sea. Coastal erosion is primarily associated with dynamic natural shoreline and Gujarat has a dynamic shoreline (Chauhan et al. 2001). This picture was brought out through satellite imagery, which was displayed at the annual conference of INCCA (Pathan 2008).

Impacts on Residential Areas
Rising waters and eroding shoreline are threatening villages along the Southern part of Gujarat. A study by the Indian Space Research Organisation has revealed that the sea has moved inland up to 80 meters in the last decade. Due to the advancement of the sea an entire village population had to leave their homes and relocate to higher grounds (Pathan 2008). The villages of Dabdi in Valsa and Kaladra which are located on the estuary of the Narmada are facing the increase in sea level.

A preliminary study taken up by the researchers at MS University on the submergence of land due to the landward movement of the Arabian Sea suggests that the coastal areas of South Gujarat have been eroding for the past few decades. Sea water has moved inland by 10 to 15 meters (from Danti to Umbergaon). The sea water level has increased by 80 to 90 meters in Danti alone (Jha & Sharma 2009). The districts of Valsad, Navsari, Surat, Bharuch and Amreli, Junagadh, Porbandar, Jamnagar has the Arabian Sea as its western eastern boundary show that there is coastal erosion in nearly 449 villages. The erosion is due to strong tidal current accompanied by wave action. Due to this erosion the shoreline has reached habitable area. Heavy damages are caused to houses, fertile land and other property due to coastal erosion. The tendency of local people of coastal villages is not to leave their original place of dwelling near sea coast which facilitate their access to sea for fishing business and therefore, it is not possible to persuade local inhabitants to shift to the another place (Narmada, Water Resources, Water Supply and Kalpsar Department, GOG).

Floods are recognized as the most frequent and damaging disasters in Gujarat. They have a short term adverse impact due to destruction (homes, land) and water logging as well as long term adverse impacts from stagnant water, epidemics, etc. Analysis of data has shown an increase in the frequency of flood over the past 3 decades. The floods of 2005 created havoc and disrupted life in central, southern and Saurashtra regions of Gujarat. According to the metrological reports, the state received 69 percent of its average rainfall during the first spell of rain, that is, by July 7th, 2005. Of all the 15 affected districts, Vadodara, Amreli, Anand, Kheda, Surendranagar, were among the worst affected. There was a deviation of nearly 241 percent from the normal rainfall during the period. In addition the high tide at the Gulf of Khambat did not let the water drain into the sea, leading to water stagnation in low lying areas close to the river bank.
RESPONSES
6 RESPONSES

From the previous chapter we understand the range and extent to which climate change can impact society, economy and ecosystems. There is a need to respond to climate change in an informed manner and policy decisions need to be taken with knowledge and understanding of how the climate system behaves and the extent of its impacts. Climate information is becoming increasingly important to public and private decision-making in various sectors, such as emergency management, water management, insurance, irrigation, power production, and construction. The emerging ability to forecast climate at seasonal-to-interannual time scales can be of tremendous value if the information is used well (Nation Academies Report 2008). Climate change is set to become an increasingly important strategic economic and political concern as it starts to disrupt Gujarat’s high economic growth rates and affect the lives and livelihoods of millions of people. There are two dimensions in the response to climate change - mitigation and adaptation. This describes the various ways and techniques used to tackle climate change. With increasing global warming caused by various factors, climate change has become a prime concern for our own existence. The demand of the hour is to adapt to the changing climate and work together to find mitigation options so that no further damage is done.

To give readers a glimpse of the contribution made by Government of Gujarat listed here are a few initiatives made to respond to the change climate and to communicate to the masses that efforts are being made to combat climate change. The Government of Gujarat was the first in the country to establish the Department of Climate Change to handle issues of climate change. The initiative is to give a human face to environmental issues; empower people to become active agents of sustainable development; promote an understanding that communities are pivotal to changing attitudes towards environmental issues; and advocate partnership, which will ensure all citizens and people in Gujarat to enjoy a safer and more prosperous future. A Management Education Centre on Climate Change (MECCC) was set up to overlook changes in curricula at college levels, introduction of various programs at university level and training of professionals and executives in relevant fields. This includes understanding natural and artificially induced factors responsible for climate change, build capacities to respond to climate change, select design and apply a range of complementary, cohesive tools as part of strategic approach to sustainability and enhance communication capabilities to inform and empower people. The Government of Gujarat executed a memorandum of understanding with TERI for helping the GoG to build capacities for developing climate change adaptation and mitigation strategies. This takes into consideration joint mission on National Action Plan for Climate Change, orientation for officers and policy planners, helping government to develop educational curricula, training of teachers and master trainers on climate change and related issues. To facilitate in-house administrative capacity and institutional set-up for promoting climate change policy. There are two sections in this chapter: the first is on mitigation and the second is on adaptation. These sections examine measures taken by the state, private and civil society organization on climate change.
6.1 Mitigation

According to the UNFCCC mitigation is a human intervention to reduce sources or enhance the sink of greenhouse gases. Examples include using fossil fuels more efficiently for industrial processes or electricity generation, switching to solar energy or wind power, improving the insulation of buildings, and expanding forests and other "sinks" to remove greater amounts of carbon dioxide from the atmosphere (UNFCCC 2011).

6.1.1 Changes in policy

6.1.1.1 Policy interventions in Power Sector

The Government of Gujarat in response to climate change has made efforts to reduce the sources of greenhouse gases. Gujarat’s power sector contributes a larger share of greenhouse gases thereby intensifying climate change. The Gujarat state power policy has incorporated some measures to reduce greenhouse gas emissions. The policy promotes the following:

- Improve Energy efficiency
- Give importance to co-generation for the purpose of steam and power recovery so as to enhance energy efficiency
- Carry out planning and building up adequate capacity in generation, transmission and distribution.
- Achieve optimum utilisation of existing equipment.
- Rationalise tariff structures.
- Improve quality of services to achieve cost effectiveness.
- Strive for energy conservation.
- Encourage power generation by utilising non-conventional energy sources.
- De-monopolise distribution of power and invite involvement of private partners

The Government of Gujarat is also working for the promotion of renewable energy. The Gujarat Energy Development Agency (GEDA) was established to oversee renewable energy development and energy conservation. GEDA is shouldering the responsibility of a State Nodal Agency (SNA) for the Ministry of New and Renewable Energy Sources (MoNRE) and the State Designated Agency (SDA) for Bureau of Energy Efficiency (BEE). Changes brought about by GEDA for the promotion of renewable energy are shown below.

Solar Energy

- Solar Power Policy – 2009 with the following salient features.
  - Promoting generation of green and clean power.
  - The policy will remain in operation from 2009 to 2014.
  - Solar power generators (SPGs) installed during this period is eligible for incentives for 20 years.
  - Electricity generated from SPGs and used for self-consumption or sale to third party, or sale to licensees, shall be exempted from payment of electricity duty.
  - Exemption from demand cut to the extent of 50 percent of the installed capacity.
Other highlights include making productive use of wasteland, thereby engendering a socio-economic transformation. MW Solar Power Generation shall be allowed for installation during the operative period of the policy.

**Bio Energy**
- GERC order determination of tariff for Biomass Based Power Projects
- GERC order - determination of tariff for Bagasse based co-generation Power Plants

**Wind Energy**
- Amendment to Wind Power Policy
- Wind Power Policy - 2007
- GERC Regulation on Wind Power dated August 11, 2006
- Wind Power Policy- 2009 GEDA

In 2009, the Government of Gujarat announced an amendment in the Wind Energy Policy to tap the 10,000 MW potential along the coastal areas of the state. Today, this policy has undergone major revisions to attract even more investors in the field. The amendments in the Wind Power Policy 2009 include:
  - Power sale tariff increased from Rs. 3.37 to Rs. 3.50 per kWh
  - Renewable energy power purchase obligation increased form the existing 2 percent to 10 percent.
  - A mechanism to facilitate the Renewable Energy Certificates for renewable energy obligation of utilities/ Open Access and captive consumers, using conventional fuel.
  - GETCO (Gujarat Energy Transmission Company) will provide grid connectivity to wind farms or permit private producers to lay transmission lines

For the **promotion of energy efficiency** in the state all power producers must have their own corporate, quality, energy efficiency, and environment policies and must fulfill the following criteria.

- Deliver reliable, quality and cost effective power and services to the customer's satisfaction by adopting cutting edge technologies, maintaining global standards of quality and striving for continual improvement through prudent operation and maintenance practices.
- Comply with all applicable legal and other requirements in respect of product, process, environment and occupational health and safety.
- Prevent pollution and conserve resources in its operations, to minimize liquid & solid waste generation and to ensure proper utilization of waste and its disposal in eco-friendly manner.
- Continual improvement in its operations and in promoting a clean, safe and healthy environment.
Other Policy Measures
Switching of technology has also been observed. The Government of Gujarat has moved from more polluting coal to a less polluting natural gas based power generation. There have been instances like GIPCL switching to gas based power generation, which is not only cleaner, but also more efficient. Similarly many private sector undertakings are promoting captive generation through wind and bagasse based power generation. The strain on the environment is less due to the use of natural gas but it is also a natural resource subject to depletion. Studies have been conducted on the impact of reforms in electricity policy specifically with respect to Gujarat. It says that along with shift in primary ownership as a result of active participation by private players, there has been a shift in the primary fuel used for energy generation from coal to gas. Further, the studies reveal that the changing fuel mix and technology have led to more energy efficient generation. This can be largely attributed to the penetration of gas-based technologies. Even in older coal-based plants, this trend is evident. This is due to investment in renovation and modernization of coal plants in the last decade. In addition, the entry of efficient coal technologies has contributed to some extent in improving the efficiency. There has been an autonomous shift to larger and more efficient coal units. It is understood from analysis that major portion of the emissions come from plants which have considerable vintage. Retirement of old plants and installation of new capacities has further scope for driving down the baseline.

Power thefts and unmetered power supply was checked by appropriate policy intervention. It was now time for the unbundling. In May 2003, the Government of Gujarat passed the Gujarat Electricity Industry (Reform and Reorganization) Act, which divided the GSEB into a holding company, a power generation company, a power transmission company and four distribution companies. This enabled better management and more efficient operations in power sector.

6.1.1.2 Policy interventions in Industry Sector

According to the industrial policy of 2009, importance is given to sustainable holistic development in the state by promoting “Creation of Wealth with Social Health” (Corporate Social Responsibility). One of the main objectives of the policy is adherence to high quality standards meaning the best manufacturing processes would be adopted in terms of environmental norms compliance, thus giving a scope to setting up of mechanisms to track the latest in technology and innovation. The policy also speaks of encouraging research and development for attracting and ushering the next generation of investments and talents. The policy promotes the use of non-conventional energy as the energy consumption of the state is increasing and the potential for hydropower is low. The concept of rurban has been proposed by the state and supposes an inclusive and sustainable development model where the energy requirements would also need to be met with, in a decentralized manner.

The policy also speaks of improving the efficiency of environmental compliance through industrial zoning, third party audit, capacity building, access to expertise and automated monitoring-better objectivity and compliance. The policy promotes the adoption of new technologies, business sophistication and innovation through research and development, awards and recognition for environment improvement measures, innovation and new product/process/technology development, the state plans to set up a fund which would provide financial support for industries vying towards a technology upgradation or updating its technologies, the
Government would also facilitate setting up of R&D institutions by defraying part of the project cost. In a view to promote sustainable development the conservation of energy and water is emphasized through providing financial assistance for equipment, for auditing by a recognized institution or a consultant (Industrial Policy, GOG 2009).

The Government of India has come out with the Perform Achieve and Trade (PAT) Scheme to incentivize industries to achieve better energy efficiency targets in a cost effective manner, the identified industries are required to improve their energy efficiency within three years or face penalty under this mandate. The scheme also provides efficient industries to trade their energy savings with other designated industries. According to GEDA there are in all 685 designated consumers in the country accounting for 60 percent of the total energy consumption of the country of which 54 are identified in Gujarat. Through the PAT Scheme it is targeted to reduce the energy consumption by 10 million MTOE (4.16 percent of the current consumption value).

**Status of PAT Scheme in Gujarat:** GEDA has conducted about 6 PAT Awareness workshops during the year 2010 in Gujarat. Baseline Energy Audits of Power Plants and Chloro Alkali Plants in Gujarat have been completed. Targets have been assigned to all the GSECL Power Plants by Bureau of Energy Efficiency (BEE).

According to the technology upgradation scheme of the Ministry of Textiles, Government of India, a scheme for technology upgradation in the textile industry has been formulated as Indian textile industries do not have the same technological edge as their counterparts in the developed countries especially in the weaving and processing segments. Under this scheme a total of 13155 applications have been sanctioned costing 8314.40 crores out of which 13152 have been disbursed which costs 6902.46 crores just for the state of Gujarat.

### 6.1.1.3 Policy interventions in Transport Sector

**Road policy – Key highlights**

- Provide connectivity to all villages by building all-weather roads to improve quality of life in rural areas.
- Constantly upgrade technology by deploying superior and quicker construction and maintenance methods.
- Induct scientific principles of resource allocation for maintenance and new construction programmes.
- Set high standards for road safety and the travel comfort of passengers.

### 6.1.1.4 Policy interventions in Waste Sector

Policies, measures and instruments shown to be environmentally effective:
The municipal solid waste (MSW) rules 2000 mandates scientific treatment and disposal of solid waste. Financial incentives for improvements in waste and wastewater management, renewable energy incentives and obligations are the other options.
6.1.2 Technology responses

Gujarat has 186 Clean Development Mechanisms (CDM) Projects which are registered, under review and are in pipeline. Gujarat leads the CDM market in the country with total of 32896 CERs till November 2010.

6.1.2.1 Technology responses in the power sector

Super critical technology in thermal power powers

Solar energy achievements

- The solar power projects would generate 1250 million units of green energy; avoid 8.75 lakh tonnes of coal and 12.50 lakh tonnes of carbon dioxide emission annually and also provide employment to over 5000 people.
- Gandhinagar solar energy project under implementation, as part of Energy Conservation Program and is under CDM projects.
- Solar PVs have been installed in government buildings like the Udyog Bhavan, Sachivalaya and GPCB. The GPCB’s new building in Gandhinagar will be the first 100 percent solar building wherein electricity generated through sunlight will power 600 fans and 1000 CFL tube lights besides 40 A/Cs.
- Solar thermal has also been introduced by installation of solar water heating systems in government buildings and hospitals.
- Energy conservation is also being undertaken by replacement of older energy intensive light sources with Light Emitting Diodes (LED) based lights, Compact Fluorescent Lamps (CFLs) etc.
- Installation for energy savers for street lights on the main roads
- Installation of solar generators in dairy sectors
- 1 MW electricity from solar panel atop the Narmada branch canal
Wind energy achievements
- At present 2466.205 MW comes from wind based power plants.
- In November 2008, Gujarat notched the first prize and won the Best Wind Power Developer State Award for maximum capacity additions in wind power generation with a growth rate of 99.65 percent (199.94 MW in 2005-06 to 1184.85 MW 2007-08) during the two fiscals - 2006-07 and 2007-08, along the coast of Saurashtra (Socio economic review 2010)

Biomass energy
- 0.945MW biogas Based Power Project at Sayaji Industries, Kathwada
- 12000 nm³ biogas per day (1MWeq.) Maize Starch Industry liquid waste based Bio-methanation plant by Gujarat Ambuja Exports Ltd., at Village Dalpur, District Sabarkantha
- 0.833 MWeq.(10000nm³/day) capacity Maize Starch Industry Liquid waste based bio-methanation plant at Sayaji Industries Ltd., Kathwada, Maize Products, Ahmadabad
- Industrial Waste based 4800nm³/day capacity bio-methanation project at Anil Starch Products Ltd., Ahmadabad.
- 2.0 MW capacity bio-gas based power generation project at Kanoria Chemicals Industries Ltd., Ankleshwar

Other achievements in Power sector
Other achievements in the power sector have been by the Gujarat Energy Development Agency. It has implemented LED project at village Amrapura, Taluka, Mansa, District: Gandhinagar and
is the first LED village demonstration Project in Gujarat. Project was jointly funded by BEE. A 500 MW capacity solar parks have been set up in Charaniya Taluka, to support solar power policy as well as develop solar infrastructure. A 1MW solar electricity plant at Raisan in Gandhinagar has been set up under the Gandhinagar solar city project. Large Urban Efficiency Program covering all Municipal Corporations and Municipalities in the State under implementation which will lead to 30 percent energy savings. As part of energy conservation and demand side management, project for replacement of existing pump sets of farmers with energy efficient pump sets to reduce the power demand in agriculture sector is taken up. With this measure, it is possible to achieve 10 to 15 percent energy savings. During the year 2009-10, 13534 existing pump sets were replaced by energy efficient pump sets.

ABB will install its proven Symphony™ distributed control system (DCS) and supply the complete control and instrumentation package for the 6x210 MW thermal power plant of the Gujarat State Electricity Company Limited (GSECL) at Wanakbori. The solution will include diagnostics and optimization packages, turbine controls, steam generator control, station controls and instrumentation, a steam and water analysis system (SWAS), flue gas analyzers, control valves, actuators and positioners. The project is scheduled to be completed by 2013 (ABB 2012).

### 6.1.2.2 Technology responses in the industry sector

As provided in the National Conservation Strategy and Policy Statement on Environment and Development (MoEF 1992) the key mitigation technologies and practices currently commercially available are:

- Cleaner Production process
- More efficient end-use electrical equipment
- Heat and power recovery/cogeneration
- Material recycling and substitution
- Control of non-CO\textsubscript{2} gas emissions and process-specific technologies
- Fuel switching, including use of waste materials
- Improving production efficiency

Key mitigation technologies and practices projected to be commercialized before 2030:

- Advanced energy efficiency
- Inert electrodes for aluminum manufacture

The energy efficient technologies that are being used/practiced by the dairy clusters in Gujarat under the BEE SME program are:
Table 10: Penetration of energy efficient technologies in Gujarat

<table>
<thead>
<tr>
<th>Technology</th>
<th>Penetration level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low loss &amp; compact thermal storage technology</td>
<td>22</td>
</tr>
<tr>
<td>Desuper heater system</td>
<td>14</td>
</tr>
<tr>
<td>Methane Capture (By anaerobic treatment) Technology</td>
<td>3</td>
</tr>
<tr>
<td>Solar water heating system</td>
<td>12</td>
</tr>
<tr>
<td>High efficiency electric motor</td>
<td>15</td>
</tr>
<tr>
<td>Energy Conservation for Motor by Soft Starter</td>
<td>21</td>
</tr>
</tbody>
</table>

Source: (Cluster Summary Gujarat Dairy n.d.)

The energy efficient technologies for steel making process followed in Gujarat is given below

Table 11: Energy efficient technologies for steel making in Gujarat

<table>
<thead>
<tr>
<th>Process</th>
<th>Energy-efficient Technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coke making</td>
<td>• Coke dry quenching (CDQ)</td>
</tr>
<tr>
<td></td>
<td>• Automatic combustion control</td>
</tr>
<tr>
<td></td>
<td>• Automatic ignition for coke oven flare</td>
</tr>
<tr>
<td></td>
<td>• Tall batteries and stamp charged batteries</td>
</tr>
<tr>
<td>Sinter making</td>
<td>• Sinter cooler waste heat recovery</td>
</tr>
<tr>
<td></td>
<td>• Multi-slit burners</td>
</tr>
<tr>
<td>Iron making</td>
<td>• Top Pressure Recovery Turbine (TRT)</td>
</tr>
<tr>
<td></td>
<td>• Hot stove waste heat recovery</td>
</tr>
<tr>
<td></td>
<td>• Coal Dust Injection (CDI)</td>
</tr>
<tr>
<td></td>
<td>• Bled BF gas recovery</td>
</tr>
<tr>
<td>Steel making</td>
<td>• Bled BOF gas recovery</td>
</tr>
<tr>
<td></td>
<td>• BOF gas sensible heat recovery</td>
</tr>
<tr>
<td>Casting</td>
<td>• Continuous casting replacing ingot casting</td>
</tr>
<tr>
<td></td>
<td>• Thin slab casting / near-net-strip casting</td>
</tr>
<tr>
<td>Rolling</td>
<td>• Walking beam furnace</td>
</tr>
<tr>
<td></td>
<td>• Reheating furnace waste heat recovery</td>
</tr>
</tbody>
</table>


Technology responses in the transport sector

- 3.6 Lac auto vehicles switched over to clean fuel of CNG/LPG in the last 7 years. Ahmadabad, which was the 4th most polluted city in India has improved to the 66th rank in the last four years
- India’s first and two LNG terminals – Dahej and Hazira are in Gujarat, with the plants to set up two additional LNG terminals at Mundra and Pipavav
- Bus Rapid Transit System (BRTS) being implemented to shift 40 percent of the trips from Personal transport vehicles to public transport
• 2200 km. of gas grid is under implementation. A master plan of Rs.8000 crores to provide 20 lakh domestic connections, CNG stations for auto fuel. Major industrial estates would be provided gas as a fuel

Key mitigation technologies and practices currently commercially available in the transport sector to reduce suspended particulate matter and greenhouse gas emissions are
• Hybrid vehicles
• Cleaner diesel vehicles
• Bio-fuels

6.1.2.3 Technology responses in the waste sector

Gujarat recognized the need for an integrated approach to Municipal Solid Waste (MSW) management in 2005. In view of the huge lacunae in treatment and disposal facilities, Gujarat adopted statewide, regional approach to meet requirements for its safe disposal. The basic model that was arrived at for initial treatment of wastes was through vermi-composting, to reduce volumes to be transported for land filling. Urban Local Bodies (ULBs) were required to identify sites for vermin compost facilities on the basis of area and location criteria provided. Each vermi-composting facility was also to serve as a transfer station at the ULB level, for transportation of residual waste for land filling on a regional basis.

According to the Gujarat Pollution Control Board, the state has 25 CETPs that are operational, 2 are under progress and 7 are proposed. There are a total of 64 STPs in the state of which 51 are in operation and 13 are under installation. There are 76 vermi-compost plants of which 70 vermi compost plants are in operation and 78 plants are proposed. There are a total of 30 oxidation ponds. Presently there are three landfill sites and it is proposed for every municipal corporation in the state to have a landfill site (GPCB 2011).

As given in the National Conservation Strategy and Policy Statement on Environment and Development (MoEF), the key mitigation technologies and practices currently commercially available in the waste sector to reduce methane emission to reduce health hazards are:
• Scientific landfill methods
• Waste incineration with energy recovery
• Composting of organic waste
• Controlled waste water treatment
• Recycling and waste minimization

The Gujarat Urban Development Company Limited has spent a total of Rs.70, 904Crores on the purchase of equipments for the ULBs these include PE buckets, hand carts, tricycles, tractors, dozing cum loading attachment, container lifting device, water tanker and hydraulic trolleys. The municipal corporation of Ahmadabad is one of the first cities in India having a full mechanized system of transporting solid waste. A total of 126 Vehicles and machinery are deployed for transportation. A CDM cell has been established which acts as the nodal agency and building agent for availing carbon credit from waste management projects implemented by the Government of Gujarat. Presently the agency is working on CDM projects for all STPs being
developed by individual ULBs and municipal energy efficiency project in the ULBs to avail carbon credit (Urban Development and Urban Housing Department, GoG).

6.1.2.4 Technology responses in the agriculture sector to mitigate climate change

**Gujarat’s smart irrigation system**
Sardar Sarovar Narmada Canal Project is, perhaps, the largest lined canal project in the world. For effective operation of the canal to manage equitable distribution of water through command area state government has planned a huge canal automation system. The automation once implemented will enhance irrigation productivity. Thus, controlling GHG emissions produced by diesel-generator pump sets to take out water from canal to a greater extent (Dave 2010).

**Soil health card programme**
Soil health card program is an initiative to reduce the GHG Emissions from agricultural soils. In this, a cropping system is suggested based on the soil moisture availability. In addition to reducing GHGs from the excessive usage of chemical inputs, it has helped in soil enrichment and also reduced the erosion of the land in great extent. Gujarat farmers who used to grow 1-2 crops can now grow 3-4 with increase in profit (Agriculture and Co-operation Department 2006).

**Biodiversity based organic farming**
Organic farming generally makes use of compost based fertilizers and bio-pesticides, produced out of locally available weed. This helps in maintaining an intact biodiversity. Since this method relies very less on chemical fertilizers, therefore soil fertility and moisture content of the fields is enhanced. This has been practiced in Gujarat and is promoted by Navsari, Anand and Junagadh agricultural universities (Modi 2011).

**System of Rice Intensification**
‘System of Rice Intensification (SRI)’ aims at addressing the reduced usage of water and also mitigating adverse climate change impacts that results from GHGs emission from continuously flooded rice fields as well as increasing productivity (IOP Science 2009). Gujarat Institute of Development Research analysed the effects of SRI introduction in the state in 2007 in collaboration with Aga Khan Rural Support Programme, India (AKRSP) in 5 talukas in the southern part of the state. The yield increased by 67 percent and seed and chemical fertilizer & pesticide requirement reduced by 80 percent and 32 percent respectively (The System of Rice Intensification 2011). During experiments at Anand Agricultural University, it was found that while the conventional practice yielded 5,840 kg/ha of grain, the SRI method yielded 5,813 kg/ha, with 46 percent less water usage (SANDRP 2005).

6.1.2.5 Technology responses in the livestock sector

**Mitigating the thermal load in cattle**
Thermal load can only be reduced by constructing *pucca* houses with proper ventilation, reduce direct solar exposure to avoid heat stress and ensuring supply of proper drinking water
An animal hostel has been set up at Akodara village in Sabarkantha district. It has been built taking scientific approach into consideration. ‘Animal hostel’ is unique concept in Gujarat. Once the hostel is launched, all 900 cattle of Akodara village will be kept only there (none of the villagers will keep cattle at home). All cattle will be managed under cooperative approach by villagers together (Desh Gujarat 2011). A gobar bank has also been set up to generate electricity from dung. Power produced by gobar bank will satisfy inside needs of ‘animal hostel’. Thus both livestock and manure management concerns are dealt with in an effective manner (Governance Now 2011).

Major share of motive power of agriculture comes from livestock. Livestock keeping - an integral part of farming system as land, labors and water can be efficiently utilized. An intensive animal vaccination program was launched in all the villages at the ‘Krushi Mahotsav’, so as to focus on disease management and the rearing of healthy livestock. In addition to vaccinating the livestock, animal health camps are also held in Gujarat (GUJARAT 2009). Un-healthy cattle in a household contribute to GHG emission through enteric fermentation also causing no-benefit situation to the owners.

6.1.3 Institutional responses and capacity building

6.1.3.1 Institutional responses in the power sector

Setting up of small power plants
In order to provide quick additional capacity to meet the minimum needs of the state grid, it is proposed to build a number of mini and micro hydel projects. Other multiple advantages such as low capital cost, reasonable operating cost, short gestation period, reduction in T & D loss and generation of employment in rural areas can also be derived (GIDB 2012).

Renovation, modernisation and management of existing power plants
The state proposed for the renovation and modernisation of the existing plants (GIDB 2012). Expansion projects in existing power stations to bring down costs. This has been undertaken strategically since the power reforms in the country (Shah, 2006).

Captive generation
- There has been encouragement by the state to generate steam through co-generation in industries. There is no cap on the quantum of co-generation that can be done by industry. This is a good option to increase the overall efficiency of the system.
- An incentives scheme for bagasse-based cogeneration is worked out to promote renewable energy production, through the Bagasse Policy of the state. According to this the state will purchase power at appropriate prices from the IPPs, which will keep this on escalating with the successive years.
- There is also consideration of purchase of surplus power from captive units on mutually agreed terms covering price, timing, quantum and the period of purchase of power by Gujarat Urja Vikas Nigam Limited (GUVNL) (GIDB 2012).
6.1.3.2 Institutional responses in the industry sector

Gujarat has been one of the highly industrialized states in India. It has a reputation of being a highly investor friendly state and has a proven record of attracting high volumes of investment. Department of Scientific and Industrial Research with TERI has initiated a project “Energy Information Support services for the Indian Industries” which is a repository of information and provides access to these information. The information repository includes case studies and information about newer technologies in the market and presently focuses on the fertilizer, paper and pulp and the sugar industry. This central repository can be viewed online at the www.eeii.org.in (Energy efficiency information support for industries 2010).

6.1.3.3 Setting up of Climate Change Department

The Establishment of Climate Change Department (2009) is an initiative in the right direction to address the impacts of climate change. Gujarat is the first state not only in India but also in entire Asia to set up a dedicated department for climate change.

6.1.3.4 The green priorities of the Department of Climate Change

Promote Green Tech- This is done through institutional setups like the Gujarat Cleaner Production Centre (GCPC) and public private partnerships. Even the industrial policy 2009 speaks of promoting green technologies by providing financial support and awards to those who adopt new technologies and/or upgrade or update their technologies.

Earn more carbon credits- a lot of industries have been switching over to cleaner production processes with the help of GCPC which is helping in creating CDM awareness programs for industry and collect data on potential of Clean Development Mechanism (CDM) in Gujarat Department of Climate Change also assists industries in preparing PCN (Project Conceptual Note) and PDD (Project Design Document). The State has set up Gujarat CDM Cell, which is the state level CDM nodal agency. Gujarat leads the country in terms of the Certified Emission Reductions (CER) issued and accounts for 42 percent of the total CER’s generated by India, even though the state has a low number of projects. Thus there is a huge potential of CDM in the small-scale industry. The CDM projects identified in the public sector for the manufacturing industries total to 7 and private sector totals to 29 (Shah 2010).

Funding research in Green Tech: Funding for research and innovation of technology is one of the priorities of the industrial policy 2009. This funding is mainly through institutes like GERMI, which promotes researches and trains personnel in industry excellence through its established R&D center in the uses of efficient technologies and policy. The CEPT University with the help of Gujarat Industrial Development Corporation has established the Center for Industrial Area Planning and Management (CIAPM), which act as a facilitator for imparting academic knowledge in the area of industrial development, planning and management.

The state of Gujarat has established Gujarat Cleaner Production Center (GCPC) in 1998, with technical support of National Cleaner Production Center (NCPC), India and UNIDO and
financial support of Gujarat Industrial Development Corporation (GIDC) to provide industries with holistic approaches towards the end of pipe treatment that is applied to the entire production cycle to:

- Increase productivity by ensuring a more efficient use of raw material, energy and water
- Promote better environmental performance through reduction at source of waste and emission

These objectives are achieved through cleaner production orientation programs, training programs, cleaner production assessments and dissemination programs thus, bridging the gap between competitive industrial production and environmental concerns. The center has a CDM cell which provides an interface between the donors and the participants (GCPC). The Government of Gujarat has taken many initiatives to promote this and some of the initiatives are as follows:

**Financial assistance for cleaner production** - The benefits of Cleaner Production (CP) are not only in terms of economic advantages to the industries, but CP has also helped in reducing the wastes and improving the environmental performance of various industries. The CP has been successful in replacing the end-of-the-pipe treatment besides improving the productivity in many cases. The Forests and Environment Department, therefore, decided to promote and undertake various activities including the CP clinic cum awareness programme for different industrial and service sectors, intensive training programme, CP database creation, practical demonstration projects, CP dissemination workshops, etc. This policy provides financial incentives for promotion and propagation of CP through the state’s budget.

**Gujarat cleaner production award** - Under the World Bank assisted Environmental Management Capacity Building – Technical Assistance project, the state government in the Forests and Environment Department took initiatives in a proactive way to tackle the industrial pollution issues through promotion and propagation of cleaner production (CP). The Forests and Environment Department built the capacity of the industrial entrepreneurs, environmental consultants, academic institutions and the NGOs in the state in addition to implementation of various practical CP demonstration projects in selected industrial sectors. The results of the CP approaches adopted by the industrial sectors were quite encouraging. The Government is keen to sustain the CP initiatives and achieve the multiplier effect of CP in the state. The state government therefore decided to institute “Gujarat Cleaner Production Award” since 2004 to appreciate an industry, which implements the CP practically and achieves significant / exemplary environmental benefits and improvement, and increasing the productivity at the same time. A certificate of appreciation and a trophy is awarded every year to one industry in small or medium scale sector and one in large-scale sector from the state. The committee considers the applications received from the industrial entrepreneurs of Gujarat, who have successfully implemented the CP in their unit / industry and would decide the winner for the award. The committee would also prepare detailed guidelines including application format, eligibility criteria, selection procedure, etc.

**Incentive schemes for cleaner production under the Industrial Policy 2009** - The Industrial Policy, 2009 of the state Government lays emphasis on inculcating systematic approach among
the industries for holistic development that includes environmental management as infrastructure. Also pollution prevention at source with issues like rational utilization of resources and cleaner process and technologies are highlighted. For sustainable development, it is necessary to introduce substantial changes in the working and practices of the industries. With this view, an incentive scheme for encouraging green practices was introduced through Government Resolution No.BGT/1008/499 (1) Government Resolution No. BGT/1008/499(2) declared on 11/6/09.

Under the “Gujarat Industrial Policy-2003: Scheme for Assistance to Cluster Development”, GCPC has worked for ‘Dyes and Dye-intermediate’ cluster. GCPC on the following areas as stated in the industrial policy, 2003:

- Creation of common facilities like R&D/testing laboratories
- Technical assistance from R&D/ technical institutions/ universities for technology upgradation and quality improvement programmes for member units.
- Creating information databank for market intelligence and improvement of productivity in clusters.
- Hiring experts, consultants or cluster development agent for cluster activities
- Activities towards environmental protection as well as energy and water conservation activities
- Use of cleaner technology
- Initiatives towards capacity enhancement programme
- Any other activity related to improvement of productivity and cost control measures among members units in the cluster

A large number of projects have been successful and presently GCPC is working on the dairy and textile industries.

GCPC provides financial assistance to the following activities/projects:
- Cleaner production clinic cum awareness programme
- Intensive training programme on cleaner production
- Practical demonstration projects on Cleaner production
- Cleaner production database creation
- Research and development work in the field of cleaner production
- Cleaner production award
- Any other project / activity related to cleaner production to be decided by the Forests and Environment Department

GCPC also presents award for exemplary application of the cleaner production implementation in small and medium scale industry and large scale industry in Gujarat state(Cleaner production Initiatives in Gujarat (GCPC) n.d.).

**Gujarat Energy Research and Management Institute (GERMI)** is a centre of excellence in industry learning and has been set up to develop human resource assets to cater to the petroleum and allied energy sectors, improve knowledge base of policy makers and technologists and provide a competitive edge to leaders to compete in the global arena. A state-of-the-art R&D
facility that enriches the knowledge economy at local, national, regional and global levels in:
scientific assessment, policy development, planning and implementation of programmes,
benchmarking, and capacity building for improved resource management and compliance, and
forecasting is developed.

6.1.3.5 Institutional responses in the waste sector

The Government of Gujarat has appointed the Gujarat Urban Development Corporation (GUDC) as the nodal agency for municipal solid waste management project for the ULBs of the state

- GUDC has supplied total 70904 numbers of vehicles/equipments to all ULBs in the state.
- Training to 9207 safai kamdars and 395 sanitary supervisors of 159 ULBs by M/s. ISWM (Institute of Solid Waste Management), Ahmadabad.
- For higher level ULB-staff and elected members (1614 number): Training to the “master trainers” of 03 organizations (ISWM, M/s. City Managers Association and All India Institute of Local Self Government), supported by the World Bank.
- The “master trainers” have started training programs for the higher level ULB-staff and elected members.
- Capacity Building and Training to 1614 municipal sanitation workers and local level political and administrative leadership
- It has constructed 76 vermi compost plants in which 70 vermi compost plants are in operation and 78 plants are proposed (GUDC 2011)

The Government of Gujarat has taken up the issue of sewage disposal (collection, treatment and safe disposal) in a holistic way and constituted an autonomous company Gujarat Infrastructure Company Limited to facilitate all the urban local bodies in the state to provide technical and infrastructural facilities for the establishment of sewage treatment plants, municipal solid waste disposal facilities. Presently there are 43 STPs in operation and 17 under implementation in municipal corporations, towns and townships. The Gujarat Infrastructure Company Limited is also setting up landfill sites in the State, many of which are under planning or under installation with few plants in operation (Municipal solid waste management in the state (GUDC) 2011).

Gujarat Pollution Control Board (GPCB) has taken up many initiatives in the field of waste tracking and information dissemination in the form of e-governance and eXtended green node(XGN) - supporting e-governance. XGN is established to expedite action on all these fronts in a systematic and transparent manner, which helps in

- Timely acceptance and disposal of industries and hospital applications
- Pre planning of work on weekly basis by regional manager
- Immediate access to efficiency/pendency of individual employees
- Alert the next stage whenever urgent action is required
- Effective prioritization of incoming visits
- Tracking of hazardous waste

After the establishment of XGN the number of applications received by the board has increased from 2750 to 10212 and consequently the number of application disposed have also risen from 1500 to 9823 in a timely manner (GPCB 2011).
The Green Environment Co-operative Services Society Ltd., which was promoted and set up by the Vatva Industries Association, the treatment facility benefits over 600 polluting units by collecting their primarily treated liquid effluent and giving it secondary treatment and proper disposal. A hi-tech internal collection system followed by technologically advanced treatment plant is capable of handling 1.6 crore litres of effluent per day. The total investment made by the industries amounts to Rs. 38 crores. The solid waste land fill site takes care of about 80,000 Metric Tons of solid waste per year according to internationally prescribed norms and standards having spent more than Rs. 10 crores(Vatva Industries Association n.d.).

6.1.3.6 Initiatives in the forest sector

Green Credit Scheme (Forest Department, Gujarat)
Unlike forests, mangroves store large amounts of carbon below the ground in soils and sediments, and once stored remains there for a long time. Gujarat has taken up extensive conservation and plantation activities in mangroves areas. More than 30,000 ha of mangrove forests have been added during last couple of years in the coastal tracts of Jamnagar, Kutch, Bhavnagar and Anand districts of Gujarat. This programme is in accordance with National Green India Mission under NAPCC. Forest Survey of India has undertaken regular monitoring of mangroves cover in the country, and according to their estimates, the mangroves cover in Gujarat has been steadily increasing. The efforts have resulted in having the second largest mangroves forest cover of 93,600 ha in the country (Forest Department 2009).

JFM Programme: Joint Forest Management Committees are in operation covering an area of 3.82 lakh ha of forest area as tool measure of people’s participation in forest conservation and management. At present 25 forest development agencies are in operation which is in line with National Mission for Green India under NAPCC (GSDES 2010).

Van-Mahotsav: Under this programme, during the year 2008-09 about 2451.80 lakh seedlings and seeds have been distributed to industries, educational institutions, government/semi-government agencies, farmers, religious institutions and individuals through farm forestry. This activity was in accordance with National Mission for Green India under NAPCC (Modi 2011).

The above programs increase the forest cover or promote to do so, there by mitigating climate change by increasing the carbon sink.

6.1.4 Further mitigation options for adoption

There are many mitigation options available worldwide. At an international level a lot of work is being done in this regard. But the adoption of these proposed technologies depends on many factors like the economy of the country, its technological advancement, availability of technology, etc. Here we are mentioning the possible mitigation options for various sectors, majorly adapted from an elaborate study by the Center for Energy, Environmental, and Economic Systems Analysis (CEEESA)
Power Sector

**Mitigation options in the coal sector**

Methane produced during the coalification process gets stored in the seams of the rock strata. During coal mining, it gets released into the atmosphere. The following can be done to mitigate it:

1. Coal bed collection and utilization/flaring
2. Coal briquetting

**Mitigation options in natural gas sector**

Natural gas is produced and delivered to the end users in four main stages: production, processing, transmission/storage, and distribution. In each of these stages; methane emissions occur during normal operations, routine maintenance and repair, and system accidents. Pneumatic devices are the largest source of vented methane emissions in this sector. Profitable mitigation options include replacing high-bleed devices, retrofitting high-bleed devices, and improving maintenance practices on the devices including cleaning and tuning, repairing/replacing leaking gaskets, and tubing fittings and seals. Another mitigation option is to do with compressors, a standard component in natural gas systems used to maintain pressure in the pipeline system. It is realized that simply keeping compressors pressurized during the off-line periods can significantly reduce emissions. Other options are to connect the vent lines for the blow down gas to the fuel gas system, and also installing static seals on pressurized compressor rods.

**Mitigation options in the oil sector**

Besides venting and flaring, GHG emissions in the oil production stage stem from fugitive emissions at the wellhead, venting of holding tanks and pneumatic devices, process upsets, and the combustion of fuels. The technologies usable are the following:

First, the amount of gas vented and flared can be reduced. Flaring should take priority over venting, wherever possible, because of the lower radiative forcing of CO₂ as compared to CH₄. Collecting and utilizing (or re-injecting) the associated gas may be an option in situations where significant amounts of gas are produced and gas-collection systems and pipeline infrastructures exists. The gas could be used in on-site boilers and small generators to meet the facility demand for heat and power. Improved maintenance to reduce leaks in the system will also reduce emissions.

**Mitigation options in the electricity sector**

Greenhouse gas mitigation in the electricity industry is closely tied to the natural capital stock turnover in the sector which is inherently long and investments tend to be large and lumpy; thus limiting the rate of technological change. However, this tends to be mitigated somewhat by recent technological advances, especially with gas turbine technology and the move toward restructuring and deregulation and its trend to favour smaller capacity increments. Mitigation options can be broadly classified into three types, which are detailed below.
I. Existing option systems
a) Improving combustion efficiency of existing system
b) Repowering
c) Fuel Switching
d) Loss Reduction in electricity transmission and distribution (T&D)

- upgrading the line voltage will decrease the current flowing through the conductor at the same power and thus cut losses
- improving the system power factor with capacitators and synchronous condensers will reduce line losses
- upgrading or replacing existing conductors and insulators with lower-resistance equipment will lower losses
- building new transmission lines to optimize power flows to distribution points will reduce system losses
- Building higher-capacity transmission systems, for example using high voltage direct current (HVDC) systems that have up to 50 percent lower losses compared to AC power lines with the same transfer capabilities.

Mitigation measures can also target the efficiency of the electricity distribution system. Measures include: (i) automating the distribution system, (ii) using voltage regulation controls, (iii) using dispersed storage and distributed generation (e.g., intermittent renewables, fuel cells, micro turbines) to optimize the utilization of the distribution system, (iv) replacing transformers with more efficient equipment, and (v) improving the billing and collection system, (vi) Enterprise GIS system which integrates all the sub-systems and other measures to prevent pilferage loss.

II. System Expansion Options

Advanced Generation Technologies
This section discusses the most commonly advanced power generation technologies that can be considered in a GHG mitigation analysis. Technologies include:

- Advanced pulverized coal combustion
- Atmospheric fluidized bed combustion
- Pressurized fluidized bed combustion
- Advanced combustion turbines
- Integrated gasification combined cycle
- Distributed generation (fuel cells, micro turbines, etc.)

III. Cogeneration
It is also called combined heat and power generation. It is the process of simultaneously producing electricity and useful thermal energy, that is, process steam and process heat. Typically, a gas turbine generates electricity, whereas the exhaust from the gas turbine is sent to a heat exchanger to generate high-pressure steam, so as to meet the steam-load. It is often used
for industrial applications. The use of cogeneration can boost the total thermal efficiencies to over 80 percent. Fuel-to-electricity conversion rates are in the 20-40 percent range whereas the fuel-to-heat conversion rates are around 50-60 percent.

Mitigation options for the Industry Sector
GHG mitigation from industries can be primarily related to energy efficiency improvements as this sector is a major consumer of energy and accounts for 35 percent (Industry on average accounts for about 25-30 percent of total energy consumption worldwide) of the total energy produced by the state.

World Energy Council has estimated that efficiency improvements made in developing countries may lead to a 16-37 percent reduction in industrial energy consumption. Refining industries hold the largest potential of 50 percent in energy improvements, and the chemical industry has a potential of up to 43 percent. Efficiency improvements are connected to attempts to improve product quality, lower production cost, and maintain profitability. As such, energy efficiency may be considered more like a “side-benefit” of many industrial investments made for non-energy reasons.

Mitigation Options in various Industries (Adopted from Greenhouse gas mitigation analysis by ENPEP 2001)

Chemical industry
Chemical Industries produce a variety of final products from ammonia to petrochemicals. These industries employ a variety of high energy consuming processes such as boilers and furnace which generate heat and steam, cooling and refrigeration, distillation and evaporation to separate components and motors to drive belts and pumps. Petroleum products, natural gas and coal are the major types of fuel used. There are a number of mitigation options available in the chemical industry. These options include the use of improved catalyst for key chemical reactions, improvement in the distillation equipment, improvement in gas turbine efficiency, process integration to conserve heat generated during exothermal reactions and use of membrane technology to separate reactants.

Crude oil refining industry
Heavy fuel oil, diesel, gasoline, LPG and lubricants are the major products of the oil refining industry. Crude oil is fractionized using multiple distillations, conversion, reforming and finishing processes, most of which require heat or steam provided by boilers and furnaces fueled by crude oil or heavier waste products. If available the refineries also use coal or natural gas for the same. Electricity is needed for running of electric motors, pumps and other equipments. The options to improve the energy efficiency and mitigate carbon emissions that can be implemented include preheating the incoming crude oil, using reflux-overhead vapour compression, use of mechanical vacuum pumps, integration of heat use between distillation units and utilization of improved catalytic cracking units.

Paper and pulp industry
Energy utilization takes place in the various stages/processes of paper making like the chipping and grinding of wood, pulping, bleaching, and chemical recovery and finally to dry the paper
which consumes substantial quantities of process heat. The energy requirement varies based on the final product and the type of raw material used. The process heat is usually provided by waste products like lumber wastes and black liquor (a by-product during the pulping stage), coal and natural gas and purchased electricity can also be used based on the energy needs. The mitigation options for the paper and pulp industry include achieving of energy efficiency through the use of continuous pulp digesters and the application of alternative chemical and mechanical pulping processes. Increasing the cogeneration of steam and electricity using process by-products as bio-fuels reduces carbon emissions. Also, the use of alcohol-based solvent pumping, shifting to oxygen or ozone bleaching and delignification increases the overall process efficiency. Additional efficiency improvements can be accomplished through the chemical recovery of black liquor via freeze concentration or gasification and the subsequent utilization as bio-fuel. Options that aim at reducing the fuel consumption in the energy-intensive drying stage include the wet-pressing of the paper products, high-consistency forming, impulse drying, and microwave drying should also be looked into.

**Cement industry**

Maximum energy is consumed during the process of clinker production in the form of heat. Energy is consumed even for grinding, moving and blending of intermediate and final products. The industry relies heavily on coal for its fuel requirements (currently about 61 percent worldwide, followed by electricity 25 percent and natural gas 8 percent). The options to reduce the Greenhouse Gas emissions from these industries are by improving the kiln combustion systems by process modifications to reduce heat loss, use of waste heat from the product cooler, improving the material preparation by using waste heat drying, differential grinding of limestone and clay, using fluidized bed drying with low grade fuels, application of electric or hybrid kilns. Modern dry-process kilns require about 50 percent less energy than the older wet-process kilns. In this, dry kiln, exhaust gases are used to pre-heat and reduce the moisture content of the raw materials. The blending of cements also leads to reduced energy requirements.

**Available mitigation option in transport sector**

There is a wide range of mitigation options available in the transportation sector. In general, they can be grouped into the following categories:

- Improving the technical efficiency of vehicles which may be expressed either as energy intensity (litres/100km) where the goal is a reduction
- Switching to fuel systems with lower specific emissions;
- Improving the overall transportation system efficiency;
- Encouraging a shift toward transportation modes with lower specific emissions;
- Improved management of transportation demand.

**Mitigation in Residential and Commercial Sector**

This sector often termed as the building sector as the energy end users are oriented towards servicing the building occupants. These end user services include heating, ventilation and air conditioning, lighting, refrigeration and other household activities like cooking, cleaning etc.
Mitigation options typically address building shell or thermal integrity issues of existing and new buildings and efficiency and technology/ fuel type issues of existing and new equipment. As the building sector has a long average lifespan than the equipment use the near term mitigation focuses on increasing efficiency of appliances used for heating, cooling and lighting, through the use of energy efficient technologies such as high efficient air conditioners, refrigerators, washers and dryers, compact fluorescent lighting, lighting and energy control systems. Additionally fuel efficient and low smoke stoves can be used. Yet another option is to switch to low or zero carbon technologies like the solar water heaters. The long term approach targets efficiency improvements in the buildings itself like increased insulation for ceilings, improved control of air infiltration, low emissivity windows, shading devices and high albedo materials to reduce the summer cooling load and passive solar design.

### 6.2 Adaptation

According to the IPCC (2001), adaptation is adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. This term refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate change. It is clear that in the present context, adaptation is an adjustment to the impacts of climate change in order to reduce the vulnerability of a community to those changes. Adaptation in this context implies measures that are taken to protect one from impacts caused due to climate vagaries. Depending on its timing, goals and motive of its implementation, adaptation can either be reactive or anticipatory, private or public, planned or autonomous. Adaptations can also be short/long term, localised or widespread (IPCC 2001).

#### 6.2.1 Changes in policy

Adapting to climate change is necessary to increase resilience and reduce climate impacts on society, economy and ecosystems. Adaptation carried out across the globe under two broad themes of ecosystem based adaptation and community based adaptation. There is a need for every state to incorporate adaptation strategies in every sector where climate change can have an adverse impact. Adaptation has not been given its due importance in Indian context. Adaptation is essential to increase resilience of poor and vulnerable communities as they are at the greatest risk of impacts due to extreme events and climate change. The National Action Plan on Climate Change highlights eight missions. Adaptation has been mainstreamed into Gujarat mainly under the following missions: National Mission for Sustainable Agriculture, National Mission on Sustainable Habitat, National Water Mission and National Mission on Strategic Knowledge for Climate Change, with uncertainty. There are a few initiatives taken by the state government and civil society organizations to adapt to climate change. There has been no alteration in any of the agricultural, industrial or health policy of the state to incorporate adaptation on a larger scale as done for mitigation. For Gujarat more emphasis needs to be given to adaptation as Gujarat is vulnerable to sea level rise impacting communities along the coast. Adaptation responses also require an agricultural system for increasing food security.
6.2.2 Technology responses

In view of the damage done due to the sea level rise and coastal erosion, anti sea erosion works are carried out by the Narmada, Water Resources, Water Supply and Kalpsar Department. The protection work is carried out by providing gabion walls. The technological responses carried out are given in the table 12.

<table>
<thead>
<tr>
<th>District</th>
<th>Taluka</th>
<th>Name of the work</th>
</tr>
</thead>
<tbody>
<tr>
<td>Valsad</td>
<td>Valsad</td>
<td>Construction of protection wall against erosion of sea coast at village Kosamba. i) Ch. 0 to 690mt. ii) Ch. 1100mt. to 1850mt</td>
</tr>
<tr>
<td>Valsad</td>
<td>Pardi</td>
<td>Construction of protection wall against erosion of sea coast at village Umarsadi.</td>
</tr>
<tr>
<td>Valsad</td>
<td>Pardi</td>
<td>Construction of protection wall against erosion of sea coast at village Kokak-Udwada.</td>
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<tr>
<td>Valsad</td>
<td>Umargam</td>
<td>Construction of protection wall against erosion of sea coast at village Umargam.</td>
</tr>
<tr>
<td>Valsad</td>
<td>Umargam</td>
<td>Construction of protection wall against erosion of sea coast at village Nargol.</td>
</tr>
<tr>
<td>Valsad</td>
<td>Umargam</td>
<td>Construction of protection wall against erosion of sea coast at village fansa-Tatawadi.</td>
</tr>
<tr>
<td>Surat</td>
<td>Choryasi</td>
<td>Anti sea erosion work at Budia.</td>
</tr>
<tr>
<td>Surat</td>
<td>Olpad</td>
<td>Anti sea erosion work at Nes karanj.</td>
</tr>
<tr>
<td>Surat</td>
<td>Olpad</td>
<td>Anti sea erosion work at Dabhari.</td>
</tr>
<tr>
<td>Navsari</td>
<td>Gandevi</td>
<td>Bhat Anti sea erosion works.</td>
</tr>
<tr>
<td>Navsari</td>
<td>Jalalpore</td>
<td>Onjal Machhiwad anti sea erosion works.</td>
</tr>
<tr>
<td>Valsad</td>
<td>Pardi</td>
<td>Udwada anti sea erosion works.</td>
</tr>
<tr>
<td>Valsad</td>
<td>Valsad</td>
<td>Nani Danti-Moti Danti anti sea erosion works.</td>
</tr>
<tr>
<td>Surat</td>
<td>Olpad</td>
<td>Anti sea erosion work at Dandi.</td>
</tr>
<tr>
<td>Surat</td>
<td>Olpad</td>
<td>Mor Bhagwa anti sea erosion works (Phase I).</td>
</tr>
<tr>
<td>Surat</td>
<td>Olpad</td>
<td>Anti sea erosion work at Dandi (Phase-II)</td>
</tr>
</tbody>
</table>

Source: (Narmada Water Resources Water Supply and Kalpsar Department, GOG (n.d.))

Technological adaptation responses have been carried out through a community based approach in two villages Thoyana and Digvijaygargard were selected, Thoyana suffers from irregular availability of irrigation water while Digvijaygarh has drinking water problem. The major initiatives taken include: *Roof top rainwater harvesting* at Digvijaygadh school building, well recharge structure and farm pond at Thoyona and training of communities in water conservation and harvesting. Some of the steps taken for action at community level include: awareness generation of water management for long term drought management, training of village community for execution of drought proofing work, impact assessment of already implemented water harvesting structures, awareness for community to deal with water problems (drinking and agriculture), awareness on mitigation measures to combat the effects of scarce rainfall,
formulation of water plans for each community and community involvement and participation right from identifying their needs and actual implementation (Sustainable Environment and Ecological Development Society n.d.).

- Water budgeting: kheralu example
- Micro-irrigation techniques in several villages

Another adaptation response was the Implementation of Drought Proofing Project. To bring an attitudinal and perceptive change within the communities and to encourage communities engage in works, which have a long term development impact. Also to create models that would strengthen their traditional water resources, enable more dry-land farmers to undertake critical irrigation for one crop- the kharif crop, undertake farmland treatment by increasing soil and moisture conservation, increase productivity of grasslands, strengthen partnership between the district government, and the network of NGOs thereby increasing the potential for more sustainable rural development planning and implementation in the district and capacity building. The program was implemented in 31 villages of Kutch. The output of the program was that the villagers were able to collect rain water effectively. In order to secure their water, village members set own rules of using the water collected in the dam (Abhiyan n.d.).

Water harvesting structures to deal with the problem of water for agricultural purposes etc. Water harvesting structures were created in Bhavnagar and Junagadh districts in 2004-05. The initiative was an adaptation strategy to reduce miseries of millions of small and marginal farmers through rainwater harvesting by micro irrigation structures. Check dams were designed to cope with the flow of water from the rivulets and streams with a maximum height of 1.5 to 2.0 m with the storage varying from 0.015 million cubic meters to 0.035 million cubic meters (Modi 2011)

Traditional agriculture management practices: This aspect mainly deals with a huge consideration on the soil and crop quality of agricultural area through traditional practices. Many districts of Gujarat with the advent of climate change are now shifting to traditional farming practices, which lower usage of high chemical inputs (like hybrid seeds, fertilizers and pesticides). Thus, this promotes a sustainable future enhancing both quality and quantity. Institutions such as AKRSP work towards increasing agricultural productivity through organic farming, scaling up of watershed, agro-processing and promote irrigation management to reduce the impact of climate change on agriculture and increase coping capacity for livelihood security (AKRSP 2011).

6.2.3 Institutional responses and capacity building

In view of the damage done due to the sea level rise and coastal erosion, anti sea erosion works are carried out by the Narmada, Water Resources, Water Supply and Kalpsar Department. The protection work is carried out by providing gabion walls. Thus damages due to coastal erosion are controlled by providing such protection wall. The activities are carried in the districts of Navsari, Surat and Valsad in Gujarat.

Setting up of agro-meteorological field unit to cope with climate change in different agro climatic zones of Gujarat, each zone has one agro meteorological field unit which provides weather based agro-advisory services to the farmers of that zone (Modi 2011). This programme
is in accordance with National Mission for Sustainable Agriculture under National Action Plan on Climate Change.

**Research initiatives** in Gujarat to ensure food security and reduce climate impacts: Agricultural universities have initiated steps to create a network of observatories in Gujarat by installing automatic weather stations at different locations in order to generate weather information and to create a data bank on climate. These universities have initiated research on the effects of climate change on breeding of heat and photoperiod insensitive crop varieties and erection of poly houses to create controlled environment (Modi 2011). This has increased the yield and reduced population dynamics of insects, pests and diseases, etc. Centre for Weather Forecasting and Climate Change in Gujarat is established at Anand, ‘Centre for Environment Studies’ at Navsari and ‘Centre for Agro-advisory Services’ at Junagadh. These centers are engaged in critical analysis of weather/ climate parameters and their likely impacts on agricultural production.

**Participatory irrigation management** has contributed to an increase in farm ponds in the district of Valsad and many other districts of Gujarat under Sardar Patel Participatory Conservation Project (SPPWCP). Structures like check dams, village ponds/tanks were created by a beneficiary group or Non-Governmental Organization with technical and financial assistance from the district panchayat (local representative body). Six prototype designs were circulated with a maximum cost of Rs. 1,000,000 (Modi 2011). A total of 353,937 check dams and village ponds have been created in last 8 years providing benefit to over 13 million people in rural Gujarat to increase water security.

**Sagarkhedu sarvangi vikas package** (multi dimensional development package for coastal communities). This is a unique convergence model covering 38 subdivisions of Gujarat coast and a population of around 6 million. Taking into consideration that the people living in coastal areas play a distinctive role not only in the economy but in the preservation of ecosystem, the program takes a holistic and integrated view to address the needs of their livelihoods, keeping in mind the dignity of life (Modi 2011). It proposes specific and time bound action plan for improving wage and self employment, capacity building and skill up-gradation, educational facilities, health infrastructure, drinking water, housing, salinity ingress, electrification and water conservation, development of salt pan workers and national security.

‘Hope and Possibility’ a joint initiative of VIKAS, SAVE and Lok Vikas Nidhi have developed a coastal eco-village programme and are involving poor communities to fight salinity ingress through regeneration of mangroves, water resource management and capacity building.

**Water Temples** (Jal Mandir) in several Parts of Gujarat have been created to promote adaptation keeping in mind the inter-linkage between society and religion. Water Temples (Jal Mandirs) are created by digging farm ponds and village ponds. Farmers due to this are obliged to conserve water in this way thus enhancing the creation of micro water harvesting structures in different parts of Gujarat (Modi 2011).

The Institute of Rural Management Anand has initiated a study on documenting climate change adaptation works for India and will create a platform for knowledge sharing.
6.2.4 Further adaptation options for adoption

6.2.4.1 Adaptation options in the Agriculture Sector

- **Use of adapted varieties**
  Arid and semi-arid: Usage of drought tolerant seed varieties (Pandey & Akermann 2011)
  Humid: Usage of early maturing seed varieties
  Coastal and other salinity infested areas: Usage of salt tolerant varieties (Chatterjee & Scholz 2011)

- **Crop management**
  Arid and semi-arid: Enhancing crop rotation practices and changing cropping patterns
  Humid: Improving the seed storage (adpc 2006)
  Coastal Areas: The method adopted integrates trees and bushes to reduce water runoff and erosion thus providing flood protection (Chatterjee & Scholz 2011).

- **Soil Management**
  Arid and semi-arid: Changes in the tillage practices to conserve soil moisture, ensure better infiltration of water and increase the soil reserves in the soil. Soil management increases the use of organic matter in the soil for enhancing water and nutrient storage capacity, soil structure and soil fertility (Lal 2011).
  Humid: Ensuring fluvial erosion control i.e. sustaining the vegetation cover, contour ploughing and contoured hedgerows. Introduction of changes in tillage practices, i.e. conservation agriculture for better water infiltration.
  Coastal areas: Adopting fluvial erosion control and seawater control by plantation of new hedgerows and restore the already existing mangroves (Chatterjee & Scholz 2011).

- **Crop management**
  Arid and semi-arid: Using adapted irrigation types of land use, crop rotation, crop diversification, change the cropping intensity, adjustments to planting and harvesting dates and alter row/plant spacing to increase root extension to soil water (Hoff 2004).
  Humid: Enhanced seed storage mechanism, improved crop rotation practices, crop diversification (adoption of mixed cropping systems), adjusting planting and harvesting dates and introducing trees and bushes around the agricultural land to reduce water runoff and erosion (IFAD 2006).
  Coastal Areas: Improving the seed storage capacity, introducing trees and bushes around agricultural land also taking into account terracing, soil cover and forests for flood protection (Chatterjee & Scholz 2011).

- **Water Management**
  Arid and semi-arid: Adopting greater number of options for water sources (small streams, shallow wells, boreholes, rainwater storage), surface irrigation systems (furrows and small
basins), rehabilitation and improvement of traditional irrigation systems and introducing
rainwater harvesting systems (Bruderle & Schwank 2009).
Humid: Adopting in-situ soil moisture conservation technology, land drainage systems and
wetlands management.
Coastal Areas: Techniques include wetland management and flood retention, constructing
dykes and check dams to reduce flood exposure and maintaining mangrove forests for
protection against storm surges (Chatterjee & Scholz 2011).

6.2.4.2 Technical options for adaptation in livestock systems

- **Adaptation in feed inputs**
  Arid and semi-arid: Usage of supplementary feeds and concentrates
  Humid: Using adapted livestock breeds (AEA Energy and Environment 2006)
  Coastal areas: Constructing livestock shelters (Chatterjee & Scholz 2011)

- **Animal management**
  Arid and semi-arid: The method here adopted includes reducing cutting frequency in
  grassland and restricting extensive livestock farming thus ensuring that stocking rates do not
  exceed the carrying capacity of grasslands (IFAD 2009).
  Humid: Special care on animal welfare has to be taken in these areas i.e. vaccinating animals
  to protect them and keep them disease free to ensure better milk production and lower
  emission
  Coastal areas: Moving herds from water logged fields (Chatterjee & Scholz 2011)

6.2.4.3 Community based adaptation

**Farmer’s field schools (FFS)**
It is a group based approach to train farmers. In this, the farmers meet regularly and are guided
by trainers to discuss relevant agricultural topics and different adaptation measures. The most
important feature of this group is that farmers apply their newly acquired knowledge in the field.
It's the group members themselves who prepare content of the learning session and strategies to
implement, thus promoting ownership (Chatterjee & Scholz 2011)

6.2.4.4 Adaptation in forests

**Maintaining and providing ecosystem services**
Major activities in maintaining the extent of forests involve first of all reducing deforestation and
enhancing forest cover through afforestation and reforestation. The species of trees to be
introduced should take into account trends in climate change (Innes & Joyce 2008) and also
offering training in husbandry and harvesting management, and marketing of non-timber forest
products (NTFP). Supporting efforts to improve welfare through sound governance,
strengthening institutions, greater participation and education, greater accountability, reinforce
monitoring and community access to benefits (Chatterjee & Scholz 2011).
This aspect basically consists of maintaining the productivity of forest ecosystems and tangible socio-economic benefits from forests under climate change. Proactive adaptation management includes initiatives like diversification of forest based and non-forest based income sources and better local governance of the forests. In this regard promoting co-management and community forestry is also useful in increasing the adaptive capacity of the local people also strengthening the traditional knowledge of the local people in forest management (Chatterjee & Scholz 2011).

6.2.4.5 Adaptation in ecosystem and biodiversity

Ecosystem vulnerability assessment
This assessment technique plays a very important role in identification and prioritization of adaptation measures across sectors at landscape level. They help identifying changes in key ecosystem processes and services under different scenarios of future climate. The identification and valuation of ecosystem services can also inform spatial planning processes (Chatterjee & Scholz 2011).

Fostering inter- and intra-species diversity
Intra and inter species diversity is very important to strengthen the resilience of different ecosystems. In cases where there are existing barriers to migration of wild species (landscape fragmentation) assisted relocation or migration may be the only approach to ensure persistence of the species. This can be supported by additional engineering measures, if the appropriate habitat in the new area must first be created or modified to allow species to survive. Successful restoration of ecosystems will require the use of a mixture of genetic provenances collected over a broad range of sites and climates. This way risks can be spread and the probability of restoration success can be increased (Chatterjee & Scholz 2011).

6.2.4.6 Adaptation to sea level rise
The selection and timing of adaptive measures in response to sea level rise would depend on the physical, social, economic, political and environmental characteristics of the affected areas. This can be done through a systematic coastal management programs. The three major objectives that a coastal management program has to consider are:

- Avoid development in areas that are vulnerable to inundation
- Ensure that critical natural systems continue to function
- Protect human lives, essential properties and economic activities against the ravages of the seas

Response strategies for sea level rise fall into three broad categories:

- **Retreat**: this deals with abandonment of land and structures in vulnerable areas and resettlement of inhabitants
- **Accommodation**: this means there would be continued occupancy and use of vulnerable areas by accommodating oneself with the sea level changes
- **Protection**: this deals with defending of vulnerable areas, importantly the centers of population and economic activity and natural resources
Coastal zones are the most vulnerable areas to climate change, which would be impacted due to sea level rise, strong coastal storms, salinity and storm surges; these parameters are associated inundation, which would increase dramatically. Integrated coastal zone management provides an effective adaptation mechanism through balanced environmental, economic and social objectives. Adaptation measures include afforestation of mangroves and declaration of protected areas (coral reefs, fish spawning grounds and sea grass meadows).

Adaptation to coastal areas can be divided into two types: Structural and Non structural interventions.

Structural interventions are technological interventions like building of dykes, sea walls, and mangrove plantations and/ or beach restoration. Non structural interventions are land use control, information dissemination and risk insurance. It has 22.5 percent of the mangrove share in the country.

The Various structural methods of protection can be divided in three: Hard, Soft and Non- Structural Options.

**Hard Structural Options:** These options include building up of sea walls and other technological options. The options are discussed below:

**Dikes, Levees and Floodwalls** are raised embankments or walls constructed for flood protection purposes. Depending on circumstances, internal drainage may be accomplished by gravity flow, tide gates, or pumping systems.

**Seawalls, Revetments and Bulkheads** protect inland properties from the direct effects of waves and storm tides. Seawalls and heavy revetments (sloping armoured surfaces) are constructed along open coast.

Areas to defend areas against severe wave attack. Lighter revetments and bulkheads usually serve as secondary lines of defense along open coast areas, or as first lines of defense along more sheltered interior shores with low to moderate wave exposure.

**Groins** are structures placed perpendicular to the shoreline. They generally extend from the land into the near shore zone, and trap sediment moving along the shore in order to widen the beach or prevent it from eroding.

**Detached Breakwaters** are robust structures placed offshore, usually parallel to the shoreline, for the purpose of dissipating the energy of incoming waves to reduce both erosion and damage from storms.

**Raising Existing Defensive Structures** Some dikes, levees, floodwalls, seawalls, revetments and breakwaters can be easily raised and strengthened in the event of sea level rise or increased storm exposure.

**Infrastructure modifications** may involve the elevation of piers, wharves, bridges, road and rail beds; modifications to drainage systems; relocations of various facilities and the institution of flood proofing measures.
**Floodgates or tidal barriers**, which are adjustable, dam like structures, can be placed across estuaries to prevent the upstream flooding from storm tides.

**Salt water intrusion barriers** in surface water streams can consist of locks or dams which directly block upstream penetration of saline water. Dams upstream of a salt penetration zone may be operated so that water released from the reservoirs at appropriate times can act to minimize the upstream movement of saltwater. Under certain conditions, underground barriers can be placed by open cut or injection methods to prevent saline water intrusion in groundwater aquifers. Fresh groundwater lenses in coastal areas can be maintained by fresh water recharging techniques.

**Soft structural options**

**Beach filling and subsequent re-nourishment** involves the placement of sandy material along the shore to establish and subsequently maintain a desired beach width and shoreline position to dissipate wave energy and enhance beaches, particularly for recreational and aesthetic purposes.

**Dune Building** and/or the maintenance and preservation of existing dunes, in combination with adequate beach strands, provides an effective measure of protection to upland properties against the effects of storm tides and wave action.

**Wetland/mangrove creation** can be accomplished through the placement of fill material to appropriate elevations with subsequent plantations.

**Other possible solutions** may be found through increasing resilience and reducing vulnerability of coastal zone features that are under threat of degradation. Options include continued field research in the use of artificial seaweed, artificial reef creation, and the rehabilitation of natural coral reefs and planting of sea grass, promoting the protection of corals from pollution in order to enhance growth, increasing coastal protection; instituting pollution controls and preventing the harvesting of mangroves (IPCC 1990; Satapathy et al. 2011).

**Non-structural adaptation interventions**

Adaptation options that reduce the risk of climate related impacts through policies, public commitment, knowledge creation, dissemination, capacity building, economic incentives and methods, and operating practices including participatory mechanisms can serve as non-structural adaptation interventions. Given below are some non-structural adaptation interventions.

- Policies, legislation & enforcement
- Insurance(crop, buildings, disaster, etc.)
- Early warning systems/forecasting
- Building codes (& allocation of related finance)
- Landuse& zoning(e.g. set back zones in coastal areas)
- Improved risk management/DRR
- Protection of biodiversity (green belts)
- Public education/preparedness
In order to restore declining mangrove cover the state government started to support mangrove plantations in the districts of Kutch and Jamnagar. In 2001 Gujarat Ecology Commission an autonomous body under the state government, started a community-based project for mangrove restoration under the India-Canada Environment Facility.

The project undertaken by the Garware wall ropes under the Swaminarayan Temple anti sea erosion walls covered a total of 10 villages in Gujarat with its key feature being capacity building in the communities to promote regeneration and sustainable management of the mangroves. In addition to mangrove plantation activities, awareness programs were conducted to educate people about their ecological and economic importance. Under this project a total of 4000 hectares of mangroves were planted and also helped create a local base of people who are able to sustainably manage the restored mangrove forests and create large-scale awareness among local communities.
7 RECOMMENDATIONS AND CONCLUSIONS

After the preparation of the GHG emission inventory for the state of Gujarat through various activities, we hereby put forth some recommendations as to how the emissions from these sectors can be controlled and initiatives taken for an inclusive growth aiming at sustainable development. It is essential to mainstream climate change adaptation and mitigation into infrastructure and development projects.

Energy and Infrastructure sector
This sector, as explained earlier will cover all the operations right from energy production to its transmission, distribution and consumption.

Energy production, being the largest source of GHG emissions, provides scope and opportunity for taking many steps to lower the emissions. Since Gujarat has reached a stage of self sufficiency in electricity generation, attention must now focus on production through cleaner and climate-friendly technologies that aim at achieving higher efficiency and lower emissions. Prioritization of projects in this regard becomes important; drawing up a list of projects showing gestation period, investment, and intended benefits can do this. Safer decentralized low-carbon energy supply mediums should be promoted through appropriate policy intervention. Decentralization reduces transit losses and environmental footprint, it is cheaper, affordable, and needs lower maintenance costs. It offers not only a more reliable and continuous source of energy but also proves beneficial to the economy, ecology as well as the society.

Coming to efficiency enhancement, the national action plan on enhanced energy efficiency speaks of increasing the efficiency of energy consuming technologies through the Perform Achieve and Trade (PAT) scheme and the Renewable Energy Credit (REC) implemented in April 2010. These schemes would provide for alternative means of finances to the power producers and industries to shift to cleaner technologies and energy efficient operations through a trading mechanism anywhere in the country. These would also provide a stimulus to the power producers and industries to invest in the development and research for energy efficient technologies and production practices specific to the power sector and individual industry sectors. These schemes thus provide opportunities and incentives to these industries for development and commercial adoption of existing and future technologies.

The Bureau of Energy Efficiency (BEE) under the National Mission for Enhanced Energy Efficiency has several programs to encourage, reduced consumption of energy in buildings, industry and irrigation. These programs include setting up efficiency/emission standards, five star ratings, green tags etc. This comes as a comparatively easily and cheaper option to reduce GHG emissions from the energy use sector.

These standards have to be made more stringent and look towards ways and means for their mandatory compliance. In this light, it is also significant that the present subsidies on the conventional fuels be reduced, to encourage a shift to cleaner fuels and/or efficient technologies. The standards can be made more effective and easier to comply with, if they are made industry-specific thus catering to the needs of individual sectors. It should be made mandatory for various residential and commercial set-ups as well as industrial installations to follow the green building
codes/standards and get it certified by the GRIHA or LEED certifications. For the residential sector promotion of energy efficient lighting such as compact fluorescent lamps (CFL) and Light emitting diode (LED) can be done using various fiscal and information (awareness campaigns) instruments. Also use of energy efficient five star rated electrical appliances like the air conditioners, refrigerators etc. must be promoted by subsidizing their costs. There should be a mechanism (tax reductions, increased market share, green tags etc.) for providing incentives and subsidies encouraging the use of climate friendly technologies and operations, thus ensuring judicious use of energy and emission reduction. This would contribute to India’s low carbon development policy.

Technology development, deployment and transfer should also be mainstreamed in the light of climate change mitigation. A framework for financing and implementing the adaptation technologies has to be put together. This can also facilitate the transfer of these technologies from the developed countries through social commitment of the government and the private players. A provision under Department of Climate Change should be provided for innovative financing for fulfilling the above said commitments. For instance, a separate committee of experts should be set up under the Department of Climate Change, GOG that can facilitate analysis of technology options and their viability through cost-benefit or multi-criteria analysis. Separate allocation of funds for the same also can be considered.

Energy audits and greenhouse gas inventorisation (for at least the large scale industries) should be made compulsory for all the industries so as to have a tab on the energy consumption pattern and emission profile of these industries. This would further enhance knowledge on the needs for research and development of technology which can be based on individual industrial sectors, thus reducing the emissions from those sectors. The ISO standards (14001, 14051 and 14064) have to be made mandatory so that the industries are at par with the global standards. Production data from the industrial sector should be easily available to researchers without any hassles. This would not only help generate authentic results for emission inventory but also reduce the time and cost taken to assess the same.

A market mechanism has to be provided to encourage green entrepreneurs, which would help in easy dissemination of technologies. They should also be provided with financial incentives through social commitments.

The Climate Change Department has to maintain a database of technologies (existing and future), identify partners for technology transfer and provide linkages to reduce transaction costs (between the producer and the consumer), develop methodologies, analyse and estimate baselines for each sector.

**Wastes**
A policy for waste management has to be formulated at the state level. This would help in an improved state level waste management practices.

A major requirement is the creation of and identifying increased number of sanitary landfill sites and not wastes dumping sites, as is the practice at several locations. These scientific landfill sites would provide for methane recovery (in case it can be used) and flaring (when the quantity is not
sufficient). Vermi-composting should be promoted to reduce methane emission from landfill especially where the landfill gas recovery is not equipped for energy use.

A framework for waste segregation and collection has to be put in place in all urban centres. This can be done through public private partnerships. The efficiency of collection, transportation and disposal has to be optimized through route mapping and constructing decentralized scientific landfill sites and decentralization of waste disposal. Pilot projects can be applied for waste from food and vegetable’s markets, cafeteria, schools, and other high organic waste generation organizations. A market mechanism has to be established to market the compost and generate revenue. This revenue can be used in upgrading and maintaining the decentralized plants. Cooperation between the municipality and the peri-urban farmers should be considered to ensure the market of compost which can be used for agricultural practices. The compost can also be used for greening of cities (parks, gardens).

Capacity building of the institutions, workers and the local people are important so as to have the institutions up to date with the use and implementation of technologies available and initiatives. The workers are also to be kept up to date with the various instruments that are being used by them.

The government should support the registration of composting project to the CDM which helps in promoting composting practices within the state. A public private partnership should be encouraged in the field of waste collection, transportation and disposal so as to increase competition and create a market. This would increase efficiency and effectiveness of waste disposal through innovative solutions such as integrated municipal solid waste management system, development of transfer stations and construction of waste processing facilities.

**Transport sector**
An exponential growth in private vehicle ownership and a decline in buses, i.e. public transportation in Gujarat have been witnessed over the years. A sincere effort should be made to bring in a modal shift to promote public transport system in the state.

Introduction of bio-fuels in the public transport system may be considered. Though clean fuels in the form of CNG and LNG have been introduced in the state, they need to be promoted at a higher scale. BRTS which is presently limited to Ahmadabad and can be extended to other urban centers. Efforts must be made to expand the initiatives already taken by the State for effective emission reductions. It is very crucial that the public transport services are worked on for improvement in their quantity as well as quality. This would be the first step towards promotion of public transportation, and deter people’s preference for private vehicles.

Future transport infrastructure development; the roads, bridges etc. should cater to the expected changes in climate trends and extreme events so as to be able to withstand any adverse impacts without bearing any costs in the future. A climate resilient urban planning can deliver the desired results, in terms of preventing an economic, social, ecologic breakdown of the state in case of any weather induced disaster.
Health sector
Building up a strategic knowledge base on the spread, regional extent, seasonal variability etc. of vector-borne diseases in the state is important for better preparedness. Studies may also extend to development of predictive models linking region-specific climate and disease incidence. Provisions for improved medical health services especially in remote, inaccessible places may be ensured.

Promoting improved surveillance and monitoring systems of the potential climate induced diseases that can affect different regions of the state. This shall help in reducing the vulnerability and enhancing the coping capacity of the masses.

Integrated Environmental Management Plans should be developed so as to tackle related issues together such as urban management and governance, integrated spatial planning, economic wellbeing and competitiveness, social inclusion, and environmental stewardship. For instance, the implementation of community laws on urban air quality not only has implications for pollution control and traffic management, but also requires combined efforts to address city and town centre management, spatial planning and urban design, health impacts and social justice (taking account of the different social groups affected and disproportionate burdens of environmental impacts).

Agriculture and Livestock Sector
Government should provide monetary incentives to agricultural institutes to take up research activities to develop thermal resistant crops, alternative cropping patterns capable of withstanding extreme weather conditions predicted for the state. Also more efficient technologies should be developed to improve productivity of rain-fed agriculture which uses minimum water and depends on organic amendments. Special incentives should be provided to farmers to adopt these technologies.

The main focus of the state should be to promote sustainable agriculture by emphasizing on community based adaptation with a focus on traditional management practices (i.e. seed storage, water storage, soil quality enhancement, etc.). The convergence and integration of traditional knowledge and practice systems with information technology and biotechnology needs further acceptance and implementation in the state.

Environmentally sustainable agricultural practices must be put into place such as soil and water conservation practices, use of organic fertilisers to increase the deficit micro-nutrients in the soil, scale up micro-irrigation and promote diversification vs. specialisation. Cropping patterns must shift towards environmental sustainability and must be suite soil, climate and water availability as nearly 68 percent of Gujarat’s land is under the process degradation and desertification.

Promotion and adoption of mixed farming approach for ecological and livelihood security is important. This basically includes practicing ‘crop-livestock integrated farming’ as part of organic farming as they are often the same.

Conserving and improving agro-biodiversity should be adopted by the state, as many farmers in the state are moving towards the cultivation of value added crops (like cash crops). The panchayats at village level should be mandated by the agriculture department to document traditional knowledge and agro-biodiversity of crops. Also special programs should be initiated
by agriculture department and civil society organizations for farmers to collect, purify and multiply traditional seeds.

Promotion of organic farming in the state should be undertaken in a widespread manner. This can be brought to effective practice by forming organic farming groups at village level, self help groups and co-operatives which promote activities like organic cultivation, seed/ seedlings production and input production.

Preparation of quality farm inputs for organic farming is an important initiative which should be promoted by the state. This can be brought to practice by conducting training programs for farmers to produce organic inputs, also ensure quality testing. Government should provide special financial assistance scheme for panchayats, local self governments/ groups to undertake the production activities.

For the efficient practice of organic farming in the state a ban on the sale and use of chemical agricultural inputs like fertilizers, pesticides, fungicides and weedicides) should be implemented.

Zero or reduced tillage systems should be adopted in the state to deal with emissions from burning of crop residues. The concept basically includes the usage of residues as fodder for animals and leaving a part of crop residues for field cover which will enhance the quality of soil should be adopted. The concept should be initiated at the village level through institutional initiatives or capacity building through governments/civil society organizations.

In the drought prone areas diversification of crops should be practiced. This includes cultivation of more perennial crops thus, improving the drought tolerance by enhancing the soil quality and moisture retention. This can be brought to practice by implementing the initiative at district / panchayat level through special subsidies for adoption.

The state’s methane emission is very less as compared to other rice intensive states in India. But since the dependence on irrigated rice is high in the state better options have to be adopted with regard to climate change. Initiatives in the past to bring into practice the system of rice intensification (SRI) in state by the Gujarat Institute of Development Research have shown that the average yield due to the practice of this technique in several parts of the state have increased by 67 percent, while seed requirements were reduced by over 80 percent and chemical fertilizers and pesticides by 32 percent. Therefore additional research on water management in this technique is needed, and also promotion of the technique is needed among farmers practicing both rain fed and irrigated rice cultivation in the state keeping in view to increased water requirement by the crop. Also it is important to make farmers aware about organic amendments.

Lowering of methane production from livestock should be dealt with by researching on the production system of animals (i.e. which feed-type will contribute to reduced emissions due to the process of enteric fermentation) and also practicing effective management, composting etc. This can be brought to practice through introducing the concepts into ‘Animal hostels’ which is already adopted by the state.

Demand Side Management (DSM) in the agricultural sector is well appreciated and has been seen to lead to phenomenal reduction in energy consumption. This is already being practiced to quite an extent in Gujarat, but there remains an opportunity to make it more effective by ensuring its compliance and timely monitoring. DSM offers to be a smart solution to problems resulting
from the outdated energy policies of the state. Also, these policies need to be revisited and tailor-made to suit to the present day scenario. As a part of DSM activities of Gujarat, energy efficient pump sets are now being promoted and used extensively. Large reduction potentials also lie in better load management, reducing water consumption and replacement of the existing pumps with efficient ones. Proper institutional mechanism needs to be adopted for ensuring efficiency of these pump-sets.

**Forestry sector**
The state must enhance its forests by reducing its emissions from forest degradation through REDD+ (Reducing Emissions from Deforestation and Forest Degradation). This mechanism by the UNFCCC plays a very important role in mitigating impacts of climate change in the forest sector. Initiatives to estimate the forest cover and carbon stocks should be taken up by developing special forest and tree cover monitoring system. This will help in estimating the potential of forest to sequester carbon and also analyzing the quality of forest health, which is very much needed to analyze the impacts of climate change on forests. Tree covers outside the forest areas are to be promoted on a large scale.

**Conclusions**

Climate change is evident around the world and is scientifically proven. Gujarat has now started to bear the brunt of climate change as mean temperatures have risen (46°C) and an increased incidence of heavy precipitation has been observed. Gujarat being in the forefront of industrial and economic development has mammoth greenhouse gas contribution to the climate system thereby accelerating global warming and climate change. The main contributors are the power generation, industrial and the transport sector. Climate change impacts will be felt on agriculture, decreasing crop yields due to increase in temperature in inevitable. Coastal communities are facing the brunt of increased cyclonic activity; damages to coastal infrastructure are also evident due to sea-level rise and coast erosion. Gujarat’s wetlands, home for migratory birds are being getting reduced due to coastal erosion and seal level rise. Climate impacts are increasing on humans due to increase in malarial incidence and extreme heat events causing incidence of severe diseases.

Gujarat has done bang-up work to offset carbon emissions through CDM projects, but the carbon being released into the atmosphere is still gargantuan and efforts made to reduce the currents levels of emission is inadequate. It is the task of Government of Gujarat to reduce its carbon emission below 2005 levels by 2025. It is still crucial that Gujarat makes efforts to reduce the flow of carbon emission being produced rather than offset its carbon along the economic model. Offsetting carbon would better serve the industrialists as they can continue polluting, by adding pressure to the climate system. The poor and the vulnerable form a major share of the population and are most susceptible to climate change. Offsetting emissions alone will not reduce the impact of climate change; and unlikely to reduce the burdens on the climate system as carbon flow will still remains. There has to be a drive to build resilience of farming and vulnerable communities who are most likely to be affected by climate change and global warming. Hence the government has to take initiatives to help communities to build resilience and adapt to the effects of climate change through scientific, indigenous knowledge and evidence-based decision. Scoping studies need to be conducted to understand communities and ecosystems that are vulnerable to climate change. Research and pilot studies need to be undertaken to understand issues and enhance
resilience through scientific and indigenous knowledge. It is the prerogative of the Government of Gujarat to protect its people and ecosystems. Under 12th Five Year Plan Gujarat has the potential to enhance adaptation and mitigation efforts and fund research and development activities to improve the current status of our vulnerable communities to the vagaries of climate change. The Government of Gujarat must take a lead on adapting communities and ecosystems to climate change and reduce pre-existing carbon stocks in the atmosphere.
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## 9 Annexe

**List of Participants of the Stakeholder Consultation held on 2nd February 2012**

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