India

Second Biennial Update Report to the United Nations Framework Convention on Climate Change

सत्यमेव जयते
Goverment Of India

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ISBN: 978-81-938531-2-2

CITATION: MoEFCC. (2018). India: Second Biennial Update Report to the United Nations Framework Convention on Climate Change. Ministry of Environment, Forest and Climate Change, Goverment of India.

Secretary
Ministry of Environment, Forest and Climate Change, Government of India
Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi-110003
Phone: +91 11 -24695262 / 24695265
Fax: +91 11 - 24695270

National Project Director
India's Third National Communication and other New Information to the UNFCCC,
Scientist-G, Ministry of Environment, Forest and Climate Change, Government of India
Indira Paryavaran Bhawan, Jor Bagh Road, New Delhi - 110003
Telefax: +91 11 - 24695293
E-mail: jrbhatt@nic.in

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Ministry of Environment, Forest and Climate Change

Government of India

December 2018

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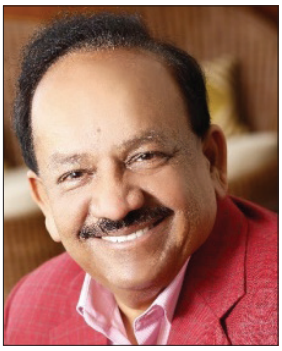


Dr. Harsh Vardhan,
Minister (Environment, Forest and Climate Change)
Government of India

I am proud to present India's second Biennial Update Report (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC) as our commitment to the Convention. BUR is an opportunity to showcase the country's initiatives and actions towards low carbon growth, poverty alleviation and sustainable development. We are doing exceptionally well on all the three fronts.

Action towards climate change is a common concern for humanity, and it is our ethical and moral responsibility to address it by using all means and wherewithal at our disposal.

Under the dynamic leadership of Hon'ble Prime Minister Shri Narendra Modi, India is taking several proactive actions at the national and international level to fulfil its obligations as per the principle of common but differentiated responsibilities and respective capabilities.

It is often missed in energy considerations that the global warming constraint on a country's energy sector does not depend on the country alone. India's policy has long emphasized that the problem of global warming requires collective action. The Earth's carbon system is one of the global commons, and any discussion on the use of the commons by a group or community is by definition a collective action problem. What one country does or has to do, depends not only on itself but also on the response of others. For India, like all other nations, carbon space is a strategic asset and getting its fair share of carbon space, while being a responsible global player, taking concerted action in protecting the planet, is a strategic goal.

India is steadily pursuing the imperative of diversifying energy supply, substantially increasing the share of renewable energy in the total energy mix and enhancing the use of energy conservation technologies and practices. These measures are significantly contributing to better air and water.

Amidst growing developmental challenges, India is sustainably managing its natural resources while adhering to the principle of sustainable production and consumption. Our forest and tree cover stands at 24.39% of the total geographical area, and the forestry sector offsets about 12% of the country's GHG emissions. India has not only been able to sustain but also increase its mangrove cover at a time when these ecosystems are disappearing at an alarming rate across the world.

India has proactively pursued mitigation and adaptation activities and achieved a reduction in emission intensity of GDP by 21% over the period 2005-2014. We are well on track to meet our Copenhagen commitments. However, to meet our Paris commitments and fully implement our NDCs in a timely manner, India requires enhanced new and additional financial, technological and capacity building support. New and additional financial and technological support to the developing countries is committed by the Paris Agreement which now needs to be operationalized.

India is committed to taking climate action in a manner that takes care of the vulnerabilities of its people while ensuring basic amenities and a life of dignity to all. In the process, the government has received enthusiastic support from the common people, academia, businesses and media, amongst others, thus making the entire process inclusive and participatory.

The BUR also has a section on sustainable lifestyles that highlights the country's efforts in maintaining a '*Samanvay*' ("a middle path") between its rich traditional heritage and modernity, while minimizing the adverse impacts on the environment. Continued unsustainable patterns of production and consumption are among the root causes of

climate change. Behavioural change and sustainable choices could make a difference. In this context, the Ministry is promoting Green Good Deeds, Green Good Behaviour, Green Good Practices and Green Social Responsibility amongst different stakeholders. The campaign has also received international recognition.

I congratulate all those involved in the preparation of India's second BUR.

Date: 31st December 2018

(Dr. Harsh Vardhan)

Preface

Shri CK Mishra,
Secretary (Environment, Forest and Climate Change)
Government of India

India as a Party to the United Nations Framework Convention on Climate Change (UNFCCC) is required to periodically communicate relevant information on the implementation of the Convention. The Conference of the Parties to UNFCCC decides the reporting requirements for the submission of these national communications in accordance with the principle of common but differentiated responsibilities and respective capabilities. Accordingly, India furnished its initial National Communication in 2004, second National Communication in 2012 and first Biennial Update Report (BUR) in 2016 to the UNFCCC.

The present document is the second BUR, which is an update of the first BUR, and provides information on national circumstances, national greenhouse gas inventory, mitigation actions, domestic monitoring, reporting and verification arrangement, as well as on finance, technology and capacity building needs and support received.

More than 100 scientists, 16 institutions and 21 studies guided the preparation of the second BUR. Additionally, some distinguished experts from institutions, both in Government and outside Government, including academic and research institutions, civil society organizations and the private sector peer-reviewed the report. India's national communication has also benefitted from the support of the Indian Space Research Organization. The reliable and transparent institutional arrangement put in place for the second BUR is detailed in the report.

The first chapter on national circumstances presents an updated account of the country's natural resources, demographic, economic, development and governance profile. Climate-friendly lifestyle and satellite-based environmental monitoring system are some of the new additions to this chapter.

The national inventory year for India's second BUR is 2014. The second chapter presents information on six greenhouse gases, *viz.*, Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF_6), and for five source / sink categories, namely- Energy, Industrial Processes and Products Use (IPPU), Agriculture, Waste, and Land Use Land Use Change and Forestry (LULUCF).

India emitted 2607.49 million tonnes CO_2e (excluding LULUCF) and 2306.3 million tonnes CO_2e (including LULUCF) in 2014. Out of the total emissions, the energy sector accounted for 73%, IPPU 8%, agriculture 16% and waste sector 3%. The Land Use, Land Use Change and Forestry sector offset about 12% of India's total emissions. The second chapter also contains the details of the methodology, activity data and emission factors as well as a comparative analysis of the country's methane emissions following a top-down approach.

The emission intensity of India's Gross Domestic Product (GDP) has reduced by 21% over the period of 2005 - 2014. This achievement has been made possible by a strong political will for climate action leading to well-designed outcome-oriented policies, programmes and measures on mitigation, detailed in the third chapter.

In the last two years, the developmental landscape of the country has transformed as is reflected in the third and the fourth chapters of this report. Domestic measurement, reporting and verification (MRV) systems for various programmes and schemes are taking account of the emission reduction potential and actual reductions. This information is in the public domain in the form of national dashboards, especially for schemes like UJALA and the Street Lighting National Programme. However, for a country as diverse and complex as India with challenging demands, setting up an MRV system for more detailed reporting including carbon emission reduction is a challenge and requires enhanced support.

As a responsible country, India has been making efforts and is well on track to meet its Copenhagen commitments.

However, to meet its Paris commitments, in a timely manner, India requires enhanced new, additional and climate-specific financial, technological and capacity building support. Climate change is a global action problem. Enhanced support, instead of enhanced deliberation and reporting, is the key to address the growing challenge of climate change which is now affecting each one of us. The real honest global action towards climate change is yet to materialize, as pointed out in the fifth chapter of this report.

The sixth chapter presents additional information on activities related to communication and outreach, adaptation and research which contribute to the implementation of the Convention.

India is a firm believer in multilateralism and is optimistic about receiving enhanced support to address global challenges like climate change.

I take this opportunity to compliment the team of scientists, experts and institutions for their involvement in this national endeavour and in particular, my colleagues Dr Arun Kumar Mehta, Additional Secretary and Dr J. R. Bhatt, Scientist 'G' in the Ministry of Environment, Forest and Climate Change.

Date: 31st December 2018

[C.K. Mishra]

Executive Summary

Key highlights

- India is committed at the highest level to meeting its national commitments made to the international community through UNFCCC and the Paris Agreement. In recognition of India's national efforts towards climate change, Hon'ble Prime Minister Shri Narendra Modi received the Champions of the Earth award in 2018, a top United Nations honour that recognises contribution in the field of environment protection.
- Total annual GHG emissions have increased from 2,136.8 million tonnes (Mt) of CO_2e (1,884.3 Mt with Land Use, Land Use Change and Forestry (LULUCF)) in 2010 to 2,607.5 Mt of CO_2e in 2014 (2,306.3 Mt with LULUCF).
- As a result of India's proactive and sustained actions on climate change mitigation, the emission intensity of India's Gross Domestic Product (GDP) has reduced by 21% over the period of 2005-2014.
- International Solar Alliance (ISA) is the vision of Hon'ble Prime Minister Shri Narendra Modi, to bring the world together for harnessing the untapped potential of solar energy for universal energy access at affordable rates. With the joint efforts of India and France, ISA was launched in 2015 at Paris which became the first treaty-based inter-governmental organisation located in India.
- Solar installed capacity in India has increased by about 9 times from 2.63 Gigawatt (GW) to 23.28 GW between March 2014 and August 2018.
- The share of non-fossil sources in installed capacity of electricity generation increased from 30.5% in March 2015 to 35.5% in June 2018.
- Supercritical thermal power units have risen from 40 (27.48 GW in 2015) to 66 (45.55 GW in 2018) with avoided emissions amounting to 7 $MtCO_2$ in 2016-17.
- A total of 170 old thermal generation units having a higher heat rate and a cumulative capacity of 10.64 GW, have been retired till March 2018.
- Forest and tree cover increased from 24.01% of the total geographical area as reported in India State of Forest Report (ISFR) 2013 to 24.39% as reported in ISFR 2017.
- Perform Achieve and Trade (PAT) scheme for energy efficiency in industries and other energy-intensive sectors, covering 478 designated consumers (DCs), avoided emissions of 31 $MtCO_2$ in cycle I (April 2012 to March 2015). In total, 846 DCs from 13 sectors are undergoing implementation of PAT cycle II, III and IV with a total targeted energy savings of 19 Mtoe.
- Around 137 $MtCO_2$ has been sequestered from 2010 to 2016 due to the National Horticulture Mission.
- India is partnering 22 member countries and the European Union in the 'Mission Innovation' on clean energy, and is a co-lead in smart grid, off-grid and sustainable biofuels innovation challenges.
- More than 312 million LED bulbs have been distributed till October 2018 under the '*Unnat Jyoti* by Affordable LEDs for All' (UJALA) programme. Replacement of incandescent and CFL bulbs by LED bulbs has resulted in energy saving of about 40 billion kWh and reduction of 33 $MtCO_2$ per year (as in October 2018).

Background information and institutional arrangements

This report embodies information on national circumstances, national GHG inventory, mitigation actions, and an analysis of the constraints, gaps, and related finance, technology and capacity building needs, including information on domestic Measurement, Reporting and Verification (MRV). The Ministry of Environment, Forest and Climate Change (MoEFCC) is the nodal ministry under the Government of India for coordination and management of climate change - related programmes, actions and reporting information. MoEFCC, with its cross-ministerial and institutional network, is implementing and executing matters related to the National Communications and Biennial Update Reports (BURs). India furnished it's Initial National Communication (INC) in 2004, Second National Communication (SNC) in 2012 and First Biennial Update Report (BUR-1) in 2016 to the UNFCCC.

The institutional arrangement for preparing BUR includes a National Steering Committee (NSC) and Technical Advisory Committee (TAC) of institutions and experts. The NSC under the chairmanship of the Secretary, MoEFCC oversees the preparation and implementation of the work programme of the BUR. Various ministries and government departments, concerned with different elements of information in this report, have representation in the NSC. These ministries and departments also provide inputs for the BUR. The TAC provides technical guidance for the preparation of the BUR. This committee has members from the government, academia and civil society.

For the purpose of the Second Biennial Update Report (BUR-2), several studies were launched, which were carried out by institutions having sector-specific expertise. The network of institutions has been expanded since the First Biennial Update Report (BUR-1). The report was reviewed by a range of academic and government experts before

the TAC and NSC meetings. There is thus a robust Quality Assurance/Quality Control (QA/QC) process in place.

National circumstances

India is the seventh largest country in the world with a geographical area of 328.73 million hectares (Mha) which is 2.4% of the global land area. India has diverse climatic conditions due to its topography and presence of Himalaya that separates the country from the rest of the Asian mainland. India has a coastline of about 7,500 km. India has the second largest human population in the world with more than 1.21 billion people (Census, 2011). A significant section of its large population depends on climate-sensitive sectors such as agriculture, fisheries and forestry for livelihood. Table ES 1 lists key features of India's national circumstances.

Table ES 1: National Circumstances – Key Features

Parameters	Measure
Total geographical area (Mha)	328.73
Area under agriculture (net sown area) as percentage of the total geographical area	42.60%
Total cropped area (gross cropped area) (Mha, 2014-15)	198.36
Gross irrigated area (Mha, 2014-15)	96.46
Foodgrain production (million tonnes, 2016-17, fourth advance estimate)	275.68
Forest and tree cover as percentage of the total geographical area (India State of the Forest Report 2017)	24.39%
Urban population as percentage of total population (2011)	31.14%
All India Poverty Head Count Ratio (2011-12)	29.50%
Life expectancy at birth in years (2012-13)	67.5
Literacy rate, 7+ years (2011)	73%
GDP in 2017-18, in trillion rupees, at constant (2011-12) prices	130.11
Share of mining and quarrying, manufacturing and construction in GVA in 2017-18 (at constant 2011-12 prices)	29.03%
Share of services in GVA in 2017-18 (at constant 2011-12 prices)	56.15%
Share of agriculture, forestry and fishing in GVA in 2017-18 (at constant 2011-12 prices)	14.82%
Livestock population excluding poultry (million), year 2012	512.06
Households with *kutcha* (mud huts) and semi-*pucca* (semi-concrete) houses	55%

India's climate ranges from continental to coastal, from extremes of heat to extremes of cold, from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall, and is greatly influenced by the presence of the Himalayas and the Thar Desert. Nearly 75% of the annual precipitation of India is received during the southwest monsoon season with large spatial variability in its distribution. The months of June to September is the core of the southwest monsoon season in most parts of the country. Many parts of India are vulnerable to floods during the monsoons which cause significant loss of life and damage to livelihood systems, property, infrastructure and public utilities. Flood risk has increased significantly over India during the recent decades. India's exposure to natural hazards can be gauged from the fact that it experienced 431 major natural disasters during the period 1980-2010. The flood events of recent years in the states of Uttarakhand, Jammu & Kashmir and Kerala are examples of such disasters.

The analysis of rainfall data from the India Meteorological Department (IMD) observational network for the period 1901-2010 shows increasing trends in the frequency of dry days in most parts of the country during winter, pre-monsoon and southwest monsoon seasons. In conformity with the rising trend observed in global surface temperatures (0.85±0.18°C) since 1901, the annual mean temperature for the period 1901-2017 over India has also shown a significant increasing trend of 0.66°C per hundred years.

India has approximately 4% of the world's freshwater resources but has approximately 17% of the world's population. The overall impact of climate change on water resources is anticipated in terms of the rise in extremes, thereby increasing flood and drought frequency, and reducing groundwater recharge.

As per the estimates released by the Central Statistics Office (CSO), the growth in Gross Domestic Product (GDP)

at constant (2011-12) prices is estimated at 6.7% in 2017-18. Agriculture plays a vital role in India's economy. About half of the workforce in India depends on agriculture as their principal source of livelihood. Contributing only approximately 15% to Gross Value Added (GVA) in 2017-18, agriculture is also the source of livelihood to a large economically and ecologically vulnerable population. India's total foodgrain production was 275.68 Mt in 2016-17. India is the largest producer, consumer and exporter of spices and spice products. India's horticulture output, comprising fruits, vegetables, spices reached a record high of 299.8 Mt in 2016-17. Livestock is also an integral part of India's agricultural economy. It is estimated that approximately 70 million rural households own livestock of one species or the other. India supports about 15% of the cattle population of the world, and its share in the world milk production is 18.5%.

India has a vast potential for fisheries and is the world's second largest producer of fish. Apart from fisheries potential, India's coastal and marine ecosystems are among the world's most diverse environments, including mangroves, coral reefs, seagrasses, salt marshes, mud flats, estuaries and lagoons. The coastal populations and their livelihoods are vulnerable to sea level rise. Altimeter data analysis over the 1993–2012 period shows that the rate of sea level rise is close to the global mean sea level rise trend (3.2 mm yr^{-1}).

In terms of land use, 42.6% of the total geographical area is under cultivation (net sown area), land not available for cultivation is 13.3%, and 24.39% is under forests and tree cover. A total of 15 states/union territories (UTs) have forest cover of more than 33% of their land area. The tree cover outside the forests out of 36 states/UTs is estimated at 93,815 sq. km, which is 2.85% of the geographical area.

Urbanisation is projected to grow and the urban population is expected to reach approximately 600 million by 2031 and 850 million by 2051. According to Census 2011, around 377 million Indians, accounting for 31.16% of the country's population (an increase from 286 million in 2001), lived in urban areas. The Government of India has undertaken a number of major initiatives to address the challenges of urbanization.

In India, 64% of the population is in the age group of 15-59 years. This demographic dividend presents both a challenge and an opportunity. The estimated rate of unemployment for the persons aged 18-29 years was 10.2% as per a survey conducted by Labour Bureau during 2015-16. The government has decided to strategically promote labour-intensive manufacturing and expand employment opportunities by promoting tourism and agro-based industries.

In terms of energy consumption, India uses only 6% of the world's primary energy, but sustained economic growth is placing an enormous demand on its energy resources. India's per capita energy consumption grew by 56.4% from 2005-06 to 2016-17, with an annual growth rate (CAGR) of 3.8%. India's per capita energy consumption is nearly 30% of the world's average. In 2016-17, primary energy supply added up to 817.37 million tonnes of oil equivalent (Mtoe). India's energy intensity has decreased over the last decade. The energy intensity (at 2011-12 prices) decreased from 0.2732 Mega Joules per rupee in 2011-12 to 0.2401 Mega Joules per rupee in 2016-17. The total installed capacity in the power sector in the country is 345,524.61 MW as on June 2018, with state sector accounting for 30%, central sector for 25% and private producers for 45%. As per present estimates, India has a renewable energy potential of about 1100 GW for commercially exploitable sources *viz.* Wind – 300 GW (at 100 m mast height), Small hydro – 20 GW; Bio-energy – 25 GW and 750 GW Solar power assuming 3% wasteland is made available.

The transport sector is one of the fastest growing sectors in India. Currently, urban transport needs in Indian cities (for both passenger and freight mobility) are met by a mix of motorized and non-motorized modes. The development of public transport infrastructure is promoted by Central funding. India has currently eleven operational metro systems in the cities of Kolkata, Delhi, Gurugram, Noida, Bengaluru, Mumbai, Jaipur, Lucknow, Hyderabad, Chennai and Kochi. The Government of India approved the National Mission on Electric Mobility in 2011, and subsequently, National Mission on Electric Mobility Plan 2020 (NEMMP, 2020) was announced in 2013 as a part of which, India is strongly encouraging and promoting hybrid and electric vehicles in the country.

The policies and programmes implemented by the government show that environmental protection is one of the central pillars of India's governance framework. The National Action Plan on Climate Change (NAPCC) was launched in 2008 with eight National Missions. Most ministries and departments have been working in collaboration to implement and to achieve the goals set in NAPCC. On the lines of the NAPCC, majority of the states and union territories have prepared their State Action Plan on Climate Change with the aim of contributing to achieving the national goals and meeting the state priorities.

Article 2.2 of the Paris Agreement states: "This Agreement will be implemented to reflect equity and the principle of common but differentiated responsibilities and respective capabilities, in light of different national circumstances". In the case of India, the most important of these 'national circumstances' are: (a) very low per

capita emissions compared not only to developed countries but even the global average; (b) very low per capita historical emissions; (c) the relatively low per capita income and the "overriding priority" of economic and social development and poverty eradication (Article 4.7 of UNFCCC); and (d) centrality of coal in our natural resource endowment. Rapid development is essential not only for attaining our Sustainable Development Goals (SDGs) but also for generating the resources required for adaptation to impacts of climate change.

National greenhouse gas inventory

India's emissions in 2014 were 2,607,488 Gg of CO_2e of greenhouse gases (GHGs) without Land Use, Land-Use Change and Forestry (LULUCF). LULUCF sector remained a net sink. Considering emissions and removals from the LULUCF sector, net national emissions were 2,306,295 Gg of CO_2e. A summary of emissions and removals from these sectors is presented in Table ES 2. The relative contribution of various GHGs by sector in the total inventory is shown in Figure ES 1.

Table ES 2: Greenhouse gas emissions by sectors in India in 2014 (Gg)

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
TOTAL without LULUCF (Gg)	**1,997,891.85**	**-**	**20,005.35**	**475.29**	**1.59**	**2.61**	**0.71**	**0.004**	**2,607,488.12**
TOTAL with LULUCF (Gg)	**2,015,107.88**	**319,860.23**	**20,053.54**	**476.71**	**1.59**	**2.61**	**0.71**	**0.004**	**2,306,295.43**
1. ENERGY	1,844,705.03	-	2,133.37	65.35	-	-	-	0.004	1,909,765.74
2. IPPU	153,186.81	-	177.85	10.36	1.59	2.61	0.71	0.00	202,277.69
3. AGRICULTURE	-	-	14,709.78	349.39	-	-	-	-	417,217.54
4. LULUCF	17,216.04	319,860.23	48.19	1.42	-	-	-	-	-301,192.69
5. WASTE	-	-	2,984.35	50.18	-	-	-	-	78,227.15
Memo Item (not accounted in total Emissions)	**812,030.60**	**-**	**0.11**	**0.11**	**-**	**-**	**-**	**-**	**812,067.87**
International Bunkers	4,943.53	-	0.11	0.11	-	-	-	-	4,980.81
Aviation	3,681.65	-	0.03	0.10	-	-	-	-	3,714.12
Marine	1,261.88	-	0.08	0.01	-	-	-	-	1,266.69
CO_2 from Biomass	807,087.06	-	-	-	-	-	-	-	807,087.06

The energy sector accounted for 73% of the total GHG emissions for the year 2014. Fuel combustion activities emitted 1,871,709 Gg CO_2e in 2014 including 1,140,983 Gg CO_2e from energy industries. Within energy industries, 94.96% of emissions were from electricity production, 4.39% from refinery and 0.66% from manufacturing of solid fuels. Thus, electricity production accounted for about 42% of the entire GHG emissions from all the sectors in 2014. The manufacturing industries and construction together emitted 351,909.54 Gg CO_2e, which was approximately 19% of total emissions from the energy sector. The sub-categories that share the total contribution to the emissions from the manufacturing industries are: Cement (13.4%), Iron & steel (43.9%), Non-ferrous metals (0.5%), Chemicals (0.6%), Pulp & paper (1.1%), Mining & quarrying (0.9%), Textile/leather (1.0%), Bricks (0.8%), Fertilizer (1.7%), Engineering Sector (0.1%), and Nonspecific Industries (36%).

Road transport accounted for 90.1% of the total emissions from the transport sector, followed by civil aviation (5.6%), railways (3.1%) and domestic water-borne navigation (1.2%). In 2014, other sectors in the energy sector together emitted 128,643 Gg of CO_2e, of which approximately two-thirds were contributed by the Residential sector, about one fifth by the Commercial sector and rest by the Biomass burnt for energy (non-CO_2 GHGs) and the Agriculture /Fisheries sectors put together. A comparison of fossil fuel combustion emissions using both, the Reference approach and the Sectoral approach was also conducted, and the difference was found to be 3.83%.

The total fugitive emissions in the year 2014 were 38,057 Gg CO_2e, of which 43% was from coal mining and post mining operations in India. Fugitive methane emissions from coal mining and handling activities have registered

a decrease of 22% between 2010 and 2014, mainly due to a relative reduction in underground mining activities. Fugitive emissions contributed to 2% of emissions from the energy sector.

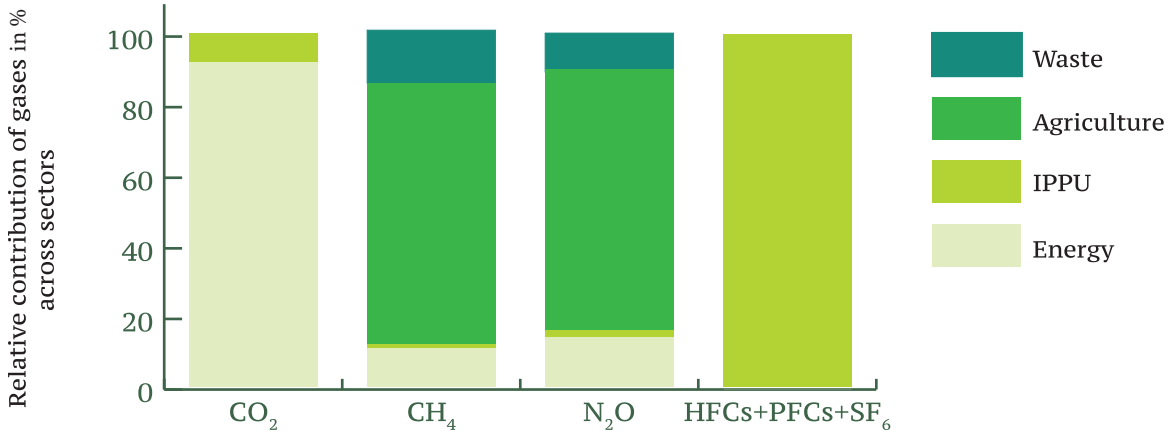


Figure ES 1: Relative contributions of greenhouse gas emissions from individual sectors (excluding LULUCF) for the year 2014

The Industrial Processes and Product Use (IPPU) category emitted 202,278 Gg of CO_2e in the year 2014, and accounted for 8% of the total GHG emissions. Within IPPU, cement production is the largest emission source, accounting for about 57% of total IPPU sector emissions. In total 42,145 Gg CO_2e was emitted as Fluorinated-gases in 2014.

Agriculture sector is the main source of Methane (CH_4) and Nitrous Oxide (N_2O) emissions. CH_4 emissions occur from this sector mainly due to livestock rearing (enteric fermentation and manure management) and rice cultivation. N_2O is principally emitted due to the application of fertilizers to the agricultural soils. In the year 2014, the agriculture sector emitted 417,218 Gg of CO_2e, which amounted to around 16% of the emissions of India for that year. Of these, 74% was CH_4, and 26% was N_2O.

LULUCF sector was a net sink of 301,193 Gg CO_2e during 2014, registering an increase in the sink activity of the sector. Cropland dominates the CO_2 emissions /removal estimates for India for the year 2014. Forest land, Cropland and Settlement categories were net sinks while grassland was a net source of CO_2. About 12% of India's GHG emissions were offset by the LULUCF sector.

The waste sector contributed to 3% to total GHG emissions in 2014. The waste sector was dominated by emissions from wastewater handling which account for more than 80% of the sectoral emissions. Methane from solid waste disposal was 717 Gg whereas CH_4 emissions from wastewater treatment and discharge, including domestic, commercial and industrial wastewater were 2,267 Gg. Domestic and commercial wastewater handling also emitted 50 Gg of N_2O.

Key category analysis has been carried out to identify sources with significant impact (up to 95%) on total emission levels or trends. The primary purpose of key category analysis is to prioritize application of higher tier methodologies for key sectors, to design additional requirements of QA/QC for these key categories, and to allocate and make the best use of available resources for sources with significant impact on total emission estimate. This would lead to a reduction in the uncertainties in the estimates to the maximum extent possible. In order to identify the key categories, both, level analysis and trend analysis have been carried out. The analysis is without LULUCF and includes all GHGs reported. The level assessment reveals that the CO_2 emissions from electricity production were the largest source with 41.4% of total emissions occurring in the country, followed by methane emissions from enteric fermentation that accounts for about 9% and by CO_2 emissions from road transport accounting for about 8.5%. The CO_2 emissions from electricity production also contribute 40% to the trend, followed by CO_2 from non-specified industries and CO_2 from Iron and steel sector contributing to around 10% and 8% to the trend respectively.

A consistent time series information on GHG inventory starting from the last full national communication (the inventory year 2000) to 2014 has been presented in Figure ES 2.

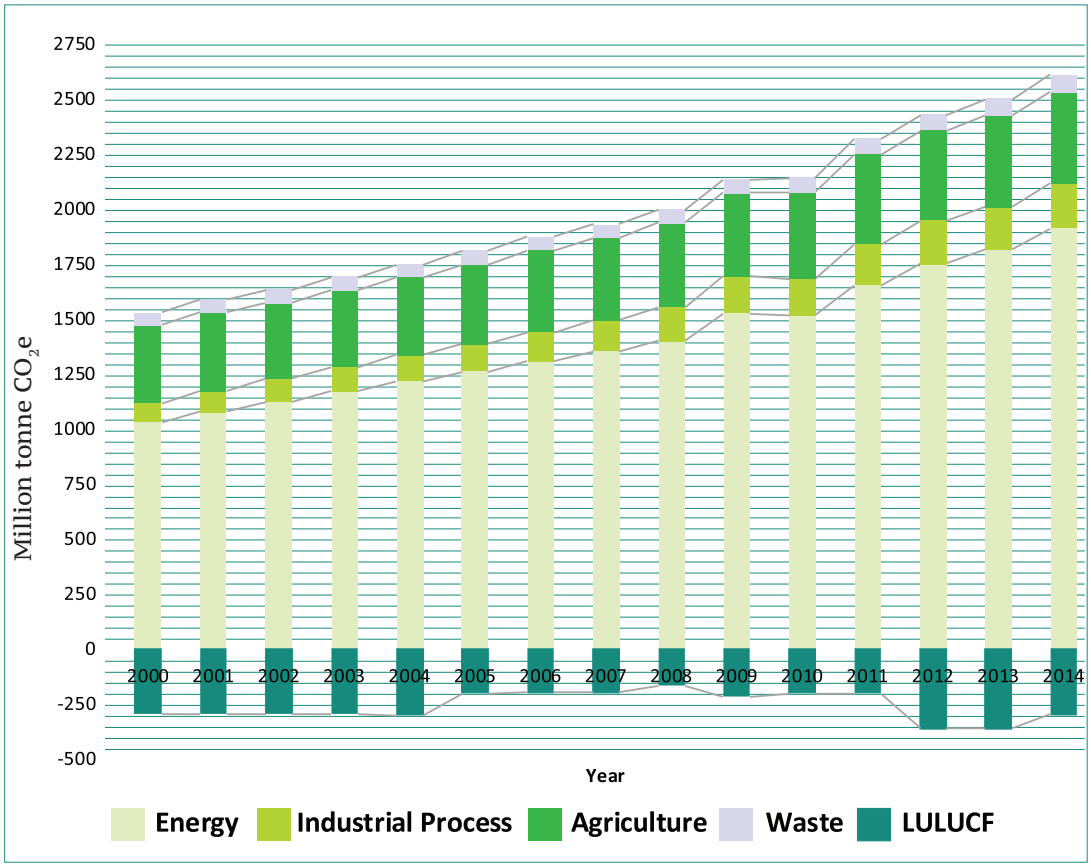


Figure ES 2: Time series of GHG Emissions (2000-2014)

Mitigation actions

India is committed at the highest level to meeting its national commitments made to the international community through the UNFCCC and the Paris Climate Change Agreement. In recognition of our national efforts towards climate change, Prime Minister Shri Narendra Modi received the Champions of the Earth award in 2018, a top United Nations honour that recognises contribution to the field of environment protection. India along with France also initiated the International Solar Alliance (ISA) of 121 sunshine countries to work for efficient exploitation of solar energy to reduce dependence on fossil fuels. India is partnering 22 member countries and the European Union in the 'Mission Innovation' on clean energy, and is co-lead in smart grid, off-grid and sustainable biofuels innovation challenges.

India traditionally believes in sustainable development and resource use efficiency. India is specifically committed to addressing the challenges posed by climate change through several key mitigation initiatives and is proactive in promoting low carbon and sustainable lifestyles. Widespread recognition of the climate challenge in key sectors of public opinion as well as aspects of India's traditional culture, including the appreciation for the virtues of abnegation and renunciation or frugality and the rejection of conspicuous consumption, contribute to the active public support received by the government's mitigation policies. It translates into India's multiple policies and programmes aimed at synchronizing development and climate change mitigation at federal, state and local levels.

The National Action Plan on Climate Change (NAPCC) aimed at achieving sustainable development, and India's mitigation targets provides an overarching umbrella for mitigation actions at all levels. There are eight National missions under the NAPCC. On the lines of the NAPCC, each state has prepared its own State Action Plan on Climate Change (SAPCC) in the light of achieving the national goals.

The Government of India and various state governments under the federal constitutional structure of India have therefore, over the years, undertaken many proactive policies and measures across sectors and regions as general steps taken or envisaged to implement the Convention and its various Protocols, and the Copenhagen commitments and the Paris Agreement, keeping in mind the national circumstances. Most of these policies and measures mitigate GHGs directly or indirectly. The Indian economy is becoming greener through these conscious actions and there are efforts to enhance energy efficiency across the economy, increase the share of renewable energy in the national mix and enhance forest and tree cover, while simultaneously meeting India's development challenges in a sustainable manner. Substantial resources are being committed internally towards this each year.

India made a voluntary pledge in 2010 to reduce the emission intensity of its GDP by 20-25% from 2005 levels by 2020 (excluding emissions from agriculture). Later in 2015, India submitted its Nationally Determined Contributions (NDCs) under the Paris Agreement, wherein India voluntarily pushed up its target of reducing emission intensity of its GDP by 33 - 35% from 2005 levels by 2030. As a result of India's multiple mitigation actions, the emission intensity has already reduced by 21% between 2005 and 2014.

Energy sector

In the energy sector, several policies and programmes have been implemented to address climate change concerns. India's NDC includes an ambitious plan to achieve 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030. The share of non-fossil fuel based electricity generation installed capacity has reached 35.5% as in June 2018. Solar energy capacity increased by about 9 times from 2.63 GW in March 2014 to 23.02 GW in June 2018. Ensuring energy security, improving access and affordability of modern energy resources for all Indians, diversifying energy resources, resource use efficiency enhancement, reducing aggregate technical and commercial losses in power transmission, and enhancing renewable energy are the pillars of Indian energy policy planning.

The Energy Conservation Act 2001, was amended in 2010 to provide stringent compliance norms to ensure energy efficiency. Through energy efficiency lighting programmes, the sales of compact fluorescent lamps (CFLs) rose to about 37% of the total lighting requirements in 2014 from 7.8% in 2005. India has also launched an ambitious plan to replace all incandescent lamps with Light-emitting Diode (LED) bulbs in the next few years leading to energy savings of up to 100 billion kilowatt hours (kWh) annually. Under the programme called UJALA, more than 312 million LED bulbs have been distributed which has led to a reduction of 33 $MtCO_2$ emissions per year till October 2018. The distribution of energy efficient LED tube lights was started in August 2016 and till October 2018, 6.7 million LED tube lights have been distributed resulting in estimated energy savings of 294.45 million kWh per year with an avoided peak demand of 135 MW and GHG emission reduction of 0.2 $MtCO_2$ per year.

The distribution of energy efficient fans was started in August 2016 and till October 2018, 2.06 million energy efficient fans have been distributed under this scheme which has resulted in an estimated energy savings of 191.41 million kWh per year with an avoided peak demand of 52 MW and GHG emission reduction of 0.1 $MtCO_2$ per year. Under the Street Lighting National Programme (SLNP), more than 7.1 million LED street lights have been installed as of October 2018 which has led to an annual energy savings of 4.77 billion kWh and reduction of 3.29 $MtCO_2$ emissions.

Because of India's Clean Coal Technology Initiative, supercritical technology for power generation has been adopted in the country. Already, 66 supercritical units with a total capacity of 45,550 MW have been installed which led to a reduction of about 7 $MtCO_2$ emissions in 2016-17. India's National Clean Energy and Environment Fund, sourced from a cess on coal, has financed 55 projects with a total viability gap funding of ₹348.11 billion.

The Government of India has set an ambitious target of 175 GW renewable energy capacity by 2022, comprising 100 GW from solar power, 60 GW from wind power, 10 GW from bio-energy and 5 GW from small hydropower. The share of renewable energy continues to progressively increase in the electricity mix and in the year 2017-18, renewable energy generation in India crossed 100 billion units. As on 30 September 2018, installed renewable power capacity (excluding hydro above 25 MW) has already crossed 72 GW, contributing about 21% of the country's installed electricity capacity and over 10% in the electricity generation mix.

There is also a need for increasing thrust on storage technologies. Hydro plants including the pumped storage plants would play a significant role as they are the best source for renewable integration and ancillary sources of supply of balancing power/grid Stabilisation, improved frequency, voltage control and network restoration. The total actual gross generation from the hydro power units (>25 MW) during 2016-17 is 122.31 billion units. CO_2 emissions reduced due to hydro power generation from units (>25 MW) during 2016-17 is 100.29 Mt.

Under the Central Electricity Act 2003, the State Electricity Regulatory Commissions (SERCs) issue Renewable Purchase Obligations (RPO) specifying the share of renewable energy in the electricity source mix of distribution companies. As per the new targets, RPOs to be achieved by 2021-22 for solar and non-solar power, uniformly for all States/Union Territories will be 21% (solar: 10.5%; non-solar: 10.5%).

To make the industry sector more energy efficient, Perform Achieve and Trade (PAT) scheme was initiated under the National Mission for Enhanced Energy Efficiency. During the first cycle of PAT (2012-15), an energy saving of 8.67 Mtoe was achieved against the target of 6.686 Mtoe assigned for 478 designated consumers. This translates into avoiding about 5,635 MW of energy demand and about 31 $MtCO_2$ emissions. In PAT Cycle-II (2016-19) that was notified in the year 2016, 621 Designated Consumers (DCs) from 11 sectors have been given Specific Energy

Consumption (SEC) targets, with intended energy saving of 8.869 Mtoe. PAT scheme is now being implemented on a rolling basis where new DCs/sectors are included every year. Subsequently, PAT Cycle-III commenced from 1st April 2017, to achieve an overall energy consumption reduction of 1.06 Mtoe and PAT Cycle-IV has commenced with effect from 1st April 2018 in which 109 DCs have been notified from the existing sectors and from two new sectors, i.e, Petrochemicals and Commercial Buildings (hotels).

Buildings sector

Buildings in residential and commercial sectors consume over 35% of India's electrical energy. To improve efficiency in the buildings sector, the Building Retrofitting Project was initiated by Energy Efficiency Services Limited (EESL) in 2014 and it has led to energy savings of 79.8 GWh and CO_2 reduction of 65,578 tonnes till October 2018. An Energy Conservation Building Code (ECBC) was also developed by the Bureau of Energy Efficiency (BEE) in 2007, prescribing a minimum standard for energy use in new commercial buildings. In order for a building to be considered ECBC-compliant, it would need to demonstrate minimum energy savings of 25%. The ECBC was updated by BEE in 2017. Ministry of Power is also in the process of developing ECBC and labelling for residential sector. Another programme of the BEE, the Standards and Labelling programme, covers 22 appliances of which 10 appliances are now made mandatory. The scheme has led to energy savings of 121 billion units from 2011 to 2018.

The Smart Cities Mission was launched in 2015 for providing a clean and sustainable urban environment through the adoption of 'smart solutions'. Resource efficiency and energy optimization are central to these smart solutions identified under the Mission. A total of 1,333 projects worth ₹5,06,260 million have been completed or are under implementation/tendering. Overall projects worth ₹20,39,790 million have been identified for 99 selected smart cities across the country.

The *Pradhan Mantri Ujjwala Yojana* was launched in 2016 to safeguard the health of women and children by providing them with clean cooking fuel – Liquefied Petroleum Gas, so that they do not have to compromise their health in smoky kitchens or in the drudgery of collecting firewood. Under this scheme, more than 50 million LPG connections have been provided to Below Poverty Line (BPL) families.

Transport sector

In the transport sector, several climate related initiatives have been taken. The Auto Fuel Policy, 2003 aims to holistically address the issues of vehicular emissions, and vehicular technologies by applying auto fuel quality standards in a cost-efficient manner. The government has decided to leapfrog from Bharat Stage IV emission norms to Bharat Stage VI emission norms by 2020. The Government has also issued average fuel consumption standards for cars on 23rd April 2015, which became applicable on all new cars from 1st April 2017. Fuel efficiency standards have also been notified for passenger cars and heavy duty vehicles.

Increasing the share of alternative fuels in the overall fuel mix is yet another strategy to reduce emissions from the sector. The number of compressed natural gas (CNG) cars and taxis in India grew from 23,166 in the year 2001 to 439,250 in 2011. In the year 2011, Delhi (64%) had the highest share of CNG cars followed by Gujarat (18%) and Maharashtra (15%). Blending of petrol with ethanol is being carried out in 21 States and four UTs.

The National Policy on Biofuels, 2018 aims to increase the usage of biofuels in the energy and transportation sectors of the country during the coming decade. Currently, biodiesel blending percentage in diesel is less than 0.1% and ethanol blending percentage in petrol is around 2%. An indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030.

The National Electric Mobility Mission Plan 2020 (NEMMP) is one of the most important and ambitious initiatives aimed at gradually ensuring a population of about 6-7 million electric/hybrid vehicles in India by the year 2020. According to the NEMMP, India aims to deploy 400,000 passenger battery electric vehicles (BEVs) by 2020. If this target is achieved, India can eschew importing 120 million barrels of oil and avoid 4 $MtCO_2$ emissions by 2020.

With increasing dependence on railways, the electrification of Indian Railways is an important step towards not only enhancing the efficiency of the system but also mitigating GHGs from its operations due to efficiency gains. By March 2016, 23,555 route kilometres, constituting 35.32% of the total railway network had been electrified. Mass-transit and urban transport projects have also been initiated under the National Urban Renewal Mission.

The Indian aviation sector has also undergone considerable changes. Apart from airports being expanded and modernised, various environment-friendly initiatives taken include engine modernization programme for better fuel efficiency, engine core water wash at regular intervals to increase fuel efficiency, adoption of Carbon Accounting

and Management System (CAMS), adoption of Environment Management System, Energy Management System and Greenhouse Gas Reporting mechanism, use of Compressed Natural Gas (CNG) vehicles and electrically operated baggage tugs and buggies, and installation of solar power plants at airport premises.

Agriculture

Several initiatives have been taken to promote sustainable development of the sector. The Rainfed Area Development programme under the National Mission on Sustainable Agriculture (NMSA) aims to make rain-fed agriculture more productive, sustainable, remunerative and climate resilient by promoting location specific Integrated/Composite Farming Systems along with conservation of natural resources through appropriate soil and moisture conservation measures.

The sub-mission on Agroforestry will result in an increase in tree cover in non-forest areas leading to higher carbon sequestration. It also compliments the national initiatives on climate change adaptation and mitigation while providing additional income opportunities for farmers.

The National Innovations on Climate Resilient Agriculture (NICRA) programme under NMSA aims at enhancing the resilience of Indian agriculture to climate change and climate vulnerability through strategic research and technology demonstration. The Pradhan Mantri Krishi Sinchayee Yojana announced on 1st July 2015, is meant to achieve convergence of investments in irrigation at the field level, expand the cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies (more crop per drop) and enhance recharge of aquifers. It has resulted in an emissions reduction of 22.82 $MtCO_2$.

The Crop Diversification Programme is being implemented in the states of Punjab, Haryana and western Uttar Pradesh since 2013-14 to divert the area under water-intensive paddy to alternative crops like pulses, oilseeds, maize, cotton and to agroforestry plantation with the objective of tackling the problem of declining soil fertility and depleting water table in these states. An emission reduction of 0.21 $MtCO_2e$ (2010-2016) has been achieved under this project.

Under the Paramparagat Krishi Vikas Yojana (PKVY), initiated in 2015-16 under NMSA, the government is promoting organic farming across the country which in turn is resulting in improvement of soil health. The National Horticulture Mission was launched in 2005-06 as centrally sponsored scheme to promote holistic growth of the horticulture sector through area-based regionally differentiated strategies. Presently, India is the second largest producer of fruits and vegetables in the world. The quantum of carbon sequestered due to this mission is estimated to be 137.72 $MtCO_2$ from 2010 to 2016.

The adoption of the System of Rice Intensification (SRI) in various regions has led to an emission reduction of 0.18 $MtCO_2$ during 2010-16, while Direct Seeded Rice system has led to an emission reduction of 0.17 $MtCO_2$ from 2014-16. The National Bamboo Mission, being implemented since 2006-07, has been renamed as National Agroforestry & Bamboo Mission (NABM). The Mission is aimed at promoting the growth of the bamboo sector. Since 2006-07, 361,791 ha has been covered with bamboo plantation, out of which 236,700 ha is under forest area, and 125,091 ha is under non-forest area.

A National Policy for Management of Crop Residues (NPMCR) was made in 2014 which stressed on the control of crop residue burning to prevent environmental degradation. The National Green Tribunal through its judgment in December 2015, directed the implementation of NPMCR in the States of Rajasthan, Uttar Pradesh, Haryana and Punjab. After implementation, an emission reduction of 0.26 $MtCO_2e$ (from 2014-2016) has been achieved. Also, with a view to enhancing nitrogen use efficiency, Government of India has made it mandatory to manufacture 100% neem coated urea from 25th May 2015.

In the livestock sector, many initiatives have been taken which includes balanced ration for livestock that contributes to improving animal productivity as well as in reducing both the cost of production and the emission of GHGs per unit of animal product. The ration balancing programme is implemented in 100 villages of Uttar Pradesh, India. Reduction in cost of feeding per kg of milk was 9.5%. The programme has resulted in an emission reduction of 0.28 $MtCO_2e$ from 2014 to 2016. Emission reductions achieved by feeding bypass proteins is 3.86 $MtCO_2e$ from 2014 to 2016.

Forestry sector

Forests are sensitive to a changing climate, and many forest biomes are likely to be affected by global warming. Various legislations and acts have been formulated by the government for the conservation of forests and their

resources. The total carbon stock in the forests for 2017 has been estimated to be 7083 Mt. The annual increase of carbon stock is 19.50 MtC, *i.e,* 71.5 $MtCO_2$ equivalent.

The implementation of the Forest (Conservation) Act, 1980 has significantly slowed down the conversion of forest land for non-forest purposes. The government has imposed certain levies on project proponents to compensate for the loss of forest land. To streamline the management of the funds, a Compensatory Afforestation Fund Management and Planning Authority has been set up. The National Afforestation Programme is also being implemented which contributes 15-20% to overall afforestation efforts in India and emphasizes the improvement of quality and productivity of the existing forest cover.

Under *Namami Gange* (for cleaning the river Ganga) programme, the target is to plant trees on over 8.39 Mha area which has the potential to sequester around 87.26 $MtCO_2$ per year. Green Highways (Plantation, Transplantation, Beautification & Maintenance) Policy, 2015 was launched to promote the greening of National Highway corridors across the country with the participation of the community, farmers, NGOs, private sector, institutions, government agencies and the State Forest Departments. Under this policy, around 140,000 kilometres of national highways will be lined up with trees. A National Green Highway Mission was also launched in July 2016 under the Green Highways Policy, 2015 to provide a holistic vision of developing eco-friendly and green National highways. An initial plantation drive on 1,500 km of national highways at the cost of about ₹3 billion has been launched under this mission.

The National Agroforestry Policy, 2014 aims to encourage and expand tree plantation in an integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households. The National Mission for a Green India under NAPCC aims to increase the forest and tree cover by 5 Mha, as well as to increase the quality of existing forest and tree cover in another 5 Mha forest/non-forest lands in 10 years. Besides this, there are several registered Clean Development Mechanism projects and pilot REDD+ (Reducing Emissions from Deforestation and Forest Degradation) projects in India.

Waste sector

India recognizes the dual benefits that can arise from efficient waste disposal leading to enhanced environmental benefits along with conversion of promoting waste to energy. There are many laws pertaining to waste management including on hazardous waste, bio-medical waste, construction and demolition waste, municipal solid waste, plastic waste, and e-waste. Municipal authorities are responsible for implementation of these rules.

Swachh Bharat Mission was launched on 2nd October 2014, the birthday of Mahatma Gandhi, with the target of making the country clean by 2nd October 2019. The Mission, among other measures, includes solid waste management, including the establishment of waste to energy plants, and provides Central Financial Assistance of up to 35% of the project cost.

Under the *Deendayal Antyodaya Yojana*, work has commenced on scaling up a waste management model which has been successfully implemented and scaled up by the Government of Tamil Nadu State, India across 9,000 villages of the state. The Tamil Nadu model has been documented, and is being replicated on a pilot basis in eight other states.

The Ministry of New and Renewable Energy (MNRE) is implementing a programme on energy recovery from urban and industrial wastes including wastewater and agricultural waste/residue. The programme supports setting up of pilot projects and provides for Central Financial Assistance (CFA) for projects of different categories.

Ministry of Power has notified a revised tariff policy in January 2016, which provides for the distribution licensee(s) to mandatorily purchase entire power generated from waste to energy plants in the states, in the ratio of their procurement of power from all sources including their own, at the tariff determined by the Appropriate Commission.

Domestic Measurement, Reporting and Verification Arrangements

It is to be noted that for many sectors and schemes, India has well-established measurement and evaluation systems at centre and state levels; such as for enhancing energy efficiency - the PAT and other demand side management programmes; for renewable energy – the RPOs and Renewable Energy Certificates; for projects under the Clean Development Mechanism (CDM) and the National Action Plan on Climate Change (NAPCC). Although most existing Measurement, Reporting and Verification (MRV) systems do not directly track GHG emissions and mitigation impact, existing reporting is useful in arriving at reasonable estimates of the impact of policies.

Establishing an integrated domestic MRV system for assessment of GHG mitigation actions is a capacity building need for India. An integrated MRV system requires streamlined data management systems, technical capacity, improved analytical capabilities, and most importantly, active coordination between all stakeholders and the various nodal agencies within the government. To develop specific (consolidated) monitoring and verification process for GHG inventory and mitigation actions in India, additional finance and capacity building would be required.

Finance, technology and capacity building needs and support received

The finance, technology and capacity-building constraints and gaps, as detailed in India's SNC (2012) and BUR-1 (2016) still exist due to limited support received.

India is a developing country with limited financial resources. The country is striving to provide basic amenities to its growing population while meeting country's developmental needs. Climate change, a global problem, further adds to country's already growing developmental challenges. Majority of the country's production/ economic sectors are vulnerable to the impacts of climate variability. Transition to low carbon ecosystem is cost-intensive even for developed countries. India has so far proactively pursued mitigation and adaptation activities by deplyoing its domestic measures. However, to meet future commitments, India requires enhanced new and additional finance, technology and capacity building support, which is not forthcoming.

Over the years, the national reporting requirements for non-Annex I Parties, including the frequency of its submission, have increased manifold without a corresponding increase in the finance, technology and capacity building support provided. Further, India's GEF STAR allocation under climate change focal area has reduced by almost 50%, i.e. from USD 87.87 million (in GEF-6 cycle) to USD 47.24 million (in GEF-7 cycle).

India's BUR-1 presented a detailed list of technology related needs in renewable, power and transport sector. However, under the climate change regime, most of these technologies were neither transferred, facilitated nor were made available to India. The chapter presents incremental technological requirements. Apart from these technologies, there are some other technologies that are commercially available in India and are being implemented by a few industries. However, the actual reflection of their GHG reduction potential depends on the scalability of such technologies which further depends on the affordability and availability of requisite financial instruments.

A large section of the population is vulnerable to climate change consequences. Thus, adaptation is as relevant to India as mitigation. Most climate adaptation-related technologies in the sectors like agriculture, forestry, water and health exist in India at a limited scale. These technologies and techniques need to be locally adapted and scaled up to ensure climate resilience of our ecosystems and population which requires substantial financial support.

The capacity building needs for enhanced national reporting as well as addressing the challenge of climate change mitigation and adaptation in India have multiplied during the reporting period of this BUR. A more detailed account of the gaps in capacity building was provided in BUR-1. The Joint Summary by India and the Convention Secretariat in relation to ICA of BUR-1 has also provided a detailed list of such gaps which continue to exist.

The upgradation of the emission inventory system is a dynamic process, and sustained efforts are being made to ensure that India's GHG emission inventory is of high quality, transparent and consistent with the requirements of the IPCC inventory guidelines. India has voluntarily adopted 2006 IPCC Guidelines for many categories of inventory. India plans to ride the tier ladder which requires new and incremental financial, technical and capacity support.

A significant upgrade of capacity remains one of the foremost challenges yet to be adequately met. The government attaches great importance to knowledge creation and capacity building.

Additional information

This chapter provides information on developmental reforms, awareness initiatives, international cooperation and climate research. It lists important policies and measures at national and state levels, their nature, and potential contribution to climate change mitigation and adaptation. The government has entered into Memorandum of Understanding with a number of countries on issues pertaining to environment, resources and climate.

Details on the International Solar Alliance and Mission Innovation have been provided. Subjects like satellite-based observations and applications, India's approach for disaster risk reduction, initiatives on education, training and awareness, National Mission on Strategic Knowledge for Climate Change, National Carbonaceous Aerosols Programme, National Water Mission, National Energy Conservation Awards and Environmental Impact Assessment have been covered.

Background Information and Institutional Arrangements

Ministry of Environment, Forest and Climate Change (MoEFCC) is the nodal ministry under the Government of India for coordination and management of climate change related programmes, actions and reporting information pursuant to Article 4.1 of the Convention. According to the Article, "All Parties, taking into account their common but differentiated responsibilities and their specific national and regional development priorities, objectives and circumstances, shall develop, periodically update, publish and make available to the Conference of the Parties (COP), information in accordance with Article 12 of the Convention and decisions of the COPs and related guidelines." Accordingly, Parties communicate information on national inventories of greenhouse gases (GHGs) not controlled by the Montreal Protocol, steps taken or envisaged to implement the Convention and any other information that the Party considers relevant to the achievement of the objectives of the Convention and suitable for inclusion in its communication. Later, through its decision 1/CP.16, paragraph 60, the COP decided to enhance reporting from Parties not included in Annex I to the Convention stating that "Developing countries, consistent with their capabilities and the level of support provided for reporting, should also submit biennial update reports containing updates of national greenhouse gas inventories, including a national inventory report and information on mitigation actions, needs and support received". MoEFCC with its cross-ministerial and institutional network is implementing and executing the matters related to the National Communication and Biennial Update Report.

Previous submissions

Towards the fulfilment of reporting obligations under the UNFCCC, India has so far furnished three communications (Figure IA 1) to the UNFCCC:

i. Initial National Communication (INC) in June 2004, containing national GHG inventory for the year 1994.

ii. Second National Communication (SNC) in May 2012, containing national GHG inventory for the year 2000.

iii. First Biennial Update Report (BUR-1) in January 2016, containing national GHG inventory for the year 2010.

In addition, national GHG inventory for the year 2007 was prepared in 2010 by MoEFCC. Summary of the 2007 inventory was provided in the Second National Communication. As a fulfilment of the requirement of enhanced reporting and updating of information, India's Second Biennial Update Report (BUR-2) is herewith presented to the UNFCCC.

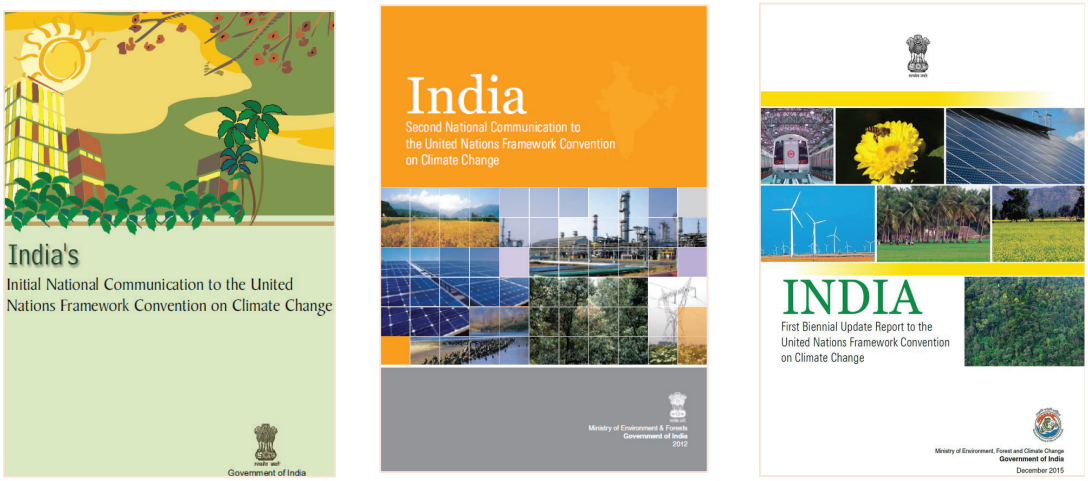


Figure IA 1: India's National Communications and BUR-1

BUR-1 gave an account of National GHG Inventory for the year 2010 and time series information for 2000-2010 covering the five IPCC Categories: Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land Use Change and Forestry (LULUCF), and Waste. Total emissions in 2010 excluding LULUCF were 2,136,841.24 $GgCO_2e$. Distribution of emissions by gases and sectors are as shown in Figure IA 2.

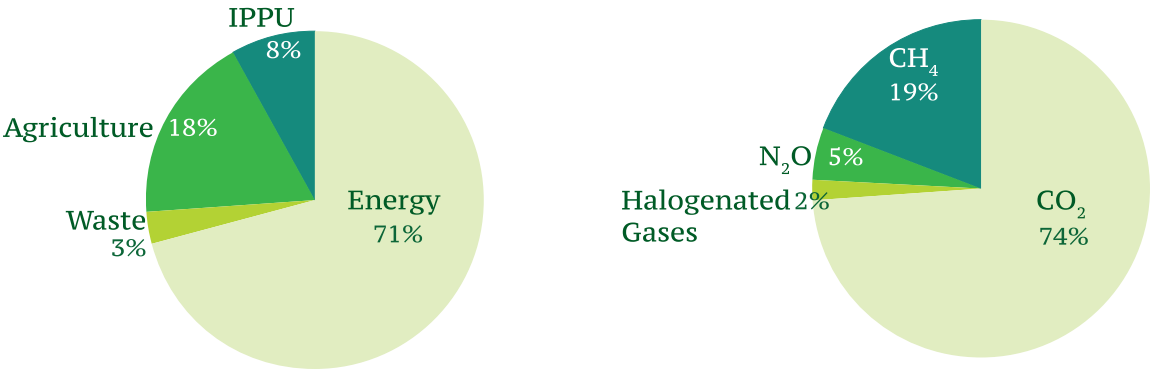


Figure IA 2: Distribution of emissions by sectors and gases in 2010

In 2010, about 12% of total emissions were sequestered by the LULUCF sector. With LULUCF sequestration included, net GHG emissions were 1,884,309 Gg CO_2e for 2010. The first BUR presented government schemes relating to low carbon economic development such as those relating to renewable energy, energy efficiency, transport, power and status of implementation of other mitigation actions in the country. The Government of India and state governments under the federal constitutional structure of India have undertaken many proactive policies and measures across sectors and regions to implement the Convention, its Kyoto Protocol and Paris Agreement keeping in mind the national circumstances. Most of these policies and measures mitigate GHGs directly or indirectly.

BUR-2 presents updated information on country's national circumstances, national GHG inventory, mitigation actions and, finance, technology and capacity building needs including information on domestic MRV arrangements. It also addresses the suggestions received during the International Consultation and Analysis (ICA) process of BUR-1 to the extent possible and within the scope of present capacity in order to enhance transparency of reporting of mitigation actions and their effects. This would be without engaging in discussion on the appropriateness of India's mitigation actions and their effects, and enhancing the consistency of the methods used for preparing GHG inventories with the appropriate methods as per Revised IPCC 1996 Guidelines and 2006 IPCC Guidelines as referred to in the UNFCCC reporting guidelines on BURs.

Institutional Arrangements

For the preparation of National Communications including the BURs, MoEFCC established National Communication (NATCOM) Project Management Unit/ NATCOM Cell, that comprises Programme Officers who assist the National Project Director in the compilation of information for the communications. The current implementation arrangement is depicted in Figure IA 3. After the submission of the SNC and BUR-1, activities for the preparation of India's BUR-2 were launched under the GEF-UNDP-GOI project "Preparation of Third National Communication and other New Information to the UNFCCC".

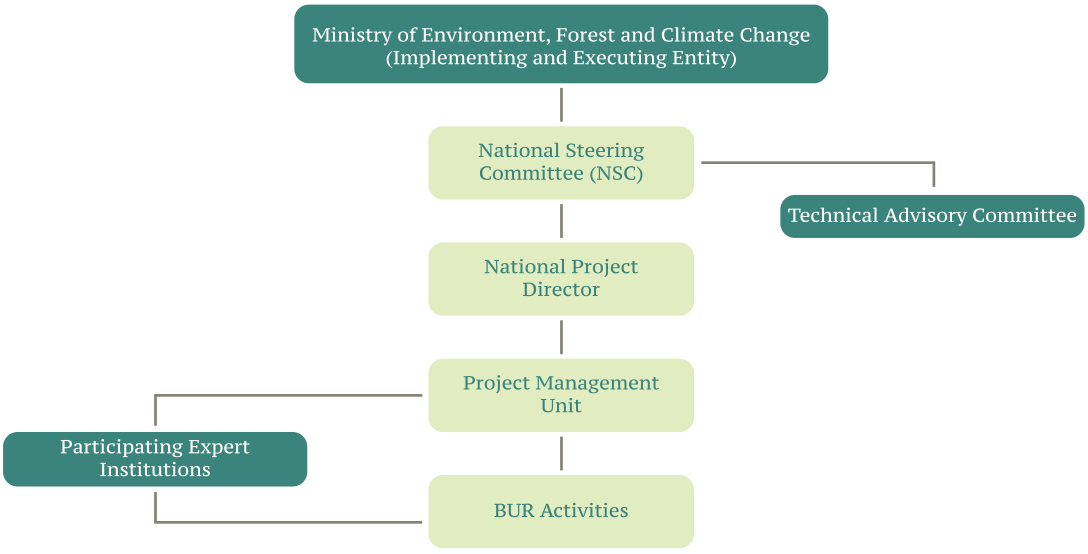


Figure IA 3: Implementation Arrangement for BUR-2

For preparation of National Communications on a continuous basis, the Government of India has taken steps and made efforts towards creating sustainable institutional arrangements. Preparation of the BUR required comprehensive study, technical as well as administrative arrangements and stakeholder's participation in various tasks and activities. To ensure adequate attention and participation, a National Steering Committee (NSC) under the chairmanship of the Secretary, MoEFCC is in place that oversees the preparation and implementation of the work programme of BUR. The line ministries and government departments that are most concerned with different elements of information in this report have representation in the National Steering Committee.

Technical consultations on multiple and multidisciplinary aspects of information relating to GHG inventory and mitigation actions were held during the process. Considering the range of requirements, it was found practical to also have a Technical Advisory Committee (TAC) to provide technical guidance for preparation of the BUR. This committee has members from the government, academia and civil society. The composition of NSC and TAC is given in Annexure-II of this report.

Several studies were launched to provide information on the components of BUR-2. These studies were carried out by institutions having sector-specific expertise. In addition, various Ministries, Government Departments and Public Sector Undertakings provided inputs for preparation of this BUR (Figure IA 4).

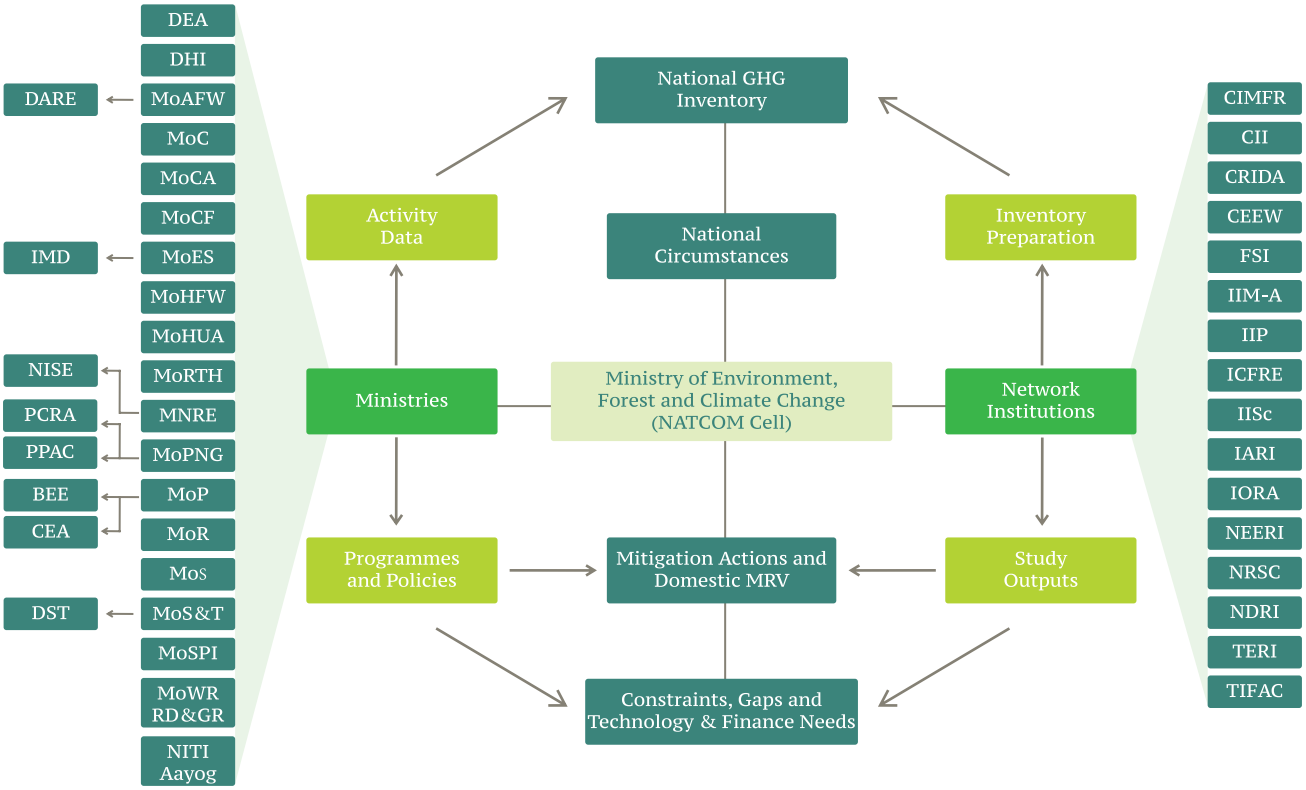


Figure IA 4: Institutional Arrangements for the Second BUR

Expert Institutions

CEEW:	Council on Energy, Environment and Water, New Delhi	IIP:	Indian Institute of Petroleum, Dehradun
CIMFR:	Central Institute of Mining and Fuel Research, Dhanbad	IISc:	Indian Institute of Science, Bengaluru
CRIDA:	Central Research Institute of Dryland Agriculture, Hyderabad	IORA:	IORA Ecological Solutions, New Delhi
CII:	Confederation of Indian Industry, New Delhi	NDRI:	National Dairy Research Institute, Karnal
FSI:	Forest Survey of India, Dehradun	NEERI:	National Environmental Engineering Research Institute, Nagpur
IARI:	Indian Agricultural Research Institute, New Delhi	NRSC:	National Remote Sensing Centre, Hyderabad
ICFRE:	Indian Council of Forestry Research and Education, Dehradun	TERI:	The Energy and Resources Institute, New Delhi
IIM-A:	Indian Institute of Management, Ahmedabad	TIFAC:	Technology Information, Forecasting and Assessment Council, New Delhi

Ministries/Departments

BEE:	Bureau of Energy Efficiency	MoHUA:	Ministry of Housing and Urban Affairs
CEA:	Central Electricity Authority	MoP:	Ministry of Power
DARE:	Department of Agricultural Research and Education	MoPNG:	Ministry of Petroleum and Natural Gas
DEA:	Department of Economic Affairs	MoR:	Ministry of Railways
DHI:	Department of Heavy Industry	MoRTH:	Ministry of Road Transport and Highways
DST:	Department of Science and Technology	MoS:	Ministry of Steel
IMD:	India Meteorological Department	MoSPI:	Ministry of Statistics and Programme Implementation
MoAFW:	Ministry of Agriculture and Farmers Welfare	MoST:	Ministry of Science and Technology
MoC:	Ministry of Coal	MoWR, RD&GR:	Ministry of Water Resources, River Development & Ganga Rejuvenation
MoCF:	Ministry of Chemicals and Fertilizers	MNRE:	Ministry of New and Renewable Energy
MoCA:	Ministry of Civil Aviation	NISE:	National Institute of Solar Energy
MoES:	Ministry of Earth Sciences	NITI Aayog:	National Institution for Transforming India Aayog
MoHFW:	Ministry of Health and Family Welfare	PCRA:	Petroleum Conservation Research Association
		PPAC:	Petroleum Planning and Analysis Cell

Institutional Network

MoEFCC, being the implementing and executing entity assigns several studies and conducts activities including workshops and national consultations for preparation of BUR. For BUR-2, 16 expert institutions were involved. Studies for preparation of the GHG inventory were carried out by 11 institutions in their respective sectors of expertise. Mitigation actions were reported by four expert institutions with expertise in different sectors relevant to the BUR. Two institutions were engaged to carry out studies pertaining to MRV arrangements and constraints, gaps and related finance, technology and capacity needs. The network of institutions is shown in Figure IA 5. The existing network of institutions is built upon the previous communications. As an effort to strengthen the system of reporting, three new institutions, i.e. TIFAC, IORA and CEEW have been included in the network.

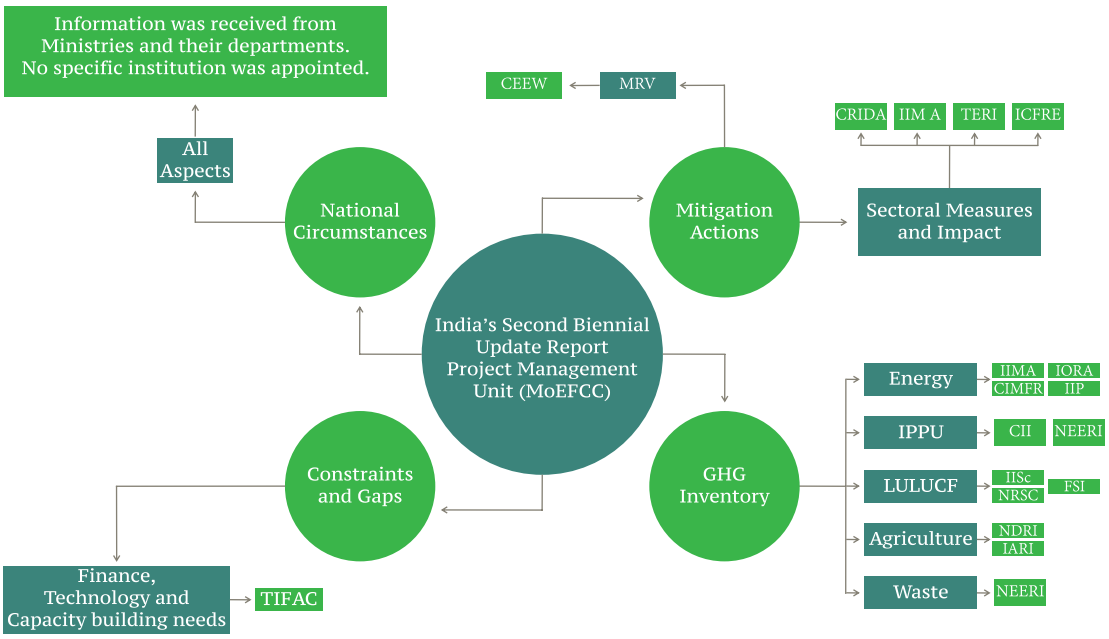


Figure IA 5: Institutional network for different components of BUR-2

The present institutional arrangement involves a 4-tier approach focusing on the components of the BUR in the following manner:

- **Expert Institutions:** These institutions are engaged in compiling the GHG inventory, mitigation actions and other components. One coordinating institution is generally appointed for each sector. A network of institutions works for each sector.
- **Resource Institutions:** These institutions provide data and information for BUR components. These include ministries and their departments/ agencies/ institutions, research institutions and universities, industrial units, Public Sector Undertakings and Industry associations and other departments involved in generating and compiling data.

- **Review Arrangement:** The BUR is peer-reviewed by independent experts (experts other than those participating in the preparation of the document) followed by the Technical Advisory Committee and ministries/concerned departments.
- **Ministry of Environment, Forest and Climate Change:** The Ministry coordinates, supervises, and processes for approval and submission of the BUR to UNFCCC. A National Steering Committee chaired by the Secretary, MoEFCC is in place with Adviser/Scientist-G, MoEFCC in his capacity as National Project Director (NPD) as Member Secretary. The members are representatives from all relevant ministries and departments. BUR is endorsed by the Minister and approved by the Cabinet, Government of India.

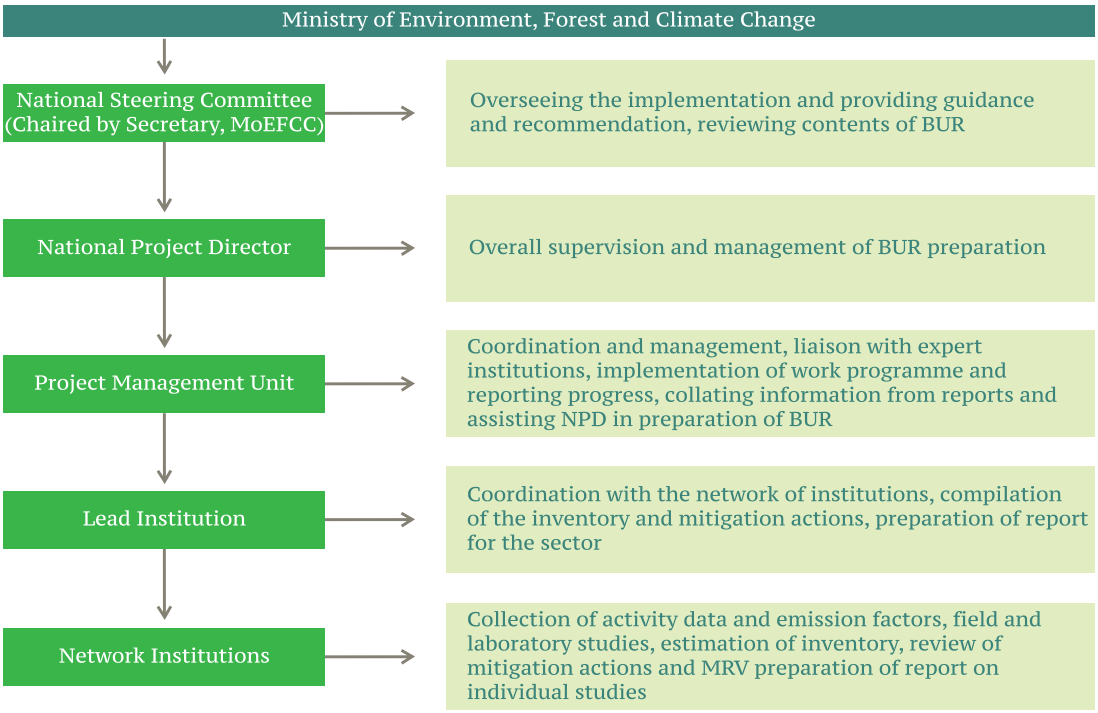
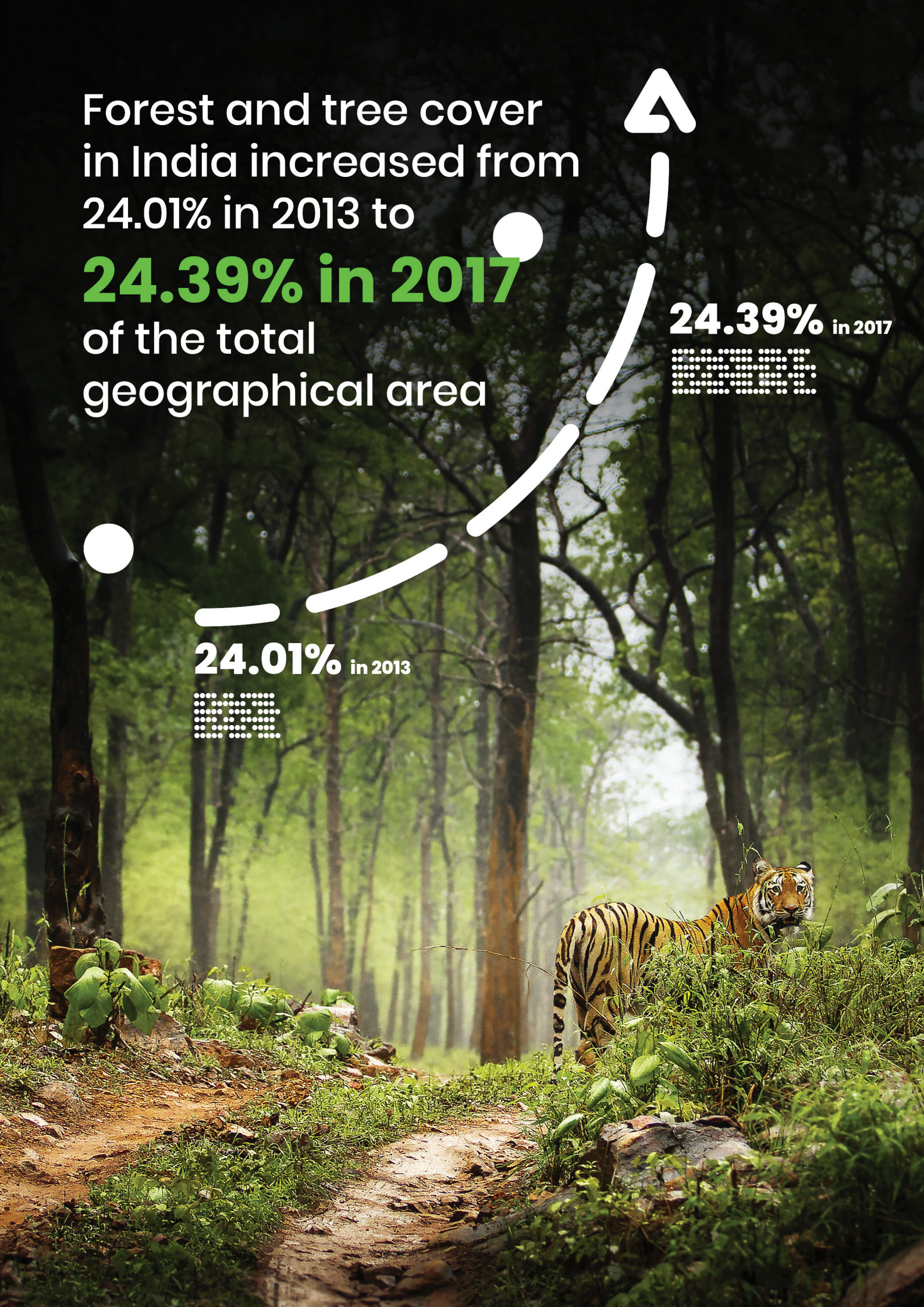


Figure IA 6: Implementation arrangement and role of institutions

Quality Assurance and Quality Control (QA/QC) and uncertainty analysis is performed at appropriate stages, including at the time of data collection and inventory preparation by the concerned institutions. The expert institutions, relevant ministries and NGOs together have supported the preparation of BUR. These coordinating institutions and supporting network institutions are in the process of developing the required technical capacity, especially for the GHG inventory preparation, which India envisages as a continuous process. India is currently in the process of developing a National Inventory Management System (NIMS) that will coordinate consistently with the supporting institutions with adequate capacity for the preparation of National Communications and BURs on a continuous basis. Formalizing such an institutional arrangement requires financial, technological and capacity building support from international institutions and Annex I parties on a continuous basis.


Forest and tree cover in India increased from 24.01% in 2013 to
24.39% in 2017
of the total geographical area
24.39% in 2017
24.01% in 2013

Chapter 1

National Circumstances

Chapter 1: National Circumstances

India is geographically the seventh largest country in the world with a total area of 328.73 Mha, extending from the snow-covered Himalaya in the north to the shores along the Indian Ocean in the south, and from the arid salt-pans of the west to the tropical rainforests of the east. The diversity of land topography and the presence of the Himalaya that separates the country from the rest of the Asian mainland are the reasons behind its diverse climatic conditions. It has a land frontier of about 15,200 km and coastline of about 7,500 km.

The total geographical area can be divided into four main regions: peninsular India, located south of the Vindhya and Satpura mountain ranges; the plains of the Indus (northwest), the plains of the Ganga (north and northeast); and the mountainous terrain of the Himalaya. However, from an environmental and biogeographical perspective, the country can be further divided into 15 agro-ecological regions: Western Himalayan Region; Eastern Himalayan Region; Lower Gangetic Plains; Middle Gangetic Plains; Upper Gangetic Plains; Trans-Gangetic Plains; Eastern Plateau and Hills; Central Plateau and Hills; Western Plateau and Hills; Southern Plateau and Hills; East Coast Plains and Hills; West Coast Plains and Ghat Region; Gujarat Plains and Hills; Western Dry Region; and the Islands. India's unique geography produces a spectrum of climates that have yielded a wealth of biological and cultural diversity. Land areas in the north have a continental climate with high summer temperatures and cold winters when temperatures may go below freezing.

For administrative purposes, India comprises 29 states and seven union territories. India has the second largest human population of the world with more than 1.21 billion people (Census, 2011) or nearly 17.6% of the world's population with only 2.4% of the global land area.

The Indian economy has diversified substantially in recent decades, yet agriculture remains the mainstay of around 49% of the working population. India has reasons to be concerned about the impacts of climate change. A significant part of its population depends on climate-sensitive sectors such as agriculture and forestry for livelihood. Any adverse impact on water availability due to the retreat of glaciers or the decrease in rainfall and drought or increased flooding in certain regions would threaten food security. Climate vagaries can cause adverse impacts on natural ecosystems housing species that sustain livelihoods of rural households, and adversely impact the coastal system due to sea level rise as well as increased frequency of extreme events. In addition to these impacts, the achievement of vital national development goals related to habitat, health, energy, and infrastructure would be adversely affected. Table 1.1 summarizes some key features of India's national circumstances as of 2017.

Table 1.1: National Circumstances - Key Features

Parameters	Measure
Total geographical area (Mha)	328.73
Area under agriculture (net sown area) as percentage of the total geographical area	42.60%
Total cropped area (gross cropped area) (Mha, 2014-15)	198.36
Gross irrigated area (Mha, 2014-15)	96.46
Foodgrain production (million tonnes, 2016-17, fourth advance estimate)	275.68
Forest and tree cover as percentage of the total geographical area (India State of the Forest Report 2017)	24.39%
Urban population as percentage of total population (2011)	31.14%
All India Poverty Head Count Ratio (2011-12)	29.50%
Life expectancy at birth in years (2012-13)	67.5
Literacy rate, 7+ years (2011)	73%
GDP in 2017-18, in trillion rupees, at constant (2011-12) prices	130.11
Share of mining and quarrying, manufacturing and construction in GVA in 2017-18 (at constant 2011-12 prices)	29.03%
Share of services in GVA in 2017-18 (at constant 2011-12 prices)	56.15%

Share of agriculture, forestry and fishing in GVA in 2017-18 (at constant 2011-12 prices)	14.82%
Livestock population excluding poultry (million), year 2012	512.06
Households with *kutcha* (mud huts) and semi-*pucca* (semi-concrete) houses	55%

Source: (Census, 2011), (MoSPI, 2018a), (Livestock Census, 2012), (FSI, 2017), (GoI, 2015), (MoSPI, 2017b), (Rangarajan et al. 2014), (MoSPI, 2018c)

1.1 Climate

India has tremendous geographical diversity with a variety of climate regimes as well as regional and local weather conditions. The climate ranges from continental to coastal, from extremes of heat to extremes of cold, from extreme aridity and negligible rainfall to excessive humidity and torrential rainfall. India's climate is significantly influenced by the presence of the Himalaya and the Thar Desert. The Himalaya helps in keeping the Indian subcontinent warmer than other locations at similar latitudes by acting as a barrier to the cold winds from Central Asia. The northern parts of the country have a continental climate with severe summer conditions that alternate with cold winters when temperatures drop to freezing point. In contrast are the coastal regions of the country, where the warmth is unvarying and the rains are frequent. This is due to several characteristic features, including southwest and northeast monsoon seasons, a hot weather season characterized by severe thunderstorms and heat waves, and cold weather season characterized by cold waves.

The months of June, July, August, and September form the core of the southwest monsoon season in most parts of the country, but the actual period of the monsoon in different regions of the country depends on the onset and withdrawal dates. The monsoon approaches with moisture-laden winds, and this sudden approach is marked with violent thunderstorms and lightning. The heavy rainfall during the season brings floods over many parts of the country. Post Retreat phase of southwest monsoon is called as northeast monsoon which starts from October and continues till December. The northeast monsoon is transition season associated with the establishment of the north-easterly wind regime over the Indian subcontinent. The meteorological subdivisions of the southern peninsula, namely coastal Andhra Pradesh, Rayalaseema, Tamil Nadu, Kerala and south interior Karnataka, receive a good amount of rainfall during this season.

1.1.1 Precipitation

Nearly 75% of the annual rainfall of the country is received during the southwest monsoon season with a large spatial variability in its distribution. The Indian monsoon is one of the most prominent of the world's monsoon systems, which blows from the northeast during cooler months and reverses direction to blow from the southwest during the warmest months of the year. This process brings large amounts of rainfall to the region during June to September and is the principal rainy season during which an average of about 890 mm of rainfall is received over the country. Overall, there is a huge inter-annual variability in its onset and withdrawal over different parts of the country.

Rainfall distribution and intensity have a significant impact over different socio-economic sectors, especially the agriculture and water beside their impact on other ecosystems. The rainfall amount exceeds 1000 mm annually in areas to the East of India and extends to over 2500 mm along almost the entire West Coast and the northeast India. On the west of the line joining Porbandar to Delhi and then to Ferozepur in Punjab, the rainfall diminishes rapidly from 500 mm to less than 150 mm in the extreme west. The pre-monsoon and post-monsoon seasons contribute about 11% and 10% of annual rainfall (on all India basis respectively). The rainfall during northeast monsoon varies from 209.6 to 480.7 mm in the states of the southern peninsula, namely Tamil Nadu, Kerala, Karnataka, and parts of Andhra Pradesh and Telangana. For these states, the rainfall received during northeast monsoon season contributes 30% of the annual rainfall.

Although, there is inter-annual variability, the total precipitation during the Indian summer monsoon has remained largely stable over the last century and has shown a slight weakening trend during the recent few decades (Figure 1.1). Based on the rainfall observations from Indian Meteorological Department (IMD) observational network, it is noted that the averaged monsoon season rainfall has increased over Bihar, Gujarat, Jharkhand, Karnataka, Lakshadweep, Meghalaya, Mizoram and West Bengal during 1951-2010. Decreasing trend in monsoon rainfall has been observed over Andaman and Nicobar Islands, Andhra Pradesh, Arunachal Pradesh, Assam, Chhattisgarh, Delhi, Goa, Haryana, Himachal Pradesh, Jammu and Kashmir, Kerala, Madhya Pradesh, Maharashtra, Manipur, Nagaland, Odisha, Punjab, Rajasthan, Sikkim, Tamil Nadu, Tripura, Uttar Pradesh and Uttarakhand. Guhathakurta et al. (2015) observed that while the southwest monsoon seasonal rainfall had a significant increasing trend during the period 1901-1950, a decreasing trend in the same was observed over the 1951-2011 period.

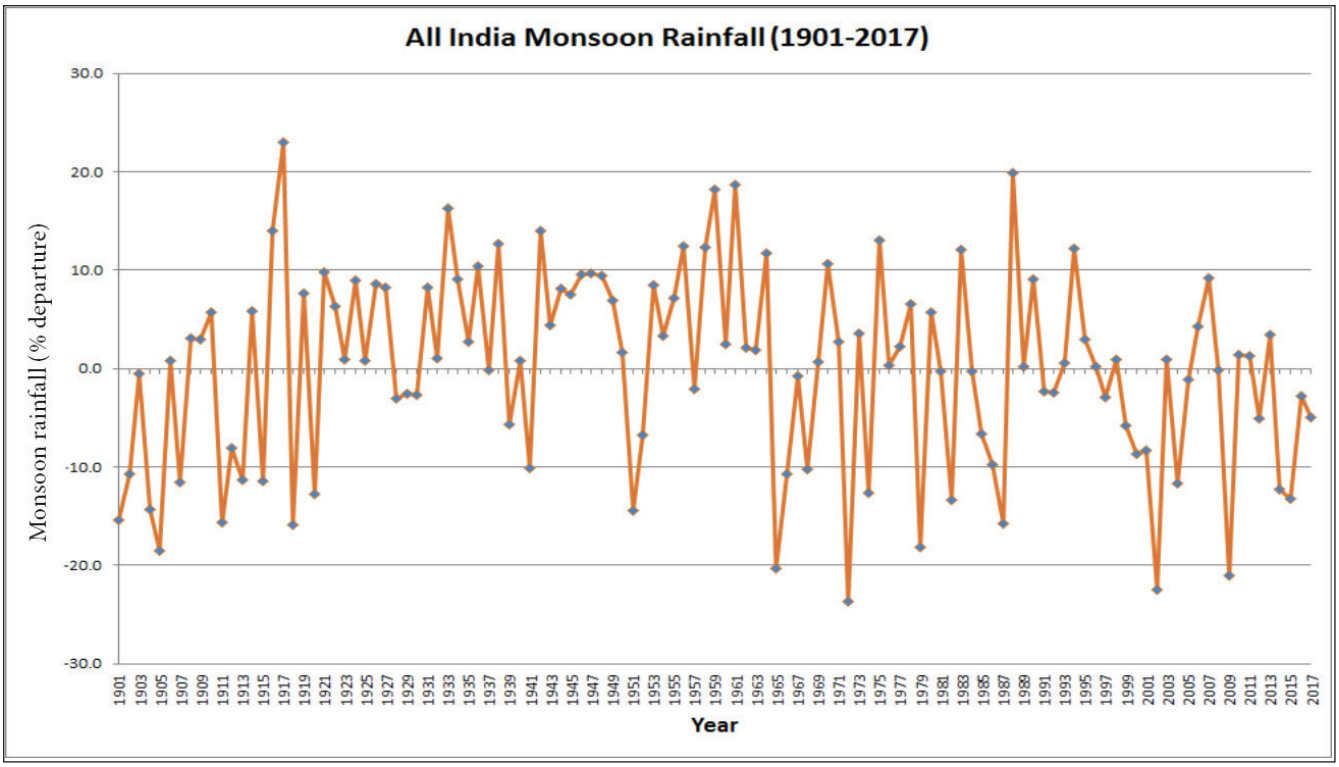


Figure 1.1: Percentage departure of area weighted monsoon season rainfall over India as a whole (1901-2017).
Source: IMD

1.1.2 Temperature

The surface air temperature shows wide spatial and seasonal variation over India. Due to the influence of continental winds over most of the country, the winter is severe in the north, but the temperature becomes moderate as one moves towards the south. During the coldest months of December and January, the mean maximum temperature varies from 33°C in some parts of the country to about 12°C in the plains of north, while the mean minimum temperature varies from about 25°C in the extreme south to about 3°C in the plains of the north.

Temperature variations are even more pronounced in mountainous regions such as the Western Ghats in the South and the Himalaya in the north. March to May is usually a period of the continuous and rapid rise of temperature. The highest temperature occurs in central and northern India, particularly in the desert regions of the north-west where the maximum may exceed 48°C for a considerable time duration often causing heat wave conditions. With onset and advent of southwest monsoon in June, there is a rapid fall in the maximum temperature in central India. The temperature stays uniform in the areas covering two-thirds of the country that gets a good amount of rainfall. The temperature falls in September when the monsoon retreats from northern India. Temperatures fall below freezing point during winter in the extreme northern parts of the country.

In conformity with the rising trend observed in global surface temperatures (0.85±0.18°C) since 1901 (IPCC, 2014), the annual mean temperature for the period 1901-2017 over India (Figure 1.2) has also shown a significant increasing trend of 0.66°C per hundred years. This rise is mainly contributed by the rise in the maximum (day) temperatures. However, the rate of rise in the annual mean temperature is higher since the 1980s, mainly due to a sharp rise in the minimum temperatures. For the 1981-2017 period, the mean, maximum and minimum temperatures increased by around 0.2°C per decade, which is higher than the trends for the period 1901-2017.

On a seasonal scale, the highest increasing trend in the mean temperature was observed in the post-monsoon and winter seasons. Further, the rise of maximum and minimum temperatures, during the past 30 years, is mostly confined to the northern, central and eastern/ north-eastern parts of the country. Spatial warming trends (Figure 1.3) obtained from mean annual temperature anomalies based on the data for the period 1901-2017 suggest significant positive (increasing) trend over most parts of the country except in parts of some states that include Rajasthan, Gujarat and Bihar, where significant negative (decreasing) trend was observed.

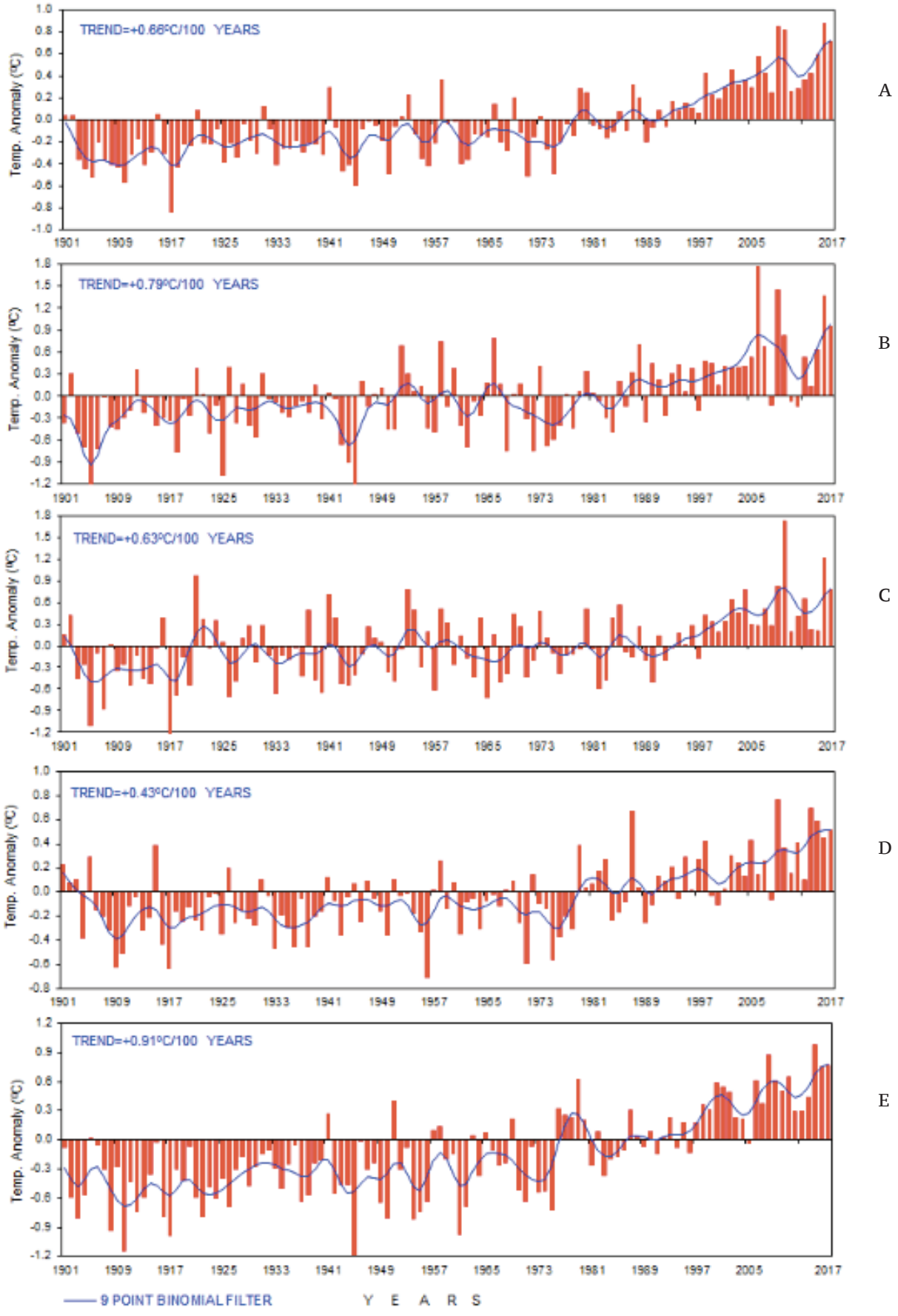


Figure 1.2: All India mean temperature anomalies: (A) Annual, (B) Winter, (C) Pre-monsoon, (D) Monsoon and (E) Post-monsoon for the period 1901 - 2017 shown as vertical bars. The solid blue curve has sub-decadal time scale variations smoothed with a binomial filter. (Departures from the 1971 - 2000 average). *Source: IMD*

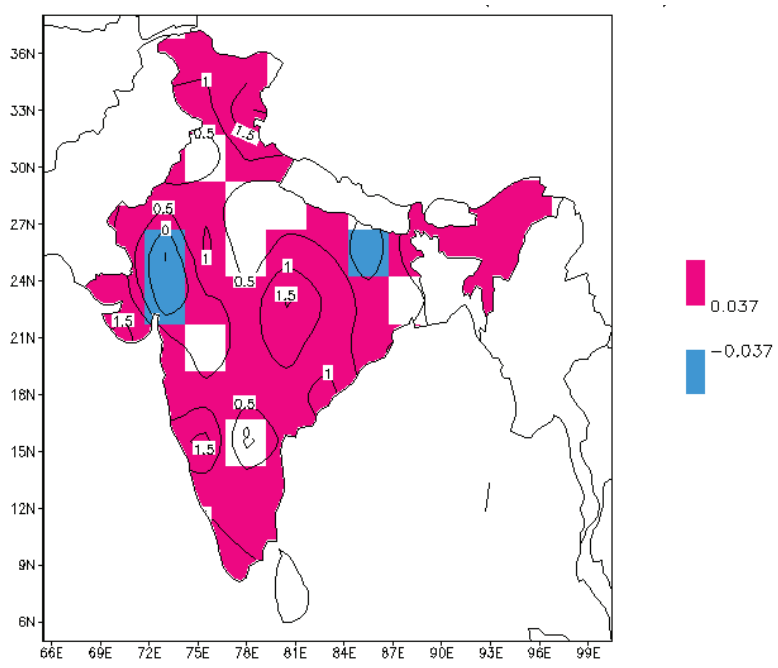


Figure 1.3: Annual mean temperature anomaly trends (°C/100 years) are shown as contour lines. The trends significant at the 95% level are shaded. Positive trends are shown in red while the negative trends are shown in blue. Period of analysis: 1901 – 2017. (Departures from 1971-2000 average). ***Source: IMD***

1.1.3 Extreme events

Spatial variation in frequency of extreme rainfall events (rainfall exceeding 15 cm per 24 hours) during the monsoon season (June to September) for the period 1901-2017 is presented in Figure 1.4. Analysis of one-day extreme rainfall series has shown that the intensity of extreme rainfall has increased over coastal Andhra Pradesh and adjoining areas, Saurashtra and Kutch, Odisha, West Bengal, parts of northeastern India, and eastern Rajasthan. Though the flood risk has increased significantly over India (IMD, 2010), there has been a significant decrease both in intensity and frequency of extreme rainfall over Chhattisgarh, Jharkhand and some parts of northern India. Pai et al. (2014) using the 0.25°x0.25° gridded data found that during the recent decades, there has been a significant decrease of moderate rainfall events, while heavy and very heavy rainfall events have increased in frequency.

The analysis of rainfall data from IMD observational network for the period 1901-2010 has revealed increasing trends in the frequency of dry days in most parts of the country during winter, pre-monsoon and southwest monsoon seasons. The frequency of very light rain and light to moderate rain events has decreased significantly over most of the states. The observatory stations, as well as gridded data, have shown significant increasing trends in very heavy to extremely heavy rainfall events over most parts of the country. There has been an increase of about 6% per decade in extreme rainfall events. The spatial distribution of origin of rainstorms (location of maximum rainfall on day 1 of the storm) over land during the period 1951-2015 is presented in Figure 1.5. It suggests that the majority of rainstorms form over the central and eastern parts of the country mostly along the seasonal monsoon trough (continental tropical convergence zone). A significant increasing trend in the frequency of rainstorms in 65 years period (1951-2015) has been reported (Figure 1.6). Also, the duration of rainstorms has shown a significant increase of about 15 days during the period 1951-2015. These rainstorms are responsible for large-scale floods over the country. The erratic nature of rainfall in different regions and the trend in below-normal rainfall occurrences are the causes of extreme events faced across the nation. For instance, in the case of Tamil Nadu, it has been observed that from 2004 to 2014, in 9 out of 11 years at least one district in Tamil Nadu has witnessed below normal rainfall. While there were 45 instances of rainfall shortages across districts during 2004 to 2008, the number of such instances doubled during 2009 to 2014.

Floods are also a recurrent phenomenon which cause loss of life and damage to livelihood system, property, infrastructure and public utilities. Urban flooding is being experienced with an increasing frequency due to insufficient drainage to carry higher runoff caused by heavy/ high-intensity rainfall, which increases the flood peaks. Events such as flash floods, Glacial Lake Outburst Floods (GLOF) and cloudbursts are also a cause of considerable concern due to high losses of human life, livestock and property especially in hilly areas. The recent flood events in the States of Uttarakhand, Kerala and Jammu & Kashmir in India are examples of such catastrophes.

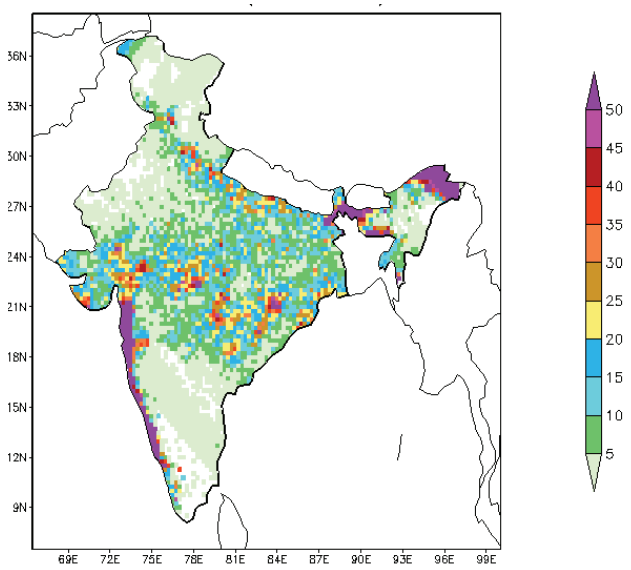


Figure 1.4: Spatial variation in frequency of extreme rainfall events (rainfall ⩾15cm per 24 hour) during the southwest monsoon season (June to September), 1901-2017. *Source: IMD*

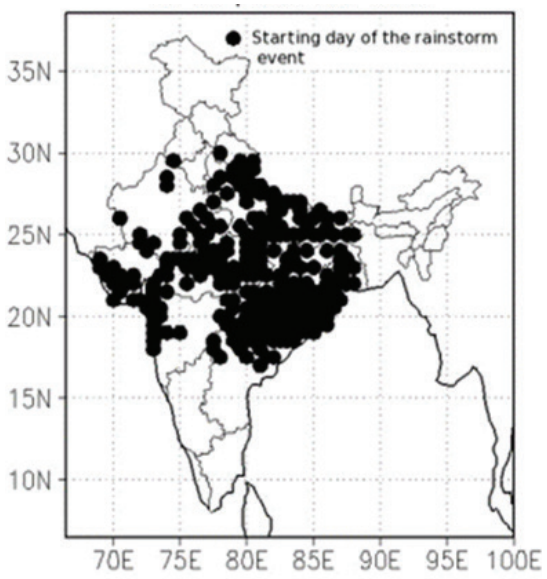


Figure 1.5: Spatial variation of origin of rainstorms over India during the southwest monsoon season (June to September) for the period 1951-2015. *Source: IMD*

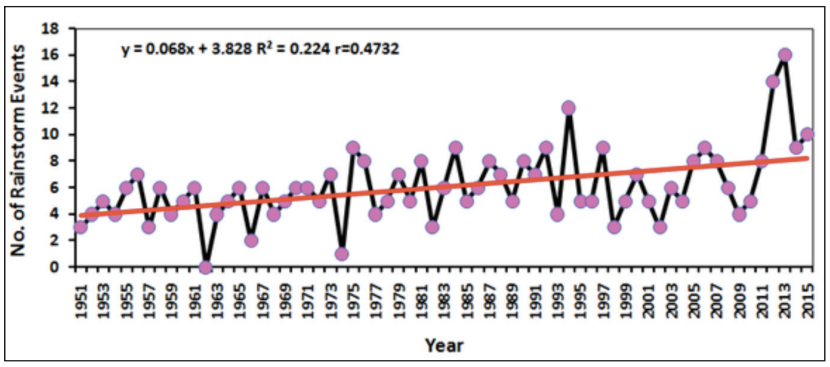


Figure 1.6: Time series (1951-2015) of the frequency of rainstorms averaged over the northern parts of the country (18°N-27°N and 75°E-85°E). *Source: IMD*

Guhathakurta et al. (2015), using data for the period 1901-2011, have shown that frequencies of wet day and rainy day (rainfall of small amount in a day) have decreased in most parts of the country except in some regions of west peninsular India *viz*, central Maharashtra, north and south interior Karnataka and Lakshadweep. In the large regions of the country *i.e*, seventeen sub-divisions out of 36 *viz*, coastal Karnataka, north and south interior Karnataka, Gujarat region, Konkan Goa, central Maharashtra, Marathwada, Rayalaseema, Telangana, coastal Andhra Pradesh, Odisha, Gangetic West Bengal, Nagaland, Manipur, Mizoram; Tripura, east Rajasthan, Haryana, Delhi, Chandigarh and Punjab, increasing trends in the frequency of heavy rainfall events dominated during the period 1901-2011. However, in the recent period (1951-2011), increasing trends in the frequency of heavy rainfall were noted in eleven subdivisions. Das et al. (2016) observed a significant increasing trend of both drought duration and magnitude during the monsoon over parts of the eastern, central and north-eastern region of India, whereas the parts of the west coast, arid western region and northern India showed a significantly decreasing trend.

Figure 1.7 gives the decadal variability of annual frequencies of rainfall events of different intensities. Trend analysis shows a significant increase in the frequency of dry days during the period 1901-2010 and a significant decrease in the frequencies of very light and light to moderate rainfall events. No significant changes in the frequency of heavy rainfall events are observed. However, a significant increase in the annual frequency of very heavy and extremely heavy rainfall events is observed over the country as a whole.

The synoptic scale systems, including low-pressure areas and cyclonic disturbances (depressions and cyclones) that form over the northern Indian Ocean and particularly over the Bay of Bengal during the southwest monsoon season (June to September), contribute significantly to the southwest monsoon rainfall over India. As shown in Figure 1.8(a), the significant decreasing trend of the frequency of cyclonic disturbances during monsoon (99%) is noticed during the last 67 years from 1951 to 2017 over the Indian region. Every year during the post-monsoon season from October to December, the tropical cyclones affect the coastal regions of India. Figure 1.8(b) shows the decreasing trend of the frequency of cyclonic storms during the post-monsoon season from October to December which is significant at 95% level.

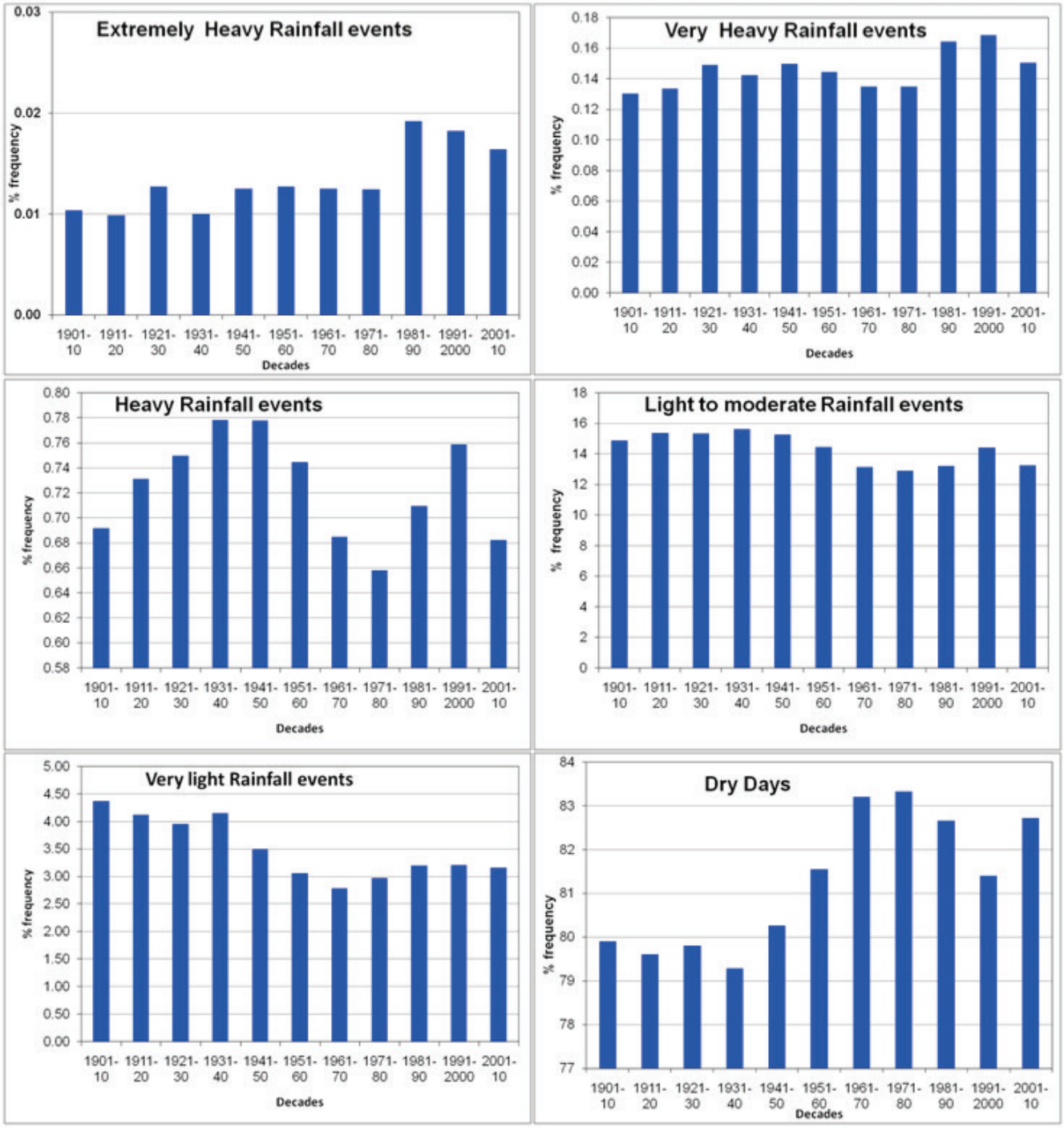
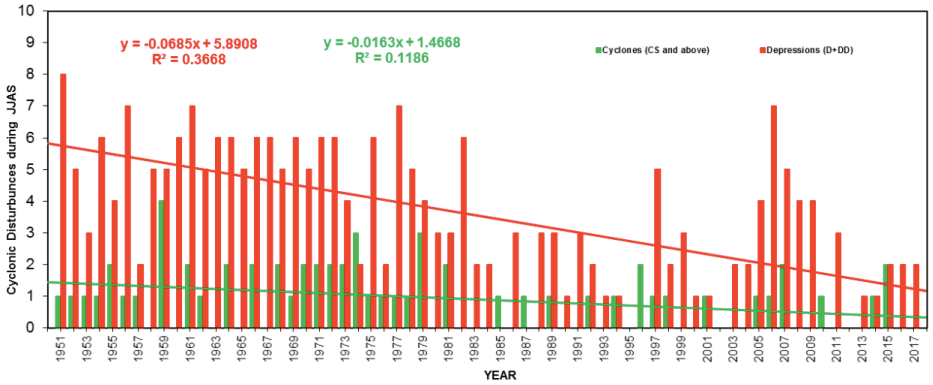


Figure 1.7: Decadal variability of annual frequencies of different rainfall events over India.
Source: IMD

Worldwide, there have been a number of mega heat waves in recent years. Recent studies suggest that the frequency, duration and intensity of heat wave events are increasing over land regions across the globe. Based on data from 103 stations of IMD for the period 1961-2010, Pai et al. (2013) observed a slight increasing trend in all India Heat Wave and Severe Heat Wave days per summer season. No noticeable long-term trends were observed in the spatial coverage and persistence of the Heat Wave and Severe Heat Wave (HW/SHW) days over the country. For the period 1961-2013, the frequency, the total duration of heat waves per season, and maximum duration of heat waves have increased over India during the summer season (Rohini et al., 2016).

The frequency of occurrence of hot days (> 90 percentile) during the pre-monsoon season shows a significant increase over the east and west coasts of India and interior peninsula. Likewise, an increasing trend in the frequency of hot nights is seen on the east coast, west coast and north-west India. The frequency and duration of heat waves over north-west India and east coast of India have also increased. The duration of heat waves over central and north-west India has increased by about five days over the past 50 years.

(a) Southwest Monsoon Season (June to September)



(b) Post-Monsoon Season (October to December)

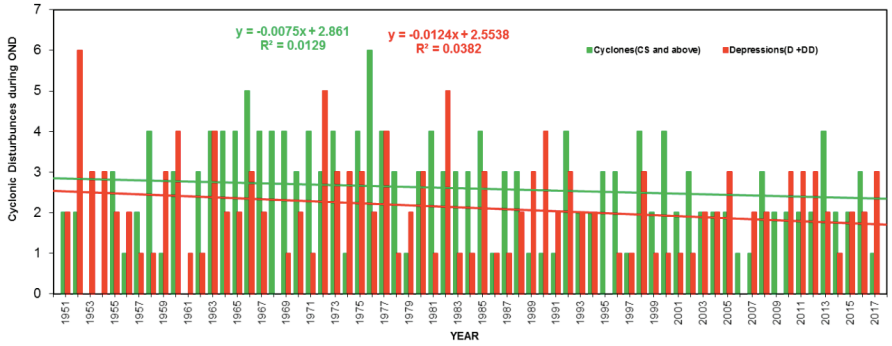


Figure 1.8: Frequency of depressions and cyclonic storms formed over the northern Indian Ocean (1951-2017). *Source: IMD*

During the hot weather season AMJ (April, May and June), stations from the north, north-west, central, east India and north-east peninsula are most prone to Heat Wave and Severe Heat Wave days with relatively highest frequency experienced during May (Figure 1.9 a). Decreasing trends in Cold Wave days were observed at most of the stations in North of about 18°N (Figure 1.9 b).

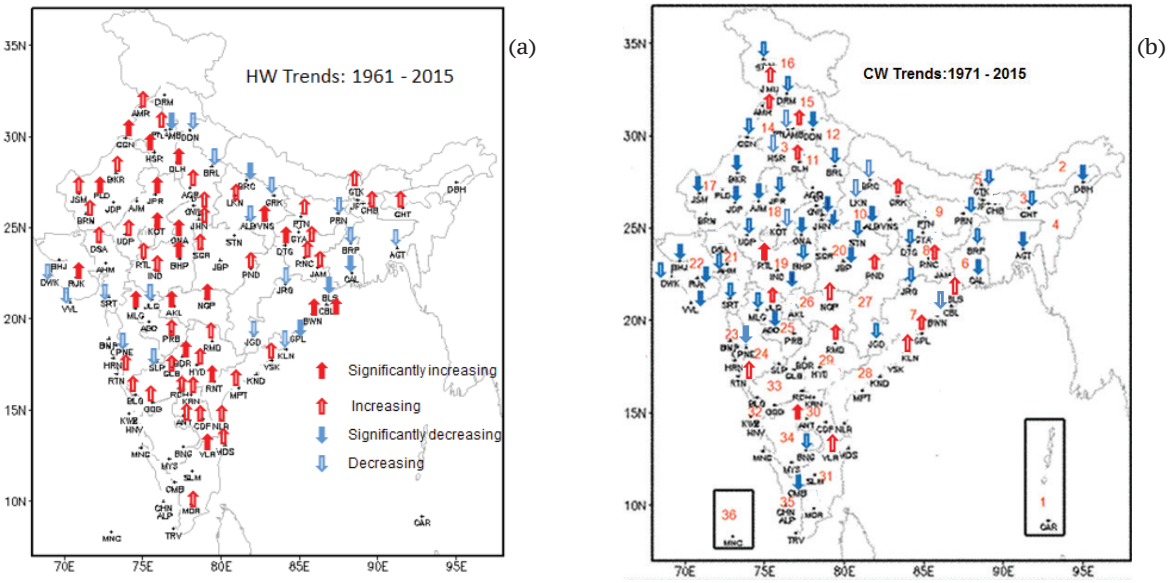


Figure 1.9: (a) Trends in the Heat Wave (HW) days of 103 stations during April, May and June for the period 1961–2015. (b) Trends in the Cold Wave (CW) days of 86 stations during December, January and February for the period 1971–2015. Red rising (blue falling) arrows represent the increasing (decreasing) trends. Filled arrows represent the trends significant at 5% level. Nonparametric Mann–Kendall test was used to test the significance of the trends. *Source: IMD*

There have also been 19 major earthquakes of 6.5-9.2 magnitude on the Richter scale during the period 1819-2016 which further increases the vulnerability in the phase of climate change. Some of the major weather extremes in India in the recent years are shown in Table 1.2.

Table 1.2: Weather extremes in India in the recent years (2014-2017)

Year	Month	Event	Details
Temperatures			
2014	Jan-Dec	Severe cold wave/cold wave	Cold wave/fog related incidents in northern parts of the country.
	May-Jun	Heat wave	Intense heat wave events which prevailed over northeastern, central and peninsular parts of the country.
2015	May-Jun	Severe heat wave	Severe heat wave incidences over the south peninsula and eastern parts of the country including the States of Andhra Pradesh, Telangana and Odisha.
2016	Mar-May	Severe heat wave	Intense heat wave conditions which prevailed over northeastern, central and peninsular parts of the country.
2017	Mar-Jun	Severe heat wave	Severe heat wave conditions which prevailed mainly over peninsular parts of the country including Andhra Pradesh and Telangana.
Precipitation			
2014	Mar	Hailstorm	Unprecedented widespread hailstorm in Maharashtra and parts of central India in the first week of March severely affected crops, livestock, animals and birds.
	Sep	Heavy rainfall resulting in floods	Heavy floods in the State of Jammu and Kashmir; Several thousand villages across the state were hit.
2015	Apr-Aug	Nor'wester, Lightening and Heavy rainfall resulting in floods	A severe Nor'wester ravaged 12 districts of Bihar during April. Gujarat State suffered with flood and heavy rains in June. Flood-related incidences also occurred in West Bengal from June to August.
	Nov-Dec	Heavy rainfall	Very heavy rainfall during northeast monsoon season in Tamil Nadu and Andhra Pradesh.
2016	Jul-Sep	Heavy rainfall resulting floods	Heavy rains and floods in State of Maharashtra caused the 'Mahad bridge collapse' incident in August. Flood-related incidences also occurred in State of Bihar from 25th July to 3rd September. Cloudburst and landslides also occurred in Uttarakhand in July.
2017	May-Oct	Lightning and Heavy rainfall resulting floods	Lightning and rainfall events caused loss of life in various parts of Odisha from May to October; in Bihar from May to July, and; in Maharashtra in June and October.
	Jul-Sep		Flood and heavy rains caused loss of life in Gujarat. Flood-related incidence, a massive landslide caused deaths at Kotrupi, Himachal Pradesh on 13th August. Floods in Ghaghara, Gomati and Rapti rivers also claimed lives during 4th to 10th September.
Cyclones			
2014	Jun	Cyclonic Storm Nanauk over the Arabian Sea	The Storm caused heavy rainfall over Lakshadweep, Kerala and coastal Karnataka.
	Oct	Very Severe Cyclonic Storm, Hudhud, over the Bay of Bengal	Caused human and animal death in north Andhra Pradesh. It caused very heavy rainfall over north Andhra Pradesh and south Odisha and strong gale winds leading to large-scale structural damage over north Andhra Pradesh and adjoining districts of south Odisha.
	Oct	Very Severe Cyclonic Storm, Nilofar, over the Arabian Sea	Under the influence of system, Konkan and Goa region experienced widespread rain with heavy rainfall at isolated places.

2015	Jun	Cyclonic Storm, Ashobaa, over the Arabian Sea	No adverse weather was reported due to this system.
	Jul	Cyclonic Storm, Komen, over the Bay of Bengal	Loss of life due to cyclonic storm 'Komen' in West Bengal and Odisha. Landslides also claimed lives in Manipur.
	Oct	Extremely severe cyclonic storm, Chapala over the Arabian sea	No adverse weather over west coast of India was reported due to this system.
	Nov	Extremely severe cyclonic storm, Megh, over the Arabian Sea	No adverse weather over west coast of India was reported due to this system.
2016	May	Cyclonic Storm, Roanu over the Bay of Bengal	It caused adverse weather like heavy rain and strong wind all along east coast of Sri Lanka and India (including Tamil Nadu, Andhra Pradesh, Karnataka, Rayalseema, Odisha, Gangetic West Bengal, Assam, Meghalaya, Nagaland, Manipur and Tripura)
	Oct	Cyclonic storm Kyant over the Bay of Bengal	The system caused rainfall at isolated places over Tamil Nadu, Puducherry and coastal Andhra Pradesh.
	Nov	Cyclonic storm Nada over the Bay of Bengal	The system caused heavy rainfall at isolated places over Tamil Nadu, and Puducherry
	Dec	Very Severe Cyclonic Storm,Vardah over the Bay of Bengal	'Vardah' caused heavy to very heavy rainfall over Andaman & Nicobar Islands. It also caused extremely heavy rainfall over Chennai, Thiruvallur, Kanchipuram districts of Tamil Nadu. It caused human and animal death in Tamil Nadu.
2017	Apr	Cyclonic Storm Maarutha over the Bay of Bengal	The system caused heavy rainfall over Andaman & Nicobar Islands.
	May	Severe Cydonic Storm 'Mora' over the Bay of Bengal	'Mora' developed in the onset phase of southwest monsoon. The system caused heavy rainfall at isolated places over Arunachal Pradesh, Manipur, Nagaland, Mizoram and Tripura and a few places over Assam and Meghalaya.
	Nov	Very Severe Cyclonic Storm "Ockhi" over the Bay of Bengal	It was a rare cyclone with rapid intensification after the genesis stage. It caused isolated heavy rainfall over south Tamil Nadu and over south Kerala. It caused heavy to very heavy rainfall over Lakshadweep and heavy rainfall over north coastal Maharashtra and adjoining south coastal Gujarat.

Source: Annual Climate Summary 2014, 2015, 2016, 2017 (IMD)

1.1.4 Development of climate resilience and disaster risk reduction

India's vulnerability to natural hazards can be gauged from the fact that it experienced 431 major natural disasters during the period 1980-2010, resulting in huge loss of human lives, property and resources. India suffered an absolute loss of US$79.5 billion during 1998-2017 (CRED and UNISDR, 2018). Increasing frequency and intensity of disasters related to the climate change impacts on weather systems, ecological dynamics and natural resources, reflect the need to adopt measures for disaster management and climate change adaptation. Climate change is known to increase people's vulnerability by intensifying underlying factors, besides aggravating frequency and intensity of hazards. The action plans to combat climate change and natural hazards should have dual objectives of Climate Change Adaptation (CCA) and Disaster Risk Reduction (DRR). For both CCA and DRR, the major shared objectives include protecting developmental goals through effective planning, managing risks and uncertainties. The purpose of engaging in DRR and CCA approaches is to reduce the vulnerability of people and their resources which are exposed to various natural hazards and increase their resilience to cope with the eventualities arising out of such disasters. Early warning of the extreme weather events is one of the critical components of DRR. For this purpose, the country has developed modern meteorological observation systems (Satellites, Doppler Weather Radars, GPS Radiosonde, AWS/ARG, Wind Profiler Radar).

The National Weather Service runs a global model at a horizontal grid resolution of 12 km for generating real-time weather reports. Meso-scale models are run to generate nowcast at a grid resolution of up to 3 km. A mechanism to issue timely warnings using Automatic Data Transmission Techniques is deployed beside the use of mobile phone, mass media and IT modes of information dissemination. The National Disaster Management Authority (NDMA) has developed a sound response mechanism for quick response in the event of any disaster by deploying teams of National Disaster Response Force (NDRF). The key challenges for a sound response mechanism are accurate prediction of extreme weather events, flash flood forecasting and induced landslides, inundation forecasting (coastal, urban, valleys), effective last mile connectivity, maintenance of automatic data collection system, and numerical modelling of processes determining weather and climate extremes.

1.2 Sea level rise

Based on the 5th Assessment Report (AR5) of the Intergovernmental Panel on Climate Change (IPCC), the mean sea level rise in the global ocean was estimated to be about 1.7 [1.5 to 1.9] mm per year between 1901 and 2010, and it increased to 3.2 [2.8 to 3.6] mm per year between 1993 and 2010. Long-term sea level estimates using tide gauge records show a rate of sea level rise of about 1.06-1.75 mm yr^{-1} in the Indian Ocean during 1878-2004 (Unnikrishnan and Shankar, 2007). However, altimeter data analysis over 1993–2012 period reveals that the rate of sea level rise is rather spatially homogeneous over most of the north Indian Ocean, reaching values close to global mean sea level rise trend (3.2 mm yr^{-1}) (Unnikrishnan et al., 2015). This clearly indicates that the rate of sea level rise has accelerated which is reinforced by Swapna et al. (2017) study which mentions that the sea level rise in the North Indian Ocean has accelerated to 2.3 ± 0.09 mm/yr during 1993–2015. Analyses of long-term climate data sets and ocean model sensitivity experiments indicated that significant increase in North Indian Ocean sea level during last three to four decades is accompanied by a weakening of summer monsoon circulation (Swapna et al., 2017).

1.3 Water resources

As per Entry 17 of List II (State List) of Schedule VII to the Constitution of India, water is a state subject. However, as per Entry 56 of List I (Union List) of Schedule VII to the Constitution, the Union Government can intervene, when considered necessary in public interest, in respect of issues relating to inter-state rivers and river valleys. Necessary measures for the implementation of different laws/policies relating to water are undertaken by the concerned authorities of the Central and State governments as per the provisions prescribed (MoWR, 2016a). The overall impact of climate change on water resources is anticipated in terms of the rise in extremes, thereby increasing the flood and drought frequency, intensity of rainfall and spatial variability. In all such events, there is a reduction in natural groundwater recharge. Alterations in the flow of the largest river system in India, Ganga-Brahmaputra-Meghna system, could significantly impact irrigation, affecting the amount of food that can be produced in their basins as well as the livelihoods of millions of people.

Rising global temperatures are expected to raise the sea level, which in turn will alter 'sea water - freshwater' dynamics and may result in substantial changes in the subterranean outflow of fresh ground water into the sea and vice versa. This may lead to sea water ingress in some of the coastal aquifers which otherwise contain freshwater. Indian coastline stretches about 7,500 km on the mainland and exhibits most of the known geomorphological features of coastal zones. The impact of global warming-induced sea level rise due to thermal expansion of near-surface ocean water has great significance to India due to its extensive, densely populated low-lying coastal zone. Sea level rise is likely to result in loss of land due to submergence of coastal areas, inland extension of saline intrusion and groundwater contamination, and may have wide economic, cultural and ecological repercussions.

Changes in groundwater quality (in space and time) in the event of temperature rise, depends on increase/decrease in the rate of evapotranspiration and rainfall pattern. The increase in water temperature can enhance the solubility of water and consequently an increase in the concentration of inorganic constituents in water, which are likely to put a negative impact on human health. Similarly, in the event of extreme rainfall events, with an increase in runoff, the flushing of surface contaminants will reduce the pollutant load that ultimately seeps underground and joins groundwater, thus positively impacting groundwater quality.

1.3.1 An overview of India's water resources

India has roughly 4% of the world's freshwater resources and receives an average annual rainfall of about 1,186 mm which corresponds to a precipitation of 4,000 billion cubic meters (BCM) including snowfall. There is considerable variation in rainfall both temporally and spatially. Nearly 75% of rainfall is received during the monsoon season. Climate change will lead to an intensification of the global hydrological cycle and can have major impacts on regional water resources, affecting both ground and surface water supply. The groundwater level data for the pre-monsoonal period (April/May 2016), monitored by the Central Ground Water Board (CGWB), when compared with the decadal average (2006-2015), indicates a decline of 65% in the groundwater level, up to 2 meters, in

almost all the States/UTs, except a few, namely Arunachal Pradesh, Goa, Puducherry, Tamil Nadu and Tripura (MoWR, 2016a).

The Government of India has formulated a National Perspective Plan for Water Resources Development which envisages the transfer of water from surplus basins to water deficit basins. The inter-basin transfer proposals envisage additional utilization of available water to bring additional area under irrigation. National Water Development Agency (NWDA) has identified 30 links (16 under Peninsular Component and 14 under Himalayan Component) for preparation of feasibility reports. After survey and investigations, feasibility reports of 14 links under Peninsular Component and two links in the Himalayan Component have been prepared. The present status of water resources in India is presented in Table 1.3.

Table 1.3: An overview of the water resources of India

Estimated average annual precipitation (including snowfall)	4,000 BCM
Average annual potential (in rivers)	1,869 BCM
Estimated utilizable water	1,123 BCM
(i) Surface water	690 BCM
(ii) Groundwater	433 BCM
Per capita water availability (from census 2011)	1,545 Cubic Metre[1]
Storage capacity of major and medium completed projects	253 BCM
Per capita water storage	208 Cubic Metre
Estimated surface water utilization	450 BCM
Annual groundwater withdrawal	245 BCM

Note: BCM = Billion cubic metre = Cubic kilometre. *Source: (MoWR, 2016d)*

1.3.2 Irrigation

The ultimate irrigation potential estimated for the country is 139.9 Mha. Irrigation Potential of 113.53 Mha had been created up to March 2013 (MoWR, 2016e). The net irrigated area in India in the year 2013-14 was 68.1 Mha and tubewells provided for 45.7% of the total irrigation (MoSPI, 2017b). *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY) was launched in 2015-16 to serve as a platform for convergence of investments in irrigation through comprehensive District and State Irrigation Plans. It envisages end to end solutions in irrigation supply chain *viz,* water resources, distribution, efficient application and extension services. The focus is on improving water use efficiency at farm level and bridging the gap between irrigation potential created and utilized (MoWR, 2016c).

Under the Accelerated Irrigation Benefit Programme (AIBP) of PMKSY, it has been targeted to fast-track completion of 99 ongoing major and medium irrigation projects with ultimate irrigation potential of 7.603 Mha by December 2019 in a phased manner. About 10 Mha area has been brought under Micro Irrigation by November 2017 to enhance water use efficiency (MoAFW, 2018).

1.3.3 Coastal and marine ecosystems

India, a recognized mega-biodiverse country abounds in rich coastal and marine wealth along the eastern and western coasts as well as the Andaman, Nicobar and Lakshadweep Islands. Dense mangrove forests of Sunderbans, which India shares with Bangladesh, world's largest congregations of nesting turtles in Odisha, beautiful seagrass beds in the Palk Bay, enigmatic sea cows in the Gulf of Mannar, majestic whale sharks frequenting the waters of the Gulf of Kutch and some of the world's most magnificent coral reefs in Gujarat, Maharashtra, Tamil Nadu, Andaman & Nicobar islands and Lakshadweep are but few examples of the rare treasures of India's coastal and marine biodiversity. Besides being repositories of biological diversity, the coastal regions in India are home to a

[1]According to Falkenmark Water Stress Indicator, annual per-capita water availability of less than 1,700 cubic metres is considered as water stressed condition, whereas annual per-capita water availability below 1,000 cubic metres is considered as water scarcity condition.

large proportion of world's human population.

India has a long coastline of around 7,500 km and the coastal region comprises 78 districts in the nine maritime states. The coastal states are West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat. The UTs are Daman & Diu, Puducherry and two Islands –Andaman & Nicobar and Lakshadweep. There are two coastal plains in peninsular India: the Eastern Coastal Plain and the Western Coastal Plain. The Eastern Coastal Plain is a wide stretch of land between the Eastern Ghats and the Bay of Bengal, stretching from West Bengal in the north east to Tamil Nadu in the south east. The Western Coastal Plain forms a narrow strip of land between the Western Ghats and the Arabian Sea, extending from Gujarat in the north-west to Kerala in the south west. There are around 1,238 large and small islands in India which are vulnerable to the impact of climate change.

The coastal and marine sector is also a source of valuable fish protein not only for the growing Indian population but also contributes to the global food basket and in turn provides valuable foreign exchange to the country. India produced 3.8 million metric tonnes of seafood during 2017, valued at ₹528,070 million at landing centre and ₹800,180 million at the retail level. The fisheries sector supports around 930,000 active and part-time fishers, one of the largest workforce of fishers in the world (CMFRI, 2018).

The sustainability of the fisheries resources in the 2.02 million sq. km of the Indian Exclusive Zone is supported through a number of domestic legislations (Marine Fishing Regulation Acts of the coastal states/UTs; Marine Products Export Development Authority Act, 1972; Coastal Aquaculture Authority Act, 2005, etc). India is also signatory to a number of international instruments of both voluntary and non-voluntary nature that provide good governance framework for sustainable exploitation of marine resources (e.g. United Nations Convention on the Law of the Sea; United Nations Fish Stocks Agreement; FAO's Code of Conduct for Responsible Fisheries).

India is implementing measures to sustainably harness the potential of blue economy while building the climate resilience of the ecosystems and local coastal communities. Around 106 coastal and marine sites have been identified as conservation or community reserves to increase participation of the local communities in governance. India's National Wildlife Action Plan for the period 2017 to 2031 identifies a number of priority areas for research as well as on-ground implementation towards the conservation of coastal and marine ecosystems from the impacts of climate change. These measures not only contribute towards achieving the Aichi Biodiversity Targets, especially Target 11 (at least 10% of coastal and marine areas are conserved under Protected Area Network) and Target 14 (ecosystems that provide water, health and well-being are restored and safeguarded) but also build climate-resilience of the ecosystems and coastal population. Notably, India has not only been able to sustain but also increase its mangrove cover at a time when these ecosystems are disappearing at an alarming rate across the world. Towards fulfilment of India's commitment to Sustainable Development Goals (SDGs), several initiatives have been taken to meet the targets set under SDG 14- Life Below Water.

To conserve and regulate development along the coastal stretches of the mainland and the Islands, MoEFCC has notified Coastal Regulation Zone (CRZ) Notification and Island Protection Zone (IPZ) Notification in 2011 with suitable amendments carried out from time to time. The Notification aims to ensure livelihood security of the fishermen and other local coastal communities, to conserve and protect coastal stretches, its unique environment and its marine area and to promote development in a sustainable manner based on scientific principles taking into account the dangers of natural hazards in the coastal areas and sea level rise due to global warming. The Notification regulates developmental activities up to 500 meters on landward side from the High Tide Line (HTL), in Inter-Tidal Zone (ITZ) and water areas from Low Tide Line (LTL) to 12 nautical miles on the seaward side. The marine and coastal sector is governed by a number of regulations of different Ministries/ Departments as per their respective mandate.

Integrated Coastal Zone Management (ICZM) is a World Bank funded project which is being implemented by MoEFCC in Gujarat, Odisha and West Bengal covering activities related to conservation, pollution abatement, livelihood and capacity building. Some of the major achievements of this project are as follows:

- India's Hazard Line has been demarcated by the Survey of India, delineating land areas that are at risk from coastal erosion (erosion line) and coastal flooding (flood line).
- Over 34,000 sq. km of Ecologically Sensitive Areas (ESA) have been mapped. The demarcated ESAs include mangroves, coral reefs, sea grass beds, seaweeds forests, turtle nesting sites, bird nesting sites and horseshoe crab habitation sites.
- Integrated Management Plans for conservation and sustainable use of ESAs are developed with community participation. As part of these Plans, one of the activity pertains to regeneration of bleached coral reefs undertaken by coastal communities in the Gulf of Kutch Marine National Park.
- Halophyte garden has been set up at Vedaranyam in Tamil Nadu to protect the low lying saline coastal areas from degradation and inundation.

- Shoreline mapping and shoreline management plans have been prepared in project sites and soft erosion control measures are being implemented.
- Integrated Coastal Zone Management Plans (ICZMPs) are being prepared for specific stretches of the Indian coast including the Gulf of Kutch in Gujarat; Paradip-Dhamra and Gopalpur-Chilika in Odisha; and Digha-Sankarpur and Sagar Island in West Bengal. ICZMPs are also being prepared for Lakshadweep and Andaman & Nicobar Islands with a focus on holistic sustainable development of the region.
- One of the world's largest mangrove plantations of 1,600 ha has been undertaken under the project.

1.4 Land use and forests

1.4.1 Land use

The subject of land including assessment and collection of revenue, maintenance of land records and land management fall under the purview of State Governments. Therefore, in the area of land utilization, there are different approaches being followed across the country.

Of the total geographical area of 328.73 Mha, 42.6% is under agriculture (net sown area), while the gross cropped area is 60.3%. Land under forests is around 21.5% and land not available for cultivation is 13.3% (FSI, 2017; MoAFW, 2017b). India's land use change from 1970-2015 is shown in Figure 1.10.

Figure 1.10: Land use change during 1970-71 to 2014-15, (P) = Provisional. ***Source of data: (MoAFW, 2017b)***

1.4.2 Forests

As per India's State of Forest Report, 7,08,273 sq. km, i.e., 21.54% of the geographical area of the country is covered by forests (FSI, 2017). A total of 15 States/UTs have a forest cover of more than 33%. The tree cover outside the forests of the country is estimated to be 93,815 sq. km which is 2.85% of the geographical area.

Thus, the total forest and tree cover of the country is estimated at 8,02,088 sq. km which is 24.39% of the geographical area of the country. Figure 1.11 shows the forested areas of the country. Forest cover has increased by 6,778 sq.km as compared to 2015 estimates. Table 1.4 shows the percentage of geographical area under forest and tree cover. The total carbon stock in the forests for 2017 has been estimated to be 7,083 million tonnes. The annual increase of carbon stock is worked out to be 19.50 million tonnes which is 71.5 $MtCO_2e$ (FSI, 2017).

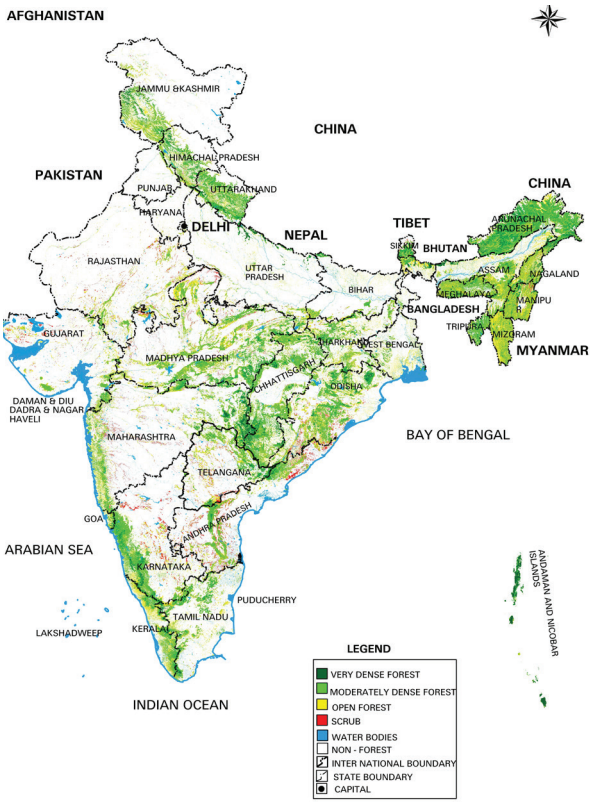


Figure 1.11: Forest cover map of India. *Source: (FSI, 2017).*

Table 1.4: Forest cover of the country

Class	Area (sq km)	Percent of Geographical Area
Very dense forest	98,158	2.99
Moderate dense forest	3,08,318	9.38
Open forest	3,01,797	9.18
Total Forest Cover*	**7,08,273**	**21.54**
Scrub	45,979	1.4
Non-Forest	25,33,217	77.06
Total Geographical Area	**32,87,469**	**100**

(*includes 4,921 sq. km under mangroves)

Source: (FSI, 2017)

1.5 Demographic profile

As per Census 2011, India's population was 1.21 billion, and the female members constituted 48.5% of the total. The average annual growth rate in population has declined from 1.95% in 2001 to 1.63% in 2011. India is the second most populous country in the world as of today. The decadal population growth is steadily declining and stood at 17.6% during 2001-2011. India's performance on critical demographic parameters is constantly improving. India's Human Development Index (HDI) went up from 0.369 to 0.586 between 1980 and 2013 that corresponds to an increase of 58.7% or an average annual increase of about 1.41%. Between 1980 and 2013, India's life expectancy at birth increased by 11 years, mean years of schooling by 2.5 years and expected years of schooling by 5.3 years. Despite the improvement in HDI, India still ranks 136th among 186 countries, indicating the effort still required for poverty erradication and improvement of standards of well being.

India alone accounts for about 17.6% of the world population (only behind China with a share of 19.1%), much more than G-8 countries put together. Amongst G-20 countries, in terms of population density, India stands

second, behind South Korea (highest density), with the number of people living per square km in India more than about 27 times of world average (MoSPI, 2017b).

1.5.1 Demographic transition

As per available data from Sample Registration System, there has been a gradual decline in the share of the population in the age group 0-14 years from 41.2 to 38.1% during 1971 to 1981 and 36.3 to 27.6% during 1991 to 2014. On the other hand, the proportion of the economically active population (15-59 years) has increased from 53.4 to 56.3% from 1971 to 1981 and 57.7 to 64.1% from 1991 to 2014. On account of better education and health facilities, and increase in life expectancy, the percentage of the elderly population (60+) has gone up from 5.3 to 5.7% and 6.0 to 8.3% respectively during the periods under reference. Marital status and female mean age at marriage are essential constituents to monitor fertility and population growth. The mean age at effective marriage for females has increased from 19.3 years in 1990 to 22.3 years in 2014 (MHA, 2017). Figure 1.12 shows the distribution of population by broad age groups in 2014.

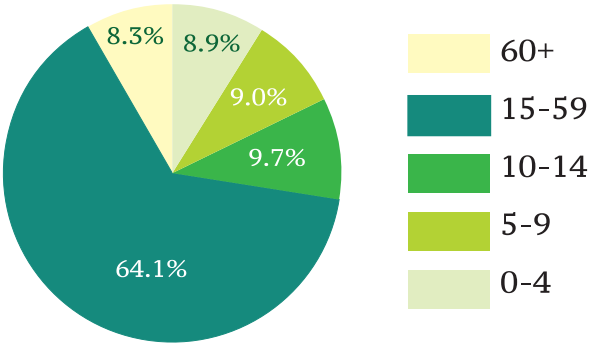


Figure 1.12: Age-wise percentage distribution of population in the year 2014. ***Source: (MHA, 2017)***

There are several challenges which still remain, specifically relating to improving the socio-economic well-being of the economically weaker sections. Around 363 million people live in poverty, about 1.77 million people are houseless. The per capita electricity consumption stands low at 917 kWh, which is barely one-third of the world's average consumption (GoI, 2015).

1.5.2 Urbanisation

According to Census 2011, about 377 million Indians comprising 31.14% of the country's population lived in urban areas which grew from 286 million as recorded in 2001. The urban population is further projected to grow to about 600 million by 2031 and 850 million by 2051. The number of statutory towns in India increased from 3,799 to 4,041 during 2001-2011, whereas the number of census towns has increased from 1,362 to 3,892 during the decade (MoUD, 2016). The urbanisation in the recent decades in India is propelling the country to become the second largest urban system globally.

Rapid urbanisation brings challenges, including meeting accelerated demand for basic services, infrastructure, jobs, land and affordable housing, particularly for the urban poor. Government of India has undertaken some major initiatives to address the challenges of rapid urbanisation, which include the launch of missions such as Atal Mission for Rejuvenation and Urban Transformation (AMRUT), Smart City Mission, Swachh Bharat Mission (SBM), and National Heritage City Development and Augmentation Yojana (HRIDAY), continuing on related efforts from earlier periods. The Swachh Bharat Mission, launched on 2nd October 2014, has the target of making the country clean by 2nd October 2019. The Mission, among other measures, focusses on Solid Waste Management including the establishment of waste to energy plants and provides Central Financial Assistance up to 35% of the project cost. There are two components of the Mission, namely, Swachh Bharat Mission Gramin for India's rural centres, and Swachh Bharat Mission Urban for India's urban centres.

1.6 Economic profile

The Indian economy has sustained a macro-economic environment of relatively lower inflation, fiscal discipline and moderate current account deficit. As per the estimates released by the Central Statistics Office (CSO), the growth in Gross Domestic Product (GDP) at constant (2011-12) prices is estimated at 6.7% in 2017-18 as compared to the growth rate of 7.1% in 2016-17 (MoSPI, 2018c). Per capita income has improved by almost 32% in 2017-18 as compared to 2012-13 (Table 1.5).

Table 1.5: Growth rate of GDP and Per Capita Income at constant (2011-12) prices

	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
GDP Growth Rate (%)	5.5	6.4	7.4	8.2	7.1	6.7
Per Capita Income (₹)	65,538	68,572	72,805	77,826	82,229	86,668

Source: Ministry of Statistics and Programme Implementation (MoSPI)

The fiscal deficit for the first eight months of 2017-18 reached 112% of the total for the year, far above the 89% norm, largely because of a shortfall in non-tax revenue, reflecting reduced dividends from government agencies and enterprises (MoF, 2018).

The Government of India has taken various initiatives to give boost to the economy which, inter alia, include: fillip to manufacturing and infrastructure sectors through fiscal incentives and concrete measures for transport, power, and other urban and rural infrastructure; substantive reforms and liberalisation of foreign direct investment in major sectors; measures to remove bottlenecks in the supply of key raw materials; Skill India and Digital India initiatives; Make in India initiative along with the attendant facilitatory measures for a more conducive environment for investment. Some other measures are: the new insolvency and bankruptcy-related legislation; Start-up India Initiative to encourage entrepreneurship and creation of jobs; Stand Up India Scheme to promote entrepreneurship; boost to agricultural sector with focus on micro-irrigation, watershed development, soil conservation and credit; and various measures to improve clarity and transparency in economic policy-making (MoF, 2016).

Table 1.6: Growth rate in GVA at constant (2011-12) prices (in percent per year)

Sectors	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Agriculture, forestry and fishing	1.5	5.6	-0.2	0.6	6.3	3.4
Mining and quarrying	0.6	0.2	9.7	13.8	13.0	2.9
Manufacturing	5.5	5.0	7.9	12.8	7.9	5.7
Electricity, gas, water supply and other utility services	2.7	4.2	7.2	4.7	9.2	7.2
Construction	0.3	2.7	4.3	3.7	1.3	5.7
Trade, hotels, transport, communication and broadcasting services	9.8	6.5	9.4	10.3	7.2	8.0
Financial, real estate and professional services	9.7	11.2	11.0	10.9	6.0	6.6
Public administration, defence and other services	4.3	3.8	8.3	6.1	10.7	10.0

Source: Central Statistics Office, Ministry of Statistics and Programme Implementation (MoSPI)

The Gross Value Added (GVA) estimates show that services sector is the fastest growing sector. There is variability in the GVA of the agriculture sector, possibly due to monsoonal perturbations. Successful economic and social transformation has always happened against the background of rising agricultural productivity. In the last four years, the level of real agricultural GDP and real agriculture revenues has remained constant, owing in part to weak monsoons in two of those years. Climate change whose imprint on Indian agriculture is already visible might reduce farm incomes by as much as 20-25% in the medium term (MoF, 2018). The growth in mining and manufacturing sectors has decreased during the last two years (table 1.6).

1.6.1 Major economic transformations

The government has enacted a package of measures to provide a boost to employment, especially women employment. The National Payments Corporation of India (NPCI) successfully finalised the Unified Payments

Interface (UPI) platform. By facilitating inter-operability, it will unleash the power of mobile phones in achieving digitalisation of payments and financial inclusion and making the 'M' an integral part of the government's flagship 'JAM' – Jan Dhan, Aadhaar, Mobile – initiative. FDI reform measures have also been implemented, allowing India to become one of the world's largest recipients of foreign direct investment. Looking further ahead, societal shifts in ideas and narratives will be needed to overcome three long-standing meta-challenges: inefficient redistribution, ambivalence about the private sector and property rights, and improving the still-challenged state capacity (MoF, 2017).

1.6.2 Poverty

The All India Poverty Head Count Ratio (PHCR) has been brought down from 47% in 1990 to 29.5% in 2011-12. As much as 260.5 million individuals were below the poverty line in rural India, and 102.5 million were under the poverty line in urban India in 2011-12 (Rangarajan et al. 2014). In 2015, a Task Force on the Elimination of Poverty was constituted to coordinate and develop synergy with the Central Ministries and State Government Task Forces and to prepare a roadmap for the elimination of poverty. The Task Force identified poverty alleviation strategies and programmes for focussed implementation.

According to the occassional paper based on the work of the Task Force, the strategy for combating poverty must rest on two legs: sustained rapid growth that is also employment intensive and making anti-poverty programmes effective. The poor predominantly reside in rural areas where incomes critically depend on agricultural growth. Therefore, anti-poverty programmes such as the Public Distribution System (PDS), Mid-day Meal Scheme, Mahatma Gandhi National Rural Employment Guarantee Act (MGNREGA) and Housing for All are important to eliminate abject poverty. Several such options have been suggested by NITI Aayog's occassional paper.

The PDS related reforms suggested the inclusion of biometric verification of PDS beneficiaries, the option of cash transfer for beneficiaries of subsidies, increased information dissemination to bring behavioural change on nutrition, and improvement in the functioning of mid-day meal schemes. The MGNREGA modifications that were recommended in the paper include allowing the programme to impart skills and improve quality of assets created, and better fiscal support to identified beneficiary regions. The Housing for All (Rural) programme has progressed well overall but can be further improved along several dimensions by better identification of beneficiaries through socio-economic census, progress reporting and using prefabricated housing technology. Jan Dhan Yojana, Aadhaar, Mobile (JAM) trinity would play a vital role in widening the reach of Government to the vulnerable sections. Jan Dhan bank accounts under Prime Minister's Jan Dhan Yojana (PMJDY), biometric identity cards under Aadhar and accessibility to the accounts through mobile phones promise to eventually revolutionize the anti-poverty programmes (NITI Aayog, 2016).

1.6.3 Employment

In India, 64% of the population belongs to the age group of 15-59 years. This demographic dividend presents both a challenge and an opportunity. As more and more people enter the workforce, there need to be institutional systems that absorb this influx, in the absence of which there will be a high incidence of unemployment. As per the result of a survey on employment and unemployment conducted by Labour Bureau during 2015-16, the estimated unemployment rate for the persons aged 18-29 years in the country was 10.2% (MoLE, 2017).

Several programmes have been initiated in both rural and urban areas to address unemployment. One such initiative is the Mahatma Gandhi National Rural Employment Guarantee Act 2005 that aims to guarantee the right to work. The Ministry of Housing and Urban Poverty Alleviation is implementing a Centrally Sponsored Scheme, namely, 'Deendayal Antyodaya Yojana – National Urban Livelihoods Mission (DAY-NULM)' to reduce poverty and vulnerability of the urban poor households by enabling them to access gainful self-employment and skilled wage employment opportunities (MoHUA, 2017). In addition, the Ministry of Micro, Small & Medium Enterprises is implementing Prime Minister's Employment Generation Programme (PMEGP) which is a major credit-linked subsidy programme aimed at generating self-employment through establishment of micro-enterprises in the non-farm sector by helping traditional artisans and unemployed youth (MoMSME, 2017).

The government has also decided to strategically promote labour-intensive manufacturing and expand employment opportunities by promoting tourism and agro-based industries. A new Ministry of Skill Development and Entrepreneurship (MSDE) has been established to enhance the skilling programme and to coordinate skilling activities across Ministries. National Skill Development Mission has been developed to create convergence across sectors and states in terms of skill training activities. As a part of this mission, aspirant candidates can register for skill training/learning and employment opportunities through the online portal.

1.7 Agriculture and livestock

1.7.1 Agriculture

Agriculture plays a vital role in India's economy. About 49% of the working population depends on agriculture as their principal means of livelihood, and 52% of agriculture is rainfed (MoAFW, 2016). Agriculture, along with fisheries and forestry, is one of the largest contributors to the Gross Domestic Product (GDP). As per estimates by the Central Statistics Office (CSO), the share of agriculture and allied sectors (including agriculture, livestock, forestry and fishery) was 14.82% of the Gross Value Added (GVA) during 2017-18 at 2011-12 prices.

India is the largest producer, consumer and exporter of spices and spice products. India's fruit production has grown faster than vegetables, making the country the second largest fruit producer in the world. India's horticulture output, comprising fruits, vegetables, spices and plantations has reached a record high of 299.8 million tonnes (MT) in 2016-17 (third advance estimate). Total foodgrain production in the country is estimated at 275.68 million tonnes (2016-17) (MoAFW, 2017b). The share of India's agricultural exports and imports in the world agriculture trade in 2015 were 2.26% and 1.74%, respectively (MoAFW, 2017a). Figure 1.13 shows that the cropping intensity has increased from 1960 to 2014. Higher cropping intensity means that a higher portion of the net area is being cropped more than once during one agricultural year. This also implies higher productivity per unit of arable land.

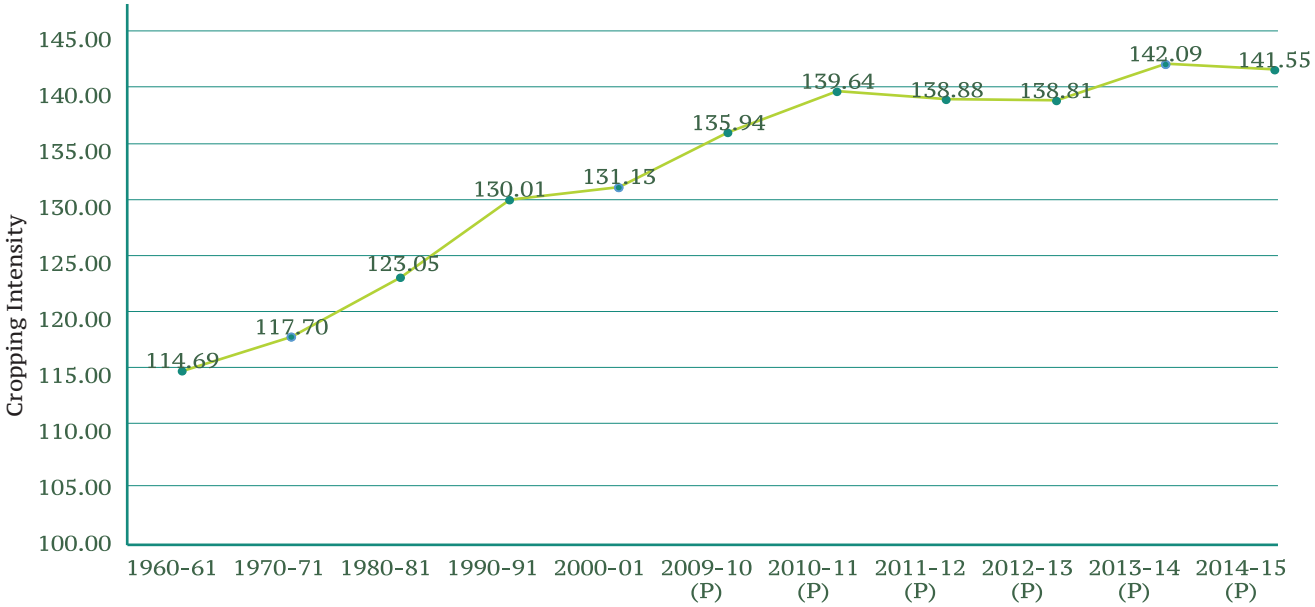


Figure 1.13: Cropping intensity (i.e. % of gross cropped area to the net sown area). P = Provisional.

Source: (MoAFW, 2017b)

In meeting the domestic requirements of foodgrain and also generating exportable surpluses, a significant role is also played by chemical fertilizers. The production of all the fertilizers during the year 2015-2016 was 41.3 million metric tonnes (DoF, 2017). The government is taking steps to correct the imbalance in chemical fertilizer use, via information technology, and promoting organic farming.

1.7.2 Livestock

Livestock is an integral part of India's agricultural economy and plays a multifaceted role in supporting rural livelihoods. The sector provides employment generation opportunities, facilitates asset creation and provides a coping mechanism against crop failure, in addition to social, nutritional and financial security. It is estimated that about 70 million rural households own livestock of one species or the other. India having only 2.4% of the geographic area, 1% of the forest area and 0.5% of pasture lands of the world supports about 15% of global cattle population.

The livestock in India namely Cow, Buffalo, Sheep, Goat, Pig, Horses and Ponies, Mules, Donkeys, Camels, Mithun and Yak are covered in the livestock census. The other species covered in the census are Dogs, Rabbits and Elephants. As compared to the 18th Livestock Census, there has been an overall decline of 3.33% in the total livestock population in the country. The total livestock population was 512.05 million in 2012, while the total poultry population was 729.2 million (Table 1.7).

Table 1.7: Number of livestock and poultry (in thousands)

Year	Total Livestock	Total Poultry
2003	4,85,002	4,89,012
2007	5,29,696	6,48,829
2012	5,12,057	7,29,209

Source: MoSPI, 2017b.

As compared to the 2007 census, milch animals (in-milk and dry) have increased by 6.75%. At the same time, the number of female cows and buffaloes has increased by 6.52% and 7.99% respectively. The exotic/crossbred milch cattle have shown a substantial increase of 34.78%. In comparison, the indigenous milch cattle have increased only marginally by 0.17%. The total milk production (from cow, buffalo and goat) has increased from 79.65 million tonnes in 2000-01 to 163.7 million tonnes in 2016-17 (MoAFW, 2017b). The country's share in world milk production stands at 18.5%. The per capita availability of milk is 337 grams per day which is higher than the world average. Initiatives from Government have been made to bring more and more women in this sector for the development of livelihoods. As of March 2016, the total number of women members in dairy cooperatives across the country was 5.01 million (NDDB, 2016). India has significantly progressed in the livestock sector in the last decade which is attributed to the fact of increasing production of milk, eggs, meat and wool, and also by the overall development of its diseases control, progeny improvement and related infrastructure.

1.7.3 Fisheries resource

India is the second largest producer of fish and also freshwater fish in the world. India has a vast potential for fisheries in view of the country's long coastline of about 7,500 km apart from the inland water resources. As per CSO estimates, the value of output from the fisheries sector during 2016-17 was ₹1,132,550 million which is about 5% of the value of the output from agriculture and allied sectors at constant (2011-12) prices.

Fish production has increased from 4.157 million tonnes (2.447 million tonnes for marine and 1.71 million tonnes for inland fisheries) in 1991-92 to 10.79 million tonnes in 2015-16. At the same time, export also increased over the years. During the financial Year 2015-16, India exported fish worth ₹304,208.3 million which is about 0.9% of the national GDP and 5.17% of the agriculture GDP of 2015-16 (DoAHDF, 2016). Table 1.8 shows salient features of marine and inland resources of India.

Table 1.8: Marine and Inland Resources

Marine Resources and Dependency on Livelihoods	
Length of Coastline (km)	7,500
Exclusive Economic Zone (million sq. km)	2.02
Number of fish landing Centres	1,537
Number of Fishing Villages	3,432
Number of Fisherman Families	8,74,749
Fisher-folk population	4,056,213
Inland Resources	
Total inland water bodies (million ha)	7.359
Rivers & Canals (km)	195,210

Reservoir (million ha)	2.907
Tanks & ponds (million ha)	2.414
Flood plain lakes/derelict waters (million ha)	0.798
Brackish water (million ha)	1.24

Source: Department of Animal Husbandry, Dairying and Fisheries

1.8 Energy profile

Energy is one of the building blocks of economic development. In the case of India, where multiple and competing priorities of development exist, energy plays a pivotal role. India's substantial and sustained economic growth is placing an enormous demand on its energy resources. Energy demand in all the sectors including agriculture, industrial, commercial and household has increased. Still, India's per capita energy consumption is nearly 30% of the world's average. Energy and climate change related concerns of the Indian economy include the growing gap between the demand and supply of energy and environmental externalities associated with energy use. Despite high growth in energy intensive sectors, the growth in energy consumption and environmental emissions with respect to GDP are low. However, due to an increased level of electrification, the electricity consumption has grown at a rate higher than the GDP.

Fossil fuels in the form of coal, oil and gas still play a major role in the energy scenario of the country. Energy transition through increasing energy efficiency and deployment of renewables, while ensuring access to affordable energy is inevitable for sustainable development and climate change mitigation. India has already taken major steps to promote energy efficiency. Replacement of inefficient bulbs with energy efficient LED bulbs under the UJALA programme has been one of the key initiatives. Improvement in energy efficiency by using more efficient appliances is a highly successful programme.

With the periodic improvements in the performance standards as well as awareness generation through campaigns, energy efficient equipment / appliances are being promoted. The government has now prescribed guidelines / norms for design and construction of energy efficient buildings using state-of-the-art technologies along with the capacity building of professionals. Because of efficiency improvements, the loss of electricity due to transmission has decreased from 27.18% during 2007-08 to 21.30% during 2016-17 (MoSPI, 2018b).

As regards the industrial sector, Perform, Achieve and Trade (PAT) is being implemented with an objective to reduce the specific energy consumption (SEC) in energy intensive industries. The government also announced the Saubhagya scheme in September 2017 to provide electricity connections to over 40 million families in rural and urban areas.

1.8.1 Energy intensity

India's energy intensity has decreased over the last decade. This decline may be attributed to the fact that GDP is growing faster than the demand for energy in the country. Furthermore, as the services sector has a growing share of the economy and the energy efficiency programmes have been successfully implemented, India has maintained a low energy intensity. The Energy Intensity (at 2011-12 prices) decreased from 0.2732 Mega Joules per rupee (MJ/₹) in 2011-12 to 0.2401 MJ/₹ in 2016-17 (MoSPI, 2018b). Trends in energy intensity are shown in Figure 1.14.

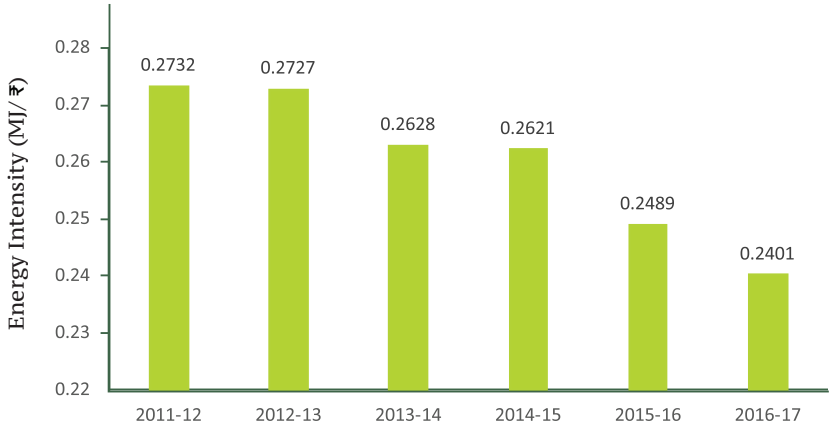


Figure 1.14: Trends in Energy Intensity.
Source: (MoSPI, 2018b)

1.8.2 Primary energy supply

India is striving to meet the basic need of access to energy at an affordable price while addressing the concerns of climate change. Enhancing energy supply and access to energy for all are key components of the national development strategy. In 2016-17, Primary Energy Supply added up to 8,17,370.21 kilotonne of oil equivalent (ktoe). The share of coal accounted for 64.17%, and the contribution of crude oil was 31.25% (Table 1.9).

As per present estimates, India has a renewable energy potential of about 1100 GW for commercially exploitable sources *viz*. Wind – 300 GW (at 100m mast height), Small hydro – 20 GW; Bio-energy – 25 GW an 750 GW Solar power assuming 3% wasteland is made available.

Table 1.9: Share of different fuels in Total primary energy supply

Fuels	Primary energy supply for 2016-17 provisional (in ktoe)
Coal	5,24,471.04
Crude Oil	2,55,419.71
Oil Products	-32,102.17
Natural Gas	46,480.41
Wind, Hydro and Nuclear	23,195.21
Electricity	-94.00

Source of data: (MoSPI, 2018b)

On lifeline energy front, the National Sample Survey 2011-12 reveals the continued dependence on firewood in rural areas for cooking, with percentage of households depending on firewood remaining at 67.3% in 2011-12. However, a drop of 8.2 percentage points was recorded in this figure since 1999-2000. The percentage of households using LPG has increased from about 5.4% to 15% over the same period. On the other hand, the incidence of dependence on firewood for cooking in urban areas has fallen from about 22.3% to 14% between 1999-2000 and 2011-12 – a drop of more than 8 percentage points. The incidence of dependence on kerosene has fallen from 21.7% to 5.7% during the same period – a fall of about 74%, while the percentage of urban households using LPG has increased from 44.2% to 68.4% (NSSO, 2015).

1.8.3 Fossil fuel reserves

As on 1st April 2018, the estimated total geological resource of coal were 319.02 billion tonnes (GSI, 2018), while the estimated balance recoverable reserves of crude oil were 4.4 Mt. There has been an increase of 1.23% in estimated coal resources and decrease of 1.59% in petroleum reserves since 1st April 2017. The estimated reserves of Natural Gas increased by 4.02% since the last estimation (1st April 2017) and stood at 1,339.57 BCM as on 1st April 2018 (MoPNG, 2018).

1.8.4 Primary energy demand

India has only 0.6% and 0.4% of the world's gas and oil reserve respectively while it has 9% of world's proven coal reserves. Owing to economic growth, India's energy consumption has almost doubled since 2000. Still, India uses only 6% of the world's primary energy demand (IEA, 2015). Energy consumption in India is characterized by low per capita level and a large disparity between urban and rural areas. It is expected that the energy basket would shift with an increase in income.

As compared to India's population, energy resources are meagre. In the year 2016-17, India's per capita energy consumption was 22,351 MJ (Figure 1.15) which is just one-third of the world average. Per capita energy consumption of India grew by 56.4% from 2005-06 to 2016-17, with an annual growth rate of 3.8% (CAGR). To meet its energy needs, India is highly dependent on the import of crude oil. Net imports of crude oil have increased from 121.67 Mt during 2007-08 to 213.93 Mt during 2016-17 (MoSPI, 2018b).

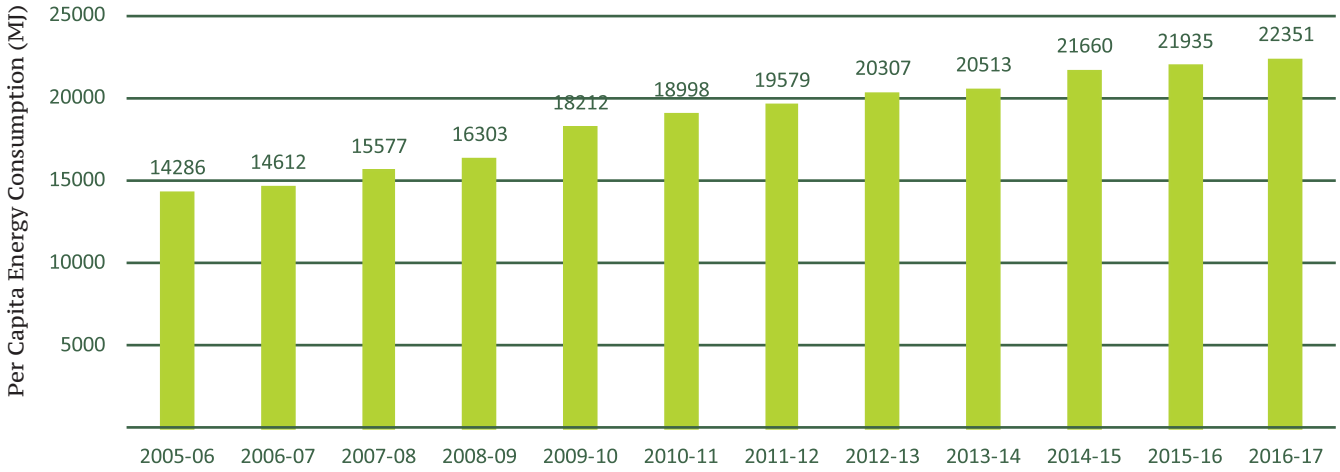


Figure 1.15: Per capita energy consumption in India. *Source of Data: (MoSPI, 2018b)*

1.9 Power sector

The Indian power sector is driven by state, central and private players. The total installed capacity in the country is 345,524.61 MW as on June 2018, with the state sector accounting for 30%, central sector for 25% and private producers for 45%. The installed capacity according to sources is given in Table 1.10. There has been a significant increase in installed capacity of electricity from 2005 to 2018. The share of hydropower plants has come down in total installed capacity from 26% to 13.14%, and there has been a significant rise in other renewable energy sources from 2% to about 20.44%.

Table 1.10: Installed Electricity Generation Capacity in India

Energy Source	Installed capacity (MW)	Percentage
Coal	196,957.50	57.00
Gas	24,897.46	7.21
Diesel	837.63	0.24
Hydro	45,403.42	13.14
RES	70,648.61	20.44
Nuclear	6,780.00	1.96
Total*	**345,524.61**	**100**

*Figures at decimal may not tally due to rounding off

Source: Central Electricity Authority. As on 30th June 2018.

Renewable Energy Sources (RES) are adding capacity into grid and are also increasingly being used for captive power generation. Transparent bidding and facilitation for procurement of power through tariff based competitive bidding process have led to significant reduction in the cost of solar and wind power. The minimum bid price for solar power began at ₹17.91/kWh in 2010-11, that has fallen as low as ₹2.44 /kWh in 2017. Similarly, for wind power, the tariff has declined from an average of ₹4.2/kWh in 2013-14 to ₹2.43/kWh in December 2017.

1.10 Transport

The transport sector, which includes road transport, railways, aviation and shipping, is one of the fastest growing sectors in India. Presently, urban transport needs in Indian cities (for both passenger and freight mobility) are met by a mix of motorized and non-motorized modes. Depending on city characteristics and variable needs, this mix varies from one city to another. India has currently eleven operational metro systems in the cities of Kolkata, Delhi, Gurugram, Noida, Bengaluru, Mumbai, Jaipur, Lucknow, Kochi, Hyderabad and Chennai. A number of other cities are planning or constructing metro rail projects. India has also undertaken the development of BRTS (bus rapid transit system) in many cities. BRT systems exist in Pune, Ahmedabad and Rajkot, and new BRT systems are being

developed in Kolkata, Visakhapatnam, Vijayawada, Surat, Naya Raipur and Hubli-Dharwad. Cities of Amritsar, Ludhiana, Pimpri Chinchwad, Bengaluru, Kolkata, Bhubaneswar, Visakhapatnam, Vijaywada, and Chennai are also planning BRTS systems.

The Government of India approved the National Mission on Electric Mobility in 2011, and subsequently, National Mission on Electric Mobility Plan 2020 (NEMMP 2020) was unveiled in 2013. As a part of NEMMP, India is strongly encouraging and promoting hybrid and electric vehicles in the country through a combination of policies aimed at gradually ensuring a vehicle population of about 6-7 million electric/hybrid vehicles in India by the year 2020. Along with this, a certain level of indigenisation of technology is planned to ensure India's global leadership in some vehicle segments. Under NEMMP, Department of Heavy Industry formulated a scheme namely FAME – India [Faster Adoption and Manufacturing of (Hybrid &) Electric Vehicles in India] to promote hybrid/electric technology in transportation so as to reduce dependence on fossil fuel.

India is one of the 16-member countries of the Electric Vehicles Initiative (EVI), a multi-government policy forum dedicated to accelerating the introduction and adoption of electric vehicles worldwide. India seeks to address future energy requirements through sustainable transportation options. It has identified electric vehicles, in particular, as one of the most promising pathways to increased energy security and reduced emissions of greenhouse gases and other pollutants. As vehicle ownership in India is set to rise substantially, an opportunity exists to diversify the transportation fuel mix to the benefit of the broader economy. Not only does vehicle electrification improve local air quality and reduce carbon dioxide emissions in support of national sustainability goals, but it also helps mitigate the effects of volatile global oil prices (CEM, 2014).

The rail infrastructure and rail transport has also increased manifold to keep pace with the economic development. The environmental impact on account of the same has been receiving increasing attention. Indian Railways has grown to be one of the world's largest rail networks with a route length of 66,000 km. It runs 21,000 passenger and freight trains daily and carries 23 million passengers every day making it the largest passenger carrying system of the world. Presently, railways are about 12 times more efficient in freight traffic and three times more efficient in passenger traffic as compared to road transport. Railways have been adopting various strategies to mitigate environmental impacts which include the adoption of modern technologies in infrastructure construction, operation and maintenance, and other initiatives like deployment of solar and wind energy.

1.11 Environmental and climate governance in India

Environmental protection is one of the central pillars of India's governance framework. The Government of India had enacted the 42nd Amendment to the Constitution in 1976 and added Article 48A to the Directive Principles of State Policy stating that "the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country." The same Amendment added Article 51 A (g) making environmental protection a fundamental duty of every citizen: "to protect and improve the natural environment including forests, lakes, rivers and wildlife, and to have compassion for living creatures." Right to wholesome environment is a fundamental right protected under Article 21 of the Constitution of India. Besides these, India has enacted several laws and policies pertaining to the protection of environment, water, air, wildlife, forests and for management of wastes.

To address the pertinent issues concerning climate change, the Prime Minister's Council on Climate Change was constituted by the Union Government in 2007. The Government re-constituted the Council to coordinate National Action for Assessment, Adaptation and Mitigation of Climate Change in November 2014. The Council is chaired by the Prime Minister and focuses on evolving a coordinated response to issues relating to climate change at the national level; on providing oversight for formulation of action plans in the area of assessment, adaptation and mitigation of climate change; and on periodically monitoring key policy decisions.

The Ministry of Environment, Forest and Climate Change is the nodal agency for environmental protection. Many other ministries including the Ministry of New and Renewable Energy, Ministry of Power and Ministry of Science and Technology undertake climate related activities. Their contribution through various policies and initiatives has been discussed in Chapter 3 (Mitigation Actions). Most ministries and departments have been working in collaboration to implement and to achieve the goals set in the National Action Plan on Climate Change (NAPCC) which was launched in 2008 with eight National Missions. Each mission has a coordinating and implementing ministry. It is a multifaceted plan that covers the essential sectors with regard to climate change. The plan emphasizes on mitigation, adaptation, vulnerability, sustainability and also promotes stakeholder engagement in climate change action. On the lines of the NAPCC, each State has prepared its own State Action Plan on Climate Change, toward achieving the National goal. To support the NAPCC, legal amendments have been carried out, wherever necessary, to improve monitoring and compliance under the missions.

1.12 India's commitment to climate change and sustainable development

India is one of the most vulnerable countries to climate change. To adapt to and mitigate climate impacts, several domestic measures are being undertaken through India's National Action Plan on Climate Change. As a part of the global effort on post-2020 climate actions, India submitted its Nationally Determined Contribution (NDC) in 2015, according to which India has committed to reducing the emissions intensity of its GDP by 33-35% by 2030 from 2005 levels. India is already on the path to achieve the voluntary target of emissions intensity reduction by 20-25% by 2020 from 2005 levels under the Copenhagen Accord. The Paris Agreement acknowledges that climate change is a common concern of humankind, and Parties should, when taking action to address climate change, respect, promote and consider their respective obligations on human rights, the right to health, the rights of indigenous peoples, local communities, migrants, children, persons with disabilities and people in vulnerable situations and the right to development, as well as gender equality, empowerment of women and intergenerational equity (United Nations, 2015). India is striving to build resilience capacity through Employment Guarantee Act and Food Security Act, which provide a safety net to the poor. Research and development in the environment, environmental protection and sustainable development are key national priorities for India. India is an active participant in global environmental negotiations and has signed most multilateral environmental agreements. NITI Aayog India has been entrusted the nodal role of overseeing the implementation of the 2030 development agenda for Sustainable Development Goals (SDGs).

1.13 India's climate friendly lifestyle

India has a history of low carbon footprint and lifestyle, and traditional practices that are sustainable and environment-friendly continue to be a part of people's lives. As per 2014 National Geographic Consumer Index (Greendex), Indians are the top-scoring environmentally sustainable consumers. Greendex is a scientifically derived sustainable consumption index of actual consumer behaviour and material lifestyles across 18 countries.

In India, people have a general inclination towards need-based consumption and an ingrained sense of responsibility which resists wasteful consumption and propagates respect for life. To fulfil their basic needs, people are dependent not on high energy-based products, but on organic farming, skilled labour and individual craftsmanship. Most daily use products are hand-made and made from locally available materials. This decreases dependence on electricity and other sources of power.

A general aversion to food wastage and respect for food are deeply ingrained in the Indian psyche. In India, locally grown food (vegetables and fruits) sourced from nearby rural areas is readily available in local markets, thereby reducing transportation and packaging requirements. Fresh food is preferred over processed, packaged and artificially preserved food. Diverse food habits exist in different parts of the country specific to local climate and availability of resources. Natural food preservation techniques such as sun drying, salt application in pickles, and grain storage in indigenous structures using natural disinfectants and biopesticides such as Neem *(Azadirachta indica)* are commonly practised. About 42% of the households in India are strictly vegetarian. The per capita meat consumption in India for the period 2011-13 was 3.3 kg, which is one-tenth of the global average.

In India, pedal rickshaws, bicycles and walking are often preferred for short distance travel. Non-Motorised Transport (NMT) dominates the modal share of Indian cities. Even in mega cities, with a population of over eight million, the modal share of NMT ranges from 40–50% (walking and bicycling). This is attributed to the dense, mixed land use patterns in Indian cities and the availability of NMT as the only accessible mode of transport for low-income households. During the dry and hot summers, most Indian households still use fans or desert coolers rather than air conditioners. For generations, earthen pots have been used to store water and keep it cool. This helps reduce the refrigeration requirement. The practice of sun-drying of clothes and hand washing dishes reduces the usage of energy-intensive tumble driers and dish-washers, respectively. People, especially in villages, and smaller towns and cities, prefer to bathe with a bucket and tumbler which is significantly less wasteful than bathing under the shower or in bathtubs.

Traditional building practices such as the use of solar-passive orientation, thermal insulation by using mud, jalis or chequered windows and large courtyards for natural ventilation are examples of practices that are designed for comfort in harmony with the natural surroundings, thus reducing energy requirements. Traditionally, Indian house construction utilises local materials like bamboo, stones and clay which is suitable for the local climate and also mitigates GHG emissions by reducing cement consumption and material transport.

The culture of repair/recycle and reuse is part and parcel of Indian lifestyle. There exists a thriving informal recycling network that has a strong door to door collection system, as well as forward linkages to the recycling industry. Newspapers, plastic, metals, woollens, cartons, and electronic discards are recycled extensively. In Indian households, metal, plastic and glassware are often reused for food packaging and other purposes. Luxury items

such as refrigerators, televisions and cars have a good second-hand market.

Conservation of sacred species, groves, forests and landscapes has been an important aspect of the Indian ethos. The Sacred Groves / Forests are important repositories of floristic and faunal diversity that have been conserved by local communities in a sustainable manner. The sacred groves in Himachal Pradesh, Maharashtra, Kerala, Karnataka, Meghalaya and elsewhere not only highlight community-managed conservation efforts but also offer the potential for carbon sequestration.

These climate-friendly traditional practices have much to offer the world in terms of perspectives in sustainability for the future. Much of India's future needs of carbon space is based on the requirements of essential production rather than consumption. This is in contrast to the developed countries whose requirements are being driven by continuing, extensive consumption patterns.

1.14 India's satellite based environmental monitoring system

India has developed an indigenous capability to launch various satellites in the required orbit using PSLV, GSLV and GSLV Mk-II class of vehicles. These satellites cater to remote sensing, meteorological, communication and navigational applications. It has also launched IRS series of the satellites with multi-tier imaging suite of sensors which are extensively used in supporting various activities including climate studies.

The three-tier imaging (LISS-III, IV & AWiFS) of IRS series of satellites provides multispectral data at various spectral, spatial and temporal resolutions for natural resources management and operational activities at different levels. Radar Satellite-1 (RISAT-1) carrying a Synthetic Aperture Radar (SAR) Payload operating in C-band (5.35 Ghz) enables applications in agriculture, particularly paddy monitoring in Kharif season and management of natural disasters like flood and cyclone.

A variety of ocean and weather forecasting system is in place, with special emphasis on satellite data assimilation. The storm surge prediction, advanced ocean state prediction (wave component), advanced ocean state prediction (circulation component) and seasonal prediction of El Nino using ocean-atmosphere coupled model are carried out in ocean applications. ISRO has developed sophisticated satellite data assimilation techniques using INSAT-3D/3R, SCATSAT-1, Megha Tropiques, SARAL/AltiKa, apart from international satellite observations.

INSAT-3D carries 18-channel Infrared Sounder (plus a visible channel). It is used for retrieving vertical profiles of atmospheric temperature and moisture along with total column ozone content in the atmosphere. INSAT-3DR similar to INSAT-3D is an advanced meteorological satellite of India configured with an imaging System and an Atmospheric Sounder. INSAT-3DR provides spatio-temporal analysis of meteorological events, and a variety of geophysical products are generated from INSAT-3D/3DR data which are used for ocean and atmospheric applications. Imager observations in TIR1, TIR2 and WV channels combined with Numerical Weather Prediction (NWP) forecasts are used for high spatial-temporal resolution rainfall estimates. Sea surface temperature is also derived from split thermal window channels.

INSAT-3D with imager data of 4x4 km in MIR, TIR1 and TIR2 helps in detecting and monitoring of large scale forest fires which are critical elements of forest fire management system in India. Aerosols can be detected using imager data in optical bands from INSAT-3D. Aerosols play an important role in numerous aspects of human life. Increasing trend in aerosol optical depth is observed at many locations in recent decades. Aerosols reduce atmospheric transparency to solar radiation (direct effect) and also affect cloud droplet formation (indirect effect).

Achievements of Indian Space Research Organisation (ISRO)

ISRO scripted history by successfully launching a record 104 satellites on 15th February, 2017, including India's earth observation satellite, on a single rocket (Polar Satellite Launch Vehicle-PSLV-37) from the spaceport in Satish Dhawan Space Centre SHAR, Sriharikota of Andhra Pradesh, India. It was the thirty-eighth consecutive successful mission of PSLV. It included Cartosat-2 Series Satellite along with 103 co-passenger satellites. Of the 103 co-passenger satellites, ISRO Nano Satellite-1 and 2 were technology demonstration satellites from India while the remaining 101 co-passenger satellites were international customer satellites from USA (96), The Netherlands (1), Switzerland (1), Israel (1), Kazakhstan (1) and UAE (1).

ISRO is committed to provide the satellite based navigation services to meet the emerging demands of the civil aviation sector and to meet the user requirements of positioning, navigation and timing based on the independent satellite navigation system. To meet the civil aviation requirements, ISRO is working jointly with Airport Authority of India (AAI) in establishing the GPS Aided Geo Augmented Navigation (GAGAN) which is a Satellite Based Augmentation System (SBAS). The system has capacity for interoperability with other international SBAS systems

and provides seamless navigation across regional boundaries. The GAGAN Signal-In-Space (SIS) is available through GSAT-8 and GSAT-10.

To meet the user requirements of the positioning, navigation and timing services based on the indigenous system, ISRO is establishing a regional satellite navigation system called Indian Regional Navigation Satellite System (IRNSS). This is an independent Indian Satellite based positioning system for critical national applications. The main objective is to provide Reliable Position, Navigation and Timing services. The IRNSS constellation was named as "NavIC" (Navigation with Indian Constellation) and dedicated to the nation. Some of the applications of NavIC include Terrestrial, Aerial and Marine Navigation, Disaster Management, Vehicle tracking and fleet management, Integration with mobile phones, Precise Timing, Mapping and Geodetic data capture, Terrestrial navigation aid for hikers and travellers and Visual and voice navigation for drivers.

GSAT-9, a Geostationary Communication satellite, provides various communication applications in South Asian countries. It was launched by GSLV-F09 on 5th May, 2017. The satellite will also be used for supporting applications that include Disaster Management Support, Broadcast of Meteorological Data, Networking of academic, scientific and research institutions.

Mass Orbiter Mission (MOM) was India's first venture into the interplanetary space. MOM explored and observed Mars surface features, morphology, mineralogy and the Martian atmosphere. MOM was launched on 5th November 2013 from Satish Dhawan Space Centre, Sriharikota. After Earth-bound Orbit raising manoeuvres, the Trans Mars Injection manoeuvre was successfully conducted to set the course of the spacecraft towards Planet Mars through a Sun-centric trajectory.

AstroSat was the first dedicated Indian astronomy mission aimed at studying celestial sources in X-ray, optical and UV spectral bands simultaneously. It was launched on 28th September, 2015. One of the unique features of the AstroSat mission is that it enables the simultaneous multi-wavelength observations of various astronomical objects with a single satellite.

High Performance Computing (HPC) augmentation in India

The Ministry of Earth Sciences has augmented its HPC facility to 6.8 Peta Flops (PF) which has been installed at two of its constituent units, namely, Indian Institute of Tropical Meteorology (IITM), Pune with 4.0 PetaFlops capacity and National Centre for Medium Range Weather Forecasting (NCMRWF), Noida with 2.8 PetaFlops capacity. The HPC facility 'Pratyush' at IITM was dedicated to the nation on 8th January 2018.

The HPC system will be a national facility for improving weather/climate forecasts and services of India. The Ministry of Earth Sciences has developed several services for societal benefits catering to a variety of sectors of the economy by building state-of-the-art systems for multi-hazard risk reduction from cyclones; floods/droughts; heat/cold waves; earthquakes; tsunamis.

Earth system model

The Indian Institute of Tropical Meteorology (IITM) at Pune has developed Earth System Model (IITM-ESM) to address the science of climate change, including detection, attribution and future projections of global climate, with special emphasis on the South Asian monsoon. IITM-ESM is the first climate model from India participating in the Coupled Model Intercomparison Project phase 6 (CMIP6) experiments for contributing to the forthcoming IPCC Sixth Assessment Report (Swapna et al., 2018).

References

CEM. (2014). Accessing and accelerating electric vehicle deployment in India. Clean Energy Ministerial and Electric Vehicles Initiative.

Census. (2011). Census of India. Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India.

CMFRI. (2018). CMFRI Annual Report 2017-18. Technical Report. Kochi, India: Central Marine Fisheries Research Institute.

CRED, & UNISDR. (2018). Economic losses, poverty & disasters: 1998-2017. United Nations Office for Disaster Risk Reduction (UNISDR) & Centre for Research on the Epidemiology of Disasters (CRED). Retrieved from https://www.unisdr.org/files/61119_credeconomiclosses.pdf

Das, P. K., Dutta, D., Sharma, J. R., & Dadhwal, V. K. (2016). Trends and behaviour of meteorological drought (1901–2008) over Indian region using standardized precipitation–evapotranspiration index. International Journal of Climatology, 36(2), 909–916. https://doi.org/10.1002/joc.4392

DoAHDF. (2016). Annual Report 2016-17. Department of Animal Husbandry, Dairying & Fisheries, Ministry of Agriculture

and Farmers Welfare, Government of India. Retrieved from http://dahd.nic.in/sites/default/files/Annual%20Report%202016-17.pdf

DoF. (2017). Annual Report 2016-17. Department of Fertilizers, Ministry of Chemicals and Fertilizers, Government of India. Retrieved from http://fert.nic.in/sites/default/files/Annual_Report_2016-2017_English%20.pdf

FSI. (2017). India State of the Forest Report 2017. Forest Survey of India, Ministry of Environment, Forests and Climate Change, Government of India.

GoI. (2015). India's intended nationally determined contribution: Working towards climate justice. UNFCCC. Retrieved from http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

GSI. (2018). Indian Coal and Lignite Resources - 2018 (Natural Energy Resources, Mission-II B). Geological Survey of India, Government of India.

Guhathakurta, P., Rajeevan, M., Sikka, D. R., & Tyagi, A. (2015). Observed changes in southwest monsoon rainfall over India during 1901–2011. International Journal of Climatology, 35(8), 1881–1898. https://doi.org/10.1002/joc.4095

IEA. (2015). India energy outlook: World energy outlook special report. Paris: International Energy Agency.

IMD. (2010). Changes in extreme rainfall events and flood risk in India during the last century (No. National Climate Centre Research Report No. 3/2010). India Meteorological Department, Ministry of Earth Sciences, Government of India.

IPCC. (2014). Climate change 2014: Synthesis report. Contribution of Working Groups I, II and III to the fifth assessment report of the intergovernmental panel on climate change [core writing team, R. K. Pachauri and L. A. Meyer (eds)] (p. 151). Geneva, Switzerland: Intergovernmental Panel on Climate Change.

Livestock Census. (2012). 19th Livestock Census 2012: All India Report. Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture, Government of India.

MHA. (2017). Sample Registration System Statistical Report 2014. Office of the Registrar General & Census Commissioner, Ministry of Home Affairs, Government of India.

MoAFW. (2016). Agricultural Statistics At A Glance 2016. Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

MoAFW. (2017a). Annual Report 2016-17. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture.

MoAFW. (2017b). Pocket Book of Agricultural Statistics 2017. Department of Agriculture, Cooperation & Farmers Welfare, Ministry of Agriculture.

MoAFW. (2018). Cultivable Area Under Irrigation. Lok Sabha Unstarred Question No. 2350. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India.

MoF. (2016). Growth of GDP. Lok Sabha Unstarred Question No. 4113. Ministry of Finance, Government of India.

MoF. (2017). Economic Survey 2016-17. Department of Economic Affairs, Ministry of Finance, Government of India. Retrieved from http://indiabudget.nic.in/es2016-17/echapter.pdf

MoF. (2018). Economic Survey 2017-18. Department of Economic Affairs, Ministry of Finance, Government of India.

MoHUA. (2017). Status of Unemployment. Lok Sabha Unstarred Question No. 6342. Ministry of Housing and Urban Affairs.

MoLE. (2017). Present rate of unemployment. Rajya Sabha Unstarred Question No. 4566. Ministry of Labour and Employment.

MoMSME. (2017). Employment in MSME Sector. Lok Sabha Unstarred Question No. 5971. Ministry of Micro, Small and Medium Enterprises.

MoPNG. (2018). Indian Petroleum & Natural Gas Statistics 2017-18. Economic and Statistics Division, Ministry of Petroleum and Natural Gas.

MoSPI. (2017a). AGRICULTURE: Statistical Year Book India 2017. Ministry of Statistics and Programme Implementation.

MoSPI. (2017b). Statistical Year Book India 2017. Ministry of Statistics and Programme Implementation. Retrieved from http://www.mospi.gov.in/statistical-year-book-india/2017

MoSPI. (2018a). Annual and Quarterly Estimates of GDP at constant prices, 2011-12 series. Ministry of Statistics and Programme Implementation. Retrieved from http://mospi.nic.in/data

MoSPI. (2018b). Energy Statistics 2018. Ministry of Statistics and Programme Implementation, Government of India.

MoSPI. (2018c). Highlights of Provisional Estimates (PE) of GDP, 2017-18 and Estimates of GDP for the Fourth Quarter, January-March (Q4), 2017-18 (No. Ministry of Statistics and Programme Implementation). Press Information Bureau, Government of India.

MoUD. (2016). Handbook of Urban Statistics. Ministry of Urban Development, Government of India.

MoWR. (2016a). Availability of Water. Lok Sabha Starred Question No. 380. Ministry of Water Resources, River Development and Ganga Rejuvenation.

MoWR. (2016b). Implementation of water policy. Rajya Sabha Unstarred Question No. 1661. Ministry of Water Resources, River Development and Ganga Rejuvenation.

MoWR. (2016c). Irrigation facilities. Lok Sabha Unstarred Question No. 4340. Ministry of Water Resources, River Development and Ganga Rejuvenation.

MoWR. (2016d). Ministry of Water Resources, River Development and Ganga Rejuvenation: E-Book 2015-16. Ministry of Water Resources, River Development and Ganga Rejuvenation.

MoWR. (2016e). Storage Capacity of Reservoirs. Lok Sabha Unstarred Question No. 4358. Ministry of Water Resources, River Development and Ganga Rejuvenation.

NDDB. (2016). Annual Report 2015-16. National Dairy Development Board, Government of India. Retrieved from http://www.nddb.org/sites/default/files/NDDB_AR_2015-16Eng.pdf

NITI Aayog. (2016). Eliminating poverty: Creating jobs and strengthening social programs. National Institution for Transforming India, Government of India.

NSSO. (2015). Energy sources of Indian households for cooking and lighting, 2011-12 (Report No. 567). National Sample Survey Office, Ministry of Statistics & Programme Implementation. Retrieved from http://mospi.nic.in/sites/default/files/publication_reports/nss_report_567.pdf

Pai, D. S., Nair, S. A., & Ramanathan, A. N. (2013). Long term climatology and trends of heat waves over India during the recent 50 years (1961-2010). Mausam, 64(4), 585–604.

Pai, D. S., Sridhar, L., Rajeevan, M., & Mukhopadhyay, B. (2014). Development of a new high spatial resolution (0.25° × 0.25°) long period (1901-2010) daily gridded rainfall data set over India and its comparison with existing data sets over the region. Mausam, 65(1):1-18. Retrieved from https://www.researchgate.net/publication/287868289_Development_of_a_new_high_spatial_resolution_025_025_long_period_1901-2010_daily_gridded_rainfall_data_set_over_India_and_its_comparison_with_existing_data_sets_over_the_region

PIB. (2018). First Advance Estimates of National Income, 2017-18. Press Information Bureau, Government of India.

Rangarajan, C., Dev, S. M., Sundaram, K., Vyas, M., & Datta, K. L. (2014). Report of the Expert Group to Review the Methodology for Measurement of Poverty. Planning Commission, Government of India. Retrieved from http://planningcommission.nic.in/reports/genrep/pov_rep0707.pdf

Rohini, P., Rajeevan, M., & Srivastava, A. K. (2016). On the Variability and Increasing Trends of Heat Waves over India. Scientific Reports, 6(1). https://doi.org/10.1038/srep26153

Swapna, P., Jyoti, J., Krishnan, R., Sandeep, N., & Griffies, S. M. (2017). Multidecadal Weakening of Indian Summer Monsoon Circulation Induces an Increasing Northern Indian Ocean Sea Level. Geophysical Research Letters, 44(20), 10,560-10,572. https://doi.org/10.1002/2017GL074706

Swapna, P., Krishnan, R., Sandeep, N., Prajeesh, A. G., Ayantika, D. C., Manmeet, S., & Vellore, R. (2018). Long-Term Climate Simulations Using the IITM Earth System Model (IITM-ESMv2) With Focus on the South Asian Monsoon. Journal of Advances in Modeling Earth Systems, 10(5), 1127–1149. https://doi.org/10.1029/2017MS001262

United Nations. (2015). Paris Agreement. United Nations Framework Convention on Climate Change. Retrieved from http://unfccc.int/files/essential_background/convention/application/pdf/english_paris_agreement.pdf

Unnikrishnan, A. S., Gangan, N., & Lengaigne, M. (2015). Sea-level-rise trends off the Indian coasts during the last two decades. Current Science, 108, 966–971.

Unnikrishnan, A. S., & Shankar, D. (2007). Are sea-level-rise trends along the coasts of the north Indian Ocean consistent with global estimates? Global and Planetary Change, 57(3), 301–307. https://doi.org/10.1016/j.gloplacha.2006.11.029

21% reduction
in emission intensity of GDP over the period 2005–2014

Chapter 2

National GHG Inventory

Chapter 2: National Greenhouse Gas Inventory

This chapter provides an update to the national GHG inventory by sectors as per the Biennial update reporting guidelines for Non-Annex I Parties. As required by the guidelines, the national inventory is prepared in accordance with the paragraphs 8-24 of the annex to decision 17/CP.8 meant for reporting of National Communications (NC) from Non-Annex I Parties to the United Nations Framework Convention on Climate Change (UNFCCC). The update is consistent with capacities, time constraints, data availabilities and the level of support received for reporting.

In this chapter, a detailed description of the greenhouse gas (GHG) inventory of the emissions of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6) by sources and their removal by sinks has been presented for the year 2014. The sectors covered include Energy, Industrial Processes and Product Use (IPPU), Agriculture, Land Use, Land-Use Change and Forestry (LULUCF) and Waste. The chapter also presents an account of the methodologies used, the quality assurance/quality control (QA/QC) measures applied, the results of the key category analysis, and approach-I quantification of the uncertainties associated with the estimates. A consistent time series of GHG inventory for the period of 2000-2014 is provided. A summary information table of inventories for previous submission years (i.e. for 1994, 2000 and 2010), as reproduced from previous submissions has also been included. India has used Revised 1996 IPCC Guidelines and also the 2006 IPCC guidelines for GHG Inventories to the extent possible as per extant capacities. There are some technological and capacity building challenges, constraints and gaps that have been highlighted in chapter 5 of this report.

2.1 Institutional Arrangement for inventory preparation

Eleven Indian institutions carried out the inventory preparation exercise in the areas of their respective sectoral expertise. Many of these institutions / experts have been part of the inventory preparation exercise since India's Initial National Communication. Various Ministries and Government Departments, Public sector undertakings provided inputs for preparation of the national inventory. Figure 2.1 gives an outline of institutions engaged in inventory preparation in different sectors.

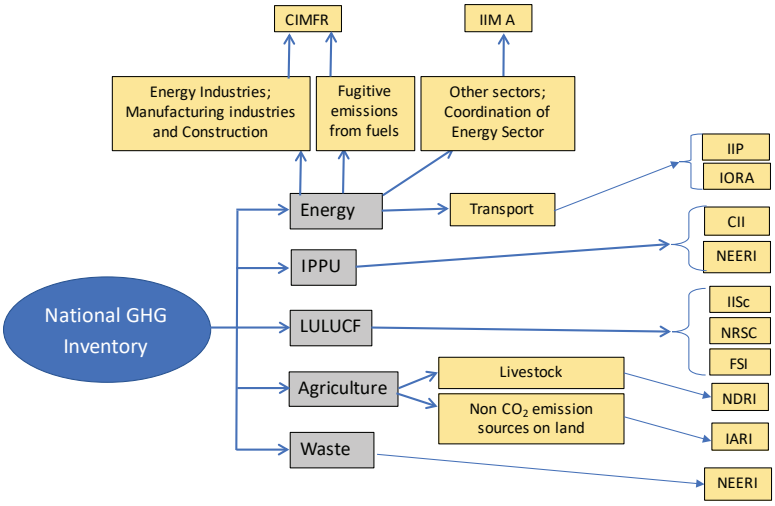


Figure 2.1 Institutions involved in GHG Inventory preparation

2.2 Methodology of inventory preparation

The IPCC guidelines (Revised 1996 and 2006) provide detailed estimation methodology for all the sectors. The tiers of estimates range between Tier 1 and Tier 3 (Figure 2.2). Both default and country-specific emission factors have been employed and are reflected in Table 2.1 for corresponding categories and gases. The table presents a summary of methodological choices for estimating emissions and removals of greenhouse gases from different source/sink categories.

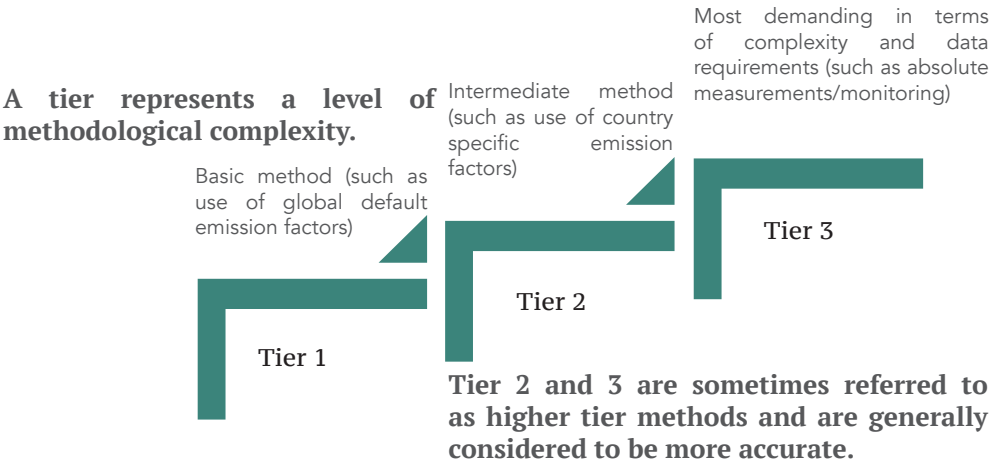


Figure 2.2: Methodology approaches: Tier levels

Table 2.1: Methodological choices in BUR-2

Type of Emission Factor and Level of Methodological Tier Employed for GHG Estimation						
Gas	CO_2		CH_4		N_2O	
Sector/ Category	Method used	Emission Factor	Method used	Emission Factor	Method used	Emission Factor
1. Energy						
A. Fuel Combustion Activities						
1. Energy Industries	T1, T2, T3	D, CS	T1	D	T1	D
2. Manufacturing Industries & Construction	T1, T2, T3	D, CS	T1	D	T1	D
3. Transport	T1, T2	D, CS	T1	D	T1	D
4. Other sectors	T1, T2	D, CS	T1	D	T1	D
B. Fugitive Emission from fuels						
1. Solid fuels			T2, T3	CS		
2. Oil and Natural gas			T1	D		
2. Industrial Process and Product Use						
A. Mineral Industry	T1, T2	D, CS				
B. Chemical Industry	T1, T2	D, CS	T1	D	T1, T2	D, CS
C. Metal Industry	T1, T2	D, CS	T1	D	T1	D
D. Non-energy products	T1	D	T1	D	T1	D
E. Production of halocarbons	T1	D	T1	D	T1	D
3. Agriculture						
A. Enteric Fermentation			T1, T2	D,CS		
B. Manure Management			T1	D	T1	D
C. Rice Cultivation			T2	CS		
D. Agricultural Soils					T2	CS
F. Field Burning of Agricultural Residues			T1	D	T1	D
4. LULUCF						
A. Forest land	T2	CS	T2	D, CS	T2	D, CS
B. Cropland	T2	CS				
C.Grassland	T2	CS				
D. Settlement	T2	CS				

5. Waste						
A. Solid waste disposal on land			T2	D, CS		
B. Wastewater handling			T1, T2	D, CS	T1, T2	D, CS
Memo Item (not accounted in total Emissions)						
International Bunkers	T1	D	T1	D	T1	D
CO_2 from Biomass	T1, T2	D, CS				
T1- Tier 1; T2- Tier 2; T3- Tier 3; CS- Country Specific; D- IPCC Default						

In accordance with the decision 17/CP.8, the aggregated GHG emissions and removals have been expressed in CO_2e using the Global Warming Potentials (GWP) provided by the IPCC in its Second Assessment Report based on the effects of GHGs over a 100-year time horizon. The GWPs are listed below:

Carbon dioxide	1
Methane	21
Nitrous Oxide	310
HFC- 23	11,700
Perfluoromethane	6,500
Perfluoroethane	9,200
Sulphur hexafluoride	23,900

2.3 Quality Assurance, Quality Control and validation

The sources of uncertainty in the preparation of GHG inventory arise from the underlying activity data and emission factors. Activity data available from government sources have been used for the estimates which have been substantiated from other data sources for cross-verification wherever possible. In case of non-availability of the calendar year's data, financial year (April to March) data of relevant years were used to arrive at the calendar year data. Due care was taken to avoid introduction of errors. Other types of errors arise from the Emission Factors or their components, such as Net Calorific Value (NCV) and Carbon Emission Factor (CEF) values of different fuel types. Country-specific NCVs and CEFs for different coal categories and those depicting sector specific values of non-coking coals have been used in this exercise for some key sources *viz*. Electricity production, Cement, Fertilizer, Nonferrous Metal, Pulp and Paper. This reduces the uncertainty in estimations as compared to the Second National Communication. For the rest of the sectors, country-specific NCV-CEF values of non-coking coal were utilized. Quality Assurance/Quality Control (QA/QC) approach was developed, taking into consideration the quality of the data, the time constraints and capacity. The procedures include cross-checking the reliability of the activity data collected from the secondary sources for proper documentation, cross-checking for transcription errors in the activity data, consistency of data as well as completeness and integrity of the database. The activity data were sourced from different ministries, government departments, industry associations, and remote sensing agency. QC is already integrated into the data sets of respective organizations. Sector-specific QC approaches were employed by concerned expert institutions. QA was conducted for the sectoral inventory estimates through experts and institutions that were not part of the inventory estimation process, and also validation through independent studies, for instance for methane estimation done as below.

A paper published in Nature Communications (Ganesan et al., 2017) investigated India's methane emissions using a top-down approach and concluded that the magnitude of India's methane emissions was consistent with that reported in First BUR. Top-down CH_4 emission estimations over India during 2010-2015 (Ganesan et al., 2017), come from five different observational sources over India: i) Satellite retrievals from the GOSAT platform: Data from the Greenhouse Gases Observing Satellite (GOSAT) was retrieved at National Centre for Earth Observation, UK. It has been providing column average dry-air mole fractions of methane (XCH_4) near-global coverage since its launch in January 2009 (Parker et al., 2015). The ground-based measurements of XCH_4 by Total Carbon Column Observing Network (TCCON) (Wunch et al., 2011) are used to validate GOSAT retrievals but no such validation was performed over India. Comparisons were instead made using surface mole fraction observations, which offer higher sensitivity to surface emissions than satellite retrievals but often with less spatial coverage. ii) Surface CH_4 mole fraction observations at Sinhagad (SNG) mountain site near Pune India: Sinhagad (18.35°N, 73.75°E, elevation = 1600 meter above surface level), is located 200 km east of Arabian Sea, over the Western Ghats mountains near Pune. Sinhagad observational site came in operation in November 2009 and greenhouse gas monitoring is performed on a weekly interval using flask-based sample collection method (Tiwari et al., 2014). Air samples collected at Sinhagad are analysed at an analytical laboratory located at the Indian Institute of Tropical Meteorology, Pune. The measurements at Sinhagad are traceable to the World Meteorological Organization

(WMO) standard scale. Calibration standards are provided by the WMO Central Calibration Laboratory (CCL) located at the National Oceanic and Atmospheric Administration (NOAA)/Earth System Research Laboratory (ESRL)/Global Monitoring Division (GMD), Boulder, Colorado, USA. iii) The coastal site at Cape Rama (CRI), Goa: Cape Rama (15.08°N, 73.83°E, elevation = 50 meter above surface level) is located closer to the shoreline at the south of Goa coast (Tiwari et al., 2011). Samples were collected at the weekly interval and were analysed at CSIRO Australia (Bhattacharya et al.,2009). Measurements were calibrated using international standards maintained at CSIRO. iv) High altitude mountain site at Darjeeling, India: Darjeeling (27.03°N, 88.25°E, 2200 above surface level) is high altitude hill station in the eastern Himalayas. The in-situ measurements were performed at a site located in relatively unpopulated area of Darjeeling (Ganesan et al., 2013). Inlet line to the instrument was installed at ten meter tower that was built on the roof of a four-story building. The measurements were calibrated using a standard at Scripps Institute of Oceanography (SIO), USA.) Upper-atmospheric *in-situ* measurements from the CARIBIC aircraft: Civil Aircraft for the Regular Investigation of the atmosphere Based on an Instrument Container (CARIBIC) uses a specially designed CH_4 monitoring instrument loaded on to Lufthansa passenger aircraft (Brenninkmeijer et al., 2007, Shuck et al., 2012). CARIBIC flights take place out of Frankfurt (Germany) to different parts of the globe. Ganesan et al., 2017 use CARIBIC CH_4 mole fraction data from flight passes over India. Measurements were made at cruise altitude. CH_4 mole fractions monitored during CARIBIC are traceable to WMO calibration standards supplied by NOAA Boulder Colorado, USA. Figure 2.3 represents a typical monthly sampling of data sources (GOSAT satellite retrievals (purple), CARIBIC aircraft flight path (light blue), surface sites Darjeeling (DJI), India (dark blue), Cape Rama (CRI) Goa, India (orange), Sinhagad (SNG) Pune, India (yellow). Further details, including above, are available in Ganesan et al., 2017.

The Lagrangian particle dispersion model NAME (Numerical Atmospheric dispersion Modelling Environment, Ryall et al., 1998, Jones et al., 2007) was used to provide the quantitative relationship between atmospheric mole fractions and emissions. NAME provides the history of air masses prior to arrival at a measurement point/time and thus, provides the sensitivity of each observation to the surface emissions field. NAME is driven by three-dimensional meteorological fields from the Unified Model. A statistical Bayesian data assimilation "inversion" framework was used to estimate the emissions that best match the observations. The method used is a hierarchical Bayesian Markov Chain Monte Carlo method, described in detail in Ganesan et al., 2014, Lunt et al., 2016 and Ganesan et al., 2017. Emissions along with boundary conditions to the modelling domain and uncertainty parameters were estimated at monthly time resolution. The majority of constraint in the inversion comes from the satellite data, owing to its spatial coverage over India, but additional sites were used to investigate sources of biases. Monthly CH_4 emissions from India are presented along with a 12-month running mean (Figure 2.4). Annual emissions are presented as the mid-point of the running mean each year. Top-down method estimated mean Indian emissions to be 22.0 Tg per year over the period 2010-2015. BUR-2 estimates mean Indian emissions to be 20 Tg per year over the period 2010-2014.

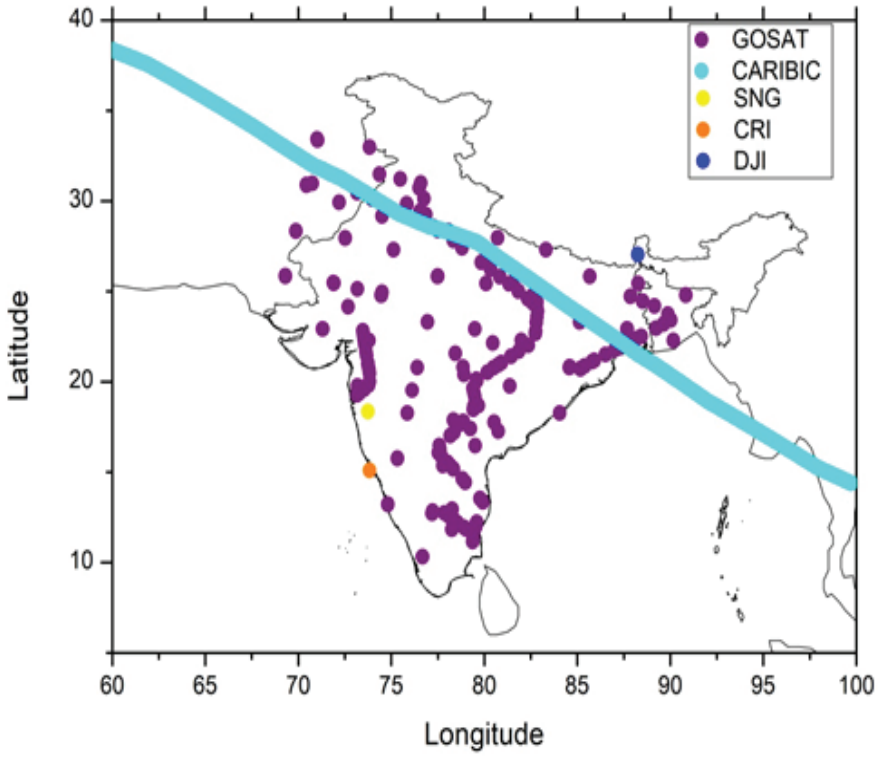


Figure 2.3: Map of observations used in top-down CH_4 estimations. Typical monthly coverage from GOSAT satellite retrievals (purple), CARIBIC aircraft flight path (light blue), surface site Darjeeling (DJI) India (dark blue), Cape Rama (CRI) Goa India (orange), Sinhagad (SNG) Pune India (yellow).

Top-down CH_4 emissions estimated by Ganesan et al. 2017; suggest that there is little growth in Indian emissions during the period 2010-2014. These results are strongly corroborated by BUR-2 inventories as well (black solid line in Figure 2.4). Also, these two estimated are 30% smaller than reported in the comprehensive global CH_4 inventory, Emissions Database for Global Atmospheric Research (EDGAR).

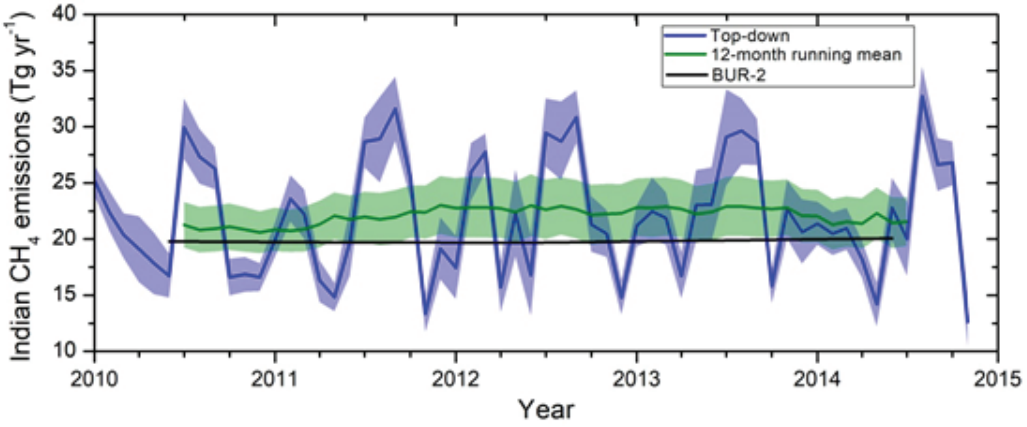


Figure 2.4: Comparison of India's top-down CH4 emissions with BUR-2. Top-down estimated CH4 emissions (as Tg yr^{-1}) (dark blue line). The green line and shading indicates a 12-month running mean of the top-down emissions. The black line corresponds to BUR-2 (Total with LULUCF).

Additionally, an assessment of loss rate of CH_4 over India is estimated based on MIROC4-ACTM model simulations (Figure 2.5). The observations of CH_4 concentrations from the remote background sites show large gradients between the northern and southern hemisphere (of about 130 ppb which is 8% of the global mean CH_4 concentration at 1700 ppb). This suggests the dominance of CH_4 emissions in the northern hemisphere. However, the removal of CH_4 from the atmosphere occurs mainly in the troposphere, up to 90%, due to the chemical reaction with hydroxyl (OH) radicals. OH is produced predominantly in the tropical atmosphere in the presence of water vapour and sunlight. Thus the removal of CH_4 takes place mainly in the tropical region. Using MIROC4-ACTM model simulations, CH_4 loss rate are estimated over India at 5.5 Tg/yr in year 2000 and 5.8 Tg/yr in 2016 (Patra et. al, 2014, 2016, 2018). This is about 1% of the global total loss rate in the period of 2000-2016, while the area of coverage was only about 0.73% of the globe.

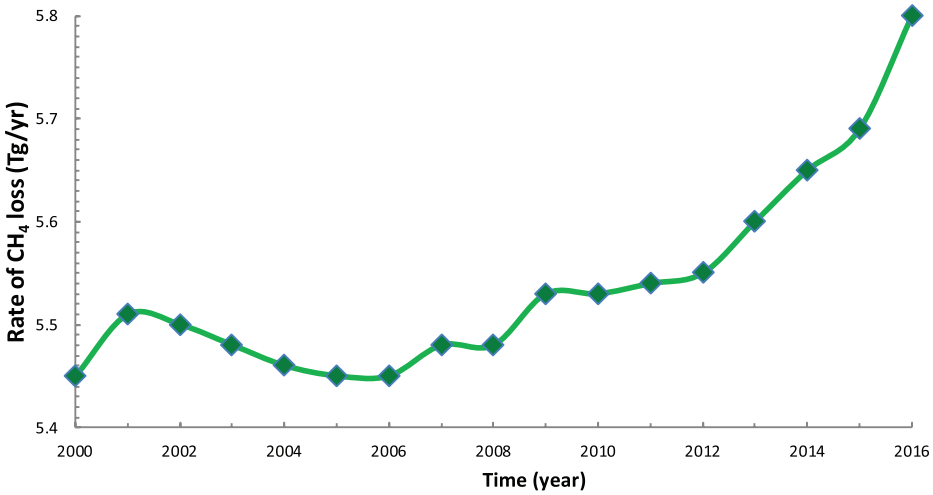


Figure 2.5: Rate of CH_4 loss approximately over the Indian domain (15.4-32.1°N, 73.1-87.2°E) covering an area of 3.71 M-km^2. The global surface area is 510 M-km^2 and the global CH_4 loss rate vary from 546 Tg/yr in 2000 to 579 Tg/yr in 2016.

2.4 National Greenhouse Gas Inventory in 2014

In 2014, India emitted 2,607,488.12 Gg of CO_2e (2,607.49 million tonne of CO_2e) greenhouse gases from Energy, IPPU, Agriculture and Waste sectors. LULUCF sector remained a net sink in 2014. Considering emissions and removals from LULUCF sector, net emissions were 23,06,295.43 Gg of CO_2e (2,306.3 million tonne of CO_2e). A summary of emissions and removals from these sectors has been presented in the Table 2.2. Figures 2.6 and 2.7 give distribution of GHG emissions sector-wise and gas-wise respectively. Figure 2.8 gives relative contribution of individual sectors in emission of different greenhouse gases.

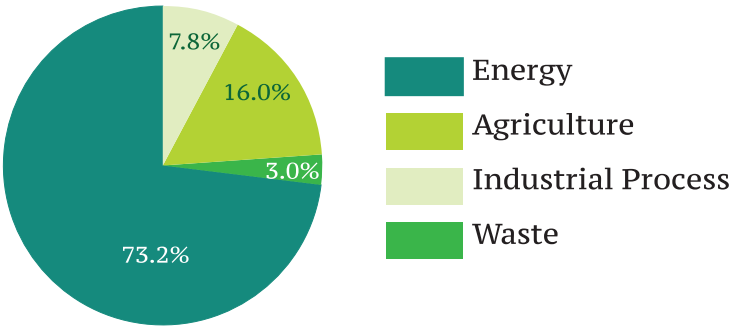


Figure 2.6: Distribution of GHG emissions (Gg CO_2e), by sector

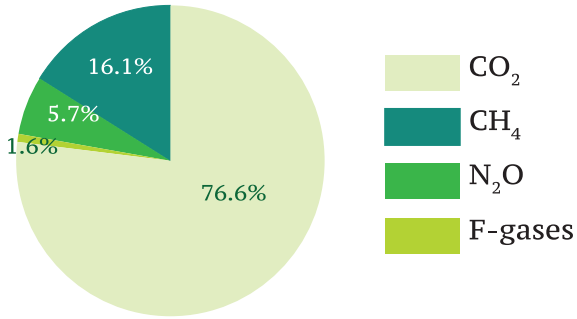


Figure 2.7: Distribution of emissions, by gas, 2014

Table 2.2: Summary table of greenhouse gas emissions (Gg), by sectors, 2014

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
TOTAL without LULUCF (Gg)	**19,97,891.85**	**-**	**20,005.35**	**475.29**	**1.59**	**2.61**	**0.71**	**0.004**	**26,07,488.12**
TOTAL with LULUCF (Gg)	**20,15,107.88**	**3,19,860.23**	**20,053.54**	**476.71**	**1.59**	**2.61**	**0.71**	**0.004**	**23,06,295.43**
1. ENERGY	18,44,705.03	-	2,133.37	65.35	-	-	-	-	19,09,765.74
2. IPPU	1,53,186.81	-	177.85	10.36	1.59	2.61	0.71	0.004	2,02,277.69
3. AGRICULTURE	-	-	14,709.78	349.39	-	-	-	-	4,17,217.54
4. LULUCF	17,216.04	3,19,860.23	48.19	1.42	-	-	-	-	-3,01,192.69
5. WASTE	-	-	2,984.35	50.18	-	-	-	-	78,227.15
Memo Item (not accounted in total Emissions)	**8,12,030.60**	**-**	**0.11**	**0.11**	**-**	**-**	**-**	**-**	**8,12,067.87**
International Bunkers	4,943.53	-	0.11	0.11	-	-	-	-	4,980.81
Aviation	3,681.65	-	0.03	0.1	-	-	-	-	3,714.12
Marine	1,261.88	-	0.08	0.01	-	-	-	-	1,266.69
CO_2 from Biomass	8,07,087.06	-	-	-	-	-	-	-	8,07,087.06

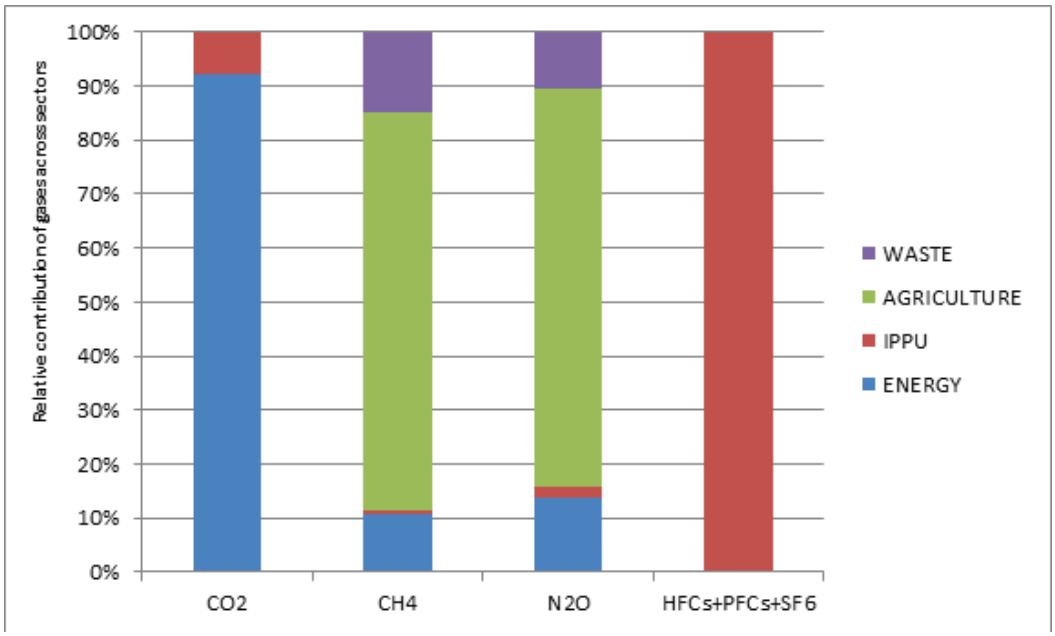


Figure 2.8: Relative contributions of individual sectors in greenhouse gas emissions (without LULUCF) for the year 2014

1 Energy

Overview of GHG Emissions from Energy Sector

The total emission from energy sector was 19,09,765.74 Gg CO_2e which contributed 73% to the total national GHG emissions (excluding LULUCF). Energy sector emitted 92% of the total national CO_2 emissions in 2014. This was predominated by fossil fuel combustion activities, comprising of energy industries, manufacturing industries, transport and other sectors, with 98% of total emissions from the energy sector. Fugitive emissions contributed 2% to the total GHG emissions from the energy sector. Figure 2.9 gives the relative distribution of GHG emissions across the energy sector.

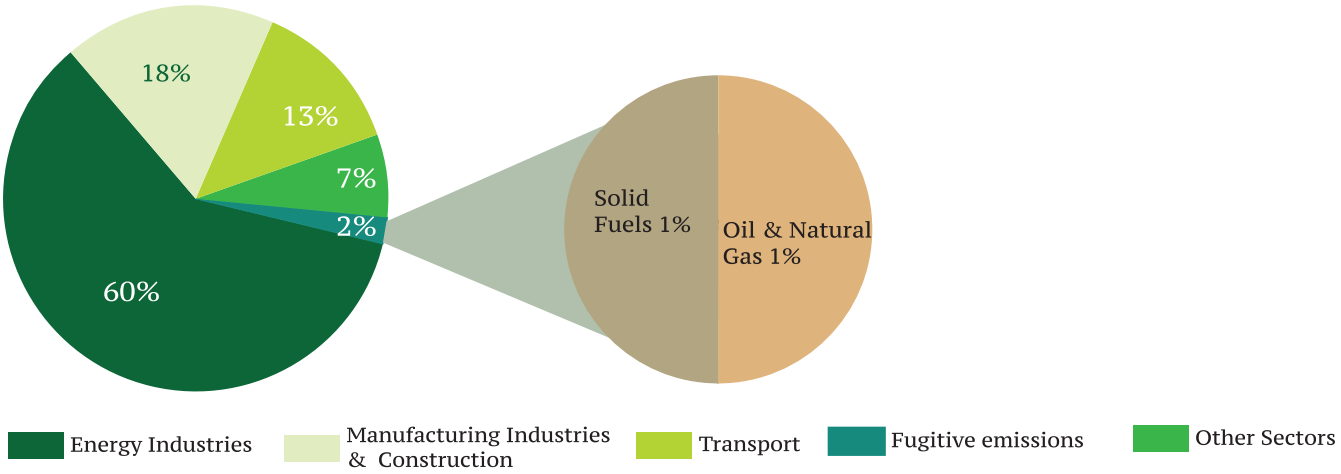


Figure 2.9: Distribution of CO_2e emissions (Gg) across the Energy Sector Categories in 2014

Comparison with reference approach

The reference approach was also used to estimate CO_2 emissions from fuel combustion for the year 2014. The difference in estimates of CO_2 emissions from fuel combustion using the sectoral and reference approaches was around 3.83%. The reference approach emissions were around 72% from solid fuel combustion, around 24% from liquid fuel and the remaining from gaseous fuel combustion. The main differences were in the estimation of solid fuel combustion. Owing to a minimal difference in the estimates of CO_2 emissions between the two approaches, the detailed explanation of the differences is not reported.

1A Fuel Combustion Activities

1A1 Energy Industries

Electricity production accounted for approximately 42% of the total national emissions without LULUCF in 2014. Within 'Energy' it is the predominant source and amounts to about 57% of emissions. Major fuels consumed in the power plants for electricity production in India are non-coking coal, natural gas (dry), lignite, diesel, residual fuel oil and naphtha. The consumption pattern of the aforesaid fuels in power sector has been shown in Figure 2.10

Coal consumption data has been sourced from Central Electricity Authority annual report (2013-14, 2014-15) and Ministry of Coal (Coal Directory). Captive power plants other than those belonging to the iron and steel sector are included in this sector (electricity and heat production). For iron & steel, fossil fuel use emissions are included in 1A2b. Imported coal, middlings, etc. have been considered during inventory preparation.

Fuel combustion activities emitted 18,71,709 Gg CO_2e in 2014 including 11,40,983 Gg CO_2e from Energy industries. Within Energy Industries, 94.96% of emissions were from electricity production, 4.39% from the refinery and 0.66% from manufacturing of solid fuels.

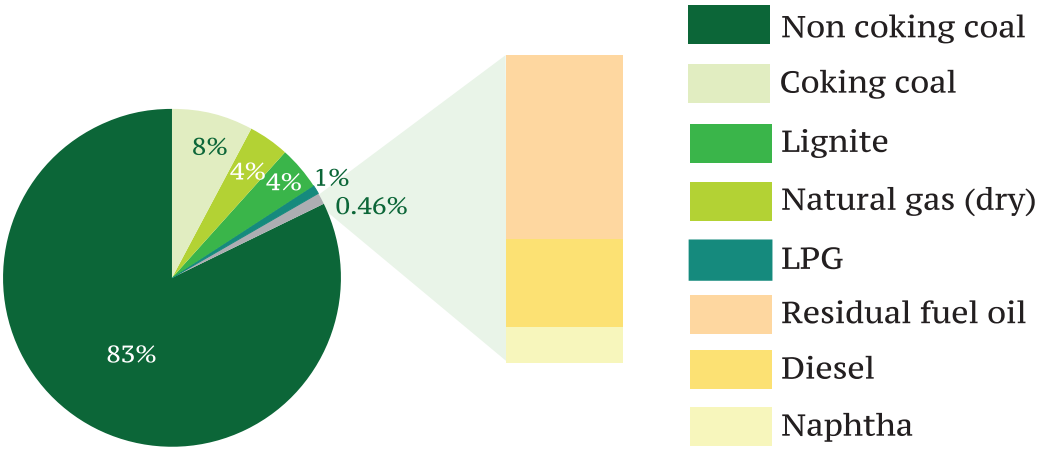


Figure 2.10: Share of fuel consumption for electricity production for the year 2014

1A2 Manufacturing Industries and Construction

The manufacturing industries and construction sector emitted 3,51,909.54 Gg CO_2e, which was approximately 18.4% of total CO_2e emissions from the energy sector. The sub-categories that share total contribution to the emission from the manufacturing industries are: Cement (13.4%), Iron & steel (44.0%), Non-ferrous metals (0.5%), Chemicals (0.6%), Pulp & paper (1.1%), Mining & quarrying (0.9%), Textile/leather (1.0%), Bricks (0.8%) Fertilizer (1.7%), Engineering Sector (0.1%), Non-specified industries (36.0%).

For the Cement sector, consumer end fuel consumption data was considered. Process emission data from the cement sector have been separately discussed in the section dealing with the IPPU sector. Sponge Iron industry is included in the Iron and Steel Industries of the Manufacturing Industries group. Non coking coal in 'Iron and Steel sector' includes boiler coal, coal for sponge iron industry and direct feed coal to Iron & Steel. Moreover, washed coals and middlings entering into this sector have also been accounted. Combustion of non-coking coal in captive power plants of iron & steel has been included in calculating energy-related emission from iron and steel sector and not included in the electricity production sector. Fuel consumption data in fertilizer industries have been taken from the delivery end data source. Any section of fuel which is not attributed in the given sectors, is allocated to Non-specified Industry.

Emission Factors in fossil fuel combustion

India specific emission factors (Net Calorific Value and Carbon Emission Factor) of coals were derived from the archived results of analysis of a large number of coal samples of different categories (coking coal, non-coking coal and lignite) that originated from different coal subsidiaries of India. Basic knowledge of coal science has been adopted for data analysis, data screening and in the evaluation process. Country-specific emission factors developed during SNC and sector-specific emission factors during BUR-1 have been utilized for estimations. New emission factors are under development (Figures 2.11, 2.12 and 2.13).

Figure 2.11: GCV determination of coal samples

Figure 2.12: Minister Dr. Harsh Vardhan observing operation of Proximate analysis of coal samples at CSIR-CIMFR, Dhanbad, India

Figure 2.13: A photograph of 2 x 525 MW Coal based Thermal Power Plant in India

Table 2.3 provides overall India specific net calorific values and carbon emission factors for coal. The country-specific values, mean Net Calorific Value (NCV) and Carbon Emission Factor (CEF) were derived for different coal categories. Sector-specific NCV and CEF were also derived for some key sectors. These NCVs and CEFs have been used in inventory preparation. The summary of some sector-specific and country specific NCVs and CEFs used is given in Table 2.4. For all other sectors, the country-specific NCVs & CEFs of non-coking coals were used.

Table 2.3: India specific conversion factors (NCV and CEF)

Coal Category	NCV(TJ/kt)	CEF(tC/TJ)
Coking	23.66	25.55
Non-coking	18.26	26.28
Lignite	9.80	28.90

Table 2.4: Sector specific NCV, CEF of non-coking coals allocated to different key sectors

Sector	NCV(TJ/kt)	CEF(tC/TJ)
Electricity	17.09	26.39
Cement	20.15	26.08
Fertilizer	20.40	26.06
Nonferrous metal	18.17	26.28
Pulp and paper	18.35	26.26

1A3: Transport—Road, railways, civil aviation, and water-borne navigation

Emissions from the transport sector are 2,50,172.79 Gg CO_2e which is about 12% of the total GHG emissions from the energy sector in the country for the year 2014. Road transport sector accounted for 90% of the total GHG emissions from the transport sector, followed by civil aviation (6%), railways (3%) and water borne navigation (1%). Fuel consumption data for road, aviation and navigation sectors have been sourced from the statistics provided by Mo PNG. For railways data has been sourced from the statistics published by the Ministry of Railways.

Road transport is the largest consumer of commercial fuel energy within the transportation system in India. Different fuel types are used in road transport sectors such as petrol, diesel, CNG, LPG and other minor fuel types like LDO (Light Diesel Oil) and FO (Fuel Oil).In addition, lubricants are also used for two-stroke engines. Off-road transportation (tractor segment) has also been accounted under road transport.

The Railways sector consumes electricity, diesel, petrol, FO and nominal coal amounts. To avoid double counting GHG emissions due to consumption of electricity in railways is not included but is covered under 1A1a in electricity generation category (1A1).

For Aviation sector, comprising of domestic and international aviation, segregated Aviation Turbine Fuel (ATF) consumption data for both the sectors is collected. The emission estimates made for the combustion of ATF in international aviation is reported separately as a memo item under international bunkers.

The Navigation sector emission estimates are based on fuel consumption (HSDO, LDO and FO) segregated across national and international maritime fleet. Emissions estimates made for international fleets is reported as memo item under marine bunkers separately.

1A4: Other sectors

Other sectors include commercial/institutional sector, residential sector and agricultural/fisheries sector. Cooking, lighting, space heating, space cooling, refrigeration, and pumping characterize the residential, commercial, and agriculture sectors included in this category. Fuels consumed are electricity (for lighting, heating, cooling, and pumping), liquefied petroleum gas (LPG; for cooking), kerosene (for lighting and cooking), diesel (for generating power for pumping and lighting),and coal, charcoal, and fuel wood (for cooking).This excludes the GHG emissions due to use of electricity which has been reported under 1A1a. The major fuels consumed in residential sector are firewood, LPG and kerosene. In 2014, the Other sectors together emitted 1,28,642.85 Gg of CO_2e, of which approximately two-third were contributed by the residential sector, about one fifth by the commercial sector and rest by the biomass burnt for energy (non-CO_2 GHGs) and agriculture /fisheries sectors put together.

1B. Fugitive emissions

Fugitive emissions are intentional or unintentional release of GHGs occuring during the extraction, processing and delivery of fossil fuels to the point of final use. The total fugitive emissions in the year 2014 were 38,057 Gg CO_2e, of which 43% was from coal mining and post mining operations and 57% was from oil and natural gas production and handling systems. Fugitive methane emission to the atmosphere has registered a decrease of 22% between 2010 and 2014.

1B1: Solid Fuels (Coal mining)

Methane is the major greenhouse gas emitted during coal mining and handling. For estimating methane emissions, activity data on coal production from opencast and underground mines were collected. Coal production data of underground mines are available under different categories viz. Degree I, II and III seams. The details are available district wise, state wise and on all India basis with the Statistics of Mines in India, Vol I (Coal) published by the Directorate General of Mines Safety (DGMS), Government of India for various years.

Emission Factors for fugitive emissions from coal mining

Emission factors for fugitive methane emission (underground and above ground mining) is the amount of methane generated per tonne of coal production. Several measurements were conducted for the determination of fugitive methane emission factor for coal mining and handling activities. The list of national emission factors for fugitive methane emission from coal mining and handling activities thus desired is presented in the Table 2.5. Estimates of methane emissions from mining activities are shown in Table 2.6.

Table 2.5: National emission factors for coal mining activities

Operation (Mining/ Post Mining)	Methane Emission Factor (m^3/tonne)			
	Surface Mining	Under Ground Mining		
		Degree - I	Degree - II	Degree - III
Mining	1.18	2.91	13.08	23.64
Post Mining (Handling)	0.15	0.98	2.15	3.12

Table 2.6: Methane emissions from mining activities in India (2014)

Operation	Emission Estimates (Gg CH_4)			
		Under Ground Mining		
	Surface	Degree - I	Degree - II	Degree - III
Mining	464.25	102.92	93.40	16.18
Post Mining (Handling)	59.02	34.66	15.35	2.13
Total				787.93

1B2: Oil and natural gas

The sources of fugitive emissions from oil and gas systems include, but are not limited to equipment leaks, evaporation and flashing losses, venting, flaring, incineration and accidental releases (e.g., pipeline dig-ins, well blow-outs and spills). While some of these emission sources are engineered or intentional (e.g., tank, seal and process vents and flare systems), and therefore relatively well characterized, the quantity and composition of the other emissions are generally subject to significant uncertainty.

For fugitive emissions from oil and natural gas handling activities such as production, processing, distribution and venting/flaring, the IPCC default values of methane emission factors have been used and estimated methane emission from oil and natural gas in India is presented in Table 2.7.

Table 2.7: Methane emissions (in Gg) from oil & gas in India (2014)

No. of Wells	Oil Production	Refinery Throughput	Gas Production	Gas Proce-ssing	Gas distri-bution	Leakage	Flaring	Total Methane Emission
51.46	12.55	15.06	121.27	354.73	291.55	177.16	0.54	1,024.31

2 Industrial Processes and Product Use

Overview of IPPU Sector Emissions

Industrial Processes and Product Use category emitted 202,277.69 Gg of CO_2e in the year 2014. Gas wise and sub category-wise distribution of emissions have been shown in the Figures 2.14 and 2.15 (a and b).

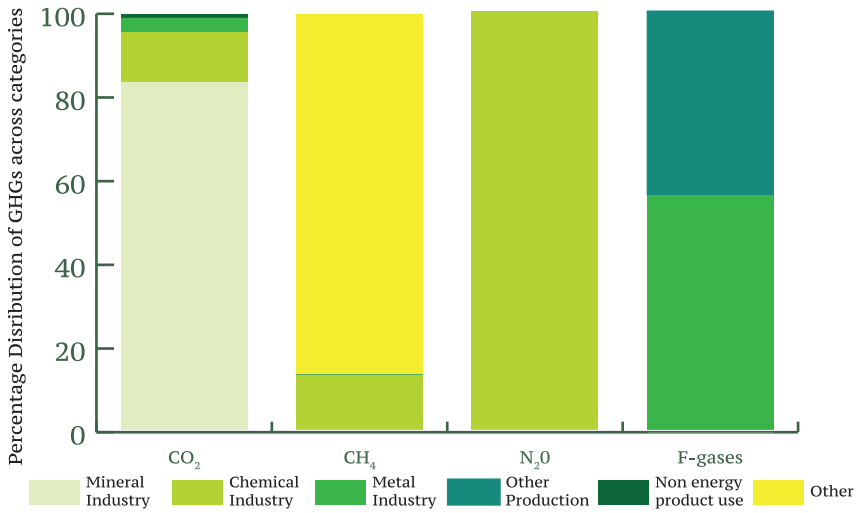


Figure 2.14: Distribution of CO_2e emissions across categories of IPPU sector in 2014 (Gg)

Non-energy greenhouse gas emissions that occur during the production processes and product use are estimated and reported under the category 'Industrial Processes and Product Use (IPPU)'. The category includes the emission estimates of CO_2, CH_4, N_2O, HFC-23, CF_4, C_2F_6, and SF_6.

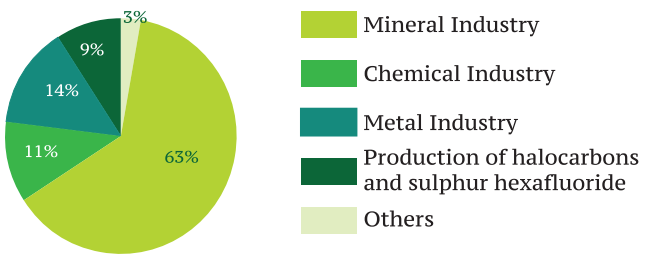


Figure 2.15 a: Sub-category wise distributions of GHG emissions in IPPU Sector in 2014

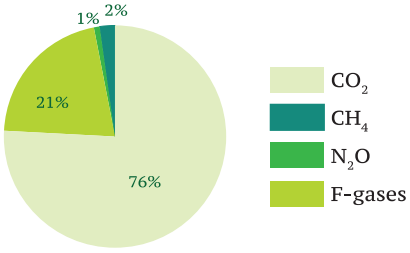


Figure 2.15 b: Gas wise distribution of emissions from IPPU sector in 2014

Methodology, Activity Data, and Emission Factors

For estimating GHG emissions from IPPU sector, 2006 IPCC Guidelines were employed. The activity data for the various industries are sourced from national statistical organizations, the annual reports of ministries of the Government of India, from listed companies, research organizations, trade magazines, and directly from various Industry associations in that order of priority.

2A Mineral Industries

In this section, process-related carbon dioxide (CO_2) emissions resulting from the use of carbonate raw materials in the production and use of a variety of mineral industry products are accounted. There are two broad pathways for release of CO_2 from carbonates: calcination and the acid-induced release of CO_2. The process related CO_2 equivalent emissions for the year 2014 from Cement, Lime, Glass and Ceramics are 115,341.60 Gg, 11,124.66 Gg, 372.00 Gg and 17.53 Gg respectively.

According to Indian Mineral Yearbook 2015, about 97% of the total production of limestone during 2014-15 was of cement grade, 2% of iron & steel grade and the rest 1 % consisted of chemical and other grades. GHG emissions associated with use of limestone in cement manufacturing sector, have been accordingly apportioned to avoid any double counting.

Activity data associated with the production of Float and Sheet Glass (which is primarily soda lime glass but contains relatively minor quantities of speciality borosilicate) and Bottle and Glassware (including both flint and amber glass) was considered for estimating GHG emissions from 'Glass' sector.

2B Chemical Industries

Production of various organic and inorganic Chemicals leads to greenhouse gas emissions which occur as a by-product of chemical transformation of raw materials. As per the estimations, Chemical industries emitted 22,174.88 Gg of CO_2 equivalent in 2014, with major contribution from ammonia manufacturing. CO_2 emission from ammonia production was 10,226.82 Gg CO_2 in 2014. Company/Plant specific emission factors have been used for most of the Nitric Acid production plants. N_2O emissions from Nitric Acid production in 2014 was 9.58 Gg. Caprolactam can be manufactured from various raw-materials like phenol, benzene, toluene, ammonia, sulfuric acid, or hydrogen depending on the process route followed. Caprolactam production emitted 0.779 Gg N_2O in 2014. In India, Soda Ash is produced mainly by Solvay's Process. Country specific emission factor was used to estimate emissions from this sector. Amount of CO_2 emitted from Soda Ash production in 2014 was 798.85 Gg.

2C Metal Industries

Emissions occurring from production process of Aluminium, Ferroalloys, Lead, Zinc and Magnesium have been accounted under the metal industries as per IPCC 2006 guidelines. Metallurgical coke related process emission in Iron & Steel making have been reported under the Energy sector. The total CO_2 equivalent emissions from metal industries for the 2014 are 29,242.38 Gg. Magnesium production is the single estimated source of SF_6 for 2014, emitting 100.4 Gg CO_2e.

2D Non-Energy Product Use

This section estimates emissions from first use of fossil fuels as a product for primary purposes other than i) combustion for energy purposes and ii) use as feedstock or reducing agent. The products covered here comprise lubricants and paraffin waxes.

Lubricants are mostly used in industrial and transportation applications. The use of lubricants in engines is primarily for their lubricating properties, and associated emissions are therefore considered as non-combustion emissions to be reported in the IPPU Sector. In India, the lubricant market is dominated by the transportation sector. The total CO_2 emissions resulting from lubricant use in 2014 were 1,950.8 Gg.

Products included under waxes are petroleum jelly, paraffin waxes, and other waxes, including ozokerite (mixtures of saturated hydrocarbons). Paraffin waxes are separated from crude oil during the production of light (distillate) lubricating oils. These waxes are categorized by oil content and the amount of refinement. Paraffin waxes are used in applications such as making candles and corrugated boxes, paper coating, board sizing, food production, wax polishes, surfactants (as used in detergents), and many others. Emissions from the use of waxes result primarily when the waxes or derivatives of paraffins are combusted during use (for example, candles), and when they are incinerated with or without heat recovery or in waste water treatment (for surfactants). Total GHG emission from the paraffin wax for non-energy purposes was 222.6 Gg CO_2e in 2014.

2E Production of halocarbons

This section estimates emission from production of halocarbons which generated 1.587 Gg HFC23 in 2014.

3 Agriculture

Overview of Agriculture Sector Emissions

In the year 2014, the agriculture sector emitted 417,217.54 Gg CO_2e, of which 74% was methane, and 26% was nitrous oxide. GHG emissions from various sub-sectors of the agriculture sector are illustrated in Figure 2.16.

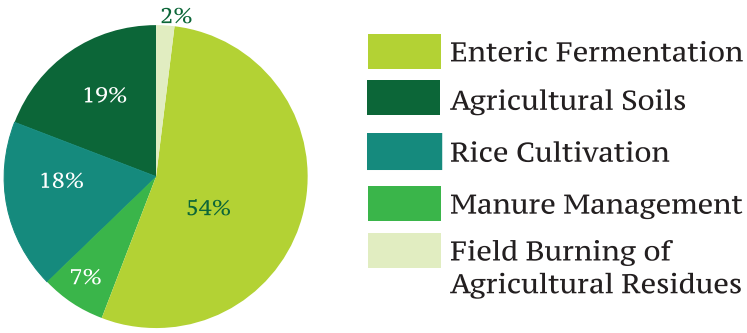


Figure 2.16: Distribution of GHG emissions by sub-sectors from the Agriculture sector in 2014 (Gg)

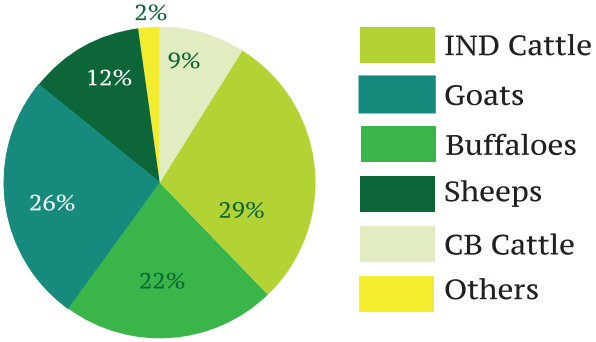
The emissions from agriculture sector amounted to 16% of the gross emissions of India in 2014. Methane (CH_4) emissions occur from this sector due to livestock rearing (enteric fermentation and manure management) and rice cultivation. N_2O is mainly emitted due to the application of fertilizers to the agricultural soils.

3A Enteric Fermentation

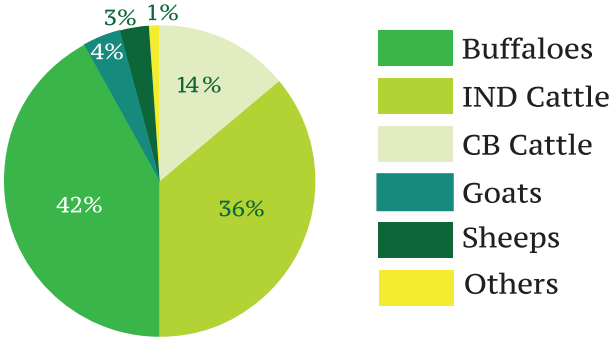
Methane is produced in herbivorous animals as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for absorption into the blood-stream. The amount of methane that is released depends on the type of digestive tract, age, and weight of the animal, and the quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, buffalo, goat, sheep) are major sources of methane and moderate amounts produced from non-ruminant livestock (e.g., pigs, horses).

Activity data, Emission Factor and Methodology

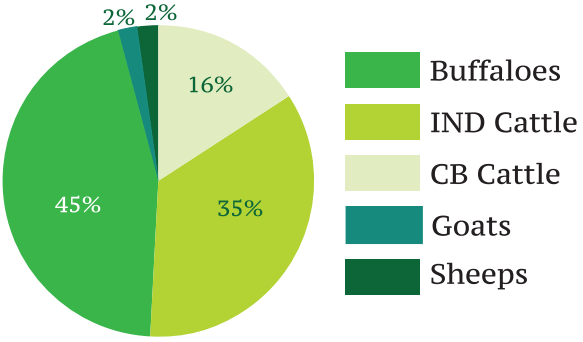
Livestock population data in each state as per the All India Livestock Census, and the average value of the methane emission factor for a particular category of the animal were used for the calculation of total methane



Population by livestock categories, 2014



Dry matter intake by livestock categories, 2014



Enteric methane emission by livestock categories, 2014

Figure 2.17: Livestock population, Dry Matter Intake and Enteric methane

(CB= Crossbred; IND= Indigenous)

emission from that livestock category. Country-specific emission factors were used for cattle, buffalo and goat, based on experiments conducted at National Dairy Research Institute, Karnal. *In-vivo* tracer technique using sulphur hexafluoride (SF_6) was employed for measuring the enteric methane emission from livestock. The methane emission factors for pigs, horses, donkey and other animals, were taken from the IPCC 2006 default values. A tier II approach has been followed as methane emission was estimated by average weights of various categories and various breeds of animals. Most authentic estimates of body weight of different categories of livestock were used in calculations. Dry Matter Intake (DMI) by different classes and species of livestock is presented in Table 2.8.

Figure 2.18: Estimation of enteric methane emission from cattle using SF_6 tracer technique

Methane Emissions: Total methane produced due to enteric fermentation was 10,816.98 Gg in 2014. Table 2.8 indicates methane emissions from various livestock categories for the year 2014. Shares of category wise livestock population, DMI and enteric methane have been presented in the charts given in Figure 2.17.

Table 2.8: Emissions from enteric fermentation in 2014

Livestock Categories	Population (million)	DMI (Mt)	Enteric Methane (Gg)
Crossbred Cattle			
Male	6.63	7.621	121
Female	37.84	84.53	1612
Indigeneous Cattle			
Male	62.06	93.00	1502
Female	89.87	138.59	2241
Buffalo			
Male	16.53	20.76	265
Female	96.02	254.23	4617
Goat			
Male	37.30	6.10	54
Female	97.60	20.40	194
Sheep			
Male	14.57	4.16	37
Female	49.18	15.68	148
Others			
Horse & Ponies	0.64	1.32	7
Mules	0.22	0.31	2
Yak	0.07	0.11	1
Donkey	0.28	0.25	1
Camels	0.33	0.64	7
Pigs	10.02	2.10	2
Mithun	0.31	0.57	7
Grand Total	**519.54**	**650.39**	**10817**

3B Manure Management

This section estimates CH_4 and N_2O produced during the storage and treatment of manure, and from manure deposited on pastures. The term 'manure' is used here collectively to include activity data from both dung and urine (i.e. the solids and the liquids) produced by livestock.

Activity Data, Emission Factors and Methodology

The livestock population in each Indian state as per the censuses conducted from time to time and published by the Government of India were taken into consideration. Methane production from volatile solids of each class of animals was estimated from each Indian state according to its animal waste management system as well as according to the climatic condition.

Total methane was estimated for a particular category of livestock by multiplying the manure management emission factor with total dung produced which is estimated by taking digestibility of the feeds into account. The total amount of dung produced by dairy animals was calculated on the basis of dry matter intake and digestibility coefficients of feeds taken from the experimental data as reported in literature.

Figure 2.19: Estimation of gases from dung

Methane Emissions:

The decomposition of manure under anaerobic conditions during storage and treatment, produces methane. These conditions occur most readily when large number of animals are managed in a confined area (e.g., dairy farms, swine and poultry farms). Emissions produced from the dung are dependent on the ambient temperature and storage system. In Indian conditions, 22.5% of dung is estimated to be used as dung cake, 46% in the pasture and 31.5% stored as solid in all the states irrespective of the environmental conditions and traditional practices followed. Total amount of dung produced in 2014 was 292.23 million tonnes, resulting in 128.35 Gg of methane emissions (Table 2.9).

Table 2.9: Dung, Dung Methane and Nitrous Oxide generation across various species

Livestock class	Dung (Million Tonne)	Dung Methane (Gg)	Nitrous Oxide (Gg)
Crossbred Cattle	39.73	18.88	11.08
Indigenous Cattle	106.63	46.28	29.73
Buffalo	124.72	53.21	34.77
Goat	10.93	4.87	3.31
Sheep	7.94	3.53	2.40
Others			
Horse & Pony	0.66	0.29	0.20
Mule	0.16	0.07	0.05
Yak	0.05	0.02	0.01
Donkey	0.12	0.06	0.04
Camel	0.32	0.14	0.10
Pig	0.75	0.90	0.20
Mithun	0.23	0.10	0.07
Others Total	**2.29**	**1.59**	**0.67**
Grand Total	**292.23**	**128.35**	**81.95**

Nitrous Oxide Emissions:

N_2O is produced directly and indirectly during the storage and treatment of manure before it is applied to land or otherwise used as fuel or for construction purposes. The emission of N_2O from manure during storage and

treatment depends on the C/N ratio of the manure, duration of the storage and type of treatment. The N_2O emissions generated by manure in the system 'pasture, range, and paddock' occur directly and indirectly from the soil, and are therefore reported under the category 'N_2O Emissions from Managed Soils'. Direct N_2O emissions occur via combined nitrification and denitrification of nitrogen contained in the manure. Indirect emissions result from volatile nitrogen losses that occur primarily in the forms of ammonia and NO_x during storage as solid. Manure management emitted 81.95 Gg of N_2O in 2014.

3C Rice cultivation

In 2014, the total area under rice cultivation in the country was 44.11 Mha, and 3,468.7 Gg of methane was emitted. Emissions from different ecosystem types under different water regimes were estimated separately and are presented in Figure 2.20. Of the approximately 44 Mha of land under rice cultivation, 44.74 % is irrigated, 39.1% is rainfed lowland, 13.2% is rainfed upland and 3.15% is deepwater rice (WRS, 2008, FAI 2012-13, SAC report 2009).

The annual amount of CH_4 emitted from a given area of rice is a function of the crop duration, water regime and organic soil amendments.

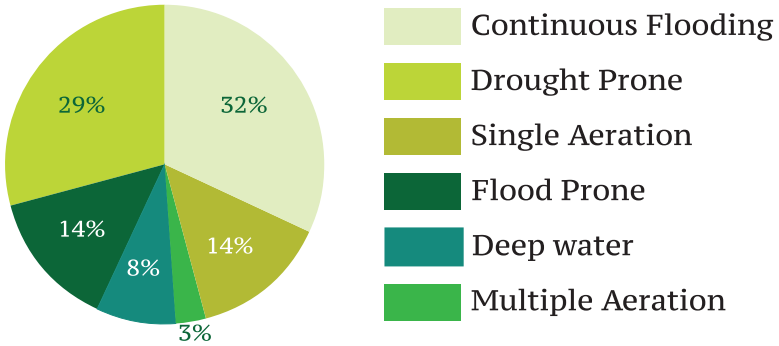


Figure 2.20: Methane emissions (in %) from Rice Cultivation under different types of water regimes for the year 2014.

Activity data, Emission Factor and Methodology

Methane emissions from rice cultivation is a factor of seasonal emission factors and the annually harvested areas. Harvested area for each sub-unit (State) was multiplied by the respective emission factor that is representative of the conditions that define the sub-unit (State). The total annual emissions are equal to the sum of emissions from each sub-unit of the harvested area, using the following equation.

$$CH_{4\ Rice}=\sum_{i,j,k}(EF_{i,j,k}\cdot A_{i,j,k})\cdot 10^{-6}$$

Where, $CH_{4\ Rice}$ = annual methane emissions from rice cultivation in India, Gg CH_4 yr^{-1};

$EF_{i,j,k}$ = a seasonal integrated emission factor for i, j, and k conditions, kg CH_4 ha^{-1};

$A_{i,j,k}$= annual harvested area of rice for i, j, and k conditions, ha yr^{-1};

i, j, and k= represent different ecosystems, water regimes, type and amount of organic amendments, under which CH_4 emissions from rice may vary.

Separate calculations were undertaken for each rice ecosystems (i.e., irrigated, rainfed, and deepwater rice production). Seasonal emission factor for different rice ecosystems is based on the coefficients generated in the published literature, INC and SNC.

Activity data and Emission factors

For preparing the present inventory, data on the area under rice cultivation for the base year 2014 was obtained from FAI databook (2015) and validated at state level with MoAFW database. Harvested area of rice under the four major rice ecosystems in the different states of the country was compiled from Indian government data, World Rice Statistics (IRRI, 2008) and FAO statistics data.

GHG emissions from rice cultivation

The emission factors used for particular ecosystems are based on published national measurement under rice-methane campaign and also those reflected in INC, SNC and BUR 1, and continuous national process backed by adequate field and laboratory processes. The emission factors applied have been tabulated in Table 2.10.

Table 2.10: Estimations of methane emissions from rice fields for 2014

Ecosystem	Water regime	Rice Area 2014 (Mha)	Emission Factor (kg/ha)	Methane (Gg)
Irrigated	Continuously Flooded	7.01	159.74	1119.7
	Single Aeration	7.25	66. 2	479.8
	Multiple Aeration	5.48	19.3	105.7
Rainfed	Drought Prone	14.64	68.84	1007.6
	Flood Prone	2.6	189	491.6
Deep water	Deep Water	1.39	190	264.2
Upland		5.74	0	0
Total		**44.11**		**3,468.70**

3D Agriculture soils

N_2O from Soils

There are two pathways of N_2O emissions from soils-direct and indirect. Direct N_2O emission was estimated using net N additions to soils (synthetic or organic fertilizers, deposited manure, crop residues) and mineralization of N in soil due to cultivation/land-use change on mineral soils. The indirect N_2O emission was estimated from volatilization of NH_3 and NO_x from managed soils and the subsequent re-deposition of these gases and their products (NH_4 and NO_3) to soils and after leaching and runoff of N, mainly as NO_3 from managed soils. Total emissions of N_2O from managed soils have been estimated. Table 2.11 reproduces the Emission Factors (EFs) used for calculating N_2O emission from this emission category.

Table 2.11: Emission factors for soil emissions

Parameter	IPCC EF	CS EF
EF1 (N_2O emission from applied fertilizer)	1%	0.58%
EF_4 (N_2O emission from volatilized N from fertilizer and manure)	1%	0.50%
EF5 (N_2O emission from leached and run-off N from fertilizer and manure)	2.50%	0.50%
FracGASF (Gas loss through volatilization from inorganic fertilizer)	10%	15%
FracGASF-AM (Gas loss through volatilization from manure)	20%	15%
Fracleach (Leaching loss of N from applied fertilizer and manure)	30%	10%

The total indirect N_2O emissions from the managed soils are 43.33 Gg, and the total direct N_2O emissions from the managed soils are 216.44 Gg.

3E Field Burning of Agricultural Residue

Non-CO_2 emissions associated with the burning of crop residues are reported in this section. CO_2 emissions from biomass burning have been reported under memo item. Crop residue burning in the fields produces CO, CH_4, N_2O, NO_x, NMHCs, SO_2 and many other gases. Generally, residues from eight crops (rice, wheat, cotton, maize, millet, sugarcane, jute, rapeseed and mustard) are burned in the field as these are widely produced in the country.

Methodology

Non-CO_2 emissions from crop residue burning were calculated as below.

$FBCR = \sum_{crops} A \times B \times C \times D \times E \times F$

Where,

FBCR = Emissions from Field Burning of Crop Residue

A = Crop production

B = Residue to crop ratio

C = Dry matter fraction

D = Fraction burnt

E = Fraction actually oxidized

F = Emission factor

The estimation of emission of targeted species was arrived at by estimation of biomass actually burnt in the field using the IPCC Revised 1996 guidelines. The state-wise crop production figures for 2014 were used as the basic activity data and sources of all EFs are mentioned in reference and data sources.

Default emission factors mentioned in IPCC (2006) guidelines were used for emission ratio.

Non-CO_2 emissions: 109.54 Mt of dry biomass was burned in 2014. Emissions from field burning of agricultural residues in the year 2014 were 295.76 Gg of CH_4 and 7.67 Gg of N_2O (Table 2.12).

Table 2.12: GHG Emissions from Field Burning of Crop Residue

Year	Total biomass of all the crops burned (Million tonne)	CH_4 (Gg)	N_2O (Gg)
2014	109.54	295.76	7.67

Total emissions from agriculture sector were 417,217.54 Gg CO_2e in the year 2014. Sub category wise distribution of GHGs emitted from the agriculture sector are shown in Figure 2.21.

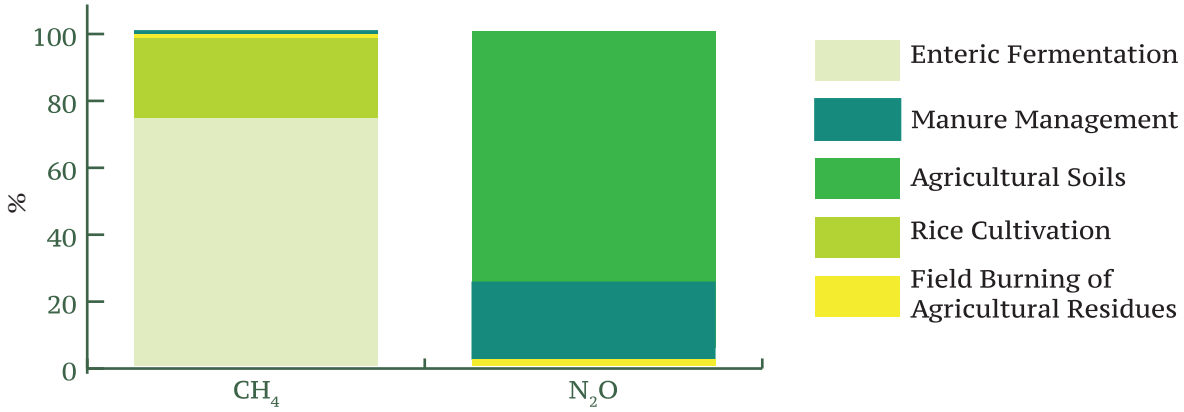


Figure 2.21: Distribution of GHGs (in percent) emitted from the agriculture sector for the year 2014

4 Land use, Land-use Change and Forestry (LULUCF)

India's first BUR showed that LULUCF sector was a net sink in 2010 and neutralized about 12% of total emissions from rest of the categories. In this report, GHG inventory for the LULUCF sector has been prepared for the year 2014, using IPCC-Good Practice Guidance (GPG), 2003 approach and elements of the 2006 IPCC Guidelines.

Land Use, Land Cover (LULC) Change Analysis

Land use change from 2004-2005 to 2014-15 was assessed for the five classes *viz.* – forest land, cropland, grassland, settlement and other land based on remote sensing data. The definitions for the different categories are as follows:

i. Forest land: all lands, more than 1 ha in area and tree canopy density of more than 10%;

ii. Cropland: includes all croplands and fallow land area;

iii. Grasslands (and Scrub): areas covered with grassy and herbaceous growth as well as degraded forests with less than 10% tree canopy density;

iv. Other land: includes all non-vegetated areas such as snow, rocky outcrops and surface water bodies; and

v. Settlement: includes major built-up areas and human habitations - both rural and urban.

The land use and land use change estimate for the period 2005-2014 are given in Table 2.13. It can be observed that the land area converted to forest has increased and so has the area under cropland, grassland and settlements.

Table 2.13: Land use change for India for the period 2005-2014 (in a million ha)

Year	Forest land	Cropland	Grassland	Settlement	Other Land	Total area
2005	69.16	160.65	20.35	8.61	69.96	328.73
2006	69.24	160.94	20.42	8.72	69.41	328.73
2007	69.25	161.23	20.48	8.84	68.91	328.73
2008	69.27	161.53	20.55	8.96	68.42	328.73
2009	69.44	161.82	20.62	9.08	67.76	328.73
2010	69.50	162.12	20.69	9.20	67.23	328.73
2011	69.79	162.41	20.75	9.31	66.46	328.73
2012	69.98	162.71	20.82	9.43	65.79	328.73
2013	70.15	163.00	20.89	9.55	65.14	328.73
2014	70.49	163.29	20.89	9.55	64.51	328.73

Note:

Land use data obtained from National Remote Sensing Centre (NRSC) and Forest Survey of India (FSI)

FL: Forest land; CL: Cropland; GL: Grassland; SL: Settlements; OL: Other lands. Data on Wetlands is unavailable according to the IPCC definition, and therefore not included.

Area under different IPCC land categories is available from NRSC for the years 2009-10 and 2013-2014. The area estimates for the intervening period have been extrapolated by taking an average of the area between two successive periods.

Land use conversions among CL, GL, SL is not included since emission factors are not available separately for land remaining the same category and land converted to another category: example – no data for rate of change in SOC between CL-CL and L-CL. Estimates are included for FL-FL and Land Converted to FL since data is available from FSI.

4A Forest Land

Activity data and emission factors for forest lands

The activity data and emission factors for carbon stock estimation are derived from two important regular activities of FSI i.e forest cover assessment and National Forest Inventory. The results of these two activities are published in ISFR, a biennial report of FSI. For the activity data, biennial forest cover assessment which is a wall-to-wall mapping exercise based on satellite data (Approach 3) has been used. In addition, forest type information has also been used for stratification of forest cover into different forest types and canopy densities. For estimation of emission factors, the data collected during the national forest inventory has been used (tier 2). IPCC GPG 2003 have been used for estimation of carbon stock in different pools i.e. Above Ground Biomass, Litter, Deadwood and Soil Organic Carbon (SOC) except below ground biomass which has been calculated using default value of IPCC.

The methodology presented in the Second National Communication to the UNFCCC (SNC) was followed for estimating the Activity Data and Emission Factors for the forest land category. The methods adopted for the period 2005-2014 for BUR-2 are similar to methods used during SNC (2012) and BUR-1 (2015).

GHG Emissions and Removal Estimates for Forest Land

Stock difference method has been used for estimation of CO_2 emissions and removals for forest land. CO_2 emissions and removal estimates are reported for the year 2014 and for the period 2005-14. The carbon stock change data given in this report are consistent with FRL India estimates under which forest area and carbon stock were recalculated for the year 2000, 2004 and 2008 using improved forest cover maps based on latest satellite data. The carbon stock estimates given in the report are based on the forest inventory of the corresponding years and as per the published figures of carbon stocks in different ISFRs.

The area under forest land remaining forest land for the year 2014 is 69.22 Mha, and the land area converted to forest land during the year 2014 is estimated to be 1.27 Mha. Forest sector in India is a net sink.

Non-CO_2 gases emissions from biomass burning in forest land

Non-CO_2 GHG emissions are estimated for the forest land subjected to biomass burning. Activity data for the area of the forest burnt and the quantity of biomass burnt per hectare was obtained from field studies conducted by FSI.

Method for estimating Non-CO_2 gases

IPCC GPG method is adopted for estimating the GHG emissions from a forest fire. The following equation from IPCC GPG is used for estimating the non-CO_2 gases emissions.

Estimation of GHGs directly released in fires

$L_{fire} = A \times B \times C \times D \times 10^{-6}$

L_{fire} = quantity of GHG released due to fire, tonnes of GHG

A = area burnt, ha

B = mass of 'available' fuel, kg d.m. ha^{-1}

C = combustion efficiency (or fraction of the biomass combusted), dimensionless.

D = emission factor, g $(kg\ d.m.)^{-1}$

CH_4 and N_2O emissions increased during the period 2005–2014. The CH_4 emissions during 2014 are estimated to be 1012 Gg CO_2e and N_2O emissions are estimated to be 439 Gg CO_2e.

4B Cropland

The area under cropland, which is the net sown area, was estimated to be 163.29 Mha during 2014. The net sown area has increased from 160.65 to 163.29 Mha between years 2005 and 2014. The net sown area varies due to rainfall, market prices and other factors. Here, the area under cropland includes both net sown and fallow land area.

Cropland includes all annual and perennial crops (which do not qualify as forest) as well as temporary fallow land (i.e., land set at rest for one or several years before being cultivated again). Annual crops may include cereals, oilseeds, vegetables, root crops and forages. Perennial crops can include trees and shrubs, in combination with herbaceous crops (e.g. agroforestry) or as orchards, vineyards and plantations. CO_2 emissions and removals are estimated only for perennial tree biomass in croplands.

Method for estimating the perennial tree biomass in croplands

The methods for estimating the perennial tree biomass in croplands are similar to the methods adopted in BUR-1. Forest Survey of India periodically makes an assessment of trees outside the forests. Trees outside forests (TOF) include tree cover comprising of small patches of trees (<1.0 ha) in plantations and woodlots, scattered trees and farms, homesteads and urban areas as well as trees along linear features such as road, canals and cropland bunds.

FSI also provides the growing stock of the trees outside the forests, which includes all land categories other than forest and including croplands. The approach adopted for estimating carbon stock changes in cropland is as follows:

i. **Change in Biomass Carbon Stock in Croplands:** Carbon stock change in Cropland Remaining Cropland is estimated by taking the tree biomass carbon stock at two successive periods during 2005-2014. Biomass of trees outside the forests is available for the years 2007, 2009, 2011, 2013 and 2015. The biomass stock is extrapolated to other years. The rate of change in biomass carbon stock is estimated using annual rate of change in growing biomass stock of TOF converted to per hectare value. The root biomass is estimated by using the IPCC default value. The IPCC default and generalized value of Biomass Conversion Expansion Factors (BCEF) is 9.0, which was very high for Indian growing stock. Hence, the wood density and Carbon data for large number of samples collected as part of National Carbon Project of NRSC (ISRO) and FSI were pooled and state wise BCEF was compiled and finally a value of BCEF of 0.9 was arrived as a national average. This national value was selected to compute the removals from TOF growing stock.

ii. **Soil Organic Carbon stock:** SOC stock difference is estimated based on annual change in SOC obtained from different studies. SOC stock change data is compiled for cropland category for which literature values are available for two periods.

iii. **Biomass and soil carbon rates of change and stocks in croplands:** Cropland in India, considering, only perennial tree biomass, is a net sink during the period 2005 to 2014. The carbon stock increased to 248,610 Gg CO_2 during 2014. The main reason for cropland to become a net sink, despite a marginal reduction in biomass stock, is due to increase in SOC due to addition of organic manure and crop residues.

4C Grassland

In India, grassland includes a large number of categories other than forest lands and croplands. These lands are largely used for livestock grazing. The area under grassland is estimated to be 20.89 Mha for the year 2014 compared to 20.35 Mha in 2005.

Method for estimating CO_2 emissions and removals

The method for estimating CO_2 emissions and removals for grasslands is same as that described in the cropland section for biomass carbon. Biomass stock change in the grassland category is estimated using the method and source of data described for croplands. The main source of data for biomass stock and rates of stock change is from the study on "Trees Outside Forests" conducted by FSI for non-forest land categories including grassland. SOC stock change for grasslands or wastelands is estimated by field measurements in Karnataka for which previous year's estimates were available.

Biomass and soil carbon stock change in grassland: The grasslands in India are a net source of CO_2 during the period 2005-2014. The total biomass and soil carbon stock change in grassland is estimated to be a net source of 17,216 Gg CO_2 for 2014. The main factors for grassland category to be a net source include reduction in biomass and SOC in grasslands which are subjected to overgrazing, soil erosion and fire leading to land degradation.

4D Settlements

The area under settlement increased from 8.6 to 9.5 Mha during the period 2005 to 2014. The biomass stock change is estimated using the method and data described for croplands. The main source of data for biomass stock change is from the study on Trees Outside Forests conducted by FSI for non-forest land categories including settlements. Rates of change in SOC are obtained from the source described for grassland.

Biomass and soil carbon stock change in settlements: The Settlement land category was a net sink of CO_2 during the period 2005-2014. The Settlement land category is a net sink of 1,583 Gg CO_2 during 2014.

4E Other Land

Other land includes snow-covered area, rocky surfaces, water bodies, extremely degraded land, deserts etc. The area under other land for the year 2014 is estimated to be 64.51 Mha. No GHG emissions and removal estimates are made for other land. Further there is no conversion of forest land or cropland or grassland to other land.

Overall GHG Emissions and Removals from LULUCF Sector during 2014

GHG emissions are estimated using the IPCC GPG -2003 and IPCC-2006 guidelines for the 5 land categories (excluding wetlands and other lands). Tier 2 and Tier 3 methods are largely adopted for the GHG inventory estimation. Emissions and removal estimates for each land category are described in the respective land category sections.

The emission and removal estimates for all the land categories are presented in Table 2.14 and Figure 2.22. It can

be observed that Cropland dominates the CO_2emissions/removal estimates for India for the year 2014. Forest land, Cropland and Settlement categories are net sinks while Grassland is a net source of CO_2. The LULUCF sector is a net sink of 3,01,193 Gg CO_2e during 2014, registering an increase of about 19% as compared to the year 2010 reported in BUR-1.

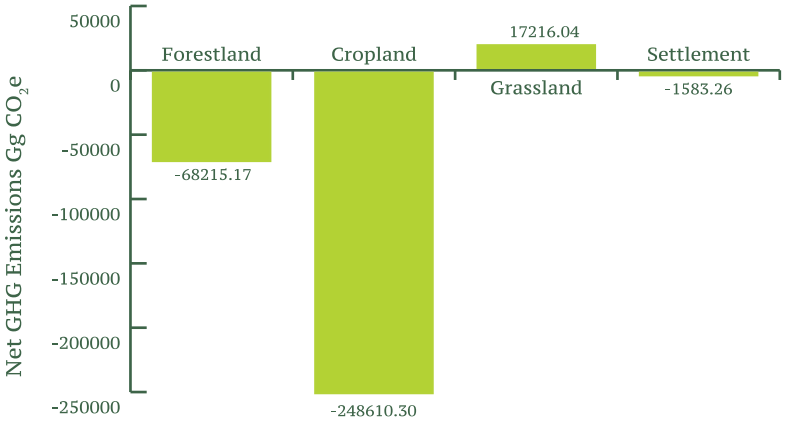


Figure 2.22: Net CO_2e emissions by land use categories in 2014 (in Gg); -ve sign represents net removals from the atmosphere

Table 2.14: Total GHG emissions for year 2014 for LULUCF sector in GgCO_2e

Land category	Annual CO_2 emissions/ removal	CH_4	N_2O	Total CO_2e emissions*
Forest land	-69,666.67	1,012.08	439.42	-68,215.17
Cropland	-248,610.30			-248,610.30
Grassland	17,216.04			17,216.04
Settlements	-1,583.26			-1,583.26
Total	-302,644.19	1,012.08	439.42	-301,192.69

* -ve values indicate removals and +ve values indicate emissions

GHG inventory was not estimated for other lands and wetlands since no changes in carbon stocks are expected in other land and no activity data is available on wetlands according to IPCC definitions.

5 Waste

The waste sector includes estimation of GHG emissions from the following sub-categories:

- Solid waste disposal
- Waste water treatment and discharge

5A Solid waste disposal: estimation of methane emission from landfill sites

In India, there is a marked difference between Rural and Urban lifestyles with rural population generating substantially less per capita solid waste. In addition, existence of Municipal Solid Waste (MSW) dumps is rural areas is minimal as most of the organic waste is recycled as cattle feed and farm compost. Also, MSW is relatively scattered and moreover shallow waste depths of disposal do not induce anaerobic conditions. These conditions are responsible for low level of methane emissions in rural areas. On the other hand, urban population produces much higher per capita MSW and thus the generation of organic fraction is relatively high. Urban areas are constrained for recycling of organic matter. Dumpsites are relatively large in area with substantial depths. These conditions are favourable to methane generation. Hence, MSW related methane emissions are mostly from urban areas in India.

Methodology of estimation

First Order Decay (FOD) model has been applied for calculation of methane emission from landfill sites. In a FOD model, the decay rate of carbon in the waste is governed by a first order reaction. Thus, the rate of decay is

directly proportional to the amount of carbon remaining in the disposal site. This model is built on an exponential factor that describes the fraction of degradable material which each year is degraded into CH_4 and CO_2. One key input in the model is the amount of degradable organic matter in the waste disposed at the solid waste disposal site. Degradable Organic Carbon (DOC) is the organic carbon in the waste that is amenable to biochemical decomposition. The basis for the calculation is the amount of Decomposable Degradable Organic Carbon (DDOCm). DDOCm is a part of the organic carbon that will be degradable under an anaerobic condition at the disposal site of solid waste after initial decomposition under aerobic condition.

The spreadsheet model estimates the amount of decomposable DOC in the disposal site, taking into account of the amount deposited each year and the amount remaining from the previous year. Generally, methane generation starts after a certain period following deposition of waste. An average delay period of six months for methane emission from deposited waste has been assumed as per IPCC guidelines.

Estimation of Methane Emission following Activity Data

An average value of waste generation for selected cities, expressed in kg/capita/day, has been used as a basis of year-wise quantity estimation. All India level estimation has been appropriately extrapolated using these and total urban population data. Activity data have been summarized in Table 2.15. Salient features of 2014 methane emission data are presented in Table 2.16.

Table 2.15: Activity data for solid waste disposal

Activity Data	Value
Average Per Capita Waste Generation Rate	0.55 kg/capita/day
Fraction of Degradable Organic Carbon in Waste (DOC)	0.11
Degradable Organic Matter fraction (DOC_f)	0.5
Methane Correction Factor (MCF)	0.4
Fraction of Methane in Generated Landfill Gas (F)	0.5
Reaction Rate Constant (K)	0.17 yr^{-1}

Table 2.16: Salient features of estimation for 2014

Urban population (extrapolated based on Census 2011)	404,300,000
Quantity of waste reaching the landfill site (Gg)	56,814
DDOCm disposed (Gg)	1,249.91
DDOCm accumulated (Gg)	6,913.63
DDOCm decomposed (Gg)	1,078.80
CH_4 generated (Gg)	717.40

5B Wastewater Treatment and Discharge

Methane is emitted from wastewater when it is handled anaerobically. Wastewater originates from a variety of domestic, commercial and industrial sources. The effluents may be treated on site (uncollected) or sewered to a centralize treatment plant (collected wastewaters) and finally disposed of untreated/partially or fully treated into nearby environment (surface waters, irrigation soils and marine disposals).

Domestic and commercial wastewater

Emissions from domestic wastewater handling are estimated for both urban and rural centres. Population forecast was done for all states based on 2011 Census Data. Methane emission estimates have been made using Tier-1 and Tier-2 approach of the IPCC by incorporating country-specific emission factors and country-specific data. Emissions from domestic and commercial wastewater treatment and disposal were 36,676 Gg of CO_2e, of which 21,120 Gg CO_2e was methane and 15,556 Gg CO_2e was nitrous oxide.

Industrial Wastewater

The industrial wastewater contribution to greenhouse gases is assessed based on methane emitting industries such as pulp and paper, sugar refining, tannery, food and beverages, poultry and meat industries. Activity data

related to emission estimations including unit production, wastewater generation, amount of organic matter, handling of effluents were collected from industries (Table 2.17).

Table 2.17: Wastewater activity data and treatment route for various industries

Industry	Wastewater Generation m^3/tonne of production	Treatment	Chemical Oxygen Demand (kg/m^3)
Pulp and Paper	250	Anaerobic Lagoons + Aerobic Processes	2
Sugar Refining	0.4	Anaerobic Lagoons + Aerobic Processes	5
Tannery	35	Anaerobic Lagoons + Aerobic Processes	4.5
Poultry and Meat	0.02	Anaerobic Lagoons + Aerobic Processes	5
Dairy Products	6	Anaerobic Lagoons + Aerobic Processes	3
Petroleum	0.6	Aerobic Treatment	1
Organic Chemicals	67	Aerobic Treatment	3
Alcohol	24	Anaerobic Treatment + Aerobic Processes	11
Vegetable oil	2	Anaerobic	0.17
Vegetable & Fruits	20	Anaerobic Lagoons + Aerobic Processes	5
Soap and Detergents	3	Aerobic Treatment	0.85
Plastics	0.6	Aerobic Treatment	3.7
Coffee	15	Anaerobic Lagoons + Aerobic Processes	9
Fish Processing	13	Aerobic Treatment	2.5
Starch Production	5.5	Anaerobic Lagoons + Aerobic Processes	10

The estimated industrial wastewater methane emission for the year 2014 was 1,261.23 Gg.

Total emissions from waste sector were 78,227.15 Gg CO_2e in the year 2014. Sub category wise distribution of GHGs emitted from the waste sector are shown in Figure 2.23.

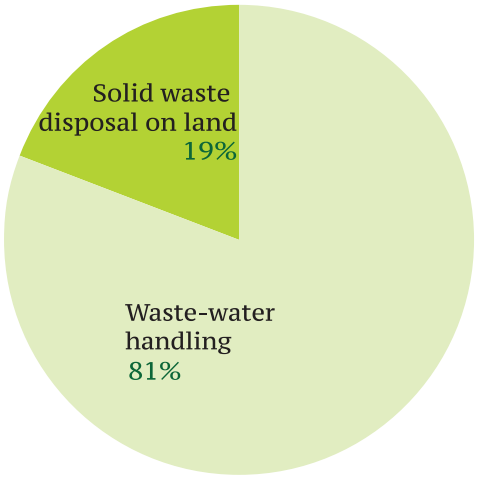


Figure 2.23: Distriubtion of emission in Waste sector

2.5 Key Category Analysis-2014

Key Category Analysis (KCA) has been carried out to identify sources with significant impact on total emissions or trend, accounting for up to 95% of the total emissions. The primary purposes of key category analysis are to prioritize higher tier methodologies for the key sectors, to design additional requirements of QA/QC for key sources, and to allocate and make best use of available resources for sources with significant impact on total emissions, which would lead to reduction in the uncertainties in the estimates to the maximum extent possible. In order to identify the key sources, both, level analysis and trend analysis have been carried out using approach 1. The analysis is without LULUCF and includes all GHGs reported. Tables 2.18 and 2.19 show level assessment for key source analyses for 2014 emissions. Further, uncertainty analysis for CO_2, CH_4, N_2O is given for corresponding key categories.

Table 2.18: Level assessment for key category analysis, 2014 emissions

Gas	Gg CO_2e	Share	Cumulative
1A1a Electricity production, CO_2	1078154	41.35%	41.35%
3A1 Enteric Fermentation, CH_4	227157	8.71%	50.06%
1A3b Road transport, CO_2	221283	8.49%	58.55%
1A2a Iron & steel, CO_2	153884	5.90%	64.45%
1A2m Nonspecific Industries, CO_2	126005	4.83%	69.28%
2A1 Cement production, CO_2	115342	4.42%	73.70%
1A4b Residential, CO_2	85539	3.28%	76.98%
3C4 Agricultural Soils, N_2O	80529	3.09%	80.07%
3C7 Rice Cultivation, CH_4	72843	2.79%	82.87%
1A1b Refinery, CO_2	49970	1.92%	84.78%
1A2f Cement, CO_2	46857	1.80%	86.58%
4D2 Industrial Wastewater, CH_4	26486	1.02%	87.60%
3A2 Manure Management, N_2O	25406	0.97%	88.57%
1A4a Commercials/Insititutional, CO_2	25380	0.97%	89.54%
2C3 Aluminium production, CF_4 & C_2F_6	23468	0.90%	90.44%
4D1 Domestic and Commercial Waste Water, CH_4	21120	0.81%	91.25%
2E Production of halocarbons and sulphur hexafluoride, HFC	18580	0.71%	91.97%
1B2b Natural gas, CH_4	16119	0.62%	92.58%
4D1 Domestic and Commercial Wastewater, N_2O	15556	0.60%	93.18%
4A Managed Waste Disposal on Land, CH_4	15065	0.58%	93.76%
1A3a Civil Aviation, CO_2	13861	0.53%	94.29%
2A2 Lime production, CO_2	11125	0.43%	94.72%
1B1aii Above ground mining, CH_4	10989	0.42%	95.14%

Table 2.19: Trend assessment for key category analysis 2011- 2014 emissions

Gas	Trend	Share	Cumulative
1A1a Electricity production, CO_2	0.04877	40.19%	40.19%
1A2m Nonspecific Industries , CO_2	0.01201	9.90%	50.09%
1A2a Iron & steel, CO_2	0.00937	7.72%	57.81%
3A1 Enteric Fermentation, CH_4	0.00777	6.40%	64.21%
2A1 Cement production, CO_2	0.00767	6.32%	70.53%
3C4 Agricultural Soils, N_2O	0.00431	3.55%	74.09%
3C7 Rice Cultivation, CH_4	0.00343	2.83%	76.91%
2A2 Lime production, CO_2	0.00282	2.33%	79.24%
1B2b Natural gas, CH_4	0.00277	2.28%	81.53%
1A4b Residential, CO_2	0.00199	1.64%	83.16%
1A1b Refinery, CO_2	0.00188	1.55%	84.71%
1A1c Manufacturing of Solid Fuel, CO_2	0.00188	1.55%	86.26%
1A3b Road transport, CO_2	0.00136	1.12%	87.38%
1A2m Fertilizer, CO_2	0.00122	1.01%	88.39%

2B1 Ammonia production, CO_2	0.00122	1.01%	89.39%
1A2k Bricks, CO_2	0.00112	0.93%	90.32%
4D2 Industrial Wastewater, CH_4	0.00104	0.85%	91.17%
3A2 Manure Management, N_2O	0.0009	0.74%	91.91%
1A2f Cement, CO_2	0.00069	0.57%	92.49%
1B2b Venting and Flaring, CH_4	0.00069	0.57%	93.05%
4D1 Domestic and Commercial Waste Water, CH_4	0.00061	0.50%	93.55%
$2C_2$ Ferroalloys production, CO_2	0.00054	0.45%	94.00%
1A3a Civil Aviation, CO_2	0.00053	0.43%	94.43%
1B1ai Underground mining, CH_4	0.00052	0.43%	94.86%
1A2d Pulp & paper, CO_2	0.0005	0.41%	95.27%

2.6 Uncertainty Analysis

Uncertainties are introduced in emission estimates due to the use of activity data and emission factors from direct measurement or from the literature, and assumptions based on expert judgement. An uncertainty assessment using approach 1 was carried out for key categories (Table 2.20). The uncertainty of estimates has been depicted by a range in which the estimated emission lies. Uncertainties associated with the activity data were sourced from the data source or from the researchers who have done the collection of such data, and are based on expert judgement of inventory estimation teams, and/or from IPCC 2006 Guidelines. The emission factor uncertainties are related to the standard deviation of the measured emission factors, and if taken from the literature, then the uncertainties mentioned in the said literature are considered.

Table 2.20: Uncertainty range for key category emissions

Sr. No.	IPCC Category	Category Number, Name	Gas	Activity Data Uncertainty (%)	Emission Factor Uncertainty (%)	Combined Uncertainty (%)
1	Energy	1A1a Electricity production	CO_2	10.00%	5.00%	11.18%
2	Agriculture	3A1 Enteric Fermentation	CH_4	5.00%	50.00%	50.25%
3	Energy	1A3b Road transport	CO_2	5.00%	3.00%	5.83%
4	Energy	1A2a Iron & steel	CO_2	5.00%	5.00%	7.07%
5	Energy	1A2m Nonspecific Industries	CO_2	20.00%	5.00%	20.62%
6	IPPU	2A1 Cement production	CO_2	5.00%	5.00%	7.07%
7	Energy	1A4b Residential	CO_2	20.00%	5.00%	20.62%
8	Agriculture	3C4 Agricultural Soils	N_2O	25.00%	100.00%	103.08%
9	Agriculture	3C7 Rice Cultivation	CH_4	0.20%	8.00%	8.00%
10	Energy	1A1b Refinery	CO_2	5.00%	5.00%	7.07%
11	Energy	1A2f Cement	CO_2	5.00%	5.00%	7.07%
12	Waste	4D2 Industrial Wastewater	CH_4	15.00%	50.00%	52.20%
13	Agriculture	3A2 Manure Management	N_2O	10.00%	75.00%	75.66%
14	Energy	1A4a Commercials/Institutional	CO_2	20.00%	5.00%	20.62%
15	IPPU	2C3 Aluminium production	CF_4 & C_2F_6	5.00%	75.00%	75.17%
16	Waste	4D1 Domestic and Commercial Wastewater	CH_4	15.00%	50.00%	52.20%
17	IPPU	2E Production of halocarbons and sulphur hexafluoride	HFC	10.00%	20.00%	22.36%
18	LULUCF	3B3 Grassland	CO_2	15.00%	15.00%	21.21%

19	Energy	1B2b Natural gas	CH_4	5.00%	100.00%	100.12%
20	Waste	4D1 Domestic and Commercial Wastewater	N_2O	15.00%	75.00%	76.49%
21	Waste	4A Managed Waste Disposal on Land	CH_4	15.00%	50.00%	52.20%
22	Energy	1A3a Civil Aviation	CO_2	5.00%	3.00%	5.83%
23	Energy	1A3a Civil Aviation	CO_2	5.00%	3.00%	5.83%
24	IPPU	2A2 Lime production	CO_2	10.00%	5.00%	11.18%

Based on the KCA (level and trend analyses as above) and uncertainty estimation of national GHG inventory, an improvement plan for India will be prepared for a phased riding of tier ladder so as to move to the higher tier-based assessment of national GHG inventory in the future.

2.7 Time series information

A summary table (Table 2.21) has been provided for national GHG inventory information contained in previous submissions. Inventory of 1994 was communicated in INC. SNC contained a national inventory of 2000. Inventory of 2007 was given in SNC as a proactive approach. In 2016, India had furnished its BUR-1 containing the national inventory of 2010.

Table 2.21: Inventory information reported in previous submissions (values in Gg CO_2e)

Category	1994	2000	2007	2010
Energy	743,820	1,027,016	1,374,098	1,510,121
Industrial Processes and Product Use (IPPU)	102,710	88,608	142,206	171,503
Agriculture	344,485	355,600	372,653	390,165
Land Use Land Use Change & Forestry (LULUCF)	14,292	-222,567	-177,028	-252,532
Waste	23,233	52,552	57,727	65,052
Total (Without LULUCF)	1,214,248	1,523,777	1,946,684	2,136,841
Total (With LULUCF)	1,228,540	1,301,209	1,771,662	1,884,309

Source: India's Initial National Communication to UNFCCC (2004); India's Second National Communication to UNFCCC (2012); India's First Biennial Update Report to UNFCCC (2016).

Consistent time series information on GHG inventory starting from the last full national communication (inventory year 2000) to 2014 has been presented in the bar chart (Figure 2.24).

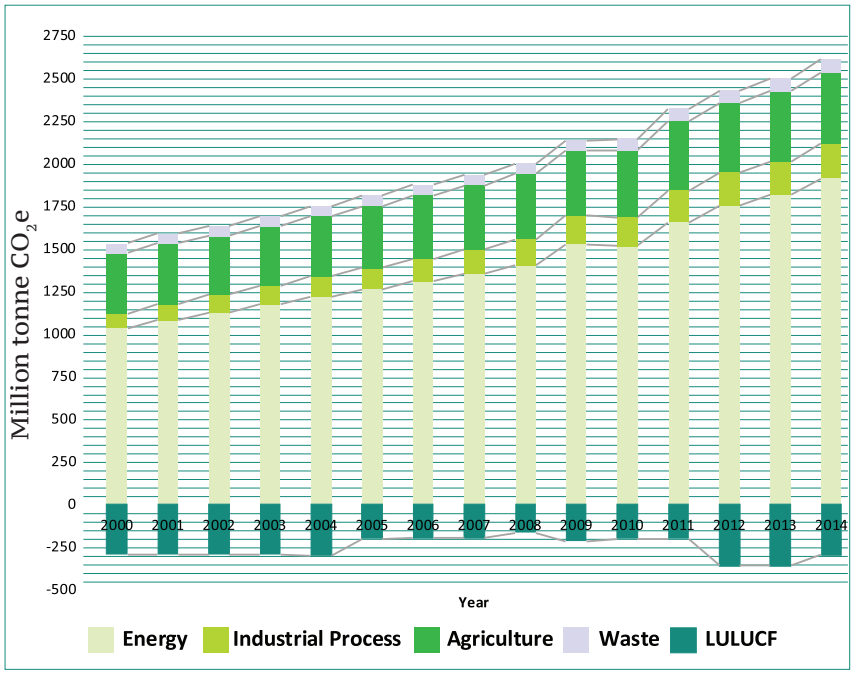


Figure 2.24: Time series of GHG Emissions

Sector-wise distribution of emissions in percentage and their change is presented in the Figure 2.25.

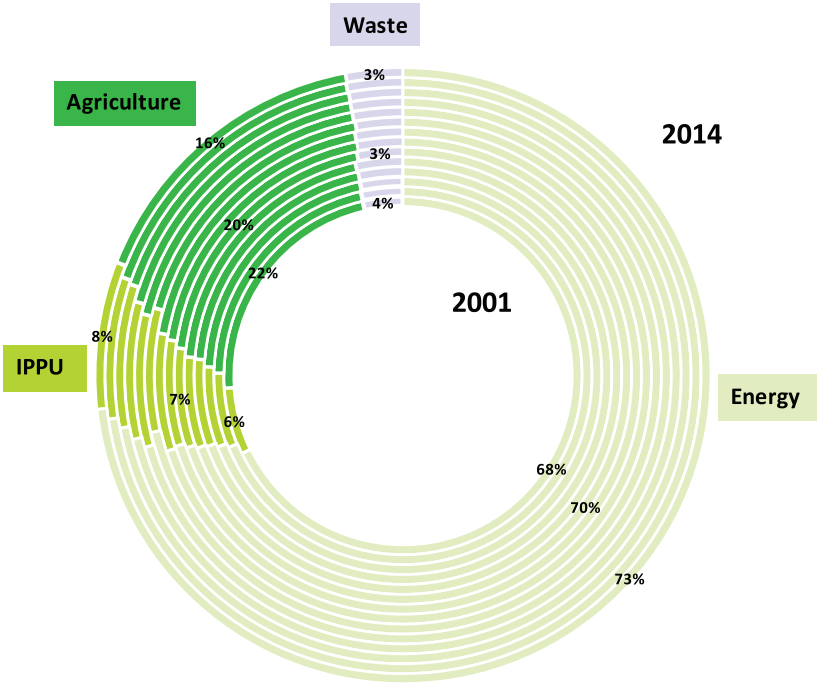


Figure 2.25: Change insector-wise GHG emissions 2001-2014

As required by the extant guidelines, India's national GHG inventory for 2014 is presented in Tables 2.22 (1 and 2). A combined table has been provided for the ease of comparability with SNC and BUR-1 as Appendix to this chapter.

Table 2.22: India's national GHG inventory for 2014 (Gg)

Table 1. National greenhouse gas inventory of anthropogenic emissions by sources and removals by sinks of all greenhouse gases not controlled by the Montreal Protocol and greenhouse gas precursors								
Greenhouse gas source and sink categories	CO_2 emissions (Gg)	CO_2 removals (Gg)	CH_4 (Gg)	N_2O (Gg)	CO (Gg)	NO_x (Gg)	NMVOCs (Gg)	SO_x (Gg)
Total national emissions and removals	**2015107.88**	**319860.23**	**20053.54**	**476.70**	**X**	**X**	**X**	**X**
1. Energy	**1844705.03**	**0**	**2133.37**	**65.35**	**X**	**X**	**X**	**X**
A. Fuel combustion (sectoral approach)	1844705.03		321.13	65.35	X	X	X	X
1. Energy industries	1135357.11		14.96	17.14	X	X	X	X
2. Manufacturing industries and construction	350211.44		4.80	5.15	X	X	X	X
3. Transport	245845.66		57.68	10.05	X	X	X	X
4. Other sectors	113290.83		243.69	33.01	X	X	X	X
5. Other (please specify)					X	X	X	X
B. Fugitive emissions from fuels			1812.24		X	X	X	X
1. Solid fuels			787.93		X	X	X	X
2. Oil and natural gas			1024.31		X	X	X	X

2. Industrial processes	**153,186.81**		**177.85**	**10.36**	**X**	**X**	**X**	**X**
A. Mineral products	126,855.79				X	X	X	X
B. Chemical industry	18,485.87		22.75	10.36	X	X	X	X
C. Metal production	5,671.71		0.10		X	X	X	X
D. Other production					X	X	X	X
E. Production of halocarbons and sulphur hexafluoride								
F. Consumption of halocarbons and sulphur hexafluoride								
G. Other (Pulp and paper)	2,173.44				X	X	X	X
1. Lubricant	1,950.84							
2. Paraffin wax	222.6							
3. Pulp & paper			155					
3. Solvent and other product use							**X**	
4. Agriculture			**14,709.78**	**349.39**	**X**	**X**	**X**	**X**
A. Enteric fermentation			10,816.98					
B. Manure management			128.35	81.95			X	
C. Rice cultivation			3,468.69				X	
D. Agricultural soils				259.77			X	
E. Prescribed burning of savannahs					X	X	X	
F. Field burning of agricultural residues			295.76	7.67	X	X	X	
G. Other (please specify)					X	X	X	
5. Land-use change and forestry	**37,895.40**	**340,539.60**	**48.19**	**1.42**	**X**	**X**	**X**	**X**
A. Changes in forest and other woody biomass stocks	37,895.40	217,524.7 0						
B. Forest and grassland conversion		1583.30			X	X		
C. Abandonment of managed lands		X						
D. CO_2 emissions and removals from soil		121,431.60						
E. Other (please specify)			48.19	1.42	X	X		
6. Waste			**2984.35**	**50.18**	**X**	**X**	**X**	**X**
A. Solid waste disposal on land			717.40		X		X	
B. Waste-water handling			2266.95	50.18	X	X	X	
C. Waste incineration					X	X	X	X

D. Other (please specify)					X	X	X	X
7. Other (please specify)					**X**	**X**	**X**	**X**
Memo items								
International bunkers	4943.53		0.11	0.11	X	X	X	X
Aviation	3681.65		0.03	0.10	X	X	X	X
Marine	1261.88		0.08	0.01	X	X	X	X
CO_2 emissions from biomass	807087.06							

Table 2. National greenhouse gas inventory of anthropogenic emissions of HFCs, PFCs and SF_6

GREENHOUSE GAS SOURCE AND SINK CATEGORIES	HFC (Gg)			PFC (Gg)			SF_6 (Gg)
	HFC-23	HFC-134	Other (to be added)	CF_4	C_2F_6	Other (to be added)	
Total national emissions and removals	**1.588**	X	X	**2.607**	**0.709**	X	**0.004**
1. Energy							
A. Fuel combustion (sectoral approach)							
1. Energy industries							
2. Manufacturing industries and construction							
3. Transport							
4. Other sectors							
5. Other (please specify)							
B. Fugitive emissions from fuels							
1. Solid fuels							
2. Oil and natural gas							
2. Industrial processes	**1.588**	X	X	**2.607**	**0.709**	X	**0.004**
A. Mineral products							
B. Chemical industry							
C. Metal production	X	X	X	2.607	0.709	X	0.004
D. Other production							
E. Production of halocarbons and sulphur hexafluoride	1.588	X	X	X	X	X	X
F. Consumption of halocarbons and sulphur hexafluoride							
G. Other (please specify)							
3. Solvent and other product use							
4. Agriculture							
A. Enteric fermentation							
B. Manure management							
C. Rice cultivation							
D. Agricultural soils							
E. Prescribed burning of savannahs							
F. Field burning of agricultural residues							
G. Other (please specify)							

5. Land-use change and forestry							
A. Changes in forest and other woody biomass stocks							
B. Forest and grassland conversion							
C. Abandonment of managed lands							
D. CO_2 emissions and removals from the soil							
E. Other (please specify)							
6. Waste							
A. Solid waste disposal on land							
B. Waste-water handling							
C. Waste incineration							
D. Other (please specify)							
7. Other (please specify)							
Memo items							
International bunkers							
Aviation							
Marine							
CO_2 emissions from biomass							

References and Data sources

General

IPCC (1996) IPCC Guideline for Estimation of National Greenhouse Gas Emission Inventory. Intergovernmental Panel on Climate Change.

IPCC (1996) Inter-Governmental Panel on Climate Change. IPCC Good Practice Guidance and Uncertainty Management in National Greenhouse Gas Inventories, Cambridge University Press, New York.

IPCC (2000) IPCC Good Practices Guidance and Uncertainty Management in National Greenhouse Gas Inventories. Intergovernmental Panel on Climate Change; 2000. p. 2.44–2.50, IGES, Japan.

IPCC (2006). Revised 2006 IPCC Guidelines for National Greenhouse Inventories. Houghton J.T., MeiraFilho L.G., Lim B., Tréanton K., Mamaty I., Bonduki Y., Griggs D.J. Callander B.A. (Eds). Intergovernmental Panel on Climate Change (IPCC), IPCC/OECD/IEA, Paris, France.

MoEF (2004). India's Initial National Communication (INC) to UNFCCC. Government of India, New Delhi, pp.1-266.

MoEF (2010). India: Greenhouse Gas Emission 2007, Indian Network for Climate Change Assessment (INCCA) report, Ministry of Environment and Forests Government of India, pp. 1-64.

MoEF (2012). India's Second National Communication (SNC) to UNFCCC. Ministry of Environment and Forests, Government of India, New Delhi, pp. 1-310.

MoEFCC (2016). India's First Biennial Update Report (BUR-1) to UNFCCC. Ministry of Environment, Forest and Climate Change, Government of India, New Delhi, pp. 1-180.

Energy

CEA (2014, 2015, 2016). Annual Reports of different years (2013-14, 2014-15), Central Electricity Authority.

CEA (2014, 2015, 2016). Performance Review of Thermal Power stations of different years (2013-14, 2014-15), Central Electricity Authority.

DGMS (Various years 1995 to 2014), Statistics of Mines in India Vol. I (Coal), The Directorate General of Mines Safety, Dhanbad, India.

MoC (2012, 2013, 2014). Coal Directory of India 2011-12, 2012-13, 2013-14, 2014-15. Coal Controller's Office, Ministry of Coal, Government of India.

MoC (2012, 2013, 2014). Annual Reports 2011-12, 2012-13, 2013-14, 2014-15. Ministry of Coal, Government of India.

MoPNG (2015). Indian Petroleum and Natural Gas Statistics 2015-16. Economics and Statistics Division, Ministry of Petroleum and Natural Gas, Government of India.

MoPNG. Indian Petroleum and Natural Gas Statistics (Various years 1991-92 to 2015-16), Ministry of Petroleum and Natural Gas, Economics and Statistics Division, Government of India, New Delhi.

MoPNG (Various years 1991-92 to 2014-15), Indian Petroleum and Natural Gas Statistics, Ministry of Petroleum and Natural Gas, Economics and Statistics Division, Government of India, New Delhi.

MSME (2007). Fourth All India Census of Micro, Small and Medium Enterprise. Development Commissioner (MSME), Ministry of Micro, Small and Medium Enterprises. Government of India.

Ministry of Steel. Performance Review- Iron & Steel; Joint Plant Committee Report, Ministry of Steel Govt. of India.

MoSPI (2014, 2015, 2016). Energy statistics, Central Statistics Office, Ministry of Statistics and Programme Implementation, Govt. of India, of different years.

Energy- Transport

Aravind, D (2012). Problem and prospects of Indian maritime. International Journal of Scientific Engineering and Technology (ISSN : 2277-1581) Volume No.1, Issue No.6, pg : 299-300

CSTEP and IUT (2014). Review of Urban Transport in India, Center for Study of Science, Technology and Policy, Institute of Urban Transport (India).

DGCA (2015). Comparative Statement Of Total Domestic Passengers Carried By All Scheduled And Non-Scheduled Operators For Last Ten Years. Available at: http://dgca.nic.in/pub/pub13-14/PART-3-%20DOMESTIC%20ALL/3-10.pdf

FICCI (2016). FICCI– KPMG India Aviation Report, 2016.

MoPNG (2010, 2011, 2012, 2013, 2014, 2015). Indian Petroleum and Natural Gas Statistics 2009-10, 2010-11, 2011-12, 2012-13, 2013-14. Ministry of Petroleum and Natural Gas, Government of India, New Delhi.

MoPNG (2016). All India Survey of Gasoline and Diesel Consumption. A survey conducted by Indian Market Research Bureau for Ministry of Petroleum and Natural Gas, Government of India, New Delhi.

MoR (2010, 2011, 2012, 2013, 2014, 2015). Indian Railways Annual Statistical Statement 2009-10, 2010-11, 2011-12, 2012-13, 2013-14. Ministry of Railways. GoI. See Table 27 a. Availability at: Indian Railways: Zone and Divisions : http://www.indianrailways.gov.in/railwayboard/view_section.jsp?lang=0&id=0,1,304,366,533,1007,1012

MoRTH (2010) Road Transport Year Book 2009-10. Transport Research Wing, Ministry of Road Transport & Highways, Government of India, New Delhi

MoRTH (2015). Motor transport statistics of India 2014–2015. New Delhi, India: Transport Research Wing, Ministry of Road Transport and Highways, Government of India; 2015

MoS (2016). Update on Indian port sector. Transport Research Wing, Ministry Of Shipping.

PPAC (2013). All India study on sectoral demand of diesel and petrol report, Petroleum Planning and Analysis Cell.

SIAM (2016). Automobile Domestic Sales Trends (http://www.siamindia.com/statistics.aspx?mpgid=8&pgidtrail=14)

Singh, H.M. (2014). Revenue From Road Transport In India, Journal of Business Management & Social Sciences Research (JBM&SSR) ISSN No: 2319-5614 Volume 3, No.4, April 2014 .

IPPU

Chemicals and Petrochemicals Manufacturer's Association of India http://cpmaindia.com/ethylene_about.php

CPCB. (2008). Development of National Emission Standards for Petrochemical Plants. Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India.

CSE (2009). Green Rating Project, 2009, Centre for Science and Environment, New Delhi

http://www.paperex-india.com/paperscene.htm

MoM. (2017). Indian Mineral Yearbook 2015. Indian Bureau of Mines, Ministry of Mines, Government of India.

Tikku et al., (2007). Effectiveness of Treatment Technologies for Wastewater Pollution Generated by Indian Pulp Mills. Environment Monitoring & Assessment, 132,453–466.

Tripathi et al., (2013). A Comparative Study on Physico-Chemical Properties of Pulp and Paper Mill Effluent. Int. Journal of Engineering Research and Applications, 3 (6),811-818.

UNFCCC CDM website, UNFCC; Available technologies for GHG emission reduction from HNO3 production industry, published by the office of Air and Radiation, USEPA.

Livestock

Acharya, R.M. (1992) Goat genetic resources and their management. In: Research on Goats Indian Experience, Central Institute of Research on Goats, Makhdoom, Mathura. Pp 14.

Alemu, A. W., J. Dijkstra, A. Bannink, J. France, and E. Kebreab (2011). Rumen stoichiometric models and their contribution andchallenges in predicting enteric methane production. Anim.Feed Sci. Technol. 166–167:761–778.

Aluwong T, Wuyep PA, Allam L (2011). Livestock - enviroment interactions: Methane emissions from ruminants. Afr. J. Biotechnol. 10(8):1265–1269.

Arora, C.L. (1992) Proc. organized goat breeding and breeding strategies. In: Research on Goats Indian Experience, Central Institute of Research on Goats, Makhdoom, Mathura. pp14

Bolle, H.-J., Seiler, W., and Bolin, B., (1986). Other greenhouse gases and aerosols.1n Bolin, B., Doos, B.R., Jager, J. and Warrick, R.A. (Eds): SCOPE 29. The Greenhouse Effect, Climatic Change, and Ecosystems. Published on behalf of SCOPE by John Wiley and Sons, New York.

Dong, H., Z. Zhu, Z. Zhou, H. Xin and Y. Chen, (2011). Greenhouse gas emissions from swine manure stored at different stack heights. Anim. Feed Sci. Technol. 166: 557-561.

Duxbury, J.M., L.A. Harper, and A.R. Mosier. (1993). Contributions of agro- ecosystems to global climate change. p 1-18. In L.A. Harper, A.R. Mosier, J.M. Duxbury and D.E. Rolston (eds.), Agricultural ecosystems effects on trace gases and global climate change.ASA Special publication. No.55. ASA, CSSA, SSSA, Madison, WI.

Enishi, O., (2007). Greenhouse gas emissions caused from livestock in Japan. Proceedings of the 4th Workshop on Greenhouse Gas inventories in Asia Jakarta, (GGIAJ' 07), National Institute for Environmental Studies, Japan

Giger-Reverdin, S., D. Sauvant, I. Ledin and P. Morand-Fehr, (1998). Methane production in sheep in relation to concentrate feed composition from bibliographic data. Am. J. Engg. & Applied Sci., 5 (1): 1-8

Hegarty RS, Goopy JP, Herd RM, McCorkell B (2007). Cattle selected for lower residual feed intake have reduced daily methane production. Journal of Animal Science 85, 1479–1486

IPCC. (2007). Summary for policymakers. In: Climate change 2007: the physical science basis. Contribution of working group to the fourth assessment report of the intergovernmental panel on climate change (Ed. S. D. Solomon, M. Qin, Z. Manning, M. Chen, K. B. Marquis, M. T. Averyt, and H. L. Miller), Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA

Iqbal, M.F., Y.F. Cheng, W.Y. Zhu and B. Zeshan, (2008). Mitigation of ruminant methane production: current strategies, constraints and future options. World J. Microbiol. Biotechnol., 24: 2747-2755

Johnson, D.E. and G.M. Ward, (1996). Estimates of animal methane emissions. Environ. Monit. Assess., 42: 133-141

Johnson, K.A.;Huyler, M.T.; Westberg, H.H.; Lamb, B.K.; and Zimmerman, P. (1994) Measurement of methane emission from ruminant livestock using SF6 tracer technique. Environment Sci. & Technol. 28:359

Lascano, C.E. and E. Cardenas, (2010). Alternatives for methane emission mitigation in livestock systems. R. Bras. Zootec., 39: 175-182

Masse, D.I., G. Talbot and Y. Gilbert, (2011). On farm biogas production: A method to reduce GHG emissions and develop more sustainable livestock operations. Anim. Feed Sci. Technol. 166: 436-445

Nivsarkar A.E., Vij P.K. and Tantia, M.S. (2000) Animal Genetic Resources of India Cattle and Buffalo, ICAR, New Delhi

Nusbaum, N.J., (2010). Dairy livestock methane remediation and global warming. J. Commun. Health, 35: 500-502

Patra A K.(2014). Trends and Projected Estimates of GHG Emissions from Indian Livestock in Comparisons with GHG Emissions from World and Developing Countries. Asian-Australas J Anim Sci. 27(4): 592–599

Rodhe, H. (1990). A comparison of the contribution of various gases to the greenhouse effect. Science. 248:1217-1219

Sahu, S. Babu, L.K., Dilip, K.K., Behera, K., Kanungo, S.,Kaswan, S., Biswas, P. and Patra, J.K. (2013). Effect of different level of concentrate supplementation on the periparturient growth performance of Ganjam goats in extensive system. Veterinary World. 6: 428-432.

Takahashi, J., (2011). Some prophylactic options to mitigate methane emission from animal agriculture in Japan. Asian-Aust. J. Anim. Sci., 24: 285-294.

Zhou, M., E. Hernandez-Sanabria and L.L. Guan, (2009). Assessment of the microbial ecology of ruminal methanogens in cattle with different feed efficiencies. Applied Environ. Microbiol., 75: 6524-6533

Agriculture

Aggarwal, RK and Kaul, P (1978) Loss of nitrogen as ammonia volatilization from urea on loamy sand soil of Jodhpur. Annals of the Arid Zone, 17, 242-245.

Aggarwal, RK; Raina, P and Kumar, P (1987) 'Ammonia volatilization losses from urea and their possible management for increasing nitrogen use efficiency in an arid region' J. Arid Env. 13, 163-168.

Amanullah, M., Mohamed, Somasundaram, E. Vaiyapuri, K. and K. Sathyamoorthi (2007) Poultry Manure to Crops-a review, Agric. Rev., 28 (3) : 216-222

Andreae M.O. and P. Merlet, (2001). Emission of trace gases and aerosols from biomass burning, Global Biogeochem. Cycles, 15, 955-966.

Bandyopadhyay, S.K., Pathak, H., Kalra, N., Aggarwal, P.K, Kaur, R., Joshi, H.C., Choudhary, R. and Roetter, R. P. (2001). Yield Estimation and Agro-Technical Description of Production Systems. 'In Aggarwal, P. K., Roetter, R. P., Kalra, N., Van Keulen, H., Hoanh, C. T. and Van Laar, H. H. (eds.). Land use analysis and planning for sustainable food security: with an illustration for the state of Haryana. Indian Agricultural Research Institute, New Delhi, India, & International Rice Research Institute, Los Banos, Wagningen University and Research Centre, Wagningen. p161-89.

Bhatia A, Jain N, Pathak H, (2013). Methane and nitrous oxide emissions from Indian rice paddies, agricultural soils and crop residue burning. Greenhouse Gas Sci Technol, 1–16; DOI: 10.1002/ghg

Bhatia A., Pathak H., Jain N., Singh P.K., Tomer R. (2012). Greenhouse gas mitigation in rice–wheat system with leaf color

chart-based urea application, Environ Monit Assess, (2012) 184:3095–3107.

Bhatia, A., H. Pathak, N. Jain, P.K.Singh and A.K. Singh (2005). Global warming potential of manure amended soils under rice-wheat system in the Indo-Gangetic Plains. Atmos. Environ. 39, 6976–6984.

Bhatia, A., Pathak, H. and Aggarwal, P.K., (2004). Inventory of methane and nitrous oxide emissions from agricultural soils of India and their global warming potential. Curr. Sci., 87, 317-324.

Bhattacharya, S. and Mitra, A.P. (1998). Greenhouse gas emission India for the base year 1990, Center on Global Change, National Physical Laboratory, New Delhi. pp. 118.

Bijay-Singh and Sekhon, G.S. (1976). Some measures of reducing leaching loss of nitrates beyond potential rooting zone. Plant Soil. 44, 193-200.

Brady, N.C. (1984). The nature and properties of soils, 9th Edition, Macmillan Publishing Co. pp. 750.

Climate Change 2013: Impacts, Adaptation, and Vulnerability, Working Group II Contribution to the Fifth Assessment Report. Cambridge University Press, Cambridge, UK and New York, NY USA.

Erenstein, Olaf (2011). Cropping systems and crop residue management in the Trans-Gangetic Plains: Issues and challenges for conservation agriculture from village surveys. Agricultural Systems. Volume 104, Issue 1, January 2011, Pages 54-62

FAO (Food and Agricultural Organization): FAO agricultural database (www.fao.org.), FAO, Rome, Italy, 2012.

FAI (2011). Fertilizer Statistics (2010-2011). Fertilizer Association of India, New Delhi.

FAI (2012). Fertilizer Statistics (2011-2012). Fertilizer Association of India, New Delhi.

FAI (2013). Fertilizer Statistics (2012-2013). Fertilizer Association of India, New Delhi

FAI (2014). Fertilizer Statistics (2013-2014). Fertilizer Association of India, New Delhi

FAI (2015). Fertilizer Statistics (2014-2015). Fertilizer Association of India, New Delhi

Gadde, B, Christoph, M .C. and Wassmann, R. (2009). Rice Straw As A Renewable Energy Source In India, Thailand, And The Philippines: Overall Potential And Limitations For Energy Contribution And Greenhouse Gas Mitigation, Biomass Bioenergy, 33: 1532-1546.Gaur, A.C. (1995) Bulky Organic Manures and Crop Residues. In: HLS Tandon (ed.) FDCO, New Delhi.

Galloway, J.N. and Cowling, E.B. 2002. Reactive nitrogen and the world: 200 years of change. Ambio. 31, 64-71.

Ghosh, S., Majumdar, D. and Jain, M.C., 2002. Nitrous oxide emission from kharif and rabi legumes grown on an alluvial soil. Biol. Fertil. Soils, 35, 473-478.

Gogoi N., Baruah K.K., Gupta P. K. (2008). Selection of rice genotypes for lower methane emission. Agron. Sustain. Dev. 28, 181–186.

Gogoi, N., Baruah K., Gogoi B., Gupta P.K. (2008). Methane emission from two different rice ecosystems (Ahu And Sali) at lower Brahmaputra valley zone Of North East India. Applied Ecology and Environmental Research 6 (3): 99-112.

Huke R. E. and Huke E. H. (1997). Rice area by type of culture: south, southeast, and east Asia a revised and updated data base IRRI, 1997, pp 53..

IPCC 2007; Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Jain N, Arora P., Tomer R., Mishra S. V., Bhatia A., Pathak H., Chakraborty D., Kumar V., Dubey D.S., Harit R.C., and Singh J.P. (2016) Greenhouse gases emission from soils under major crops in northwest India' Science of the Total Environment 542, 551–561.

Jain N, Bhatia A, Pathak H, (2014). Emission of Air Pollutants from Crop Residue Burning in India". Aerosol and Air Quality Research, 14: 422–430.

Kumar, U. Jain, M.C., Pathak, H., Kumar, S. and Majumdar, D. (2000). Nitrous oxide emission from different fertilizers and its mitigation by nitrification inhibitors in irrigated rice. Biol. Fertil. Soils, 32, 474-478.

Kumar, U., Jain, M.C., Sushil Kumar, Pathak, H. and Majumdar, D.: (2000), 'Role of nitrification inhibitors on nitrous oxide emissions in a fertilized alluvial clay loam under different moisture regimes', Curr. Sci. 79, 224-228.

Leonard S. Bull (2002) Animal and poultry waste-to-energy, www.cals.ncsu.edu/ waste_mgt/

Li, C., (2000). Modeling trace gas emissions from agricultural ecosystems. Nutrient Cycling in Agroecosystems. 58, 259–276.

Khan, M.A. and Zargar, M.Y. (2013). Experimental quantification of greenhouse gas (CH_4) emissions from fertilizer amended rice field soils of Kashmir Himalayan Valley. Journal of Environmental Engineering & Ecological Science, doi: 10.7243/2050-1323-2-5.

Majumdar D., Pathak, H., Kumar, S. and Jain, M.C., (2002). Nitrous oxide emission from a sandy loam Inceptisol under irrigated wheat in India as influenced by different nitrification inhibitors. Agric. Ecosys. Environ., 91, 283-293.

Majumdar, D., Kumar, S., Pathak, H., Jain, M.C. and Kumar, U., (2000). Reducing nitrous oxide emission from an irrigated rice field of North India with nitrification inhibitors. Agric. Ecosys. Environ., 81, 163-169.

Khosa, M.K, Sidhu, B.S., Benbi D.K. (2011). Methane emission from rice fields in relation to management of irrigation water. J. Environ. Biol. 32, 169-172.

Manrique, L.A., Jones, C.A., (1991). Bulk density of soil in relation to soil physical and chemical properties. Soil Science Society America Journal 55, 476–481.

Mathew Reena, Balachandran, P.V. Iyer C.S.P and Jaikumaran U. (2010). Diurnal And Phenological Variation In Methane Emission From Wetland Rice Fields, Vol. XVII: No.1 & 2 SB Academic Review : 82 – 87.

MOA (2011-2013) Agricultural Statistics at a glance 2014. Directorate of Economics and Statistics, Department of Agriculture and Cooperation (DAC), Ministry of Agriculture, Government of India. http://dacnet.nic.in/eands/APY_96_To_ 06.htm

DAHD&F, (2013); 19th Livestock census report. Department of Animal Husbandry, Dairying & Fisheries. Government of India.

Motsara M.R., Bhattacharya, P. and Srivastava, V. (1995) Bio-fertilizer Technology, Marketing and Uses, FDCO, New Delhi.

NBSS and LUP (1998), Benchmark Soils of India. National Bureau of Soil Survey and Land Use Planning, Nagpur, India, p. 398, .

Parashar, DC; Kulshreshtha, UC; and Sharma, C (1998) 'Anthropogenic emissions of NOx, NH3 and N2O in India' Nutr. Cyc. Agroecos., 52, 255-259.

Patel, SK, Panda, B and Mohanty SK (1989) Realtive ammonia loss from urea based fertilizers applied to rice under different hydrological situations. Fert. Res. 19:113-119.

Pathak, H. and Wassmann, R. (2007) Introducing greenhouse gas mitigation as a development objective in rice-based agriculture: I. Generation of Technical Coefficients. Agril. Systems. 94:807-825.

Pathak, H., Bhatia, A., Shiv Prasad, Jain, M.C., Kumar, S., Singh, S. and Kumar, U. (2002) Emission of nitrous oxide from soil in rice-wheat systems of Indo-Gangetic plains of India. J. Environ. Monitoring Assessment 77(2):163-178.

Pathak, H., Jain, N., Bhatia, A., Mohanty, S., and N. Gupta (2008) Global warming mitigation potential of biogas plants in India, Environ Monit Assess, DOI 10.1007/s10661-008- 0545-6

Purkait N N, Sengupta M K, De Sanghamitra and D K Chakrabarty (2005). Methane emission from the rice fields of West Bengal over a decade. Indian Journal of Radio & Space Physics, 34, 255-263.

Rajkishore S.K., Doraisamy P., Subramanian K.S. and Maheswari M. (2013). Methane emission patterns and their associated soil microflora with SRI and conventional systems of rice cultivation in Tamil Nadu, India. Taiwan Water Conservancy 61 (4) December 2013.

Reena Mathew (2003). Methane emission from wetland rice fields of kerala. Thesis submitted to Department of agronomy, College of Horticulture, KAU, Thrissur, Kerala, India.

SAC (Space application centre (ISRO)) (2009) Methane emission inventory from Indian rice-ecosystems using remote sensing, GIS and field observations. Scientific report,. SAC/AFEG/AMD/EIAA/SN/03/08

Sarkar, M.C., Banerjee, N.K., Rana, D.S. and Uppal, K.S. (1991) Field measurements of ammonia volatilization losses of N from urea applied to wheat. Fert. News. 33:25-29.

Seligman, N.G., Van Keulen, H., 1981. PAPRAN: A simulation model of annual pasture production limited by rainfall and nitrogen. In: Frissel, M.J., Van Veen, J.A. (Eds.), Simulation of N behavior of soil-plant systems. Pudoc, Wageningen, pp. 60–97.

Singh, Bijay; Singh, Y; Khind, CS and Meelu, OP (1991) 'Leaching losses of urea-N applied to permeable soils under lowland' Fert. Res. 28, 179-184.

Subrian, P., Annadurai, K. and Palaniappan, S.P. (2000) Agriculture Facts and Figures, Kalyani Publishers, New Delhi. pp 133-134.

TIFAC, (1991). Techno market survey on Utilization of agricultural residues (farm and processes), March 1991, Technology Information Forecasting & Assessment Council, Department of Science and Technology, New Delhi.

TERI (2001) Tata Energy Research Institute-Energy data directory and year book, 2000-01.

Velayutham, M., Bhattacharya, T., (2000). Soil Resource Management, In: Natural Resource management for agricultural production in Indian International conference on managing natural resources for sustainable agricultural production in the 21st century, 14–18 February, 2000, New Delhi, India.

World Rice Statistics (IRRI), (2008); International Rice Research Institute.

Yadav, Manoj; Sharma, M.; Prawasi, R.; Khichi, Rajeev; Kumar, Pavan; Mandal, V.; Salim, Abdul; Hooda, R (2014). Estimation of Wheat/Rice Residue Burning Areas in Major Districts of Haryana, India, Using Remote Sensing Data. Journal of the Indian Society of Remote Sensing , June 2014, Vol. 42 Issue 2, p343-352, Publisher: Springer Science & Business Media B.V.

Waste

CPCB (2005). Status of sewage treatment plant in India. New Delhi: Central pollution Control Board.

CPCB (2013). Performance evaluation of sewage treatment plants under NRCD, Central Pollution Control Board.

Daelman, M. R. (2012). Methane Emission during Municipal Wastewater Treatment, Water Research, 46(11): 3657-3670.

Daelman, M. R. (2015). Seasonal and diurnal variability of N2O emissions from a Full- scale municipal wastewater treatment plant. Science Total Environment, 536: 1- 11.

Doorn, M. S. (1997). Estimate of global greenhouse gas emissions from industrial and domestic wastewater treatment, Final Report, EPA-600/R-97-091, Prepared for United States Environmental Protection Agency.

Eggleston H.S., B. L. (2006). 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Prepared by the National Greenhouse Gas Inventories Programme, Japan.: IGES.

Hiraishi, T. K. (2014). IPCC 2014, 2013 Supplement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories: Wetlands. Switzerland: IPCC.

Kaplan, W. A. (1985). The biogeochemistry of nitrous oxide: A review, advances in aquatic microbiology.

Kushwaha, J. P. (2013). A review on sugar industry wastewater: Sources, treatment technologies and reuse, Desalination and Water treatment, Volume 52.

M. N. Rao, A. D. (2008). Waste Water Treatment. Oxford & IBH.

M.R.J. Daelman, E. M. (2013). Methane and nitrous oxide emissions from municipal wastewater treatment – Results from a long-term study. Environmental Science and Technology, 67(10): 2350-2355.

NEERI (2005). Assessment of Status of Municipal Solid Waste Management in Metro Cities, State Capitals, Class – 1 Cities and Class – II Towns, NEERI Report, 2005

R. A. Ramanujam, R. G. (2010). Wastewater treatment technology for tanning industry, Water and Wastewater Treatment technologies, 1-

Supriya Rattan, A. K. (2015). A comprehensive review on utilization of wastewater fromcoffee processing. Environmental Science and Pollution Research, Volume 22, 6461-6472.

Wang, J. C. (2015). Effect of dissolved oxygen and nitrogen on emission of N2O from rivers in China. Atmospheric Environment, 103: 347-356.

Yoshida, N. (1988). N-depleted N2O as a product of nitrification, Nature, 335: 2.

Yu, Z. D. (2013). Nitrous Oxide Emissions in the Shanghai River Network: Implications for the Effects of Urban Sewage and IPCC Methodology. Global Change Biology, 19(10): 2999-3010.

Validation

Bhattacharya, S. K.; Borole, D.V.; Francey, R.J.; Allison, C.E.; Steele, L.P.; Krummel, P.; Langenfelds, R.; Masarie, K.A.; Tiwari, Y. K.; and Patra, P.K., (2009), Trace gases and CO_2 isotope records from Cabo de Rama, India, Current Science, VOL. 97, NO. 9, pp 1336-1344, 10 Nov. 2009, ISSN: 0011-3891

Brenninkmeijer, C. A. M., et al. (2007), Civil aircraft for the regular invetigation of the atmosphere based on an instrumented container: The new CARIBIC system, Atmos. Chem. Phys., 7(18), 4953–4976, doi:10.5194/acp-7-4953-200

Ganesan et al, (2013), The variability of methane, nitrous oxide and sulfur hexafluoride in Northeast India, Atmos. Chem. Phys., 13, 10633–10644, 2013

Ganesan, A.L., Rigby, M., Lunt, M.F., Parker, R.J., Boesch, H., Goulding, N., Umezawa, T., Zahn, A., Chatterjee, A., Prinn, R.G., Tiwari, Y.K., van der Schoot, M., and Krummel, P.B.: Atmospheric observations show accurate reporting and little growth in India's methane emissions., Nature Communications 8, Article 836 (2017), doi: 10.1038/s41467-017-00994-7

Parker, R. J. et al. (2015). Assessing 5 years of GOSAT Proxy XCH_4 data and associated uncertainties. Atmos. Meas. Technol. 8, 4785–4801 (2015).

Patra, P. K., M. C. Krol, S. A. Montzka, T. Arnold, E. L. Atlas, B. R. Lintner, B. B. Stephens, B. Xiang, J. W. Elkins, P. J. Fraser, A. Ghosh, E. J. Hintsa, D. F. Hurst, K. Ishijima, P. B. Krummel, B. R. Miller, K. Miyazaki, F. L. Moore, J. Mühle, S. O'Doherty, R. G. Prinn, L. P. Steele, M. Takigawa, H. J. Wang, R. F. Weiss, S. C. Wofsy, D. Young, (2014). Observational evidence for interhemispheric hydroxyl-radical parity, Nature, 513, 219-223, 2014.

Patra, P. K., T. Saeki, E. J. Dlugokencky, K. Ishijima, T. Umezawa, A. Ito, S. Aoki, S. Morimoto, E. A. Kort, A. Crotwell, K. Ravikumar, T. Nakazawa, (2016). Regional methane emission estimation based on observed atmospheric concentrations (2002-2012), J. Meteorol. Soc. Jpn., 94, 91-113.

Patra, P. K., M. Takigawa, Shingo Watanabe, N. Chandra, K. Ishijima,(2018). Improved Chemical Tracer Simulation by MIROC4.0-based Atmospheric Chemistry-Transport Model (MIROC4-ACTM), SOLA, 14, 91-96.

Schuck, T. J., K. Ishijima, P. K. Patra, A. K. Baker, T. Machida, H. Matsueda, Y. Sawa, T. Umezawa, C. A. M.Brenninkmeijer, and J. Lelieveld (2012), Distribution of methane in the tropical upper troposphere measured by CARIBICand CONTRAIL aircraft, J. Geophys. Res., 117, D19304, doi:10.1029/2012JD018199

Tiwari, Y. K, Ramesh K. Vellore, K. Ravi Kumar, Marcel van der Schoot, Chun-Ho Cho, (2014), Influence of monsoons on atmospheric CO_2 spatial variability and ground-based monitoring over India, Science of The Total Environment,

Volume 490, 15 August 2014, Pages 570–578, ISSN: 0048-9697 http://dx.doi.org/10.1016/j.scitotenv.2014.05.045

Tiwari, Y. K., Prabir K Patra, Frédéric Chevallier, Roger J Francey, Paul B Krummel, Colin E Allison, J V Revadekar, Supriyo Chakraborty, Ray L Langenfelds, S K Bhattacharya, D V Borole, K Ravi Kumar, L Paul Steele, (2011). CO_2 observations at Cape Rama, India for the period of 1993-2002: implications for constraining Indian emissions. Current Science, Vol.101, No.12, pp 1562 – 1568, 25 Dec. 2011, ISSN: 0011-3891 [IF=0.967]

Wunch, D., Toon, G. C., Blavier, J.-F. L., Washenfelder, R. A., Notholt, J., Connor, B. J., Griffith, D. W. T., Sherlock, V., and Wennberg, P. O (2012). The total carbon column observing network, Philos. T. R. Soc. A, 369, 2087–2112, https://doi.org/10.1098/rsta.2010.0240, 2011 Schuck, T. J., K. Ishijima, P. K. Patra, A. K. Baker, T. Machida, H. Matsueda, Y. Sawa, T.Umezawa, C. A. M. Brenninkmeijer, and J. Lelieveld (2012), Distribution of methane in the tropical upper troposphere measured by CARIBIC and CONTRAIL aircraft, J. Geophys. Res., 117, D19304, doi:10.1029/2012JD018199.

Appendix

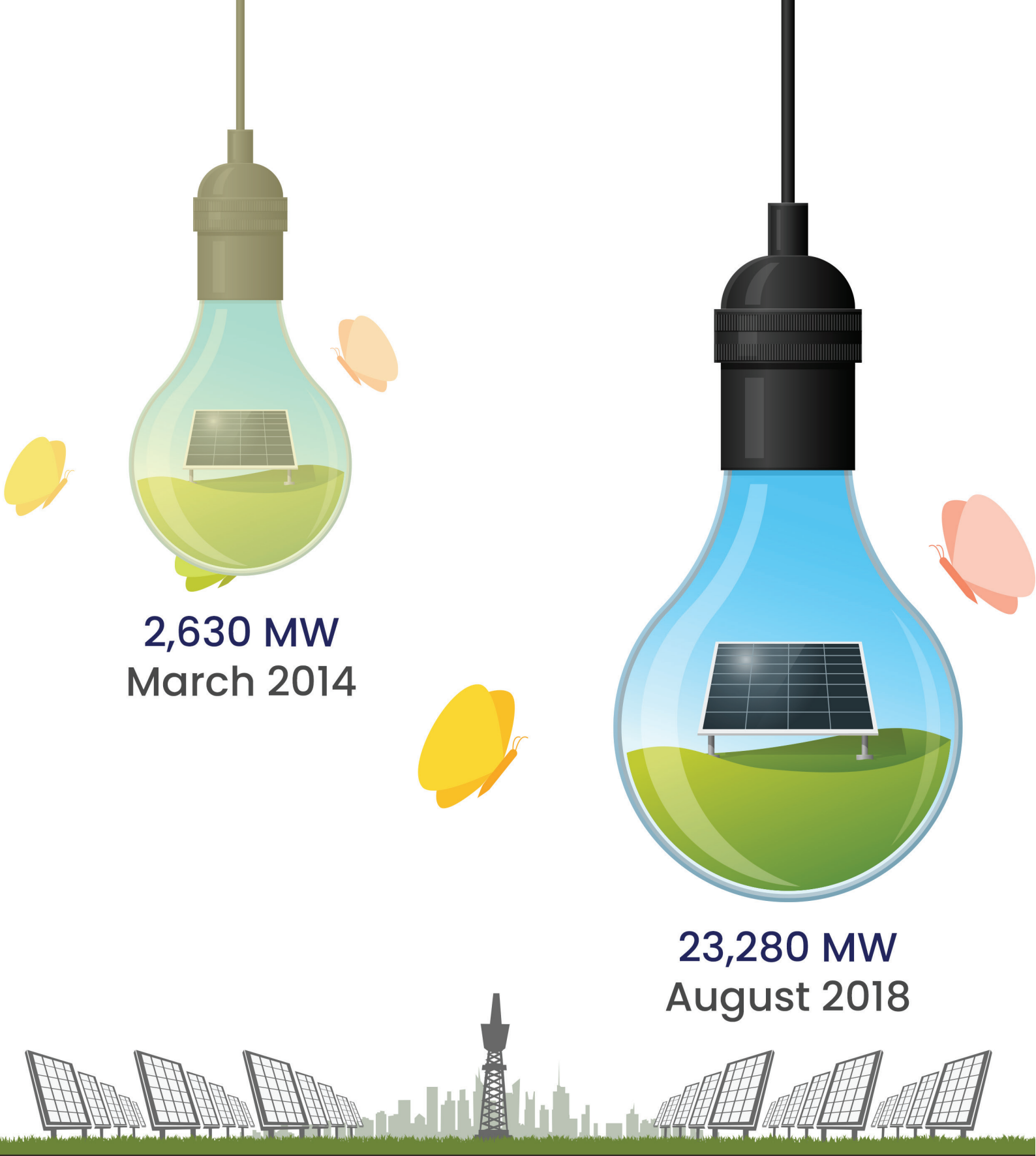
Combined Table of India's Greenhouse gas emissions by sources and removals by sinks for the year 2014 (values in Gg)

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC-134a	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
TOTAL without LULUCF (Gg)	**1997891.85**		**20005.347**	**475.288**		**1.588**	**2.607**	**0.709**	**0.004**	**2607488.12**
TOTAL with LULUCF (Gg)	**2015107.88**	**319860.23**	**20053.542**	**476.705**		**1.588**	**2.607**	**0.709**	**0.004**	**2306295.43**
1. ENERGY (Gg)	**1844705.03**		**2133.37**	**65.355**						**1909765.74**
A. Fuel Combustion Activities	1844705.03		321.127	65.355						1871708.65
1. Energy Industries	1135357.11		14.956	17.136						1140983.46
a. Electricity production	1078153.76		11.816	16.245						1083437.78
b. Refinery	49969.71		2.604	0.087						50051.3
c. Manufacturing of Solid Fuel	7233.64		0.536	0.805						7494.38
2. Manufacturing Industries & Construction	350211.44		4.802	5.152						351909.54
a. Cement	46857.24		0.895	0.544						47044.77
b. Iron & steel	153883.85		1.735	2.444						154677.9
c. Nonferrous metals	1749.59		0.041	0.021						1756.94
d. Chemicals	1994.09		0.05	0.022						2002.1
e. Pulp & paper	3866.91		0.039	0.059						3886.04
f. Food & beverages	NE									
g. Non-metallic minerals	NE									
h. Mining & quarrying	3227.15		0.13	0.026						3237.98
i. Textile/leather	3542.1		0.046	0.049						3558.14
j. Bricks	2665.71		0.027	0.04						2678.8
k. Fertilizer	5999.76		0.102	0.086						6028.47
l. Engineering Sector	419.99		0.017	0.003						421.28
m. Nonspecific Industries	126005.04		1.717	1.858						126617.12
n. Glass Ceramic	NE									
3. Transport	245845.66		57.676	10.051						250172.79
a. Road transport	221282.86		56.859	9.577						225445.83
b. Civil Aviation	13861.21		0.097	0.388						13983.44
c. Railways	7618.43		0.514	0.062						7648.35

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC-134a	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
d. Navigation	3083.17		0.206	0.025						3095.17
4. Other sectors	113290.83		243.693	33.014						128642.85
a. Commercials/Institutional	25379.95		0.303	0.332						25489.2
b. Residential	85538.86		1.852	0.477						85725.5
c. Agricultural/fisheries	2372.01		0.185	0.023						2383.05
d. Biomass burnt for energy			241.354	32.183						15045.1
B. Fugitive Emission from fuels			1812.243							38057.09
1. Solid fuels			787.93							16546.56
a. Above ground mining			523.27							10988.67
b. Underground mining			264.661							5557.89
2. Oil and Natural gas			1024.31							21510.53
a. Oil			79.064							1660.35
b. Natural gas			767.553							16118.61
c. Venting and Flaring			177.694							3731.57
2. Industrial Processes and Product Use	**153186.81**		**177.85**	**10.36**		**1.588**	**2.61**	**0.71**	**0.004**	**202277.69**
A. Mineral Products	126855.79									126855.79
1. Cement production	115341.6									115341.6
2. Lime production	11124.66									11124.66
3. Limestone and Dolomite Use	NE									
5. Glass Production	372									372
6. Ceramics	17.53									17.53
B. Chemical Industry	18485.87		22.746	10.359						22174.88
1 Ammonia production	10226.82									10226.82
2 Nitric acid production				9.581						2970
4. Carbide production	93.59									93.59
5. Titanium dioxide production	68.01									68.01
4. Soda ash Production	798.85									798.85
6. Methanol production	156.91		0.539							168.22
7. Ethylene production	6246.23		9.692							6449.75
8. EDC & VCM production	267.86									267.86

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC-134a	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
9. Ethylene Oxide production	160.95		0.334							167.96
10. Acrylonitrile production	27.45		0.006							27.58
11.Carbon Black production	439.2		12.176							694.9
12. Caprolactam				0.779						241.34
C Metal Production	5671.71		0.1				2.607	0.709	0.004	29242.38
1 Iron & Steel production	IE									
2 Ferroalloys production	2449.58		0.1							2451.68
3 Aluminium production	3138						2.607	0.709		26606.19
4. Lead production	49.07									49.07
5. Zinc production	35.06									35.06
6. Magnesium Production									0.004	100.38
D. Non Energy Product Use	2173.44									2173.44
1. Lubricant	1950.84									1950.84
2. Paraffin wax	222.60									222.60
E. Production of halocarbons and SF_6						1.588				18576.19
H. Other (Pulp & paper)			155.00							3255.00
3. AGRICULTURE			**14709.781**	**349.394**						**417217.54**
A. Enteric Fermentation			10816.978							227156.53
B. Manure Management			128.348	81.954						28101.05
C. Rice Cultivation			3468.695							72842.6
D. Agricultural Soils				259.77						80528.7
Direct N_2O Emissions				216.44						67096.4
Indirect N_2O Emissions				43.33						13432.3
E. Field Burning of Agricultural Residues			295.76	7.67						8588.66
4. LULUCF	**17216.04**	**319860.23**	**48.194**	**1.417**						**-301192.69**
A. Forest land		69666.67	48.19	1.42						-68215.17
B. Cropland		248610.3								-248610.3
C.Grassland	17216.04									17216.04
D. Settlement		1583.26								-1583.26

	CO_2 emission	CO_2 removal	CH_4	N_2O	HFC-134a	HFC 23	CF_4	C_2F_6	SF_6	CO_2 equivalent
E. Otherland	NE	NE								
5. WASTE			**2984.35**	**50.18**						**78227.15**
A. Solid waste disposal on land			717.4							15065.4
1. Managed Waste Disposal on Land			717.4							15065.4
B. Waste-water handling			2266.95	50.18						63161.75
1. Industrial Wastewater			1261.23							26485.83
2. Domestic and Commercial WasteWater			1005.72	50.18						36675.92
Memo Item (not accounted in total Emissions)	**812030.6**		**0.108**	**0.113**						**812067.87**
International Bunkers	4943.53		0.108	0.113						4980.81
Aviation	3681.65		0.026	0.103						3714.12
Marine	1261.88		0.083	0.01						1266.69
CO_2 from Biomass	807087.06									807087.06



Solar installed capacity in India increased by about 9 times in last 4 years from 2,630 MW to 23,280 MW

Chapter 3

Mitigation Actions

Chapter 3: Mitigation Actions

India is committed to the implementation of mitigation policies and is proactively promoting low carbon and sustainable lifestyles. As an update on mitigation actions reported under the Second National Communication and the First Biennial Update Report (BUR-1), the present report includes, in accordance with Article 12, paragraph 1(b) of the UNFCCC, the steps taken or envisaged by India to implement the Convention. This has been done taking into account the specific national development priorities, objectives, and circumstances. The information provided regarding these actions conforms to the guidelines on BUR and includes the associated methodologies and assumptions. It covers the nature of mitigation actions, coverage and progress indicators. An account of key climate-related existing policies/actions/programmes/projects, both at the national and state levels is also included. One such initiative is India's National Action Plan on Climate Change (NAPCC), which is aimed at achieving sustainable development and mitigation targets of the country in various sectors. Although the agriculture sector is not a part of India's voluntary pledge on climate change, proactive measures for both climate change mitigation and adaptation in the agriculture sector have also been discussed in this chapter.

India's mitigation policies and actions must be understood in the context of its long-standing position that climate change is a global challenge, a position in accordance with the spirit of the UNFCCC. This global challenge requires collective action, specifically to solve the problem of managing the global commons that is the Earth's carbon system. Greenhouse gas emissions anywhere in the world contribute to global warming, and as a result, global cooperation among all countries is required – an individual country's efforts alone will not bear fruit unless accompanied by adequate action by the others. India has always emphasized the importance of basing such collective effort on equity and the concept of common but differentiated responsibilities in line with the Convention.

Advances in climate science, particularly emphasized for the first time in the Fifth Assessment Report (IPCC, 2013), have enabled the quantification of the global commons in the context of the total carbon budget. The total carbon budget defines the permissible cumulative greenhouse gas emissions from the pre-industrial period for the entire world that would ensure that temperature rise stays within a specified limit. It is evident that the collective action problem lies in ensuring an equitable division of this budget.

Developed countries have occupied a considerable share of carbon space, far more than their fair share (fair defined by varied measures), but the recognition and redressal of this over-occupation has always been a contentious issue. One of the reasons for this is that a country's carbon space, a due share of the global commons, is also a country's strategic asset. Those who have occupied it are reluctant to let go since it is much cheaper for an economy to limit its transition costs in energy in the short term. While it is often suggested that developing countries must undertake development differently, it must be recognized that there is an overall deficiency of developed countries in leading the way of developing actual modalities of achieving this. This deficiency results in the continued over-occupation of even what remains of the total carbon budget (apart from what has been occupied already) by the developed countries.

For India too, carbon space is a strategic asset and getting its fair share of carbon space - even while being a responsible global player, concerned and taking the lead in protecting the planet - is a strategic goal. However, the past and continued over-occupation of the total carbon budget by the developed countries puts an additional burden on India. On the one hand, it is essential to meet its development needs, which requires adequate carbon space. On the other hand, India's own adaptation needs demand that temperature goals be appropriately set. Even with the reduction of emissions intensity of GDP and large-scale and massive deployment of renewable sources, India will still need carbon space.

It is also important to note that the improvement in emissions intensity of GDP and the numerous other transformative efforts that India is undertaking, is part of its commitments under the Paris Agreement. Thus, the mitigation effort of these developments should not be subsumed into the emissions baseline for the Indian economy.

Finally, in the context of the reference in the Paris Agreement to the 2°C temperature target as well as the need to strive to reach the 1.5°C target, it must be emphasised that India's Nationally Determined Contributions (NDCs) are not linked specifically to any temperature target. It represents what India can achieve at its current stage of development. Going beyond this would represent a further effort that is not the subject of any consideration here.

3.1 Voluntary pledge

As detailed in Chapter 2, India's total GHG emissions (including LULUCF) in 2014 were 2,306.3 $MtCO_2e$. India's per capita GHG emission in 2014 was 1.8 tonnes CO_2e. In accordance with the provisions of Article 12, paragraphs 1(b) and 4, and Article 10, paragraph 2(a), of the Convention, India took a voluntary pledge to reduce the emission intensity of its GDP by 20-25% by 2020 from 2005 levels (excluding emissions from agriculture) in 2010 (UNFCCC, 2010). As a result of supportive policies and institutions, an emission intensity reduction of 21% between 2005 and 2014 has been achieved. In 2015, India further enhanced ambition in its NDCs to reduce emission intensity of its GDP by 33-35% by 2030 from 2005 level (GoI, 2015).

The decrease in the emission intensity of India's GDP has been made possible through consistent efforts by the government towards establishing commensurate policies, institutions and capacities for the adoption of energy conservation and efficiency improvement practices across all sectors. Therefore, over the years, the Government of India and various state governments have undertaken proactive policies and measures. These efforts to implement the Convention, keeping in mind the national circumstances, have spanned across sectors and regions. Most of these policies and measures mitigate greenhouse gases directly or indirectly. In addition, increasing the share of cleaner and renewable energy sources such as solar, wind, nuclear, waste to fuels and biofuels in its energy mix through replacing the fossil fuels has contributed significantly to emission reduction. The Indian economy is, therefore, becoming greener through conscious actions, and there are efforts to enhance energy efficiency across the economy, increase the share of renewable energy and enhance forest and tree cover, while simultaneously meeting our development challenges in a sustainable manner. Substantial resources are being committed internally towards this each year. Climate change related activities have been further strengthened through the National Action Plan on Climate Change that has targeted missions on solar energy, enhanced energy efficiency and greening India. The next section provides an update of the latest achievements of the National Missions adopted for climate change mitigation.

3.2 Implementation of the National Action Plan on Climate Change

The National Action Plan on Climate Change (NAPCC) was launched in 2008 to address climate change concerns and promote sustainable development. There are eight National Missions, which form the core of the NAPCC. These represent "multi-pronged, long-term and integrated strategies for achieving key goals in the context of climate change". Implementing the NAPCC requires appropriate institutional mechanisms for each of the missions. The targets and key achievements under these missions are highlighted in Table 3.1. A detailed progress of the programmes running under these umbrella missions is covered in the later part of the chapter under sector sub-heads.

Table 3.1: Implementation of NAPCC

Mission and Description	Target/Deliverables	Key Achievements
Jawaharlal Nehru National Solar Mission: Aims at increasing the share of solar energy in the total energy mix through the development of new solar technologies.	• Achieve 100 GW of solar power by 2022. • Enabling policy framework for implementation of the mission • Promoting 2000 MW of off-grid solar applications, including 20 million solar lights by 2022 • Creating a conducive environment for developing solar manufacturing capability in the country • Supporting research and development and capacity building activities • The target of 100 GW solar power is to be achieved in seven years starting from 2014-15, with 40 GW of grid-connected rooftop projects and 60 GW of large and medium land-based solar-power projects	• A cumulative capacity of 23,280 MW has been installed and commissioned till August 2018 and is continuously being increased. This includes solar rooftop and off-grid systems. Globally, India is on the 5th position in total solar power installed. • Solar energy promotion through fiscal incentives such as capital and interest subsidies, generation-based incentives, viability gap funding (VGF), financing solar rooftop systems, concessional excise and custom duties, preferential tariff for power generation from renewable sources, foreign direct investment (FDI) up to 100%, and a Modified Special Incentive Package Scheme (M-SIPS). • Issuance of the renewable purchase obligation • Green energy corridors (GEC) with dedicated transmission system are being created. • 194,700 solar pumps set up till August 2018. • 45 solar parks in 21 states with aggregate capacity of 26,500 MW sanctioned.

National Mission for Enhanced Energy Efficiency (NMEEE): The Mission aims to strengthen the market for energy efficiency by creating a conducive regulatory and policy regime. It envisages fostering innovative and sustainable business models.	• Mandating specific energy consumption reduction in large energy-consuming industries, with a system for companies to trade energy-savings certificates. • Energy incentives, including reduced taxes on energy-efficient appliances. • Financing public-private partnership to reduce energy consumption through demand-side management programmes in municipal buildings and agricultural sectors. • NMEEE includes four initiatives: Perform, Achieve and Trade; Energy Efficiency Financing Platform; Market Transformation for Energy Efficiency; and Framework for Energy Efficient Economic Development.	• Under NMEEE, Perform, Achieve and Trade (PAT) was launched in 2012. The first cycle of PAT (from 2012–15) resulted in an energy saving of 8.67 Mtoe and an emission reduction of 31 $MtCO_2$ (Details in Section 3.4.1). • In PAT Cycle II (2016–19), 621 Designated Consumers (DCs) from 11 sectors have been given Specific Energy Consumption (SEC) targets, with an intended energy saving of 8.869 Mtoe. The third PAT cycle was notified in March 2017 to achieve an overall energy consumption reduction of 1.06 Mtoe. The fourth cycle of PAT has commenced from 1st April 2018 in which 109 DCs have been notified from the existing sectors of PAT and two new sectors namely Petrochemicals and Commercial Buildings (hotels).
National Mission for a Green India (GIM): Aims at enhancing ecosystem services and carbon sinks through afforestation on degraded forest lands in line with the national policy of expanding the forest and tree cover to 33% of the total land area of the country.	• To increase forest/tree cover to the extent of 5 Mha and improve quality of forest/tree cover on another 5 Mha of forest/non-forest lands • To improve/enhance ecosystem services like carbon sequestration and storage (in forests and other ecosystems), hydrological services and biodiversity; along with provisioning services like fuel, fodder, and timber and non-timber forest products (NTFPs). • To increase forest based livelihood income of about three million households.	• In the preparatory phase of GIM, a fund of ₹626 million was released during the financial years 2011–12 and 2013–14 to 27 states/UTs for undertaking preparatory activities, including institutional strengthening, training, identification of landscapes and preparation of perspective plans at the state/UT level. • An amount of ₹1,439.6 million has been spent till March 2018. • Nagar Vana Udyan Yojana was launched to promote urban forestry. • Convergence guidelines of GIM with MNREGS and CAMPA have been framed.
National Mission on Sustainable Habitat (NMSH): The mission attempts to promote energy efficiency in buildings, management of solid waste and modal shift to public transport including transport options based on biodiesel and hydrogen.	• Development of sustainable habitat standards that lead to robust development strategies while simultaneously addressing climate change-related concerns. • Preparation of city development plans that comprehensively address adaptation and mitigation concerns. • Preparation of comprehensive mobility plans that enable cities to undertake long-term, energy-efficient and cost-effective transport planning. • Capacity building for undertaking activities relevant to the mission.	• Standards and guidelines have been developed for solid waste management, water and sanitation, storm water drainage, urban planning, energy efficiency and urban transport. • Energy Conservation Building Code 2017 has been launched and is applicable to buildings that have a connected load of 100 kW or greater, or a contract demand of 120 kVA or greater, and are intended to be used for commercial purposes. • Specific guidelines have been issued for enhanced lighting system efficiency. • Since 2015, new initiatives including AMRUT, Smart City initiative, HRIDAY, Swachh Bharat Mission, National Policy on Biofuels 2018, National Electric Mobility Mission Plan 2020 and National Urban Livelihoods Mission have been launched that would support NMSH.
National Water Mission (NWM): Aims to ensure integrated water resource management, conserve water, minimize wastage and ensure equitable distribution of water within states	• Creating a comprehensive water database in the public domain and assessing the impact of climate change on water resource. • Promoting citizen and state action for water conservation, augmentation and preservation. • Focusing attention on overexploited areas • Increasing water-use efficiency by 20% • Promoting basin-level integrated water resources management.	• Preparation of State Specific Action Plan for water sector based on scientific assessment of the supply and demand side of water resources and vulnerability to climate change. • Bridging the critical governance gap through an institutional mechanism of state water budgeting on lines similar to that of financial budgeting. • 26 baseline studies for improving water use efficiency for irrigation projects have been taken up in six states, namely Assam, Manipur, Telangana, Andhra Pradesh, Maharashtra and Kerala • Comprehensive water database in the public domain: Developed India WRIS (Water Resource Information System), a portal for providing all information pertaining to surface and ground water. • Created 1082 new groundwater monitoring wells. • Revised National Water Policy (2012) adopted. • Studies initiated aimed at water resource conservation in the context of climate change • Capacity building exercises of the farmers and other stakeholders have been undertaken.

National Mission on Sustainable Agriculture: Aims to transform agriculture into an ecologically sustainable, climate-resilient production system by devising appropriate adaptation and mitigation strategies. (Details in Section 3.8.1)	• To make agriculture more productive, sustainable, remunerative and climate resilient. • To conserve natural resources through appropriate soil and moisture conservation measures. • To adopt comprehensive soil health management practices. • To optimize the utilization of water resources through efficient water management. • To develop the capacity of farmers and stakeholders.	• A total of 1,59,813 ha of the area has been brought under System of Rice Intensification, and 1,62,274 ha has been brought under Direct Seeded Rice system till 2016-17. • 24.2 million tonnes of neem coated urea (as fertilizer) was manufactured in 2016-17, thus reducing N_2O emissions • 99 climate resilient varieties have been identified in 2015-16.
National Mission on Sustaining Himalayan Ecosystem (NMSHE): The main goal of NMSHE is to assess scientifically the vulnerability of the Himalayan region to climate change in physical, biological and socio-cultural context. NMSHE also aims to build and support capacities at the central and state levels to assess climate change and formulate adequate response measures to the challenges in the Himalayan region.	• To understand the complex processes affecting Himalayan ecosystem. • To continuously assess the health status of the Himalayan Ecosystem • Enable policy bodies in their policy-formulation functions. • Assist states in the Indian Himalayan region with their implementation of actions selected for sustainable development. • Networking and strengthening of knowledge institutions. • Start of new centres relevant to climate change in the existing institutions in the Himalayan States. • Regional cooperation with neighbouring countries in Glaciology.	• In order to address the various technical thematic issues in the Himalayas, NMSHE has set up six Task Forces with coordinating institutions for each one. • Mission proposed to train 100 persons in areas relevant to the Himalayan ecosystem, 100 in conducting EIA and also conduct 6 theme based training systems for community based organizations, and develop 25 capacity building programmes. • An Observational Network to monitor the health of the Himalayan system has been developed. • Against the mission deliverable of preparing six annual thematic status reports, five have been prepared. • 11 state climate change cells have been setup in Himalayan region for: vulnerability and hazard assessment; development and implementation of training programmes; and public awareness programmes.
National Mission on Strategic Knowledge for Climate Change (NMSKCC): The mission intends to identify the challenges and the responses to climate change through research and technology development and ensures funding of high quality and focused research in various aspects of climate change.	• Formation of knowledge networks among the existing knowledge institutions engaged in research and development relating to climate science and facilitate data sharing and exchange. • Establishment of global technology watch groups with institutional capacities to carry out research on risk minimisation technology selection for developmental choices • Development of national capacity for modelling the regional impact of climate change on different ecological zones within the country. • Establishing research networks and encouraging research in the areas of climate change impacts. • Generation and development of the conceptual and knowledge basis for defining sustainability of development pathways. • Providing an improved understanding and awareness of the key climate processes and the resultant climate risks. • Creating institutional capacity for research infrastructure.	• Department of Science and Technology, Government of India, has initiated several major R&D programmes in key areas of climate science, adaptation and mitigation. National and state level institutions are participating in these programmes. • Thematic knowledge network: Two National Knowledge Networks viz., a Network on Climate Change and Human Health and on Climate Modelling have been set up. Two more networks are being launched shortly: Network on Climate Change and Agriculture and a Network on Coastal Vulnerability. • Three centres of excellence one each in Indian Institute of Science, Bengaluru; Indian Institute of Technology, Mumbai; and Indian Institute of Technology, Chennai have been setup. • Global Technology Watch Group programme has been initiated to bring out technology selection and prioritization in the climate change adaptation and mitigation areas. Two Technology Watch Groups on Renewable Energy and Advanced Coal Technology have been setup with National Institute of Advanced Studies, Bengaluru and Indian Institute of Technology, Chennai as lead institutions. • State Climate Change Centres in Madhya Pradesh and Punjab have been set up.

Sources: Ministry of New and Renewable Energy, Ministry of Power, Bureau of Energy Efficiency, Ministry of Environment, Forest and Climate Change, Ministry of Water Resources, Department of Science and Technology, Ministry of Agriculture and Farmers' Welfare

3.2.1 State action plans on climate change

The states are actively contributing to the NAPCC by preparing State-level action plans, which are envisioned to be extensions of the NAPCC at various levels of governance, aligned with the eight National Missions. 32 States/UTs have prepared their State Action Plans on Climate Change (SAPCC). All the SAPCCs are endorsed by the Expert Committee on Climate Change (ECCC). Based on the recommendations of this committee, the National Steering Committee on Climate Change (NSCCC) considers and endorses the SAPCC. The SAPCCs of all 32 States/UTs have been endorsed by the NSCCC. The process of revision of SAPCCs by States/UTs is underway.

Various programmes under these national plans are being implemented separately targeting different sectors. Subsequent sections discuss important sectoral policies. Sectors such as forest and biodiversity, agriculture, water resources, energy, and urban development and transportation have been prioritised by the States/UTs. The sectors covered by SAPCCs are shown in Figure 3.1. Measures have been identified by States/UTs in additional sectors like health, industries, disaster management, tourism and coastal development. The timeline for the implementation of climate actions ranges from 1 to 5 years.

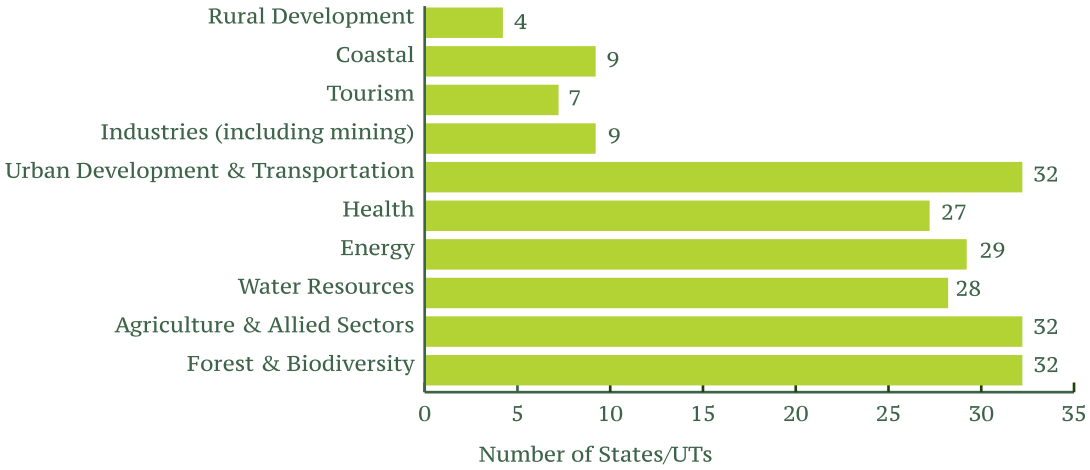


Figure 3.1: Sectors covered by SAPCCs

Budgetary requirements for the implementation of the options have also been determined. A combined budgetary requirement of almost ~₹14,524,470 million has been assessed for the implementation of SAPCCs in a five-year timeframe.

Some States/UTs have indicated a conceptual monitoring and evaluation framework in their respective SAPCCs. However, financial and technological constraints are hampering their effective implementation. SAPCCs have been envisaged as dynamic and effective planning tools for sub-national climate action which can evolve over a period of time, taking into account the enhancements in expertise and capacity of stakeholders, new scientific evidence and research.

3.3 Mitigation actions in power sector

The energy sector contributes 73% to India's total emissions. In recent years, several policies and programmes have been implemented in the energy sector to address climate change concerns. India's NDC includes a target to achieve 40% cumulative electric power installed capacity from non-fossil fuel based energy resources by 2030. This is with the help of transfer of technology and low-cost international finance including from Green Climate Fund (GCF). The share of non-fossil fuel based electricity generation installed capacity reached 35.5% as on June 2018 (CEA, 2018a). It may also be noted that solar PV power capacity increased by about 9 times from 2.63 GW in March 2014 to 23.02 GW in June 2018. Ensuring energy security, improving access and affordability of modern energy resources for all Indians, diversifying energy resources, enhancement of resource use efficiency, reducing technical and commercial losses in power transmission, and enhancing renewable energy are pillars of Indian energy policies.

This section presents stages of implementation of policies and measures in the energy sector (power and energy efficiency) mentioned in the first BUR and newer policies adopted in this period.

3.3.1 Renewable energy

India is running one of the largest renewable capacity expansion programmes in the world. As per present estimates, India has a renewable energy potential of about 1100 GW for commercially exploitable sources *viz.* Wind – 300 GW (at 100 m mast height), Small hydro – 20 GW; Bio-energy – 25 GW and 750 GW Solar power

assuming 3% wasteland is made available. Among states, Rajasthan has the highest share of about 14% of the estimated renewable power potential.

The installed capacity of electricity has tripled since 2005. While the percentage share of coal based power generation in the total energy mix in 2017 has remained almost the same when compared with 2005 (~58%), the percentage share of hydro has reduced to half during the same period. The share of renewable energy continues to progressively increase in the electricity mix and in the year 2017-18, renewable energy generation in India crossed 100 billion units. As on September 2018, installed renewable power capacity (excluding hydro above 25 MW) has already crossed 72 GW, contributing about 21% of the country's installed electricity capacity and over 10% in the electricity generation mix. In addition, the comparison between 2005 and 2008 shows that reliance on other sources like gas, diesel and nuclear for fulfilling the energy has declined over the years (Table 3.2).

Table 3.2: Installed electricity generation capacity in India.

	2005		2018 (June)	
Fuel	MW	% share	MW	% share
Coal	67,166	58.13%	196,957	57.00%
Gas	11,840	10.25%	24,897	7.20%
Diesel	1,196	1.04%	838	0.24%
Nuclear	2,720	2.35%	6,780	1.96%
Hydro	30,135	26.08%	45,403	13.14%
Renewables	2,489	2.15%	70,649	20.44%
Total*	115,546		345,524	

*Figures may not tally due to rounding off

Source: Central Electricity Authority

As is evident from Table 3.2, renewable energy sources are rapidly adding capacity to the grid. While the annual growth rate of coal based electricity generation was around 9%, the renewables capacity grew by 29% annually from 2005 to 2018. The status of renewable energy based power in the country is presented in Table 3.3.

Table 3.3: Installed capacity of Renewables in India upto June 2018

I. GRID-INTERACTIVE POWER (CAPACITIES IN MW)	
Wind Power	34,293.48
Solar Power	23,022.83
Small Hydro Power	4,493.20
Biomass Power/Cogeneration	8,700.80
Waste to Power	138.30
Total	70,648.61
II. OFF-GRID/ CAPTIVE POWER (CAPACITIES IN MWe)	
Waste to Energy	171.15
Biomass Gasifiers	163.37
SPV Systems	737.85
Total	1,073.37

Source: Central Electricity Authority and Ministry of New and Renewable Energy

The renewable energy (RE) sector in India is experiencing rapid expansion, buoyed by strong government focus and policy support. The Government of India has set an ambitious target of 175 GW renewable energy capacity by FY 2022, comprising 100 GW from solar PV power, 60 GW from wind power, 10 GW from bioenergy and 5 GW from small hydropower. During the last five years, solar and wind sectors have observed exponential growth owing to policy and regulatory support, at both Central and State levels. The per unit cost for solar and wind energy has decreased substantially, further incentivizing its deployment (Figure 3.2).

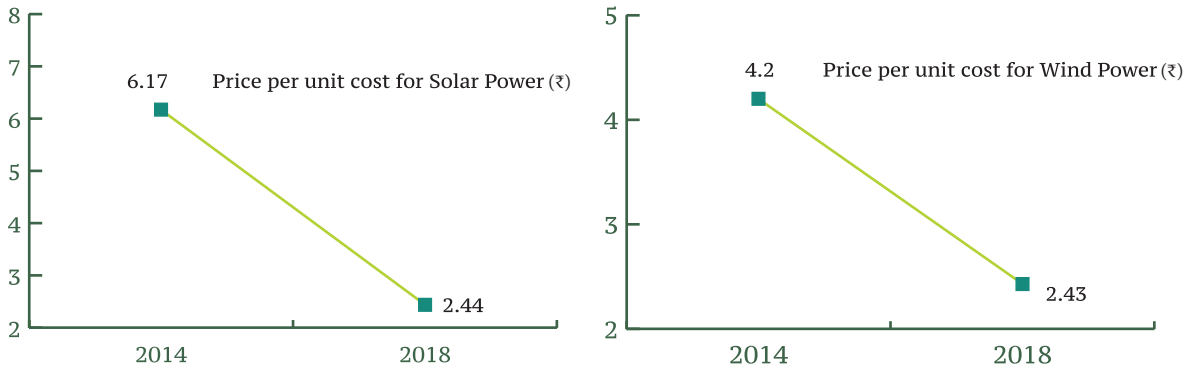


Figure 3.2: Decrease in per unit cost for solar and wind power (2014-2018). ***Source: (MNRE, 2018)***

State regulators have been periodically issuing policies and regulations for renewable energy with a special focus on solar energy. It is estimated that about 268 $MtCO_2$ emission will be avoided annually by the end of the year 2021-22 from renewable energy sources (CEA, 2018b). A combination of policies in place to regulate and promote the renewable energy sector is summarized in Table 3.4.

Table 3.4: Policies regulating the renewable energy sector in India

Act/Policy/Programme	Description
Electricity Act, 2003	Promotes generation of electricity from renewable sources.
National Electricity Policy, 2005	Emphasizes on the full development of feasible hydro projects and laid down procedures for the speedy implementation of the same.
Integrated Energy Policy, 2006	Emphasizes use of renewables for reducing dependence on energy imports.
Rural Electrification Policy, 2006	Recognizes that non-conventional energy sources can be appropriately and optimally utilized to make available reliable supply of electricity to each and every household.
National Policy on Biofuels, 2018	Aims to increase the usage of biofuels in the energy and transportation sectors of the country. Also aims to utilize, develop and promote domestic feedstock and its utilization for production of biofuels thereby increasingly substitute fossil fuels while contributing to national energy security and climate change mitigation.
Jawaharlal Nehru National Solar Mission	Set the ambitious target of deploying 100 GW of grid connected solar power by 2022. Aimed at reducing the cost of solar power generation in the country.
Renewable Purchase Obligations (RPO), 2010	Targets have been set by State Electricity Regulatory Commission (SERCs) for distribution companies, which are obligated to purchase a certain percentage of their total power requirement from RE sources. Renewable Purchase Obligations (RPOs) mandate the minimum quantum of electricity which distribution utilities and large consumers with one MW and above consumption in the States have to source from renewable sources (failing which, a penalty may be imposed on them).
Renewable Energy Certificates (REC) Mechanism, 2010	These certificates serve as a mechanism to fulfill the RPO obligations thereby reducing penalties. It enables and recognizes inter-state RE transactions to address the mismatch between the availability of RE sources and the requirement of obligated entities to meet their stated RPO.
National Offshore Wind Energy Policy, 2015	To explore and promote deployment of offshore wind farms in the Exclusive Economic Zone (EEZ) of the country, including those under Public Private Partnership.
Priority Sector Lending, 2015	RE sector is included as priority sector under the Reserve Bank of India (RBI) norms, which means banks are obliged to earmark certain percentage of their lending for the RE sector.

Renewable energy and Renewable Purchase Obligations (RPO)

Pursuant to Section 86 (1) (e) of the Electricity Act, the State Electricity Regulatory Commissions (SERCs) have issued RPO regulations specifying the share of renewable energy in the electricity mix. Further, in order to assist in meeting RPO, the Central Electricity Regulatory Commission (CERC) has notified the Renewable Energy Certificates (RECs) mechanism, and almost all SERCs have notified follow up regulations enabling the obligated entities to purchase RECs to meet their RPOs. The Ministry of Power notified the long-term growth trajectory of RPOs for non-solar as well as solar for three years (2016-17 to 2018-19), according to which there were 17% RPO targets with 6.75% solar RPO by 2019. The obligations were on total consumption of electricity by an obligated entity, excluding consumption met from hydro sources of power. In continuation of these targets, the Ministry of Power has notified targets for a further period of three years from 2019-20 to 2021-22. As per the new targets, 21% total RPOs are to be achieved, of which 10.50% must be from solar (MoP, 2018a).

Green Energy Corridor project

Green Energy Corridor (GEC) project for evacuation of renewable energy from generation points to the load centres by creating intra-state and inter-state transmission infrastructure is under implementation in renewable resource-rich states. The intra-state transmission component of the project is being implemented by the respective State Transmission Utilities (STU), and the inter-state transmission component is being implemented by the Power Grid Corporation of India (PGCIL). In order to integrate solar parks with the grid, Ministry of Power assigned PGCIL to implement inter-state transmission scheme for evacuation from eight solar parks (7200 MW). Transmission scheme for six solar parks (5750 MW) is already under implementation. To evacuate power from the renewable capacity addition, transmission systems are being strengthened, control infrastructure is being implemented, and a Renewable Energy Management Centre (REMC) is being set up under the GECs (PIB, 2016). This is being done in eight renewable rich states: Andhra Pradesh, Gujarat, Himachal Pradesh, Karnataka, Maharashtra, Rajasthan, Madhya Pradesh and Tamil Nadu.The Intra-state Transmission Scheme (InSTS) is being implemented by the eight states mentioned above, with an investment of ₹101.41 billion to set up about 9400 circuit km transmission lines and substations of a total capacity of approximately 19000 MVA. This will be completed by March 2020 (MNRE, 2018).

Renewable energy and revised Tariff Policy 2016

In compliance with Section 3 of the Electricity Act 2003, the Central Government notified the Tariff Policy on 6th January 2006. Further amendments to the Tariff Policy were notified on 31st March 2008, 20th January 2011 and 8th July 2011. The latest revision of Tariff Policy was notified by Government of India in January 2016. It has several provisions aimed at accelerating deployment of renewable energy in the country. It mandates Renewable Purchase Obligations and Renewable Generation Obligation, and has waived inter-state transmission charges for solar and wind energy. Among other objectives such as ensuring electricity availability at reasonable prices, promoting transparency and competition, it aims at promoting electricity generation from renewable sources and hydroelectric power generation including Pumped Storage Projects (PSP) to provide adequate peaking reserves, reliable grid operation and integration of variable renewable energy sources.

Ministry of Power has issued an Order dated 13.2.2018 extending the waiver of Inter-state transmission system (ISTS) charges and losses on transmission of the electricity generated from solar and wind sources based generation projects commissioned till 31st March 2022. Such waiver will be available for the period of 25 years from the date of commissioning of such solar and wind projects. The ISTS waiver will be available for solar and wind projects entering into power purchase agreements with all entities, including distribution companies, for sale of power from solar and wind projects for compliance of their RPOs. As a condition, the above waiver will be allowed only to those solar and wind projects that are awarded through competitive bidding process issued by the central government.

Renewable energy related amendments to Indian Electricity Grid Code (IEGC) 2010

The IEGC lays down rules, guidelines and standards to be followed by various participants in the system to plan, develop, maintain and operate the power system in the most secure, reliable, economic and efficient manner, while facilitating healthy competition in the generation and supply of electricity (CERC, 2010). IEGC was amended in 2016 for facilitating large-scale integration of renewables (DST, 2017). The following was added as a part of the amendment:

a. Forecasting: The Central regulator has mandated that forecasting may be done both by the wind/solar generator(s) and the concerned Regional Load Dispatch Centre (RLDC).

b. Scheduling: Wind/solar generators at the inter-state level whose scheduling is done by the RLDCs.

c. Incentivizing Flexibility: Additional compensation for degradation of Station Heat Rate (SHR) has been allowed along with defining 55% of installed capacity as the technical minimum considering the flexibility requirements of conventional plants in the high renewable scenario.

National Clean Energy and Environment Fund 2010

Through the Finance Bill 2010-11, a corpus called National Clean Energy and Environment Fund (NCEEF) was created out of cess on coal produced / imported for the purpose of financing and promoting clean energy initiatives, funding research in the area of clean energy or for any other related purpose. Subsequently, the scope of the fund was expanded to include clean environment initiatives. An Inter- Ministerial Group (IMG) chaired by the Finance Secretary approves the projects/schemes eligible for financing under the NCEEF. These projects include innovative schemes like Green Energy Corridor, Namami Gange, Green India Mission, Jawaharlal Nehru National Solar Mission (JNNSM)'s installation of solar photovoltaic (SPV) lights, installation of SPV water pumping systems, SPV Power Plants, Grid Connected Rooftop SPV Power Plants, and a pilot project to assess wind power potential.

IMG has recommended 55 projects with total Viability Gap Funding of ₹348.11 billion spread over the years. The Coal Cess was levied at the rate of ₹50 per tonne of coal starting 22nd June 2010, and was increased to ₹100 per tonne of coal w.e.f. July, 2014 in Budget 2014-15. The same was increased to ₹200 per tonne w.e.f. March, 2015 in the 2015-16 Budget. Further, the Coal Cess had been increased to ₹400 per tonne in the Union budget 2016-17. Table 3.5 mentions details on total cess collected and financing of projects from NCEEF (DoE, 2018).[1]

Table 3.5: National Clean Energy and Environment Funds Utilization

Year	Coal Cess Collected (in billion ₹)	Amounts financed from NCEEF for projects (in billion ₹)
2010-2011	10.66	0
2011-2012	25.79	22.07
2012-2013	30.53	24.64
2013-2014	34.71	121.87
2014-2015	53.93	208.79
2015-2016	126.75	523.48
2016-2017 (RE)	285	690.27
2017-2018 (BE)	297	-
Total	864.4	1591.14

Source: Department of Expenditure, Government of India

3.3.2 Clean coal technology initiative

Coal-based power accounts for about 57% (196.96 GW) of India's installed capacity as on June 2018. The status of various clean coal technologies being adopted is as follows:

i. Supercritical technology: Supercritical technology has been adopted in the country to enhance the efficiency of coal fired power plants. Already, 66 supercritical units with a total capacity of 45,550 MW have been installed, and 51,260 MW of supercritical capacity was under construction as on March, 2018. The average emission rate from coal-based units has been declining (Figure 3.3) due to the commissioning of these new plants. Thus, 7.01 million tonnes of CO_2 emissions in 2016-17 have been averted due to the installation of super-critical units in place of sub-critical units.

ii. Ultra Supercritical Plants: This technology is in the process of being adopted. It has an efficiency of around 42%. The steam pressure is 280 kg/cm^2, and the temperature is around 600^{o}C. Depending on their operational expertise and site-specific techno-economics, utilities may adopt higher / Ultra Supercritical steam parameters. The improvement in design efficiency of Ultra Supercritical technology is around 2% over supercritical units.

iii. Advanced Ultra Supercritical Technology: Indigenous research is being pursued for the development of this technology with a target efficiency of about 46%. The programme targets an 800 MW demonstration plant, which will be the World's first in this league. The initiative envisages the development of indigenous capabilities in the field of Advanced Ultra Supercritical technology with 17% less CO_2 emissions compared to a typical Sub-Critical plant (500 MW). If successful, this will prove to be a major national achievement in the direction of self-reliance in getting an efficient, cleaner and affordable power generation technology. An Over-Arching Committee (OAC) under Principal Scientific Advisor (PSA) to Government of India is monitoring the progress of the R&D Project activities.

iv. IGCC technology: The alternate coal energy conversion approach of using integrated gasification combined cycle (IGCC) had been considered to be a potential technology for achieving very high efficiency using large size advanced class gas turbines. The efficiency of the present day IGCC plants is comparable to conventional supercritical plants. IGCC, however, leads to very low emissions of Sulphur Oxides and Nitrogen Oxides and Suspended Particulate Matter (SPM). Efforts have been made to develop IGCC technology suitable for Indian coal. BHEL Trichy has set up a 6.2 MW coal-based IGCC plant and is attempting to scale up the same for IGCC development. NTPC Limited, the Indian power major, also carried out a feasibility study for a 100 MW plant. Further work is required to develop a gasifier for syngas production suited to Indian coal types.

Efficiency improvements due to supercritical technology

i. Fossil energy based power plants have a total installed capacity of 222,692 MW as on June 2018 (excluding captive power). Total thermal capacity of 45,550 MW has been commissioned as on 31st March 2018 based on supercritical technology and capacity aggregating to 51,260 MW of supercritical thermal units are under construction out of total 70,491 MW capacity of thermal power plants.

[1]The Goods and Services Tax (Compensation to States) Act, 2017 which has been notified on April, 2017, provides that coal cess, along with some other cess, would constitute GST Compensation Fund and the same would be utilized to compensate the states for five years for potential losses on account of GST implementation

ii. Based on design efficiency, an efficiency improvement of 2% over sub-critical unit (500 MW) is achievable resulting in estimated reduction of 22.61 million tonnes of CO_2 emissions from 2011-12 to 2016-17. All Ultra and Mega power projects are necessarily required to adopt this technology.

Renovation, modernization and life extension of old power generating units

i. Renovation, modernization and life extension of old power generating units provide an opportunity to get additional generation at low cost in a short gestation period. Besides, it results in efficiency improvement, thus reducing fossil fuel consumption. Modernization works for 7202.26 MW were completed during the 12th Plan (2012-17). Owing to renovation, modernization and introduction of clean technologies, the average emission rate from coal based power stations was reduced from 1.07 kg CO_2/kWh in 2009-10 to 0.98 kg CO_2/kWh in 2016-17 (Figure 3.3).

ii. Inefficient thermal generation units are planned to be retired in a phased manner in case their renovation and modernization is not feasible. A total of 170 thermal generation units amounting to a total generation capacity of 10,642.32 MW has already been retired as of March 2018.

iii. Government of India has also decided to replace old inefficient coal based units with more efficient supercritical units.

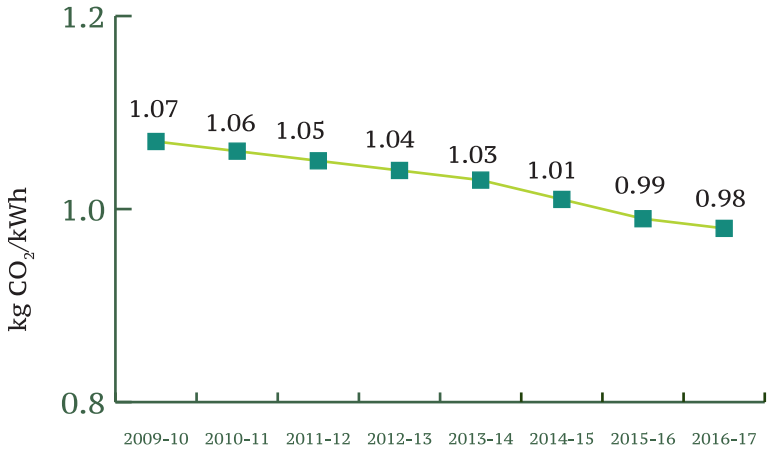


Figure 3.3: Declining trend of average CO_2 emission rate from coal-based stations.

Data source: Central Electricity Authority

In addition to clean coal technology initiative, other initiatives have also been taken to reduce emissions from thermal power stations. Ministry of Power has issued a notification on 5th April 2018 to provide flexibility in generation and scheduling of thermal stations.

3.3.3 Efficiency in electricity distribution systems

The Integrated Power Development Scheme (IPDS) was launched by MoP in December 2014 with the following scope of components in urban areas:

i. Strengthening of sub-transmission and distribution networks;

ii. Metering of distribution transformers / feeders / consumers;

iii. IT enablement of distribution sector and strengthening of the distribution network for completion of the targets laid down under erstwhile Restructured Accelerated Power Development & Reforms Programme (R-APDRP) for 12th Plan and 2017-22.

Components (i) and (ii) have an estimated outlay of ₹326.12 billion including budgetary support of ₹253.54 billion from the Government of India during the entire implementation period. Component (iii) is a part of Restructured Accelerated Power Development and Reforms Programme (R-APDRP), which was approved by Government of India for continuation in 12th Plan and 2017-22. An outlay of ₹440.11 billion including budgetary support of ₹227.27 billion has been subsumed in this scheme. This outlay will be carried forward to the new scheme of IPDS in addition to the outlay indicated above.

The objective of R-APDRP programme is to facilitate State Power Utilities to reduce the level of Aggregate Technical and Commercial (AT&C) losses to 15%. The programme has two major components under which the investments through this scheme will lead to a reduction in loss level. Part–A (IT enablement and SCADA) includes projects for establishment of Information Technology based energy accounting and audit system leading to finalization of verifiable baseline AT&C loss levels in the project areas, and Part-B (network strengthening) for the strengthening of distribution networks. The total outlay for the programme is ₹515.77 billion, out of which the major outlay is ₹100 billion for Part-A and ₹400 billion for Part-B of the scheme.

To improve the distribution sector, the Government also launched the Ujwal DISCOM Assurance Yojana (UDAY), which is the most comprehensive power sector reform ever proposed in India. As part of this scheme, attention

has been devoted to improving operational efficiencies which would reduce AT&C losses by improving billing efficiency through metering and tracking of losses, infrastructure augmentation and smart metering, and by improving collection efficiency through public participation. As on October 2018, 100% feeder metering has been achieved, and 60% and 59% DT metering have been achieved in urban and rural areas respectively. Electricity access to unconnected households has reached 86%. AT&C losses have been reduced to 18.76% (MoP, 2018e).

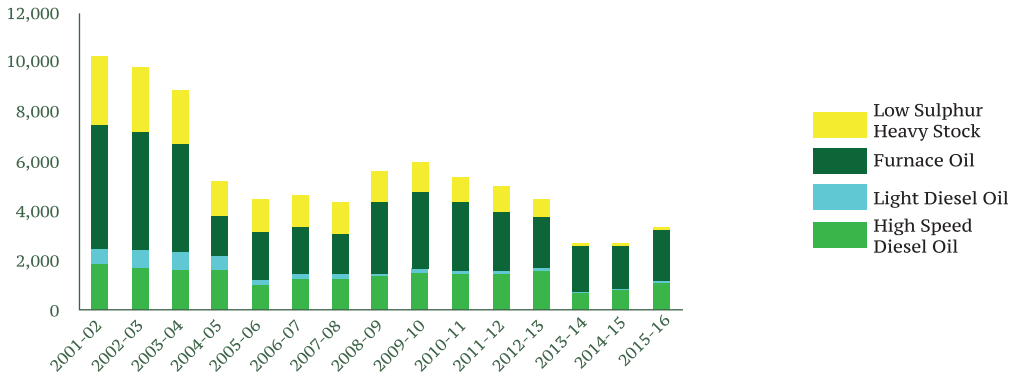
The National Smart Grid Mission (NSGM) has also been launched to bring efficiency in the power supply network, facilitate a reduction in losses and outages, and to accelerate Smart Grid deployment in India. The Mission has been established vide MoP Office Memorandum dated 27th March 2015. NSGM has been operational since January 2016 and is housed under the Ministry of Power. Under the mission, 15 Smart Grid projects are currently being implemented in different cities of India. Green Energy Corridor projects worth ₹380 billion (USD 6 billion) are also being rolled out to ensure evacuation of renewable energy.

3.4 Energy efficiency related mitigation actions

In this section, energy efficiency related measures and initiatives in the power and industry sector are discussed. Energy efficiency plays a very important role in the efficient management of load, which helps in reducing peak demand and overall energy consumption. To improve energy efficiency in various sectors, the Bureau of Energy Efficiency (BEE) was constituted along with the Energy Efficiency Services Limited (EESL) which is a joint venture of NTPC Limited, Power Finance Corporation, Renewable Energy Corporation and Power Grid. The Ministry of Power, through BEE and EESL, has initiated a number of energy efficiency initiatives in the areas of industry, household lighting, commercial buildings, standards and labelling of appliances.

Both power and industry sector are large consumers of energy in the country. The estimated consumption of raw coal by industry has increased from 502.82 MT during 2007-08 to 841.56 MT during 2016-17 with a CAGR of 5.89%. The maximum use of Natural Gas is in the fertilizers industry (30.38%) followed by power generation (24.28%) and 14.47% natural gas was used as domestic fuel (MoSPI, 2018). The use of petroleum products in the industry sector fell by 7.65% from 2001-2016 while the use of Liquefied Petroleum Gas (LPG) increased by 12% between 2007 and 2016 (Figure 3.4 a and Figure 3.4 b).

Figure 3.4 a: Consumption of Petroleum Products in Industry Sector (in thousand tonnes).



Source: Energy Statistics, 2001 to 2017. Central Statistical Office and Ministry of Statistics and Programme Implementation.

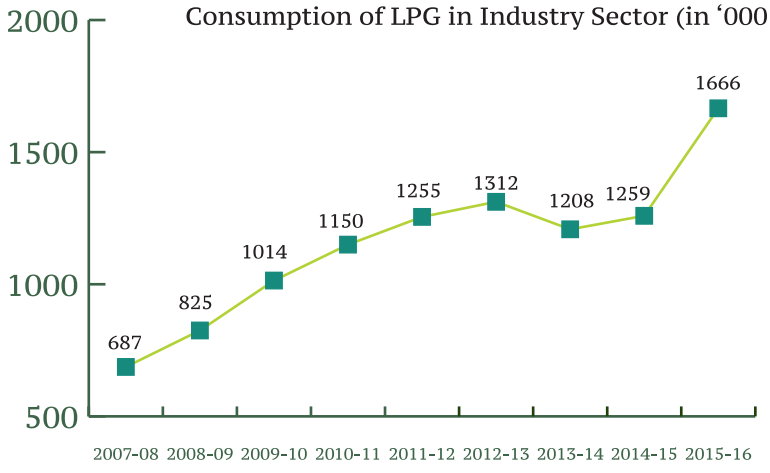


Figure 3.4 b: LPG Consumption in Industry Sector (in thousand tonnes). *Source: Energy Statistics, 2001 to 2017. Central Statistical Office and Ministry of Statistics and Programme Implementation.*

Recent initiatives like Make in India, Digital India, Skill India, the creation of National Industrial Corridors, streamlining environment and forest approvals, labour reforms and other measures for the ease of doing business have also fueled the spurt in their growth rates. Amidst all this, policies to enable industries to reduce their energy consumption play a critical role as an instrument for sustainable development through various interventions.

3.4.1 Energy Conservation (Amendment) Act 2010

The Energy Conservation Act came into existence in 2001, with the objective of conservation and the efficient use of energy. It was amended in 2010 to include stringent compliance norms. Through the Energy Conservation Act, the Government is laying emphasis on promoting renewable energy by harvesting solar and wind power, while for the coal-based power plants, it has become mandatory to adopt supercritical technologies. On the demand side, importance is being given to the efficient use of energy through various innovative measures. The Act established the Bureau of Energy Efficiency (BEE), norms for Energy Auditing, energy conservation building codes for compliance with energy conservation. Most other energy policy measures fall within the purview of this Act. The National Mission on Enhanced Energy Efficiency (NMEEE) under the NAPCC is also built on this Act. Figure 3.5 shows the structure and components of the mission.

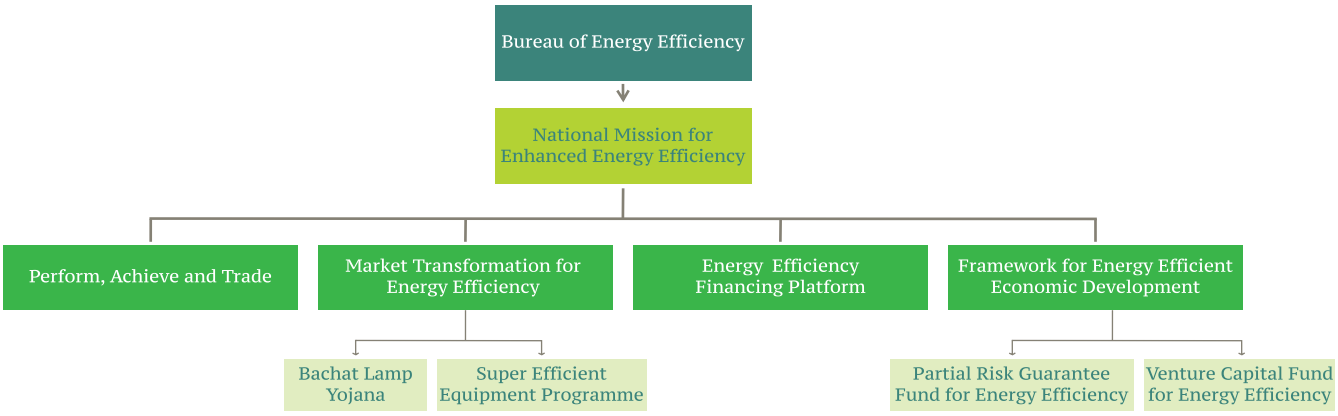


Figure 3.5: Structure and components of NMEEE under the Energy Conservation (Amendment) Act 2010

Perform Achieve and Trade (PAT) Scheme

The PAT scheme has been developed as per the legal requirement under the Energy Conservation Act 2001 and as one of the mechanisms under NMEEE of the NAPCC. The achievements of PAT cycle-I and commencement of newer cycles have been described in this section.

PAT cycle I

In the first cycle of PAT (2012 to 2015), 478 industrial units in 8 sectors (Aluminium, Cement, Chlor-Alkali, Fertilizer, Iron & Steel, Paper & Pulp, Thermal power, Textile) had been mandated to reduce their specific energy consumption (SEC), i.e., energy used per unit of production. Energy saving targets for these 478 designated consumers (DCs) were notified in March 2012. The sector- wise coverage of DCs is provided in Figure 3.6.

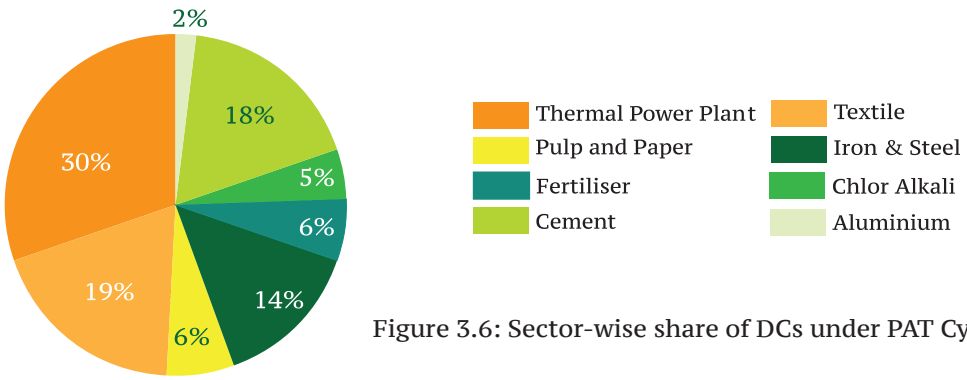


Figure 3.6: Sector-wise share of DCs under PAT Cycle-I

The target reduction for each industrial unit was based on their current levels of energy efficiency, so that energy efficient units will have a low target of percentage reduction, as compared to less energy efficient units.

Overall, the SEC reduction targets are aimed at securing 4.05% reduction in the total energy consumption of these industries corresponding to an energy saving of 6.686 Mtoe. Units, which are able to achieve SEC levels that is lower than their targets, can receive energy savings certificates (ESCerts) for their excess savings. Out of the 478 designated consumers notified for PAT Cycle-I, 448 were operational. Based on the monitoring and verification reports submitted by 427 designated consumers, the achievement in terms of energy saving was 8.67 Mtoe against the target of 6.686 Mtoe assigned for 478 designated consumers. A total of 309 DCs exceeded their targets, adding a total of 3.825 million positive ESCerts. For PAT-I, out of 110 DCs who failed to achieve their target, 96 complied by purchasing ESCerts. Sector-wise achievement under PAT Cycle-I is given in Figure 3.7.

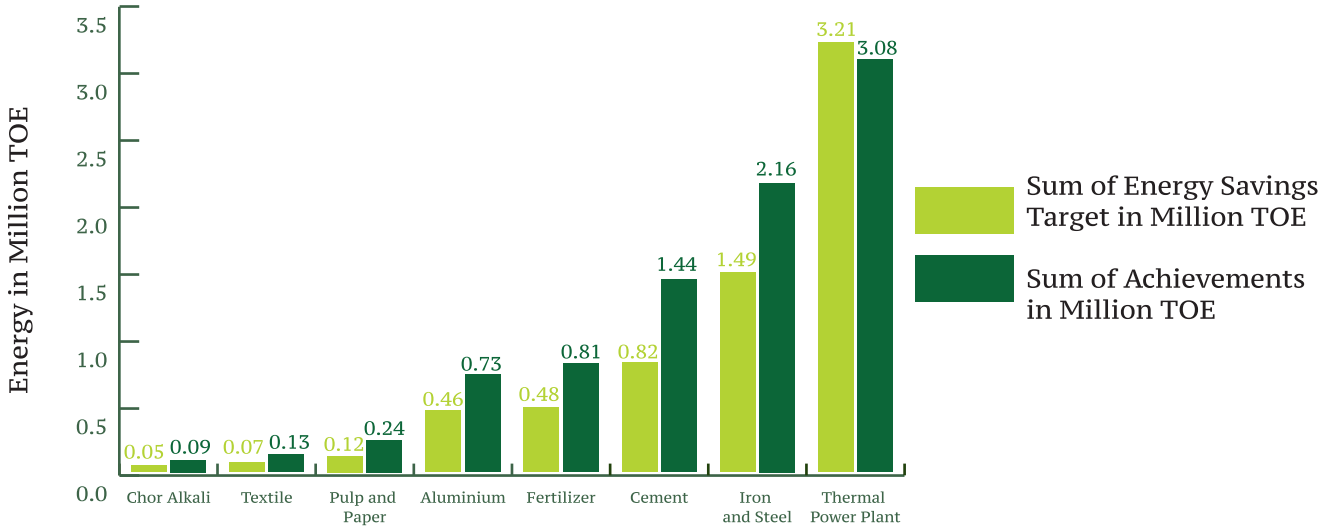


Figure 3.7: Sector-wise achievements under PAT Cycle-I

The energy saving of 8.67 Mtoe translates into avoiding of about 5,635 MW of energy demand and about 31 $MtCO_2$ emissions. The maximum contribution in CO_2 emission reduction is from the thermal power plant sector (44%) followed by iron and steel (21%), cement (14%), aluminium (10%) and others (11%).

In terms of monetary value, the saving of energy consumption under PAT Cycle-I is about ₹95,000 million. The DCs which participated in PAT cycle-I had invested approximately ₹261,000 million on energy efficiency related projects to improve the plant performance in terms of specific energy consumption. The maximum share in the total investment is from the Private Sector Industries ₹137,140 million (52%), followed by Central PSUs ₹77,640 million (30%) and State PSUs ₹27,860 million (11%). There are six Cooperative Industries in the fertilizer sector which have also contributed ₹18,370 million (7%) of the total investment. A trading worth around ₹1,000 million took place in 17 sessions with 1.29 million ESCerts being traded.

PAT has had a strategic impact on industries by creating a conducive environment to help them identify and remove barriers and exploit opportunities to accelerate the adoption of all cost-effective energy efficiency measures as a matter of standard practice so as to make it sustainable in the long run.

PAT cycle II

PAT has been expanded with an objective of increasing the number of designated consumers (DCs) under PAT. For deepening, 89 DCs that were identified from the existing sectors have been notified under PAT Cycle-II (2016-17 to 2018-19). Under widening, three new sectors that are Railways, Refineries, and Electricity DISCOMs have been notified and published in the Gazette on 29th December 2015. From these newly identified sectors 84 DCs have been included under PAT Cycle-II.

The second cycle aims to achieve an overall energy consumption reduction of 8.869 Mtoe for which reduction targets have been given to DCs under 11 notified sectors. The cycle has commenced from April 2016 under which 621 DCs (448 existing operational units and 173 new units) have been notified. This energy saving will translate into avoiding of about 5,764 MW of energy demand. Sector-specific energy consumption of designated consumers under PAT Cycle-II is presented in Table 3.6.

Table 3.6: Sector specific Consumption and Saving Targets of Designated Consumers in PAT II

Sector	No. of Designated Consumers	Energy Consumption (Mtoe)	Saving Targets (Mtoe)
Aluminium	12	10.66	0.57
Cement	111	21.43	1.12
Chlor-Alkali	24	1.77	0.10
DISCOMs	44	*	*
Fertilizer	37	8.25	0.45
Iron and Steel	71	40.44	2.14
Pulp and Paper	29	2.68	0.15
Textile	99	1.48	0.01
Railways	22	1.39	0.03
Refineries	18	18.5	1.1
Thermal Power Plants	154	120.16	3.13
Total	621	226.76	8.88

** For DISCOM sector, BEE has assigned T&D loss reduction targets. After the completion of PAT Cycle-II, it is expected that the total loss reduction of the 44 DISCOMs would be around 10723 MU.*

Source: Bureau of Energy Efficiency

PAT cycle III & IV

PAT Cycle–III & IV will operate from 2017-18 to 2019-20 and was notified on 31st March 2017. It became effective from April 2017 with the inclusion of 116 new DCs from six sectors *viz*. Thermal Power Plant, Cement, Aluminum, Pulp & Paper, Iron & Steel and Textiles. These 116 DCs which consume energy of about 35 Mtoe, have been assigned energy saving target of 1.06 Mtoe at the end of the cycle in 2019-20.

As PAT scheme is now being implemented on a rolling cycle basis, new DCs will be notified every year. The fourth cycle of PAT was notified on 28th March 2018. The baseline year has been taken as 2016-17 and the target year is 2020-21. A total of 109 DCs have been assigned a total reduction target of 0.6998 Mtoe. At present, 846 designated consumers from 13 sectors with a total targeted energy savings of 19 Mtoe under PAT Cycle–II, III and IV are undergoing implementation of energy efficiency projects.

Market Transformation for Energy Efficiency (MTEE) achievements

This initiative is meant to accelerate the shift to energy efficient appliances in designated sectors through innovative measures to make the products more affordable. Under this initiative, refrigerators, ceiling fans, air-conditioners, water heaters, and motors were identified as the priority products for initial Standards and Labelling development. Ceiling fans have been covered in the first phase. The second phase will include appliances like air conditioners and refrigerators. The programme also supports the Make in India initiative through accelerated market transformation and innovative measures. Two programmes were developed under this scheme: *Bachat Lamp Yojana*, now renamed as *Unnat Jyoti* by Affordable LEDs for All (explained in section 3.4.2), and Super Efficient Equipment Program (SEEP). The SEEP is designed to bring accelerated market transformation for super-efficient appliances by providing financial stimulus innovatively at critical point/s of intervention.

Super-Efficient Equipment Program (SEEP)

SEEP aims to bring market transformation towards super-efficient equipment/appliances. There is a provision of a time-bound financial incentive to manufacturers for producing and selling super-efficient equipment that consumes 50% less energy than market average. Under this programme, SEEP for ceiling fans (Super-efficient Fan) was developed. The Energy Efficient Fan Programme was launched in April 2016 to replace conventional 75 Watt fans with 50 Watt 5-star rated energy efficient fans.

Energy Efficiency Financing Platform (EEFP)

The programme is meant to create mechanisms that will help finance demand side management programmes in all sectors by capturing future energy savings. Under this programme, the Bureau of Energy Efficiency (BEE) signed a MoU with Indian Banks' Association for a training programme on Energy Efficiency. BEE had organized four Training-of-Trainers (ToT) workshops, and 12 training workshops have been conducted till October 2018 to create awareness amongst the loan officers/ risk managers/ credit managers towards technical/financial appraisal of energy efficiency projects. About 500 officials from different banks, NBFCs and institutes have been trained under this training programme. The following publications have also been released under the financing initiative of BEE for the promotion of energy efficiency financing platform:

- Training manual for energy efficiency financing in India
- Success stories for energy efficiency projects financed in India
- Market assessment for Partial Risk Guarantee Fund for Energy Efficiency (PRGFEE) and Venture Capital Fund for Energy Efficiency (VCFEE)
- Guidelines for financing energy efficiency projects in India
- Operations manual for PRGFEE

Framework for Energy Efficient Economic Development (FEEED)

One of the key elements of the NMEEE is the Framework for Energy Efficient Economic Development (FEEED), which focuses on developing fiscal instruments to promote energy efficiency financing. FEEED is designed to provide comfort to lenders with the provision of a risk guarantee for performance contracts through PRGFEE and VCFEE. The PRGFEE is a risk sharing mechanism to provide financial institutions with a partial coverage of risk involved in extending loans for energy efficiency projects. The VCFEE is a trust fund to provide "last mile" equity capital to energy service companies (ESCOs). The initial capital is from government funds and can be supplemented with contributions from other sources. To operationalize the fund, PRGFEE rules have been notified and presently there are five financial institutions that have been empanelled under PRGFEE, namely Andhra Bank, Yes Bank, Tata Cleantech Capital Ltd., IDFC Bank and IndusInd Bank. These institutions are eligible to get risk guarantees of up to 50% of the loan amount or ₹100 million per project, whichever is less (BEE, 2017).

VCFEE Fund shall provide last mile equity support to specific energy efficiency projects, limited to a maximum of 15% of total equity required, through Special Purpose Vehicles or ₹20 million, whichever is less. The support under VCFEE has been provided to government buildings, private buildings (commercial or multi-storey residential buildings) and municipalities. VCFEE has been constituted under the provisions of Indian Trust Act 1882, and its Rules got notified on 31st March 2017.

3.4.2 Efficient lighting in India

A vast amount of lighting is provided by incandescent bulbs, which are extremely energy inefficient. In the last few years, technological advancements in lighting have led to the development of energy-efficient lighting systems that consist of components such as low loss ballasts; constant wattage high-intensity electronic ballasts; energy-efficient luminaires; and better monitoring and control mechanisms. Through energy efficiency lighting programmes like the Bachat Lamp Yojana, the sale of Compact Fluorescent Lamps (CFLs) has risen. India also launched an ambitious plan to replace all incandescent lamps with Light-emitting Diode (LED) bulbs. This has led to energy savings of up to 100 billion kilowatt hours (kWh) annually. Energy Efficiency Services Limited (EESL) distributes LED tube lights to consumers in various states at an upfront cost (₹230 per unit) which is 1/3rd of the cost of similar tube light in the retail market. These tube lights have a technical warranty of 3 years against defects. LED tube lights of 20 W are replacing conventional fluorescent tube lights of 40 and 52 W leading to at least 50% of minimum energy and cost savings to consumers.

On 1st May 2015, *Unnat Jyoti* by Affordable LEDs and Appliances for All (UJALA) was launched, replacing the "*Bachat Lamp Yojana*". Within 1 year of its launch, 90 million LED bulbs were sold in the country, reducing the electricity bills by ₹55 billion (US$860 million). The scheme was announced as "Domestic Efficient Lighting Programme (DELP)" on 5 January 2015, and urged the people to use LED bulbs in place of incandescent bulbs, tube lights and CFL bulbs as these are more efficient, long-lasting and economical in their life cycle duration. As on October 2018, more than 312 million LED bulbs have been distributed, leading to a reduction of about 33 million tonnes of CO_2 per year (MoP, 2018c).

Under the Street Lighting National Programme (SLNP), more than 7.1 million LED street lights have been installed until October 2018. The programme has led to an annual energy savings of 4,777 million kWh/year and reduction in 3.29 $MtCO_2$ (MoP, 2018d). The programme is voluntary in nature without any budgetary support from Government of India and is based on a sustainable business model where the cost is repaid by consumer/Urban

Local Body (ULB) from savings in energy and maintenance expenditure over a period of time through savings in electricity bill. The target under SLNP was to launch in 100 ULBs, but this target has already been far surpassed.

3.4.3 Demand Side Management programmes

Demand Side Management (DSM) has been recognized as one of the major interventions to achieve energy efficiency. These programmes include:

Agriculture Demand Side Management (Ag DSM)

Agriculture sector comprises two major components utilizing energy for its processes - irrigation and machinery. Out of these, irrigation component utilizes almost 70% of total energy consumption through operation of approximately 21 million pump sets in the country. Statistics show that a quarter to half a million new pump sets connections are added every year to the sector. Most of the pump sets installed, are inefficient having energy efficiency of 25-35% whereas star rated energy efficient pump sets have an efficiency level of 45-50%. Studies reveal that energy saving potentials of 25-40% exist by mere replacement of inefficient pump sets with energy efficient pumps.

Eleven Detailed Project Reports (DPRs) in the states of Maharashtra, Haryana, Punjab, Rajasthan, Gujarat, Andhra Pradesh, Madhya Pradesh and Karnataka were prepared to estimate the savings potential by replacing inefficient agricultural pump sets with efficient ones.

Taking cognizance of the aforementioned statistics, Agriculture Demand Side Management (AgDSM) scheme was initiated by BEE to reduce the energy consumption in agricultural pumping sector. One of the detailed projects reports implemented by BEE was for Mangalwedha subdivision of Solapur circle, Maharashtra A pilot Ag-DSM project was implemented in Solapur, in which M/s CRI Pumps Pvt. Ltd. was selected by Maharashtra .State Electricity Distribution Company Limited (MSEDCL) as an Implementer/Investor. M/s CRI pumps successfully installed 2209 pumps.

Getting encouragement from the success of Solapur project in Maharashtra implemented by BEE, Energy Efficiency Services Limited (EESL) is trying to capture the market of replacing inefficient agricultural pump sets with energy efficient pumps and for this, EESL is tying up with the DISCOMs. EESL has signed a contract on behalf of Andhra Pradesh Southern Power Distribution Company Limited (APSPDCL) & Andhra Pradesh Eastern Power Distribution Company Limited (APEPDCL) with M/s Vashishta Engineering Services as the Implementing Agency. The target is for installation services of 1,00,000 new BEE 5 star labelled agricultural submersible pumps in the state of Andhra Pradesh for a period of 2 years. In addition, EESL has also signed an agreement with UPPCL & UPNEDA for installation and replacement of 9,000 such pumps.

In order to create awareness among farmers on benefits of energy efficient pump sets, a MoU was signed between the Indian Council of Agricultural Research (ICAR) and Bureau of Energy Efficiency (BEE), in July 2018. The MoU envisages imparting training at Krishi Vigyan Kendras (KVKs) across the country for creating awareness among farmers for energy efficient pump sets, other equipment and operational practices so as to adopt energy and resources efficiently.

Municipal Demand Side Management (MuDSM)

The Municipal sector/urban local bodies (ULBs) consume electricity for various utility services like street lighting, water pumping, sewage treatment, and in various public buildings. The energy consumption of the municipality sector is characterized by frequent changes and rising peaks in power load curves in the morning hours due to water pumping and evening hours for street lighting. Identifying the immense energy saving potential in the municipal sector, BEE initiated Municipal Demand Side Management (MuDSM) project. The basic objective of the project was to improve the overall energy efficiency of ULBs, which could lead to substantial savings in the electricity consumption, thereby resulting in cost reduction/savings for the ULBs.

3.4.4 Standards and labelling programme

With the launch of the star labelling programme for chillers on a voluntary basis on 14th September 2018, the Standards and labelling programme covers 22 appliances of which 10 appliances are under the mandatory regime. BEE had made the display of labels mandatory for colour television and direct cool refrigerator with effect from May 2016 and for storage type electric water heater from September 2016. Labelling for variable capacity air conditioners and LED bulbs has also been made mandatory since January 2018. The programme has contributed to an increase of 25% to 30% in the energy efficiency of an average refrigerator or air conditioner in 2014 compared to those sold in 2007. The scheme has been extended to cover 2500 kVA rating transformers

with effect from July 2017. The scheme has led to energy savings of 121 BU from 2011 to 2018. Over the years, the sale of the higher star labelled appliances has gone up which would result in substantial avoiding of CO_2 emissions.

3.4.5 Zero Effect, Zero Defect (ZED)

The Make in India campaign with ZED is a policy initiative to rate Micro, Small and Medium Enterprises (MSMEs) on quality control and certification for energy efficiency, enhanced resources efficiency, pollution control, use of renewable energy and waste management using ZED Maturity Assessment Model. Clean energy is a very important aspect of the model. Zero effect basically means that there should be no negative impact on the environment. Enterprises are being encouraged and supported to adopt clean technology into their processes to attain a sustainable growth trajectory. The scheme, launched in 2015, envisages coverage of about one million medium and small enterprises (GoI, 2015). Benefits to MSMEs due to ZED include:

- Easy access to loans
- Credible and reliable vendor database
- Reducing the negative effect on our environment
- Aligning with best practices
- Enhanced competitiveness of the vendors in the global marketplace
- Visibility and brand recognition through a "ZED Mark."

3.4.6 Energy audit of the industries

As per the Energy Conservation (Amendment) Act 2010, energy-intensive industries have to get an energy audit conducted by an accredited energy auditor in such manner and intervals of time as may be specified by regulations. The Energy Audit includes the verification, monitoring and analysis of use of energy including submission of technical reports containing recommendations for improving energy efficiency with cost-benefit analysis and an action plan to reduce energy consumption (MoLJ, 2010). The Government may also direct any designated consumer to get an energy audit done whenever it deems necessary. The BEE has been designing training modules and regularly conducting a national level examination for certified energy managers and energy auditors. So far, 18 examinations have been conducted through which more than 15000 energy managers and energy auditors have been certified. This is further supplemented by the accreditation of energy auditors through recommendations of "Accreditation Advisory Committee". Accredited energy auditors would undertake mandatory energy audits in the energy-intensive industries mandated in the Energy Conservation Act (BEE, n.d.).

3.5 Energy access and clean fuels

Energy access and clean fuels constitute two key areas of concern for the Government of India as these are closely related to fundamental aspects of the well-being of the population, especially women. Two of the flagship schemes of the Government of India are discussed in this section.

3.5.1 Pradhan Mantri Ujjwala Yojana

Pradhan Mantri Ujjwala Yojana (PMUY), launched in 2016, aims to safeguard the health of women and children by providing Below Poverty Line (BPL) families with a clean cooking fuel-LPG so that they do not have to compromise on their health by working in smoky kitchens or spend time collecting fuelwood.

Under this scheme, upto ₹1,600 of support per LPG connection is provided to BPL families. For ensuring women empowerment, especially in rural India, the connections are issued in the name of women in the households. Under this scheme, the original target was to release 30 million connections by the end of FY 2017-18, but as a result of efficient implementation, the target was overachieved. Till June 2018, 715 districts were covered, and 44.49 million LPG connections were released under the scheme (MoPNG, 2018b). In addition, the target connections were also raised from 50 million to 80 million.

3.5.2 *Deen Dayal Upadhyaya Gram Jyoti Yojana* (DDUGJY)

Government of India scheme for rural areas

Deen Dayal Upadhyaya Gram Jyoti Yojana (DDUGJY) was launched by the Ministry of Power (MoP) on 3rd December 2014 with the following components:

i. Separation of agriculture and non-agriculture feeders facilitating judicious rostering of supply to agricultural and non-agricultural consumers;

ii. Strengthening and augmentation of sub-transmission and distribution infrastructure in rural areas, including metering of distribution transformers/ feeders/consumers;

iii. Rural electrification for completion of the targets laid down under the erstwhile Rajiv Gandhi Grameen Vidyutikaran Yojana (RGGVY) for 12th Plan (2012-17) and beyond.

Components at (i) and (ii) of the above scheme have an estimated outlay of ₹430.33 billion including a budgetary support of ₹334.53 billion from Government of India during the entire implementation period. The scheme of RGGVY will get subsumed in this scheme as a separate Rural Electrification component {component (iii) above}, for which Government has already approved the scheme cost of ₹392.75 billion including a budgetary support of ₹354.47 billion. This outlay will be carried forward to the new scheme of DDUGJY in addition to the outlay indicated above.

Under the new scheme, 60% of the project cost will be extended by Government of India as Grant in respect of States other than special category (85% for the Special Category States i.e. all the North Eastern States including Sikkim, J&K, Himachal Pradesh and Uttarakhand). Minimum 10% (5% for the Special Category States) shall be contributed through own sources by the State Government/ State Power Utility and the balance 30% (10% for Special Category States) may be arranged through a loan or own sources by the State Government/ State Power Utility. Additional grant up to 15% (5% in case of Special Category States) by conversion of 50% of loan component will be provided by Government of India on achievement of prescribed milestones such as timely completion, reduction in AT&C losses and upfront release of revenue subsidy by State Government. Progress of the scheme is presented in table 3.7.

Table 3.7: Progress of Renewable Energy Components of DDUGJY in India (as on January 2018)

No. of Projects		Funds (₹ Billion)		Un-electrified Villages (Nos.)		Intensive electrification of Villages (Nos.)		BPL HH Connections (Nos.)	
Covered	Closed	Sanction	Total Release	Scope	Cumulative Achievement	Scope	Cumulative Achievement	Scope	Cumulative Achievement
5,934	531	1,085.12	537.61	129,064	125,149	780,464	487,892	43,771,365	28,323,244

3.6 Buildings sector

Currently, buildings in both the residential and commercial sectors consume over 35% of India's electrical energy, and these sectors' energy consumption is rising by 8% annually. A significant part of this percentage goes into heating, cooling and lighting. India's initiatives for sustainable growth include setting up standards for buildings apart from reducing electricity consumption through sustainable and green technology. India currently has about 2.68 billion sq. ft. of registered green building space across 3,000 projects (second largest in the world), of which 600 are certified and fully functional (GoI, 2015). Some of the major initiatives to mitigate emissions from the buildings sector are presented in the following subsections.

3.6.1 National Building Code of India (NBC) 2016

This comprehensive building code is a national instrument providing guidelines for regulating construction activities across the country. It serves as a model code for adoption by all agencies involved in building construction works. The code mainly contains administrative regulations, development control rules and general building requirements; fire safety requirements; stipulations regarding materials, structural design and construction (including safety); building and plumbing services; approach to sustainability; and asset and facility management (BIS, 2016). An addendum to the NBC has incorporated the Energy Conservation Building Code (ECBC), through a new chapter named 'Approach to Sustainability' which gave ECBC a broader coverage.

3.6.2 Energy Conservation Building Code (ECBC)

The ECBC was updated by the Bureau of Energy Efficiency (BEE) in 2017, prescribing a minimum standard for energy use in new commercial buildings having a connected load of 100 kW or contract demand of 120 kVA and above and major retrofits. To address the energy efficiency improvements in existing buildings, BEE has taken up the task of institutionalizing energy efficiency services, and of promoting energy efficiency delivery mechanisms, such as the development of a market for Energy Service Companies (ESCOs). The updated version of ECBC provides current as well as futuristic advancements in building technology to reduce further building

energy consumption and promote low-carbon growth. It sets parameters for builders, designers and architects to integrate renewable energy sources in building design with the inclusion of passive design strategies. The major components of the building which are being addressed through the code are:

- Envelope (walls, roofs, windows)
- Lighting systems
- HVAC System
- Water heating and pumping system
- Electrical power system

The code aims to optimise energy savings with the comfort levels for occupants and prefers life-cycle cost-effectiveness to achieve energy neutrality in commercial buildings. The code is voluntary at the national level, but its enforcement lies with the state government. Twelve states and one Union territory (U.T) viz Rajasthan, Uttarakhand, Karnataka, Andhra Pradesh, Odisha, Telangana, Punjab, Haryana, West Bengal, Kerala, Uttar Pradesh, Assam and U.T. of Puducherry, have notified ECBC to make it operational for new construction.

In order for a building to be considered ECBC-compliant, it would need to demonstrate minimum energy savings of 25%. Additional improvements in energy efficiency performance would enable the new buildings to achieve higher grades like ECBC Plus or Super ECBC status leading to further energy savings of 35% and 50%, respectively.

With the adoption of ECBC 2017 for new commercial building construction throughout the country, it is estimated to achieve a 50% reduction in energy use by 2030. This will translate to energy savings of about 300 billion units by 2030 and peak demand reduction of over 15 GW in a year (PIB, 2017a). The scheme has avoided 14.2 MW of consumption during the period 2006-2014 (CEA, 2018b). The Ministry of Urban Development (MoUD) and state governments are responsible for its implementation and enforcement.

3.6.3 Building retrofitting project

Energy Efficiency Services Limited (EESL) initiated the Building Retrofitting Project in 2014. The major interventions in the retrofitted buildings are in the area of lighting and air-conditioning systems. On 20th May 2017, EESL launched 'National Building Dashboard' which provides information of real-time/deemed energy savings after EESL energy efficiency intervention measures in all buildings on pan India basis. It also provides annual CO_2 reduction and avoided peak demand due to retrofit of energy efficient equipment. As on October 2018, 9,740 buildings have been completed, which has led to energy savings of 79.8 GWh and CO_2 reduction of 65,578 tCO_2 per year (MoP, 2018b).

3.6.4 Star rating system for buildings

BEE buildings star rating system: In order to promote a market pool for energy efficient buildings, BEE has also developed a voluntary Star Rating Programme called the BEE Buildings Star Rating System. This is based on the actual performance of a building in terms of its specific energy usage in kWh/sqm/year. The programme rates buildings on a one- to five-star scale, with five star labelled buildings being the most energy efficient. The rating considers operational characteristics that define building use, hours of operation, climatic zone, and conditioned space. Star labels for day use office buildings, BPOs, hospitals and shopping malls have been developed. A total of 184 commercial buildings have been star rated under different categories of buildings till June 2018. The Code would be made more stringent to promote construction of even more (Near-Zero) energy-efficient buildings. Design Guidelines for Energy Efficient Multi-storey Residential buildings have also been launched. Energy Service Companies (ESCOs) provide a business model through which the energy-savings potential in existing buildings can be captured, and the risks faced by building owners can be addressed as well. BEE does an accreditation exercise for ESCOs through a process of rating these applicants in terms of success in the implementation of energy efficiency projects based on performance contracting, availability of technical manpower, financial strength, etc. A total of 125 ESCOs have been empanelled by BEE based on the revised methodology for empanelment in 2018. The energy efficiency market in India is estimated to be worth ₹1,500.00 billion, out of which only 5% potential has been tapped by ESCOs.

Complementing other efforts of the Government of India, the ECBC has been integrated in other rating and compliance systems being followed in the country such as Environmental Impact Assessment (EIA) for large area development, Green Rating for Integrated Habitat Assessment (GRIHA) rating system of ADARSH and Leadership in Energy & Environmental Design (LEED) rating system of the Indian Green Building Council (IGBC).

Green Rating for Integrated Habitat Assessment (GRIHA): In order to recognize energy-efficient buildings, as well as to stimulate their large scale replication, India has developed its own building energy rating system GRIHA

(Green Rating for Integrated Habitat Assessment), based on 34 criteria such as site planning, conservation and efficient utilization of resources. A number of buildings including Commonwealth Games Village in Delhi have been rated using GRIHA system. Indira Paryavaran Bhawan, the headquarters of Ministry of Environment, Forest & Climate Change is a model building of Government of India and has received LEED India Platinum and a 5 Star GRIHA rating. It is a 'Net Zero Energy' building with 100% onsite power generation. As in August 2018, India has 1,200 GRIHA registered projects with approximately 70 million sq.m of 'green' built-up area (GRIHA, 2018).

IGBC rating systems: Indian Green Building Council (IGBC) rating system addresses green features under the following categories:

- Sustainable architecture and design
- Site selection and planning
- Water conservation
- Energy efficiency
- Building materials and resources
- Indoor environmental quality
- Innovation and development

The guidelines detailed under each mandatory requirement and credit enables the design and construction of new buildings of all sizes and types. Different levels of green building certification are awarded based on the total credits earned. However, every new green building should meet certain mandatory requirements, which are non-negotiable (IGBC, n.d.). Till June 2018, there were 4,573 registered projects under this certification representing 5.30 Billion sq.ft. green building footprint. Some of the registered buildings may have both, GRIHA and IGBC Rating.

3.6.7 Smart cities mission

Smart Cities Mission, launched in 2015, adopts an ICT-driven area-based development approach for providing a clean and sustainable environment through the adoption of 'smart solutions'. Resource efficiency and energy optimization are central to these smart solutions identified under the Mission. The smart cities were identified based on their existing service levels, institutional and financial capacities to implement smart solutions, past track record of urban governance and reforms. Projects ranging from Smart Public Transport Systems, Public Information Systems, Public Bike Sharing to Smart Water Management, Smart Grids, Green Buildings, and Waste Management Systems identify measurable targets and adopt frugal innovation for improving the efficiency of systems to attain sustainable urban growth. A total of 1,333 projects worth ₹5,06,260 million have been completed or are under implementation/tendering. Overall projects worth ₹20,39,790 million have been identified for 99 selected smart cities across the country. Out of these 99 smart cities, 91 have already incorporated Special Purpose Vehicles, and nine smart cities *viz*. Ahmedabad, Rajkot, Vadodara, Visakhapatnam, Bhopal, Pune, Kakinada, Surat and Nagpur have already established Integrated City Command and Control Centres. Smart road projects in 4 cities and smart solar projects in 6 cities have been completed (MoHUA, 2018).

3.7 Mitigation actions in transport sector

The transport sector is one of the fastest growing sectors in India. It is home for the largest motorcycle manufacturer and fifth largest commercial vehicle manufacturer. The industry produced about 4 million passenger vehicles, 0.9 million commercial vehicles and 23.1 million two-wheelers in 2017-18 (SIAM, 2018). Market share of electric vehicles in 2015 was 0.1% (IEA & EVI, 2016). India is one of 16 member countries of the Electric Vehicles Initiative (EVI), a multi-government policy forum dedicated to accelerating the introduction and adoption of electric vehicles worldwide. The Government of India aims at aggressive upgradation of standards to expedite reaching global benchmarks, especially in safety, emissions and fuel consumption. In this direction, major regulatory announcements have taken place recently such as skipping of Bharat Stage (BS)-V emission norms and earlier introduction of BS-VI from 2020, the requirement of average fuel consumption standards for Passenger Vehicles and approaching implementation of Bharat New Vehicle Safety Assessment Programme (BNVSAP).

3.7.1 Emission standards and Auto Fuel Policy 2003

The policy aims to holistically address the issues of vehicular emissions, vehicular technologies and auto fuel quality in a cost-efficient manner while ensuring the security of fuel supply. In line with the Auto Fuel Policy (2003), Bharat Stage-IV petrol and diesel (having 50 ppm sulphur) were introduced in 13 major cities from September 2010. Expansion of Bharat Stage-IV fuels to 50 additional cities by 2015 had been taken up by the Ministry of Petroleum and Natural Gas (MoPNG). According to the 2018 amendment in the Central Motor Vehicles Rules 1989, new motor vehicles conforming to Emission Standard Bharat Stage-IV, manufactured before 1st April 2020

shall not be registered after June 2020 (MoRTH, 2018). The Motor Vehicles (Amendment) Bill, 2015 was passed to amend the Motor Vehicles Act, 1988 and incentivize e-rickshaws and e-carts.

The National Auto Fuel Vision and Policy 2025 was published in May 2014 to update the National Auto Fuel Policy (2003) with more stringent fuel and emission standards. Accordingly, the Government issued G.S.R. 643(E) dated 19.08.2016 vide which the Mass Emission Standards for Bharat Stage IV shall come into force all over the country in respect of four-wheeled vehicles manufactured on or after April 2017. Bharat Stage IV emission norms have come into effect from 1st April 2017.

The Government, vide G.S.R. 889(E), in September 2016 has mandated mass emission standard for BS-VI throughout the country with effect from 1st April 2020 to bring down emissions. This means that Bharat Stage V will be leapfrogged to implement Bharat Stage VI emission norms which were earlier to be adopted by 2024. The Ministry of Road Transport and Highways has issued G.S.R. 953(E) dated 5th October 2016 vide which an amendment has been made in Central Motor Vehicle Rules, 1989 making it mandatory for all vehicle manufacturers to give a detailed declaration about the emission level of vehicles from April 2017 onwards.

3.7.2 Alternative fuels

Increase in share of alternative fuels in the overall fuel mix is yet another strategy to reduce emissions from the sector. The number of CNG cars and cabs in India grew from 23,166 in 2001 to 439,250 in 2011. In the year 2011, Delhi (64%) had the highest share of CNG cars followed by Gujarat (18%) and Maharashtra (15%). Apart from the increase in CNG vehicles, an increase in electric vehicles is also envisaged. Given that electric vehicles have higher operational efficiencies than internal combustion engines increasing the shares of electric vehicles is expected to enhance the overall energy efficiency of the transport sector with the corresponding reduction of energy demand. Electric vehicles in the form of electric-rickshaws have already made their appearance in several urban centres across the country.

Ethanol Blended Petrol Programme (EBP)

Blending of petrol with ethanol is being carried out in 21 States and four UTs with an aim to dispense up to 10% blended petrol. In order to give a stimulus to this programme, Government took series of steps including administering ethanol prices, excise duty waiver and easing of the procurement process, which helped in doubling the ethanol supplies during the year 2014-15 wherein 674.2 million litres have been supplied for blending in petrol. For the year 2015-16, Oil Marketing Companies (OMCs) had contracted 1,300 million litres of ethanol. Further, Government has allowed procurement of ethanol produced from other non-food feedstock besides molasses. It is planned that Oil Public Sector Units will set up 12 second generation ethanol bio-refineries across different states of the country. Between the ethanol supply years 2013-14 and 2017-18, 4,338 million litres of ethanol was blended with petrol, which resulted in reduction of 8.64 $MtCO_2$.

National Policy on Biofuels 2018

This policy has been notified in June 2018. It aims to increase usage of biofuels in the energy and transportation sectors of the country. It also aims to utilize, develop and promote domestic feedstock and its utilization for production of biofuels, thereby increasingly substituting fossil fuels while contributing to national energy security, climate change mitigation, apart from creating new employment opportunities in a sustainable way. The policy also dwells on the development of next generation biofuel conversion technologies based on new feedstocks. Currently, the ethanol blending percentage in petrol is around 2%, and biodiesel blending percentage in diesel is less than 0.1%. An indicative target of 20% blending of ethanol in petrol and 5% blending of biodiesel in diesel is proposed by 2030 (MoPNG, 2018a).

This policy provides for ethanol production from other sources *viz.* sugar containing materials like sugar beet, sweet sorghum etc.; starch containing materials such as corn, cassava, rotten potatoes, algae etc.; cellulosic materials such as bagasse, wood waste, agricultural and forestry residues or other renewable resources like industrial waste including petrochemical route; damaged food grains, surplus food grains during surplus season and fruit and vegetable wastes. PSU OMCs are also offering differential pricing for ethanol derived from damaged food grains.

The Government has allowed direct sale of biodiesel by private manufacturers to bulk consumers like railways and state public undertakings. The OMCs have started biodiesel blended diesel sale in the country, and more than 2200 retail outlets across the country are selling B-5 blended diesel. The OMCs are in the process of setting up plants based on plastic waste and municipal solid waste (MSW) in 8 cities across the country to produce biodiesel.

3.7.3 Public transport and mass transit

The provision of public transport is an essential element of mitigation in the transport sector. Among the major objectives of urban transport initiatives in India is the provision of efficient and affordable public transport. A National Urban Transport Policy was laid down in 2006, with the objectives of ensuring easily accessible, safe, affordable, quick, comfortable, reliable, and sustainable mobility for all. In order to provide better transport, proposals for bus rapid transit system (BRTS) were approved for Ahmedabad, Bhopal, Indore, Jaipur, Pune, Rajkot, Surat, Vijayawada, and Vishakhapatnam cities under the JNNURM. During 2009-10, one more proposal for a BRTS in Kolkata has been approved under the JNNURM taking the number of cities supported for BRTS to 10, covering a total length of 453.20 km. Modern intelligent transport system (ITS)-enabled, low floor and semi-low floor buses are being delivered to States/Cities.

The mass-transit and urban transport projects initiated under the National Urban Renewal Mission will also have positive climate change impacts in the long-run. The mass transit systems in cities/ urban agglomeration can be broadly classified into the following five categories:

- Busways and Bus Rapid Transit System (BRTS): It is an enhanced form of a busway which incorporates features such as facilities for pedestrians, Non-Motorised Vehicles (NMV) and many other associated infrastructures including operations and control mechanism.
- Light Rail Transit (LRT): LRT is generally at-grade rail-based mass transit system, which is generally segregated from the main carriageway
- Tramways: These are at-grade rail-based system that is not segregated and often move in mixed traffic conditions.
- Metro Rail: Metro rail is a fully segregated rail-based mass transit system, which could be at grade, elevated or underground. Due to its physical segregation and system technology, metro rail can have a very high capacity of 40,000 - 80,000 passengers per hour per direction.
- Regional Rail: Regional rail caters to passenger services within a larger urban agglomerate or metropolitan area (GoI, 2017).

India has currently eleven operational metro systems in the cities of Kolkata, Delhi , Gurugram, Noida, Bengaluru, Mumbai, Jaipur, Lucknow, Kochi, Hyderabad and Chennai. The Government of India has approved the implementation of additional Metro Rail Transport System (MRTS) projects in several cities and extention of metro rail network in Kolkata and Delhi. Metro Rail Projects on PPP basis in Mumbai and Viability gap funding (VGF) for Hyderabad are proposed.

In order to give proper legal cover to metro projects, the Metro Railways Amendment Act 2009 was brought into effect in September 2009, providing an umbrella 'statutory' safety cover for metro rail work in all the metro cities of India.

3.7.4 National Electric Mobility Mission Plan 2020

The National Electric Mobility Mission Plan (NEMMP) is one of the most important and ambitious initiatives undertaken by the Government of India and has the potential to bring about a transformational paradigm shift in the automotive and transportation industry in the country. This is a culmination of a comprehensive collaborative planning for promotion of hybrid and electric mobility in India through a combination of policies aimed at gradually ensuring a vehicle population of about 6-7 million electric/hybrid vehicles in India by the year 2020. It is also intended to achieve a certain level of indigenisation of technology ensuring India's global leadership in some vehicle segments. It is a composite scheme using different policy-levers such as:

- Demand side incentives to facilitate the acquisition of hybrid/electric vehicles
- Promoting R&D in technology including battery technology, power electronics, motors, systems integration, battery management system, testing infrastructure, and ensuring industry participation in the same
- Promoting charging infrastructure
- Supply side incentives
- Encouraging retro-fitment of on-road vehicles with a hybrid kit

According to the NEMMP, India aims to deploy 400,000 passenger battery electric cars (BEVs) by 2020. If this target is achieved, India can avoid importing 120 million barrels of oil and avoid 4 million tonnes of CO_2 emissions by 2020 based on real-world conditions of use. If these BEV adoption rates continue beyond 2020, India could save 4.8 billion barrels of oil and 270 million tonnes of CO_2 emissions by 2030.

As a part of NEMMP, the Government has launched a scheme for Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles in India (FAME), aimed at incentivizing all vehicle segments, i.e., 2-wheelers, 3-wheeler auto, passenger 4-wheeler vehicles, light commercial vehicles and buses. Government is committed to instill

confidence in the industry and allow them to plan requisite investments and create needed capacity. Phase I of the scheme is, at present, under implementation, which was originally for a period of 2 years i.e. FY 2015-16 and FY 2016-17 commencing from 1st April 2015, and now has been extended further till 31st March 2019. Based on experience gained during the implementation of the FAME scheme, significant modifications have been made to the scheme through ceasing of support through fiscal incentives to Mild Hybrid vehicles, unregistered vehicles and non-lithium ion battery EVs.

Fully electric buses have been added to the scope of the scheme enabling a critical segment of public transport to draw fiscal support from the scheme. Accordingly, as a part of a pilot project for electrification of public transport, Department of Heavy Industry is providing ₹2559.70 million as fiscal incentives to 9 cities, for launching electric buses. The cities include Bangalore, Jaipur, Mumbai, Lucknow, Hyderabad, Indore, Kolkata, Guwahati and Jammu. A total of 455 electric buses will be provided for these cities. Support has also been extended to the ecologically sensitive state of Himachal Pradesh by sanctioning nearly 150 electric buses and maxi cabs for public transport during the course of the scheme. Till November 2018, 2,59,676 electric and hybrid vehicles have been sold through this scheme.

3.7.5 Average fuel consumption standards

The Government issued average fuel consumption standards for cars on 23rd April 2015. This standard is applicable for motor vehicles which are approved under the Central Motor Vehicle Rules, 1989 and with at least four wheelers other than quadri-cycles, used for the carriage of passengers and their luggage, comprising not more than nine seats including driver's seat and of Gross Vehicle Weight not exceeding 3500 Kg. While the norms have been already implemented from April 2017, the emission reduction target in 2017 was 130gCO_2/km and will further reduce to 113 gCO_2/km in 2022. Fuel efficiency norms for heavy duty vehicles were also notified on 16th August 2017. These norms are applicable for M3 and N3 category vehicles complying with BS IV norms with gross vehicle weight exceeding 12 tonnes.

Additionally, targets have been set for various fuel technologies (categories) such as CNG, diesel, LPG and electric. The emission targets based on fuel technologies will ensure strict regulations for tailpipe emissions.

3.7.6 Rail transport

The Indian Railways have recorded growth at a CAGR of 0.62% in the track length in terms of total route-km from 2006-07 to 2016-17. With an increasing dependence on railways, electrification of Indian Railways (IR) is an important step towards not only enhancing the efficiency of the system but also mitigating GHGs from operations. By March 2016, 23,555 Route kilometres which are 35.32% of the total Railway network have been electrified. On this electrified route, 64.80% of freight traffic and 51.30% of passenger traffic is hauled with fuel cost on electric traction being merely 38.70% of the total traction fuel cost on Indian Railways (MoR, 2016).

Along with transition to electric locomotives, the railways have also taken initiatives such as the production of all Electric Multi-Unit (EMU) trains with three-phase technology having regeneration capability. Additionally, the Indian railways plan to replace the existing End on Generation (EOG) to Head on Generation (HOG) system wherein the electric loads of passenger coaches would be fed directly from electric power drawn by a locomotive from the grid. As of March 2018, ten trains (14 rakes) have already been replaced by HOG system which can reduce CO_2 emissions by 350 tonnes/rake/year.

With a mission to enable IR to introduce alternative energy sources, fuel efficient and emission control technologies, the government has established an institution called the Indian Railways Organization for Alternate Fuels (IROAF). The IROAF functions as a single window entity for knowledge and database on technologies, carbon market, suppliers, business partners and consultants. Indian railways have started blending 5% biodiesel in high-speed diesel for traction purposes. Efforts are also underway to replace diesel with CNG/LNG/BioCNG/BioLNG or dual fuel mode engines. IR has introduced CNG based Dual fuel Diesel engines with 20% CNG substitution for Diesel Electric Multiple Unit (DEMU) trains. Trailer coaches of one rake of DEMU have been provided with Solar PV system on the roof which takes care of fan and lighting load inside the coach.

3.7.7 Civil aviation

The Indian aviation sector has undergone considerable changes with new airlines introducing new routes, both domestic and international. Airports are being expanded and modernised. India is well-placed to adopt an environment-friendly growth path, which is preferable to post-hoc remedies to entrenched systems. With aviation equipment being internationally fungible, India is likely to automatically benefit from technological advances that improve fuel efficiency and reduce emissions. The major domestic regulatory impetus will lie on policies that encourage more efficient flight paths, glide landings, fleet modernisations and renewals, and higher capacity

utilisations. India's first test flight powered by biojet fuel flew from Dehradun to Delhi in August 2018.

At present, India is the world's ninth largest aviation market with more than 80 operational airports with 17 airports having international operations and more than 700 aircraft. The growth in the aviation sector is inevitable, but to follow a sustainable path, Indian aviation sector has taken several initiatives including awareness programmes aimed at sensitizing the stakeholders about simple measures that can be adopted to minimize the adverse impacts of climate change. Following are some implemented measures:

i. Upgradation of aircraft fleet through renewal and engine modernization programme for better fuel efficiency and adoption of airframe and engine performance improvement packages.

ii. The average age of fleet with Indian carriers is comparatively low. With a view to further improve fuel efficiency, airlines have started working towards new aircraft models with state-of-the-art technologies and more fuel efficient engines that may result in substantial reduction in emissions in future.

iii. Engine core water washes at regular intervals to increase fuel efficiency.

iv. Computing fuel requirements for a flight path with information of taxi out and congestion at destination airports which can avoid carriage of extra fuel.

v. Usage of Auxiliary Power Unit (APU) run time has been replaced by ground electrical power and air conditioning by the airport-based support system.

vi. Airlines have also adopted 'Single Engine Taxi-in/out' policies and procedures specific to their operations leading to saving in their operational cost besides environmental savings.

vii. Preparation of flight plans by optimizing the routes and provides cost-effective routing on day to day basis.

viii. Adoption of Carbon Accounting and Management System (CAMS) for reducing airports GHG emissions and for quantification and reporting of GHG emissions and removals. Airports are also using Environment Management System, Energy Management System and Greenhouse Gas Reporting mechanism which helps them to develop and implement policy, and action plans are taking into account legal and other requirements for GHG reduction.

ix. Participation in Airport Carbon Accreditation Programs at various levels for emission reduction.

x. Participation in Leadership in Energy and Environment Design (LEED) with an objective to reduce pollution and promote waste management.

xi. Use of Compressed Natural Gas (CNG) vehicles and electrically operated baggage tugs and buggies.

xii. Installation of the solar power plant at airside premises and solar water heaters at the terminals in order to promote renewable energy use.

xiii. Implementation of environment friendly initiatives by Airports Authority of India for reducing the carbon footprint of civil aviation by providing better connectivity, flexibility and reduction in track miles.

xiv. Implementation of Continuous Descent Approach (CDA) airports that permits an aircraft to maintain a fuel-efficient arrival flight path while landing to reduce emissions and noise loads.

3.7.8 Shipping

India has 12 major ports, and nearly 200 non-major (minor/intermediate) ports along the coast-line and sea-islands. Coastal Shipping and Inland Water Transport are being promoted, keeping in view fuel efficiency, environmental friendliness and cost-effectiveness of these modes. The Ministry of Shipping is implementing the *Jal Marg Vikas* Project for augmentation of the navigation capacity of river Ganga (National Waterway 1). It has also initiated the Green Port project to make major ports across India cleaner and greener by monitoring their environmental pollution, setting up waste water treatment and garbage disposal plants and energy generation from renewable sources.

The International Maritime Organization's (IMO) Marine Environment Protection Committee (MEPC) has given extensive consideration to control GHG emissions from ships. In July 2009, it finalized a package of specific technical and operational reduction measures. The work was completed in July 2011 with the adoption of the first ever mandatory global reduction regime for entire industry sector. The adopted measures add to MARPOL Annex VI, a new chapter entitled 'Regulations on energy efficiency for ships'. With this, in 2011, IMO adopted mandatory technical and operational energy efficiency measures which are expected to significantly reduce the amount of CO_2 emissions from international shipping. These mandatory measures, namely Energy Efficiency Design Index (EEDI) for new ships, and the Ship Energy Efficiency Plan (SEEMP) for all ships entered into force in January 2013 and applied to all ships of over 400 gross tonnage and above. The same has been incorporated in all the Indian vessels as per the applicability. Existing Indian vessels registered under Merchant Shipping Act, 1958 are strictly following the same.

3.8 Agriculture sector

The agriculture sector is responsible for 16.2% of the total GHG emissions of India. It plays a vital role in India's economy. About 55% of the population is dependent on agriculture and allied activities (Census, 2011), and it

contributes almost 14.82% to the country's Gross Value Added (at constant 2011-12 prices). The average farm size continues to shrink from 1.33 ha during 2000-01 to 1.15 ha during 2010-11. Subsistence agriculture is mostly practised. Though the agriculture sector is not included in India's voluntary pledge under FCCC/AWGLCA/2011/INF.1, several climate-friendly initiatives have been taken proactively to promote sustainable development of the sector. These initiatives are discussed in the following sub-sections.

3.8.1 National Mission on Sustainable Agriculture (NMSA)

A sub-mission of the National Action Plan on Climate Change, it aims to transform agriculture into an ecologically sustainable, climate-resilient production system by devising appropriate adaptation and mitigation strategies for ensuring food security, equitable access to food resources, enhancing livelihood opportunities and contributing to economic stability at the national level. A brief introduction to NMSA has been given in Section 3.2.

Several interventions are proposed as part of the mission which would be embedded in research and development activities, development and spread of improved technology and best practices, the creation of physical and financial infrastructure and institutional framework, facilitating access to information and promoting capacity building. The mission is also focusing on strengthening existing farming systems by way of integration of livestock and fisheries, so as to minimise the risk in variable climates. Some major components of the NMSA include the following:

Rainfed area development

It aims to make rain-fed agriculture more productive, sustainable, remunerative and climate resilient by promoting location specific Integrated/Composite Farming Systems along with the conservation of natural resources through appropriate soil and moisture conservation measures.

Sub-mission on agroforestry

The implementation of the sub-mission will result in providing additional income opportunities for farmers along with enhanced risk management. Increase in tree cover will lead to higher carbon sequestration and compliment the national initiatives on climate change adaptation and mitigation

Soil health management

Soil Health Management (SHM) will aim at promoting location as well as crop-specific sustainable soil health management including residue management, organic farming practices by way of creating and linking soil fertility maps with macro-micro nutrient management, appropriate land use based on land capability, judicious application of fertilizers and minimizing the soil erosion/degradation

National bamboo mission

Restructured National Bamboo Mission was launched in 2018 for promoting holistic growth of the bamboo sector by adopting area-based, regionally differentiated strategy to increase the area under bamboo cultivation outside forests and development of complete value chain. Under the Mission, steps have been taken to increase the availability of quality planting material by supporting the setting up of new nurseries and strengthening of existing ones. The Mission would help in increasing the green cover area of the country and also supplement the farm income of participating communities.

Climate change and sustainable agriculture: monitoring, modeling and networking

This will provide creation and bidirectional dissemination of climate change related information and knowledge by way of piloting climate change adaptation/mitigation research/model projects. A consortium approach will be evolved by the State Government with various stakeholders including knowledge partners like State Agricultural Universities (SAUs), Krishi Vigyan Kendras (KVKs) and Indian Council of Agricultural Research (ICAR) Institutes etc. to provide a single window service/knowledge provider system for the benefit of farming community. Financial support may be provided through States to institutionalize the concept and to meet supplementary developmental activities.

Paramparagat Krishi Vikas Yojana (PKVY)

Considering the existing potential of organic farming and the future demand for organic produce, the Government is promoting organic farming across the country. The PKVY is a comprehensive scheme under NMSA to promote organic farming through a cluster approach along with Participatory Guarantee System (PGS) of certification. The scheme was initiated in the year 2015-16.

3.8.2 National Innovations in Climate Resilient Agriculture (NICRA)

National Innovations on Climate Resilient Agriculture (NICRA) is a network project of the Indian Council of Agricultural Research (ICAR), Ministry of Agriculture and Farmers Welfare, Government of India launched in February 2011. The project aims at enhancing the resilience of Indian agriculture to climate change and climate variability through strategic research and technology demonstration. The research on adaptation and mitigation covers crops, livestock, fisheries and natural resource management. The project consists of four components *viz*. Strategic Research, Technology Demonstration, Capacity Building and Sponsored/Competitive Grants. The strategic research has been planned at leading research institutes of ICAR in a network mode covering crops, horticulture, livestock, natural resource management and fisheries sectors.

The technology demonstration component deals with demonstrating proven technologies for adaptation of crop and livestock production systems to climate variability. This component is implemented in selected climatically vulnerable districts of the country through location-specific interventions by *Krishi Vigyan Kendras* in a participatory mode. The project is implemented in 121 districts involving over one hundred thousand farm families across the country. The interventions in the village panchayats are finalized following a participatory approach through the Village Climate Risk Management Committee (VCRMC) to assess the climate-related problems in the village and baseline survey. The programme was launched formally in all the villages by involving the state line department functionaries and leaders of the panchayats to ensure local ownership of the project from the beginning and convergence of related schemes currently in operation in the panchayat.

3.8.3 *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY)

The scheme is meant to achieve convergence of investments in irrigation at the field level, expand cultivable area under assured irrigation, improve on-farm water use efficiency to reduce wastage of water, enhance the adoption of precision-irrigation and other water saving technologies (more crop per drop), enhance recharge of aquifers and introduce sustainable water conservation practices by exploring the feasibility of reusing treated municipal wastewater for peri-urban agriculture and attract greater private investment in precision irrigation systems. It provides end-to-end solutions in irrigation supply chain and aims to use micro irrigation technologies extensively to save water, increase production and productivity of crops in a sustainable manner and help in achieving food security. Assured irrigation and increased use of micro irrigation technologies will provide increased income to farmers, ushering in much-needed prosperity in rural areas. The programme was earlier being implemented as National Mission on Micro-irrigation which has been relaunched with an outlay of ₹500 billion (for 2015-16 to 2019-20) as PMSKY in July 2015. Table 3.8 provides the area covered under micro-irrigation. It has resulted in an emissions reduction of 22.82 $MtCO_2$ during 2010-2016.

Table 3.8: Area under micro-irrigation

Year	Drip (in ha)	Sprinkler (in ha)	Total (in ha)
2014-15	285,196	140,339	425,535
2015-16	355,654	217,325	572,979
2016-17	487,389	352,572	839,961

Source: Ministry of Agriculture

Micro-irrigation technologies are being promoted extensively in all crops to minimise the impact of variable climate on crops. As far as possible these technologies will be made the only method of irrigating plants over time. As a short-term measure, this strategy is being used in water-stressed blocks only. Special focus is on use of micro irrigation technologies in water-guzzling crops like sugarcane, banana, cotton, etc. in arid and semi-arid parts of the country.

3.8.4 Crop diversification programme

Crop Diversification Programme was launched in the States of Punjab, Haryana and Uttar Pradesh as a subscheme of Rashtriya Krishi Vikas Yojana (RKVY) in 2007 for holistic development of agriculture and allied sectors. Incentivizing the states to increase public investment in this sector and providing optimum flexibility and autonomy to states in planning and executing projects to maximize returns to the farmers in agriculture and allied sectors. Crop diversification has been implemented since 2013-14 to divert the area of water-guzzling paddy to alternative crops like pulses, oilseeds, maize, cotton and agroforestry with the objective of tackling the problem of declining of soil fertility and depleting water table in these states (MoAFW, 2017). Continuous paddy cultivation in these three States resulted in stagnancy in crop yields, the decline in soil quality, and higher incidence of pests and diseases. The extent of area diversified is given in Table 3.9. An emission reduction of 0.21 $MtCO_2e$ (2010 to 2016)

has been achieved.

Table 3.9: Area diversified (in ha) from paddy to other crops

Year	Target envisaged for crop diversification from paddy to other crops (ha)	Target achieved (ha)
2014	249,730	196,820
2015	188,462	92,606
2016	184,060	13,083

Source: National Food Security Mission, Ministry of Agriculture

3.8.5 System of Rice Intensification (SRI)

The SRI is a method of rice cultivation which uses less water, reduces production costs and enhances profitability. Unlike the traditional transplanted paddy system, standing water is not maintained in the SRI system and the field is maintained at saturation. Due to alternate wetting and drying cycles, methane emission gets reduced significantly. The SRI method of cultivation is being promoted in 199 districts in India. An emission reduction of 0.186 $MtCO_2e$ (2010 to 2016) has been achieved due to SRI.

3.8.6 Direct Seeded Rice (DSR) cultivation

Cultivation Direct seeded rice is a method of rice cultivation where in the rice seeds are directly sown in the field, and doing away with rising of nurseries, puddling and transplanting. Unlike the traditional transplanted paddy cultivation, standing water is not maintained in the DSR system and the field is maintained at saturation. The quantum of water application gets reduced significantly resulting in energy saving due to irrigation. The extent of coverage of area with DSR is given in Table 3.10. An emission reduction of 0.17 $MtCO_2e$ (2014 to 2016) has been achieved due to DSR.

Table 3.10: Area Covered with Direct Seeded Rice Cultivation

Year	Target envisaged (ha)	Target achieved (ha)
2014	9,899	8,489
2015	93,586	102,036
2016	59, 975	51,749

Source: National Food Security Mission, Ministry of Agriculture and Farmers Welfare

3.8.7 Production of neem-coated urea

Nitrogenous fertilisers play an important role in enhancing agricultural production in the country. Much of the nitrogen applied to soil is subject to several losses. With a view to enhancing nitrogen use efficiency, Government of India has made it mandatory to manufacture 100% neem (*Azadirachta indica*) coated urea from 25th May 2015, replacing the ceiling of 35%. Further, the Government has made it mandatory to coat all the imported urea with neem oil. Neem coating of urea has helped in reduction of nitrous oxide emissions and improvement in soil health. Table 3.11 gives the amount of neem coated urea produced. Due to this initiative, an emission reduction of 8.89 $MtCO_2e$ has been achieved during 2014-2016.

Table 3.11: Neem-coated urea produced (hundred thousand tonnes)

Year	Target envisaged	Target achieved
2014-15	7.91	9.40
2015-16	24.47	23.12
2016-17	24.20	24.20

Source: Ministry of Agriculture and Farmers Welfare

3.8.8 Avoiding crop residue burning

Crop residues are usually burned to clear the field for sowing of the wheat crop in time as delay in wheat sowing may result in reduced wheat yields due to the higher temperatures at the time of wheat harvest during the months of March and April. Farm equipment which can help farmers to take up timely sowing of wheat in the standing paddy residues was made available to the farmers directly and through custom hiring centres so that burning of paddy residues is avoided. Farm machinery banks has also been established which can support operations like sowing of the wheat crop in standing residues, baling of paddy residues and slashers which facilitate timely sowing.

A National Policy for Management of Crop Residues (NPMCR) was announced in 2014 which stressed on the control of crop residue burning to prevent environmental degradation and suggested formulation and implementation of suitable legislative measures to curb burning of crop residue. The National Green Tribunal through its judgement in December 2015, directed the implementation of NPMCR in the States of Rajasthan, Uttar Pradesh, Haryana and Punjab. It also directed the State Governments to immediately take steps to educate and advise the farmers through media, gram panchayats and corporations that crop residue burning is injurious to human health, causes serious air pollution and is now banned or prohibited by law. Every State Government is to evolve the mechanism for collection of crop residue, its transportation and utilization for appropriate purposes. After the implementation of NPMCR, an emission reduction of 0.26 $MtCO_2e$ (from 2014 - 2016) has been achieved.

In 2018, the Cabinet Committee on Economic Affairs has given its approval for the promotion of Agricultural Mechanization for in-situ Management of Crop Residue in the States of Punjab, Haryana and Uttar Pradesh and NCT of Delhi. The total outgo from the Central funds would be ₹11.51 billion (₹5.91 billion in 2018-19 and ₹5.60 billion in 2019-20).

3.8.9 National Horticulture Mission

The National Horticulture Mission was launched in 2005-06 as centrally sponsored scheme to promote holistic growth of the horticulture sector through area based regionally differentiated strategies. Some of the broad objectives include enhancing the production of fruit and vegetables in the country, strengthening nutritional security in the country, providing technology support for high value fruits and vegetables, enhancing water use efficiency and doubling the farm income by growing high value fruits and vegetables. Horticulture systems under rainfed conditions provide reasonably high returns and serve as risk minimization strategy against crop failures under drought conditions particularly in low rainfall regions. Presently India is the second largest producer of fruits and vegetables in the world.

The horticulture sector encompasses a wide range of crops such as fruits, vegetables, flowers, spices and nuts of which the fruit crops produces relatively higher biomass and retained in the field for a relatively long period and thus sequesters carbon both in the above ground and below ground parts. The area under selected fruit tree species is furnished in Table 3.12. The quantum of carbon sequestered is estimated to be 137.72 $MtCO_2$ from 2010 to 2016.

Table 3.12: Area Under Different Fruit Tree Species (in'000 ha)

S No	Fruit crop	2014	2015	2016
1	Apple	319	277	277
2	Citrus	953	1024	970
3	Guava	246	255	258
4	Litchi	85	90	91
5	Mango	2,163	2,209	2,253
6	Sapota	106	107	108
7	Coconut	1,976	2,088	2,122
8	Cocoa	78	81	83
9	Arecanut	450	474	473
10	Almond	21	12	15
11	Amla	95	88	84
12	Custard apple	30	37	34

S No	Fruit crop	2014	2015	2016
13	Jackfruit	118	151	152
14	Peach	19	18	18
15	Plum	23	22	22

Source: National Horticulture Mission, Ministry of Agriculture

3.8.10 Balanced ration for livestock

Balanced nutrition to livestock contributes to improving animal productivity as well in reducing both the cost of production and the emission of greenhouse gases per unit of animal product. Considerable potential exists for increasing production levels across the range of growing and milch animals by addressing the problem of imbalanced nutrition with the existing feed and animal resources. Optimum feeding of animals through Ration Balancing Programme (RBP) helps to enhance the milk production commensurate with the genetic potential of the animals. A mobile app has been developed to help farmers to balance their animal's ration. Ration balancing programme is implemented in 100 villages of Uttar Pradesh, India. Reduction in cost of feeding per kg of milk was 9.5%. The programme has resulted in an emission reduction of 0.28 $MtCO_2e$ from 2014 to 2016.

Table 3.13: Animals Covered with ration balance programme

Year	Target envisaged (million no.)	Target achieved (million no.)
2014-15	0.45	0.57
2015-16	0.7	0.97
2016-17	0.7	0.81

Source: Department of Animal Husbandry, Dairying and Fisheries, Ministry of Agriculture and Farmers Welfare

In India, crop residues that form the bulk of feed resources are of inferior quality with less protein. High yielding milch animals like crossbreds and graded buffaloes require more undegradable protein in the form of bypass protein to increase the milk production potential of the animal. As such protein supplements are expensive, but optimizing the use of protein supplement within the ruminant system can enhance the income to the farmers through increased production. Emissions reductions achieved by feeding bypass proteins is 3.86 $MtCO_2e$ from 2014 to 2016.

3.8.11 Mitigation projects under CDM

A large number of initiatives were taken up by the industry and private individuals for reducing the GHG emissions and also to sequester carbon in the agricultural sector. A significant number of projects have been taken up in the category of biomass energy wherein fossil fuels such as coal, petroleum products are being replaced with agricultural residues mainly the crop residues for heating. Residues used were rice husk, sugarcane bagasse, stubbles of cotton, jute, mustard, etc. In the category of biomass energy, about 270 projects were registered, and the total emission reduction envisaged from these projects were to the tune of 56.85 $MtCO_2$ from 2010 to 2016. Tree planting either as agroforestry or sole plantations have been taken up mostly in private land holdings and the carbon sequestered from these projects is about 2.28 $MtCO_2$. Apart from the above, biogas generated from the manure pits, crop residues and kitchen waste has used for replacing fossil fuels and thus reduced emissions to the tune of 1.81 $MtCO_2$. One CDM project has been registered which reducing the electricity consumption by switching irrigation systems from flood method of irrigation to micro irrigation and aimed at reducing emission to the extent of 0.072 $MtCO_2e$. Table 3.14 gives the details of CDM projects, and the quantum of mitigation envisaged.

Table 3.14: Mitigation Projects aimed at Regulatory Markets (CDM) and the Quantum of Mitigation Envisaged

S. N	Category of projects	No. of registered projects	Main activity	Total emission reductions (2010-16) (tCO_2e)
1	Biomass Energy	270	To replace the fossil fuels (coal, petroleum and petroleum gases, furnace oils, etc.) with biomass fuels (rice husk, paddy straw, crop residues of different grams, jute, sugarcane bagasse, biogas, other agricultural residues for heating in electricity generation	56,851,174
2	Afforestation/ Reforestation	19	Afforestation/ Reforestation with trees in degraded lands to arrest land degradation, to sequester carbon, to improve food security and to generate additional income for the community.	2,278,814
3	Methane avoidance	19	To displace carbon intensive grid energy produced by the fossil fuels with biogas produced from manure pits, kitchen wastes, crop residues etc.	1,814,469
4	Agriculture	1	The purpose of the project is to replace Flood Method of Irrigation with Micro Irrigation Systems that reduce electricity consumption required for pumping of water.	71,568

In addition to the regulated markets, a number of projects were registered and implemented aiming at voluntary markets. About 39 projects aimed at reducing the fossil fuel consumption with agricultural residues are in operation and the emission reductions achieved by this category of projects is to the tune of 7.25 $MtCO_2$. Afforestation and reforestation projects under Voluntary Carbon Standard (VCS) stream sequestered about 0.84 $MtCO_2$ of carbon. Table 3.15 gives the details of implemented projects.

Table 3.15: Mitigation Projects Aimed at Voluntary Markets and the Quantum of Mitigation envisaged

Sn	Category of market	Category of projects	No. of registered projects	Main activity	Total emission reductions (2010-16) (tCO_2e)
1	Voluntary Carbon Standards	Biomass energy	39	Generating thermal energy for electricity generation using biomass instead of fossil fuels	7,248,075
2	Voluntary Carbon Standards	Afforestation/ Reforestation	6	Planting high value tree species. in degraded lands to sequester carbon and generate additional income for the community.	839,610

3.9 Forestry sector

Forests react sensitively to changing climate as climate and forest are intrinsically linked. Various legislations and acts have been formulated by the Indian government for conservation of forests and their resources. LULUCF sequestered 301,193 Gg of total CO_2 emissions in year 2014, which is about 18% of India's total GHG emissions. The estimated carbon stock in the forests increased from 6,941 million tonnes in 2011 to 7,044 million tonnes in 2013, which is a net increase of 1.46% in the country's carbon stock within two years. As per India State of Forest Report 2017, 708,273 sq. km, i.e. 21.54% of the geographical area of the country is covered by forests (FSI, 2017). The total carbon stock in the forests for 2017 has been estimated to be 7083 million tonnes. The annual increase of carbon stock is worked out to be 19.50 million tonnes which are 71.5 million tonnes of CO_2 equivalent.

Approximately 80% of the country's terrestrial biodiversity exists in forests, and more than 300 million people have a high dependency on the forest for their livelihood (MoEFCC, 2016). Besides meeting 40% energy need and 30% fodder requirement, other non-timber forest products is also provided by the forests. Mitigation and adaptation measures are thus encouraged by the government through plantation/ afforestation/reforestation programmes to conserve and enhance the carbon sink. This section discusses the impacts of those policies on the forests of India.

3.9.1 Forest (Conservation) Act, 1980

The implementation of the Forest (Conservation) Act, 1980 has significantly slowed down the conversion of forest land for non-forest purposes. After the enactment of this Act, conversion of forest land for non-forestry purposes has declined from 0.165 ha per annum (in 1951-1976) to 0.032 Mha per annum (in 1980-2016). The Government ensures a rigorous Environmental Impact Assessment (EIA) of developmental projects for diversion of forest land for urgent national developmental needs. As on 31st January 2016, total 1.138 Mha forest land had been diverted to non-forest purposes between 1980-2016, much less than 4.13 Mha for the period 1951-1976 (Table 3.16). The Act was amended in 1988, to include two new provisions: i) to restrict leasing of forest land to private individuals, authorities, corporations not owned by the Government; ii) and to prevent clear felling of naturally grown trees. Forest (Conservation) Second Amendment Rules, 2016 made the procedure of use of forest land for a non-forest purpose more organized with proper documentation.

Table 3.16. Diversion of Forest Land Before and After Forest Conservation Act (1980)

S.No.	Year	Mha
1	1951-1976	4.13
2	1980-2016	1.138

Source: MoEFCC, 2016

Compensatory Afforestation Fund Act 2016

This legislation has made afforestation mandatory, in case of diversion of forest land to non-forestry uses. For industrial and developmental projects of national importance, forest areas are diverted to non-forest use after a rigorous EIA process. The government has thus imposed certain levies on project proponent to compensate for the loss of forest land. The funds are utilized for afforestation activities elsewhere. The concept of "Compensatory Afforestation" is defined as afforestation done in lieu of diversion of forest land for non-forestry use under the Forest (Conservation) Act, 1980. To streamline the management of these funds, the Compensatory Afforestation Fund Management and Planning Authority (CAMPA) has been set up.

Compensatory Afforestation Fund Management and Planning Authority (CAMPA)

The corpus lying with CAMPA has grown progressively to over ₹400 billion. With the Compensatory Afforestation Fund Act 2016, the Government of India now seeks to make this corpus available to state governments to initiate the necessary compensatory afforestation programme. It will facilitate the availability of more than ₹60 billion per annum to State/UTs. It will also assist local communities to ensure better management of their forest resources and will create more than 150 million man-days of direct employment. A majority of tribal-dominated and backward areas will be benefited through the employment generation. The utilization of fund will also increase the availability of timber and non-timber forest products and will help in the upliftment of livelihood of forest-dependent communities.

The rationale behind including NPV in addition to compensatory afforestation is to account for the uncompensated benefits of the forest ecosystem lost under the diversion of land until the time the compensatory afforestation area starts providing comparable benefits. Current NPV, prices range from ₹0.438 million per hectare for low-quality forests to ₹1.043 million per hectare for very dense forests. Recently a manifold increase in NPV rates from ₹0.57 million per hectare for low quality to ₹5.5 million per hectare for very dense forest has been recommended by an expert committee of the central government (Bhan et.al 2016).

The Act mandates the use of the fund for multiple activities, including activities under the Green India Mission of compensating for the lost forest land. Efficient utilization of these funds is crucial to maintain the integrity of India's forest cover in the coming years, and to protect the fragile habitat in Protected Areas. Year-wise allocation of funds likely to be made available to states/UTs is given in Table 3.17.

Table 3.17: Funds released to states under CAMPA

Funds released to states under CAMPA	₹ (in Million)
2017-18	4,647.6
2016-17	18,274.7
2015-16	22,131.9
2014-15	20,569.38
2013-14	10,079.58
2012-13	10,285.69
Total	65,701.30

3.9.2 National Afforestation Programme

The programme contributes to around 15-20% of afforestation efforts in India and emphasizes on the improvement of quality and productivity of the existing forest cover. It is a centrally sponsored scheme of government launched in 2000-02 with a participatory approach for sustainable forest development. It is the flagship programme of National Afforestation and Eco-Development Board (NAEB). The scheme has acquired a pan India ambit over the last nine years of its implementation and is being implemented by 29 states of the country through a twin institutional set up of Forest Development Agencies at the forest division level and Joint Forest Management Committees at the village level. Revised guideline of NAP has been issued to further decentralize the project cycle management of the scheme with a view to expedite fund transfer to village level implementing organization i.e. Joint Forest Management Committees (JFMCs) and Eco-Development Committees (EDCs), to embed the scheme in the overall forestry development programme of the States/UTs, capacity building of the institutions, and promote livelihoods of JFMC members by linking forest development to value addition and marketing of forest products. From the year 2010-11, State Forest Development Agency (SFDA) has been constituted at the State level to smoothen the fund flow to the FDAs.

The objectives of the scheme are as follows:

- Protection and conservation of natural resources through active involvement of the people.
- Checking land degradation, deforestation and loss of biodiversity.
- Ecological restoration and environmental conservation and eco-development.
- Evolving village-level people's organization which can manage the natural resources in and around villages in a sustainable manner.

NAP merger with GIM: The National Afforestation Programme and Desertification Cell have been merged with National Mission for a Green India (GIM) to achieve the objectives of increasing forest cover, carbon sequestration/ storage, hydrological services and biodiversity.

At the central level, the National Governing Council will provide overall guidance and maximise synergy with other programmes. The four-tier structure adopted at central, state, district level and village level for execution and implementation of Mission activities at different levels. Measurement, reporting and verification (MRV) of activities will be undertaken digitally. Year-wise details of NAP from 2000 to 2018 is given in Table 3.18.

Table 3.18: Year-wise progress of National Afforestation Programme

Year	Number of new FDA projects approved	Number of new JFMCs involved	Project area approved (ha.)*	Release (₹ in million)**
2000-02	47	1,843	71,068	475.30
2002-03	237	8,197	404,799	1,512.60
2003-04	231	7,902	282,536	2,079.80
2004-05	105	3,404	106,743	2,330.00
2005-06	94	2,362	54,432	2,481.20

Year	Number of new FDA projects approved	Number of new JFMCs involved	Project area approved (ha.)*	Release (₹ in million)**
2006-07	15	494	0	2,927.50
2007-08	53	3,979	493,061	3,929.50
2008-09	13	6,598	173,435	3,456.20
2009-10	5	7,756	103,556	3,181.70
2010-11	26	-	57,126	3,099.90
2011-12	26	-	141,448	3,030.00
2012-13	27	-	55,529	1,933.70
2013-14	26	-	80,583	2,576.20
2014-15	25	-	74,435	2,124.50
2015-16	-	-	35,986	941.60
2016-17	-	-	2,359	593.50
2017-18	-	-	39,397	760.00

*Area approved for advance soil work/preparatory plantations during the year for all ongoing FDA projects.

**Total (financial assistance provided during the year for planting, advance soil work, maintenance, etc.) for all ongoing FDA projects.

The progress of the programme so far:

i. 28 SFDA projects have been operationalized in the country at an expenditure of ₹36,124.30 million to treat an area of 2.14 Mha since inception of NAP scheme.

ii. During the year 2015-16 till December 2015, ₹6.73 million was released under the NAP scheme. An advance area of 35,186 ha has been sanctioned for afforestation.

iii. Up scaling the afforestation efforts.

Under '*Namami Gange*' (for cleaning the river Ganga) programme, the target has been set up to plant trees on over 8.39 million ha area which has potential to sequester around 87.26 million tonnes of CO_2/year.

3.9.3 Green highways (plantation, transplantation, beautification and maintenance) policy, 2015

The policy was launched to promote the greening of national highway corridors across the country with participation of the community, farmers, NGOs, private sector, institutions, government agencies and the State Forest Departments. The development of highways/ road networks involves felling of trees and clearing of forest land, that leads to a reduction of forest carbon sink. Under this policy, around 140,000 kilometres of national highways will be lined up with trees. Assuming modest productivity of plantations at 5 m^3/ha/ year, the carbon captured by the plantations raised under the Green Highways Policy will be capable of capturing 8.92 tonnes of CO_2/ha/year. The Green Highways Policy has the following major objectives:

i. Develop a systematic framework for Integrated Green Corridor Development along National Highways

ii. Build resilient ecosystem in the form of "Green Corridors" along with National Highways for combating global warming and climate change effects, optimum GHG sequestration and *ex-situ* conservation of native RET species of the region

iii. Make Green Highways Mission self-sustainable

iv. Develop unique green corridors with aesthetic appeal

v. Reduce the impacts of dust, air and noise pollution

vi. Provide shade on glaring hot roads during summers

vii. Reduce soil erosion at embankment slopes

viii. Reduce the effects of wind and incoming UV radiation

National Green Highway Mission

The Mission was launched in July 2016 under the Green Highways Policy 2015 to provide a holistic vision of developing eco-friendly and green National Highways. The Government of India has launched the initial plantation

drive on 1,500 km of national highways at the cost of about ₹3 billion under this mission. It is mandatory for the road developers to earmark 1% of the project's total cost to Green Fund corpus for planting trees and shrubs along national highways. It is also expected that the afforestation drive will help in sequestering approximately 1.2 million tonnes CO_2 annually. Presently 26 green highway projects are running in different states of India with a total road length of 1,915.53 km. The status of the plants raised under National Green Highway Mission for the year 2016 to 2019 is given in table 3.19

Table 3.19. Status of the plants raised under National Green Highway Mission

Year	Agency Type	Length of project (in kms)	Estimated project cost (in million)	Target no. of plants	Trees Planted
2016-17	Government	933	1,491.0	856,840	272,657
	Private	611	1,251.8	800,648	351,328
Subtotal for 2016-17		1,544	2,706.8	1,657,488	623,985
2017-18	Government	1,155	1,518.8	972,473	925
	Private	40	30	20,000	7,800
Subtotal for 2017-18		1,195	1,548.8	992,473	8,725
2018-19	Government	538	524.6	357,017	-
	Private	1.6	1.0	-	-
Subtotal for 2018-19		540	525.6	357,017	-
Grand total		3,278	4,781.2	3,006,978	632,710

Source: (NHAI, 2018)

The Government of India is implementing The *Pradhan Mantri Gram Sadak Yojana* (PMGSY) to provide connectivity to unconnected Habitations. The PMGSY also employs green technologies like use of waste plastic, fly ash, copper and iron slag, geo textile, cold mix, paneled cement concrete, cell filled concrete.

3.9.4 National Agroforestry Policy, 2014

This policy aims to encourage and expand tree plantation in an integrated manner with crops and livestock to improve productivity, employment, income and livelihoods of rural households, especially the smallholder farmers; to protect and stabilize ecosystems and promote resilient cropping and farming systems to minimize the risk during extreme climatic events and to achieve the target of increasing forest/tree cover to promote ecological stability, especially in the vulnerable regions.

3.9.5 National Mission for a Green India

Among various mitigation strategies of Government, National Mission for a 'Green India' or Green India Mission (GIM) has made a remarkable contribution to address the issue of climate change. The mission is one of the eight key missions of NAPCC. The broad objective of the mission is to increase the forest and tree cover by 5 Mha, as well as to increase the quality of existing forest and tree cover in another 5 Mha forest/non-forest lands in 10 years. The success of GIM has encouraged its convergence with other schemes/programmes for better coordination in developing forests and fringes in a holistic and sustainable manner. Recently two schemes namely Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and Compensatory Afforestation Fund Management and Planning Authority (CAMPA) have been converged with GIM (Tables 3.20 and 3.21). Convergence of GIM with aforesaid schemes ensures the optimal use of resources and uninterrupted flow of funds. The MGNREGS is social security scheme of the Government that guarantee the employment of 100 days in each financial year to any adult registered for rural employment. The MGNREGS looks after the water harvesting, afforestation and farm forestry while GIM has focus to increase 10 Mha of forest cover. This convergence will bring co-ordination in developing forests , fringe areas and community/ privately owned forests. To achieve the set targets, Ministry of Environment, Forest and Climate Change and Ministry of Rural Development have come out with convergence guidelines, so that the efforts of MGNREGS and GIM can be further synergized and concerns to climate change can be collectively addressed. The guidelines of convergence are as follows:

- All types of lands including common village land, community land, revenue wastelands, shifting cultivation areas, private agriculture lands, wetlands will be eligible for afforestation under this convergence.
- Forest works such as pre-plantation, digging pits, planting and watering, fencing, protection activities, and plant support as well as weeding, mulching and manuring will be carried out under MGNREGS.

- State Forest Development Agencies (SFDA) will provide technical advice for the selection of plant species suitable for the area, raise nurseries and provide required planting material to each *Gram Panchayat* (a village-level committee) before July of each year, meeting the cost from MGNREGS funds.
- If insufficient fund available under MGNREGS, it may be topped up from Green India Mission.
- SFDA will buildup Green Volunteers by training the youth from MGNREGS houses to engage in forest conservation, basic forestry operations and other ecological activities.
- Under MGNREGS, wages will constitute 100% central grant, and material component will be shared on a 75:25 ratio between State and Central governments.
- Being Centrally Sponsored Scheme, 90% of funds for implementing of the Green India Mission in the north east and special category states will come from central government.
- The Ministry of Rural Development and Ministry of Environment, Forest & Climate Change will ensure that adequate funds are made available at the field implementation levels to achieve the given targets.
- Plantation progress will be monitored periodically by using remote sensing data obtained by National Remote Sensing Centre.
- Programme will be continuously monitored with active involvement of stakeholders.

Table 3.20: Activities taken up in MGNREGS under Convergence with GIM

Sub- mission/ Intervention	Category	Activities which may be included in MGNREGS
Enhancing quality of forest cover and improving ecosystem services	Moderately dense forest cover but showing degradation	Soil and moisture conservation (SMC) works, improving hydrological regime through infiltration zone identification and protection
	Eco- restoration of degraded open forests	
	Type A with plenty of root stock, with little or no scope for planting	SMC works, gap plantation
	Type B with open blanks having limited root stock	Through aided natural regeneration (ANR)
	Type C largely open areas with sparse undergrowth	Through artificial regeneration
	Restoration of grasslands	SMC work and planting of fodder plants
Ecosystem restoration and increase in forest cover	Rehabilitation of shifting cultivation areas	Planting of fast-growing species which may be managed by the community.
	Restoring scrublands	SMC works and planting of multipurpose native species
	Restoring/ planting Sea- buckthorn	Afforestation of sea-buckthorn in suitable areas
	Restoration of mangroves	Planting of littoral species and mangroves to restore vegetation cover, development of artificial channels and restore mangrove through planting of indigenous mangrove species species.
	Ravine reclamation	Ravine reclamation through dorbandi (bunds)and gully plugging, building big bund at the tail end to serve as a percolation dam for water storage on revenue and forest land and planting of indigenous species etc.
	Restoration of abandoned land in mining areas	Planting in abandoned mines after filling and SMC works
Enhancing tree cover in urban and peri urban areas (including institutional lands)	This sub-mission will be carried out on the recorded notified forest patches.	Planting in peri-urban (rural) category of land may be taken up under MGNREGA
Agroforestry and Social Forestry (increasing biomass and creating carbon sink)	Multipurpose species for agroforestry/ social forestry which are preferred by farmers will be planted.	Plantation and farm forestry, development of fallow or wasteland of households can be taken up under MGNREGS
Livelihood improvement activities	Technology for value added products, certification and marketing of NTFP for sustainable NTFP management and improved marketing	Capital assets required for the self-help groups can be taken up under MGNREGA

Source: (MoEFCC, 2015a)

The Government has allocated ₹1.85 billion for Green India Mission-National Afforestation programme, and ₹370 billion were allocated to MGNREGS for the financial year 2016-17 (http://indiabudget.nic.in, accessed on 10th January 2017).

Compensatory afforestation fund also has a sizeable amount of fund for artificial regeneration, assisted natural regeneration, protection of forest and wildlife and other activities. Green India Mission works on similar activities. Therefore, the government has converged CAMPA and GIM activities. This convergence will ensure a synergized approach, which is required to address the challenges being faced by the environment; forest and wildlife sector thereby contributing to ecological security in the context of climate change. The main target of this convergence is to achieve the goal of sustainable forest management and to achieve environmentally sound interventions to minimize adverse effects of climate change. The Government has allocated an outlay of ₹4.64 billion under CAMPA for the year 2017-18.

Table 3.21: Activities under CAMPA in Convergence with GIM

S. No.	Intervention under GIM	Category under GIM	Activities which may be taken up in CAMPA under convergence with GIM
1	Enhancing quality of forest cover and improving ecosystem services	a. Moderately dense forest cover but not showing degradation	Conservation of wildlife habitats
		b. Eco-restoration of degraded open forest	Reinstating animal corridors which are lost
		c. Type A with plenty of root stock with little or no scope for planting	Gap plantation
		d. Type B with open blanks having limited root stock	through aided natural regeneration
		e. Type C largely open areas with sparse undergrowth	Compensatory afforestation
2	Ecosystem restoration and increase in forest cover	a. Rehabilitation of shifting cultivation areas	Planting fast growing species which may be managed by the community training of forest officials to strengthen their eco-restoration skills, promote research
		b. Restoration scrubland	Planting native species
		c. Restoration/ planting sea-buckthorn	Afforestation of Sea-buckthorn in suitable areas
3	Support activities	Monitoring and evaluation	Web-based monitoring
		Strengthening forest department	Training programme for frontline staff

Source: (MoEFCC, 2015b)

3.9.6 The Indian Forest (Amendment) Act, 2017

Introduced on 5th January 2018, it amends Section 2, Clause (7) of the Indian Forest Act, 1927 by omitting the word 'bamboos' from the earlier definition of trees which included palms, stumps, bamboos, brush-wood and canes, thereby dispensing with the requirement of felling/transit permit for their economic use by farmers in non-forest areas. A major objective of the amendment is to promote cultivation of bamboo in non-forest areas to achieve twin objectives of increasing the income of farmers and also increasing the green cover of the country. The act consolidates the laws relating to forests, transportation of forest-produce and the duty to be imposed on them.

The amendment will encourage bamboo plantation and promote income opportunities, which will eventually contribute to enhanced economic growth, increased green cover as well as bring reforms in the bamboo sector.

3.9.7 Twenty Point Programme

The Twenty Point Programme was launched by the Government of India in the year 1975 and was restructured in 1982, 1986 and again in 2006. The restructured programme, known as Twenty Point Programme-2006, became operational with effect from 1st April 2007.

The targets for afforestation and tree planting activities taken up under the Twenty Point Programme are set under two mutually exclusive categories, viz., seedling distribution for planting on public and forest lands and area coverage (under plantation) with respect to public lands including forest lands.

Since the inception of the scheme, ₹452.25 billion has been released for afforestation until 30th November 2017. Area brought under plantation from April to December 2017 was 1.1 Mha and the number of seedlings planted were 0.78 billion.

3.9.8 Clean Development Mechanism

Carbon trading in the forestry sector is under the ambit of Clean Development Mechanism (CDM) and voluntary markets have proved as highly successful instruments for financing emission reductions. However, the domestic carbon market mechanism for the forestry sector has not developed so far in India. About 19 CDM projects are registered under A/R (Afforestation/ Reforestation) with per year emission reduction potential of 429,614 tCO_2e. A list of registered A/R CDM projects from India is given in Table 3.22.

Table 3.22: A/R CDM projects registered in India

S. No.	Date of Registration	Title	Reduction in tCO_2e per year
1	26-Nov-15	Small scale Mirzapur JFM A/R CDM Project on degraded lands in Mirzapur Forest Division, Uttar Pradesh, India.	10,667
2	26-Nov-15	Small scale Kashi JFM A/R CDM Project on degraded lands in Kashi Forest Division, Uttar Pradesh, India	4,694
3	26-Nov-15	Small scale Lalitpur JFM A/R CDM Project on degraded lands in Lalitpur Forest Division, Uttar Pradesh, India	5,375
4	26-Nov-15	Small scale Obra JFM A/R CDM Project on degraded lands in Obra Forest Division, Uttar Pradesh, India	5,571
5	26-Nov-15	Small scale Sonbhadra JFM A/R CDM Project on degraded lands in Sonbhadra Forest Division, Uttar Pradesh, India	8,721
6	26-Nov-15	Small scale Renukoot JFM AR CDM Project on degraded lands in Renukoot Forest Division, Uttar Pradesh, India	7,670
7	26-Nov-15	Small scale Mahoba JFM A/R CDM Project on degraded lands in Mahoba Forest Division, Uttar Pradesh, India	4,356
8	26-Nov-15	Small scale Jhansi JFM A/R CDM Project on degraded lands in Jhansi Forest Division, Uttar Pradesh, India	3,376
9	14-Oct-15	Small scale Chitrakoot JFM A/R CDM Project on degraded lands in Chitrakoot Forest Division, Uttar Pradesh, India	3,743
10	3-Aug-15	Small scale Allahabad JFM A/R CDM Project on degraded lands in Allahabad Forest Division, Uttar Pradesh, India	3,794
11	30-Jan-13	Rehabilitation of Degraded Wastelands at Deramandi in Southern District of National Capital Territory of Delhi through Reforestation	12,138
12	19-Nov-12	Agro-forestry Interventions in Koraput district of Orissa	1,130
13	1-Aug-11	Reforestation of degraded land by MTPL in India	146,998
14	27-May-11	Bagepalli CDM Reforestation Programme	92,103
15	4-Mar-11	India: Himachal Pradesh Reforestation Project – Improving Livelihoods and Watersheds	41,400

S. No.	Date of Registration	Title	Reduction in tCO_2e per year
16	28-Feb-11	Improving Rural Livelihoods Through Carbon Sequestration By Adopting Environment Friendly Technology based Agroforestry Practices	4,896
17	15-Jan-10	The International Small Group and Tree Planting Program (TIST), Tamil Nadu, India	3,594
18	5-Jun-09	Reforestation of severely degraded landmass in Khammam District of Andhra Pradesh, India under ITC Social Forestry Project	57,792
19	23-Mar-09	Small Scale Cooperative Afforestation CDM Pilot Project Activity on Private Lands Affected by Shifting Sand Dunes in Sirsa, Haryana	11,596
Total			429,614

Source: http://cdm.unfccc.int/Projects/projsearch.html accessed on 13th February 2017

3.9.9 Reducing Emissions from Deforestation and Forest Degradation in developing countries (REDD+)

3.9.9.1 National REDD+ Strategy

National REDD+ strategy, 2018 has an overarching objective to facilitate implementation of REDD+ programme in the country in conformity with relevant decisions of UNFCCC, in particular, the Cancun Agreements, Warsaw Framework for REDD+, Paris Agreement, and the national legislative and policy framework for conservation and improvement of forests and the environment. The REDD+ strategy has been aligned with the percepts of National Forest Policy. It also proposes to establish a National Governing Council to coordinate and guide REDD+ related actions at the national level.

Institutional mechanism: roles and responsibilities of stakeholders

National Governing Council for REDD+ (NGC-REDD+) shall be chaired by Union Minister for Environment, Forest and Climate Change. A National Designated Entity for REDD+(NDE-REDD+) shall also be established at the Ministry of Environment, Forest and Climate Change to liaise with UNFCCC and states. The strategy devolves major responsibility for execution of REDD+ activities on the State Forest Departments. Each State will create a REDD+ Cell in the State Forest Department. In line with National REDD+ strategy, states are also encouraged to develop their State Action Plan for REDD+. The strategy proposes to revisit the Green India Mission (GIM) objectives and the timeframe in the light of new developments under global climate change regime.

Capacity building

The strategy focuses on the creation of trained human resource capable of carrying out forest-related measurements at all levels of REDD+ implementation. It will support the empowerment of youth cadres as Community Foresters to lead the charge at the local level. Green Skill Development programme for imparting forestry related specialised skill will be implemented. The REDD+ programme will create additional jobs in the forestry sector. In order to keep forests well adapted to climate change impacts, some of the activities where "community foresters" can be engaged effectively are: (i) assisted natural regeneration, (ii) soil and moisture conservation, (iii) harvesting, thinning, and hygienic removals, (iv) forest nurseries and raising of quality planting stocks, and (v) control of forest fires, pest, disease and invasive species.

Centrality of local community

Capacity building will be organised for the local communities including for the *Gram Sabha* (Village Council) and JFM Committees. Local communities will bear the responsibility of protecting, regenerating and managing forests. The National REDD+ Strategy develops a roadmap for addressing drivers of deforestation and forest degradation and issues like safeguards for rights of the local community, first right of use with the local community, gender equity and creation of green jobs to the local youths etc.

National REDD-plus Strategy: roadmap and action Plan

- Establishment of a National Governing Council for REDD+ (NGC-REDD+) at the national level having the task of coordinating and guiding REDD+ related actions at the national level
- Creation of a REDD+ Cell in each State Forest Department (SFD)
- Capacity building of all cadres of the SFDs including Forest Working Plan Officers on assessment of forest carbon stocks and other REDD+ related activities.
- Green Skill development of community youths for various forestry activities
- Creation of additional infrastructure for SFDs comprising technical expertise, trained manpower, a latest equipment and facilities for forest carbon measurement.
- Expansion of the technical and technological capability of ICFRE, FSI and the SFDs by upgrading its existing technical capacity.
- Creation of modern measuring capability with latest equipment in each State. The existing space application centres and GIS facilities in the States will be strengthened and upgraded for the purpose.
- Focus of forestry research on productivity in an integrated and multidisciplinary manner on forests and forest products aiming at increasing livelihood support and economic growth.
- A Forest Reproductive Material (FRM) Certification Policy-cum-Strategy shall be developed

Flow of incentives

The REDD+ incentives may be generated internationally through wide variety of sources (public and private, bilateral and multilateral, including alternative sources, including Green Climate Fund in a key role), and also at national level in shape of performance-based awards and financial devolution from Government of India (GoI) to State Governments and down to the local communities. GoI/NGC-REDD+ will formulate the guidelines for the flow of international and national incentives in a transparent and equitable manner.

National Forest Reference level for REDD+

Decision 1/CP. 16 encourages developing countries to develop a "National Forest Reference Emission Level (REL) and/or National Forest Reference Level (RL) or, if appropriate, as an interim measure, sub-national REL and/or RL, in accordance with the national circumstances". REL and or RL serve as a benchmark for assessing the performance of an implemented REDD+ project in a country. For India, in accordance with its strategy of increasing the forest and tree cover, this decision necessitates the development of a National Forest Reference Level (RL). The Government of India on voluntary basis has submitted the National Forest Reference Level to UNFCCC in January 2018.

The process of developing RL draws strength from data and information from FSI's National Forest Inventory (NFI) which provide information for Monitoring Reporting and Verification (MRV). The NFMS provides forest-related emissions by sources and removals by sinks. The comparison of MRV emission estimates coming from REDD+ implementation with the RL(s) will indicate the performance of the REDD+ activity. Therefore, the definitions, methodologies, scope etc. followed in MRV and RL are kept the same for consistency and comparability (Decision 14/CP.19). The available data and information about forest area, change in area and GHG inventories were analysed, and necessary calculations and changes were carried out in order to construct relevant RL.

For the construction of FRL, the action taken is 'Sustainable Management of Forest (SMF)'. By analysing the forest cover assessment between 2000 to 2008, it has been observed that activities such as deforestation, forest degradation, enhancement of canopy densities and afforestation (leading to enhancement of carbon stocks) have been observed in significant forest area. All the five pools namely Above Ground Biomass, Below Ground Biomass, Dead Wood and Litter and Soil Organic Carbon have been taken into account for construction of FRL because India has a good quality time series data through regular National Forest Inventory programme for all the pools. Only CO_2 gas has been taken into account for construction of FRL.

Proposed Reference Level: Historical emission estimates are developed using the modified time series activity data of the year 1994, 2000, 2004 and 2008. During the late 1990s and early 2000, the number of new acts and policies were introduced to safeguard ecological security and interest of common man *viz*. Biological Biodiversity Act 2002, Scheduled Tribes and Other Traditional Forest Dwellers (Recognition of Forest Rights) Act 2006, National Environment Policy 2006, Agroforestry Policy 2014, etc. Many of these have a significant bearing on the management of forests. Considering these facts, the historical period of 2000 to 2008 was considered for construction of forest reference level. Based upon above, India's proposed Forest Reference Level as communicated to UNFCCC is -49.70 million CO_2 equivalent.

3.9.9.2 REDD+ Pilot Projects in India

Umiam Sub-watershed REDD+ Project: Umiam Sub-watershed Conservation Project in the East Khasi Hills of Meghalaya State of India is the country's first REDD+ project. It started in 2005 with the aim to preserve sacred groves and other forest areas and to replant surrounding land. The project covers an area of 8,379 ha consisting of dense forest and open degraded forest (Indo-German Environment Partnership). The project area has suffered a loss of 5% forest cover per year from 2000 to 2010 as a result of agriculture expansion, mining and settlement. The project is run by Community Forestry International (CFI) with Mawphlang tribal community. The project seeks to support indigenous communities to conserve dense forest and restore degraded forest through assisted natural regeneration and afforestation activities along with income generation activities. The project follows the Free Prior and Informed Consent guidelines and Plan Vivo standards, thus ensuring maximum control and benefit to participating communities. The project anticipates generating 13,761 carbon credits each year, which it hopes to sell for between US$42,000 and US$80,000.

Uttarakhand REDD+ Project: Indian Council of Forestry Research and Education (ICFRE) has initiated a REDD+ pilot project in the *Van Panchayat* (Village Community Forests) of Uttarakhand (India). The pilot project is financed by Uttarakhand Forest Department. Under the project, ICFRE intends to develop modalities for giving financial incentives to local communities that can make the REDD+ a success at local, sub-national and National level. The project will ensure people's participation and sharing of the benefits accruing from REDD+ incentives at the local project level.

Forest Plus by USAID: This program is strengthening capacity to develop systems for forest carbon measurement and monitoring, as well as assessing the change in status of degradation and deforestation at various jurisdictions and estimating carbon loss or gain from the forests over a period of time, and support the application of science and technology for improved and more cost-efficient management and monitoring systems. Under Forest Plus, pilot projects are selected in Shimoga (Karnataka), Harda District (Madhya Pradesh), Sikkim and Chamba/Mandi (Himachal Pradesh).

Norwegian Government and MoEFCC REDD+ projects: The Energy and Resources Institute (TERI), New Delhi is implementing small REDD+ pilot projects financed by the Norwegian Government in close association with the Ministry of Environment, Forest and Climate Change and State Forest Departments. Pilot study for project design in 6 sites in different states of India has been initiated: (i) Temperate forests (Mussoorie, in Uttarakhand), (ii) Dry-Deciduous Mixed Forests (Renukoot, Uttar Pradesh), (iii) Moist –Deciduous Forests (Chhindwara, Madhya Pradesh), (iv) Moist deciduous-Mixed forests (Angul, Odisha), (v) Mangrove Forests of Sundarbans (West Bengal) and (vi) Tropical Moist Deciduous forests (Nagaland).

ICIMOD-ICFRE-GIZ transboundary REDD+ Himalaya programme: The overall goal of this programme is to build the capacity of the REDD+ focal points in four countries namely India, Nepal, Bhutan and Myanmar to develop and implement National REDD+ Strategy through conservation and sustainable use of natural sinks. In India, this partnership focuses on REDD+ capacity building in the North East region. The programme will assist in developing and implementing REDD+ projects that will focus on training, technology sharing and knowledge dissemination. Pilot REDD+ projects will be established in each country for all stakeholders. The broad objectives of the programme are:

a. Developing methods for calculating, modelling and forecasting carbon storage.

b. Developing instruments in preparation for regional REDD readiness.

c. Working towards harmonisation in the region, an exchange of experience and mutual learning so that good REDD implementation practices are established as South-South cooperation

3.9.8 State level and local initiatives

Plantation drive of Delhi Metro Rail Corporation (DMRC) to combat climate change: The DMRC formulated a policy to plant 10 saplings as compensatory afforestation for every single tree that is required to be felled. The trees planted during different construction phases have high potential to sequester about 5,500 tonnes of CO_2. The tree plantation data of different construction phases of DMRC is given in Table 3.23.

Table 3.23: Compensatory Plantation data of DMRC (Number of trees)

Felled	Transplanted	Planted
31,855	6,636	344,251

Source: http://www.delhimetrorail.com, accessed on 20th January 2017

Telangana *Ku Haritha Haram* (a programme of Telangana Government to increase forest cover): In July 2015, Telangana State Government launched a programme called 'Telangana Ku Haritha Haram' with the aim to increase the forest and tree cover of the state from 24% to 33% of the geographical area of the State. Initiatives in notified forest areas and initiatives in areas outside forest were taken as the major objectives to achieve the targeted goal. To attain the first objective of the programme, an approach of rejuvenating degraded forests followed by a watershed approach has been followed. Under the second objective massive plantation was done in areas like roadside avenues, river and canal bank, barren hill, tank bunds, institutional premises, religious places, housing colonies, community land, municipal and industrial parks etc. Plantation of about 2.30 billion seedlings has been proposed during a three years period.

Tree plantation on vacant railway tracks: In the year 2016, Ministry of Railways in consultation with Ministry of Environment, Forest and Climate Change finalized a model agreement for tree plantation under Green India Mission on railway land alongside railway track and station yard towards environmental improvement through afforestation. The cost of protection and maintenance of plantation can be shared by the state forest department or railway administration or by both. Ministry of Railways has targeted a plantation of 50 million saplings along the tracks and block plantation on its land across the country. During 2016-17, 12.5 million saplings have been planted, and 8.9 million have been planted during 2017-18. Nearly 40,000 ha of railway land is under the afforestation programme.

Maharashtra *Harit Sena* (Green Army): Maharashtra State Forest Department has initiated the 'Maharashtra *Harit Sena*' (Green Army) which is a body of dedicated volunteers to participate in the plantation, protection, and activities in the forest, wildlife, and related sectors around the year. State forest department has set the target of the plantation of 40 million, 130 million and 330 million saplings in the three consecutive years *viz.* 2017, 2018 and 2019. Under this mission, a total of 500 million saplings are to be planted by the end of 2019. Until July 2018, 120.81 million saplings have been planted. For transparency, the forest department has created a mobile application called 'My Plants' to record details of the plantation such as numbers, species and location into the computer system of the forest department.

***Ama Jungle Yojana* (Odisha):** Government of Odisha implemented a new scheme to increase green cover with the help of *Van Sanraksha Samiti*. State Government plans to regenerate about 0.26 Mha and create 5,000 ha of new forest cover in the next six years (2016-17 to 2021-22). The scheme will be implemented at an estimated cost of ₹11.7 billion by diverting funds from different sources. More than 12,500 Joint Forest Management Committees have been assigned for protection and management of more than 11,68,000 ha of forests. This scheme has proposed to create 7,000 *Van Suraksha Samitis* (Forest Protection Societies) located in 30 territorial and wildlife divisions of the State.

Massive tree planting programme (Tamil Nadu): This scheme was implemented with an objective to increase green cover. During the year, 2011-12 to 2012-13, this scheme was initiated and is one of the most successful programmes of Tamil Nadu. Under the programme, 6.7 million seedlings have been planted in 32 districts of the State from 2014-15 to 2016-17.

Palmyra palm seed plantation programme (Tamil Nadu): A mass palmyra palm (*Borassus flabellifer*) seed planting programme was launched in 2017 by Government of Tamil Nadu to strengthen the bunds of water bodies and to increase the population of the 'official tree of Tamil Nadu' (Palmyra palm). Government and community lands in Tamil Nadu have been earmarked for the plantation activity for a period of five years from 2016-17 to 2020-21.

Development of Agroforestry in Community/ Farmlands (Haryana): It is a state-run scheme of Government of Haryana with a proposed outlay of ₹600 million. The main objectives are to increase the tree cover outside forests, to encourage the practice of agroforestry on farmlands for crop-diversification and to increase the productivity of farmlands, to raise woodlots on non-forest lands, to create shelter-belts on private farmlands along National and State highways, and to plant grafted fruit plants and other plants.

Greenbelt in urban areas (Haryana): This is an on-going State plan of Government of Haryana with a proposed outlay of ₹90 million. The main objectives are to take up tree planting activity in urban areas along roads, in

parks and in vacant areas available in various localities to increase tree cover in urban areas for improvement of environment and to check air pollution. About 474 RKM green belt was developed by the year 2015-16.

3.10 Waste Sector

The waste sector contributed 3% to India's GHG emissions. Waste sector emissions mainly cover waste management activities such as solid waste disposal and wastewater treatment and discharge. In order to manage waste efficiently, the Indian government has significantly invested in solid waste management (SWM) programmes. The current focus of the Government of India is on the rapid expansion of modernization of sanitation facilities and infrastructure and waste management infrastructure in general. These are indispensable for future mitigation in the waste sector. India recognizes the dual benefits that can arise from efficient waste disposal leading to enhanced environmental benefits along with initiatives promoting conversion of waste to energy.

3.10.1 Laws pertaining to waste management

For efficient waste management, specific laws for different types of wastes have been enacted and amended from time to time to accommodate the changing environmental conditions. These are:

i. Hazardous Wastes (Management, Handling & Transboundary Movement) Rules, 2016 (This supersedes 2008 version).
ii. Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989.
iii. Bio-medical Waste (Management & Handling) Rules, 2016 (This supersedes 1998 version).
iv. Construction and Demolition Waste Management Rules, 2016.
v. Municipal Solid Waste (Management & Handling) Rules, 2016 (This supersedes 2000 version).
vi. Plastic Waste (Management and Handling) Rules, 2016 (This supersedes 2011 version)
vii. Fly Ash management rules 2008
viii. E-Waste (Management) Rules, 2016 (This supersedes 2015 version).

Municipal authorities are to implement these rules

State Pollution Control Boards: State Boards are implementing the following activities:

i. Pollution control in 17 categories of highly polluting industries
ii. Pollution control in industries discharging waste water into rivers and lakes
iii. Inventorization of polluting industries in the State and ensuring their compliance to the pollution control norms
iv. Restoration of environmental quality in critically polluted areas

3.10.2 Swachh Bharat Mission

Ministry of Urban Development (MoUD) has launched 'Swachh Bharat Mission' (SBM) on 2nd October 2014 with the target to make the country clean by 2nd October 2019. The Mission, among other measures, includes Solid Waste Management including the establishment of waste to energy plants and provides Central Financial Assistance up to 35% of the project cost. There are two components of the Mission, namely, Swachh Bharat Mission Gramin for India's rural centres and Swachh Bharat Mission Urban for India's urban centres.

Waste Management: Swachh Bharat Mission – Urban and Gramin

The Swachh Bharat Mission-Urban: This was launched on 2nd October 2014 and aims at making urban India free from open defecation and achieving 100% scientific management of municipal solid waste in 4,041 statutory towns in the country. The targets set for the Mission, which have to be achieved by 2nd October 2019 include:

- Construction of 6.64 million individual household toilets (IHHL);
- Construction of 0.25 million community toilet (CT) seats;
- Construction of 0.25 million public toilet (PT) seats; and
- Achieving 100% door-to-door collection and scientific management of municipal solid waste (MSW).

Swachh Bharat Mission-Gramin: The Mission was launched on 2nd October, 2014. It is a comprehensive programme to:

- Bring about an improvement in the general quality of life in the rural areas, by promoting cleanliness, hygiene and eliminating open defecation.
- Accelerate sanitation coverage in rural areas to achieve the vision of Swachh Bharat by 2nd October 2019.
- Motivate communities and Panchayati Raj Institutions to adopt sustainable sanitation practices and facilities through awareness creation and health education.

- Encourage cost effective and appropriate technologies for ecologically safe and sustainable sanitation.
- Develop wherever required, community managed sanitation systems focusing on scientific solid and liquid waste management systems for overall cleanliness in the rural areas.

The focus of the strategy is to move towards a '*Swachh Bharat*' (clean India) by providing flexibility to State Governments, as sanitation is a state subject, to decide on their implementation policy and mechanisms, taking into account state specific requirements (MDWS, 2014).

Role of *Gram Panchayats* (Village elected council): Under the Fourteenth Finance Commission (FFC) award, grants to the tune of ₹2,002.92 billion for the period 2015-2020 are being devolved to Gram Panchayats (GPs) in 25 States constituted under Part IX of the Constitution and Jammu and Kashmir. The grant is provided to GPs for delivering basic services including sewerage and solid waste management. Further, funds are also being provided to the GPs under the Swachh Bharat Mission (Gramin). Such projects can also be converged with other schemes such as Mahatma Gandhi National Rural Employment Guarantee Scheme.

Deendayal Antyodaya Yojana-National Rural Livelihoods Mission

This mission under the Ministry of Rural Development has commenced work on scaling up a waste management model which has been successfully implemented and scaled up by the Government of Tamil Nadu state, India across 9,000 villages of the state. The Tamil Nadu Model has been documented and is being replicated in eight States of Bihar, Uttar Pradesh, Rajasthan, Madhya Pradesh, Chhattisgarh, Jharkhand, Maharashtra and West Bengal. In each of the States, the plan is to work in at least 50 villages for a period of one year.

There are significant contributions from DAY-NRLM in promoting Green Livelihoods through activities approved under Annual Action Plan and farm livelihood activities through *Mahila Kisan Sashaktikaran Yojana*.

Atal Mission for Rejuvenation and Urban Transformation (AMRUT)

In the AMRUT and Mission for Smart Cities for 500 Class-I cities approved by Govt. of India, one of the eligible components is sewerage and sewage treatment plants, including recycling and re-use of wastewater (MDWS, 2015).

Waste to Energy

i. 33 Waste to Energy (WtE) Plants with a cumulative installed capacity of over 275 MW are operational in the country.

ii. Swachh Bharat Mission and one of the admissible components under this is Solid Waste Management, including the establishment of Waste to Energy (WtE) plants with the Central support of up to 35% of the project cost.

iii. WtE plants that are currently operational in the country are based on thermal (mass incineration/RDF burning) technology or on biological (biomethanation) technology. Dry mixed waste is used in projects based on thermal conversion technology whereas source segregated wet waste is used in projects based on biological conversion technology. Both the technologies do not have any adverse impact on the environment and emissions remain within limits prescribed by the Central Pollution Control Board.

iv. The estimated potential to generate power from Municipal Solid Waste is about 500 MW which would be increased to 1,075 MW by 2031, as urbanisation grows.

v. In the Electricity (Amendment) Bill, 2014 introduced in Parliament on 19th December 2014, the waste, including municipal and solid waste, has been proposed to be included in the definition of "Renewable Energy Sources".

vi. Ministry of New and Renewable Energy (MNRE) is implementing a programme on energy recovery from urban and industrial wastes including waste water. The technology options for energy recovery being promoted under this programme include biomethanation technology, which also treats the waste water for its safe disposal or utilization with simultaneous generation of power.

vii. Ministry of Railways had taken up a pilot project for disposal of municipal solid waste generated at railway terminals in an environment friendly manner, including conversion of waste to energy. Biogas or electricity are the two possible forms of energy to be generated from these plants which would be utilized for suitable services at/near Railway Station.

viii. Production of biogas and power from waste water is a commercial technology. A number of Indian industries have been installing such projects.

Programme on Energy from Urban, Industrial and Agricultural Wastes/Residues

The Ministry of New and Renewable Energy (MNRE) is currently implementing a programme on Energy from Urban, Industrial and Agricultural Wastes/Residues. The programme supports setting up of pilot projects and provides Central Financial Assistance (CFA) for projects of different categories. Central financial assistance under the programme is provided for the following kinds of processes and technologies:

i. Power generation from Municipal Solid Waste

ii. Power generation from biogas at Sewage Treatment Plant or through biomethanation of Urban and Agricultural waste/ residues including cattle dung or production of bio-CNG

iii. Biogas generation from Urban, Industrial and Agricultural wastes/residues

iv. Power Generation from Biogas (Engine/gas turbine route) and production of Bio-CNG for filling into gas cylinders

v. Power Generation from Biogas, Industrial, Agricultural Waste/residues

Tariff Policy

Ministry of Power has notified the revised Tariff Policy on 28th January 2016, which provides for the distribution licensee(s) to mandatorily purchase, the entire power generated from Waste to Energy Plants in the State, in the ratio of their procurement of power from all sources including their own, at the tariff determined by the appropriate commission. The policy includes mandatory usage of treated sewage water and compulsory procurement of power from WtE plants (making it must-run) by DISCOMs.

Central Electricity Regulatory Commission (CERC) has issued amendments to CERC (Terms and Conditions for Tariff determination from Renewable Energy Sources) Regulations, 2012 on 7th October 2015, for determination of tariff of electricity generated from Waste to Energy plants. Accordingly, CERC has determined the generic tariff of ₹7.04 per unit for plants operating on Municipal Solid Waste and ₹7.90 per unit for plants using Refuse Derived Fuel.

Bio-toilets in railway coaches

Indian Railways have set a target to fit bio-toilets in the entire fleet of coaches by the year 2021-22. In line with '*Swachh Bharat Mission*', the pace of fitment of bio-toilets has been increased and the task is now targeted to be completed by 2019. Key highlights are:

i. More than 126,000 bio-toilets have been installed in about 34,700 passenger coaches by Indian Railways until 2017-18.

ii. Anaerobic digestion process is applied for the digestion of human excreta in these bio-toilets. Anaerobic bacteria convert human waste mainly into water and biogas.

iii. 21 sections on Indian Railways have been commissioned as 'Green Corridors' where no human waste gets discharged on tracks from trains, as all trains running over these routes/sections have all the coaches fitted with bio-toilets.

iv. The additional cost of providing bio-toilets in one coach (4 bio-toilets) is ₹0.4 million approximately and for the in-service coaches, which require replacement of structural members for fitment of bio-toilets, the additional cost is approximately ₹1.6 million per coach.

3.11 Mitigation actions: nature, coverage, objectives, methodologies, steps taken, results achieved and emission reductions achieved

In accordance with AWGCLA/2011/INF.1, information on Description of the mitigation action, methodologies and assumptions, objectives of the action and steps taken or envisaged, and Progress of implementation is provided in a set of Tables in the following section, for Energy (Table 3.24), Forestry (3.25), Agriculture (Table 3.26) and Transportation (Table 3.27). Table 3.28 provides annual estimates of GHG mitigated from some of the major policies and programmes for the years 2011, 2012, 2013 and 2014. Those mitigation actions that are not covered for annual estimation in Table 3.28, are covered in Tables 3.24 to 3.27 for cumulative mitigation estimation. These tables are indicative and non-exhaustive.

Some other national level policies and programmes that would have indirect mitigation benefits are mentioned in Chapter 6 (Table 1, Appendix-1). Their mitigation contributions could not be estimated. Further, Table 2 (Appendix-1) covers mitigation actions at the state level. Their mitigation contributions could not be estimated due to lack of capacity. This remains a capacity building need for India. Some of the programmes in tables in Appendix-1 are also adaptation measures.

Table 3.24: Mitigation Actions in Energy Sector

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Mission/
National Solar Mission	Aims at increasing the share of solar energy in the total energy mix through the development of new solar technologies, while attempting to expand the scope of other renewable and non-fossil options such as nuclear energy, wind energy and biomass.	Regulatory	Renewable energy	CO_2	To establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.	To deploy 100 GW solar power by 2022.	The CO_2 emission factor (CO_2EF) numbers are the average carbon content of the national power grid and have been obtained from CEA. The total CO_2 saved during 2011-2014 has been estimated using the following formula: Total CO_2 saved = Electricity generation from solar × Grid emission factor	As of June 2018, a total of 23.02 GW Grid connected Solar Power Projects have been commissioned. Total cumulative emission reductions from grid connected solar power from 2014-15 till July 2018 is 60 $MtCO_2e$.	National Action Plan on Climate Change
Wind Energy	Target of 60 GW wind power by 2022.	Regulatory	Renewable energy	CO_2	To catalyse commercialization of grid interactive wind power.	Deployment of 60 GW by 2022 and stable at the same level until 2030	The CO_2EF has been obtained from CEA. The total CO_2 saved during 2011-2014 has been estimated using the following formula: Total CO_2 saved = Wind Power Generation × Grid emission factor	As on 31 June 2018, installed capacity of wind energy was 34.2 GW. It has led to an emission reduction of 183 $MtCO_2e$ during 2014-15 to July 2018.	National Action Plan on Climate Change
Other Renewables	MNRE has been vested with the responsibility of developing Small Hydro Power (SHP) projects up to 25 MW station capacities. The estimated potential for power generation in the country from such plants is about 20,000 MW.	Regulatory	Renewable energy	CO_2, CH_4	Small Hydro and Biomass based power	Deployment of 15 GW by 2022	The CO_2EF has been obtained from CEA. The total CO_2 saved during 2011-2014 has been estimated using the following formula: Total CO_2 saved = cumulative generation × Grid emission factor	It has led to an emission reduction of 92.5 $MtCO_2e$ during 2014-15 to July 2018.	National Action Plan on Climate Change
T&D Losses reduction	By the end of 2013, each of the country's five regional grids was interconnected to operate at a synchronous frequency in an effort to transfer power from generation sources to load centres more efficiently.	Economic	Power sector	CO_2	Loss reduction in national grid	Reduction in transmission and distribution losses	The CO_2EF has been obtained from CEA. The total CO_2 saved during 2011-2014 has been estimated using the following formula: Total CO_2 saved = Total electricity generation × T&D loss for that year from previous year × Grid emission factor	It has led to an emission reduction of 889 $MtCO_2e$ during 2008-2017.	Central Electricity Authority

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Mission/
Supercritical Power Generation	Enhancement of energy efficiency through Supercritical technology. Only 1% rise in efficiency reduces CO_2 emission by 2-3%	Economic	Energy efficiency	CO_2	To reduce the emission for each kWh of electricity generated	To improve thermal efficiency and reduce CO_2 emissions	Total CO_2 saved = Total electricity generation from supercritical power plants X (emission factor of subcritical power plant – emission factor of supercritical power plant)	It has led to an emission reduction of 7.01 $MtCO_2e$	Central Electricity Authority
UJALA	Unnat Jyoti by Affordable LEDs for All	Mitigation	Energy efficiency	CO_2	To promote efficient lighting, reducing energy consumption and energy savings.	Target to distribute 770 million LEDs by March 2019 across 100 cities	The CO_2 emission reduction value has been taken from UJALA dashboard of Ministry of Power, Government of India.	A total of 312 million LEDs distributed till October 2018. It has lead to an annual emission reduction of 32.83 $MtCO_2$	National Mission on Enhanced Energy Efficiency
SLNP	Deployment of LED street lights that are approximately 50% more energy efficient than incandescent bulbs and High-Pressure Sodium (HPS) lighting.	Mitigation	Energy efficiency	CO_2	To promote efficient lighting, reducing energy consumption and energy savings	Aims to replace India's 14 million conventional street lights in India with Smart LED variants by 2019.	The CO_2 emission reduction value has been taken from SLNP dashboard of Ministry of Power, Government of India.	Till October 2018 over 7.1 million streetlights have been completed, leading to an annual emission reduction of 3.29 $MtCO_2$	National Mission on Enhanced Energy Efficiency
PAT scheme	A market-based mechanism to facilitate energy efficiency improvements in large energy-intensive industries and facilities, by issuing energy saving certificates that can be traded.	Mitigation	Energy efficiency	CO_2	To reduce specific energy consumption in energy-intensive industries.	An energy savings target of 6.68 Mtoe was given during the first PAT cycle (2012-2015)	The CO_2 emissions saved through this scheme has been taken from BEE	It has led to an emission reduction of 31 $MtCO_2e$ during the first PAT cycle (April 2012- March 2015).	National Mission on Enhanced Energy Efficiency
Pradhan Mantri Krishi Sinchayee Yojana	It provides end-to-end solutions in irrigation supply chain and aims to use micro irrigation technologies extensively to save water, increase production and productivity of crops in a sustainable manner and help in achieving food security.	Mitigation	Agriculture	CH_4	The scheme is meant to expand cultivable area under assured irrigation, improve water use efficiency, enhance adoption of precision-irrigation, enhance recharge of aquifers and introduce sustainable water conservation practices.	Area covered under drip and sprinkler irrigation from 2014-17 is 1,838,467 ha.		It has led to an emission reduction of 22.82 $MtCO_2e$ during 2010-2016	Ministry of Agriculture

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Mission/
Star rated appliances (AC and Refrigerator)	The star rating plan is different for products manufactured/ imported or assembled in different years. Manufacturers are required to place a label showing how much electricity the appliance will consumer under certain conditions.	Economic	Energy efficiency	CO_2	To provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment.	Estimated saving of electricity consumption by households in 2030 is 136.8 billion units.	BUR (2016) gives the shares of BEE labelled AC and frost free refrigerators sold in India till 2011-12. The share for 2012 and 2013 is taken from BEE (2014). For refrigerator, the sales of 5 star rated appliances are taken around 2% per year. The total CO_2 emissions saved in star rated are due to the efficiency change over the years and the number of star rated appliances sold. It is estimated using the following formula: Total CO_2 saved = Total Units sold Dsale of star rated appliances (%) for previous year× Energy consumed ×CO_2EF	It has led to an emission reduction of 111 $MtCO_2e$ during 2013-14 to 2017-18.	Energy Conservation Act 2001
Energy Efficient Buildings Programme	Large scale transformation to retrofit commercial buildings in India into energy efficient complexes	Mitigation	Energy efficiency	CO_2	To reduce cost and energy consumption, and significantly contribute to management of peak demand.	Investment of around ₹100 crore (USD 154 million) covering more than 10,000 large government/ private buildings by 2020.	The value of CO_2 emissions saved has been taken from National Building Dashboard, Ministry of Power, Government of India	It has led to an emission reduction of 0.065 $MtCO_2e$ till October 2018.	Ministry of Power

Table 3.25: Mitigation Actions in Forestry

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Green India Mission: Increase in forest/tree cover by 5 Mha	Aimed at increasing forest cover and improving the livelihoods of forest dependent communities.	Economic	Forestry	CO_2	To use a combination of adaptation and mitigation measures in enhancing carbon sinks in sustainably managed forests and other ecosystems, adaptation of vulnerable species/ecosystems, and adaptation of forest-dependent communities	Increased forest/tree cover on 5 Mha of forest/non-forest lands and improved quality of forest cover on another 5 Mha (a total of 10 Mha). To increase forest based livelihood income of about 3 million households.	Under GIM, 32,368 ha plantation has been created.	It has led to additional sequestration of 50-60 $MtCO_2$	National Mission for a Green India
Namami Gange (forestry intervention)	Afforestation and reforestation on identified diverse forest area	Mitigation and adaptation	forestry	CO_2	• Review and assess the existing situation of Ganga River Basin, past river management and implications and lessons learned. • Identify and involve stakeholders and build consensus for design and development of strategies. • Assess ongoing forestry activities of the states engaged in the Ganga rejuvenation program. • Identify and prioritize critical areas/ field sites in the catchment for regeneration and improvement. • Assess the condition of riparian forests and potential of biological filters. Examine the possibilities of allied and other alternate income generation activities • Assess the potential of cultivation of medicinal plants and restoration of 'Bhoj' (*Betula utilis*) forests and identify appropriate species • Identify research and monitoring needs and develop strategy for future research	Plantation on 8,394, 600 ha area	Conservative assessment subject to full implementation of proposed forestry intervention	87.26 $MtCO_2$/yr	Co-benefits of Ganga rejuvenation programme

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
National Green Highway Mission	Avenue plantation on highways	Mitigation and adaptation	Forestry	CO_2	• Develop a systematic framework for integrated green corridor development • Build resilient ecosystem in form of green corridors along national highway. • Make green highway mission self-sustainable • Develop green corridors with aesthetic appeal • Reduce impact of dust, air and noise pollution. • Provide shade on glaring hot roads. • Reduce soil erosion at embankment slopes • Reduce effect of wind and incoming UV rays	To develop 140,000 km long 'tree line' with plantation along both sides of the national highway in five years	1915.53 km length national highway awarded for avenue plantation	1.2 $MtCO_2/yr$	
CDM A/R	Plantations under Clean Development Mechanism	Economic	Forestry	CO_2	To achieve net additional Carbon sequestration.	Only 19 CDM projects are registered under A/R (Afforestation/ Reforestation) with per year emission reduction potential of 429,614 tCO_2e.	CDM Methodology	It has led to an emission reduction of 1.28 $MtCO_2e$ during 2014-2016	National Clean Development Mechanism Authority
Voluntary carbon markets	Plantations for carbon sequestration	Economic	Forestry	CO_2	To achieve net additional Carbon sequestration.		VCS Methodology	It has led to an emission reduction of 0.46 $MtCO_2e$ during 2014-2016	Voluntary Carbon Market
REDD+	Reducing emissions from deforestation and forest degradation in developing countries to stabilize and increase carbon sinks	Mitigation and Adaptation	Forestry	CO_2	To achieve additional carbon sequestration, emission reduction, improve forest based livelihoods, conservation of rare, endemic, and endangered species found in the area and improvement of watershed hydrology.		REDD+ standard methodology		Voluntary Action

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Low carbon strategy	Protected Areas (PAs)	Mitigation and Adaptation	Forestry	CO_2	GHG emission reduction/ removal	Protection of 16 Mha forest	Continued protection of PAs will add 47 $MtCO_2e$ to forest carbon sink every year. (16*2.0*0.4= 12.8 MtC= 47.0 $MtCO_2e$)	Protection	
	Sustainable Management of Forests other than Pas	Mitigation and Adaptation	Forestry	CO_2	GHG emission reduction/removal	Sustainable management of 16 Mha forest	This will add 62.0 $MtCO_2e$ to the forest carbon sink every year. (53*0.8* 0.4= 16.96 MtC= 62.0 $MtCO_2e$)	Forests subject to sustainable harvests. (53 Mha)	
	Improvement in Forest and Tree Cover	Mitigation and Adaptation	Forestry	CO_2	GHG emission reduction/removal	Improving 1 mha area each of open forests and medium dense forests	This improvement is capable of adding 7.3 $MtCO_2e$ to the forest carbon sink every year. (10*(0.2+0.3)* 0.4= 2.0 MtC= 7.3 $MtCO_2e$)	Improving 1 Mha area each of open forests and medium dense forests to upgrade the forests.	
	Increase in Forest and Tree Cover in Forest Fringe Villages	Mitigation and Adaptation	Forestry	CO_2	GHG emission reduction/removal	1.7 Mha afforestation/reforestation per annum	This initiative will be able to capture additional 12.5 $MtCO_2e$ every year.	17 Mha can be added by creating forest and tree cover in and around 170,000 forest fringe villages	
National Afforestation Programme	Includes afforestation and reforestation of degraded forests and non forest areas.	Mitigation	Forestry	CO_2	Afforestation/reforestation: 3 Mha (2002-07) and rehabilitation of ~ 20 Mha of land	Area afforested, biomass growth rate, timber and fuelwood production			National Afforestation and Eco-Development Board
CAMPA	Promote afforestation and regeneration activities as a way of compensating for forest land diverted to non-forest uses.	Mitigation	Forestry	CO_2	Funding mechanism for enhancing forest and tree cover and conservation and management of wildlife by utilising funds received towards Compensatory Afforestation, Net Present Value (NPV), etc.,	Against a target of 8,60,791 ha, the area covered under compensatory afforestation in the period 1980 to 31st March 2015 is 6,87,809 ha		Not available	Compensatory Afforestation Fund Act, 2016

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Nagar Van Udyan Yojana	Environmental improvement of cities by pollution mitigation, cleaner air, noise reduction, water harvesting and reduction of heat islands effect	Adaptation and Mitigation	Forestry	CO_2	Aims at ecological rejuvenation of the city forests by creating/ developing at least one city forest in each city having Municipal Corporation/ Class I Cities for providing wholesome healthy living environment.	To create forest parks in 200 cities and initiated plantation programmes in partnership with Railways. The estimated cost per hectare will be ₹0.2 million including fencing and other items. Plantation/ Enrichment component- ₹50,000/= per ha.		Not available	Ministry of Environment, Forest and Climate Change

Table 3.26: Mitigation Actions in Agriculture

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
System of Rice Intensification	This activity is a part of National Mission for Sustainable Agriculture.	Adaptation with mitigation co-benefits	Agriculture	CH_4	Water conservation, reduction in production costs, reduction in emissions	The SRI method of cultivation is being promoted in 199 districts in India.		It has led to an emission reduction of 0.186 $MtCO_2e$ during 2010-2016	National Mission for Sustainable Agriculture
Direct Seeded Rice (DSR)	This activity is a part of National Mission for Sustainable Agriculture.	Adaptation with mitigation co-benefits	Agriculture	CH_4	Water conservation, do away with rising of nurseries, puddling and transplanting, reduction in emissions	Area covered under DSR from 2014-16 is 162,274 ha.		It has led to an emission reduction of 0.17 $MtCO_2e$ during 2014-2016	National Mission for Sustainable Agriculture
Crop Diversification Programme	The programme is being implemented in the states of Punjab, Haryana and Uttar Pradesh since 2013-14.	Adaptation with mitigation co-benefits	Agriculture	CH_4	To divert the area of water guzzling paddy to alternate crops like pulses, oilseeds, maize, cotton and agroforestry with the objective of tackling the problem of declining soil fertility and depleting water table.	The extent of area diversified from 2014-16 is 302,509 ha		It has led to an emission reduction of 0.21 $MtCO_2e$ during 2010-2016	Rashtriya Krishi Vikas Yojana
National Horticulture Mission	Centrally sponsored scheme to promote holistic growth of the horticulture sector through an area based regionally differentiated strategies.	Adaptation with mitigation co-benefits	Agriculture	CO_2	Enhancing the production of fruit and vegetables in the country, strengthening nutritional security in the country, providing technology support for high value fruits and vegetables, enhancing water use efficiency and doubling the farm income by growing high value fruits and vegetables.	The area under major fruit tree species is 6.96 Mha.		It has led to an emission reduction of 137.72 $MtCO_2e$ during 2010-2016	Ministry of Agriculture
Balanced Ration for Livestock	Optimum feeding of animals through Ration Balancing Programme (RBP)	Adaptation with mitigation co-benefits	Livestock	CH_4	Improving animal productivity as well in reducing both, the cost of production and the emission of greenhouse gases per unit of animal product.	Animals covered under the Ration Balancing Programme are 2.34 million		It has led to an emission reduction of 0.28 $MtCO_2e$ during 2014-2016	
Feeding bypass proteins	Optimizing the use of protein supplement within the ruminant system	Adaptation with mitigation co-benefits	Livestock	CH_4	Enhancing the income to the farmers through increased production			It has led to an emission reduction of 3.86 $MtCO_2e$ during 2014-2016	

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Avoiding crop residue burning	Avoiding burning of paddy residues in the filed	Adaptation with mitigation co-benefit s	Agriculture	CO_2	Reduction in emissions and air pollution	Farm equipment for timely sowing during standing paddy residues were made available to the farmers. Farm machinery banks were also established to support crop sowing in standing residues and baling of paddy residues.		It has led to an emission reduction of 0.26 $MtCO_2e$ during 2014-2016	
Neem Coated Urea	Government of India has made it mandatory to manufacture 100% neem coated urea from 25th May 2015	Adaptation with mitigation co-benefits	Agriculture	N_2O	To enhance nitrogen use efficiency	A total of 56.72 million tonnes of neem coated urea was produced from 2014-2017		It has led to an emission reduction of 8.89 $MtCO_2e$ during 2014-2016	National Mission for Sustainable Agriculture
CDM in Agriculture	Projects on biomass energy, methane avoidance, irrigation	Mitigation	Agriculture	CO_2, CH_4, N_2O	Additional reduction in emissions	265 registered projects		It has led to an emission reduction of 58.73 $MtCO_2e$ during 2010-2016	Clean Development Mechanism
Voluntary carbon market	Projects on biomass energy	Mitigation	Agriculture	CO_2	Additional reduction in emissions	31 registered projects		It has led to an emission reduction of 8.09 $MtCO_2e$ during 2010-2016	VCS

Table 3.27: Mitigation Actions in Transport Sector

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Ethanol blending policy*	Oil Marketing Companies sell ethanol blended petrol with percentage of ethanol upto 10%. Also, the Government has allowed procurement of ethanol produced from other non-food feedstocks, like cellulosic and ligno cellulosic materials and including petrochemical route.	Regulatory	Transport	CO_2	To push biofuels into the mainstream to supplement gasoline and diesel in transportation, as well as in stationary applications		The data for Gasoline consumption and ethanol blending in India have been taken from MoPNG and subsequent reports of the Government. The net calorific value (NCV) and CO_2 emission (CO_2EF) factor numbers are taken from IPCC. The total emissions saved have been estimated using the quantity of ehtanol blended.	It has led to an emission reduction of 1.68 $MtCO_2e$ during 2011-2014	

Name of Mitigation Action	Description	Nature	Coverage (sector)	Coverage (gases)	Objectives of the Action	Quantitative Goal/ Progress indicator	Methodology/ Assumption	Steps taken/ envisaged and Results achieved	Relevant National Legislation
Metro Rail	The Metro railway system and services are operational in 11 cities of India of which one has been launched recently. These are Kolkata, Delhi, Bengaluru, Gurugram, Mumbai, Chennai, Jaipur, Noida, Kochi, Hyderabad, and Lucknow. The Kolkata Metro rail is the oldest metro service in the country.	Economic	Transport	CO_2	Provide Metro railway system in 15 Indian cities	During the years 2011-14, only Metro rail at Delhi, Kolkata, Chennai and Bangalore cities were operational.	The total ridership of these metro rail systems has been estimated using the year average ridership for the city from reports of the Government, assuming ridership has stabilized since the operation. The average emission reduction (tCO_2 per passenger) has been arrived at after factoring in baseline emissions (trip length, ridership etc), project emissions and leakages (nil). The total CO_2 saved have been estimated using the following formula: Total CO_2 saved = Total Passengers × Average emission reduced per passenger.	It has led to an emission reduction of 2.69 $MtCO_2e$ during 2011-2014	
BRTS	Bus Rapid Transit System is a bus-based public transport system designed to improve capacity and reliability relative to a conventional bus system	Economic	Transport	CO_2	Provide BRTS is some Indian cities	During the period of 2011-2014, BRTS was operational only in 5 Indian cities, viz. Ahmedabad, Delhi, Pune, Jaipur and Rajkot.	The data for 2013 of the average daily ridership and total length of the corridor for these cities have been obtained from Global BRT Data. The CO_2 emissions saved from the BRTS is estimated using the following formula: Total CO_2 saved = Fuel consumed × Average emission reduction (tCO_2e / passenger)	It has led to an emission reduction of 0.16 $MtCO_2e$ during 2011-2014	
Efficiency gains in Railways	Fuel consumption/gross tonne/kilometres in passenger and goods trains have been measured	Economic	Transport	CO_2	Fuel consumption reduction		The data for fuel consumption and gross tonne kilometers in passenger and goods trains have been obtained from annual statistical statement of Indian Railways. The total CO_2 emissions saved in railways are due to the efficiency change over the years. It is estimated using the following formula: Total CO_2 saved = Fuel consumed ×	It has led to an emission reduction of 0.14 $MtCO_2e$ during 2011-2014	

Table 3.28: Year wise Mitigation quantification for some major policies and programmes for 2011 - 14

S. No.	Policy	Sectors Affected	GHG Affected	Objective and or Activity Affected	Type of Instrument	Status of Implementation	Brief Description	Start Year of Implementation	Implementing Entity of Entities	Emission Mitigated (Mt CO_2e)			
										2011	2012	2013	2014
1	National Solar Mission - 100 GW by 2022 and stable at the same level until 2030	Renewable Energy	CO_2, CH_4, N_2O	To establish India as a global leader in solar energy, by creating the policy conditions for its diffusion across the country as quickly as possible.	Regulatory	Adopted	The Mission has adopted a three phase approach. The first phase (2010-2013) was designed to focus on capturing the low-hanging options in solar thermal; promoting off-grid systems to serve populations without access to commercial energy and modest capacity addition in grid-based systems. In the second (2013-2017) and third (2017-2022) phases, capacity will be aggressively ramped up to create conditions for scaled-up and competitive solar energy penetration in the country.	2010	National Action Plan on Climate Change, MNRE	4.48	5.4	6.04	6.86
2	National Wind Mission - 60 GW by 2022 and stable at the same level until 2030	Renewable Energy	CO_2, CH_4, N_2O	To catalyse commercia-lization of grid interactive wind power.	Regulatory	Adopted	The Twelfth Five Year Plan proposed a National Wind Energy Mission. India's INDC set a target of 60 GW wind power by 2022.		National Action Plan on Climate Change, MNRE	19.85	21.19	20.8	20.93
3	Other Renewables: 15 GW by 2022 and stable at same level until 2030	Renewable Energy	CO_2, CH_4, N_2O	Small Hydro and Biomass based power	Regulatory	Adopted	MNRE has been vested with the responsibility of developing Small Hydro Power (SHP) projects up to 25 MW station capacities. The estimated potential for power generation in the country from such plants is about 20,000 MW.		National Action Plan on Climate Change, MNRE	9.08	11.4	12.86	14.42
4	T&D Losses reduction	Power Sector	CO_2, CH_4, N_2O	Loss reduction in national grid	Economic	Implem-ented	By the end of 2013, each of the country's five regional grids was inter-connected to operate at a synchronous frequency in an effort to more efficiently transfer power from generation sources to load centers.	2009	Ministry of Power, CEA	2.46	5.42	14.49	-12.91

S. No.	Policy	Sectors Affected	GHG Affected	Objective and or Activity Affected	Type of Instrument	Status of Implementation	Brief Description	Start Year of Implementation	Implementing Entity of Entities	Emission Mitigated (Mt CO_2e)			
										2011	2012	2013	2014
5	Supercritical Power Generation	Energy Efficiency	CO_2, CH_4, N_2O	To reduce the emission for each kWh of electricity generated	Economic	Under implementation	Super Critical Technology is the most economical way to enhance efficiency. 27.48 GW of capacity has been added until 2015 and 45.55 GW by June 2018. Methodology and emission factors have been used from http://cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver10.pdf	2012	Ministry of Power	0	0.28	1.68	7.23
6	UJALA LED replacements Scheme	Energy Efficiency	CO_2, CH_4, N_2O	To promote efficient lighting, reducing energy consumption and energy savings.	Economic	Under implementation	UJALA scheme: Overall target of number of LED lights to be replaced in 3 years - 770 million, expected annual energy savings - 105 billion KWh, Expected reduction of peak load – 20 GW, Annual estimated greenhouse gas emission reductions - 79 Mt CO_2.	2015	National Mission for Enhanced Energy Efficiency, MoP				10.24
7	Street Light National Programme	Energy Efficiency	CO_2, CH_4, N_2O	Reducing Energy consumption in lighting by replacing conventional street lights with LEDs, helping DISCOMs to manage peak demand	Economic	Under implementation	Street Lighting National Programme (SLNP) aims to replace India's 14 million conventional street lights in India with Smart LED variants by 2019. The programme has picked up pace in the last two years mitigating 3.38 MtCO_2 as of November 19, 2018.	2015	National Mission for				0. 0004
8	PAT scheme	Energy Efficiency	CO_2, CH_4, N_2O	To reduce specific energy consumption in energy intensive industries.	Economic	Under implementation	A market based mechanism to facilitate energy efficiency improvements in large energy intensive industries and facilities, by issuing energy saving certificates that can be traded.	2012	National Mission for Enhanced Energy Efficiency		7.5	10	10
9	Irrigation	Agriculture	CO_2, CH_4, N_2O	National Water Mission under NAPCC	Regulatory	Under implementation	The CO_2 saved from the Drip Irrigation system all over India.		Ministry of Agriculture	0.0001	0.0001	0.0002	0.0002
10	Metro	Transport	CO_2, CH_4, N_2O	Provide Metro railway system in 15 Indian cities	Economic	Under implementation	The Metro railway system and service are operational in 10 cities in India. These are Kolkata, Delhi, Bengaluru, Gurugram, Mumbai, Chennai, Jaipur, Kochi, Hyderabad, and Lucknow.		Ministry of railways, MoUD, respective state governments	0.63	0.66	0.69	0.72
11	BRT	Transport	CO_2, CH_4, N_2O	Provide BRTS is some Indian cities	Economic	Under implementation	BRTS (Bus Rapid Transport System) is designed to improve capacity and reliability relative to a conventional urban bus system.	2006	MOUD and state government	0.039	0.04	0.041	0.044

S. No.	Policy	Sectors Affected	GHG Affected	Objective and or Activity Affected	Type of Instrument	Status of Implementation	Brief Description	Start Year of Implementation	Implementing Entity of Entities	Emission Mitigated (Mt CO_2e)			
										2011	2012	2013	2014
12	Efficiency gains in Railways	Transport	CO_2, CH_4, N_2O	Fuel consumption reduction	Economic	Under implementation	Fuel consumption and Gross tonne kilometers in passenger and goods trains have been measured		Ministry of Railway	0.31	0.22	0.17	-0.56
13	Star rated appliances (AC and Refrigerator)	Energy Efficiency	CO_2, CH_4, N_2O	To provide the consumer an informed choice about the energy saving and thereby the cost saving potential of the marketed household and other equipment.	Economic	Under implementation	The star rating plan is different for products manufactured/imported or assembled in different years. Manufacturers are required to place a label showing how much electricity the appliance will consumer under certain conditions.	2006	Ministry of Power, BEE	0.039	-0.01	0.007	0.009

As would be noted from the foregoing:

- India's mitigation efforts are far-ranging, covering many key sectors.
- All these initiatives represent nationally determined efforts that take into account climate change mitigation as well as a range of development objectives and hence should be considered as such in any assessment of India's policies for future projections.
- India's mitigation efforts should be understood in the context of India's due share of the available global carbon budget, recognizing that India may need access to its fair share to achieve development needs. .
- These mitigation efforts are not tied to any particular temperature target, though formulated in the context of the Paris Agreement.

References

BEE. (2016). Market Assessment for Partial Risk Guarantee Fund for Energy Efficiency and Venture Capital for Energy Efficiency. Bureau of Energy Efficiency and United States Agency for International Development. Retrieved from https://beeindia.gov.in/sites/default/files/ESCO%20Report%20-%20Market%20Assessment%20for%20PRGFEE%20%26amp%3B%20VCFEE.pdf

BEE. (2017). Workshop on Accelerating financial assistance to Energy Efficiency projects. Bureau of Energy Efficiency.

BEE. (n.d.). Energy Professionals: Bureau of Energy Efficiency. Retrieved from https://www.beeindia.gov.in/content/energy-professionals

Bhan, M., Sharma, D., Ashwin, A. S., & Mehra, S. (2016). Critical observations on National CAMPA Bill, 2016. Current Science, 3(7), 1141–1142.

BIS. (2016). National Building Code of India 2016. Bureau of Indian Standards. Retrieved from http://bis.org.in/sf/nbc.asp

CEA. (2018a). All India installed capacity (in MW) of power stations (Utilities). Central Electricity Authority, Ministry of Power, Government of India.

CEA. (2018b). National Electricity Plan (Volume I): Generation. Central Electricity Authority, Ministry of Power, Government of India.

CERC. (2010). The Gazette of India. Central Electricity Regulatory Commission, Government of India. Retrieved from http://www.cercind.gov.in/2016/regulation/9.pdf

DoE. (2018). National Clean Energy and Environment Fund (NCEEF). Department of Expenditure, Government of India. Retrieved from https://doe.gov.in/sites/default/files/NCEF%20Brief_post_BE_2017-18.pdf

DST. (2017). India Country Report: Research, Development, Demonstration and Deployment of Smart Grids in India. New Delhi: Department of Science and Technology, Ministry of Science and Technology, Government of India.

FSI. (2017). India State of the Forest Report 2017. Forest Survey of India, Ministry of Environment, Forests and Climate Change, Government of India.

GoI. (2015). India's intended nationally determined contribution: Working towards climate justice. UNFCCC. Retrieved from http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

GoI. (2017). Metro Rail Policy. Government of India.

GRIHA. (2018). Green Rating for Integrated Habitat Assessment. Retrieved from http://www.grihaindia.org/#&home

IEA & EVI. (2016). Global EV Outlook 2016. International Energy Agency.

IGBC. (n.d.). IGBC Green New Buildings. Indian Green Building Council. Retrieved from https://igbc.in/igbc/redirectHtml.htm?redVal=showGreenNewBuildingsnosign

IPCC. (2013). Climate Change 2013: The physical science basis. Contribution of Working Group I to the fifth assessment report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge ; New York: Cambridge University Press.

MDWS. (2014). Guidelines for Swachh Bharat Mission (Gramin). Ministry of Drinking Water and Sanitation, Government of India. Retrieved from http://www.mdws.gov.in/sites/default/files/SwachBharatGuidlines.pdf

MDWS. (2015). Waste water and sewage treatment plants. Rajya Sabha Unstarred Question No. 1561. Ministry of Drinking Water and Sanitation.

MNRE. (2018). Renewable Energy Powering India. Ministry of New and Renewable Energy, Government of India.

MoAFW. (2017). Annual Report 2016-17. Department of Agriculture, Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India. Retrieved from http://agricoop.nic.in/sites/default/files/Annual_rpt_201617_E.pdf

MoEFCC. (2015a). Guidelines for convergence of CAMPA and GIM of Ministry of Environment, Forest and Climate Change. Ministry of Environment, Forest and Climate Change, Government of India.

MoEFCC. (2015b). Guidelines for convergence of MGNREGS with GIM of Ministry of Environment, Forest and Climate Change (MoEF&CC). Ministry of Environment, Forest and Climate Change, Government of India. http://www.moef.nic.in/sites/default/files/MGNREGS-GIM.pdf

MoEFCC. (2016). Annual Report 2015-16. Ministry of Environment, Forest and Climate Change, Government of India.

MoHUA. (2018). Smart Cities Mission - 1,333 projects worth Rs.50,626 crores completed or under implementation / tendering. Press Information Bureau, Government of India. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=179368

MoLJ. The Energy Conservation (Amendment) Act 2010, No. 28 of 2010 Ministry of Law and Justice § (2010). Retrieved from http://www.delhisldc.org/Resources/Amended%20EC%20Act.pdf

MoP. (2018a). Long term growth trajectory of Renewable Purchase Obligations (RPOs) for Solar and Non-solar for a period of three years i.e. 2019-20 to 2021-22 - regarding. Ministry of Power, Government of India. Retrieved from https://powermin.nic.in/sites/default/files/webform/notices/RPO_trajectory_2019-22_Order_dated_14_June_2018.pdf

MoP. (2018b). National Building Dashboard. Energy Efficiency Services Limited, Ministry of Power. Retrieved from http://www.eeslbeep.com

MoP. (2018c). National Dashboard. Energy Efficiency Services Limited, Ministry of Power. Retrieved from http://ujala.gov.in

MoP. (2018d). SLNP Dashboard: Streetlight National Programme. Energy Efficiency Services Limited, Ministry of Power. Retrieved from https://slnp.eeslindia.org

MoP. (2018e). UDAY National Dashboard. Retrieved from https://uday.gov.in/home.php#

MoPNG. (2018a). National Policy on Biofuels 2018. Government of India.

MoPNG. (2018b). Pradhan Mantri Ujjwala Yojana. Retrieved from http://www.pmujjwalayojana.com

MoR. (2016). Indian Railways Yearbook 2015-16. Ministry of Railways.

MoRTH. (2018). The Gazette of India: Ministry of Road Transport and Highways Notification.

MoSPI. (2018). Energy Statistics 2018. Ministry of Statistics and Programme Implementation, Government of India.

NHAI. (2018). Green Highways Projects. Green Highways Division, National Highways Authority of India.

PIB. (2016). India to Receive Euro 1 Billion Soft Loan for 'Green Energy Corridors' from Germany. Press Information Bureau, Government of India. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=155455

PIB. (2017). Adoption of the ECBC could lead to 30%-50% energy savings by commercial buildings. Press Information Bureau, Government of India. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=165748

SIAM. (2018). Automobile Domestic Sales Trends. Society of Indian Automobile Manufacturers.

UNFCCC. (2010). Communications received from Parties in relation to the listing in the chapeau of the Copenhagen Accord. United Nations Framework Convention on Climate Change. Retrieved from http://unfccc.int/meetings/items/5276.php

Perform Achieve and Trade (PAT) Scheme

was initiated under the National Mission for Enhanced Energy Efficiency to make the industry sector more energy efficient. During the first cycle of PAT (2012-15), an energy saving of 8.67 Mtoe was achieved against the target of 6.686 Mtoe assigned for 478 designated consumers.

Outcome of PAT 1
2012-15

Savings
₹ **95,000** million saved due to reduction in energy consumption

Trading
1.29 million ESCerts traded worth ₹ **1000** million in **17** sessions

Energy Savings
5,635 MW

8.67 Mtoe

Emission Reduction
31 Million tonnes of CO_2

In PAT Cycle II (2016–19), 621 Designated Consumers (DCs) from 11 sectors have been given Specific Energy Consumption (SEC) targets, with an intended energy saving of 8.869 Mtoe. The third PAT cycle was notified in March 2017 to achieve an overall energy consumption reduction of 1.06 Mtoe. The fourth cycle of PAT has commenced from 1st April 2018 in which 109 DCs have been notified. In total, 846 Designated Consumers from 13 sectors are undergoing implementation of PAT cycle II, III and IV with a total targeted energy savings of 19 Mtoe.

Chapter 4

Domestic Measurement, Reporting and Verification Arrangements

Chapter 4: Domestic Measurement, Reporting and Verification

4.1 Background

The Bali Action Plan adopted at COP 13 in 2007 introduced the principle of applying measurement, reporting and verification (MRV) to developing country Parties in the context of undertaking enhanced national and international level action to mitigate climate change (Decision 1/CP.13). COP 19 adopted several decisions on the elements of the MRV framework. According to the Annexure to Decision 21/CP.19, developing country Parties are encouraged to voluntarily establish domestic MRV of domestically supported Nationally Appropriate Mitigation Actions (NAMAs). In the case of India, measurement and review are confined to various financial and physical parameters that are embedded in the project design and are not meant particularly for GHG emission mitigation.

4.2 Status of MRV implementation in India

Several programmes and schemes of the Government of India have developed a measurement, reporting and verification system for various financial and physical parameters in the last one to two years. Some of these have a strong relation with GHG emission mitigation (e.g. PAT scheme), but they do not conduct any MRV for GHG emissions mitigation directly. A dedicated domestic MRV arrangement at the national level is yet to take shape in India. Current climate change mitigation policies and programmes vary in their scope and the administrative level at which implementation is managed (state, regional, national, sectoral, and voluntary at individual unit level). Any available estimate at the national level comes from a bottom-up aggregation of the actions reported at the project level. Projects under the Clean Development Mechanism (CDM) and the National Action Plan on Climate Change (NAPCC) have an established measurement and review mechanism associated with them. Table 4.1 presents several domestic initiatives which are in line with MRV presently operational in India, along with the key institutions involved in their implementation. It may be noted that as a developing country, most of these MRV processes do not directly involve the measurement of GHG emissions. The following sub-sections present a detailed description of major policies across various sectors.

Table 4.1: Sector-wise MRV initiatives in India

Name of the Sector	Schemes and Processes	Objective	MRV	Measuring and reporting agencies	Frequency/ Events of measuring and reporting	Verification agencies	Type of verification
Power sector	User Guide for CO_2 Baseline	Developing CO_2 baseline database for the power sector	M&R Identified	CEA	Annual monitoring and reporting	CEA	Self-verification
	Adoption of clean coal technologies	Achieving resource efficient generation	M&R Identified	CEA, CERC, SERC	Annual monitoring and reporting	CEA	Self-verification
Renewable energy	Renewable Purchase Obligation (RPO)	To promote renewable sources of energy by creating a quota for it	MRV Identified	SERC, DISCOMs, POSOCO, CAG	Annual monitoring and reporting	POSOCO, CAG	Third Party Verification

Name of the Sector	Schemes and Processes	Objective	MRV	Measuring and reporting agencies	Frequency/ Events of measuring and reporting	Verifi-cation agencies	Type of verification
Buildings	Buildings Star Rating System, GRIHA, LEEDs	Minimum standard for energy use in construction of buildings	MRV Identified	BEE, IGBC, TERI, MNRE	Regularly-Based on certification	BEE, IGBC, TERI, MNRE	Certification System
	Domestic Efficient Lighting Program	LEDs/CFL as replacement to incandescent bulbs	MRV Identified	EESL, DISCOMs	Real Time Monitoring (UJALA Dashboard)	BEE, IGBC, TERI, MNRE	Certification System
	Street Lighting National Program	Promote efficient lighting	MRV Identified	EESL, DISCOMs	2015 - EESL & PwC conducted audit	PwC	Third Party Verification
Industry	Perform Achieve and Trade – I, II III, IV	Market based mechanism to reduce specific energy consumption in energy intensive industries	MRV Identified	BEE, Designated Consumers (Industries)	End of each PAT cycle	Empanelled Energy Auditor	Third Party Verification
	Zero Defect Zero Effect	Signifies production mechanisms wherein products have zero adverse environmental and ecological effects	MRV Identified	Department of Industrial Policy and Promotion, MSME, QCI	Regularly - Based on certification	QCI - Accredited Agency for Assessment & Rating	Certification
Transpor-tation	Electrification of Railways	Enhancing the efficiency of the railways	M&R Identified	Indian Railways	Annual monitoring and reporting	Indian Railways	Self-verification
	Dedicated Freight Corridors of Indian Railways	Planning and development, construction, maintenance and operation of dedicated freight corridors	MRV Identified	Dedicated Freight Corridor Corporation of India, CPCB, SPCB	Annual monitoring and reporting	Dedicated Freight Corridor Corporation of India; CPCB, SPCBs	Self-Verification and Third Party Verification
	Aviation	Fuel efficiency improvements	M&R Identified	Directorate General of Civil Aviation	2013 - Carbon Footprint of Indian Aviation	Directorate General of Civil Aviation	Self-verification
Forestry	Afforestation	Stabilization of the forest area - forest conservation and restoration	MRV Identified	FSI, CAMPA, CAG	Annual monitoring and reporting 2012 - CAG conducted audit	FSI, CAMPA, CAG	Self-Verification and Third Party Verification
	Twenty Point Programme	Schemes relating to afforestation, poverty alleviation, employment generation, education, health	MRV Identified	Ministry of Statistics and Programme Implem-entation	Annual monitoring and reporting	Ministry of Statistics and Programme Implem-entation	Third Party Verification

Name of the Sector	Schemes and Processes	Objective	MRV	Measuring and reporting agencies	Frequency/ Events of measuring and reporting	Verification agencies	Type of verification
Agriculture	System of Rice Intensification (SRI), Crop Diversification, Cool Farm Tool model	Natural resource management, improving soil health, improving crop production, make the farmers self-reliant for adaptation under changing climate	M&R Identified	Department of Animal Husbandry, Dairying & Fisheries, Department of Agriculture Cooperation & Farmers Welfare, Department of Agricultural Research and Education	Annual monitoring and reporting	Department of Agriculture Cooperation & Farmers Welfare	Self-verification
Waste	Solid Waste Management Programmes, Waste Water Recycling and Waste to Energy	Manage waste efficiently	M&R Identified	MoEFCC, CPCB, SPCBs, PCCs	Annual monitoring and reporting	CPCB	Self-verification

M&R – Measuring and Reporting

MRV – Measuring, Reporting and Verification

4.3 MRV in various sectors in India

As discussed in Chapter 3, transformative mitigation initiatives are underway across several sectors such as thermal power, renewables, buildings, industry, transport, forestry, agriculture and waste sectors. The following section presents the existing state of MRV arrangement for various parameters (and not GHG emissions) in five key sectors.

4.3.1 Power sector

The total installed capacity in India has grown from 1,713 MW in 1950 to 345,524 MW as in June 2018 (CEA, 2018). India's perseverance towards meeting its sustainable development goal targets, especially ensuring access to affordable, reliable, sustainable and modern energy for all with complete rural electrification, is further going to drive the power demand in a more efficient manner. Various initiatives such as accelerating the pace of supercritical technology adoption, achieving 45.5 GW by June 2018; Integrated Gasification Combined Cycle Technology (IGCC); advances in indigenous nuclear technology; efficient T&D; retirement of old and inefficient units; increasing adoption of hydropower and contribution towards efficient resource generation; would lead to reduction of GHG emissions from the use of fossil fuels.

Regional and State Load Dispatch Centres (RLDC/ SLDC) balance electricity generation and load across the country. The Central Electricity Authority (CEA) receives regular data on generation, and the Central Electricity Regulatory Commission (CERC) along with the various State Electricity Regulatory Commissions (SERC) monitor the generation efficiency of power plants. In submitting their annual petitions for tariff increase and sanctioning for their revenues, power plants must report various aspects of plant operation. Hence, an MRV of improvements in power generation efficiency is already in-built.

In addition, the CEA has developed a CO_2 baseline database for the power sector. It assists in establishing a consistent CO_2 emissions baseline. All the power plants provide their data to the CEA, and this allows the calculation of absolute emissions and emissions intensity (in tonnes of CO_2 per MWh) on a regular basis. Figure 4.1 shows emission factor of electricity generated in the grid. Weighted average emission factor describes the average CO_2 emitted per unit of electricity generated in the grid. Operating margin describes the average CO_2 intensity of existing stations in the grid. It includes weighted average emissions rate of all generation sources except low-cost or must-run source (hydro and nuclear stations). Build margin reflects average CO_2 intensity of newly built thermal power stations and covers units commissioned in the last five years (CEA, 2016). A consistent

improvement in build margin is noticeable in recent years, while the weighted average and operating margin have remained constant.

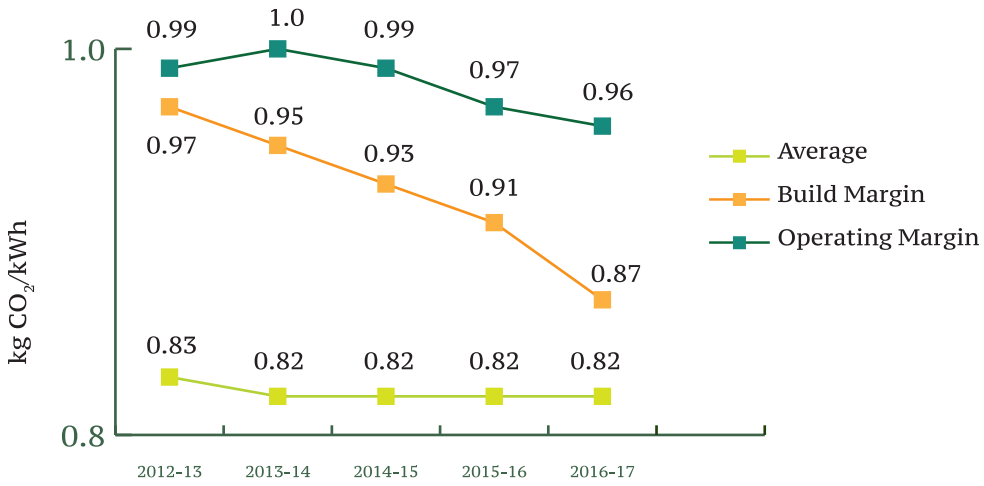


Figure 4.1: Trend of emission factor for grid from 2012-13 to 2016-17. ***Source: CEA, 2018b***

An accomplished MRV arrangement enables achievement of maximum mitigation through end-to-end information management of a given system. Hence, in recent years, to promote more transparency and real-time tracking of power sector developments, the government has introduced several information-technology enabled initiatives pertaining to electricity generation and consumption. These transparency measures extend from optimisation of power utilisation through demand side management; prioritising coal for more efficient plants through supply side management; real-time generation of data to make stakeholders more responsible and efficient; and, minimising transmission losses and power thefts. Some of such web-based information platforms are mentioned below:

- Vidyut Pravah mobile app: It provides crucial information on the market price of electricity, and power availability (surplus or deficit), to make stakeholders more responsive and efficient with power generation and supply. It also makes States more accountable with their power generation, distribution and transmission (MoP, 2018a).
- MERIT (Merit Order Despatch of Electricity for Rejuvenation of Income and Transparency): One of the objectives of this web-based portal is to promote overall operational efficiency. It also facilitates renewable integration into the system by handling the variabilities and uncertainties. It, along with e-bidding portal, provides flexibility of utilisation of domestic coal at more efficient power plants independently owned by private sector. This minimises the cost of generation, as well as lowers CO_2 emissions. (PIB, 2017b).
- URJA (Urban Jyoti Abhiyan): This integrated power development scheme targets IT enablement of the distribution network. It ranks towns on the basis of aggregated technical and commercial losses (AT&C) in the distribution networks through energy audits, thus, minimising wasteful use of power and reducing emissions (MoP, 2018b).
- UDAY (Ujwal Discom Assurance Yojana): This webportal also targets improving operational efficiency of the power utilities. It promotes indirect mitigation measures through: mapping of power losses; checking power thefts; smart metering at the consumer end; and demand side management to reduce peak load and energy consumption (MoP, 2015).

4.3.2 Renewables

India has set up an ambitious plan to scale up electricity generation from renewable energy sources. This includes the National Solar Mission under the NAPCC and various other initiatives like standalone power generation from renewable sources (wind, biomass and industrial/urban waste), rural energy programme (biogas, improved cook-stoves) and decentralised solar energy applications (thermal water heaters, solar photovoltaic applications for lighting and water pumping).

To lend credence to these initiatives, a regulatory measure in the form of renewable purchase obligation (RPO) was introduced in 2003, that sets a minimum requirement on renewable energy in the procured electricity mix for utilities and large consumers, and distribution licensees. A market-based mechanism is conceptualized in the form of Renewable Energy Certificates (REC). RECs can be traded between States that are well endowed with RE and those that are not, to enable the target RPOs to be met nationally (as well as regionally). A Central Agency, Power System Operation Corporation (POSOCO) is responsible for scrutiny and issuance of the RECs via the Energy Injection Report, submitted by the various State Load Despatch Centers (REC Registry India, 2016). This is an MRV mechanism for REC in India.

India has set an aim to achieve cumulative 175 GW installed capacity, including 100 GW solar energy by the year

2022. Renewable Purchase Obligation (RPO) is the policy instrument for increasing the share of renewables in the electricity mix. In the larger perspective, renewables are a strategic national resource and their progressively increasing share puts the nation on the path of energy security, energy access and also reducing the carbon footprint. RPO trajectory as notified by the Ministry of Power requires 21% share of renewables, equally 10.5% both from solar and non-solar, by the year 2022. The RPOs specified for solar and non-solar power are to be adhered to uniformly by all the States and Union Territories.

Ministry of New and Renewable Energy (MNRE) is the nodal ministry overseeing initiatives in the renewable energy sector. Through affiliated technical agencies it conducts resource assessment for renewables and supports R&D towards renewable energy technologies. Region-specific initiatives are implemented by nodal agencies and departments operating under state governments. The Indian Renewable Energy Development Agency (IREDA) provides financial assistance to these initiatives acting as a financial arm of MNRE. The National Bank for Agriculture and Rural Development (NABARD) channels the money received from MNRE/ Ministry of Finance to rural areas.

4.3.3 Buildings

The Bureau of Energy Efficiency has developed Energy Conservation Building Code (ECBC) which ensures a minimum standard for energy use in new buildings and major retrofits. The Ministry of Housing and Urban Affairs (MoUA) and state governments are responsible for implementation and enforcement of ECBC.

The Indian Green Building Council (IGBC) administers the Leadership in Energy and Environmental Design (LEED) India ratings, an adaptation of the international rating system for buildings. Green Rating for Integrated Habitat Assessment (GRIHA) is the national rating system for green building design, developed and implemented by The Energy and Resources Institute (TERI) and the MNRE. All new central government buildings need to comply with the requirements of at least three-star GRIHA ratings. In addition, LEED and GRIHA have adopted ECBC as a minimum compliance requirement.

The Domestic Efficient Lighting Programme (DELP) or UJALA scheme is the latest energy efficiency initiative in which bulbs (both incandescent and CFL) are being replaced by LEDs at the household level. This would reduce the power consumption of households and result in economic savings. Targets and performance of this programme are already detailed out in Chapter 3 of this report.

Energy Efficiency Services Limited (EESL) is implementing these programmes along with DISCOMs, who are ultimately responsible for distribution of LEDs/CFLs to every household and maintain a list of such distribution. EESL had engaged an external agency to monitor and verify the impact of these programmes by conducting surveys. The UJALA scheme is being monitored in a transparent manner through a real-time dashboard. For instance, the latest information suggests that as on October 2018, EESL had distributed more than 312 million LED bulbs across India and the programme has led to annual savings of about 33 $MtCO_2$. This entire process illustrates that a clear and well-defined MRV is already a part of this mitigation effort.

4.3.4 Industry

Rapid growth and developmental activities have resulted in an increased share of industrial energy consumption in India. In terms of energy conservation within the industry segment, the government has introduced several mechanisms-based reforms such as the Perform Achieve and Trade (PAT) and Zero Effect Zero Defect (ZED) schemes. As detailed in Chapter 3, PAT was introduced under the National Mission on Enhanced Energy Efficiency (NMEEE), one of the eight missions under NAPCC. The BEE, under the Ministry of Power (MoP), is the implementing agency. It directs Accredited Energy Auditors (AEAs) to verify the data reported by Designated Consumers (DCs). It has developed a robust MRV structure internally as seen in Figure 4.2.

Another policy initiative that targets medium and small scale industries (MSME) is the ZED approach to manufacturing. It focuses on production mechanisms wherein products have no defects as well as minimal or no environmental and ecological effects. Quality Council of India (QCI) along with the MoMSME is responsible for exploring the idea of creating a holistic scheme to engage the MSME sector. It also plays the role of National Accreditation Body (NAB) which is tasked with creating a mechanism for third-party assessment of products, services and processes (QCI, 2016).

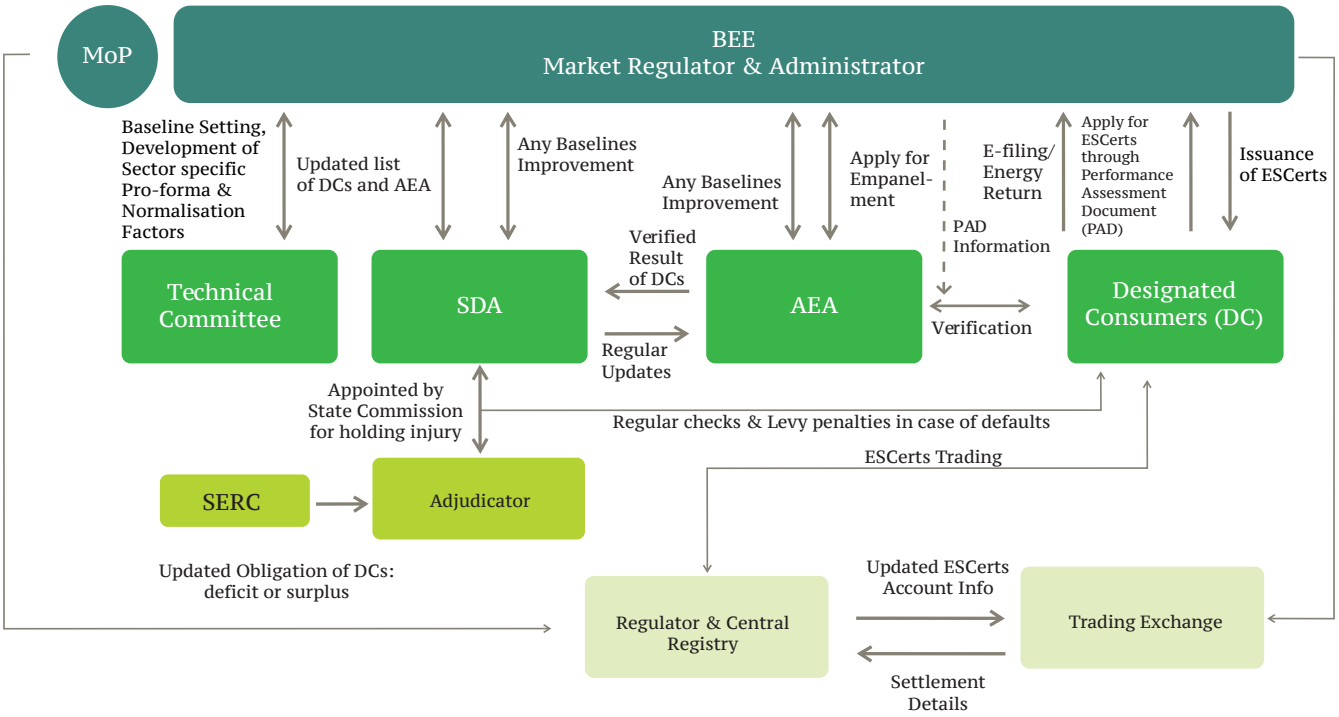


Figure 4.2: MRV structure of the Perform, Achieve and Trade scheme. *Source: (BEE, 2016)*

In addition, Ministry of Corporate Affairs (MCA) via Companies Rules, mandates companies to report on energy conservation along with their financial statements (MCA, 1989) to their board of directors. The report shall contain detailed information on:

i. Energy conservation measures taken;
ii. Additional investments and proposals, if any, being implemented for reduction of consumption of energy;
iii. Impact of the measures at (i) and (ii) above for reduction of energy consumption and the consequent impact on the cost of production of goods;
iv. Total energy consumption and energy consumption per unit of production

This reporting provision (Form A) is applicable to 21 industries. It serves the documentation requirement needed to create greater accountability and transparency

4.3.5 Transportation

The Government has adopted several strategies to reduce emissions from the transport sector. The Indian Railways has pursued electrification of various routes replacing diesel-based locomotives and has prioritised the construction of the dedicated freight corridor, which would increase capacity on the existing network and allow for a modal shift away from road transport. Indian Railways in its annual statistical publication monitors fuel consumption (coal, electricity and diesel), the overall tonnage of freight transport, and distances over which it is hauled. Dedicated Freight Corridor Corporation of India Limited (DFCCIL) undertakes planning and development, construction, maintenance and operation of dedicated freight corridors. DFCCIL interfaces with MoEFCC at central and regional levels (via CPCB & SPCB) for environment clearance such as environment impact assessment. In order to better manage the energy and water resource use, the Ministry of Railways constituted a dedicated, Environment Management Directorate in 2015. (PIB, 2015).

In addition, Indian Railways operations are now included in PAT–II cycle, which has an inbuilt MRV process that will better establish the overall improvement in performance in terms of energy efficiency. Further, Delhi Metro is the first railway project in the world that is registered under the Clean Development Mechanism, namely regenerative braking project, modal shift project, and energy efficiency project. These are under complete MRV system for GHG mitigation. With an aim to mainstream the use of biofuels in the transport sector, the national policy on biofuel focuses on blending of ethanol. MoPNG periodically publishes statistics pertaining to petroleum and natural gas (both production and consumption), which provides details on sector-wise consumption of petroleum products. This provides another avenue, in the form of a top-down approach, which can be used to measure the overall impact of mitigation actions in the transport sector.

The primary focus of the aviation sector in India is on improving the energy performance metrics. This is largely promoted through fuel efficiency improvements (new aircraft with top-of-the-line features) and single engine taxi. The Directorate General of Civil Aviation (DGCA), in its annual report on the carbon intensity of the aviation operations of Indian (flag) carriers, shows a consistent decline and improved performance (DGCA, 2013).

4.3.6 Forestry

The Government of India is implementing several large-scale afforestation programmes and conservation programmes for mangroves, coral reefs and wetland ecosystems. Green India Mission (GIM) is one such initiative that promotes afforestation, agroforestry and urban forestry. Also, National Agroforestry Policy and Reducing Emissions from Deforestation and Forest Degradation Plus (REDD+) policy supplements GIM and leads to stabilization of the forest area, significantly contributing to the conservation of the forest carbon sink. Various bodies and institutions have been constituted to monitor the implementation of these programmes:

- The National Afforestation and Eco-Development Board (NAEB) is responsible for promoting afforestation, tree planting, ecological restoration and eco-development activities in the country and also monitors the action plans for afforestation.
- The National Wasteland Development Board was established mainly to tackle the problem of degradation of lands, restoration of ecology and for regenerating degraded non-forest and private lands.
- The Forest Survey of India (FSI) is responsible for assessment and monitoring of the forest resources of the country regularly. FSI publishes the data on forest and tree cover biennially in State of Forest Report (SFR).
- The Compensatory Afforestation Fund Management and Planning Authority (CAMPA) acts as a facilitator to regenerate vegetation cover and promote afforestation as a way of compensating for forest land which is diverted for non-forest uses.

In 2012, the Comptroller and Auditor General (CAG) conducted an audit of the compensatory afforestation process to measure the diversion of forest land for non-forest use, steps were taken for conservation, afforestation and preservation of forest lands and use of funds in compliance with applicable legislation and rules. The key outcomes of the CAG audit were:

- 28,086 hectares of non-forest land was received by the Government during the period 2006-12 which constituted 27% of receivable non-forest land.
- The afforestation over the degraded forest land was done on 49,733.76 hectare and 49 km^2 which worked about 49% (in area).
- Out of ₹29.25 billion of the compensatory afforestation funds released by Ad-hoc CAMPA during the period 2009-12 for compensatory afforestation activities, only ₹17.75 billion were utilised by the States/ UTs leaving an un-utilised balance of ₹11.49 billion.

A Twenty Point Programme (TPP) has been in operation since 1975 to achieve package of programmes comprising schemes relating to afforestation, poverty alleviation, employment generation, education, health, etc. The monitoring of this programme has been assigned to the Ministry of Statistics and Programme Implementation, Government of India (MoSPI, 2015). India State of Forest Report (ISFR) by FSI, gives a comprehensive assessment of the forest sector. Apart from the regular assessment of forests, MoEFCC has developed tools like Decision Support System (DSS) and e-Green Watch that facilitate informed decisions in matters dealing with use of forest land and resources. DSS is a web-based GIS System. It provides qualitative, quantitative and administrative attributes of forests to facilitate, informed, unbiased and expeditious decisions on management of forest and forest clearances. The e-Green Watch portal is a system that showcases the compensatory afforestation, diverted land, plantations, other plantations and assets categories on the Google Earth platform. Thus, these mechanisms and bodies as constituted facilitate the monitoring and evaluation aspect in forestry sector.

4.3.8 Agriculture

The Ministry of Agriculture and Farmers Welfare has introduced various interventions for improving agriculture productivity and to adapt to climate change. The National Innovations on Climate Resilient Agriculture (NICRA) is one such initiative which facilitates natural resource management, improving soil health, improving crop production and livestock to make the farmers self-reliant for adaptation under changing climate. Also, the government has introduced various practices to reduce GHG emissions, such as the system of rice intensification (SRI), crop diversification and energy efficiency through micro irrigation.

A formal mechanism for measuring and reporting of inventory and livestock needed for calculation of GHG emissions is ensured within the Ministry of Agriculture in their departments through annual reporting.

- Department of Animal Husbandry, Dairying & Fisheries (DADF): Reports on livestock census across the country (DADF, 2016).

- Department of Agriculture Cooperation & Farmers Welfare (DACFW): Reports on production scenario (area, production and yield) of major crops like rice, wheat, pulses, cotton, oilseeds, sugarcane. In addition, this department also reports on initiative taken under National Mission for Sustainable Agriculture (DACFW, 2016).
- Department of Agricultural Research and Education (DARE): Reports on methodology and tools used to monitor GHG emissions (ICAR, 2016).

The Ministry of Agriculture and Farmers Welfare has set up Climate Change and Sustainable Agriculture Monitoring, Modelling & Networking (CCSAMMN) system that would support and monitor climate change adaptation/ mitigation research/modelling projects. Also, a central scheme has been introduced which has three components: Timely Reporting Scheme (TRS), Improvement of Crop Statistics (ICS) and Establishment of an Agency for Reporting of Agricultural Statistics (EARAS). This would facilitate collection of data, its supervision and monitoring, especially for use in climate change adaptation.

Presently, Cool Farm Tool model is used to estimate GHG emissions which integrates several globally determined empirical GHG quantification models. It was found that on an average, rice-wheat system emitted 1,823 kg CO_2e/ ha, whereas maize-wheat, fodder, vegetables and horticulture emitted 410,245,188 and 117 kg CO_2 e/ha from the respective areas of these cropping systems. Also, diversified agriculture system emitted 1,547 kg CO_2e/ha as compared to 2,862 kg CO_2 e/ha in rice-wheat system. Cumulative seasonal methane emissions was reduced by 75% in aerobic rice as compared to continuously flooded rice, and the seasonal emissions were lower in slow-release N fertilizer (ICAR, 2016).

The National Mission on Sustainable Agriculture (NMSA) will also replicate the learning of the NICRA.

Under the NMSA, the following 10 quantifiable deliverables have been identified:

i. Area under organic farming
ii. Production of biofertilizer
iii. Precision irrigation
iv. SRI/DSR against conventional rice cultivation
v. Diversification to less water consuming crop/cropping system
vi. Additional area under plantation in arable land
vii. Climate resilient varieties (CRV) identified/Released
viii. a) Identification of genotypes of crops with enhanced CO_2 fixation potential and less water consumption & nutrients
b) Climate resilient genotypes with greater adaptation to drought, flood, salinity and high temperature
ix. Coverage of Milch Animal under Ration Balancing Programme.
x. Establishment of bypass protein feed making unit

These variables are regularly reported and the entire process strengthens the measurement and reporting mechanism in the agriculture sector.

4.3.9 Waste

In order to manage waste efficiently, the Government has significantly invested in solid waste management (SWM) programmes. The central government provides grants-in-aid to States and Urban Local Bodies, specifically for SWM through public-private partnerships (GoI, 2015). Also, various initiatives in wastewater recycling and waste to energy have been undertaken across the country.

The CPCB and the SPCBs play a vital role in monitoring and evaluating the performance of the waste sector in India. Municipal SWM, plastic waste, hazardous waste management and others fall under their purview. As per the provisions against these aspects, the CPCB is mandated to prepare a Consolidated Annual Review Report (CARR) on the implementation of various measures, based on the information received from annual reports of SPCBs and Pollution Control Committees (PCCs) (CPCB, 2015). This annual report is then forwarded to the Central Government (MoEFCC) along with suggestions/recommendations before 15th December every year.

The information provided in Table 4.2 helps in calculation of GHG emissions on a periodic basis. A more real-time measurement system would further require capacity building support at national/sub-national levels.

Table 4.2: MSW Implementation, CARR 2016-17

States	Reporting of MSW				Monitoring at Waste Processing/Landfills Sites				
	Solid waste generation (TPD)	Collected (TPD)	Treated (TPD)	Landfilled (TPD)	Ambient Air Monitoring	Ground water Monitoring	Leachate	Compost Quality	VOCs
Andaman Nicobar*	115	115	26	89	0	0	0	0	0
Andhra Pradesh*	6470	6396	1623	233	Yes	Yes	Not Monitored	Not Monitored	Not Monitored
Arunachal Pradesh	16	11	0	0	0	0	0	0	0
Assam	8110	7200	200	0	Nil	Nil	Nil	Nil	Nil
Bihar	Data not available	_	_	_	Nil	Nil	Nil	Nil	Nil
Chandigarh	450	450	61	411	Yes	Yes	Yes	No	No
Chhattisgarh	6000	4200	20	Nil	Nil	Nil	Nil	Nil	Nil
Daman Diu*	-	-	-	-	-	-	-	-	-
Delhi*	-	-	-	-	-	-	-	-	-
Goa	227	219	0	26	Yes	Yes	Nil	Nil	Nil
Gujarat	-	10527	757	9770	No	Yes	Yes	No	No
Haryana	4514	3160	188	2372	3	3	1	0	0
Himachal Pradesh	342.35	0	0	0	Nil	Nil	Nil	Nil	Nil
Jammu & Kashmir*	-	-	-	-	-	-	-	-	-
Jharkhand *	-	-	-	-	-	-	-	-	-
Karnataka	11186	9706	3475	5170	Yes	Yes	Yes	Yes	Yes
Kerala*	-	-	-	-	-	-	-	-	-
Nagaland	337	255	28	7	Nil	Nil	Nil	Nil	Nil
Lakshadweep*	-	-	-	-	-	-	-	-	-
Madhya Pradesh	6773	5480	1141	4339	Yes	Yes	No	No	No
Maharashtra	23450	23080	7543	15536	Yes	Yes	Yes	Yes	Yes
Manipur*	-	-	-	-	-	-	-	-	-
Mizoram	160	160	0	0	Nil	Nil	Nil	Nil	Nil
Meghalaya	187	156	36	120	Yes	Yes	Yes	No	No
Odisha	19	14	30	0	Nil	Nil	Nil	Nil	Nil
Punjab	4544	4520	39	3279	Nil	Nil	Nil	Nil	Nil
Puducherry	398	398	10	388	Yes	Yes	Nil	Nil	Nil
Rajasthan*	-	-	-	-	-	-	-	-	-
Sikkim	76	62	11	0	Nil	Nil	Nil	Nil	Nil
Tamil Nadu	14658	14417	4776	7337	Yes	Yes	Yes	Yes	-
Telangana	-	-	-	-	-	-	-	-	-
Tripura	428	379	134	245	Not Done	Done In Khowai Municipal Council	Done In Agartala	Not Done	Not Done

Uttarakhand	1180	1180	0	0	Not Done	Not Done	Not Done	Not Done	Not Done
Uttar Pradesh*	15500	12000	3115	-	-	-	-	-	-
West Bengal	14000	12600	830	515	Nil	Nil	Nil	Nil	Nil

Source: Consolidated Annual Review Report on implementation on MSW (CPCB, 2018)

*Information Not Received

4.4 Transition towards an integrated domestic MRV system

Like many other developing countries, India is yet to evolve a robust domestic MRV system based on in-depth scientific and technical research. So far multiple efforts have been made at the Central and State levels to establish MRV systems for specific programmes and projects for specific parameters and not GHG mitigation directly. PAT (Phase-I, II, III & IV), RPO and other demand side management programmes are some of the mitigation programmes which have seen significant success in their implementation.

Drawing on the experience from the diverse MRV systems established for various policies, an integrated system would be developed. Establishing an integrated domestic MRV system for GHG mitigation actions is a capacity building need for India. As it has been noted in the case of various sectors, the MRV may be based upon a listing of actions and physical attributes, financial attributes as well as their emissions reductions. An integrated MRV system for GHG mitigation requires streamlined data management systems, technical capacity, improved analytical capabilities, and most importantly, active coordination between all stakeholders and the various nodal agencies within the government for GHG mitigation across regions, sectors and time. To develop specific (consolidated) monitoring and verification process for GHG inventory and mitigation actions in India, additional finance and capacity building would be required.

India will look to leverage existing capacities and identify areas for priority action. Such a collaborative network, as envisioned by MoEFCC would also be a prerequisite in the creation of the National Inventory Management System (NIMS) and will help propagate a more transparent and structured way of reporting. It is expected that the establishment of improved data gathering processes, data management systems and the resources required to drive institutional collaboration and capacity building would eventually become available. Studies to determine the requirements of a projected MRV in the future are beginning to be undertaken in project mode.

References

BEE. (2016). Perform, Achieve and Trade Scheme: Status & Way Forward. Bureau of Energy Efficiency. Retrieved from https://beeindia.gov.in/sites/default/files/PAT_Status_Powerline_Conference_09-05-2016_-_Copy.pdf

CEA. (2016). User Guide: CO_2 Baseline Database for the Indian Power Sector. Central Electricity Authority. Retrieved November 2, 2016, from http://cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver11.pdf

CEA. (2018). Installed Capacity as on 30.06.2018. Central Electricity Authority

CEA. (2018b). CO_2 Baseline Database for the Indian Power Sector, User Guide, Versions 13, Page 31 http://www.cea.nic.in/reports/others/thermal/tpece/cdm_co2/user_guide_ver13.pdf; Assessed on 30 October 2018

CPCB. (2015). Consolidated Annual Review Report 2014-15. Central Pollution Control Board. Retrieved from http://www.cpcb.nic.in/MSW_AnnualReport_2014-15.pdf

CPCB (2018). Consolidated Annual Report 2016-17 on Implementation of Solid Waste Management Rules, 2016. Central Pollution Control Board. Retrieved from http://cpcb.nic.in/uploads/hwmd/MSW_AnnualReport_2016-17.pdf

DACFW. (2016). Annual Report 2015-16, Department of Agriculture, Cooperation & Farmers' Welfare. Retrieved from http://agricoop.nic.in/sites/default/files/Final%20Annual%20Report%20English.pdf

DADF. (2016). Annual Report 2015-16, Department of Animal Husbandry, Dairying & Fisheries. Ministry of Agriculture and Farmers Welfare. Retrieved from http://aipvt.vci.nic.in/REPORT.pdf

DGCA. (2013). Carbon Footprint of Indian Aviation. New Delhi: Directorate General of Civil Aviation, India

GoI. (2015). India's intended nationally determined contribution: Working towards climate justice. Government of India. Retrieved from http://www4.unfccc.int/submissions/INDC/Published%20Documents/India/1/INDIA%20INDC%20TO%20UNFCCC.pdf

ICAR. (2016). Annual Report 2015-16, Indian Council on Agriculture Research. Department of Agricultural Research and Education

MCA. (1989). Companies (Disclosure of Particulars in the Report of Board of Directors) Rules. Ministry of Corporate Affairs. Retrieved from: http://www.mca.gov.in/Ministry/actsbills/rules/CDoPitRoBoDR1988.pdf

MoP. (2015). Office memorandum. Ministry of Power. Retrieved from https://powermin.nic.in/pdf/Uday_Ujjawal_Scheme_for_Operational_and_financial_Turnaround_of_power_distribution_companies.pdf

MoP. (2018a). Vidyut PRAVAH. Ministry of Power. Retrieved from http://www.vidyutpravah.in/FAQ

MoP. (2018b). Urban Jyoti Abhiyaan. URJAIndia. Ministry of Power. Retrieved from https://urjaindia.co.in/about-us.php

MoSPI. (2015). Twenty point programme - 2006, Annual Report 2014-15. Ministry of Statistics and Programme Implementation. Retrieved from http://www.mospi.gov.in/sites/default/files/twenty_point_programme_2006/annual_report_of_tpp2006/AR_report_tpp-06_2014-15.pdf

PIB. (2015). Creation of a new 'Environment Management' Directorate in Railway Board. Press Information Bureau. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=114475

PIB. (2017a). Steps Taken to Improve The Efficiency of Coal Based Thermal Power Plants. Press Information Bureau. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=160206

PIB. (2017b). MERIT app and e-Bidding portal for utilization of domestic coal in IPP Power Stations for reducing the cost of power generation launched. Press Information Bureau. Retrieved from http://pib.nic.in/newsite/PrintRelease.aspx?relid=167149

QCI. (2016). About QCI. Zero Effect Zero Defect. Quality Council of India. Retrieved from http://www.zed.org.in/about-qci.php

REC Registry India. (2016). Procedure For Issuance of REC. Renewable Energy Certificate Registry of India. Retrieved from https://www.recregistryindia.nic.in/index.php/general/publics/ProcedureIssuanceREC

Coal still accounts for 28% of global primary energy use.

As a responsible country, India uses its coal judiciously. India is increasing the share of non-fossil sources of electricity generation significantly.

170 old thermal generation units having a higher heat rate cumulative capacity, of 10.64 GW have been retired till March 2018

Supercritical thermal power units have risen from 40 (27.48 GW in 2015) to 66 (45.55 GW in 2018) with avoided emissions amounting to 7 million tonnes of CO_2 in 2016-17

The share of non-fossil source in installed capacity of electricity generation increased from 30.5% in March 2015 to 35.5% in June 2018

Coal with ash content more than 34% is not allowed to be transported beyond 1000km

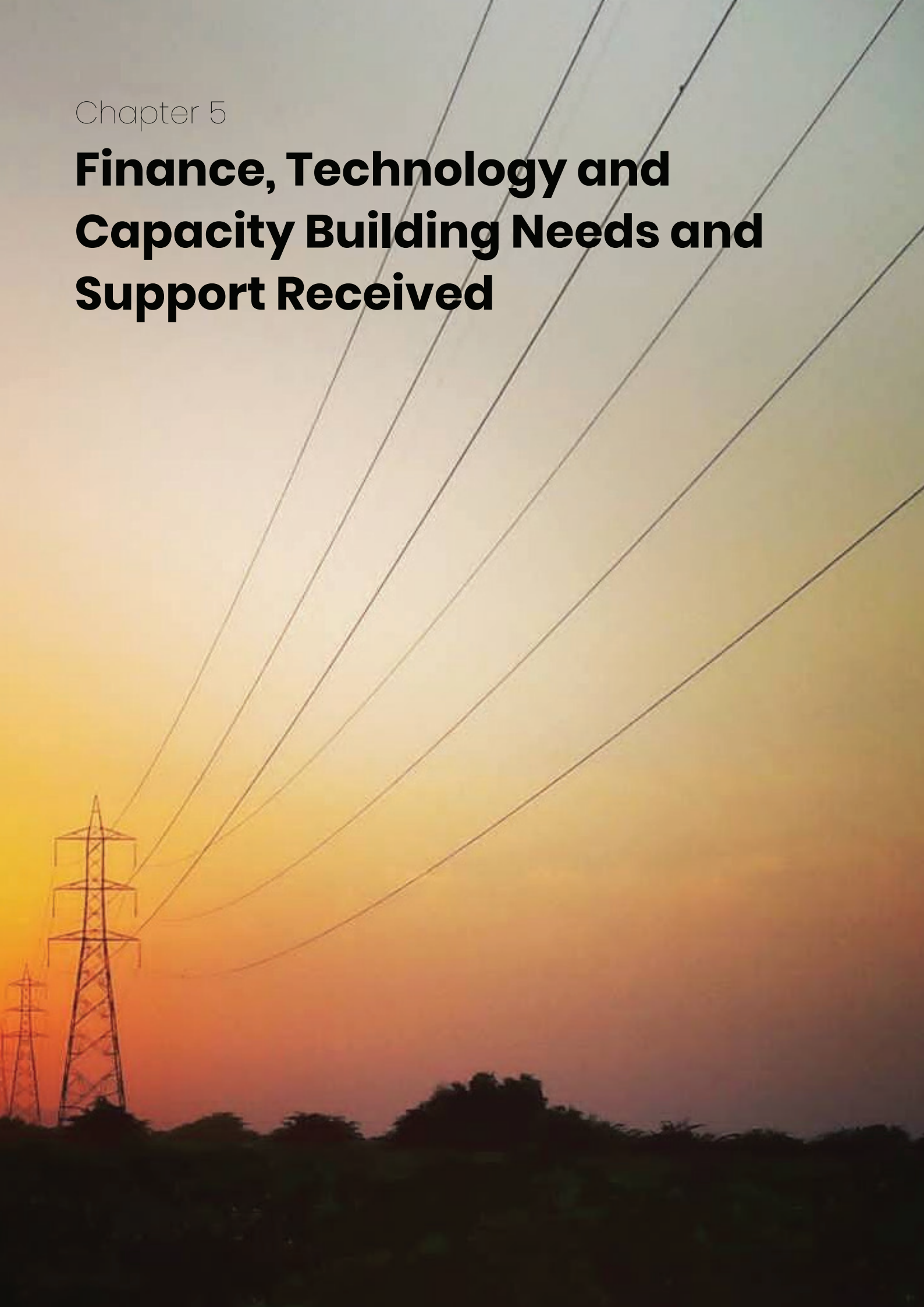
Mining coal in environment friendly manner

Undertaking Coal Beneficiation

Fly Ash being optimally utilised for brick making, road construction, back-filling of mines

Chapter 5

Finance, Technology and Capacity Building Needs and Support Received



Chapter 5: Finance, Technology and Capacity Building Needs and Support Received

5.1 Introduction

Decision 2/CP.17 Annex III, Para 15 requires, "Non-Annex I Parties should provide updated information on financial resources, technology transfer, capacity-building and technical support received from the Global Environment Facility (GEF), Parties included in Annex II to the Convention and other developed country Parties, the Green Climate Fund (GCF) and multilateral institutions for activities relating to climate change, including the preparation of the current Biennial Update Report (BUR)".

This chapter provides updated information which should be read in conjunction with the information provided on constraints and gaps, and related financial, technical and capacity-building needs furnished by the Government of India to UNFCCC in the Second National Communication in May, 2012 and First BUR in January, 2016.

5.1.1 Enhanced national reporting requirements and financial support provided

Over the years, the national reporting requirements for non-Annex I Parties, including the frequency of its submission, have increased manifold without a corresponding increase in the financial, technological and capacity-building support provided.

As per Article 4 of the UNFCCC, financial resources are to be provided for meeting the agreed full cost incurred by developing country Parties in fulfilling their reporting obligations under Article 12.1 of the Convention. However, the interim operating entity for the financial mechanism of the UNFCCC, the GEF, provides up to USD 500,000 per member developing country of GEF for national reporting. For any additional resources required, the member countries have to access their respective System for Transparent Allocation of Resources (STAR) allocation under the climate change focal area. For a vast developing country like India, USD 500,000 is not adequate to meet its national reporting requirements under the UNFCCC.

Furthermore, it is important to note that India's STAR allocation under climate change focal area has reduced by almost 50%, i.e., from USD 87.87 million (in GEF-6 cycle) to USD 47.24 million (in GEF-7 cycle). As a result, about one-fourth of country's STAR allocation under climate change focal area will be needed for national reporting to meet the additional requirements under UNFCCC Enhanced Transparency Framework (ETF) arising from the Paris Agreement[1], thus, leaving meager resources for climate action.

5.1.2 Outline

The present chapter covers information on the financial, technological and capacity-building needs, gaps and support received from January 2016 to August 2018. Section 5.2 of the chapter presents the support received, needs and gaps in climate finance. Section 5.3 presents the technology support required for climate mitigation. Section 5.4 focuses on the improvements made in reporting on GHG inventory and constraints, as well as the current gaps and enhanced support required to improve reporting. Section 5.5 presents the capacity needs, gaps and support required to empower climate action.

5.2 Financial needs and support received

India is a developing country with limited financial resources. The country is striving to provide basic facilities to its growing population while meeting their developmental aspirations. Climate change further adds to our already growing developmental challenges. Majority of the country's economic sectors are vulnerable to the impact of climate variability. Transition to a low carbon ecosystem is cost-intensive even for developed countries. The poorer sections of the society are worst affected. Mainstreaming and integrating climate imperatives into developmental

[1]Article 13 of the Paris Agreement (2015) envisages an Enhanced Transparency Framework to provide clarity on the support provided and received by relevant individual Parties in the context of climate change……and….to provide a full overview of aggregate financial support provided, to inform the global stock take. The ETF also requires developing country Parties to report on financial, technology transfer and capacity-building support needed and received on a voluntary basis (Article 13.10).

sectors require technological support, skill and capacity development and upgradation, and substantial financial investments.

India's Nationally Determined Contributions (NDCs) submitted to the UNFCCC in 2015 is a rare combination of country's traditional values (in the form of sustainable lifestyles) and present-day aspirations. They present India's ambitions and targets towards low carbon growth and, are India's contribution towards addressing the global problem of climate change. According to NDCs estimate, India would need around USD 206 billion (at 2014-15 prices) between 2015 and 2030 for implementing adaptation actions in agriculture, forestry, fisheries infrastructure, water resources, and ecosystems. Apart from this, there will be additional investments needed for strengthening climate resilience and disaster management.

Financial requirements for undertaking mitigation actions are even more. Estimates by Planning Commission (now known as NITI Aayog) indicate that the mitigation activities for moderate low carbon development would cost around USD 834 billion till 2030 (at 2011 constant prices) (Planning Commission, 2014). An Asian Development Bank (ADB) study, while assessing the cost of climate change adaptation in South Asia, indicates that approximate adaptation cost for India in the energy sector alone would roughly be about USD 7.7 billion in the 2030s. The report also projects that the economic damage and losses in India from climate change are likely to be around 1.8% of its GDP annually by 2050 (Ahmed et al., 2014). International Finance Corporation (IFC) estimates a USD 3.1 trillion climate investment for India in key sectors between 2018 and 2030, to fully meet its NDCs (IFC, 2017).

India has harvested most of the low-hanging fruits by optimally deploying its domestic resources and has achieved a reduction in emission intensity of GDP by 21% over the period 2005-2014. The country is well on track to meet its Copenhagen commitments. However, to meet its Paris commitments and implement NDCs, India requires new and additional financial, technological and capacity support, which are not forthcoming.

5.2.1 Support received

Global Environment Facility (GEF)

During the sixth cycle (July 2014 to June 2018) of GEF, an interim operating entity for the financial mechanism of the UNFCCC, India received an indicative allocation of USD 87.87 million under the climate change focal area of which only USD 59.08 million was approved. Due to the difference between the pledges and actual contribution to the GEF Trust Fund during GEF-6 cycle, the indicative allocations of the member countries were reduced. In other words, the financial pledges made by the developed countries during the year-long replenishment process of GEF cycle are increasingly not being fulfilled. Further, in GEF-7 cycle (July 2018 to June 2022), India's indicative allocation under climate change focal area has reduced by almost 50% or USD 40.63 million (as compared to GEF-6 cycle). India's allocation under climate change focal area in GEF-7 cycle is USD 47.24 million.

During GEF-6 period, the climate change focal area allocation was programmed for 'Cities-IAP: Sustainable Cities Integrated Approach Pilot in India', 'Creating and Sustaining Markets for Energy Efficiency', 'Grid-Connected Rooftop Solar Program' and 'Green-Ag: Transforming Agriculture for Global Environmental Benefits and the Conservation of Critical Biodiversity and Forest Landscapes'. It is important to note that the process of accessing GEF grant remains time-consuming and cumbersome, thus impacting its overall effectiveness.

GEF also administers the 'Special Climate Change Fund (SCCF)' and 'Adaptation Fund'. The replenishment levels under SCCF were negligible during GEF-6 cycle, thus India was not able to access SCCF funds. Here, it is important to note that India is climate vulnerable country with greater need to undertake adaptation-related activities and actions. However, due to the principle of incremental reasoning and cost, the GEF STAR allocation under the climate change focal area primarily funds projects related to mitigation (Global Environment Facility, 2018).

India has accessed USD 9,885,436 from the Adaptation Fund since 2014 of which USD 6,685,318 were accessed for five projects in 2015 – 2016. These projects are, 'Technical Assistance Grant for ESP and Gender', 'Building Adaptive Capacities in Communities', 'Livelihoods and Ecological Security in the Kanha-Pench Corridor in Madhya Pradesh', 'Building Adaptive Capacities of Small Inland Fishers for Climate Resilience and Livelihood Security in Madhya Pradesh', 'Climate Smart Actions and Strategies in North Western Himalayan Region for Sustainable Livelihoods of Agriculture-dependent Hill Communities and Climate Proofing of Watershed Development Projects in the States of Tamil Nadu and Rajasthan' (Adaptation Fund, 2018).

Green Climate Fund (GCF)

The National Bank for Agriculture and Rural Development (NABARD) and the Small Industries Development Bank of India (SIDBI) are the two Direct Access Accredited Entities from India to access funds from Green Climate Fund

(GCF). In April 2017, USD 34.4 million of GCF grant was approved for a project titled 'Ground Water Recharge and Solar Micro Irrigation to Ensure Food Security and Enhance Resilience in Vulnerable Tribal Areas of Odisha' and in March 2018, USD 100 million of GCF grant was approved for a project titled 'Line of Credit for Solar Rooftop Segment for Commercial, Industrial and Residential Housing Sectors' to be implemented by NABARD. Another project to be implemented by United Nations Development Programme (UNDP) titled 'Enhancing Climate Resilience of India's Coastal Communities' worth USD 43.4 million of GCF grant has been recently approved. The disbursement is yet to commence under these approved projects. In Dec 2015, a readiness grant of USD 300,000 was approved for 'National Designated Agency (NDA) Strengthening and Country Programming' which is being administered by UNDP (Green Climate Fund, 2018).

Climate Investment Fund (CIF)

Since the Climate Investment Fund's (CIF) inception in 2008, it has received over USD 8 billion in support of scaling up mitigation and adaptation action in developing countries. CIF resources are held by the World Bank. India has accessed USD 774.37 million from CIF of which USD 449.46 million were accessed during 2015 – 2018 for five projects. These projects are 'Solar Rooftop PV' by International Bank for Reconstruction and Development (IBRD), 'Solar Rooftop PV' by ADB, 'Solar Park Transmission' by ADB, 'Solar Parks Infrastructure' by the IBRD and 'Innovations in Solar Power and Hybrid Technologies' by the Climate Investment Fund, 2018.

Bilateral funding and support

India has a bilateral programme with the Department for International Development (DFID) titled 'Climate Change Innovation Programme' worth £12 million to be implemented by 2019 with a focus on adaptation-related activities. Four GiZ projects are operational which are 'Climate Change Adaptation in Rural Areas of India', 'Development and Management of Nationally Appropriate Mitigation Actions (NAMA) in India', 'Global Carbon Markets' and 'Supporting the Institutionalization of Capacities on Climate Change Studies and Action'. India is working with the World Bank on 'India: Final Market Readiness Proposal' which was approved in March 2017 with an estimated grant of USD 8 million to assess the existing policy landscape, developing flexible registry infrastructure to accommodate changing carbon market requirements, developing and piloting new market-based mechanisms and exploring the potential for linking carbon markets in the future.

Clean Development Mechanism (CDM) projects

The Government of India had set up a National CDM Authority (NCDMA) in December 2003 which has since then accorded Host Country Approval to 3,028 projects, of these about 1,667 have been registered by the CDM Executive Board. Till August 2018, Certified Emission Reductions (CERs) issued to Indian projects amount to 240 million (or 12.6% of the total CERs issued). These projects are in the sectors of energy efficiency, fuel switching, industrial processes, municipal solid waste, renewable energy and forestry which are spread across the country. The sector-wise details are presented in Table 5.1.

Table 5.1: Host Country Approval of the CDM Projects by the National CDM Authority (as on June 2018)

Sector	No. of Projects
Energy industries (renewable-/ non-renewable sources)	2,400
Energy distribution	9
Energy demand	226
Manufacturing industries	241
Chemical industries	18
Construction	0
Transport	13
Mining/mineral production	4
Metal production	4
Fugitive emissions from fuels (solid, oil and gas)	4
Fugitive emissions from production & consumption of halocarbons and sulphur hexafluoride	6
Solvent use	0
Waste handling and disposal	72
Afforestation and reforestation	28
Agriculture	3
Total	3,028

5.2.2 National initiatives

India's climate actions are largely financed from its domestic sources, both budgetary as well as a mix of market mechanisms together with fiscal instruments and policy interventions. The eight missions under the National Action Plan on Climate Change (NAPCC) on solar, energy efficiency, habitat, water, agriculture, forestry, Himalayan ecosystem and knowledge management have a specific budgetary allocation and other mobilized sources.

Climate Change Action Programme (CCAP)

CCAP is a Government of India scheme which was approved in January 2014 at a total cost of ₹2,900 million for the duration of five years. The allocation of funds for the Fiscal Year (FY) 2017-18 to 2019-2020 is ₹1,324 million. Its objective is to create and strengthen the scientific and analytical capacity for assessment of climate change in the country, putting in place an appropriate institutional framework for scientific and policy initiatives, and implementation of climate change related actions. Three demonstration projects have been approved under CCAP and these are, 'Enhancing Adaptive Capacity to Climate Change through Conservation of Traditional Water Supply Sources (wells and *bawadis*) of Indore city', 'Coastal Habitat Rehabilitation for Climate Change Adaptation in Gulf of Mannar', 'South-eastern India: Improving Ecosystem Services and Fisher Livelihood and Technological Adaptation for Gainful Utilization of Paddy Straw in Punjab'.

National Adaptation Fund on Climate Change (NAFCC)

NAFCC is another scheme which was launched in 2015 with an initial outlay of ₹3,500 million to fund adaptation actions which are not otherwise covered under the ongoing schemes/ programs. The allocation of funds for the FY 2017-18 to 2019-2020 is ₹3,640 million. About 27 projects worth ₹6,736.6 million have been approved by NAFCC. These projects are listed in Table 5.2.

Table 5.2: List of approved projects under NAFCC

S. No.	Project Title
1	Towards climate resilient livestock production system in Punjab
2	Conserve water through the management runoff in the river basin to reduce vulnerability and enhance resilience for traditional livelihood in Nuapada
3	Sustainable livelihoods of agriculture – dependent rural communities in drought prone district of Himachal Pradesh through climate smart solutions
4	Integrated surface water management for climate resilient agriculture through rejuvenation of traditional tanks in Puducherry
5	Model carbon positive eco-village in Phayeng of Manipur
6	Promotion of integrated farming system of Kaipad in coastal wetlands of North Kerala
7	Management and rehabilitation of coastal habitats and biodiversity for climate change adaptation and sustainable livelihood in Gulf of Mannar, Tamil Nadu
8	Climate adaptation strategies in wetlands along Mahanadi River Catchment Areas in Chhattisgarh
9	Climate resilient sustainable agriculture in rain-fed farming (Kandi) areas of Jammu & Kashmir
10	Resilient agricultural households through adaptation to climate change in Mahbubnagar district, Telangana
11	Spring-shed development works for rejuvenation of springs for climate resilient development in the water stressed areas of Meghalaya
12	Sustainable agriculture development through expansion, enhancement and modelling in the state of Mizoram
13	Climate resilient interventions in dairy sector in coastal and arid areas in Andhra Pradesh
14	Enhancing adaptive capacity to climate change through developing climate-smart villages in select vulnerable districts of Madhya Pradesh
15	Conservation and management of Indigenous varieties of livestock (Cattle and Sheep) in the Wake of climate change in Karnataka
16	Scaling-up resilient agriculture practices towards climate smart villages in Haryana
17	Management of ecosystem of Kaziranga National Park in Assam by creating climate resilient livelihood for vulnerable communities through organic farming and pond based pisciculture
18	Rainwater harvesting and sustainable water supply to the hilly areas in Darjeeling, West Bengal adaptive measures climate change impacts
19	Efficient water management and agriculture technology adoption for climate adaptive and resilient farming system in 51 villages of Nundurbar and Buldhana districts of Maharashtra
20	Climate Change adaptation for Natural Resource Dependent communities in Kachchh, Gujarat
21	Addressing climate change vulnerability of water sector at gram panchayat level in drought prone areas of Sikkim
22	*Mukhya Mantri Jal Swavlamban Abhiyaan* (MJSA) in Rajasthan for climate change adaptation and water harvesting

23	Scaling up climate smart agricultural through mainstreaming climate smart villages in Bihar
24	Gene pool conservation of indigenous rice varieties under traditional integrated rotational farming system for promoting livelihood and food security as climate change adaptation strategy in Nagaland
25	Enhancing climate resilience of forests and its dependent communities in two landscapes of Jharkhand
26	Ecosystem services based adaptation to climate change project in Bundelkhand region of Uttar Pradesh
27	Climate resilience building among farmers through crop residue management in Punjab, Haryana, UP and Rajasthan

To conclude, India is a diverse and complex developing country. Climate change adds on to the country's existing developmental challenges while requiring enormous additional resources. India is a responsible country and is doing its due diligence, but climate change is a global problem. Its addressal requires time-bound global action and new and additional financial support.

5.3 Technology needs and support received

The Government of India considers science and technology as a crucial facilitator to meet the requirements and goals for the country's development and energy security in a timely manner. Transfer and grounding of appropriate technologies and know-how is key to enhancing adaptation and mitigation measures. Adequate financing is required for viable cutting-edge technologies. Therefore, India advocates and strongly reiterates the importance of global collaboration in Research & Development (R&D), enabling the transfer of its outcomes, free of Intellectual Property Rights (IPR) costs, to developing countries.

The government is making concerted efforts to enhance the pace of innovation and scale of transformation in different sectors of national importance. The 'Technology Vision 2035 document' for the country, prepared by Technology Information, Forecasting and Assessment Council (TIFAC), India's think-tank under the Department of Science & Technology, Government of India, was released in 2016. This document scripted the technology innovation path in achieving the aspirations of India by 2035 (TIFAC, 2015). Realising that innovation is the engine for the growth, prosperity and national competitiveness in the 21st century, the President of India declared 2010 as the 'Decade of Innovation' (National Innovation Council, 2018). Various schemes have been launched to attract, nurture and retain young researchers and scientists. Over the years, progress has been made in R&D and innovation. As per the Economic Survey of 2017-2018, "According to the WIPO, India has the world's 7th largest Patent Filing Office." Government of India has launched several technology innovations and development programmes to nurture and promote the country's vast innovation potential by encouraging start-up's (Startup India), entrepreneurship (Self Employment and Talent Utilization), incubation centres (Atal Incubation Centers) under the Atal Innovation Mission (AIM).

India, by virtue of its commitment to environmental protection, became instrumental in shaping Mission Innovation (MI)[2]. It was launched on 30th November 2015 during UNFCCC CoP-21 in Paris with the goal to accelerate the pace of clean energy innovation so as to achieve performance breakthroughs and cost reductions that can deliver widely affordable and reliable clean energy solutions across the world in the next two decades and beyond[3]. MI members have also "pledged to double Government funded clean energy research and development over 5 years (from USD 15 to 30 billion per year) and enhance international engagement in programmes on clean energy R&D which will enable its deployment on the large commercial scale". India is co-lead in three of the seven[4] innovation challenges identified under MI for international collaboration. These three challenges are on the smart grid, off-grid and sustainable bio-fuel (Government of India, 2017).

India has been a fertile ground for technological innovations. Since independence, the country has made significant progress in the fields of agriculture, telecom, ICT, space, atomic energy, defence, pharma and biotech. The country began to develop the 'Indigenous Remote Sensing System (IRS) Satellite Programme' to support national economy in the areas of agriculture, water resources, forestry and ecology, geology, watersheds, marine fisheries and coastal management. With 12 operational satellites, the IRS system is the largest constellation of remote sensing satellites for civilian use in operation today in the world (TIFAC, 2015).

Notwithstanding India's efforts, financial resources and trained manpower, India needs to adapt technologies

[2]There are 23 members of MI including Australia, Brazil, Canada, Chile, China, Denmark, European Union, Finland, France, Germany, India, Indonesia, Italy, Japan, Mexico, Netherland, Norway, South Korea, Saudi Arabia, Sweden, United Arab Emirates, United Kingdom and United States of America.

[3]"By the end of 2020, MI proposes to deliver: 1) a substantial boost in public sector investment in clean energy R&D at national level in the MI member states; 2) increased private sector engagement and investment in energy innovation and in particular in key energy innovation challenges; and, 3) many new or strengthened voluntary cross-border networks and partnerships on energy innovation, greater engagement from innovators and accelerated progress in addressing specific innovation challenges."

[4]Smart Grid, Off-Grid, Carbon Capture, Sustainable bio-fuel, Converting Sunlight, Clean Energy Materials and Affordable Heating and Cooling of Buildings.

developed elsewhere to suit its own needs in order to avoid reinventing the wheel, learn from the collective wisdom of innovators elsewhere, complement its own efforts and fast-track the development of environmental friendly technologies appropriate to its national circumstances and requirements. India also needs technical know-how in several key areas.

India's first BUR to UNFCCC presents a detailed list of technology needs in renewable, power and transport sector. However, under the climate change regime, most of them were neither transferred, facilitated nor were made available to India. Therefore, the technology need as identified in BUR-1 remain unfulfilled. India continues to have a specific interest in the following areas (GoI, 2017):

i. Energy Efficiency (reduction of energy intensity in industry; residential and commercial buildings, appliances and equipment; transport sector through the use of better fuels and automobiles; light-weighting; and, energy savings through advanced traffic management protocols)
ii. Renewable Energy sources (solar energy, on-shore and off-shore wind energy, sustainable bioenergy, geothermal energy, hydro-electricity and other renewable energy sources)
iii. Hydrogen and Fuel Cells
iv. Other Power and Storage Technologies (efficient electricity transmission and distribution; energy storage (non-transport applications) and smart grids)
v. Other Cross-cutting Technologies (energy system analysis; carbon capture, storage and utilization technologies, etc.)

Some of India's identified technology needs are presented in the following sections.

5.3.1 Renewable energy

India's renewable energy programme is one of the largest and among the most vibrant. Support for renewable energy and manufacture of renewable technology components has been growing in the country. India has been undertaking research and development activities through budgetary support, which is limited. Though this has resulted in achievements in many areas, efforts for technology development are not commensurate with the deployment scales. There are major technology-related gaps that would require to be addressed to unleash the potential of renewable energy in the country.

India cannot go for large-scale deployment of renewable energy technologies unless a facilitative technology transfer regime is put in place, and incremental costs as well as associated costs on these technologies are met from multilateral climate change funds. This apart, research institutions and laboratories in developed countries allow researchers and technologists from India for pre-competitive research. Availability of pertinent technologies at concessional rates is a prerequisite to integrate technological advances seamlessly to industry on a real-time basis and also support the industry to take technology risks by providing adequate finance and skill upgradation.

In addition, to technology gaps mentioned in first BUR, the support required by country for the renewable energy sector is presented in Table 5.3.

Table 5.3: Technology Needs in Renewable Energy Sector

Area	Technology Gap	Technology Areas
Solar Photovoltaic	Import dependence for wafers, cells and modules. Mass manufacturing of cells and modules. Availability of alternative options in emerging technologies.	Indigenous PV cell technology with globally competitive prices and performance; Cutting edge manufacturing techniques for indigenous modules manufacture; Emerging PV technologies including Copper Zinc Tin Sulphide (CZTS), Multi-Junction Solar Cells, Organic Photovoltaic (OPV) and Perovskites.
Solar Thermal Applications	Import dependence for solar field components.	Indigenising Reflector materials with good outdoor durability, high solar reflectivity, good mechanical resistance.
Waste to Energy	Lack of standardization of process leads to unfavorable economics.	Standardization of technologies for conversion of waste into bio-fuel or electricity at economic costs.

Wind Energy	Import dependence for technologies for offshore wind deployment. Modelling and simulation to ensure accurate forecasting.	Cost reduction; Development of materials, techniques and technologies for offshore wind; Modelling and simulation including Big Data and Artificial Intelligence to improve weather forecasting and system management; Small wind turbines with storage options.
Hydrogen and Fuel Cells	Availability of hydrogen of desired purity at viable costs. Import dependence for hydrogen storage materials. Import dependence for fuel cell components and stacks. Lack of infrastructure for transportation/ distribution of hydrogen to end user locations.	Increasing efficiency and indigenous content of electrolysers (alkaline and PEM); Indigenous development of type II and type IV cylinders, as well as hydride and carbon materials; Development of indigenous catalysts, membranes and balance of system components and stacks of stationary and transport application; Development of hydrogen distribution networks through pipelines, dispensing stations, and on-site hydrogen production.
Energy Storage	Limited experience with new energy storage technologies, like li-ion, sodium ion, sodium sulphur batteries. Lack of standardized controls and interfaces. Energy storage can provide multiple services and multiple technology choices are available, there is a need to benchmark performance and economic viability of various options in different application scenarios.	Batteries for grid-scale storage at economic cost; Standardization of controls and interfaces to allow flexible operation; Simulation and Modelling for evaluation of storage requirement for different applications including grid support, ancillary services, e-mobility, peak shifting etc, so that appropriate technology choices could be implemented for each scenario.
Small hydro	Indigenously available. However, need to develop modular systems.	Modular turbines with reduced weight and higher conversion efficiency at lower cost.
Biomass	Conversion of agricultural and municipal solid waste to drop-in-fuel not available	Biomass-to-liquid Drop-in fuels and ethanol.

5.3.2 Coal and Energy

Coal is the main fuel used for power generation in India. The power sector alone consumes more than 65% of total coal consumption in India. In this regard, it is stated that "though a majority of coal fired power plants in India are based on subcritical boiler technology, most of these plants operate at efficiency levels of around 38% on Higher Heating Value (HHV) basis". The ash content of Indian coal is high ranging between 25 to 45% by weight resulting in low heating value (about 15 to 18 MJ/kg). Many Advanced Coal Technology (ACT) developed for low ash coals are not directly adaptable to Indian high ash coal. The country is partly dependent on the import of expensive low ash coal. Some of the challenges which the sector is facing are: i) to make a shift to clean coal (for example, Ultra-Supercritical) technologies, ii) to reduce dependency on imported coal, iii) control of fugitive emissions from mining, iv) high energy consumption in coal transportation from mining area to power plants and other end-use areas, v) economically viable coal beneficiation technologies for reduction of ash and sulphur content, vi) limited commercially demonstrated and economically viable CO_2 separation, capture, utilization and storage technologies, and vii) coal to fluid fuel technologies to support the automobile and other industries.

India has already started progressively upgrading its existing (only old and inefficient) coal-based power plants from sub-critical to super-critical technology. Coal beneficiation techniques can enable the lowering of the carbon footprint per unit of electricity generated and thereby lowering CO_2 intensity. However, these technologies too are not widely available. In order to facilitate quick deployment, multilateral technology cooperation can play an enabling role.

In addition, to technology gaps mentioned in first BUR, India requires financial support to access and implement the following technologies in coal and energy:

- Pulverized Combustion Ultra Super Critical (PS USC) – Main Steam and Reheat Temperature around / above 600°C
- Pulverized Combustion Advanced Ultra Super Critical (PS Advanced USC) – Main Steam and Reheat Steam Temperature more than 700°C
- Integration of Coordinated/ Central Control System with Computation Fluid Dynamics (CFD) Analysis of Flue gas path in ducts

- Underground Coal Gasification – Integrated Gasification Combined Cycle (UCG-IGCC)
- Coal to methanol, DME and other fluid fuels technology
- Advanced Coal Beneficiation technologies
- Gas hydrates exploration and production
- Gasification technology for firing kilns with high ash coal and solid alternative fuels
- Carbon capture and transport and storage technologies
- Micro Oil Ignition System (MOIS). This technology is commercially available in India however, its scalability requires financial and technical support to ensure GHG reduction.

Nuclear energy is also expected to play a key role. Government of India has targeted to establish 63 GWe nuclear capacity by the year 2032. Efforts, both domestic as well as through international co-operation, are underway in this regard. Nuclear energy being a clean source of energy should get a level playing field *vis-à-vis* other clean energy sources. In particular, financing of this programme especially for Pressurised Water Reactor (PWR) and Boiling Water Reactor (BWR) through low-cost finance is an important aspect that needs international attention and support.

5.3.3 Industrial Processes and Product Use (IPPU)

Make in India initiative of Government of India has provided thrust to domestic manufacturing with the expected increase in energy demand. Hence, there is a growing need for efficient technologies related to different industrial processes and product use (IPPU) to ensure that the sector remains commercially competitive as well as environment-friendly. Indian manufacturing sector has been on the forefront in adopting energy efficient measures which are on par with global standards. However, it is important to note that Indian manufacturing is a diverse sector (comprising of MNCs as well as MSMEs) with varying requirements related to technology, finance and capacity building, thus requiring incremental global support.

In addition, to technology gaps mentioned in first BUR, India requires new and additional support to access and implement the following technologies in the IPPU Sector (Table 5.4a):

Table 5.4a: Technology Needs in IPPU Sector

Sector	Technology Need
Aluminium	• Zero Gap Electrolyzer
Iron & Steel	Converter Gas Sensible Heat Recovery
Cement	CO_2 capture and transformation into fuel including algae-based biofuel
Pulp & Paper	• Black Liquor Gasification • Nansulate Coating of Dryer end of Paper Machine for Surface Temperature Reduction thereby Lowering Radiation Heat-Loss Demonstration • Extended Delignification System for Cooking of Wood • Oxygen Delignification and Efficient Screening to obtain Low Kappa • Multi-Port Dryer in Paper Machine to Reduce Steam Consumption
Textile	• Ultrasonic Assisted Wet Processing • Supercritical CO_2 Dyeing Technique • Closed Codensate Recovery Pump • Free Float Steam Trap
Chlor Alkali	• Zero Gap Electrolyzer • Oxygen – Depolarized Cathodes (ODCs)

Apart from these technologies, there are some other technologies that are commercially available in India and have been implemented by few industries. However, the actual reflection of their GHG reduction potential depends on the scalability of such technologies which further depend on the affordability and availability of requisite financial instruments. Such technologies are mentioned in Table 5.4b:

Table 5.4b: Technology Needs in IPPU Sector

Sector	Technology Need
Fertilizer	• Zirconium Coating • Installation of Secondary Reformer Heat Exchanger

Aluminum	• Drained cell technology with wet table cathodes • Cu-insert collector bar technology in aluminum smelter
Iron & Steel	• Coke Dry Quenching (CDQ) • Waste Heat recovery generation from Low TPD Sponge Iron Plants • Regenerative/ recuperative Burner for Reheating Furnace • Sinter Plant Heat Recovery (Steam Recovery from Sinter Cooler Waste Heat) • Sinter Plant Heat Recovery (power generation from Sinter Cooler Waste Heat) • Coal Moisture Control (CMC) system (Top Charged) • Top Pressure Recovery Turbine (TRT) • Pulverized Coal Injection (PCI) system • Hot stove waste heat recovery • Converter gas recovery device • Ecological and economical arc furnace • Waste heat recovery from electric arc furnace • Regenerative Burner Total System for Reheating Furnace • Energy monitoring and management system • Cogeneration (include Gas Turbine Combined Cycle (GTCC)) • Low Grade Heat Recovery Using Organic Rankine Cycle • Hot Blast Superheating with Plasma technology • Advanced automation L-3 model online simulation of Blast Furnace • Gas Oxygen refining technology
Textile	Mechanical Vapour Recompression technology
Cement	• Utilization of Advanced Automation systems in Cement Manufacturing with online CFD analysis, Analytics and Predictive Control (data analysis and remote asset monitoring) • Oxy-fuel combustion technology • Technology for recovery of radiating heat of Kiln and Preheater sections • Manufacturing technology of Polymer Cement from Waste of Iron Sludge • Horomill for cement grinding

The experience of implementing energy efficiency initiatives across various sectors including appliances, buildings, industries etc. makes it clear that energy efficiency improvement is a continuous process which could be done in stages depending upon the availability of adequate and predictable finance, skill upgradation and system for adaptation of technologies to meet the customised local requirements. The financial requirement to scale up such technologies and techniques is enormous. For example, as per the estimates, more than ₹ 560 billion will be required to ensure scale up of iron and steel technologies as mentioned in Table 5.4b. Therefore, India could meet its low carbon development commitments only upon the availability, accessibility, and affordability of technologies as well as new and additional finance.

5.3.4 Transport

Government of India is focusing on low carbon infrastructure and public transport systems to reduce its environmental impacts. Presently, transport is the second largest contributor to the country's CO_2 emission after the industrial sector. Indian transport sector is also a leading consumer of fossil fuels and is responsible for high import bill, traffic congestion, air and noise pollution, and road fatalities, especially in urban areas. India has given focus on indigenous technology development with various national programmes in transport sector like Make in India, Digital India, Faster Adoption and Manufacturing of Electric Vehicles, Green Mobility Fund, Smart Cities Mission among others. Government of India believes that "with rapidly evolving technologies and business models, there is a need to adopt new and fundamentally different pathways to provide clean, cost-effective, and efficient mobility services that are safe, create jobs, reduce dependence on oil imports, and achieve more efficient land use in cities with the least environmental footprints and impact on human health. A rapidly developing India is at the cusp of making such a transition to new mobility solutions" (NITI Aayog, 2017).

Roadways is the dominant mode of transportation in India with around 65% of freight and around 86% of passenger traffic. The infrastructure for charging electric vehicles is limited. High-quality fuel is not widely available. The Ministry of Road Transport and Highways (MoRTH) has set the target of implementing Bharat Standards-VI (BS-VI) emission norms from 1st April 2020 for all vehicles. Additionally, fuel efficiency standards with stringent limit are targeted for 2021 with enhanced safety standards.

Indian Railways (IR) is predominantly driven by fossil fuel, which needs to be shifted to use of alternate and renewable sources of energy to reduce the GHG emissions. There are a limited number of semi high-speed trains.The existing routes are comon for both passengers and freight transport. Dedicated corridors will help in increasing the speed and efficiency of traction and will shift the load from road to rail. There is a need for the intermodal connectivity through an intelligent traffic management system to increase the efficient movement of freight. IR has set a target to reduce its emission intensity up to 32% by 2030 over the base year 2005. There is

a target of 8 to13% reduction of traction energy and fuel consumption instensity by 2030 from 2005 level with technological intervention.

There is high air traffic congestion resulting in air and noise pollution. Air traffic management at airports and in the air should be upgraded through advanced technologies. Waterways are the most underutilized mode of transport though it is a relatively cheaper and more environment-friendly mode. There is limited intelligent infrastructure at ports as well as limited intermodal connectivity with ships for the efficient handling of cargo leading to delay in the delivery of goods. There is a need to harness the potential of inland and coastal shipping to reduce the load on road and rail. There is also a need to explore and use alternate energy sources in waterways to reduce the emissions.

In addition, to technology gaps mentioned in first BUR, India requires following support in the transport sector (Table 5.5).

Table 5.5: Technology Needs in Transport Sector

Sector	Technology Needs
Roadways	Advanced Internal Combustion Engine (ICE) Development (Setting up a center in India for Combustion research in the area of LTC, HCCI, RCCI, cycle changes to Miller/Atkinson etc.)
	• EV Infrastructure • Development of Low cost EV charging infrastructure and advanced battery technology
	Light weighting – Development of ultra-high strength steel. (Also, the migration to Aluminum and Composites have to be targeted to get enhanced fuel efficiency and reduced emissions)
Railways	Fuel Cell (PEM) technology for traction
	Methanol engine technology for DEMU power cars
	Advanced Solar Panels with enhanced efficiency for use on rolling stock
	Development of Lithium Ion batteries for storing solar energy

5.3.5 Waste

Government of India recognizes that efficient waste management leads to enhanced environmental benefits along with energy. *Swachh Bharat Abhiyan* (SBA) aims to achieve 100% collection, transportation, processing and disposal of municipal solid waste in all statutory towns in a phased manner. *Namami Gange* is an integrated mission which aims to clean and rejuvenate river Ganga and its tributaries while restoring geological and ecological integrity, community participation, and river-front development among other things.

The increased waste generation and its inefficient collection, segregation, treatment and disposal by municipalities is among India's foremost technological challenges. Limited awareness, huge financial requirements, unskilled labour, lack of innovative approach and lack of proper monitoring of waste management are some of the key issues.

In addition to technology gaps mentioned in first BUR, India requires following support in the waste sector (Table 5.6).

Table 5.6: Technology Needs in Waste Sector

Sector	Technology Needs
Municipal Solid Waste	Mechanical Extrusion Press
	Biogas to Bio-CNG: Compressor and bottling units
	Waste to energy: Thermal technologies – Incineration, Pyrolysis, Gasification, Plasma
	Hydrothermal Carbonization (HTC)
	In Vessel Composting Technologies/Mechanical Biological Treatment Technologies
Industrial Wastewater	Zero Liquid Discharge (Anaerobic/ aerobic reactors, RO & Evaporation), Mechanical Vapor Compression, Effluents with recalcitrant properties
	Plasma with power
	Electric Arc

Plastic Waste	Alternatives to Plastic Food and Beverage Packaging and Recycling
	Biodegradable polymers (safe for packaging food, beverages and for medical infusions)
	Biodegradable and compostable polymers for wet waste
	Alternatives to PVC in medical field
	Alternatives to Polystyrene and thermocol for food and beverage packaging
Bio-medical Waste	Laser pyrolysis
	Thermal de-polymerization
	Modular incineration plants with high combustion efficiency
E-Waste	Recycling of Li-ion batteries
Biomass (Agro residue)	Technologies for safe disposal of biomass waste
	Technology to convert bio mass to Fuel like drop-in-fuel and ethanol to be developed
Organic (dry)	Thermal gasification
Others (mixed waste)	Micro-porous polyurethane or PTFE membrane suitable for de-humidification of mixed waste
Non-Industrial Hazardous Waste	Tyres Recycling/ Cracking

To conclude, it is difficult to project future requirement of technologies in the rapidly and ever-evolving realm of technology development. In addition, to the technology needs mentioned in India's first BUR and section above, there are many other mitigation technologies which are being indigenously developed but are not yet ready for commercial use. Further development of these technologies needs to be facilitated through adequate and predictable financial support.

As large section of the population is vulnerable to climate change consequences, thus, adaptation is as relevant to India as mitigation. Most of climate adaptation-related technologies in the sectors like agriculture, forestry, water, health etc. exist in India at a limited scale. These technologies and techniques need to be locally adapted and scaled up to ensure climate resilience of country's ecosystem and local population which requires substantial financial support.

5.4 GHG inventory reporting: constraints, gaps and improvements

As mentioned under the Institutional Arrangements section of this report, 16 institutions were engaged for the preparation of BUR-2, of these 11 institutions were entrusted with the task of preparing the national GHG inventory. In other words, a robust technical team has worked on the preparation of national GHG inventory.

The upgradation of the emission inventory system is a dynamic process, and sustained efforts are being made to ensure that India's GHG emission inventory is of high quality, transparent and consistent with the requirements of the IPCC inventory guidelines. India has voluntarily adopted 2006 IPCC Guidelines for many categories of inventory. But there is always scope of improvement. For instance, emission factors (EF) of some of the core sectors can be upgraded to tier 3 instead of using IPCC default EF values for these sectors. This is considered necessary to provide a comprehensive representation of the Indian GHG inventory. The Government of India plans to ride the tier ladder using key category analysis and uncertainty assessment which requires new and incremental financial, technical and capacity support.

5.4.1 Energy sector

India has also established a methodology for gas concentration measurement since methane is a major gas in mining processes. The country is working towards two main improvements in this sector. For fugitive emissions from the oil and natural gas sector, the tier advancement is challenging as the equipment for inventory estimation is expensive. The requirements for assessing the leaks at various stages of the petroleum and natural gas life-cycle are also complex. As a separate initiative, India's major oil exploration and production company, the Oil and Natural Gas Corporation Limited (ONGC) has tried to estimate such leaks at four locations. Subsequently, attempts have also been made to recover flared gas at their urban facility. The results from this study showed that there are significant variations amongst the contributions of various stages of fugitive emissions (fugitives, venting, flaring) in different projects, which necessitates field-level measurements.

While activity data for coal mining and handling oil and natural gas systems is available, the data on emission estimation is not easily available. Coverage domain and assumptions in different Government and sectoral annual reports/ publications may often be different due to various reasons. Therefore, selection of data becomes crucial and it needs back up knowledge, and further detailing followed by validation through secondary data. Grade-

wise coal utilization is much more difficult to obtain. In India, most of the available data is based on financial year, in contrast with the IPCC guideline, which is on the calendar year basis. Often, the data is not in a proper format for segregation and use for sectoral inventory preparation. Country-specific values of Net Calorific Values (NCVs) and Carbon Emission Factors (CEFs) for liquid and gaseous fuel used in the energy sector are under development. Detailed quality parameters of coal imported from different sources are not available. Source wise NCVs and CEFs are not available for coal supplies to India. Another key issue is the incorporation of uncertainty assessment.

5.4.2 Industrial Processes and Product Use (IPPU) sector

Challenges are associated with the collection of activity data, for estimation of GHG emissions from some of the IPPU sub-sectors. For instance, the glass industry represents a number of definable product segments, which includes; flat glass including float glass, container glass and hollow ware, vacuum glass, domestic and industrial glassware, crystal glass, fibreglass, glass wool, TV picture tube glass shells and laboratory glass. In India, the demand for glass is expected to increase, driven by growing consumer awareness of health, hygiene, and eco-friendly and energy conserving products. However, the Indian glass industry is mostly in the unorganized sector, and thus collation of production data from this sector for various categories of glass production is a challenge. For flat and sheet glass, the production data has been provided by the All India Glass Manufacturers' Federation (AIGMF), and for bottle glass, the production data has been sourced from Indiastat database. Some other informal and unorganised sub-sectoral data could also be improved.

5.4.3 Agriculture sector

Reliable data on different sources of emissions in the agriculture sector is not available. The emission sources in the sector include rice cultivation, cultural practices, application of organic amendments, lime and fertilisers, stubble burning, and animal husbandry.

In India, indigenous cattle of high yielding variety and low yielding breeds are not separated, which is desirable to have, as the feeding pattern of these animals is different leading to variations in methane emissions. Total methane, dung methane as well as N_2O emission vary depending upon their feeding habits. Thus, actual values of enteric methane emission are not available. Dry Matter Intake (DMI) was calculated based on the values in the literature. However, DMI by lactating animals in studies conducted during inventory preparation for BUR have shown lower values. These values are suitable for animals which are under average production and kept in normal conditions. The values taken for calculations are however on the higher side and may be appropriate for high producers which are kept in urban and peri-urban dairies. Hence, if the populations can be segregated into urban and rural categories and into high and low producers, methane emission figures are expected to be lower than those reported.

For estimation of dung produced, digestibility coefficients of feed were taken for this study. However, reports from some of the states providing information on total dung produced per animal and their disposal require further validation.

5.4.4 Land Use, Land-use Change and Forestry (LULUCF) sector

Some of the constraints and gaps that India underlined in BUR-1, still remain to be addressed requiring improvements for preparing the LULUCF sector GHG inventory.

India is periodically monitoring the areas under different land use and land use change categories using the latest satellite and remote sensing techniques. The National Remote Sensing Centre (NRSC) is undertaking remote sensing-based monitoring of land use and land cover in India. The Forest Survey of India (FSI) biennially generates a report on the State of Forests in India which publishes data on the area under forests in different tree crown density classes at the state and district level. The forest area estimates are based on remote sensing data. FSI also provides data on the area under the category Trees Outside the Forests (TOF). It also periodically estimates the carbon stock changes of forests based on the stock change method. FSI monitors the carbon stock change in trees outside the forests. India has initiated a National Forest Inventory programme and carbon flux estimation in future will be based on this inventory. The National Bureau of Soil Science and Land Use Planning (NBSSLUP), the Central Research Institute for Dryland Agriculture (CRIDA) and other institutions are involved in monitoring and estimation of soil carbon stocks in different land categories.

India has been pursuing efforts to shift the GHG inventory for the LULUCF sector to Tier 3 method. India is planning to adopt a model-based GHG inventory system for the LULUCF sector, but the plan is hampered due to the absence of suitable land-use models and data. Models such as Full Carbon Accounting Model (FullCAM) of Australia and CBM-CFS3 of Canada, and soil carbon models such as CENTURY and ROTH-C being used by other countries for carbon accounting purposes are not of much use to India as the data required for these models and

the capacity for development of country-specific carbon accounting models are not in place.

Of late, India has initiated the Long-Term Ecological Observatories (LTEO) programme. Under this programme, the carbon fluxes of natural and man-made ecosystems at the landscape scale and carbon stock changes in soils associated with different forest types and land use patterns are proposed to be measured and monitored. However, this may take several years before carbon flux data becomes available for inventory purposes. Further, carbon fluxes of not all land categories are monitored. Thus, availability of carbon flux data for all land categories, in particular, non-forestland categories, is a constraint at present.

As the area under wetlands, according to IPCC definition is not available, thus, there is a need to generate this data as well as estimates of related methane and nitrous oxide emissions.

NRSC has the requisite technical capability and is already generating georeferenced data on LULUCF for India. But, the absence of georeferenced biomass and soil carbon emission factors still needs to be addressed to enable India to adopt Approach 3 and preferred model-based carbon stock estimates.

India has the institutional and technical capacity to adopt Tier 3 methods and Approach 3 for land use measurement and analysis. However, modelling capacity is required for adopting models such as FullCAM, CBM-CFS3, CENTURY and ROTH-C. Capacity building is required to utilise the georeferenced data from NRSC with the application of the EF data. Additional financial support is required to build capacity for the adoption of suitable carbon measurement models and for generating EFs (such as stocks and fluxes of five carbon pools) in different land categories.

5.4.5 Waste sector

Reduction in uncertainties improves the methane and nitrous oxide emission estimates across tier levels. However, climbing the tier level requires sustained improvement through the creation of infrastructure and capacity building. The challenges faced in inventorying GHG emissions from the waste sector are presented in Table 5.7.

Table 5.7: Challenges in Inventorying GHG emissions

Parameter	Gaps/Barriers/Constraints	Needs
Degree of utilization of treatment discharges pathways or systems	IPCC 2006 Guidelines are used for the assessment for treatment of pathways viz., septic tanks, latrines, sewers, other treatment (Centralised Wastewater Treatment) and no treatment.	Creation of centralized database to inventorize emissions from each sector. Respective activity data identified for emissions assessment such as treatment pathway, emission factors, wastewater characteristics, unit waste water generation. Periodic data collection.
Total industrial products for respective industrial sector (tone/year)	Consistent annual industrial production data of all methane and nitrous oxides emissions generation sectors are not compiled. Therefore, only a few specific industries qualify for such estimation. GHG emitting industries like textile, food and beverage and food processing do not generate requisite data. Measures are on to include a good number of operational STPs and CETPs for estimation of emissions.	Identification of data for industrial sectors comprising a large number of products.
Maximum CH_4 producing capacity (kg CH_4/kg BOD)	Since country-specific values for methane production from wastewaters of domestic and industrial origin are not available, IPCC default values are used for the purpose.	Additional funding support to research institutes is required for initiating the study, and for capacity building to estimate industrial and domestic wastewater produced.
Methane Correction Factor	No country-specific data is available for the years 2011-2014.	
Correction factor for additional industrial BOD discharges into sewers	Since no country-specific data is available for the industrial discharges into the STPs, IPCC default values are used.	
Amount of CH_4 recovered in inventory year (kg CH_4/year)	Accurate information is not available across the country on the quantity of methane recovered for power production or flared from sewage treatment plants.	
Nitrous Oxides	Variable deciding nitrous emissions from wastewaters have been estimated from IPCC Guidelines 2006. Data on Annual per-capita protein consumption (kg/person/year), fraction of nitrogen in protein, factor for non-consumed protein-Nitrogen removed with sludge, (kg N/year), % Fraction of industrial and commercial co-discharged protein is not available for India. The protein consumption in India varies largely and has strong correlation with income criteria and standard of living.	

To conclude, substantial financial, infrastructure upgradation and capacity building-related support is required by India to ride the tier ladder and meet the enhanced national reporting requirements under the Convention and Paris Agreement. The support thus provided should be new, additional, incremental and climate-specific to what is presently available which is rather meagre and decreasing.

5.5 Capacity building needs and support received

The capacity building needs for enhanced national reporting as well as addressing the challenge of climate change mitigation and adaptation in India have multiplied during the reporting period of this BUR. This section should be read in conjunction with the preceding sections of this chapter.

India notes that the capacity-building needs reported in its second national communication are still relevant, that capacity-building is a dynamic process and that new needs continue to emerge with time. Prioritizing these needs for a vast developing country like India may not be possible, especially as its needs are dynamic and evolving. India considers all capacity-building needs equally important.

The initiatives mentioned in the following paragraphs do not approach the levels of adequacy in a capacity building required by a large developing country like India. A more detailed account of the gaps in capacity building was provided in BUR-1. The Joint Summary by India and the Convention Secretariat in relation to International Consultation and Analysis (ICA) submission by India has also provided a detailed list of such gaps. These gaps persist and are reiterated here below. In a country like India, the requirements in capacity cover a vast range including technology assessment, technology identification, adaptation to local context and diffusion, preparation of detailed emission inventories and updating EF for the Indian context and much more. A significant upgrade of capacity in this context remains one of the foremost challenges, yet to be adequately met. The Government of India attaches great importance to knowledge creation and capacity building for climate change.

Some of the critical capacity gaps are as follows:

- Estimating and reporting of GHG inventories
    i. Establishing a long-term institutional and operational system for periodic, continuous and enhanced GHG emission estimation for national reporting under various UNFCCC reporting requirements (a national inventory management system (NIMS));
    ii. Enhancing the GHG inventory to higher-tier levels in all sectors using key category analysis;
    iii. Refining energy sector data for reference and sectoral approaches, including non-commercial and other sectors;
    iv. Estimating country-specific EF for key categories (level and trend) for all sectors and gases;
    v. Collecting and mapping data on individual industrial processes and product use plants and micro, small and medium enterprises;
    vi. Collecting agricultural data, including for the establishment of country specific EF for fruit tree systems, for allometric equations and biomass expansion factors for horticultural species, and for enhancing and refining data on livestock dung production and collection;
    vii. Establishing an inventory system for estimating GHG emissions from municipal solid waste and industrial wastewater;
    viii. Establishing a national forest inventory system;
    ix. Adopting the IPCC Approach 3 for activity data on areas under different land categories and conversions;
    x. Georeferencing areas under different land categories and areas subjected to change for the GHG inventory by using remote sensing and global information systems;
    xi. Modelling for tier 3 estimation of carbon stock changes in forests, plantations and land area subjected to mitigation actions;
    xii. Estimating carbon stocks and collecting data on changes in baseline carbon stocks for the estimation of mitigation potential;
    xiii. Identifying carbon sequestration rates for different forest types and plantations;
    xiv. Additional finance for designing and implementing afforestation/reforestation projects;
    xv. Strengthening local capacity to collect LULUCF data at the regional level;
    xvi. Capacity-building for data collection from primary sources in the forestry sector;
    xvii. Coordinating the dispersed technical and institutional capacity for REDD+;
    xviii. Enhancing capacity in forest resource assessment and improving the process at the state and local levels;
    xix. Enhancing resolution of forest data generated through satellite imagery; and,

xx. Capacity-building at all levels (including state- and district-level forest departments, research organizations and non-governmental organizations) to enable the design, implementation and MRV, to implement the REDD+ mechanism

- Establishing and implementing an integrated domestic MRV system for GHG mitigation actions,including integrating it with NIMS, institutional arrangements, building capacity.
- Improving the capacity of government ministries and other agencies to provide sectoral information and other inputs for reporting on a continuous basis.
- Developing a dynamic training plan for existing, new, and upcoming technical experts involved in the reporting process.
- Enabling better coordination among relevant regions and institutions to design, implement and measure, report and verify a REDD+ system.
- Identifying the most appropriate methodologies to develop progress indicators to facilitate reporting the progress of the implementation of mitigation actions, including emission reductions.

In addition to the above capacity-building needs the following additional specific capacity-building, technology transfer and financial support needs are also identified:

a. Conducting impact and vulnerability assessments at the sectoral, sub-regional and integrated levels;
b. Sensitizing the Indian population vulnerable to the adverse impacts of climate change;
c. Implementing adaptation needs assessments;
d. Providing training and upgrading skills across sectors;
e. Providing funding for solar power and wind power projects;
f. Improving technology for renewable energy;
g. Capacity building for manufacture of hydrogen and fuel cells;
h. Reactivating the implementation of clean coal technologies;
i. Developing advanced ultra-supercritical technology for clean coal;
j. Developing integrated gasification combined cycle technology suitable for high ash content Indian coal;
k. Improving access to technology for hydropower;
l. Building capacity to manufacture nuclear equipment in India;
m. Financing to scale up and deploy other atomic energy technologies;
n. Identifying linkages between the impacts of climate change and adaptation and mitigation options;
o. Developing cost-effective solutions for mitigation at local level.

5.5.1 Support received

The projects funded by multilateral institutions including GEF invariably have a component on capacity building. The GEF-funded project on 'Preparation of Third National Communication to the UNFCCC and Strengthening Institutional and Analytical Capacities on Climate Change' has conducted training on national GHG inventory preparations and reporting while developing the infrastructural and technical capacities of the national institutions working in the sector. Under this project, studies have been commissioned to analyze the impact of climate change on various mitigation and adaptation sectors.

India accessed the Readiness Grant from GCF to strengthen country's access of its resources. On 15th March 2018, a joint declaration was signed between International Solar Alliance and GCF in New Delhi to strengthen collaboration for renewable energy, and to promote solar energy solutions as part of the steps needed to reach the ambition of the Paris Agreement. This partnership is expected to bring together technical expertise and financial leverage to catalyze the transformation of global energy systems.

India is a member of the WGIA (Workshop on GHG Inventories in Asia), a network of Asian countries on GHG inventory, initiated by Government of Japan to assist countries to improve the quality of their inventories by promoting the exchange of information and experience obtained in the region. India participates in annual WGIA sessions, and the 16th WGIA was organized in India in 2018. Bilaterally, India has entered into Memorandum of Understanding (MoU) with a number of countries to exchange and strengthen expertise on climate change mitigation and adaption matters during the reporting period of this BUR.

5.5.2 National initiatives

As per the National Policy for Skill Development and Entrepreneurship 2015, it is estimated that the average age of the population in India by 2020 will be 29 years as against 40 years in the USA, 46 years in Europe and 47 years in Japan. In next 20 years, the labour force in the industrialized world is expected to decline by 4%,

while in India it will increase by 32% which creates a need and opportunity to provide its workforce with required skill sets and knowledge, to enable them to contribute substantially to the economic growth of the country. The skill ecosystem in India is undergoing major reforms and policy interventions as India embarks on its journey to become a knowledge economy.

Government of India's programmes invariably have a component on capacity building/ training/ awareness creation, and most of the programmes have started accounting for climate variabilities in their respective sectors to ensure economic growth and sustainable development. Furthermore, the eight national missions under the NAPCC are being reviewed and strengthened to meet the current needs and priorities. In 2015, the Prime Minister Council on Climate Change approved the addition of four new missions under NAPCC which are on wind energy, coastal system and resources, human health, and waste to energy.

One of the NAPCC's mission is on 'Strategic Knowledge for Climate Change' which is being coordinated by the Department of Science and Technology, Government of India (GoI, 2018). The main objectives of this mission are as follows:

- Formation of knowledge networks among the existing knowledge institutions engaged in research and development relating to climate science, and facilitate data sharing and exchange through a suitable policy framework and institutional support.
- Establishment of global technology watch groups with institutional capacities to carry out research on risk minimized technology selection for developmental choices.
- Development of national capacity for modelling the regional impact of climate change on different ecological zones within the country for different seasons and living standards.
- Establishing research networks and encouraging research in the areas of climate change impacts on important socio-economic sectors like agriculture, health, natural ecosystem, biodiversity, coastal zones, etc.
- Providing an improved understanding and awareness of the key climate processes and the resultant climate risks and associated consequences.
- Building alliances and partnerships through global collaboration in research & technology development on climate change under international and bilateral S&T cooperation arrangements.

As part of the knowledge mission, four Centres of Excellence (CoE) have been supported, including Divecha Centre for Climate Change, IISc-Bangalore; IIT-Bombay; IIT-Madras and ICRISAT-Hyderabad. During 2017 – 18, four new CoEs were launched and positioned at IIT-Delhi, BHU-Varanasi, IIT-Kharagpur and ICMR-National Institute of Malaria Research, Delhi. During 2017-18, seven major R&D programmes were launched to (Government of India, 2018):

i. reconstruct the natural variability of the Indian monsoon and identify its drivers on decadal and centennial timescales;
ii. improve the understanding of the regional climate, especially studying the underlying physical and meteorological processes impacting monsoon in southern peninsular India (SPI) region using a regional coupled model (RCM);
iii. undertake geoengineering research in India;
iv. provide a comprehensive regional climate assessment for the Indian sub-continent and to identify societal impacts related to two important issues of climate change on agriculture and air quality-health;
v. undertake assessment of impact of climate change on crop water requirements and productivity of major crops in Himalayan Region of northeast India;
vi. understand the vulnerability of this region in terms of precipitation patterns, evaporation losses and over-utilization of irrigation water due to impacts of climate change and to investigate the impacts of climate change on hydro-meteorological processes and extreme events, and their implications on sustainable development over the eastern India region; and,
vii. undertake state-of-the-art field measurement of Biogenic Volatile Organic Compounds (BVOCs) and ground truthing of land use land cover data for building an accurate BVOC emission inventory over Indian region.

A CoE for Combustion Research under DST has been set up jointly between IIT-Madras and IISc-Bangalore to enhance combustion research in the Automotive sector

Three new National Knowledge Network Programmes were launched in areas including climate modelling, climate change and human health, and climate change and coastal vulnerability. State Climate Change Cells (SCCC) have been established at the State Government's nodal departments designated to implement the State Action Plan on Climate Change. During 2017-18, two new SCCC for the States of Arunachal Pradesh and West Bengal were established. During 2017-18, a Human Capacity Building Programme (HCBP) in climate change adaptation was initiated.

In September 2014, a Joint Statement was signed between the Prime Minister of India and the President of

the United States of America which launched a new U.S.-India Climate Fellowship Program to build long-term capacity to address climate change related issues in both countries. In pursuance of this statement, the Fulbright-Kalam Climate Doctoral and Post-doctoral Fellowship programme was launched. The selection process for the first batch of six candidates was completed during 2016-17, and selected candidates have proceeded to US institutions for undergoing their respective courses. The selection process for the second batch of six candidates for above fellowship for the year 2017-18 is underway.

Skill India Programme aims to create job opportunities for the unemployed youth in various service and manufacturing sectors throughout the country. This flagship programme aims to create 500 million skilled manpower by 2020. Renewable energy is one among the targeted sectors under skill India. *Pradhan Mantri Kaushal Vikas Yojana* (PMKVY), approved for four years (2016-2020) with an allocated budget of ₹120 billion, is the flagship scheme of the Ministry of Skill Development & Entrepreneurship (MSDE). The objective of this Skill Certification Scheme is to enable a large number of Indian youth to take up industry-relevant skill training that will help them in securing a better livelihood including green jobs. Individuals with prior learning experience or skills will also be assessed and certified under Recognition of Prior Learning (RPL). PMKVY is implemented by the National Skill Development Corporation (Government of India, 2016).

Prime Minister of India along with French President launched International Solar Alliance (ISA) during UNFCCC CoP 2015. The Paris Declaration was issued on 30th November 2015 at the time of launching of ISA. It *inter-alia* states that the prospective member countries share the collective ambition to undertake innovative and concerted efforts for reducing the cost of finance and cost of technology for immediate deployment of competitive solar power generation. It further aims to formulate financial instruments to effectively mobilize more than USD 1,000 billion in investments that will be required by 2030 for the massive deployment of affordable solar energy (NISE, 2017 and MNRE, 2018).

The National Institute of Solar Energy (NISE) has been entrusted with the duty to execute various skill development programmes throughout the country in the field of renewable energy technologies. NISE has been conducting various solar and renewable energy and skill development training for both national and international participants.

'*Suryamitra* Skill Development Programme' is a flagship programme under Skill India, funded and supported by Ministry of New and Renewable Energy (MNRE) and implemented in collaboration with State Nodal Agencies, at various locations across the country for a number of stakeholders (Figure 5.1). The program aims at developing capacities and capabilities in renewable energy sector, thus creating employment opportunities at multiple levels. The duration of *suryamitra* programme is 600 hours (approx. 90 days) for ITI/ Diploma holders (Electrical/ Electronics). From October 2016 onwards, the course curriculum of Skill Council of Green Jobs was adopted. The Qualification Pack SGJ/Q0101 was introduced for the *Suryamitra* programme. In last four years, about 18,000 *suryamitras* have been trained which is expected to create around 10 million man days employment per annum.

Figure 5.1: Participants of *Suryamitra* program performing solar photovoltaic experiments

The Skill Development Division of NISE organizes and conducts
various International training programmes for delegates from different countries under Indian Technical and Economic Cooperation (ITEC) and its corollary Special Commonwealth African Assistance Programme (SCAAP) and for ISA. Every year the officials nominated by different countries attend these training programmes (Figure 5.2 and 5.3). Table 5.8 presents the details of international training programmes conducted in 2016 - 17.

Figure 5.2: Participants of International Training Programme under India-Africa Forum Summit (2018)

Figure 5.3: Participants of Skill Development Programme for SAARC member countries (2017)

Table 5.8: List of International Training Programmes under ISA (NISE, 2017)

S No	Programme	Period	No of Countries	No of Participants
1	Eurasia	22 Aug to 2 Sept 2016	5	17
2	ITEC/ SCAAP	28 Nov to 16 Dec 2016	25	32
3	AOP for ISA member countries I	4 Jan to 12 Jan 2017	11	12
4	AOP for ISA member countries II	17 Jan to 25 Jan 2017	10	10
5	ITEC/ SCAAP II	30 Jan to 17 Feb 2017	17	26
6	AOP for ISA member countries III	5 Apr to 13 Apr 2017	17	17

In addition, MNRE has taken up the issue of incorporation of solar lighting, solar thermal and small hydropower in the regular syllabus of ITI students of certain trades such as electrician, fitters, turners, welders, plumbers etc. The course material was prepared and passed on to Directorate General of Employment and Training (DGET), and it has been incorporated in the syllabus of trades of ITIs so that about 16-60 hours will be devoted on Renewable energy skill development during regular two-year ITI course. DGET is also planning to start a special programme of skill development under their Craftsman Training Programme (CTS) and Modular Employment Skill Development Programme (MES), wherein they provide special training for 60-960 hours. Ministry will provide technical input as well as assess these courses from time to time. MNRE has also launched a special fellowship scheme entitled 'National Solar Science Fellows Programme' for eminent scientists. Furthermore, to facilitate scalable new business models and startups in the sustainable energy space, MNRE has joined hands with IIM Ahmedabad's Centre for Innovation Incubation and Entrepreneurship (CIIE) to set-up the Indian Fund for Sustainable Energy (Infuse).

The Ministry of Environment, Forest and Climate Change (MoEFCC), Government of India has taken up the initiative for skill development in the environment and forest sector to enable India's youth to get gainful employment and/ or self-employment by launching a Green Skill Development Programme (GSDP). The course is conducted through a decentralized network of 66 Environment Information System (ENVIS) centres providing scientific, technical and semi-technical training on various environmental issues.

The Government of India has launched *Apada Mitra* scheme for training 6,000 community volunteers as a disaster response in 30 most flood-prone districts (200 volunteers per district) of 25 States in India at a total outlay of ₹150.7 million. The scheme aims to provide the community volunteers with the skills that they would need to respond to their community's immediate need in the aftermath of a disaster and enable them to undertake basic relief and rescue tasks in emergency situations like floods, flash-floods and urban flooding. As on 03.08.2017, ₹68.1 million has been released to all 25 project states under this programme. (LS Unstarred Question 3,468, 2017).

MoEFCC has launched a Green Good Deeds Campaign, a societal movement to protect the environment and promote sustainable lifestyles in the country. This initiative found acceptance at BRICS Environment Ministerial meeting at Durban in 2018 to be included as an official agenda in its next Ministerial meetings. The details are presented in Chapter 6. The Ministry supported WWF's Earth Hour 2018 campaign as an opportunity to spread awareness on the need for a shifting of the consumption culture and behaviour change towards sustainability, helping economise operations and reduce the costs. The Ministry was also the global host of the World Environment Day 2018 focusing on the issue of banning the single-use plastic.

India's efforts to address climate change, therefore, require extensive upgradation of infrastructure as well as technical manpower on a regular basis. Enhanced collaboration and networking with international partners is required to exchange best practices and knowledge systems on climate mitigation and adaptation. There is a need to strengthen the process of mainstreaming climate change concerns with various State governments by developing technical capacities at different levels to understand the role, impact and options available to address the challenge of climate change. There is a need to integrate and join the dots keeping in mind climate adaptation, disaster risk reduction, enhancing climate resilience etc., to plan and execute developmental interventions in a holistic manner. There is also a need to develop the capacity of local communities to understand climate variability, its impact on the local economy, ecology and livelihoods and the viable options available for climate proofing. Though a firm projection is difficult, rough estimates indicate that around 2.5% of Government's salary budget would be required for capacity building initiatives, while some part of it would need to be financed internationally (MoEFCC, 2015).

5.6 Concluding remarks

Time-bound climate action requires new, additional and climate-specific financial resources to be made available on a predictable basis to developing countries. These resources are required to bridge the widening gap between increasing GHG emissions and depleting carbon budget *vis-a-vis* the resources available for mitigation as well as adaptation. These investments are required to protect the present generation from growing extreme events, health hazards, hunger and malnutrition, displacement etc. Ms Patricia Espinosa, Executive Secretary of UNFCCC, said "When it comes to climate change, finance is about more than money. It's about helping people impacted by climate change. It's about reducing their suffering. And, in some cases, it's about saving lives"(UN Climate Speech, 17th October 2018).

India as a responsible nation, is mobilizing and stretching its domestic financial resource base to meet the developmental imperatives of its population, in a sustainable manner. India is on track to meet its Copenhagen commitment of reduction in emissions intensity of GDP by 20-25% by 2020 with reference to 2005 level. However, to meet the growing global challenge and to limit the temperature rise to 1.5°C by 2030, new and additional financial and technological support is required from the developed country Parties. These resources are required to ensure the survival of life on planet Earth while"Leaving No One Behind".

References

Adaptation Fund. (2018). Adaptation Fund. [online] Available at: https://www.adaptation-fund.org

Ahmed, M.et al. (2014). Assessing the costs of climate change and adaptation in South Asia. Asian Development Bank.

Climate Investment Fund. (2018). Climate Investment Funds. [online] Available at: https://www.climateinvestmentfunds.org/

Global Environment Facility. (2018). Special Climate Change Fund - SCCF. [online] Available at: https://www.thegef.org/topics/special-climate-change-fund-sccf.

GoI. (2016). Skill Development Sector – Achievements Report. Ministry of Skill Development and Entrepreneurship.

GoI. (2017). India – Country Report and Mission Innovation Challenges Action Plan. Department of Biotechnology.

GoI. (2017). Lok Sabha Unstarred Question No 3468, Capacity Building for Disaster Management. Lok Sabha Secretariat website.

GoI. (2018). Annual Report 2017 - 18. Department of Science & Technology.

Green Climate Fund (2018). Green Climate Fund. [online] Available at: https://www.greenclimate.fund/home

IFC. (2017). Climate Investment Opportunity in South Asia: An IFC analysis International Finance Corporation .

MoEFCC. (2015). India's Nationally Determined Contributions to UNFCCC.

National Innovation Council website- http://innovationcouncilarchive.nic.in/index.php?option=com_ontent&view=article&id=26&catid=5&Itemid=5

NISE. (2017). Annual Report 2016 - 17. National Institute of Solar Energy.

NITI Aayog. (2017). India Leaps Ahead: Tranformative Mobility Solutions for All. NITI Aayog.

Planning Commission. (2014). The Final Report of the Expert Group on Low Carbon Strategy for Inclusive Growth.

TIFAC. (2015). Technology Vision 2035. Technology Information, Forecasting and Assessment Council.

UNFCCC. (2012). Decision 2/CP.17, Annex III, UNFCCC biennial update reporting guidelines for Parties not included in Annex I to the Convention.

UNFCCC. (2018). Patricia Espinosa: Climate Finance is About Saving Lives, UN Climate Speech. 17th October 2018.

INTERNATIONAL SOLAR ALLIANCE

International Solar Alliance (ISA) is the vision of Hon'ble Prime Minister Shri Narendra Modi to bring the world together for harnessing the untapped potential of solar energy for universal energy access at affordable rates. It is the first treaty-based inter-governmental organisation. 71 countries have signed the Framework Agreement of the ISA. Out of 71 countries, 48 countries have deposited instrument of ratification.

Chapter 6

Additional Information

Chapter 6: Additional Information

Decision 2/CP.17, Annex 3, Para 2, Point (g) states, "Any other information that the non-Annex I Party considers relevant to the achievement of the objective of the Convention and suitable for inclusion in its Biennial Update Report (BUR)". This chapter provides information additional to what is provided in Chapters 1 – 5. It comprises success stories from the rapidly evolving solar energy landscape, climate change adaptation, international cooperation, civil society initiatives, knowledge management, as well as communication and outreach.

Many of the important climate change mitigation policies, programmes and activities have been covered in the preceding chapters of this report. In the first BUR, a non–exhaustive list of policies and measures was provided which has been revisited, updated and provided in Appendix I.

6.1 Rapidly evolving solar energy landscape of India

Globally, India holds the 5th position in installed capacity of renewable energy as well as of solar power. India is a vast country blessed with an abundance of sunshine, which is increasingly being harnessed by different stakeholders to meet their respective energy needs. Chapter 3 in this report contains details of the government policies and programmes, in the solar energy sector. This section highlights some of these exemplary initiatives which are illustrative and not exhaustive.

M. Chinnaswamy stadium

In 2015, a 400 kW grid interactive rooftop solar power plant was installed at M. Chinnaswamy Stadium located in Bengaluru, Karnataka, thus making it the world's first solar-powered cricket venue (Figure 6.1). The stadium is the home ground of the Karnataka State Cricket Association (KSCA); with a seating capacity of around 40,000, it hosts not only cricket matches but also other cultural events. The solar plant is designed to produce about 0.6 million units of power annually, thus meeting all the power-related needs of the stadium. The excess power generated is sold to BESCOM for ₹9.56 per unit and the proceeds are paid to KSCA. This system has the potential to reduce approximately 600 MT of CO_2 emissions annually (MNRE, 2018).

Figure 6.1: Solar rooftop at the M. Chinnaswamy Stadium, Bengaluru

Cochin International airport

In 2015, the Cochin International airport, servicing more than 10 million people annually, became the world's first airport to be fully powered by solar energy. The 12 MWp solar PV power plant was installed on 45 acres of land adjacent to the airport's cargo complex (Figure 6.2). The 12 MWp, along with already operational 1.1 MWp, plant generates an average of approximately 52,000 units every day, which is more than the airport's requirement. The excess power is sent to the Kerala State Electricity Board grid (using the connectivity at the 110 kV sub-station of the airport) to be used during non-sunshine hours. The project follows a public-private participation model with more than 18,000 investors and within a month of commissioning generated about 1.7 million units of power, worth more than ₹10 million. The airport grounds also house a solar farm, where organic vegetables are grown, to be sold to the airport staff and nearby markets. Increasingly, the airports in India are harnessing sun for their day-to-day operations (MNRE, 2018).

Figure 6.2: A 12 MWp solar PV power plant at Cochin International airport

Cochin International airport was one of the six winners of the 2018 Champions of the Earth Awards. The airport received the award for Entrepreneurial Vision, for being the world's first fully solar-powered airport, thus showcasing that green business can be good business.

Solar parks

The country's first solar park came up at Charanka village in Gujarat and world's largest solar park Shakti Sthala, with a capacity of 2,000 MW, is under installation at Pavagada, Karnataka. A solar park is a concentrated zone of development of solar power generation projects, providing developers an area that is well characterized, with appropriate infrastructure and access to related facilities. The target is to set up solar parks with 40,000 MW capacity of which about 26,694 MW has already been sanctioned comprising 47 solar parks in 21 states (Figure 6.3) (MNRE, 2018).

Figure 6.3: Kurnool Solar Park, Andhra Pradesh, with a capacity of 1,000 MW is operational since March, 2017

Indian Railways initiatives

Indian Railways (IR) cover around 67,368 km connecting different parts of the country. IR plans to install 1,000 MW of solar power plants (both rooftop and land-based) at railway stations, other buildings and on land. Up to March 2018, more than 55 MW of rooftop solar power plants have been set up and work awarded for an additonal 130 MW. IR has tied up for 450 MW of land-based solar plants. Katra railway station is one of the largest solar rooftop power plants in Jammu and Kashmir, with an installed capacity of 1 MW (Figure 6.4) (PIB, 2018).

The trailer coaches of one rake of 1,600 HP Diesel Electric Multiple Unit (DEMU) have been provided with rooftop Solar PV system which takes care of electric supply for the fan and lighting load inside the coach. This will reduce 1,350 tonnes of CO_2 emissions per train over a lifetime of 25 years (Figure 6.5) (MoR,2018).

Figure 6.4: Solar rooftop power plant, Katra railway station, Jammu and Kashmir

Figure 6.5: Solar DEMU

Solar energy in Islands

Figure 6.6: 5 MWp Solar PV Plant commissioned at Garcharma, Port Blair, Andaman & Nicobar islands

Figure 6.7: 100 KWp grid interactive solar power plant, set up on Kalpeni island, Lakshadweep.

Solar projects are coming up in islands to meet their energy requirements. A 5 MWp solar PV plant was commissioned at Garcharma, Port Blair, Andaman & Nicobar Islands commissioned by NTPC in March 2013 (Figure 6.6). The power generated is sold to the Andaman & Nicobar electricity department through Power Purchase Agreement (PPA) and is supplementing the demand for electricity for the island. Similarly, a 100 kWp grid-interactive solar power plant was set up on Kalpeni island, Lakshadweep (Figure 6.7) (MNRE, 2018).

Transforming lives and livelihoods

Figure 6.8: Solar Water Pumps

The Ministry of New and Renewable Energy (MNRE) is implementing an off-grid and decentralized renewable programme for meeting energy demand for cooking, lighting, motive power, space heating, hot water generation etc. The deployment of decentralized solar appliances like solar lanterns, solar street lights, solar home lights, and solar pumps is supported. As on October 2018, over 4 million lanterns and lamps, 1.7 million home lights, 0.64 million street lights, 0.2 million solar water pumps (Figure 6.8) and 187.99 MWp of standalone capacity have been installed in the country (MNRE, 2018).

Solar study lamps

In December 2016, MNRE sanctioned the 7 million Solar Study Lamp Scheme to be implemented in five Indian states of Assam, Bihar, Jharkhand, Odisha and Uttar Pradesh, where more than 50% households lacked access to grid electricity (Figure 6.9). Till 11th December 2018, more than 2.4 million students benefitted and 4,269 local people were trained in 173 blocks, with a reduction of approximate 15,367 $MtCO_2$. Such renewable energy initiatives are transforming rural India, leading to enhanced economic benefits and overall well-being (MNRE, 2018).

Figure 6.9: Solar study lamps

6.2 India, a responsible global partner

India is a responsible developing country and a firm believer in multilateralism. India has actively participated in international fora related to environment and climate change. It recognizes the importance of working together with other countries for achieving similar objectives. India's commitment to international cooperation on climate change and its willingness to address the challenge of global warming, under the Convention, is based on the principle of common but differentiated responsibilities and respective capabilities. India has lived and led by example be it in meeting energy needs by harnessing the sun or converting waste to wealth. Some of these engagements are discussed in the following pages.

6.2.1 International Solar Alliance (ISA)

International Solar Alliance (ISA) was launched by the Prime Minister of India and the President of France during the 21st session of Conference of Parties to UNFCCC at Paris, France. ISA brings together potential 121 solar resource-rich countries lying fully or partially between the Tropic of Cancer and the Tropic of Capricorn to optimize the use of available solar resources to meet their respective energy needs. The Paris Declaration signed during CoP-21 underlined the need to undertake innovative and concerted efforts for reducing the cost of finance and technology to promote immediate deployment of competitive solar generation capacity in ISA member countries. It was agreed to mobilize more than USD 1,000 billion of investments by 2030 to facilitate a massive deployment of affordable solar energy while paving the way for future solar generation, distribution and storage technologies to meet the respective needs of ISA member countries.

Figure 6.10: The First Assembly of the ISA, New Delhi

In order to make ISA a treaty-based international intergovernmental organisation, a Framework Agreement was drafted with inputs from the prospective ISA member countries. The Framework Agreement opened for signature on 15th November 2016 in Marrakesh, Morocco, on the sidelines of CoP-22. As on date, of 121 prospective member countries, 71 have signed the Framework, of which 48 countries have deposited their instrument of ratification. As per the Framework Agreement, 30 days after ratification by the 15th country on 6th December 2017, ISA became a full-fledged treaty-based international intergovernmental organization.

On 11th March 2018, the Prime Minister of India and the President of France co-hosted the Founding Conference of ISA. Forty-eight countries, including India, participated. The Delhi Solar Agenda was adopted at this conference. It stated that ISA member countries *inter-alia* have agreed to pursue an increased share of solar energy in the total energy consumption in their respective energy mix, as a means of tackling the global challenge of climate change as well as a cost-effective solution by supporting/ implementing policy initiatives and participation of all relevant stakeholders, as applicable, in respective states.

ISA has signed Joint Declarations for development and deployment of solar energy with a number of organizations such as the World Bank, United Nations Development Programme, European Investment Bank, the European Bank for Reconstruction and Development, Green Climate Fund and Climate Parliament. ISA has engaged in a dialogue with the Commonwealth Secretariat by working together for affordable deployment of solar energy among its member countries. In addition, with India's concessional financing of USD 1.4 billion, ISA has developed a portfolio of 27 projects in 15 countries. YES Bank has also committed USD 5 billion credit disbursement by the year 2030. Call for Expression of Interest (CEI) for fast-tracking projects and solar portfolio development in ISA member countries led to the identification of a project portfolio of 227 projects from 55 countries. Of these, 119 projects from 46 countries had already secured funding, where ISA has undertaken capacity building to create employment and attract further investment on a need basis.

On 26th March 2018, the Headquarter Agreement was signed between the Government of India and ISA. The Government of India has allotted 5 acres of land to ISA in the National Institute of Solar Energy (NISE) campus

and released a sum of ₹1450 million for creating a corpus fund, building infrastructure and recurring operational expenses. The Public Sector Enterprises of India have also contributed USD 12 million for augmenting the ISA corpus fund. The Government of India issued a Gazette Notification on application of UN (Privileges and Immunities) Act, 1947 to representatives and officers of ISA. The Ministry of External Affairs, Government of India has also set aside USD 2 billion for solar projects in Africa out of its line of credit in close coordination with ISA countries in Africa.

The First Assembly of the ISA was held on 3rd October 2018 in New Delhi (Figure 6.10). Thirty-seven ISA member countries, including India and France, attended the Assembly. In addition, 25 countries that have signed the Framework Agreement but are yet to ratify, 13 prospective member countries that are yet to sign the Framework Agreement; and 3 Partner countries that are beyond the inter-tropical zone attended the Assembly as Observers. The meeting provided a platform for experts to discuss energy needs within the region and to identify hurdles in cooperation and coordination among concerned agencies. In the First Assembly *inter-alia* India's resolution for amending the Framework Agreement of the ISA for opening up the ISA membership to all countries that are members of United Nations was also adopted.

6.2.2 Mission Innovation (MI)

Mission Innovation (MI) is a global initiative to accelerate widespread public and private clean energy innovation for an effective long-term global response towards climate challenge. The aim is to provide affordable and reliable energy for everyone and promoting economic growth, which is critical for energy security (Figure 6.11). India, along with 22 other countries and the EU is a member of all seven MI challenges for clean energy development and is a co-lead in three challenges on smart grid, off-grid and sustainable bio-fuel. Department of Biotechnology, Government of India, is the coordinating agency for MI programmes in India. Indian participation and progress has been appreciated and acknowledged by MI.

MI was established as it was felt that the present set of technologies will not be sufficient to meet the challenge and thus new innovative technologies are required. It was also felt that advanced R&D in these new technologies can effectively take place by collaboration between the member countries.

Figure 6.11: Inaugural Mission Innovation Ministerial, San Francisco, USA

MI programmes being undertaken jointly by MI countries lead to information sharing, current status of R&D in the concerned area and bring together subject matter experts on a common programme. This exercise is very helpful to avoid reinventing and brings in focus to the R&D objectives. Each country is free to select the areas in a given innovation challenge that are relevant and important for that country. There is a provision of exchange of researchers among the participating countries.

The selection of latest R&D programmes jointly with MI countries and exchange of scientists lead to capacity building in the areas which still have low Technology Readiness Level (TRL). Under MI, India has announced several joint R&D programmes covering different innovation challenges in clean energy technologies and the response of the Indian scientific community has been overwhelming. This initiative shall lead to tremendous

capacity building as a large number of Indian researchers and PhD students will get much-needed exposure to the latest developments in clean energy technologies.

Each country funds its own R&D programmes according to its national needs and matching funding announcements may be made by different countries. However, at present, there is no provision of common pool funding by MI. R&D funds are made available by each country according to the accepted mandate of doubling the R&D funding by 2020 from the base year of 2015. Currently, MI is working on developing different multi and bilateral collaboration models among MI countries (DBT, 2018).

6.2.3 Kigali Amendment

The 28th meeting of the Parties to the Montreal Protocol on Substances that Deplete the Ozone Layer, held in Kigali, Rwanda, in 2016 adopted an amendment to the Protocol for phasing down the Hydrofluorocarbons (HFCs) within a specific time frame in the interest of protecting the environment from adverse effects of global warming related to its production and consumption. HFCs have a high global warming potential, and their phase down under the Kigali Amendment is estimated to have the potential to avoid temperature rise up to 0.5°C by the year 2100.

Under the Kigali Amendment, the developed countries have undertaken to phase down HFCs by 2036. It has been agreed that the developing countries will have a differentiated time schedule for such phase down. There are two sets of baselines agreed for the purpose of phase down by developing countries. While China and a few other countries will have 2020-2022 as their baseline, India along with some of the developing countries will have 2024-2026 as the baseline years, with a commitment to freeze production and consumption in 2028. The freeze year can be deferred to 2030 subject to a technology review. In addition to production and consumption of HFCs in the baseline year, 65% of Hydrochlorofluorocarbons (HCFCs) baseline has also been added to provide for an adequate carbon space for the development of the country. India has undertaken to complete its phase down in 4 steps from 2032 onwards with a cumulative reduction of 10% in 2032, 20% in 2037, 30% in 2042 and 85% in 2047.

On India's insistence, the energy efficiency of refrigeration and air conditioning equipment while transitioning away from HFCs was included in the Amendment. India also piloted an agreement with respect to enhanced support for the servicing sector as part of agreed finance solutions. In addition, the costs of patents and designs and the incremental cost of royalties have been included as agreed cost elements for support by the Multilateral Fund for Implementation of the Montreal Protocol.

It is recognized that about 80% of the total emissions associated with active refrigeration and air conditioning (RAC) technologies are because of energy consumption. To address the need to have an integrated long-term vision towards cooling requirement and ways and means to address the same, the process for development of a Cooling Action Plan was initiated. India is the first country to develop and put in the public domain such a plan. The India Cooling Action Plan (ICAP), presently at the draft stage, seeks to address the cooling requirement across sectors and lists out actions which can help reduce the cooling demand and thus help in reducing both direct and indirect emissions. The ICAP seeks to provide an integrated vision towards cooling across sectors encompassing *inter-alia* reducing cooling demand, refrigerant transition, enhancing energy efficiency and better technology options with a 20-year time horizon.

In the past, while phasing out Ozone Depleting Substances, India has consciously chosen a path for environment-friendly and energy efficient technologies, unlike many of the developed countries. India is among the few countries globally, and a pioneer in some cases, in the use of technologies which are non-ozone depleting and have a low global warming potential (MoEFCC, 2018).

6.2.4 Bilateral Cooperation

The Government of India has entered into Memorandum of Understanding (MoU) and Agreements with different countries to achieve its climate change and sustainable development goals. An illustrative but not exhaustive list of the MoUs and Agreements signed by India is provided in Appendix 2. It covers a wide range of issues under climate change and energy sector, echoing India's desire and commitment to work in partnership with the international community to address the challenge of climate change.

6.3 Adapting to climate change

6.3.1 Disaster management

Due to its unique geo-climatic and socio-economic conditions, India is vulnerable (in varying degrees) to floods, droughts, cyclones, urban flooding, landslides, avalanches and forest fire. Out of the 36 States and Union Territories in the country, 27 are disaster prone. 12% land is prone to flood and river erosion; of the around 7,500 km coastline, 5,700 km is prone to cyclones; 68% of the cultivable land is vulnerable to drought; hilly areas are at risk from landslides and avalanches; and 15% of the landmass is prone to landslides. Disaster risks in India are further compounded by changing demographics and socio-economic conditions, unplanned urbanization, development within high-risk zones, environmental degradation, climate change, geological hazards, epidemics and pandemics. To strengthen disaster preparedness and to manage its impacts, several legal regulations were implemented.

The Government of India enacted a Disaster Management Act in 2005, providing a holistic approach to disaster management. The Act is a paradigm shift from the 'response and relief' centric to a 'prevention-mitigation and preparedness' centric management approach. It lays down the institutional, legal, financial and coordination mechanisms at the national, state, district and local levels, for drawing up and monitoring the implementation of the disaster management plans, ensuring measures by various wings of the Government for prevention and mitigation of the effects of disasters and prompt response to any disaster situation.

Under this Act, a National Disaster Management Authority (NDMA) was also set up in 2005. It has the responsibility of laying down policies on disaster management and issuing guidelines to be followed by different Ministries/ Departments of the Government of India for the purpose of integrating Disaster Risk Reduction (DRR) measures in their development plans and projects. It is responsible for preparing the National Disaster Management Plan (NDMP). The NDMP was launched in May 2016 and incorporates the approach enunciated in the Sendai Framework for Disaster Risk Reduction while also integrating the principles of the Paris Agreement and SDGs. NDMA lays down guidelines to be followed by the States in drawing up their respective State Disaster Management Plans (SDMPs). SDMPs are prepared by the State Disaster Management Authorities. 35 States/UTs have already prepared their SDMPs and shared them with NDMA. NDMA has laid down National Disaster Management Guidelines for 26 themes including cyclones, floods, drought, landslides, nuclear emergencies and biological disasters.

The National Institute of Disaster Management (NIDM), a think tank of the Government of India, has been set up at New Delhi to work on all aspects of disaster management capacity building including policy planning, research, training, awareness creation and documentation. NIDM works in partnership with the concerned agencies within and outside the country. A dedicated and specialized National Disaster Response Force (NDRF) has been constituted for the purpose of specialised response to a threatening disaster situation or disasters/emergencies, both natural and man-made.

The National Policy on Disaster Management (NPDM) was approved by the Union Cabinet on 22nd October 2009 with the vision "To build a safe and disaster resilient India by developing a holistic, proactive, multi-disaster oriented and technology driven strategy through a culture of prevention, mitigation, preparedness and response". NPDM provides for an integrated management approach emphasising on building strategic partnerships at various levels. The institutional mechanism put in place at the centre, state and district levels helps states to manage disasters in an effective manner. This policy has been fruitful in developing a holistic, proactive, multi-disaster-oriented and technology-driven approach in the country.

A flexi fund has been created to earmark specific share of all centrally sponsored projects for facilitating disaster resilience capacities. Disaster education has also been integrated into environmental education at various levels.

A World Bank supported 'National Cyclone Risk Mitigation Project' is being implemented with the objective to reduce vulnerability to cyclone and other hydro-meteorological hazards of coastal communities in project states (Kerala, Gujarat, Goa, Karnataka, Maharashtra, West Bengal, Andhra Pradesh and Odisha), and enhance the capacity of the state entities to effectively plan for and respond to disasters (NPDM, 2018).

6.3.2 National Mission on Sustaining the Himalayan Ecosystem

The National Mission on Sustaining the Himalayan Ecosystem (NMSHE) is one of the eight national missions under the National Action Plan on Climate Change (NAPCC). The mission focuses on conservation measures for sustaining and safeguarding the Himalayan ecosystems through the establishment of a monitoring network, promotion of community-based management, human resource development, and strengthening regional cooperation (Figure 6.12). Major initiatives include establishment of a Centre for Himalayan Glaciology at the Wadia Institute of Himalayan Geology, Dehradun. Under the mission, State Climate Change Cells (SCCC) in the

Himalayan States have been set up. These cells provide support for vulnerability and risk assessment studies at district and sub-district levels as well as for institutional and capacity building. At the state level, a training institute or a university has been designated for conducting the capacity building programmes. A training manual has also been developed following a consultative process. The manual provides information on climate change impacts and risk mitigation and adaptation measures in the Indian Himalayan region.

Figure 6.12: Agricultural fields in Kailash Sacred Landscape, Pithoragarh, India.

In addition, MoEFCC launched the National Mission on Himalayan Studies in 2015 with a focus on building a body of scientific and traditional knowledge on conservation and management of the Indian Himalayan ecosystem (MoEFCC, 2018).

6.3.3 National Water Mission

Government of India initiated the National Water Mission (NWM) as one of the eight national missions of NAPCC, with an objective of 'conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management'. Table 6.1 presents the progress against NWM goals.

Table 6.1 Progress on NWM goals

S No	NWM Goal	Achievement (as on 9th August 2018)
1	Comprehensive water data base and assessment of the impact of climate change on water resources	Comprehensive water data base in public domain is hosted on the India WARIS website. For assessment of the impact of climate change on water resources, studies on impact of climate change on 7 river basins – (Mahanadi, Mahi, Luni, Tapi, Sabarmati, Subarnarekha and western flowing rivers from Tadri to Kanyakumari) are being by conducted by expert national institutions.
2	Promotion of citizen and state action for water conservation, augmentation and preservation	Under capacity building programmes, more than 14,259 participants were trained on issues related to water conservation, water use efficiency, participatory irrigation management, etc.
3	Focused attention on vulnerable areas including over exploited areas	Asian Development Bank (ADB) study on 'Mainstreaming Integrated Flood Management under Climate Change in Burhi Gandak basin in Bihar and Brahmani-Baitarani basin in Odisha', along with a pilot project being, carried out in Gujarat, on cost-effective water purification and desalination technologies.

4	Increasing Water Use Efficiency by 20%	Around 26 baseline studies for improving Water Use Efficiency (WUE) in the irrigation sector undertaken in the states of Assam, Manipur, Telangana, Andhra Pradesh, Maharashtra and Kerala. A scoping study for a National WUE for major and medium irrigation projects has been completed. Two pilot projects in Gujarat and Madhya Pradesh have been completed for increasing water use efficiency. Efficiency labeling of water appliances and fixtures is being done for washing machine, water purifier, dish washer, tap, bath shower and cistern in partnership with Bureau of Indian Standards (BIS). Benchmarking study in industrial water use for Thermal Power plants, Textile, Pulp & Paper and Steel Industry is being undertaken. A pilot project on Grey Water to Blue Water for developing natural treatment techniques for the reusing wastewater is being undertaken.
5	Promotion of basin-level integrated water resources management	State Specific Action Plans (SSAP) for the water sector in respect of 11 States (Andhra Pradesh, Telangana, West Bengal, Uttarakhand, Gujarat, Karnataka, Madhya Pradesh, Maharashtra, Odisha, Tamil Nadu and Arunachal Pradesh) have been taken up in first phase and the remaining states will be taken up subsequently.

Source: LS US Qs 3856, 09.08.2018

6.3.4 Agriculture and allied sector

Many initiatives have been launched to enhance farmers' income while reducing the impact of climate change. *'Krishonnati Yojana'* is an umbrella scheme comprising 11 schemes. The aim is to ensure a holistic and scientific development of the agriculture and allied sector, thereby augmenting income of farmers by enhancing production, productivity and returns. The *'Pradhan Mantri Fasal Bima Yojana'* provides insurance coverage and financial support to farmers in the event of failure of any of the notified crops as a result of natural calamities, pests and diseases. It aims to stabilise the income of farmers to ensure their continuance in farming and to encourage farmers to adopt innovative and modern agricultural practices. In the first year of scheme launch, i.e., 2016-17 the claim ratio was as high as 73% despite being a good monsoon year. Overall ₹153.4 billion were paid to 13.9 million farmers in 2016-17 alone (PIB, 2018).

The *'Rastriya Krishi Vikas Yojana'* (RKVY) provides flexibility for selection, planning, approval and execution of projects/programmes under the scheme as per their need, priorities and agro-climate requirements. This programme facilitates climate adaptation in agriculture in a number of ways. High Yield Variety Programme (HYVP) promotes crop productivity by cultivating new varieties that sustain high inputs to meet increasing food demand and self-sustenance in production and develop improved irrigation technologies with relaxed financial support by the Reserver Bank of India (RBI) through the Central Cooperative Banks. National Food Security Mission is an initiative directed at achieving food security and improved nutrition and promoting sustainable agriculture. The Mission targets additional production of food grains in a sustainable manner. The mission for Integrated Development of Horticulture is a centrally sponsored scheme aimed at the holistic growth of the horticulture sector, covering fruits, vegetables, root and tuber crops, mushrooms, spices, flowers, aromatic plants, coconut, cashew, cocoa and bamboo.

Realizing the immense scope for development of fisheries and aquaculture, a Central Plan Scheme, 'Blue Revolution: Integrated Development and Management of Fisheries (CSS)' provides for a focused development and management of the fisheries sector to increase both fish production and fish productivity from aquaculture and fishery resources of the inland and marine fisheries sector, including deep sea fishing. The Blue Revolution is being implemented to achieve economic prosperity of fishermen and fish farmers while contributing towards national food and nutritional security through optimum utilization of water resources for fisheries development in a sustainable manner, keeping in view the bio-security and environmental concerns. Under the scheme, it has been targeted to enhance the fish production from 10.8 million tonnes in 2015-16 to about 15 million tonnes by the end of the financial year 2019-20.

The initiatives in the livestock sector mainly focus on the control of animal diseases, scientific management and upgradation of genetic resources, increasing the availability of nutritious feed and fodder, sustainable development of processing and marketing facilities and enhancement of production and profitability of livestock and fisheries enterprises. Schemes that are being implemented in this sector include the National Mission of Protein Supplement (NMPS), National Livestock Mission, National Control Programmes of Major Animal Diseases and National Programme of Bovine Breeding and Dairy Development.

6.4 Additional initiatives in energy and industry sector

6.4.1 Environment Impact Assessment

Environment Impact Assessment (EIA) is a management tool for environmental conservation which also helps in addressing the adverse impacts of climate change. MoEFCC has taken a number of steps for ensuring the effective implementation of this tool through measures like e-governance, which has led to a substantial

reduction in the time taken for processing and granting approvals based on scientific and technical inputs. In this context, the Government of India launched *'PARIVESH'* (Pro Active and Responsive facilitation by Interactive and Virtuous Environmental Singlewindow Hub), a Single-Window Integrated Environmental Management System for expeditious and transparent clearances in environment, forest, wildlife and coastal regulatory zone. The Ministry is using EIA to promote climate-friendly sustainable infrastructure development. One such example is related to the building and construction sector. Under the EIA process, the Ministry gives higher priority for environmental clearance to construction projects which have obtained green building rating by integrating a high-level of environmental norms into their building plans.

6.4.2 *SAMEEEKSHA*

Sameeeksha is a e-platform providing comprehensive information as well as an opportunity to the representatives of Micro, Small & Medium Enterprises (MSME) sector for an interface with policymakers, funding and development agencies, R&D institutions and academia to promote energy efficiency and best operating practices in the sector. This platform is supported by the Ministry of MSME, Bureau of Energy Efficiency, Swiss Agency for Development and Cooperation and Shakti Sustainable Energy Foundation. The secretariat of *Sameeeksha* is housed at The Energy Resource Institute (TERI). A MSME Energy Map has been developed, which is a dynamic tool that provides insights into energy-intensive MSME clusters across the country, on which detailed energy-related information and data is available. So far, the *Sameeeksha* database accounts for about 27.3 Mtoe of energy consumption in 109 MSME clusters across the country (*sameeeksha*.org, 2018).

6.4.3 Super-efficient Equipment and Appliance Deployment (SEAD)

India is a member country of the Super-efficient Equipment and Appliance Deployment (SEAD) initiative, which is a voluntary collaboration among governments working to promote the manufacture, purchase, and use of energy-efficient appliances, lighting, and equipment worldwide. SEAD is an initiative under the Clean Energy Ministerial (CEM). The SEAD Initiative works with manufacturers, purchasers, purchase influencers, and policymakers to award feature-rich, energy-efficient products that provide top-quality services while reducing energy costs (CEM, 2016).

6.4.4 *PAHAL* – Mass Collaboration for Clean Cooking Fuel

The Ministry of Petroleum and Natural Gas (MoPNG), Government of India, launched a modified Direct Benefit Transfer of LPG (DBTL) scheme '*Pahal* (*Pratyaksh Hanstantrit Labh*)' in 54 districts on 15th November 2014, which was extended to the entire country on 1st January 2015.

Figure 6.13: *PAHAL* acknowledged by Guinness Book of World Records (2015)

Liquefied Petroleum Gas (LPG) is used in most urban and rural households and is subsidized. To reduce subsidies, a programme was launched to encourage well-to-do households to voluntarily give up their LPG subsidy so that it could be targeted to the poor who generally use fuelwood, cow dung, crop residue and coal as cooking fuel. Data from the MoPNG indicates that as of January 2018, more than 0.57 million households had voluntarily surrendered their LPG subsidy. The availability of subsidy encourages people to move away from fuelwood, cow dung and crop residue to LPG.

LPG consumers who join the *PAHAL* scheme will get LPG cylinders at market price and receive LPG subsidy (as per their entitlement) directly into their bank accounts.

In 2015, *PAHAL* was acknowledged by the Guinness Book of World Records for being the largest cash transfer programme, with 125.7 million households receiving cash transfer as of 30th June 2015 (PIB, 2015) (Figure 6.13).

As on 1st March 2018, around 198.8 million LPG consumers have joined the scheme and an amount of ₹6,80,203.5 million has been transferred to the bank accounts of LPG consumers since the inception of the scheme (PIB, 2018). Direct transfer modality under the scheme has ensured substantive savings on supply of LPG consumers to the households by replacing inactive accounts.

6.5 Knowledge management

6.5.1 Satellite-based application and observation

India's *Bhuvan* web portal

Indian Space Research Organization (ISRO) conducts customized training on climate change and meteorological applications. It has developed a web portal called *Bhuvan* to facilitate climate change studies that provides visualisation services and Earth observation data to users in public domain. *Bhuvan* made a modest beginning in 2009 with simple display of satellite data and basic GIS functionality with many thematic maps on display. Presently, more than 6,000 map services are offered by *Bhuvan*.

Meteorological and Oceanographic Satellite Data Archival Centre (MOSDAC) is a data repository for ISRO missions dealing with meteorology, oceanography and tropical water cycles. Data acquired from different missions is disseminated real time through its website. ISRO has formulated the National Information System for Climate and Environment Studies (NICES) with the mandate to build an information base for climate change impact assessment and mitigation. The program works under the guidance of NICES Programme Management Council (NICES-PMC) with representatives from inter and intra-departmental institutions. The NICES portal hosts data on a variety of Essential Climate Variables such as terrestrial, ocean, atmospheric and cryospheric (*Bhuvan* Indian Geo-Platform for ISRO, 2018).

Satellite-based observations

In the following paragraphs, some key satellite-based observational programmes, being undertaken by ISRO are listed.

Coral reefs

Indian coral reefs have experienced widespread bleaching events since 1989. Climate change is expected to fundamentally alter the attractiveness of coral reefs through inevitable reduction in biodiversity. The existing, medium to high resolution, broadband, multi-spectral sensors provide synoptic data on live coral cover at community level, albeit to limited capability. The live coral cover assessment through space-based imaging is confined to emergent, shallow, reef flat environments preferably at low tides. The coral reef features have been mapped using LISS-IV data. ISRO has developed a two-stage conceptual model on coral reef health using multispectral IRS satellite imageries and field data.

Snow and glaciers

Himalayan Cryosphere plays an important role as a sensitive indicator of climate change and as a major source of water for northwest to northeast Indian region. Himalayan snow cover monitoring for 33 sub basins of Indian region is being carried out since 2004 (during October to June) using AWiFS data of Resourcesat-2 satellite at every five-day interval. The analysis of the snow cover products, shows no significant increase or decrease in snow cover during 2004-2016 timeframe. The glacier inventory carried out on 1:50,000 scale using Resourcesat-1 AWiFS and LISS III satellite data shows 34,919 glaciers covering 75,779 sq km area in Indus, Ganga and Brahmaputra basins of Himalayan–Karakoram region. Changes in two thousand eighteen glaciers of Himalayan region have been observed for the timeframe between 2000 and 2010/2011 using multi-date satellite data. The analysis depicted that 87% of the glaciers showed no change, 12% retreated and 1% glaciers have advanced. A Himalayan Glacier Information System (HGIS) has been developed.

In addition, six hundred and seven (607) glaciers of the Karakoram region were also monitored using satellite data of 1977-2013. 341 glaciers exhibited no change throughout the 36 years of the study. In remaining glaciers, fluctuations have been seen, however no sustained pattern of retreat or advance was observed.

Wetlands

Wetlands are among the most productive ecosystems of the world although they account only about 4% of the earth's ice-free land surface. ISRO has carried out extensive research work during the past two decades to address various issues related to Indian wetlands through development of standard classification system, atlas and creation of spatial digital database and a retrieval system.

Desertification

Desertification and Land Degradation Atlas of India (based on IRS AWiFS data for time frame 2011-13 and 2003-05) were prepared. It contains desertification /land degradation status maps depicting land use, process of degradation and severity level along with area statistics consolidated for entire country as well state-wise for 2011-13 and 2003-05 time frame.

Solar and wind energy potential

To augment India's renewable energy share, assessment of the assured potential of such resources is a basic need. Frequent observation of solar insolation using weather satellites has helped to derive the assured solar potential. An application has been developed which provides information on monthly and yearly potential solar, wind and wave energy at a location. Such information is required for locating potential sites for extracting/tapping new and renewable energy resources.

One such example is rooftop solar power availability at various locations of India. The MOSDAC website provides the technical solar energy potential peak power generation potential, built-up area, temperature profile and optimum tilt-angle of solar panels for smart and solar cities in India. It provides the monthly average solar insolation and air temperature, annual sun path and daily solar hours for each of these cities as well as at any given location in India.

Alpine Treeline Ecotone

ISRO has also established a multi-summit approach based on long-term ecological record sites, known as a network of "HIMADRI" (Himalayan Alpine Dynamics Research Initiative) in partnership with subject expert institutions to study changes in the Alpine treeline ecotone due to climate change. This will map species level migration. The archived satellite data (from 1976 to 2014) show that the alpine ecosystem is definitely undergoing changes and alpine treeline has shifted upward with the positive greening trend observed at the alpine treeline ecotone.

The satellite information thus collected will contribute in strengthening country's scientific response towards addressing the impacts of climate change.

6.5.2 Long-Term Ecological Observatories

The Long-Term Ecological Observatories (LTEO) programme aims to understand the biophysical and anthropogenic drivers of ecosystem change in the selected biomes and their effects on socio-ecological responses by involving a number of expert scientific institutions of the country. A 'Science Plan' of LTEO was released during the 21st UNFCCC CoP at Paris in December 2015.

The activities under this programme include experimental work to assess the change of structure and function in the natural ecosystems, identification of patterns and drivers of change in the natural ecosystems by monitoring populations of freshwater fish, birds, mammals, animal movements, soil processes in forests and grasslands and biophysical climatic variables. The LTEO programme is site-based, covering the range of diversity and complexity of representative landscapes in the country to understand the link between climate change and ecological processes.

6.5.3 National Carbonaceous Aerosols Programme (NCAP)

The National Carbonaceous Aerosols Programme (NCAP) aims to study carbonaceous aerosols. This programme is being implemented by a consortium of 17 leading research institutions that are engaged in the preparation of the inventory of carbonaceous aerosols including black carbon, development of national emission factors, as well as conducting modelling studies and assessing their impact on the regional and global climate system. The programme focuses on the sources and impacts of carbonaceous aerosols on climate and air quality in the Indian region while reducing uncertainties in existing scientific understanding of the subject.

6.5.4 Developing scientific understanding of the impacts of mitigation through modelling exercise

NITI Aayog, Government of India, undertook a series of modelling exercises on various mitigation-related aspects. The results of this initiative are presented below.

a. Study on Water Energy Nexus: The study shows that there is reduction in water withdrawal when water conservation rules of MoEFCC are effectively implemented in Thermal Power Plants. Decline in water withdrawal occurs due to switching to efficient cooling tower technology and shift in share of power capacity from fossil fuels to renewable energy (Srinivasan et al., 2018).

b. Study to Access Water Foot Prints of India's Long-Term Energy Scenarios: This study, among other things, assessed the impact of *Pradhan Mantri Krishi Sinchayee Yojana* (PMKSY), a national scheme to expand cultivated area with assured irrigation, reduced water wastage and improved water use efficiency. The PMKSY scenario result show that water saving is possible in the agriculture sector, which could be extremely helpful in reducing future water stress for other sectors like domestic and industrial (TERI, 2017).

c. Study to Assess Mitigation Impact of Transport Sector Decarbonisation: The results of this study show that increased fuel efficiency and modal shift towards public transportation will have a high potential for CO_2 emissions reduction (Paladugula et al., 2018).

d. Inhouse-Energy Modelling for Climate Change Mitigation: To develop in-house capacity, steps were taken to develop an energy model at NITI Aayog. An energy systems model, using the MESSAGEix (Huppmann et al., 2018) platform of International Institute of Applied System Analysis, was developed. Through sensitivity analysis, the modelling results show increase in solar penetration with decrease in solar cost (Thambi et al, 2018).

6.6 GHG platform India – A civil society initiative

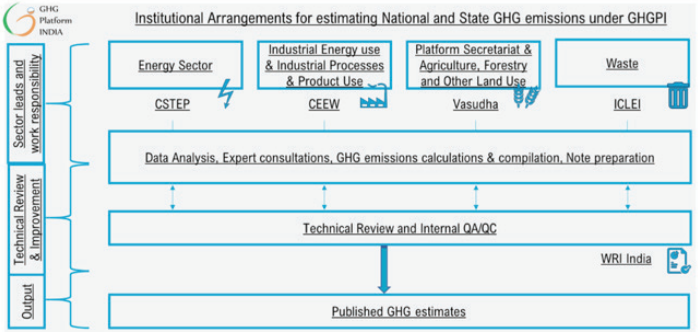


Figure 6.14: GHG Platform India

India has a vibrant civil society network and range of climate change actions are being undertaken by these organizations across the country. GHG Platform India is one such initiative which was set up in 2015. The Platform comprises Council on Energy, Environment and Water (CEEW), Center for Study of Science, Technology & Policy (C-STEP), ICLELI – Local Government for Sustainability, Vasudha Foundation and World Resources Institute (WRI) India, in addition to a few sectoral experts. The Platform provides an independent estimation and analysis of India's GHG emissions across key sectors, namely Agriculture Forestry and Other Land Use (AFOLU), Energy, Industry and Waste. The platform is funded by Shakti Sustainable Energy Foundation.The schematic diagram of GHG Platform India is presented in (Figure 6.14).

6.7 Communication and outreach

India recognizes the need and importance of education, training and awareness in facilitating and enhancing participation of people in climate action. The communication and outreach programmes are broadly focussed on harmonizing traditional and modern climate-friendly values and practices. Some of the major initiatives undertaken by India in creating awareness on climate action among different stakeholders are presented below.

6.7.1 Science Express Climate Action Special

India is a diverse country with 22 official languages and thousands of local dialects, traditions, customs and beliefs which identify the communities as well as bring them together to work for the betterment of the country. Indian Railways is a unique connecting medium which has been used by the Government of India to create and promote awareness on various environment-related issues including climate change (Figure 6.15).

Figure 6.15: Children visiting the Science Express Climate Action Special

Mounted on a 16 coach AC train, Science Express is an innovative mobile science exhibition of the Department of Science & Technology (DST), Government of India, running across the country since 2007. Till date, this unique mobile exhibition has completed its 9 phases which includes, 4 phases of 'Science Express', 3 phases of

'Biodiversity Special' (SEBS) and 2 phases of 'Climate Action Special' (SECAS), travelling more than 160,800 km and reaching out to more than 20 million people (Figure 6.16).

Figure 6.16 Route of Science Express – Phase IX

Figure 6.17: Inside view of SECAS coach

Science Express has been recognized as the longest running mobile science exhibition with the largest climate change awareness programme. Science Express has a total of twelve entries in the Limca Book of Records, including one world record.

The SECAS is a unique collaboration initiative of MoEFCC, DST, Department of Biotechnology and Ministry of Railways, Government of India, and Vikram A Sarabhai Community Science Centre. The basic objective of SECAS was to enhance understanding of climate change science, its impacts and possible responses (Figure 6.17).

A booklet on "Climate Action: We Must Not Delay" was brought out for students, providing facts and information on various topics such as global warming, carbon footprints, deforestation, human health, glacier melt, biodiversity loss, how to reduce carbon footprint, and the Paris Agreement. The booklet was printed in 11 Indian languages. English and Hindi braille versions were also prepared (Science Express, 2018).

6.7.2 Environment education

Environment Education, Awareness and Training (EEAT) is a MoEFCC scheme aimed to promote environment awareness among children and youth across the country. The programme has three major components, namely, National Green Corps (NGC) / Eco-club Programme, National Nature Camping Programme (NNCP) and Capacity Building activities.

Figure 6.18: Plantation drive by children under NGC

Under the NGC programme, eco-clubs are set up in schools across the country which provide education, training and awareness on various environmental themes such as biodiversity conservation, waste management, climate change mitigation and adaptation issues (Figure 6.18). During the financial year 2017-18, the financial support to eco-clubs has doubled from ₹2,500 to ₹5,000 per eco-club. The programme supports about 90,000 eco-clubs across the country (MoEFCC, 2018).

Under the EEAT scheme, "*Prakriti Khoj*", an online environment quiz was launched on 5th September 2017 as an interactive learning tool on environment protection and conservation. Web portal *www.pkeq.nic.in* is the quiz portal wherein registered students of the NGC programme of the age group 8-12 years, 13-15 years and 16-18 years are eligible to participate.

6.7.3 Green Good Deeds

Green Good Deeds (GGD), a societal movement launched by the Union Minister for Environment, Forest and Climate Change, Dr Harsh Vardhan, to protect the environment and promote good living in the country, has found acceptance by the global community (Figure 6.19).

Figure 6.19: Infographic on Green Good Deeds

During the BRICS Ministerial on Environment in 2018 at Durban, South Africa, GGD was agreed to be adopted as part of the official agenda in its next Ministerial meetings. GGD has been accepted by United Nations Environment Programme (UNEP) and steps are undertaken for wider dissemination.

GGD are small voluntary positive actions to be performed by individuals or organisations to strengthen the cause of environmental protection.

MoEFCC has drawn up a list of over 500 GGDs which are designed as infographics and shared through social media platforms, television and radio channels. The programme is also implemented across eco-clubs set up under the NGC programme of the Ministry focusing on various themes like waste segregation, air pollution, climate change and sustainable lifestyles.

6.7.4 Media fellowship

Both at the central and state level, several initiatives are being undertaken to sensitize the media on various environmental issues. The DST is also providing assistance for organizing media workshops to sensitize the media community about success stories and practices on climate change adaptation. In partnership with the Indian Himalayas Climate Adaptation Programme (IHCAP), DST has organized a series of state-level media workshops on adaptation to climate change. On an average two such workshops are being organized in each state annually. Also, a three-month fellowship programme has been launched for environment journalists, across all media, to report in-depth about climate change impacts on Himalayan communities and how they are responding to and coping with the impacts.

6.7.5 Energy conservation day and award

Since 1991, the National Energy Conservation Day is celebrated in India to connect people across sectors (homes, offices and industries) on the issue of energy efficiency. On this day, the National Energy Conservation Awards instituted by the Bureau of Energy Efficiency (Ministry of Power, Government of India) are given as national recognition towards innovation and achievements in the energy sector. As on 2017, around 322 industrial units and establishments from key sectors participated in the National Energy Conservation Awards. Additionally, a variety of energy conservation competitions for school students were also organized wherein more than 12.2 million children participated in the National Painting Competition.

In 2017, an interactive online portal, ECO-NIWAS (Energy Conservation – New India Way for Affordable & Sustainable homes), was launched for increasing awareness in building sustainable and energy-efficient homes in the country.

References

Bhuvan Indian Geo-Platform for ISRO website - https://nrsc.gov.in/nices

CEM. (2016). SEAD Announces International Competition to Recognize the Most Efficient Industrial and Outdoor Lighting. Clean Energy Ministerial. Retrieved from http://www.cleanenergyministerial.org/News/sead-announces-international-competition-to-recognize-the-most-efficient-industrial-and-outdoor-lighting-73913

DBT. (2018). Communication from DBT. Email dated 22nd November 2018

GoI. (2018). Lok Sabha Unstarred Question No 3856, National Water Mission. Ministry Of Water Resources, River Development & Ganga Rejuvenation. Lok Sabha Secretariat website

Huppmann, D., Gidden, M., Fricko, O., Kolp, P., Orthofer, C., Pimmer, M., Krey, V. (2018). The MESSAGEix Integrated Assessment Model and the ix modeling platform (ixmp). Environmental Modelling & Software. Retrieved from http://pure.iiasa.ac.at/id/eprint/15157/

MNRE. (2018). Communication from MNRE. Email dated 12th December 2018

MoEFCC. (2018). Communication from MoEFCC. Email dated 13th December 2018

MoEFCC. (2018). Annual report 2017-18

MoR. (2018). Communication from Ministry of Railways. Email dated 14th December 2018

NIDM. (2018). Communication from NIDM. Email dated 13th December 2018

Paladugula, A. L., Kholod, N., Chaturvedi, V., Ghosh, P. P., Pal, S., Clarke, L., Wilson, S. A. (2018). A multi-model assessment of energy and emissions for India's transportation sector through 2050. Energy Policy, 116(C), 10–18

PIB. (2015). PAHAL – Guinness World Record. 5th December 2015 by PIB Delhi

PIB. (2018). Beneficiaries under DBT. 6th March 2018 by PIB Delhi

PIB. (2018). Solar Panels at Railway Stations. 10th April 2018 by PIB Delhi

PIB. (2018). Cabinet approves continuation of Umbrella Scheme 'Green Revolution — Krishonnati Yojana' in Agriculture. 2nd May 2018 by PIB Delhi

Science Express. (2018). www.scienceexpress-in/index-html

Srinivasan, S., Kholod, N., Chaturvedi, V., Ghosh, P. P., Mathur, R., Clarke, L., Sharma, K. (2018). Water for electricity in India: A multi-model study of future challenges and linkages to climate change mitigation. Applied Energy, 210, 673–684. https://doi.org/10.1016/j.apenergy. 2017.04.079

TERI. (2017b). Study on Assessment of Water Foot Prints of India's Long Term Energy Scenarios

Thambi, S., Bhatacharya, A., & Fricko, O. (2018). India's Energy and Emissions Outlook: Results from India Energy Model. NITI Aayog

Appendix 1

Climate change related programmes, policies, measures and projects at the national level

Description of programmes, policies, measures and projects	Sector	Span	Target	Type of Instrument		Launch Year
National Mission on Green India	Forestry	National	To increase forest & tree cover on 5 Mha area, improve quality of forest cover on another 5 Mha area, to enhance CO_2 sequestration by 50-60 MT by 2020	Regulatory	Regulation/ Rules	2014
Urban Transport Fund	Transport	National	Levy of dedicated taxes to be credited to UTF to be used exclusively to meet Urban transport needs and to serve as a disincentive for personalized vehicles	Economic & Fiscal	Directed Financial Incentives	2014
Pradhan Mantri Jan Dhan Yojana	Financial	National	To Achieve 100% Financial Inclusion	Economic & Fiscal	Directed Financial Incentives	2014
Make in India	Urban	National	To make India a global manufacturing hub, Manufacturing sector to grow over 10%, It will create 10 million jobs per year	Regulatory Measures	Market Development	2014
Swachh Bharat Mission	Urban	National	To make India 100% open-defecation free by 2019, Eradication of manual scavenging is also a part, focus is on attitudinal change	Regulatory Measures	Regulation/ Rules	2014
Sansad Adarsh Gram Yojana	Urban	National	To realize the ideal of Gram Swaraj. It is a village development scheme under MPLADs, One Adarsh Gram in each Lok Sabha Constituency to be developed by its MPs; one Adarsh Gram by 2016 and 3 by March 2019	Regulatory Measures	Market Development	2014
Rashtriya Gokul Mission	Agriculture	National	It aims to conserve and develop indigenous bovine breeds in a focused and scientific manner	Regulatory Measures	Regulation/ Rules	2014
Nagar Van Udyan Yojana	Forestry	National	To create forest parks in 200 cities and to initiate plantation programmes	Regulatory Measures	Regulation/ Rules	2014
Namami Gange Programme	Water	National	It is an Integrated Ganga Conservation Mission, Focus is on pollution abatement and socio-economic development, Implemented under National Ganga River Basin Authority	Regulatory Measures	Regulation/ Rules	2014
Mission *Indradhanush*	Health	National	To achieve full immunization coverage for all children by 2020, Coverage against 7 life-threatening diseases	Regulatory Measures	Regulation/ Rules	2014
Direct Benefit Transfer Scheme for LPG	Financial	National	To plug leakages in subsidized LPG. Subsidy amount transferred to beneficiary account	Economic & Fiscal	Directed Financial Incentives	2014

Description of programmes, policies, measures and projects	Sector	Span	Target	Type of Instrument		Launch Year
Deen Dayal Upadhyaya Antyodaya Yojana	Urban	National	To alleviate poverty in rural & urban areas, to uplift the urban poor people by enhancing sustainable livelihood opportunities through skill development	Regulatory Measures	Regulation/ Rules	2015
Pradhan Mantri Awas Yojana (Housing for All Urban)	Urban	National	To provide housing by 2022 to all eligible, also called Sardar Patel Urban Housing Mission	Economic & Fiscal	Directed Financial Incentives	2015
Digital India	Financial	National	To achieve digitally empowered knowledge economy, Transformed version of National e-Governance Plan, Worth ₹1 lakh crore and has 9 thrust areas	Regulatory Measures	Market Development	2015
Skill India	Urban	National	To fast track skill development efforts, Provides for an overall institutional framework, 300 million will be skilled by 2022. Four initiatives were launched	Regulatory Measures	Regulation/ Rules	2015
Pradhan Mantri Krishi Sinchayee Yojana	Agriculture	National	To achieve water efficiency by 2020, It will be achieved through converging existing programmes, It has an outlay of ₹50000 crore for 2015-20	Regulatory Measures	Regulation/ Rules	2015
Soil Health Card Scheme	Agriculture	National	To improve farm productivity, Achieved by using appropriate nutrients and fertilizers	Regulatory Measures	Regulation/ Rules	2015
Pradhan Mantri Suraksha Bima Yojana	Health	National	It is a accident insurance scheme, offers death and disability cover on account of an accident, For ₹12 premium offers 1-2 lakhs coverage	Regulatory Measures	Regulation/ Rules	2015
Pradhan Mantri Jeevan Jyoti Bima Yojana	Health	National	To provide for life insurance cover to the needy, for ₹330 premium offers ₹2 lakh coverage, Administered by the Life Insurance Corporation	Regulatory Measures	Regulation/ Rules	2015
Atal Pension Yojana	Financial	National	To enhance old age income security of the working poor, Linked to National Pension System & administered by PFRDA, Will get fixed pension between ₹1000 and ₹5000 per month	Regulatory Measures	Regulation/ Rules	2015
Smart Cities Mission	Urban	National	To make urban areas more sustainable & inclusive, Focus is on building urban infrastructure, Outlay of ₹50000 Crore for 2015-20	Regulatory Measures	Market Development	2015
Amrut (Atal Mission for Rejuvenation and Urban Development) Yojana	Urban	National	To provide basic civic amenities like water supply, sewerage, urban transport, parks as to improve the quality of life	Regulatory Measures	Market Development	2015

Description of programmes, policies, measures and projects	Sector	Span	Target	Type of Instrument		Launch Year
Hriday Yojana (Heritage Development and Augmentation Yojana)	Urban	National	HRIDAY - Heritage Development and Augmentation Yojana, To promote inclusive & sustainable development of heritage sites, In Phase 1 - 12 cities will be developed at ₹500 crore	Regulatory Measures	Market Development	2015
Indradhanush for Public Sector Banks	Financial	National	The framework is meant to revamp PSBs, Consists of seven strategies, Includes establishment of Bank Board Bureau and structural reforms	Economic & Fiscal	Directed Financial Incentives	2015
Start Up India	Education	National	To promote bank financing for start-ups	Regulatory Measures	Regulation/ Rules	2015
Nai Manzil Scheme	Education	National	To address educational & livelihood needs of minorities, Focus will be on skill development for 17-35 age group	Regulatory Measures	Regulation/ Rules	2015
Ujwal Discom Assurance Yojana	Renewable Energy	National	To obtain operational and financial turnaround of state-owned power distribution companies	Regulatory Measures	Regulation/ Rules	2015
Unnat Jyoti by Affordable LEDs for All (UJALA)	Renewable Energy	National	To provide LED bulbs to domestic consumers with a target to replace 770 million incandescent bulbs with LED bulbs by March, 2019	Regulatory Measures	System Efficiency	2015
Direct Benefit Transfer Scheme for Kerosene	Financial	National	To plug leakages in kerosene delivery through PDS, Subsidy amount transferred to beneficiary accounts, Implemented in selected 26 districts of 8 states	Economic & Fiscal	Directed Financial Incentives	2016
Pradhan Mantri Fasal Bima Yojana	Agriculture	National	It is a revamped agriculture insurance scheme, Overcomes the shortcomings in the existing schemes	Regulatory Measures	Regulation/ Rules	2016
Shyama Prasad Mukherji Rurban Mission	Urban	National	To develop smart village on the line of smart cities, 300 Rurban clusters developed in 3 years, Has an outlay of ₹5142 crore	Regulatory Measures	Market Development	2016
Pradhan Mantri Ujjawala Yojana	Financial	National	To provide LPG connections to 5 crore BPL families, Financial support of ₹1600 per family, Allocated ₹8000 crores for 3 years	Economic & Fiscal	Directed Financial Incentives	2016
Stand Up India	Education	National	Applicable to SC, ST & Women, it will help in entrepreneurship and job creation	Regulatory Measures	Regulation/ Rules	2016

Mapping of some Programmes, Policies, Measures and Projects for climate change mitigation and related initiatives at the state level

Description of programmes, policies, measures and projects	Sector	State	Target	Type of Instrument
River Bank Stabilisation	Water Resources	Assam	Piloting out approaches for river bank stabilization at three specific locations, introducing geotextile material for river bank training.	Regulatory
Development district wise climate smart adaptation action plans	Agriculture	Assam	Assessing District wise exposure and vulnerability of agriculture systems to climate variability and change and developing climate smart Adaptation Strategies through stakeholder consultation for all 27 districts, taking into consideration the agro-climatic zone in which they are located	Regulatory
Protect irrigation schemes from siltation due to soil erosion	Agriculture	Assam	Plantation of trees every 25 m on both sides of irrigation canals and reservoirs and beside inspection roads- cover 19,244 km	Supportive measures
Water efficient technologies – sprinkler and drop irrigation	Agriculture	Assam	Coverage: small holders in 1/4th of area under small holders	Supportive measures
Restoration of natural fish breeding and feeding grounds	Fisheries	Assam	Eviction of illegal encroachment around the natural water resources. Demarcation, de-silting and removal of aquatic weed of beels and their connecting channels	Regulatory
Intensive Management of Wetlands	Forest and Biodiversity	Assam	Conservation of wetland biodiversity - Recharge of ground water (20) - Collateral benefits to communities (Ecotourism)	Regulatory
Gene Banks (Ex-situ)	Forest and Biodiversity	Assam	Conservation for Biodiversity of the State / Specimen Lab / Herbarium / Multilocation repositories of germplasm, 2 central facilities and 35 site banks	Regulatory
Potable water during floods	Water Resources	Assam	Board mounted WTP (water treatment plants) for flood-affected areas	Regulatory
Small Hydro Policy	Renewable Energy	Assam	90 nos. of potential small hydro generating stations ranging from 0.1 MW to 20 MW (total 148.50 MW), in different parts of the state. However, of this 148.50 MW, only 91.5 MW has the proven potential for small hydro power	Supportive measures
Solar Power	Renewable Energy	Assam	Setting up of 60 MW SPV Power Plant at Amguri, Assam. Setting up of 2 MW SPV Power Plant at Namrup. Setting up of 2 MW SPV Power Plant at Lakwa	Regulatory
Installation of Solar Photovoltaic Power Pack for Anganwadis	Renewable Energy	Gujarat	To install 30,000 Solar Power Packs in Primary Health Centres of the State of Gujarat each consisting of 1 kWh for meeting their electricity requirement. These Power packs will generate 2,70,00,000 units of electricity.	Regulatory
Installation of Solar Pumps for small farmers in Gujarat	Renewable Energy	Gujarat	Installation of 2,000 Solar Pumps (of 2 HP each) for small farmers in Gujarat with minimum holding of 5 acres of land and maximum 30 m water table.	Regulatory
Solar Photovoltaic Rooftop Programme under Gandhinagar Solar City	Renewable Energy	Gujarat	Creation of 5MW Solar Photovoltaic Rooftop Programme under Gandhinagar-Solar City Project under Public Private Partnership mode	Regulatory
Solar Photovoltaic Power Plant at Gandhinagar Thermal Power Station	Renewable Energy	Gujarat	Installation of 3 MW Solar Photovoltaic Power Plant at the Ash Dyke of Gandhinagar Thermal Power Station under Gandhinagar-Solar City	Regulatory
LED lamps in APMCs spread in Gujarat	Renewable Energy	Gujarat	Replacing conventional light with 3090 LED lamps in 183 APMCs in Gujarat, especially in economically weak and tribal belt of the state.	Regulatory

Description of programmes, policies, measures and projects	Sector	State	Target	Type of Instrument
Irrigation development through Micro Irrigation Systems	Agriculture	Gujarat	Efficient use of resources including water/ fertilizer, limiting evaporation, reducing weed growth, and making cultivation possible during and immediately after an irrigation cycle by setting up approx. 900 micro-irrigation units in an area of around 900 acres	Regulatory
Soil Health Improvement through use of Biofertilizers	Agriculture	Gujarat	To safeguard the soil health and improve the quality of crop products by using natural products like Biofertilizers in a total of 67,150 acre area will be covered across Gujarat.	Supportive measures
Climate Change Implications on Crop Growth in Gujarat	Agriculture	Gujarat	Classify land areas and their suitability for growth of crops based on threshold analysis specifically in the context of warmer temperatures; Quantify the impacts of predicted climate change on agricultural output for the following crops – wheat, groundnut and cotton;	Supportive measures
Participatory Irrigation Management	Water Resources	Gujarat	Institutional strengthening and decentralization of water management and enhancement of water use efficiency and crop productivity	Supportive measures
Extension, Renovation and modernization of schemes	Water Resources	Gujarat	To effectively increase the irrigated area in the state	Supportive measures
Water Conservation Scheme through check dams construction	Water Resources	Gujarat	Construction of approx. 4000 checkdams each year in the State	Regulatory
Drought proofing measures for scarcity prone areas	Water Resources	Gujarat	Undertaking drought proofing works in the state for approx. 2000 habitations	Supportive measures
Water and Energy Audit to be extended in the entire state	Water Resources	Gujarat	Undertaking extensive audits for water and energy conservation	Supportive measures
Dug well recharge project	Water Resources	Gujarat	Construction of approx. 4,00,000 dug wells to improve ground water recharge	Regulatory
Creation of Roof-top rain water harvesting structures	Water Resources	Gujarat	Decentralized rainwater harvesting in approx. 40,00,000 Households resulting in additional water availability, reduction of energy footprint due to inadequate pumping, groundwater recharge	Regulatory
Setting up water pumps based on renewable sources of energy	Water Resources	Gujarat	Solar pumps-1000; Wind pumps-500	Regulatory
Project for Desalinization of Sea water	Water Resources	Gujarat	Desalination through setting up 4 desalination plants and 500 Brackish Water desalination plants.	Regulatory
Inter-basin water transfer to water scarce and coastal regions	Water Resources	Gujarat	To balance the water availability in depleted regions and the areas likely to be affected due to climate change.	Regulatory
Save Water and Energy Campaign both at State and village level.	Water Resources	Gujarat	Carrying out community-based campaigns for water and energy awareness through carbon footprinting	Regulatory
Recycling of used water	Water Resources	Gujarat	Wastewater collection, treatment and reuse in 2000 villages	Regulatory

Description of programmes, policies, measures and projects	Sector	State	Target	Type of Instrument
Inventorization of Bio-diversity through identification of important species and their interrelation & independence, Biophysical parameters and understanding impact of Climate Change on Nanikarad Weland as the Pilot Project	Forest and Biodiversity	Gujarat	Potential of carbon sequestration and threats to such wet lands; its utilization patterns & dependence of local communities; Ecosystem services assessment provided by the wetlands; Public participation in conservation & awareness building	Supportive measures
Project on survey of various species for carbon sequestration potential, sustainable production and utillization	Forest and Biodiversity	Gujarat	To study the potential of various forest species to sequester carbon. and give a detailed account of the utilization pattern of various forest species, identify the threats on the species to devise proper conservation plans. It will provide baseline data for the preparation of Forest Working plans	Supportive measures
Activity Development of a research cell at Indian Institute of Public Health (IIPH) Gandhinagar	Health	Gujarat	To strengthen the overall health system in the country through education, training, research, advocacy and policy initiatives	Supportive measures
Heat-stress and health (HSH) impact :Adaption strategies for Gujarat	Health	Gujarat	Planning and management of adaptation solutions to increasing heat wave events focusing on Ahmedabad, Sabarkantha, Surendranagar, Patan, Rajkot and Amreli	Supportive measures
Climate change impact on cities of Gujarat	Urban Development	Gujarat	To provide a framework for the development of Climate Resilience Strategies for the cities of Gujarat	Supportive measures
Rain Water Harvesting for Infrastructure Projects	Urban Development	Gujarat	To conserve water, reducing ground water depletion/dependenc e by rain water harvesting systems for large-scale housing and infrastructure projects taken up by Corporations	Regulatory
The Kerala Conversion of Paddy Land and Wetland Bill, 2007	Agriculture	Kerala	To conserve the paddy land and wetland and to restrict the conversion or reclamation thereof in Kerala	Supportive measures
Kumdumbashree	Agriculture	Kerala	It has helped women farmers to stay on in agriculture for their livelihood. The major crops cultivated by the Kudumbashree group is paddy (27 % of area) followed by plantation and vegetables during 2009-10 under the lease land farming	Supportive measures
Matsya Keralam	Fisheries	Kerala	To enhance the fish production from inland and brackish water areas, create new employment opportunities in rural areas and increase the export of fish and fish products by developing a well-designed marketing system	Supportive measures
Forest profile augmentation	Forest and Biodiversity	Kerala	Identification and survey of ecologically important biomes for notification and preservation as biodiversity heritage sites (BHS) with community participation	Regulatory
Integrated water resource management plan for the forest areas	Forest and Biodiversity	Kerala	Spring recharge and enhancing ground water recharge at areas within the forest that are vulnerable to water stress due to climate change	Regulatory
KRWSA -"JALANIDHI"	Water Resources	Kerala	To facilitate and support year–round supply of adequate quantities of potable water to rural Kerala, through the active participation of the user group themselves.	Supportive measures

Description of programmes, policies, measures and projects	Sector	State	Target	Type of Instrument
Integrated Disease Surveillance Programme	Health	Kerala	Syndromic disease surveillance data collected from the field level (in S form) and health institution level data based on the presumptive diagnosis (P form) and Laboratory confirmed case (L form based) data are collected and analyzed at the district level and forwarded to the state level and from there to the national level	Regulatory
Energy Clinics	Renewable Energy	Kerala	Awareness creation among housewives, who are the true energy managers of the household, is being implemented through women volunteers.	Regulatory
Total Energy Security Mission	Renewable Energy	Kerala	Creating grassroot-level energy security through intensively drawn out plans for decentralized energy generation and demand side management.	Supportive measures
Kerala Sustainable Urban Development Project	Urban Development	Kerala	Improvements, upgradation and expansion of existing urban infrastructure facilities and basic urban environmental services in five Municipal Corporations of the state i.e. Thiruvananthapuram, Kollam, Kochi, Thrissur and Kozhikode.	Regulatory
Lok Vaniki Act	Forest and Biodiversity	Madhya Pradesh	To facilitate the owners of woodlots (forest tree crops on private lands) to grow forestry crops & maintain forests on private lands.	Regulatory
Project Tiger Scheme and Development of National Parks and Sanctuaries Scheme	Forest and Biodiversity	Madhya Pradesh	An eco-development scheme which is a site-specific village (around PAs) level planning by the villagers for sustainable development of village resources	Regulatory
Madhya Pradesh Water Sector Restructuring Project (MPWSRP)	Water Resources	Madhya Pradesh	To improve the productivity of water and integrate 654 schemes (completed prior to 1986) spread over 30 districts of 5 river basin (Betwa, Chambal, Sindh, Ken and Tons).	Regulatory
Promote basin-level integrated watershed management	Water Resources	Madhya Pradesh	Undertake integrated watershed management in identified areas within a basin where livelihood opportunities are being affected due to changes in water resources due to climate change. Department have identified 69 major watersheds in the State in which the declining trend of ground water levels exceeds 0.1 m/ year.	Regulatory
Water conservation, augmentation and preservation with special focus on areas with over exploited conditions of ground water	Water Resources	Madhya Pradesh	Establishing state water authority to monitor regulation, management and allocation of water for different purposes. Particular attention should be given to artificial recharging of groundwater in over exploited regions.	Regulatory
Madhya Pradesh Organic Farming Policy, 2011	Agriculture	Madhya Pradesh	To reduce the impacts of climate change and globalization on agriculture products and increase the productivity.	Supportive measures
State Illness Assistance Programme	Health	Madhya Pradesh	To providing grants to below poverty line cases that need major surgical procedures within and outside the state	Supportive measures
Rogi Kalyan Samiti	Health	Madhya Pradesh	Ensure compliance to minimal standard for facility and hospital care and protocols of treatment as issued by the Government.	Regulatory
Prasav Hetu Parivahan Evam Upachar Yojana	Health	Madhya Pradesh	Medical and transport facility for pregnant women	Regulatory
Madhya Pradesh Housing and Habitat Policy 2007	Urban Development and Transport	Madhya Pradesh	Encompass an ambitious resolution to develop Housing for all ensuring a slumless urban environment, to draft integrated rural development plans in order to Providing Urban amenities in Rural Areas (PURA), to focus on city development plans ensuring sustainability and urban infrastructure & land development	Supportive measures
State Transport Policy 2010	Urban Development and Transport	Madhya Pradesh	To make public transport user friendly by introducing new technology so that more people are able to use the public transport system. It also focuses on introducing faster and safer transport systems like BRTS, ITS etc. and encouraging use of cleaner fuels like CNG.	Supportive measures

Description of programmes, policies, measures and projects	Sector	State	Target	Type of Instrument
Feeder Segregation Program	Renewable Energy	Madhya Pradesh	Strengthening of sub-transmission and distribution infrastructure, including metering at all levels in rural areas	Regulatory
Government efforts to increase Investment	Renewable Energy	Madhya Pradesh	Industrial investment promotion assistance - 50 to 75% of commercial tax for 4-5 years, 5 year electricity duty exemption on captive power generation, For thrust sector industries - 25 % capital subsidy, Interest Subsidy of 3 - 5 % on term loan for 5-7 years, Land on 75 % concessional rate for mega projects, Subsidy on ISO Certification, patent registration & technology acquisition	Supportive measures
MP Industrial Promotion Policy, 2010	Industry	Madhya Pradesh	To ensure faster economic development & employment generation by sustainable use of the resources available in the state, with special attention on promotion of Small & Medium enterprises to avert the adverse impact of global recession on industrialization in MP	Supportive measures
MP Small Scale Industries Revival Scheme, 2010	Industry	Madhya Pradesh	Revival of the sick units in the state while also addressing the issues of outdated technology, lack of skilled workers, inefficient management, lack of professionalism etc.	Supportive measures
Rajasthan Solar Energy Policy 2014	Renewable	Rajasthan	To create an enabling environment for installation of 25,000 MW of solar power through state or private enterprises or through PPP or through individual efforts	Regulatory
Watershed management	Forest and Biodiversity	Uttarakhand	To improve the productive potential of natural resources and increase incomes of rural inhabitants in selected watersheds through socially inclusive and environmentally sustainable approaches	Regulatory
Increasing the seed replacement ratio	Agriculture	Uttarakhand	Technology to produce good quality seeds is being made available to farmers through TDC (responsible for producing, procuring, certifying and distributing quality seeds)	Regulatory
Herbal and medicinal plants	Forest and Biodiversity	Uttarakhand	An increase in the area under cultivation of medicinal and aromatic plants (MAPs). Intercropping of MAPs with foodgrains can help diversify the income basket for small and marginal farmers.	Regulatory
Agro-climatic Planning and Information Bank (APIB)	Agriculture	Uttarakhand	Detailed mapping of natural resources to harness the natural resources in a sustainable manner	Regulatory
Kissan Soochana and Salah Kendra	Agriculture	Uttarakhand	Information and advisement centres are established to advise farmers about technological advances in agriculture	Regulatory
Nirmal Nagar Puraskar Yojna	Water Resources	Uttarakhand	To encourage ULBs for sanitation works. ULBs are rewarded annually for best performances	Regulatory
Sparsh Ganga	Water Resources	Uttarakhand	To keep the River Ganga clean by not allowing untreatable urban waste flow into it through townships such as Uttarkashi, Tehri Garhwal, Devprayag, Rishikesh and Haridwar	Regulatory

Appendix 2

Memorandum of Understanding (MoUs) and Agreements

Thematic Area: Climate Change		
S No	Date of Signing	Details
1.	9-May-01	MoU between ISRO and French Space Agency, CNES for Atmospheric Research Mission
2.	16-Dec-10	MoU between India and China upon Provision of Hydrological information of the Langqen Zangbo/Sutlej River in Flood season
3.	20-May-13	MOU between India and China upon Provision of Hydrological information on Yaluzangbu/Brahmaputra River in Flood season
4.	16-Jul-14	MoU between India and Brazil on cooperation in the field of Environment
5.	5-Sep-14	MoU between India and Australia on cooperation in the field of Water Resource Management
6.	6-Jun-15	MoU between India and Bangladesh for a Project under India Endowment for Climate Change – South Asia (IECC-SA) of SAARC to supply 70000 Improved Cook Stoves to Bangladesh
7.	10-Apr-17	MoU between India and Australia on cooperation in the fields of Environment, Climate Change and Wildlife
8.	10-Mar-18	MoU between India and France on cooperation in the field of Environment
9.	27-Jun-17	MoU between India and Netherlands on cooperation in the field of Water Resources Management

Thematic Area: Biodiversity		
S No	Date of Signing	Details
1.	6-Sep-11	MoU between India and Bangladesh on conservation of Sundarban
2.	6-Sep-11	Protocol between India and Bangladesh on conservation of Royal Bengal Tiger of the Sundarbans
3.	1-Feb-14	MoU between India and Morocco on Cooperation in Marine Fisheries
4.	1-Feb-14	Agreement on Environmental cooperation between India and Morocco
5.	1-Jun-15	MoU between India and Sweden on cooperation in the field of Sustainable Urban Development
6.	11-Dec-15	MoU between India and Japan on cooperation in the field of Forests and Forestry

Thematic Area: Energy		
S No	Date of Signing	Details
1.	11-Feb-10	Joint Declaration by India and the United Kingdom on Civil Nuclear Cooperation
2.	19-Apr-10	MoU between India and Sweden on India-Sweden Renewable Energy Cooperation
3.	30-Apr-10	Agreement between India and Bhutan regarding the Mangdecchu Hydroelectric Project
4.	30-Apr-10	Joint statement between India and Japan on the occasion of the Fourth Meeting of the Japan India Energy Dialogue
5.	27-Jun-10	Agreement between India and Canada on cooperation in peaceful uses of Nuclear Energy
6.	9-Jul-10	MoU between India and Iran on cooperation in the field of New and Renewable Energy
7.	23-Sep-10	Agreement between India and Argentina for cooperation in the peaceful uses of Nuclear Energy
8.	14-Jan-10	Agreement between India and France concerning Intellectual Property Rights on the development of the peaceful uses of Nuclear Energy
9.	11-Dec-10	Gas Pipeline Framework Agreement between Turkmenistan-Afghanistan-Pakistan-India
10.	21-Dec-10	MoU between India and Russia concerning broader scientific and technical cooperation in the field of peaceful uses of Nuclear Energy
11.	5-Jan-11	Cooperation Agreement between India and France in the field of Nuclear Science and Technology for peaceful uses of Nuclear Energy
12.	15-Apr-11	Agreement between India and Kazakhstan for cooperation in the peaceful uses of Nuclear Energy

Thematic Area: Energy		
13.	25-Jul-11	Agreement between Republic of India and Republic of Korea for cooperation in the peaceful uses of Nuclear Energy
14.	6-Sep-11	MoU between India and Bangladesh on Renewable Energy Cooperation
15.	15-Feb-12	MoU between India and Rwanda on Renewable Energy Cooperation
16.	17-Jul-12	Protocol to the Agreement dated December 5, 2008, between India and Russia on cooperation in the construction of additional Nuclear Power Plant Units at Kudankulam Site as well as in the construction of Russian designed Nuclear Power Plant at new sites in India
17.	14-Nov-12	MoU between India and Belarus on Renewable Energy Cooperation
18.	11-Apr-13	MoU between India and Germany on Solar Energy System
19.	11-Apr-13	Joint Declaration of Intent between India and Germany on Indo-German Development Cooperation regarding the establishment of Green Energy Corridors
20.	23-Aug-13	MoU between India and Iraq on cooperation in the field of Energy
21.	11-Sep-13	MoU between India and Liberia on cooperation in the field of Oil and Gas
22.	16-Jan-14	Implementing Agreement between India and Korea for cooperation in the peaceful sses of outer space
23.	6-Aug-14	MoU between India and Japan concerning the Model Project for Energy Management Systems in Telecommunication Towers in India
24.	5-Sep-14	Agreement between India and Australia on cooperation in the peaceful uses of Nuclear Energy
25.	11-Dec-14	Provisions for the Technical Data and Information Non-Disclosure in the Framework of Cooperation in the field of peaceful uses of Nuclear Energy between India and Russia
26.	11-Dec-14	Strategic vision for strengthening cooperation in peaceful uses of Atomic Energy between Indian and Russia
27.	16-Feb-15	Agreement between India and Sri Lanka on cooperation in the peaceful uses of Nuclear Energy
28.	17-Feb-15	MoU between India and Dominican Republic on Renewable Energy Cooperation
29.	11-Mar-15	MoU between India and Seychelles on Renewable Energy Cooperation
30.	10-Apr-15	MoU between India and France in the field of Renewable Energy
31.	17-May-15	MoU between India and Mongolia to establish basis for cooperative institutional relationship to encourage and promote technical bilateral cooperation on new and renewable energy
32.	18-May-15	MoU between India and Korea concerning cooperation in the fields of Electric Power development and New Energy Industries
33.	25-May-15	MoU between India and Russia on expansion of cooperation in the field of the exploration and the use of outer space for peaceful purposes
34.	5-Oct-15	MoU between India and Germany on Indo-German Development cooperation regarding the Indo-German Solar Energy Partnership
35.	9-Nov-15	MoU between India and United Kingdom of Great Britain and Northern Ireland concerning cooperation with India's Global Centre for Nuclear Energy Partnership
36.	11-Nov-15	MoU between India and United Kingdom of Great Britain and Northern Ireland on cooperation in the Energy Sector
37.	13-Nov-15	MoU between India and United Kingdom of Great Britain and Northern Ireland on Peaceful uses of Nuclear Energy
38.	9-Dec-15	Statement of Intent between India and Japan on cooperation in Energy Sector and in analysing issues related to the energy sector
39.	24-Dec-15	Programme of Action between India and Russia for localization of manufacturing in India for Russian-Designed Nuclear Power Plants
40.	11-Feb-16	General Framework Agreement between India and the United Arab Emirates on Renewable Energy Cooperation
41.	29-Aug-16	MoU between India and Myanmar in the field of Renewable Energy
42.	11-Nov-16	Agreement between India and Japan for cooperation in the peaceful uses of Nuclear Energy
43.	9-Dec-16	Agreement between India and Vietnam on cooperation in the peaceful uses of Nuclear Energy
44.	8-Apr-17	Agreement between India and Bangladesh for the exchange of technical information and cooperation in the regulation of Nuclear Safety and Radiation Protection
45.	8-Apr-17	MoU between India and Bangladesh on cooperation in the peaceful uses of Nuclear Energy
46.	30-May-17	MoU between India and Spain in the field of Renewable Energy

Thematic Area: Energy		
47.	30-Oct-17	MoU between India and Italy on cooperation in the field of Renewable Energy

Waste		
S No	Date of Signing	Details
1.	December 16, 2011	Protocol of Intentions between India and Russia on Fly Ash Utilization and Safe Management

Annexure I - List of Acronyms

Abbreviations

BEE	Bureau of Energy Efficiency
BUR	Biennial Update Report
CAGR	Compounded Annual Growth Rate
CDM	Clean Development Mechanism
CERC	Central Electricity Regulatory Commission
CH_4	Methane
CII	Confederation of Indian Industry
CIMFR	Central Institute of Mining and Fuel Research
CNG	Compressed Natural Gas
COP	Conference of Parties to UNFCCC
CPCB	Central Pollution Control Board
CRRI	Central Road Research Institute
CSIR	Council of Scientific and Industrial Research
DST	Department of Science and Technology
FICCI	Federation of Indian Chamber of Commerce and Industry
FSI	Forest Survey of India
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GIS	Geographic Information System
GOI	Government of India
GVA	Gross Value Added
GWP	Global Warming Potential
IMD	India Meteorological Department
INC	Initial National Communication
INDC	Intended Nationally Determined Contributions
IPCC	Inter-governmental Panel on Climate Change
ISFR	India State of Forest Report
JFM	Joint Forest Management
LED	Light Emitting Diode
LNG	Liquefied Natural Gas
LULUCF	Land Use, Land-use Change and Forestry
MRV	Measurement, Reporting and Verification
MNREGA	Mahatma Gandhi National Rural Employment Guarantee Act
MNRE	Ministry of New and Renewable Energy
MoC	Ministry of Coal
MEA	Ministry of External Affairs
MoEFCC	Ministry of Environment, Forest and Climate Change
MSW	Municipal Solid Waste
Mt	Million tonnes
N	Nitrogen
N_2O	Nitrous Oxide
NAPCC	National Action Plan on Climate Change
NATCOM	National Communication
NCR	National Capital Region
NGO	Non-Governmental Organization
NMVOC	Non Methane Volatile Organic Compound
NO_x	Nitrogen Oxides
NPD	National Project Director
NPL	National Physical Laboratory
NRSC	National Remote Sensing Centre
NSC	National Steering Committee
NTFP	Non-Timber Forest Product
NTPC	National Thermal Power Corporation
OC	Organic Carbon
PAT	Perform, Achieve and Trade
PC	Planning Commission
PFC	Perfluorocarbon
PMU	Project Management Unit
PSU	Public Sector Undertaking
PV	Photovoltaic

R&D	Research and Development
R&M	Renovation and Modernization
REDD	Reduced Emission from Deforestation and Degradation
REC	Renewable Energy Certificate
RET	Renewable Energy Technology
RKM	Route Kilometres
RPO	Renewable Purchase Obligations
SEB	State Electricity Board
SERC	State Electricity Regulatory Commission
SF_6	Sulphur Hexafluoride
SLNP	Street Lighting National Programme
SNC	Second National Communication
SO2	Sulfur Dioxide
SPV	Solar Photo Voltaic
T&D	Transmission and Distribution
UJALA	Unnat Jyoti By Affordable LEDs for All
UNDP	United Nations Development Programme
UNEP	United Nations Environmental Programme
UNFCCC	United Nations Framework Convention on Climate Change
VOC	Volatile Organic Compound

Units and Quantities

BCM	Billion Cubic Meter (equals 1km3)
C	Celsius
Gg	Giga gram
GW	Giga Watt
GWh	Giga Watt hour
ha	Hectare
km	Kilometer
km2	Square kilometer
km3	Cubic kilometer
kW	kilo Watts
kWp	kilo Watts peak
M	Million
m3	Cubic meter
Mha	Million hectare
MJ	Mega Joule
Mt	Million tonne
$MtCO_2$	Million tonnes of Carbon dioxide
$MtCO_2e$	Million tonnes of Carbon dioxide equivalent
MW	Mega Watts
t	tonne
Tg	Tera gram
TJ	Tera Joule
toe	tonnes of oil equivalent

Conversion Table

1 Giga gram (Gg) = 1000 tonnes = 10^9 g
1 Tera gram (Tg) = 1 Million tonnes = 1000 Gg = 10^6 tonne = 10^{12} g
1 Tera Joule (TJ) = 10^3 GJ = 10^{12} Joules
1 Calorie = 4.18 J
1 Lakh= 100,000 = 10^5
1 Crore = 10,000,000 = 10^7

Annexure II - Institutional Arrangements

Composition of the National Steering Committee (NSC) for India's Third National Communication (TNC) and Biennial Update Reports (BUR) to the United Nations Framework Convention on Climate Change (UNFCCC)

Chairman

i. Secretary, MoEFCC

Members

ii. Special/ Additional Secretary (In-charge: Climate Change matters), MoEFCC
iii. CEO, NITI Aayog or his representative
iv. Secretary, Department of Agricultural Research and Education, Ministry of Agriculture and Farmers Welfare or his representative
v. Secretary, Department of Agriculture Cooperation and Farmers Welfare, Ministry of Agriculture and Farmers Welfare or his representative
vi. Secretary, Department of Economic Affairs, Ministry of Finance or his representative
vii. Secretary, Ministry of New and Renewable Energy or his representative
viii. Secretary, Department of Science & Technology or his representative
ix. Secretary, Ministry of Coal or his representative
x. Secretary, Ministry of Power or his representative
xi. Chairman, Railway Board or his representative
xii. Secretary, Ministry of Road Transport & Highways or his representative
xiii. Secretary, Ministry of Shipping or his representative
xiv. Secretary, Ministry of Petroleum & Natural Gas or his representative
xv. Secretary, Ministry of Water Resources, River Development and Ganga Rejuvenation or his representative
xvi. Secretary, Ministry of Health & Family Welfare or his representative
xvii. Secretary, Ministry of Earth Sciences or his representative
xviii. Secretary, Department of Rural Development or his representative
xix. Secretary, Ministry of Housing and Urban Affairs or his representative
xx. Secretary, Department of Industrial Policy & Promotion, Ministry of Commerce and Industry or his representative
xxi. Secretary, Ministry of Steel or his representative
xxii. Secretary, Ministry of Civil Aviation or his representative
xxiii. Secretary, Ministry of Statistics and Programme Implementation or his representative
xxiv. Director General, India Meteorological Department or his representative
xxv. Joint Secretary (UNES), Ministry of External Affairs
xxvi. Representative, United Nations Development Programme, India-Office, New Delhi
xxvii. Joint Secretary (Climate Change), MoEFCC

Member Secretary

xxviii. Advisor (Climate Change), MoEFCC

Composition of the Technical Advisory Committee for India's Third National Communication and Biennial Update Reports to the United Nations Framework Convention on Climate Change

Chairman

i. Additional Secretary / Special Secretary (In-charge: Climate Change matters), MoEFCC

Members

ii. Representative, Indian Space Research Organization
iii. Advisor (Energy), NITI Aayog
iv. Director General or representative, Indian Council of Agricultural Research
v. Director General or representative, Forest Survey of India
vi. Dr. Ajay Mathur, Director General, TERI
vii. Prof. J. Srinivasan, Divecha Centre for Climate Change, IISc, Bengaluru
viii. Prof. Chandra Venkatraman, IIT Bombay
ix. Dr. K. Kavi Kumar, Madras School of Economics
x. Dr. L.S. Rathore, Former Director General, India Meteorological Department
xi. Dr. Kirit Parikh, Chairman, IRADe, New Delhi
xii. Prof. T. Jayaraman, Tata Institute of Social Sciences, Mumbai
xiii. Prof. Amit Garg, Indian Institute of Management, Ahmedabad
xiv. Prof. Raman Sukumar, Indian Institute of Science, Bengaluru
xv. Dr. Subodh Sharma, Former Adviser, MoEFCC
xvi. Dr. Navroz Dubash, Centre for Policy Research, New Delhi
xvii. Dr. Arvind Kumar, Chair, India Water Foundation, New Delhi
xviii. Joint Secretary (Climate Change), MoEFCC

Member Secretary

xix. Advisor (Climate Change), MoEFCC

Contributors to India's Second Biennial Update Report

Project Management Unit

National Project Director

Dr. J.R. Bhatt

Scientist 'G'/ Adviser
National Project Director, NATCOM
Ministry of Environment, Forest and Climate Change
Government of India,
Room number 326, 'Jal' Wing, Indira Paryavaran Bhavan
Jor Bagh Road, New Delhi
Telefax No.+91-11-24695293
E-mail: jrbhatt@nic.in

Programme Officers

Mr. Lokesh Chandra Dube	**Dr. Himangana Gupta**	**Dr. Nayanika Singh**
lokesh.dube@gov.in	himangana@gmail.com	nayanika.singh@nic.in
Dr. Abhijit Basu	**Dr. Simi Thambi**	**Ms. Biba Jasmine Kaur**
bsbhjt@gmail.com	simi.thambi@gov.in	biba.kaur@gov.in

NATCOM Cell, Room no. 115, Pt.Deendayal Antyoday Bhawan, CGO Complex, Lodhi Road, New Delhi-110 003

Participating Institutions and Experts

Laboratories of the Council for Scientific and Industrial Research (CSIR)

Central Institute of Mining and Fuel Research (CIMFR)

Barwa Road, Dhanbad – 826015,
Phone: +91-326-229 6023

Dr. Pinaki Sarkar
Dr. Santi Gopal Sahu
Dr. Ashis Mukherjee
Dr. Manish Kumar

Dr. Ajay Kumar Singh
Dr. D. Mohanty
Mr. Jaywardhan Kumar

Indian Institute of Petroleum (IIP)

Mohkampur, I I P, Rajpur Road, Dehradun - 248001
Phone: +91-135-266 0203

Dr. Sunil Pathak
Dr. Iranna Gogeri

National Environmental Engineering Research Institute (NEERI)

Nehru Marg, Nagpur - 440 020
Phone: +91-712-224 9755

Dr. Atul Vaidya
Dr. M. Karthik
Dr. S.Y. Bodkhe
Dr. J.K. Bhattacharyya
Ms. K.V.V.K Sravya

Institutes of Indian Council of Agricultural Research (ICAR)

Central Research Institute of Dryland Agriculture (CRIDA)

Santoshnagar, Hyderabad - 500 059
Phone : +91-40-24530177

Dr. K. Sammi Reddy
Dr. Ch. Srinivasa Rao
Dr. J.V.N.S. Prasad
Dr. C.A. Rama Rao
Dr. K.V. Rao
Dr. D.B.V Ramana
Dr. G. Venkatesh
Dr. V. Girija Veni
Dr. B.M.K. Raju
Dr. Sumantha Kundu

Indian Agricultural Research Institute (IARI)

Pusa Road, New Delhi 110 012
Phone: +91-11-2584 1490

Dr. Niveta Jain
Dr. Arti Bhatia
Dr. Himanshu Pathak

National Dairy Research Institute (NDRI)

Karnal-132001
Phone: +91-184-225 9088

Dr. Madhu Mohini
Dr. S Thakur
Dr. Goutam Mondal
Mr. Babar Ali
Ms. Reena Kashyap

Autonomous bodies of Ministry of Environment, Forest and Climate Change

Forest Survey of India (FSI)

Kaulagarh Road, PO-IPE, Deharadun-248194
Phone: +91-135-275 6139

Mr. Rajesh Kumar
Mr. Prakash Lakhchaura

Indian Council of Forestry Research and Education (ICFRE)

PO- New Forest, Dehradun-248006
Phone: +91-135-275 0296

Mr. V.R.S. Rawat
Dr. R.S. Rawat
Dr. Gurveen Arora
Dr. Deepti Verma

Other Institutions of the Government of India

National Remote Sensing Centre (NRSC)

CRF Colony, Balanagar, Hyderabad, Telangana
Phone: +91-40-2388 4000

Dr T R Kiran Chand
Dr K Sreenivas
Dr P V N Rao
Dr C S Jha

Technology Information Forecasting and Assessment Council (TIFAC)

Vishwakarma Bhavan, Shaheed Jeet Singh Marg, New Delhi, Delhi 110016

Dr. Anil Kakodkar
Dr. Gautam Goswami
Shri Manish Kumar
Mrs. Jancy A
Ms. Mukti Prasad
Dr. T Chakradhar
Ms. Swati Sharma

Universities/ Educational institutions

Indian Institute of Management Ahmedabad (IIM A)

Vastrapur, Ahmedabad - 380015, India
Phone: +91-79-6632 4952

Prof. Amit Garg
Mr.Bhushan Kankal
Mr. Jaypalsingh Chauhan

Indian Institute of Science (IISc)

CV Raman Road, Bengaluru - 560 012
Phone: +91-80-2334 1838

Prof. N.H. Ravindranath
Dr. Rajiv Kumar Chaturvedi
Ms. Indu K Murthy
Ms. Shruthi B V Rajesh

Non-governmental research organizations

Confederation of Indian Industry (CII)

Thapar House, 2nd Floor, 124 Janpath, New Delhi 110001 India
Phone: +91-11-4150 2307

Dr. Seema Arora
Mr. Kamal Sharma
Ms. Priyanka Yadav

Council on Energy, Environment and Water (CEEW)

Sanskrit Bhawan, A-10, Qutab Institutional Area, Aruna Asaf Ali Marg,
New Delhi - 110067
Phone: +91-11-4073 3300

Mr. Vaibhav Gupta
Mr. Sumit Prasad
Mr. Karthik Ganesan

The Energy and Resources Institute (TERI)

Habitat Place, Lodhi Road, New Delhi -110003
Phone: +91-11-2468 2100

Dr Ritu Mathur

Iora Ecological Solutions

225 B, FF, Indraprastha Gyan Mandir Complex, Lado Sarai Village Complex
New Delhi - 110030
Phone: +91-11-4107 7547

Dr. Sumana Bhattacharya
Ms. Shweta Pandey

Comments/ Inputs

Ministry of Environment, Forest and Climate Change

Dr. A.K. Mehta, Additional Secretary and in-charge of climate change division,
Dr. Hardik Shah, PS to Minister
Mr. Ravi Shankar Prasad, Joint Secretary
Mr. Jigmet Takpa, Joint Secretary
Mr. James Mathew, Deputy Director General
Mr. Ajay Raghava, Deputy Director

Other Ministries / Experts

Mr. Abhay Bakre, Bureau of Energy Efficiency

Mr. Abhinav Misra, CSTEP

Dr. Anjan Ray, Indian Institute of Petroleum, Dehradun

Dr. Anshu Bharadwaj, CSTEP

Dr. A.K. Tripathi, National Institute of Solar Energy

Dr. Ashish Chaturvedi, GIZ

Dr. Chhemendra Sharma, National Physical Laboratory, Delhi

Dr. D.S. Pai, India Meteorological Department

Dr. J. Srinivasan, Indian Institute of Science, Bangalore

Dr. K.J. Ramesh, DGM, India Meteorological Department

Dr. Kurian Joseph, Anna University, Chennai

Dr. L.S. Rathore, Former DG, India Meteorological Department

Mr. Karan Mangotra,TERI

Ms. Manda Verma, Ministry of Agriculture and Farmers' Welfare

Mr. Manish Sarada, Ministry of Petroleum and Natural Gas

Dr. Mathew Abraham, Mahindra & Mahindra

Mr. Merlin Francis, CSTEP

Mr. Narender Singh, Central Electricity Authority

Dr. Panjab Singh, Former, Indian Council of Agricultural Research

Ms. P. Bhanumati, Ministry of Statistics and Programme Implementation

Dr. Purnamita Dasgupta, Institute of Economic Growth, Delhi University

Ms. Riya Rachel, CSTEP

Mr. Sanjay Jain, Central Electricity Authority

Dr. S.D. Attri, India Meteorological Department

Mr. Shivendra Mohan, Ministry of Railways

Ms. Shweta Srinivasan, CSTEP

Dr. Suneel Pandey, TERI

Dr. T S Nayar, Formerly JNTBGRI

Dr. Vimal Mishra, Indian Institute of Technology, Gandhinagar

Dr. Ajay Mathur, TERI

Dr. Ajit Kolar, Indian Institute of Technology, Chennai

Dr. Akhilesh Gupta, Department of Science and Technology

Dr. Ashok Kumar, Bureau of Energy Efficiency

Dr. Arunabha Ghosh, CEEW

Dr. Ashok Bhatnagar, Formerly Head, Department of Botany, University of Delhi

Mr. C.P. Jain, Central Electricity Authority

Mr. Devaditya Bhattacharya, CSTEP

Ms. Divya Shah, Ministry of Agriculture and Farmers' Welfare

Dr. Jagdish Kishwan, Fomer Additional Director General, Forests, MoEFCC

Mr. J.K. Jethani, Ministry of New and Renewable Energy

Dr. K.R. Shanmugam, Madras School of Economics

Dr. Kirit Parikh, IRAde

Dr. M R Nouni, NISE

Ms. Mandeep Kaur, Bureau of Energy Efficiency

Dr. M. Mohapatra, India Meteorological Department

Mr. Murali Ananthakumar, CSTEP

Dr. Neha Pahuja, TERI

Dr. P.C. Maithani, Ministry of New and Renewable Energy

Ms. Poornima Kumar, CSTEP

Dr. Rangan Banerjee, Indian Institute of Technology, Mumbai

Dr. S. Mahendra Dev, IGIDR

Mr. Shantanu Goel, Bombay Natural History Society

Dr. Shyam Gupta, Ministry of Petroleum and Natural Gas

Dr. Srinivas Jayanthi, Indian Institute of Technology, Chennai

Dr. T. Jayaraman, TISS

Dr. V.K. Soni, India Meteorological Department

Dr. Yugraj Yadav, Bay of Bengal Programme Inter-Governmental Organisation

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Annexure III - List of events/ consultative meetings

i. Consultative meeting of sectoral experts on GHG inventory (IPPU, LULUCF, Agriculture, Waste) on 27 January 2016, New Delhi.

ii. Meeting on Development of National GHG Inventory Management System (NIMS) on 13th June 2016, at Indira Paryavaran Bhawan, New Delhi.

iii. Consultative meeting on India's National GHG Inventory for Biennial Update Reports and Third National Communication to UNFCCC on 1 August 2016 at Kaveri Hall, Indira Paryavaran Bhawan, New Delhi.

iv. Energy Sector Expert Group for National GHG Inventory for Second BUR on 10 August 2016 at MoEFCC, New Delhi.

v. Meeting of the National Advisory Committee on Preparation of second BUR on 8th September 2017 at Ministry of Agriculture, Cooperation and Farmers Welfare, Krishi Bhawan, New Delhi.

vi. A Review Meeting on Status of Preparedness for India's BUR-2 including Inventory, Mitigation, Technology Needs Assessment, and Domestic Measurement, Reporting and Verification on 12 October 2017 at WWF India office, New Delhi.

vii. A Workshop to Share Experiences between India and Norway on GHG Emission Inventory on 26-27 October 2017 at TERI University, New Delhi.

viii. A quality check meeting for National GHG Inventory at MoEFCC, New Delhi on 12 January 2018.

ix. A Meeting to review the preparation of National GHG Inventory for BUR- 2 on 8th February 2018 at Narmada Hall, Indira Paryavaran Bhawan, MoEFCC.

x. A National Validation Workshop on Technology Needs Assessment at Indira Paryavaran Bhawan, New Delhi on 9th March 2018.

xi. A meeting to review national GHG inventory for BUR-2 on 12th September 2018 at MoEFCC, Indira Paryavaran Bhawan, New Delhi.

xii. Meeting of the Technical Advisory Committee to India's Third National Communication and BURs to the UNFCCC on 26th October 2018 at Indira Paryavaran Bhawan, New Delhi.

xiii. Meeting of the National Steering Committee to India's Third National Communication and BURs to the UNFCCC on 8th November 2018 at Indira Paryavaran Bhawan, New Delhi.

Annexure IV - Publications

Publications under the aegis of India's second BUR