# GREEN HOUSE GASES INVENTORY FOR PUDUCHERRY, EVOLVING A CLIMATE ACTION PLAN AND INDUSTRIAL CASE STUDIES FOR SUSTAINABLE DEVELOPMENT

THESIS SUBMITTED TO BHARATHIAR UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF **DOCTOR OF PHILOSOPHY IN ENVIRONMENTAL SCIENCES**

By

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(i) Case study of GHG reduction and sustainable solutions in a Chemical Industry with reference to the climate change action plan of the Puducherry region, India with vol. no. Volume.2, No.3, Page-406-411 (2016) ISSN : 2395–5341 page Nos 406 and year of publication 2016 published by Journal of Applied Science and Engineering Methodologies and

(ii) (ii) Sector-wise GHG Inventorization for Union Territory of Puducherry with Special Reference to Agriculture – Phase I with vol. no. Vol. 34, No. 2, 2016 page Nos 509 and year of publication 2016 published by IJTA National Academy of Agricultural Science (NAAS).

The contents of the publication incorporates part of the results presented in his thesis.

**Signature of the Scholar** **Research Supervisor**

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| | |
|---|---|
| CCAP | Climate Change Action Plan |
| **CDM** | Clean Development Mechanism |
| **CER** | Certified Emission Reduction |
| **GHG** | Greenhouse Gas |
| **GREP** | General Research Ethics Procedures |
| **GWP** | Global Warming Potential |
| **INCCA** | Indian Network for Climate Change Assessment |
| **IPCC** | Intergovernmental Panel on Climate Change |
| **NAPCC** | National Action Plan on Climate Change |
| **NATCOM** | National Communication |
| **SAPCC** | State Action Plan on Climate Change |
| **TSA** | Tourism Satellite Accounts |
| **UNEP** | United Nations Environment Programme |
| **UNFCCC** | United Nations Framework Convention on Climate Change |
| **UNWTO** | UN-World Tourism Organization |
| **USEPA** | US Environmental Protection Agency |
| **WMO** | World Meteorological Organization |

## VI. EXECUTIVE SUMMARY

Undoubtedly, over the years the global warming and its impacts have been felt all across the globe and more immediately for the tropics. The predominant reason for global warming is attributable to anthropogenic emissions of Green House gases (GHGs). In 2007, the Intergovernmental Panel on Climate Change (IPCC) of the United Nations reported with more than 90% certainty, that man-made generation of $CO_2$ is the primary cause of global warming IPCC's, climate models predict that the average temperature at the earth's surface is likely to increase from 0.5 to 8.6ºF (-17.5$^0$C to -13$^0$C) above 1986 through 2005 levels by the end of this century, depending on future emissions.

Environmental Protection Agency-USA also indicated that with increasing population, more and more countries are facing the problem of global environmental change originating from industrial sector. Observations over India show that, in the last 100 years, the mean annual surface air temperature has increased by 0.4°C, which ultimately had necessitated this emission inventory study.

India also being a signatory to the UN convention on climate change, the GHG inventory is a critical pre-requisite for policy support and response toward mitigation. In the present study, the GHG inventorisation is carried out for the Union Territory of Puducherry, which paved the way for preparation of mitigation and adaption plans. Case studies with respect to industries have been taken up for the trend analysis of their GHG emissions and the impacts of various policy directives / interventions on the GHG emissions.

The present research topic has been chosen because of a number of significant issues associated with it. The study area chosen is the Union Territory of Puducherry, which is predominantly coastal area and is experiencing a number of impacts of Climate Change in the form of salinity, intrusion, ground water depletion, increase in the sea level and loss of livelihood associated with these impacts.

The Union Territory of Puducherry has also witnessed a devastating impact during the 2004 Tsunami. The Karaikal region, especially has witnessed loss of life, loss of livestock, uprooting of trees, inundation / flooding and loss of livelihood especially for the fishermen community and also in the coastal villages. Public Health impact and vector borne, water borne associated with flood was experienced.

The Union Territory of Puducherry especially Puducherry and Karaikal have witnessed the phenomenon of Tsunami in 2004. At the National level itself, we do not have any base line data or perspective planning and management plan for combating the impacts. Besides, no authentic base line data or management plan was in place with Government Academic Institutions or with any agency in respect of this. This is one of the primary reasons that this research study was undertaken, so as to give a base line information in respect of various data associated with the Climate Change and also to evolve sectoral action plan for controlling Climate Change at the state level.

The main Scope of this action research study was to evolve a regional description followed by evolving a mitigation and adaptation plans for low, medium and high priority actions and finally concluded with industrial case studies.

The rationale for this study is that, Puducherry being a small Union Territory, experiences more developmental pressures from all quarters due to higher population density, rapid growth rate of industries and lesser available space. Availability of better infrastructure, health care system, educational facility and cosmopolitan atmosphere in Puducherry has attracted migration from neighboring areas over the recent decades. This has resulted in increased demand for housing, natural resources (including energy), transportation and generation of all types of wastes. All these have resulted in the increased emission of GHGs in Puducherry. Besides, the Union Territory of Puducherry has more numbers of Higher Educational Institutions of medical and engineering disciplines and hospitals, which generate large amount of GHGs.

By measuring and analyzing GHG emissions, the City would be able to track the progress, it is making towards achieving many of the sustainability policy measures, such as improving buildings' energy efficiency, cleaning the city's power supply, creating low-carbon transportation options, and reducing GHG emissions from City government buildings, wastewater treatment, solid waste disposal, and other sources. Inventorisation in this study comprehensively covers industrial, domestic, transportation, municipal solid waste, and sewage and agriculture sectors. Based on the inventorisation, an action plan, aimed to categorize the programme / activities into mitigation and adaptation. Further, activities are categorized with high, medium and low priority actions with short term, medium term and long term actions, has been formulated. Such platforms enabled by GHG inventories would help to identify and develop these achievable objectives and the targeted and transformative actions that are needed in the long term (Sonia et al., 2015).

When it comes to Materials and Methods, the secondary data had been collected after developing a standard template, evolved based on the available literature, UNFCCC protocol, discussion with academic institution, World Bank documents, etc. Once, the data collection template was finalized, baseline data was collected from the concerned Government departments such as Agriculture, Animal Husbandry, Irrigation Division of PWD, State Ground Water Authority, Hydro-geologist Division of Agriculture Department, Electricity, Economic & Statistics, Forests and Wildlife, Health and Family Welfare, Industries and Commerce, Pollution Control Committee, Science, Technology & Environment, Tourism, Revenue and Disaster Management, Local Administration and concerned local bodies were closely involved in data collection.

Based on the data collected, sectoral GHG inventorisation was done. Data in respect of fossil fuel consumption, electricity consumption across industrial, domestic, agriculture and transport sectors was estimated. Emission of Methane and Nitrous oxide from both liquid and solid was also estimated. Tier I method of IPCC relating to total fuel being (FCCC/CP/2013) sold was used to estimate the GHG from transportation sector. This is due to the lack of authentic data relating to actual consumption of fuel oil by the vehicle users of the Union Territory (the problem of excluding the transit vehicles), However, considering the fact that a considerable proportion of the oil sold to the transportation sector in UTs used by vehicle of adjacent states due to the lower price of the fuel oil in the UT. The calculations were made as per the UNFCCC protocol for estimation of GHG emission.

The comprehensive inventorisation of GHG emissions in Puducherry has indicated that industrial sector is the biggest contributor almost 78% of the total GHG emission. The total GHG emission is estimated at 3.4641 million tons of $CO_2$ equivalent. Industrial sector is the highest contributor with 2.354 million tons of $CO_2$ equivalent followed by domestic 0.66 million tons, transportation 0.134 million tons of $CO_2$ equivalent, municipal solid waste and sewage 0.181 million tons and agriculture 0.132 million tons in all the sectors.

Following sectoral inventorisation, appropriate action plan has been formulated. In line with the National Policies of various ministries of Government of India such as Solar Mission, Enhanced Energy Mission, Sustainable Habitat Mission, Green Puducherry and Sustainable Agriculture Mission, Water Mission, Strategic Knowledge Mission and Coastal and Disaster Management Mission, besides special projects such as smart city , solar city /solar campus . The action activities were categorized into high, medium and low on the basis of priority and short term, medium term and long term based on temporal dimension. Industrial case studies have been selected based on the following criteria:

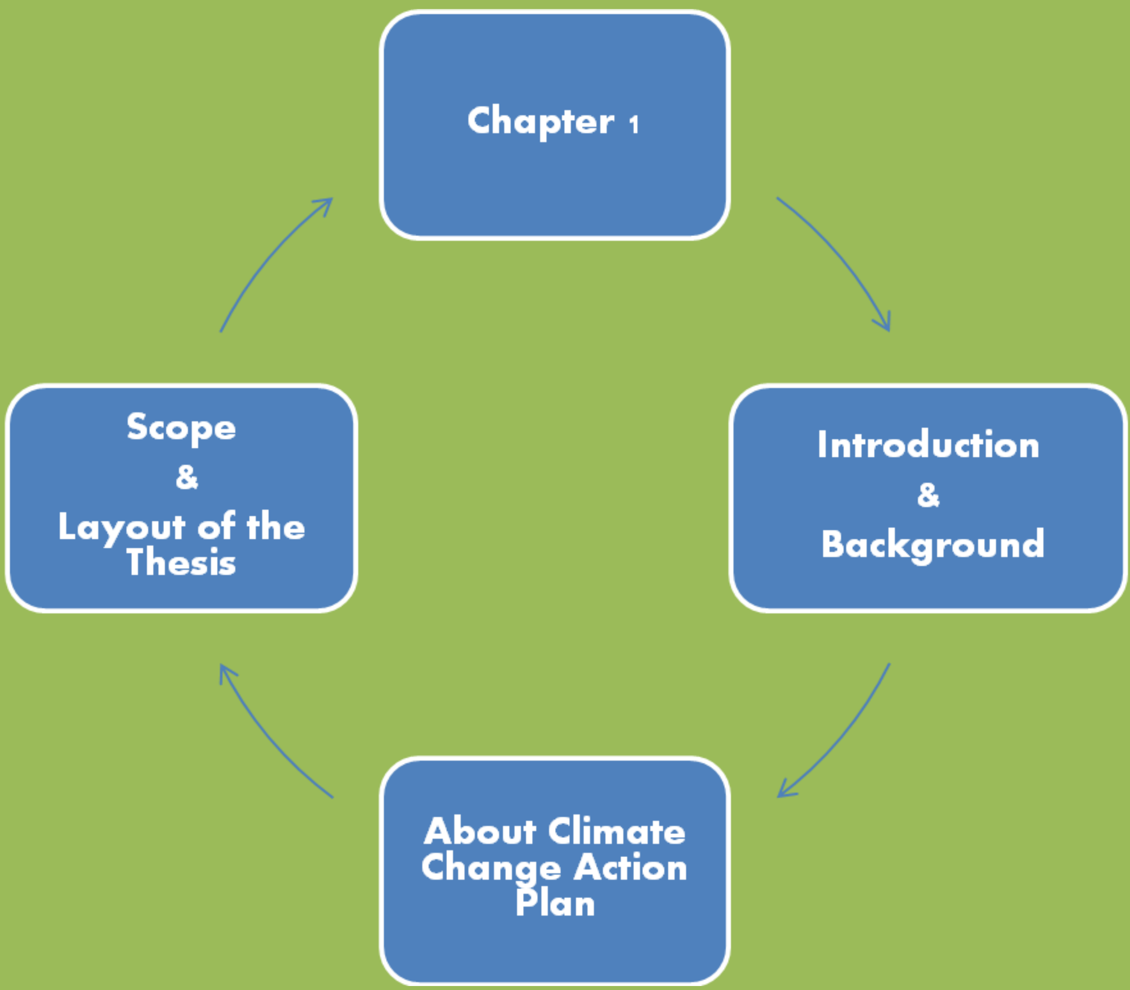
- Elevated power and fuel consuming Industries;
- Have commitment towards Sustainable Development;
- Enthusiasm to co-operate for this study;
- Have adequate technical resource persons to document and disseminate/share etc.

Industrial case studies of four major industries wherein the data of energy consumption for different activities like water pumping, re-cycling, conservation through wastage reduction, the water conservation through process alteration, recovery and re-use of waste heat, rain water harvesting and its use, adaptation of various fuel conservation measures, importance of energy efficiency in lighting, cooling, adaption of renewal energy for energy generation etc., have indicated that considerable amount of energy is conserved in all the above mentioned activities and in the process, have resulted in reduction of $Co_2$ equivalent in these industries. Though this is a small effort by these industries, replicating such practices by all the major industries will go a long way in achieving the sustainable development goals.

**Keywords:** Greenhouse Gas Inventory, Sustainable Development, Environmental Sustainability.

# CHAPTER 1

# 1 INTRODUCTION AND OUTLINE OF THESIS



## 1.1 Introduction

"Across South Asia, due to rapid increase in population, the demand for housing, water, food and clothing along with Municipal services are also on the increase. This results in increased utilization of resources, which leads to increased emissions of Greenhouse Gases (GHGs)" (Ahmad et al., 2015). "If greenhouse gases continue to increase, climate models predict that the average temperature at the earth's surface is likely to increase from 0.5 to 8.6ºF above 1986 through 2005 levels by the end of this century, depending on future emissions" (IPCC 2013). Global warming refers to the continuous increase of the earth's climate system. It is going to be one of the biggest environmental and humanitarian crises in the very near future. Many reasons are responsible for global warming. "In 2007, the Intergovernmental Panel on Climate Change (IPCC) of the United Nations reported with more than 90% certainty that manmade generation of $CO_2$ is the primary cause of global warming" (Gore 2006, EPRI, 2007). "In 2013, the IPCC concluded that the largest driver of global warming is carbon dioxide ($CO_2$) emissions from fossil fuel combustion, cement production, and land use changes such as deforestation. Within scientific communities, global warming refers to surface temperature increases while climate change includes global warming and everything else that increase greenhouse gases" (NASA 2011, Rajesh 2016, NOAA, Climate.gov).

"According to Environmental Protection Agency-USA, (USEPA), with increasing population, more and more countries are facing the problem of global environmental change originating from large expansion of industrial sector" (Rai and Rai, 2013a and 2013b). "Researchers believe that anthropogenic global warming has either already begun or will become manifest in the very near future, with average global temperatures predicted to rise by 1.5-4.5°C by the middle of next century" (IPCC, 1990; IPCC, 2007; Rai and Rai, 2013b). "Observations over India show that in the last 100 years the mean annual surface air temperature has increased by 0.4°C" (Hingane et al., 1985, Srivastava et al., 2017). Hence, there exists a need for a global parameter to assess the global GHG emissions.

"In order to effectively understand the phenomenon of global warming and its impacts, it is essential to have an assessment and estimation of GHGs from a country or a state or a city" (Karna et al., 2017). In cities, GHG inventory is particularly valuable as the first step in a city's response to climate change. The inventory serves as an indicator of particularly emissions intensive sectors, as well as providing verifiable metrics upon which to facilitate targeted project financing. "As further actions on climate change are taken, methodologically consistent GHG inventories can indicate if the actions are reducing emissions as expected, or if their impacts are negated by unforeseen circumstances. An inventory that reveals few emissions may also point to areas of greater concern to the city, such as the need for low-carbon development of services or adaptation to climate change" (Sugar 2010). The cities are often blamed for high levels of GHG emissions. However, an analysis of emission inventories shows that – in most cases – per capita emissions from cities are lower than the average for the countries in which they are located. Dodman (2009) "assessed these patterns of emissions by city and by sector, discussed the implications of different methodological approaches to producing inventories, identified the main drivers for high levels of GHG production, and examined the role and potential for cities to reduce global GHG emissions".

Smaller states/UTs like Puducherry experience more pressure in the recent decade. Availability of better infrastructure, health care system, educational facility and cosmopolitan atmosphere in Puducherry city has attracted migration from neighboring areas over the recent years. This has resulted in increased demand for housing, all resources, transportation and generation of all types of wastes. Being an erstwhile French colony, presence of Sri Aurobindo Ashram and scenic beaches has increased tourist inflow, especially during week ends as well. All these have resulted in the increased emission of GHGs.

"In 1992, UN Conference at Rio de Janeiro, the importance of evolving a control mechanism had been realized. Hence, in the UN resolution, an agenda 21 was included for ensuring sustainable development. As a follow up, globally all the countries have to prepare inventory of GHG and also evolve a Climate Change Action Plan (CCAP). All the states in the country, has to follow this. Puducherry also prepared an inventorisation of GHGs as a part of the programme. GHG inventorisation is the first step to prepare an action plan for combating the climate change. It is an essential document, which needs to be periodically updated. The GHG inventory (GHG) is a critical pre-requisite for policy support and response towards mitigation but has to be supported by strategy development and implementation" (Uganda Bureau of Statistics, 2007, Davies et al., 2010, Shuaib 2013). "The inventory was conducted with the Global Protocol for Community-Scale GHG Emissions, which is adapted from various frameworks based on internationally accepted tools for quantifying the GHG emissions attributable to cities and local regions" (Yunus Arikan Rishi Desai et al., 2012). GHG inventories provide a valuable snapshot of the major activities in a city. They can form an important input into a city's urban development planning processes and tools (such as targeted climate action plans or green city action plans) or under frameworks that seek to mainstream environmental management as a core part of urban planning (such as the Green cities operational framework).

"Climate change mitigation in the urban development sector are often most effective when there is a 'coincidence of agendas' between a city's local priorities (including economic growth and service delivery) and its climate change mitigation objectives. The platforms enabled by GHG inventories would help to identify and develop these achievable objectives and the targeted and transformative actions that are needed in the long term" (Dulal et al., 2012, Sonia et al., 2015).

"The annual levels of GHG emissions and reports the causes of variations in emissions levels over time. By measuring and analyzing GHG emissions, the City is able to track the progress it is making toward achieving many of the sustainability policy measures, such as improving buildings' energy efficiency, cleaning the city's power supply, creating low-carbon transportation options, and reducing GHG emissions from City government buildings, wastewater treatment, solid waste disposal, and other sources" (Pasion et al., 2014). The GHG emission forms the basis upon which, the action plan can be prepared. Inventorisation comprehensively covers industrial, domestic transportation, municipal solid waste, sewage and agriculture sectors. Such sectoral estimation of GHG emission is essential to evolve sectoral action plans. Inventorisation is carried out as per UNFCC Protocol.

The comprehensive inventorisation of GHG emissions in Puducherry has indicated that industrial sector is the biggest contributor for the overall GHG emissions. This has given the opportunity to study the trend of inherent emissions. For the present study, based on the high levels of pollution possibilities and the impact of various policy interventions on the GHG emissions of particular industries were chosen. A multi spectrum of industries have been chosen for assessing, their trend of GHG emission. Appropriate policy interventions have also been suggested.

## 1.2 Objectives

The main objective of this research study is to:

- ✓ Evolve an inventorisation of sectoral GHG emissions for Puducherry Union Territory.

- ✓ Suggest appropriate mitigation and adaptation plans for low, medium and high priority actions with short, medium and long-term actions.
- ✓ Study and analyse GHG emission and impacts of policy interventions on the GHG emissions in selected industries,

### 1.3 Scope of the Thesis

Undoubtedly, over the years the global warming and its impacts have been felt all across the globe. The reason for global warming is attributable to emissions of GHGs. Because of growing awareness regarding global warming and also to formulate an action plan for combating the global warming, quantification of GHGs at national and state levels are essential. India also being a signatory to the UN convention on climate change is preparing GHG inventorisation at national, state and city level. This is essential to formulate an appropriate action plan. In the present study, the GHG inventorisation is done for the Union Territory of Puducherry, which paved the way for preparation of mitigation and adaption plans. Case studies with respect to industries have been taken up for trend analysis of their GHG emissions and impact of various policy directives / interventions on the GHG emissions.

### 1.4 Study Area

“The Union Territory of Puducherry comprises the former French establishments of Puducherry, Karaikal, Mahe and Yanam, which lie scattered in South India (*Figure 1.1* and *Figure 1.2*). Puducherry, the capital of the Territory was once the original headquarters of the French in India is situated on the Coromandel Coast of the Bay of Bengal and is about 135 kms from Chennai Airport. It is bounded on the east by the Bay of Bengal and on the three sides by Tamil Nadu. About 130 kms south of Puducherry on the East Coast placed in Karaikal. Mahe is situated on the Malabar Coast on the Western Ghats surrounded by Kerala and is about 70 kms from Calicut Airport. Yanam is situated adjoining the East Godavari district of Andhra Pradesh and is about 200 kms from Visakhapatnam Airport. The Union Territory with legislature extends over an area of 479 Sq. kms. Total population of the Union Territory is 1244464, with a literacy rate of 86.55, as per 2011 Census (Provisional)” (https://www.py.gov.in)

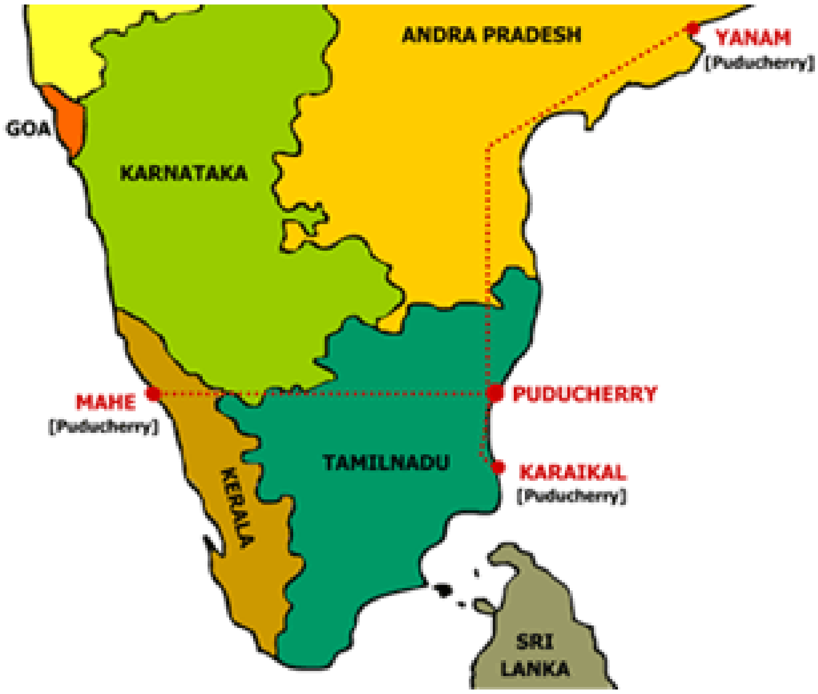



***Figure 1.1. Geographically disconnected regions of UTP (Source: https://www.py.gov.in)***

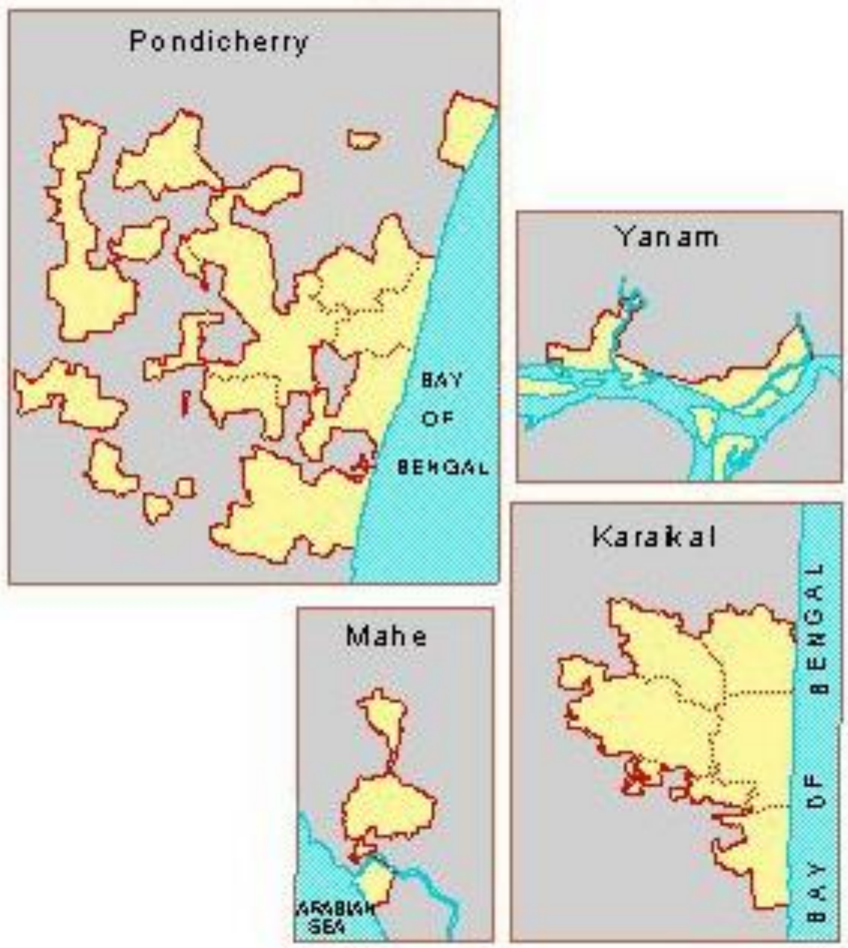



***Figure 1.2. District map of UTP (Source: https://www.py.gov.in)***

## 1.5 Layout of the thesis

The present study has attempted to make an inventorisation of GHG in the Union Territory of Puducherry based on which sectoral action plans has been formulated. The action plan endeavor to categorize the programme / activities into mitigation and adaptation strategies with high, medium and low priority actions with short term, medium term and long-term actions. Besides, the study has attempted to assess the case study in different industries analyzing their trend of GHG emissions and to study the impact of appropriate policy interventions initiated by the industries.

**Chapter 1** – deals with the general introduction on climate change, followed by objectives and scope of the thesis. This Chapter also deals with the study area and layout of the thesis (*Figure 1.3*)

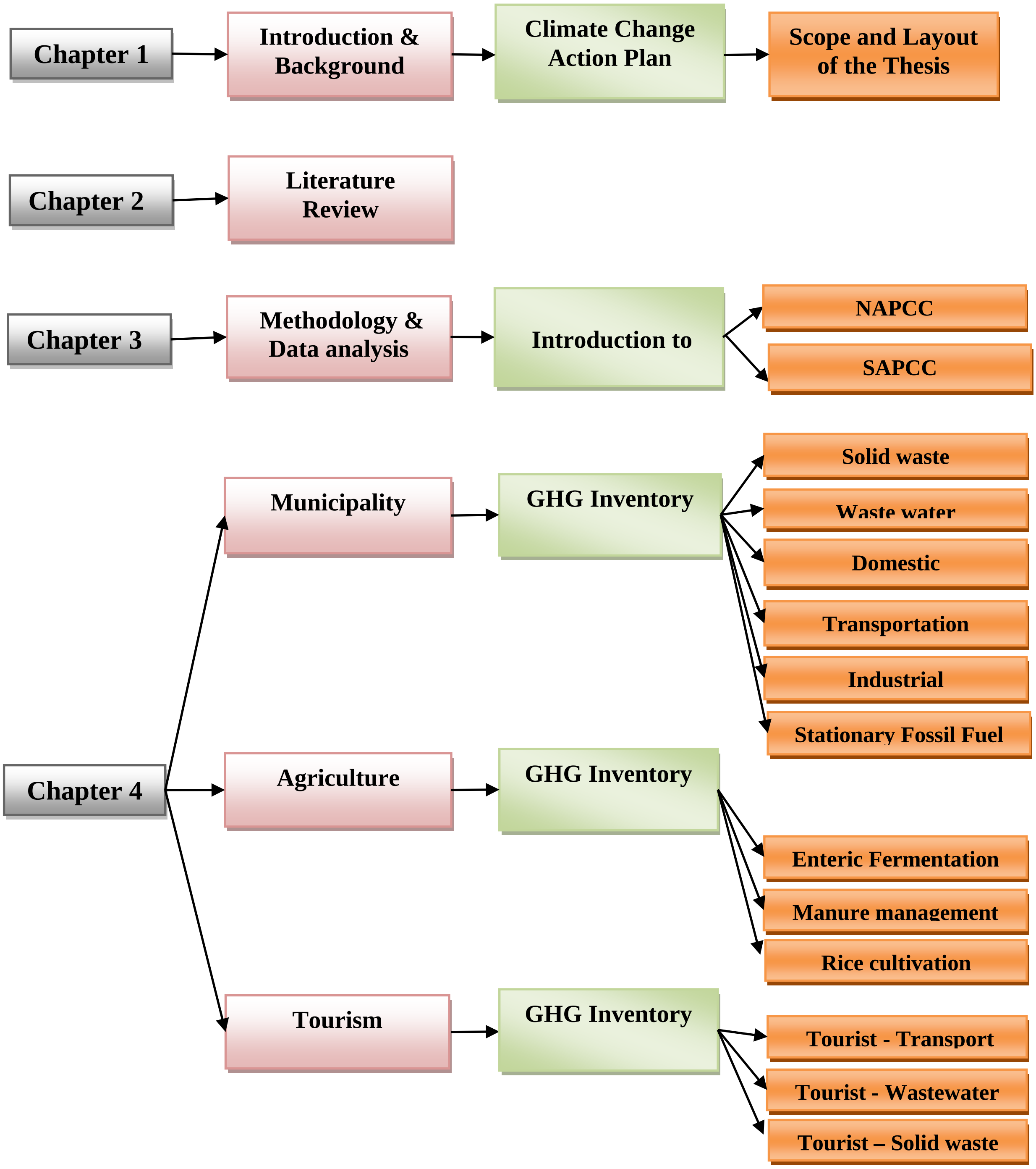
**Chapter 2** – this chapter deals with the detailed literature review under various sub headings like climate change, global warming, impact of climate change, followed by highlighting few points related with GHG-I. Finally, the chapter concludes with the measures taken by governments for mitigating climate change.

**Chapter 3** –covers the countries action plan on climate change and state action plan on climate change.

**Chapter 4** – deals with the detailed inventorisation of GHG at state level under part A and B. Part-A deals with the $CO_2$ emission inventory from domestic sector, transportation sector and industrial sector, followed by $CH_4$ emission inventory from municipal solid waste and municipal wastewater, in addition to enteric fermentation, manure management, rice cultivation from agriculture and animal husbandry sector. The $CO_2$ emission from stationary fossil fuel consumption. Part B deals with the $CO_2$ emission inventory from Tourism Sector, covering Emission from transport sector associated with the tourism; municipal wastewater generated by tourist sector; and from municipal solid waste generated by tourist sector.

**Chapter 5** – describes various plans formulated under Puducherry climate change action plan identifying and prioritizing strategies that simultaneously advance the UTs development goals while yielding co-benefits of climate change mitigation and adaptation effectively.

**Chapter 6** – concludes the study through industrial case studies.



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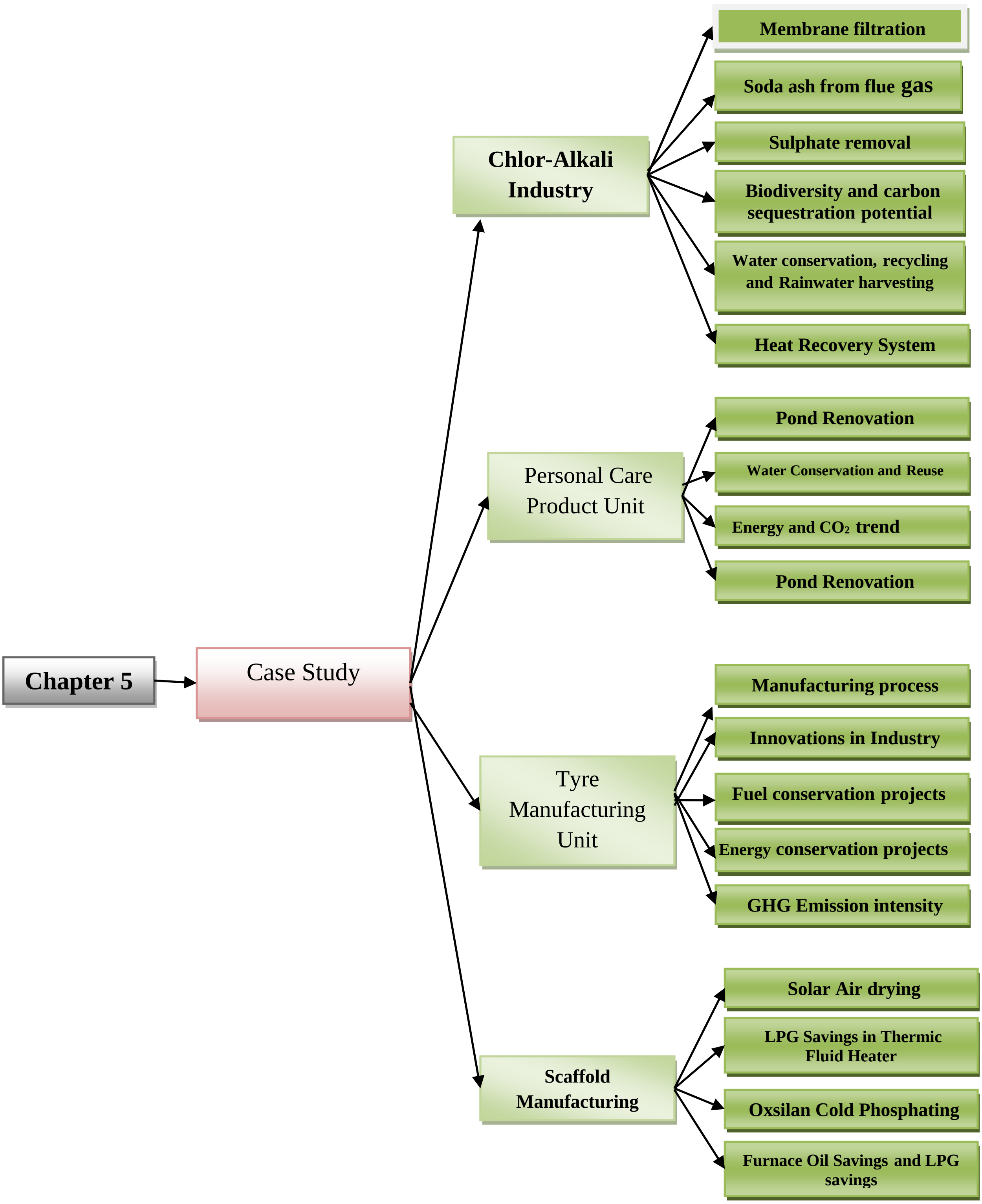
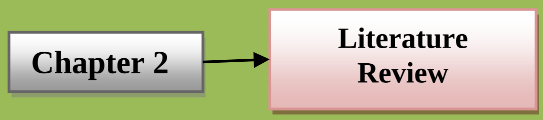



*Figure 1.3. Schematic representation of the thesis layout*

# CHAPTER 2

# 2 LITERATURE REVIEW



## 2.1 Introduction

"The basic science is straightforward and climate researchers have shown a phenomenon known as the greenhouse effect, caused as a result of greenhouse gases, due to anthropogenic activities, such as industry, transport, energy generation and deforestation. Due to the raise in their concentration since the start of the Industrial Revolution in Europe, the scientists were notified the disorderly effects on the Earth's climate. As the result, the Intergovernmental Panel on Climate Change (IPCC), was set up in 1988, jointly by the United Nation Environment Program (UNEP) and the World Meteorological Organization (WMO), with the objective to be the main source of scientific information on climate change, by not doing research, rather to gather thousands of scientists to review the global body of knowledge about climate change and to summarize it in a way that policymakers can use" (EJN, 2016).

"In industrialized countries, many people would rather believe that climate change was not real than accept that their lives must change to meet the threat. Contradictorily in the non-industrialized countries, people think that it is under divine control and that humans cannot alter it. While many businesses accept it as real but are waiting for signals from governments before making long-term investments, many powerful forces, notably the polluting industries and fossil fuel sector, have deep stakes in maintaining business-as-usual. While the very best scientific information points to a clear threat to the future of humanity, the political and public responses to this challenge have been relatively weak, because it being a paradoxical subject" (EJN, 2016).

## 2.2 What is Climate Change?

'Climate change' means "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods that may have resulted as part of Earth's natural processes UNFCCC) (1992)**, w**hereas America's Climate Choices (2010) reported that, the climate change is a change in the statistical distribution of weather patterns when that change lasts for an extended period of time (i.e., decades to millions of years) by factors such as biotic processes, variations in solar radiation received by Earth, tectonic plate, and volcanic eruptions. Certain human activities have also been identified as significant causes of recent climate change, often referred to as global warming, on the other hand NASA (2011) indicates that within scientific communities, global warming refers to surface temperature increases while climate change includes global warming and everything else that increasing GHG levels affect" (NASA, 2011). In the context of environmental policy, the term 'climate change' has become synonymous with 'anthropogenic global warming'.

## 2.3 What is Global Warming?

"Global warming refers to the continuous increase of temperature in the Earth's climate system, and is going to be one of the biggest environmental and humanitarian crises in the very near future. In 2007, the Intergovernmental Panel on Climate Change (IPCC) of the United Nations reported with more than 90% certainty that man-made carbon dioxide ($CO_2$) is the primary cause of global warming" (Gore, 2007; EPRI, 2007). "In 2013, the IPCC concluded that, the largest driver of global warming is $CO_2$ emissions from fossil fuel combustion, cement production, and land use changes such as deforestation. Tropical deforestation is also considered as another major contributor to global warming. When the forests are blistered they release huge amounts of carbon into the atmosphere and the forest covers are no longer available to absorb $CO_2$, either through natural or manmade" (www.ucsusa.org). Bhattacharjee (2010) concluded that, "Global Warming is causing the temperature rise in the global environment may affect the change in the atomic properties of the elements like motion, magnetism, electrostatic, conduction, electronic structure, crystalline structure, electro positivity, electro negativity etc. Also this Global Warming has a great impact on earth's magnetism, gravitation, polar ice melting, sea level rise, change of weather, disease affective bacteria-virus explosion etc. Due to the change of atomic nature and properties with respect to rise of temperature, human and plant life will be highly exaggerated. IPCC Climate Change (2001) further stressed that, *"g*lobal warming is no longer just a prediction - it is actually happening".

"For each GHG, a Global Warming Potential (GWP) is calculated by the international climate change scientists, to reflect how long it remains in the atmosphere on an average, and how strongly it absorbs energy. Gases with a higher GWP absorb more energy, per pound, than gases with a lower GWP, and thus contribute more to warming Earth" (http://www3.epa.gov). *Table 2.1*, shows the relative six "greenhouse gases (GHG)" and its "global warming potential (GWP)" covered by the Kyoto protocol (Perfluorocarbons and Hydrofluorocarbons are sub-families of halocarbons) (source: http://www.manicore.com).

***Table 2.1. The relative six "greenhouse gases (GHGs)" and their "global warming potential (GWP)" covered by the Kyoto Protocol***

***(Source: http://www.manicore.com)***

| S. No. | List of major Gases | Relative GWP / $CO_2$ (100 years) |
|---|---|---|
| **1.** | **Carbon dioxide (**$CO_2$ ) | 1 |
| **2.** | **Methane (**$CH_4$) | 25 |
| **3.** | **Nitrous oxide (**$N_2O$) | 298 |
| **4.** | **Perfluorocarbons (**$CnF_{2n+2}$) | 7400 to 12200 |
| **5.** | **Hydrofluorocarbons (**CnHmFp) | 120 to 14800 |
| **6.** | **Sulfur hexafluoride (**$SF_6$) | 22800 |

## 2.4 What are the impacts of Climate Change?

The concept of climate change assumes a progression of extreme weather and environmental changes at an unprecedented rate and scale. IPCC (2007) "reported that 'Climate change impacts' are the 'effects of climate change on natural and human systems. Depending on the consideration of adaptation, one can distinguish between potential and residual impacts:

- Prospective impacts are the impacts that may occur given a projected change in climate, without considering adaptation;
- Although residual impacts are the impacts of climate change that would occur after adaptation"

According to the various global scientists, professionals, organizations, NGOs "the warming of the climate system is unequivocal and without significant changes, the trend in global emissions of GHGs and climate change will continue resulting in wide ranging impacts and economic costs across different sectors and regions". "Several workers such as Venkataramanan et al. (2011) indicated that, on one hand the earth is getting hotter and hotter, whereas on the other hand, the disasters like hurricanes, droughts and floods are becoming more frequent. It is also important to recognize that, the severity of impacts is not only, solely due to extreme weather or other natural events following from global climate change but rather to the interaction between human systems and these events (National Research Council, 2008) and in conjunction with this, EPA (2015) has reported that ever increasing GHG emissions from human activities, is resulting in many climate change impacts are also expected to increase in both magnitude and frequency over the upcoming decades, with risks to human health, the economy, and the environment".

Mann (2009) has stated that, "CC can be viewed as consisting of two components, one of which is human (i.e., anthropogenic) in origin and coincides in timing with the industrial period of the past two centuries, and the other of which is natural and has played a role in both past and current climate variability”. “According to USEPA, with increasing population, more and more countries are facing the problem of global environmental change originating from large expansion of industrial sector. Hand in hand, the population growth will also cause a rapid increase in the number of industries manufacturing agro-chemicals to support agricultural production as well as will uplift the industrial demand for resources as indicated” by Rai and Rai (2013).

“Researchers across the globe and IPCC had indicated that, anthropogenic global warming is already begun and will become manifested in the very near future, with average global temperatures predicted to rise by 1.5-4.5°C by the middle of next century (IPCC 1990; IPCC 2007). The IPCC declared that ‘warming of the climate system is unequivocal’ (IPCC 2007 a). The Geological Society of America (GSA) concurs with assessments by the National Academies of Science (2005), the National Research Council (2011), the Intergovernmental Panel on Climate Change (IPCC, 2013) and the U.S. Global Change Research Program (Melillo et al., 2014) that global climate has warmed in response to increasing concentrations of $CO_2$ and other GHGs. The concentrations of GHGs in the atmosphere are now higher than they have been for many thousands of years and the anthropogenic GHG emissions are the predominant cause of the rapid warming since the mid-1900s” (IPCC, 2013).

“When it comes to raise in temperature, the global mean temperature had increased by 0.76°C between 1850–1899 and 2001–2005 and the IPCC concluded that most of the observed increases in global average temperatures since the mid-20$^{th}$ century are ‘very likely’ (> 90% probability) the result of human activities. Moreover IPCC (2007), Rajesh (2012) also predicts that the pace of climate change is ‘very likely’ (> 90% probability) to accelerate with continued GHG emissions at or above current rates, while globally averaged surface temperatures estimated to rise by 1.8°C to 4.0°C by the end of the 21$^{st}$ century. It is very likely that hot extremes, heat waves and heavy precipitation events will continue to become more frequent. Tropical cyclones will likely become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures. Decreases in snow cover, already observed in some regions, and are projected to continue” (IPCC, 2007; Shah, 2015). IPCC (2013) also had highlighted that “the earth's averaged land and ocean surface temperature has increased by about 1.2 to 1.9$^{o}$ F since 1880 and he last three decades have each been progressed as the warmest decades successively at the Earth’s surface since 1850 (IPCC 2013) almost very likely as the result of human activities”.

IPCC Third Assessment Report (2001), Michael (2017) stated that, “Climate change is more likely to have important impacts on the development of settlements in resource-dependent regions or coastal or riverine locations. Most of the concerns were of possible negative impacts on development (e.g., on the comparative advantage of a settlement for economic growth compared with other locations), although impacts on some areas were considered likely to be positive.”

## 2.5 Whether CC can be mitigated?

In spite of this warming scenario, UNFCCC (2013) announced that “GHG fell by 3.3 % in the EU during 2011, leading to the lowest level of emissions in reports going back to 1990 and also the third largest over this period, according to official data compiled by the European Environment Agency (EEA) as reported by the EU to the United Nations Framework Convention on Climate Change. In tune with his EU greenhouse gas inventory (GHG-I) data submitted that CO2 emissions from fossil fuel combustion (covering approximately 80% of EU total GHG emissions) also point to a 2.1% decrease between 2011 and 2012. EU GHG-I (2013) also announced that, the EU’s total GHG emissions in 2011 were 18.4% below 1990 levels, and when international aviation is included, in line with the climate and energy package. GHG emissions fell 17% in the EU since 1990. Jacqueline McGlade, EEA Executive Director states that, “The GHG emissions cut in 2011 is good news, however, it was largely due to a warmer winter. Nonetheless, the EU is making clear progress towards its emission targets” (http://www.eea.europa.eu). Supporting this view, Wellington City Council (2016) announced that the gross GHG emission has been reduced by 2.1% between 2001 and 2015, with an overall 24,760 tonnes CO2-e reduction per year, resulted because of more efficient electricity use and reduced solid waste heading into our landfills”.

IPCC (2007) report stated that, “the increasing interest in quantification of GHG emissions comes as a result of growing public awareness of global warming and many global metropolitan cities and reputed organizations were estimating their GHG emissions and developing strategies to reduce their emissions. A recently released "Greenhouse Gas Emission Inventory" showed approximately 203775 metric tons of carbon dioxide reciprocal ($MTCO_2e$) during 2014, inside La Cañada. More than half of those emissions came from vehicle trips beginning or ending inside city limits, while emissions resulting from the use of electricity and natural gas in commercial and residential accounted for about 33%. At periodic meeting, consultants and city staff provided information regarding progress and changes, since the last inventory report was conducted in 2007, which helped to evolve the city’s ‘2013-Energy Action Plan’ ”.

UNFCCC (2007) found that “$CO_2$ emissions of all industrialized countries declined by 1.3% during 1990-2006. This reduction was primarily due to the countries whose economies are in transition”.

## 2.6 What is greenhouse gas inventorisation (GHG)?

“Climate change poses one of the toughest challenges facing us today. It’s not just an environmental issue – it’s an economic issue that has the potential to put prosperity out of the reach of millions of people” as announced by World Bank Group President, Jim Yong Kim (2013). Along with World Bank Group President Jim Yong Kim (2013), IPCC (2013) and various other global scientists have also reported that, “since GHG continue to increase and the climate models predict that the average temperature at the Earth's surface is likely to increase from 0.5 to 8.6ºF above 1986 through 2005 levels by the end of this century (depending on the anthropogenic future emissions), cities offer a unique opportunity to tackle climate change, and the good news is that, city leaders are not waiting for international agreements to take action (World Urban Forum. 2014). Currently, there are many cities in the developed and developing world that want to take a climate-smart development path and that is where this initiative ‘State Action Plan on Climate Change for Union Territory of Puducherry’ comes in (discussed in Chapter 3) and furthering the very purpose of inventorisation of GHG for the development and mitigation as necessitated”

“The impacts of cities on global climate change, and, in turn, the impacts of climate change on cities are topics that have received significant attention in the literature. The problems and the solutions are explored simultaneously: urban infrastructure strategies for climate change mitigation and adaptation are developed and piloted as the debate ensues about standardized methodologies for inventorying GHG emissions. However, if the effectiveness of the action on climate change is to be maximized, there is an increasing need for coordination and planning. The GHG for nations assign any emissions that occur within the jurisdictional borders of a country as that country’s responsibility” (IPCC 2006).

Ibrahim et al. (2011) reported that “the GHG emissions inventory protocols and methodologies use common terminology, the differences in inventorying approaches are many, and the implications of the inventorying results at the city level are important to climate change policy and decision-makers”. Asian Development Bank (ADB-2009) provided more climate financing for GHG inventories. Southeast Asian countries can benefit from various international and regional initiatives and programs that provide climate financing, technology transfer, and capacity building.

"Ramaswami et al. (2008) demonstrated that the emissions of eight U.S. city case studies increase urban inventories by an average of 45%. Whereas Khanna et al. (2014) stated that, the Chinese cities have been analyzed their power consumption and reporting their inventories, energy intensity, and carbon intensity. With knowledge of their emissions, cities are identifying potential energy savings and emissions reductions in order to set specific targets. City-level GHG target-setting in China has focused on carbon intensity ($CO_2$/GDP), in line with the national target in the 12th FYP. Carbon intensity targets range from 15% to 50% reduction from 2005 levels by 2020".

"Sharma (2006) scrutiny based on the improvements made in GHG estimation reported in the Initial National Communication with respect to the earlier published estimates and highlights the strengths, the gaps that still exist and the future challenges for inventory refinement. An assessment of the current and projected trends of GHG emission from India and some selected countries indicates that though Indian emissions grew at the rate of 4 per cent per annum during 1990 and 2000 period and are projected to grow further to meet the national developmental needs, the absolute level of GHG emissions in 2020 will be below 5% of global emissions and the per capita emissions will still be low compared to most of the developed countries as well as the global average. Sharma (2006), IPCC, (2014) also studied that, GHG of the anthropogenic sources, like: combustion of fossil fuels, and are not concerned with $CO_2$ that is part of the "natural" carbon cycle, for example vines that take in $CO_2$ as they grow, and release $CO_2$ when they and grapes are composted/fermented".

Sugar (2010) reported that, "a city's GHG is particularly valuable as the first step in a city's response to climate change. The inventory serves as an indicator of particularly emissions intensive sectors, as well as providing verifiable metrics upon which to facilitate targeted project financing. As further actions on climate change are taken, methodologically consistent greenhouse gas inventories can indicate if the actions are reducing emissions as expected, or if their impacts are negated by unforeseen circumstances. An inventory that reveals few emissions may also point to areas of greater concern to the city, such as the need for low-carbon development of services or adaptation to climate change".

International Institute for Sustainable Development IISD (2015) reported that, "GHG must include all the major GHG as indicated in the Kyoto Protocol like carbon dioxide ($CO_2$), nitrous oxides ($N_2O$), methane ($CH_4$), Sulphur hexafluoride (SF6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs). The goal of inventories is that their values should be neither far over nor below the real values in accordance with GHG development principles of transparency, accuracy, completeness, relevancy and consistency". Similarly, Pasion et al. (2014) also stated that "GHG reports annual levels of GHG emissions and causes of variations in emissions levels over time. By measuring and analyzing GHG emissions, the City is able to track the progress in making toward achieving many of the sustainability policy measures outlined in the climate change action plan, such as improving buildings' energy efficiency, cleaning the city's power supply, creating low-carbon transportation options, and reducing GHG emissions from City government buildings, wastewater treatment, solid waste disposal, and other sources. The citywide GHG consists of all direct and indirect GHG emissions from energy used by buildings and other stationary sources, on-road transportation, and public transit (excluding aviation and marine transportation) within the geographic borders; fugitive GHG emissions from wastewater treatment, in-city landfills, solid waste disposed of out of the city, and electricity and natural gas distribution within the city; and GHG emissions associated with the transportation of solid waste outside of the city".

World Bank (2013) "developed GHG for Cebu city in the Philippines, Da Nang in Viet Nam, and Surabaya in Indonesia, and as a part of the recent World Bank study exploring sustainable urban energy and emissions planning and development in these cities. The GHG inventories were done to establish baseline emissions mapping, that complimented baseline energy balances, to gain insights into the relative share of emissions from different energy sources and on policies and initiatives that the city could undertake to mitigate GHG emissions while also meeting its energy goals".

The GHG by Dulal and Akbar (2012), "provide a valuable snapshot of the major activities in a city. They can form an important input into a city's urban development planning processes and tools (such as targeted climate action plans or green city action plans) or under frameworks that seek to mainstream environmental management as a core part of urban planning (such as the Green cities operational framework). Climate change mitigation measures in the urban development sector are often most effective when there is a 'coincidence of agendas' between a city's local priorities (including economic growth and service delivery) and its climate change mitigation objectives. The platforms enabled by GHG would help to identify and develop these achievable objectives—and the targeted and transformative actions that are needed in the long term”. “Even though Dodman (2009) explained that, the cities are often blamed for high levels of greenhouse gas emissions. However, an analysis of emissions inventories shows that – in most cases – per capita emissions from cities are lower than the average for the countries in which they are located, the climate change workers Sugar *et al.,* (2012) further reported that the GHG for Shanghai, Beijing, and Tianjin point to sectors requiring the most attention in terms of low-carbon growth. Compared to ten other global cities, Chinese cities are among the highest per capita emitters, alluding to the important challenge China faces in reducing emissions while improving the quality of life for urban residents. Accordingly, they conclude that low-carbon growth should incorporate the potential for renewable energy and the difficulties associated with emissions relocation and policy adoption”.

## 2.7 What are the measures taken by the Government of India towards Climate Change?

“Climate change due to anthropogenic activities is a serious threat for all the countries and India is no exception. Over the last 100 years, the average air temperature near the Earth’s surface has risen by a little less than 1ºC (Venkataramanan et al., 2011) and observations over India showed that in the last 100 years the mean annual surface air temperature has increased by 0.4°C” (Hingane et al., 1985, Srivastava et al., 2017), which necessitates, a need for a global parameter to assess the global greenhouse gas emissions.

“Climate change may occur faster than the capacity of people, ecosystems and institution. Based on the scale vulnerability of exposure, sensitivity and adaptive capacity, as indicated by IPCC (2014) report, India is vulnerable to the impacts of climate change due to its higher exposure and lower adaptive capacity. India is the fastest growing economy in the world. It is the fourth largest GHG emitter, accounting for 5.8 percent of global emissions. India’s emission increased by 67.1 percent between 1990 and 2012, and is projected to grow 85 percent by 2030 under business-as-usual scenario. By other measures, India's emissions are relatively low compared to those of other major economies. India accounts for only 4 percent of global cumulative energy-related emissions since 1850, compared to 16 percent and 15 percent for the United States and China” (WRI, 2011) respectively. India produces about 2 tons of $CO_2$e per capita.

“India continued to increase its CO2 emissions to 2.47 billion tonnes in 2015, which was 5.1% more than in 2014. The largest increase in global CO2 emissions – 5.3% came from India, making it the world’s fastest-growing major polluter. Still India has been conscious of the global challenge of Climate Change. India’s per capita emissions of 1.9 tonnes $CO_2$/cap are more than three times lower than the average per capita emissions in the EU and even lower than the average per capita emissions in developing countries" (WRI, 2011).

"As a signatory to the United Nations Framework Convention on Climate Change (UNFCCC), India has undertaken to communicate information about the implementation of the Convention, taking into account the common but differentiated responsibilities and respective capabilities and their specific regional and national development priorities, objectives and circumstances. The elements of information provided in the communication include a national inventory of anthropogenic emissions by sources and removals by sinks of all GHGs, a general description of steps taken to implement the Convention including an assessment of impacts and vulnerability and any other relevant information. India has submitted the Second National Communication (NATCOM) to the UNFCCC in 2012. The first National Communication was submitted in 2004. As per the Second national Communication submitted by India to the UNFCCC, it is projected that the annual mean surface air temperature rise by the end of the century ranges from 3.5$^{0}$c to 4.3$^{0}$c, whereas the sea level along the Indian coast has been rising at the rate of about 1.3mm/year on an average. These climate change projections are likely to affect human health, agriculture, water resources, natural ecosystems, and biodiversity" (Economic Survey 2012-13).

"India's strategy for addressing Climate Change is reflected in many of its social and economic policies. Gross Domestic Product (GDP) of India is growing twice as fast as GHG emissions are being decoupled from economic growth due to constant efforts to increase the share of renewable energy in energy mix and to enhance energy efficiency. India has achieved 12% reduction in emission intensity between 2005 and 2010 and emission intensity of GDP by 33-35% by 2030, compared to 2005 level. India's per capita GHG emission is less than one-third of the world average" (UNFCCC (2011) and Charles (2016).

National Environment Policy (2006), "India's response to Climate Change-*inter-alia*, include adherence to principle of common but differentiated responsibility and respective capabilities of different countries, identification of key vulnerabilities of India to Climate Change, in particular impacts on water resources, forests, coastal areas, agriculture and health, assessment of the need for adaptation to Climate Change and encouragement to the Indian Industry to participate in the Clean Development Mechanism (CDM).

The National Action Plan on Climate Change (NAPCC) coordinated by the Ministry of Environment and Forests is being implemented through the nodal Ministries in specific sectors/areas.

The plan identifies eight core ‘national missions’ viz. National Solar Mission, National Mission for Enhanced Energy Efficiency, National Mission on Sustainable Habitat, National Water Mission, National Mission for Sustaining the Himalayan Ecosystem, National Mission for a “Green India”, National Mission for Sustainable Agriculture, National Mission on Strategic Knowledge for Climate Change.

Emphasizing the overriding priority of maintaining high economic growth rates to raise living standards, the plan ‘identifies measures that promote our development objectives while also yielding co-benefits for addressing Climate Change effectively’.”

“In Paris Agreement, 2015, countries adopted an international agreement to address climate change that requires deeper emissions reduction commitments from all countries-developed and developing. Countries responsible for 97% of global emissions submitted their climate commitments prior to the conference. These commitments will now be enshrined in the coming months once countries formally join the agreement. The agreement contains provisions to hold countries accountable to their commitments and mobilize greater investments to assist developing countries in building low-carbon, climate resilient economies” (NRDC, 2015).

## 2.8 What is climate related bond/financial/investment market/climate credits?

Climate Bonds Initiative (2014) reported that, “GHG-I can be a key input for enabling cities to raise financing through the global climate related bond market, which focus on financial instruments that generate economic returns as well as carbon savings. Municipal climate bonds, at $2 billion, are currently a small share of the global climate bonds market of about $500 billion, suggesting significant potential for scaling up the issuance of these bonds by cities. GHG-I can help to raise public awareness and establish green city brands and can engage the public in understanding the magnitude and sources of a city’s carbon and GHG footprint, and on the city’s climate action plan to address this. Recent developments in big data analysis and visualization tools present opportunities to simplify and present technical information to non-technical audiences in visually powerful ways. GHG-I also form the basis for cities or areas to develop green brands, through registering or being certified with organizations and institutions that offer these. This, in turn, makes the city more competitive on a global scale" (www.carbonvisuals.com)

According to Gouldson et al., (2014) "GHG-I can help to engage the private sector and drive green investments that will make cities more competitive globally. With cities, being key drivers of global economic growth-and of GHG emissions-investments to mitigate climate change in cities will yield significant benefits for the global economy and climate. Through GHG inventories, quantifying these benefits by subsector and in economic and financial terms becomes possible, as recent studies have done for selected cities around the world".

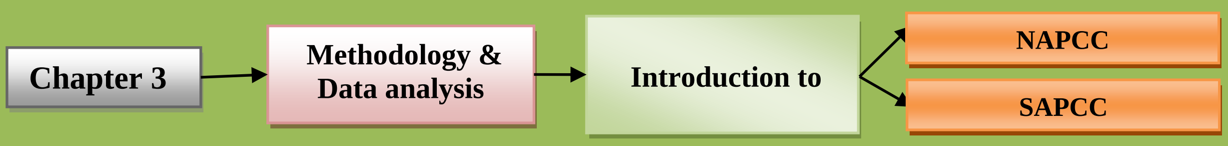
"GHG inventories could be a useful tool for cities seeking to access financing from the evolving global carbon market" (World Bank, 2010). "The new international climate agreements expected at the UN climate talks in Paris in December 2015 will play a big role in determining the future of the carbon market. Regulated carbon markets have been a central feature of the Kyoto Protocol, which established three flexible mechanisms that can be used by Parties in meeting their emission limitation commitments. The flexibility mechanisms are International Emissions Trading (IET), the Clean Development Mechanism (CDM), and Joint Implementation (JI), where the Clean Development Mechanism (CDM), is meant to encourage market-based reductions in carbon emissions" (http://unfccc.int; https://cdm.unfccc.int). "A key part of the CDM process is establishing a baseline for emissions, and certifying emission reductions relative to this baseline, a process that is greatly facilitated by citywide GHG inventories. There is a growing recognition for the need for city authorities to directly tap into carbon markets, reversing a historic trend where as low as less than 1% of CDM projects were credited to cities. A GHG inventory can serve as a vital tool to aggregate different emissions to a scale that is suitable to access carbon markets. It also helps to prevent double counting of emissions and reductions, which can happen when discrete projects or sectors independently claim credits for the same reduction in emissions (for example, if credits are claimed by the producer as well as the consumer for a green energy project). Comprehensive inventories will help cities and their constituents in monitoring, reporting, and verification of emissions as the global carbon market continues to mature and evolve" (http://unfccc.int; https://cdm.unfccc.int).

## 2.9 How to measure GHG in the Inventory?

Sridevi **(**2014) has reported that " 'Carbon footprint' can be defined as a measure of the impact of human activities on the environment in terms of the amount of GHG produced. The total GHG emissions from various anthropogenic activities are expressed in terms of carbon dioxide equivalent, which indicate the carbon footprint of a region. Carbon dioxide equivalent ($CO_2$e) is a unit for comparing the radioactive forcing of a GHG to that of carbon dioxide. It is the amount of carbon dioxide by weight that is emitted into the atmosphere that would produce the same estimated radioactive forcing as a given weight of another radioactively active gas. $CO_2$e are calculated by multiplying the weight of the gas being measured by its estimated Global Warming Potential (GWP)".

# CHAPTER 3

# 3 METHODOLOGY AND DATA ANALYSIS



## 3.1 Introduction

Significant GHG emissions reductions have been identified as necessary to mitigate global warming. According to Stern (2007) and Jonathan (2012) “stabilization of atmospheric GHGs at a concentration of 450 parts per million of Carbon dioxide equivalent, which is associated with a 2° C global temperature increase, has been reported to require a 70% reduction of GHG emissions by 2050”. “To cope up with this target, in the last 10 years many cities and countries have adopted climate action plans (CAPs), primarily to reduce GHG emissions or address issues with climate vulnerability” (Coleman, 2014). Coleman (2014) “pointed out that climate action plans can be named in a variety of ways - Energy Action Plan, Sustainability Plan etc., Including components universally recognized, but for the purpose of this research”, all policy documents that include these requisite components will be referred to as State Action Plan on Climate Change (SAPCC) of Union Territory of Puducherry (UTP).

Several workers- Betsill (2001); Betsill and Bulkeley (2004); Feiock et al. (2010); Millard-Ball (2012); Coleman (2014) have indicated that “many climate action plans created in politically liberal communities reinforce and condense planning efforts and policies already present in their target communities”. While Coleman (2014) suggested that, “for local climate action planning to be successful on a national scale, it seems important for communities to adopt emission reduction and adaptation strategies in places that may not be naturally receptive to ‘*environmental concerns*’ ”. “Even though various researchers had shown that indirect benefits of planning efforts (providing information and generating social capital) can be created through the CAP, adoption, and implementation process” (Betsill ,2001; Kousky and Schneider 2003; Kamal-Chaoui and Roberts , 2009; Dolan et al. 2010; Feiock et al. , 2010; Coleman , 2014). Coleman (2014) have concluded that “in order to achieve a nationwide reduction in GHG emissions, communities that already apply many environmental policies and programs cannot be the only jurisdictions that employ CAP in their long term policy goals, rather, c*onservative* communities must see it as imperative to adopt various CAP strategies for their own benefit and stability in order for this type of planning to be successful in reducing GHG emissions on a meaningful scale”. “Hence, to encompass various strategies like mitigation and adaptation, the researcher of this study had identified ‘mixed method approach’ ” as recommended by Patton (1990), Commander and Ward (2009), Finlay (2010) and Nandhivarman (2017).

Various studies have analyzed the phenomenon of increased climate action planning (CAP) (Betsill, 2001; Betsill&Bulkeley, 2004; Lindseth, 2004; Wheeler, 2008; Bassett et al., 2010; Pitt, 2010a; Sharp et al., 2011; Coleman, 2014). "Each of these has identified unique attributes of CAPs such as structure, content, stakeholder involvement and efficacy. Some have studied the variables of political will (Betsill, 2001; Wheeler, 2008) and political climate (Leiserowitz, 2006; Bassett and Shandas, 2010; Reams et al., 2012; Coleman, 2014) as well, as elements of the research, coupled with research gaps in the study of climate action planning" as indicated by Coleman (2014). However, no concluded study was currently available in India that specifically analyzes climate action planning for urban areas until recently, especially for UTP. Other CAP workers Zahran et al. (2008a), Millard-Ball (2012) and Coleman (2014) concluded that "a broader spectrum and more purposeful evaluation of CAP case study research should be pursued for meaningful implementation. Others have stated that more information is needed in terms of the characteristics jurisdictions possess that have adopted CAPs; and how nonparticipants can become engaged in climate policies and planning" (Pitt, 2010). This thesis seeks to elucidate the characteristics of SAPCC.

## 3.2 Methodology

Based on the available body of literatures, IPCC indicates that, "many risks constitute particular challenges for the least developed countries and vulnerable communities, with limited ability to cope. People who are socially, economically, culturally, politically, institutionally marginalized are especially vulnerable to climate change" (https://www.ipcc.ch). According to the sources, although GHG-I is prepared at the national level no initiatives has been undertaken to down scale it at the regional level. Hence in this study 'GHG-I', the standard that is provided by Intergovernmental Panel on Climate Change by 2006 and recommended by the Ministry for Environment Forest and Climate Change (http://www.ipcc-nggip.iges.or.jp; http://envfor.nic.in; http://www.moef.nic.in; Dwarakanath et al., 2016) was adopted. The IPCC 2006 guideline suggests "a three tier approach for estimation of GHG emission (http://www.ipcc-nggip.iges.or.jp; http://envfor.nic.in; http://www.moef.nic.in; Dwarakanath et al., 2016):

- ***Tier I:*** In this approach, the activity data are relatively coarse, for example, nationally or globally available estimates of deforestation rates; agriculture production statistics and global land cover maps, etc are used.

- ***Tier II:*** This approach uses the same methodological approach like that of Tier 1, but along with it, the emission factors and activity data, which are defined by the country, are applied.

- ***Tier III:*** This approach applies higher order methods, including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by disaggregated levels".

## 3.3 Data Analysis

"Statistical analysis of data derived from the questionnaires through formal and informal interviews with key stakeholders was done to establish theme, patterns, and league to examine and judge the effectiveness of the study. In general, by combining multiple theories and mixed-methods, the greenhouse gas inventorisation was found to better able to overcome the weaknesses and intrinsic biases inherent from a single method, single-theory study" (Patton, 1990; Commander and Ward, 2009; Finlay, 2010; Nandhivarman, 2017) and when it comes to inventorisation, 'three tier approach' as recommended by Intergovernmental Panel on Climate Change (IPCC, 2006) was adopted. "The mixed-methods approach not only allowed for a rich and in-depth analysis but also enabled a deeper exploration" as indicated by Commander and Ward (2009) and Nandhivarman (2017). Finally, "the mixed-methods approach expanded the breadth and range of inquiry as the findings from one method were used to elaborate, illustrate, enhance, and clarify results from the other methods" (Commander and Ward, 2009; Nandhivarman, 2017) whereas, the 'three tier approach' for estimation of GHG emission, provides less complex data and depends mostly on default emission factors (tire I, related to this study); the higher the tier is approached from I to II and III (that require longer time and can be carried out during the post-doctoral study) will require data in greater details and specific emission factors which are discussed in Chapter 4, 5 and 6.

"In tune with the General Research Ethics Procedures (GREP) (Finlay, 2010; Golda, 2017 and Nandhivarman, 2017), participants (like various Departments, Industries, etc.) were first approached through a letter of information explaining the purpose (GHG-I) and the interview format (structured and semi structured)". They were selected as department/ sector specific (administrative/rural/industrial) key informants because of their key involvement in the administrative activities, and the interview with the help of structured and semi-structured instruments were subsequently extended throughout the study period (from 2012 to 2015). The qualitative data gathered from the interviews and focus group complemented the quantitative data of the questionnaires to provide a comprehensive analysis of the study. "By combining multiple theories and mixed-methods, it would be possible to overcome the weaknesses and intrinsic biases inherent from a single method, single-theory study" as advocated by Patton (1990), Commander and Ward (2009), Finlay (2010) and Nandhivarman (2017).

The template for data collection was evolved based on the available literature, UNFCCC protocol (UN, 1992), discussion with academics institution, World Bank documents, etc. Once, the data collection template was finalized baseline data from various departments of the Government of Puducherry were collected viz. Agriculture, Animal Husbandry, Economic & Statistics, Electricity, Forests and Wildlife, Health and Family Welfare, Hydro-Geology Division of Agriculture Department, Industries and Commerce, Irrigation Division of PWD, Local Administration, Pollution Control Committee, Science, Technology and Environment, Revenue and Disaster Management, State Ground Water Authority, Tourism and concerned Local Bodies were closely involved in data collection.

From the data collected, sectoral GHG inventory was prepared. Data in respect of fossil fuel consumption, electricity consumption across industrial, domestic, agriculture and transport sectors was estimated. Emission of Methane and Nitrous oxide from both liquid and solid was also estimated. Tier I method of IPCC relating to total fuel being sold (FCCC-CP, 2013) was used to estimate the GHG from transportation sector due to the lack of authentic data relating to actual consumption of fuel oil by the vehicle users of the Union Territory (the problem of excluding the transit vehicles), However, considering the fact that a considerable proportion of the oil sold to the transportation sector in UTs used by vehicle of adjacent states due to the lower price of the fuel in the UT and by transits vehicles, the per capita based approach is considered. The calculations were made as per the UNFCCC protocol for estimation of GHG emission.

Descriptive statistics was used for analyzing and consolidation of data, which provided not only an explanation of the key variables of the research, but also allowed further analyses. Results from the statistical analysis were reported as Tables and presented as illustrative Figures and Charts. Frequency distributions were converted to percentages and were used in order to provide a standardized comparison between and among the categories. The interpretation of data thus obtained highlighted the current and emerging trends in understanding and commitment to sustainability. All data sets obtained from the GHG-I was subjected to one-way analysis of variance (ANOVA). Statistical significance was determined using Tukey-Kramer minimum significant difference. Significance levels were compared at $p < 0.05$.

## 3.4 Government of India action plan on climate change

"In the recent period, the anthropogenic increase in atmospheric GHGs has become a cause of serious concern due to their impact on the earth' s radiation budget and related global environmental change issues" (IPCC, 2007; Jens Malmodin et. al., 2010; AbhaChhabra et.al., 2013). "Human influence on the climatic system is currently very clear, and the recent anthropogenic emissions of greenhouse gases (GHG's) are highest in history" (IPCC, 2014; http://climatechange.procon.org). "Anthropogenic emission of GHGs is identified as the major sources of GHGs accumulating in the atmosphere and resulting in global warming" (Pacheco et al., 2015; Tsur and Zemel, 2015). "Hence, the understanding and the quantification of the non-CO2 GHGs emissions is also important because of the fact that, the abatement strategy is less expensive and more effective in mitigating climate change" (Hansen et al. 2000; IPCC 2001; AbhaChhabra et.al, 2013).

Climate variability is manifested through alteration in frequency, intensity, spatial extent, and duration of weather and climate extremes, including climate and hydro-meteorological events such as heat waves, heavy precipitation events, drought and tropical cyclones (eg. Thane in 2011) followed by natural disasters like Tsunami in 2004 is posing greater risks to human life by endangering the sustainability of the natural systems and the economy in the Union Territory of Puducherry (UTP). Hence, sector wise GHG inventory is necessitated to quantify the $CO_2$ equivalent emissions. For this purpose, a methodology was developed for Phase I, focusing on the emission calculation and mitigation plan for agricultural sector of the UTP.

"Globally, the decade of 1990 is which saw the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) and the publication of the update on Climate Change 1992 by the Inter-Governmental Panel on Climate Change (IPCC) were taken as the beginning for the preparation of the dedicated assessments on climate change. More over India's environment policy is anchored in the Constitution of India, Article 48-A of the Constitution which states that, 'the State shall endeavour to protect and improve the environment and to safeguard the forests and wildlife of the country'. The broad policy framework on environment and climate change is laid down by the National Environment Policy (NEP) 2006, addressing climate change without compromising the economic growth. Incidentally, on June 30, 2008, India's first National Action Plan on Climate Change (NAPCC) delineation of existing and outlook policies and programs addressing climate related mitigation and adaptation measures along with the identification of eight core missions—running through 2017 by providing, a sharper focus with multiple strategies, implemented through eight National Missions, outlining priorities for mitigation and adaptation to combat climate change, supplemented by actions of the State Governments, Non-governmental organizations (NGOs), initiatives of the private sector and other stakeholders" (NAPCC, 2008; Dwarakanath et al., 2016). "Thirty two States and Union Territories have put in place the State Action Plan on Climate Change (SAPCC) attempting to mainstream climate change concerns in their planning process" (Dwarakanath et al., 2016).

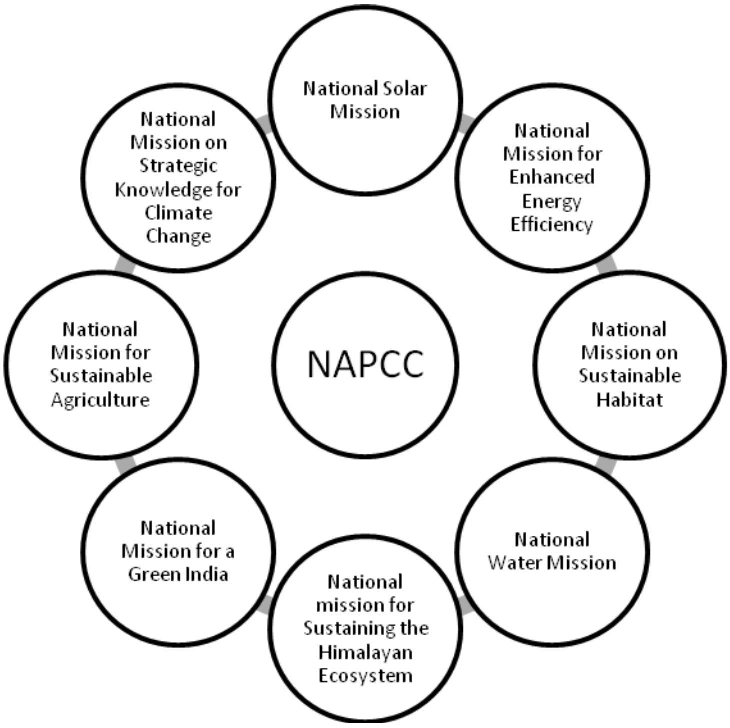



***Figure 3.1. Missions conceived under National Action Plan on Climate Change* (http://dste.puducherry.gov.in)**

## 3.5 State Action Plan Climate Change

"The National Action Plan on Climate Change (NAPCC, 2008) calls for the launch of missions on Agriculture, Water, Solar, Energy, Forestry, Sustainable Habitat, Himalayan Ecosystems and Strategic Knowledge on Climate Change (http://www.moef.nic.in). By August 2009, the states and UT's were suggested to develop their own climate change action plan to address the state specific context under the overarching guidelines of NAPCC. In line with the Govt. of India decision, the Union Territory of Puducherry has formulated the state level action plan on climate change. As a part of the action plan, a Steering Committee was established under the chair of Chief Secretary with the Secretaries of the participating departments as members for the development of CCAP (Climate Change Action Plan). For the Union Territory of Puducherry, DSTE (Department of Science, Technology and Environment) was selected as the nodal department by the steering committee to convene and facilitate the development of CCAP. The

Climate Change Action Plan (2014) was developed in line with the '*National Action Plan on Climate Change (2008)*' with six fold missions and disaster management (*Figure 3.2*). The CCAP

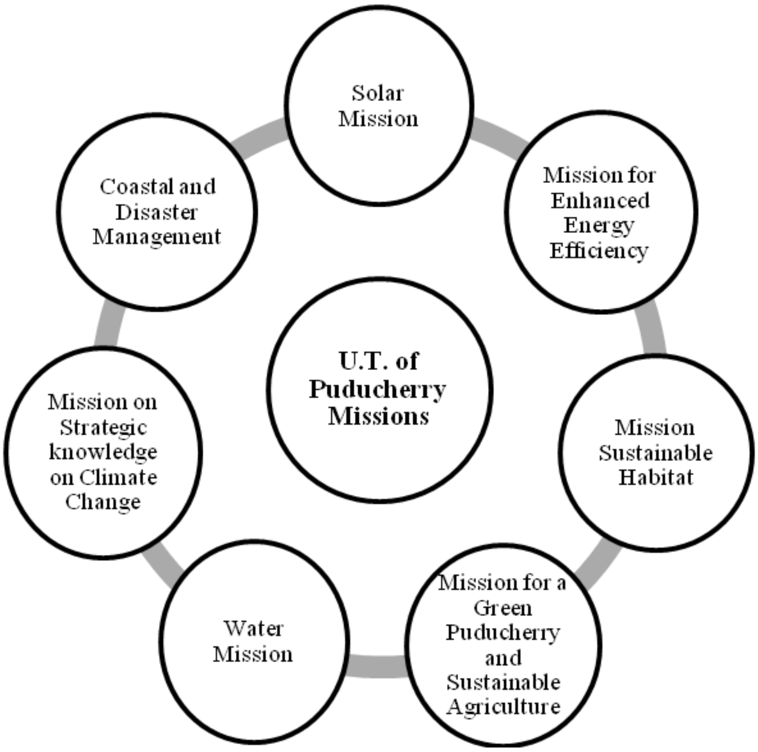



***Figure 3.2. Missions conceived under CCAP for Union Territory of Puducherry***
**(http://dste.puducherry.gov.in)**

The CCAP aims to develop climate resilient policies, knowledge management mechanisms for decision-making and to undertake effective monitoring and evaluation for identifying entry points for climate proof actions and for identifying the existing interval. Fostering CCAP, at UTP, the DST&E (http://dste.puducherry.gov.in) is authorized as the promoter and regulator of GHG assessment, adoption, policy planning and mitigation on climate change".

### 3.6 Principles of the UT CAP

"The Puducherry Climate Change Action Plan is guided by the principles identified in the NCCAP in order to achieve sustainable development of the society by increasing the standard of living of the people and reducing their vulnerability to climate change hazards. The key principles are (PDAPCC, 2014):

- Protecting the poor and vulnerable sections of society through an inclusive and sustainable development strategy, sensitive to climate change.

- Achieving UTs growth objectives through a qualitative change in direction that enhances ecological sustainability, leading to further mitigation of greenhouse gas emissions.

- Devising efficient and cost-effective strategies for the end use Demand Side Management.

- Deploying appropriate eco technologies for both adaptation and mitigation of GHG emissions extensively as well as at an accelerated pace.

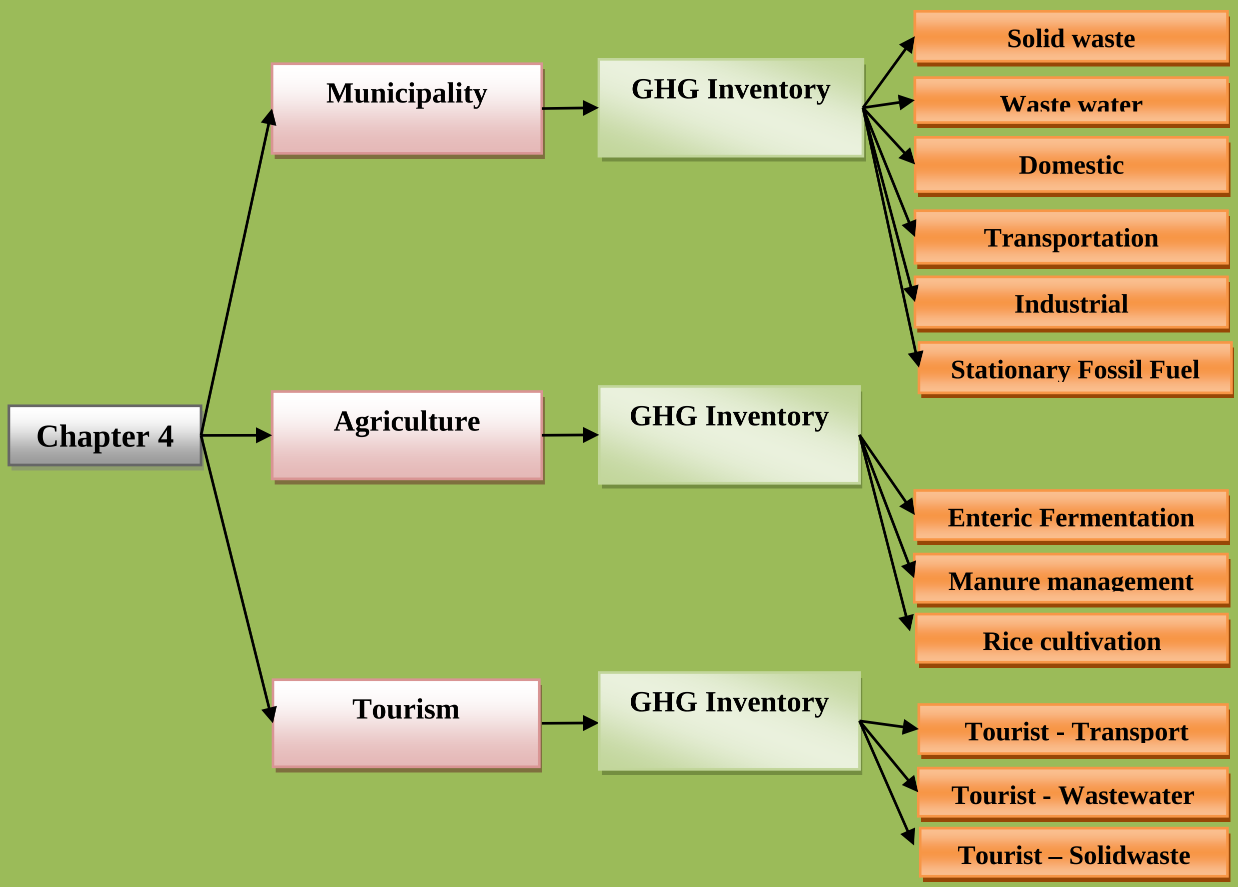
- Engineering new and innovative forms of market, regulatory and voluntary mechanisms to promote sustainable development.

- Facilitating implementation of programmes through unique linkages, including with civil society and local government institutions and through public private-partnership.

- Welcoming international cooperation for research, development, sharing and transfer of technologies enabled by additional funding and a global IPR regime that facilitates technology transfer to developing countries under the UNFCCC"

# CHAPTER 4

# 4 GHG-I AT UTP



## 4.1 Introduction

"The concentration of carbon dioxide ($CO_2$) in the atmosphere is increasing and the climate is changing (IPCC, 2007; Malmodin et. al., 2010). Human influence on the climatic system is clear, and recent anthropogenic emissions of GHG's are highest in history (IPCC, 2014; http://climatechange.procon.org). Anthropogenic emission of GHGs is identified as the major sources of GHGs accumulating in the atmosphere and resulting in global warming (Pacheco et al., 2015; Tsur & Zemel, 2015). Of the six potential major GHGs, causing global warming carbon dioxide ($CO_2$) is the most abundant. Urbanization, urban sprawl, changing life style and modern consumerist cultures together have paved the way for rapid industrialization and also for ever expanding uses of fossil fuel and natural resources, resulting in elevated anthropogenic emission. It is also pertinent to note that proposition of anthropogenic emission reduction through change of the current lifestyle pattern of the consumerist society will be inevitably challenging. Apart from this, equally challenging will be the disagreements and conflicts over the merits and demerits of options in relation to the strategies and policies for pursuing/ adopting them. The resource consumption trends indicate that the implemented policies have failed to bring significant reductions in resource and energy throughput (Kalmykova et al., 2015). Continued emissions of GHGs will cause further warming and long-lasting changes in all components of the climate system, increasing the likelihood of widespread and profound impacts affecting all levels of society and the natural world" (https://www.ipcc.ch). Reducing demand for energy (by changing lifestyle and enabling policies, reducing subsidies); producing and using energy more efficiently; supplying the reduced amount of energy from non-fossil sources, management of solid/liquid waste, management of existing tourism related practices, by enabling policy and incentive measures is outlined in this context as the State Action Plan on Climate Change (SAPCC) (Chapter 5).

"Globally, the decade of 1990 is which saw the adoption of the United Nations Framework Convention on Climate Change (UNFCCC) and the publication of the update on Climate Change 1992 by the Inter-Governmental Panel on Climate Change (IPCC) were taken as the beginning of preparation of the dedicated assessments of climate change. In the Indian context, researchers initiated work related to climate change in their own limited fields, while all the means of information was scattered, diffused and fragmented on various aspects of Climate Change" (http://www.moef.nic.in). Currently, 127 institutions are working on different aspects of climate change in the country. The National Action Plan on Climate Change (NAPCC, 2008) "calls for launch on missions on Agriculture, Water, Solar, Energy, Forestry, Himalayan

Ecosystems and Strategic Knowledge on Climate Change (http://www.moef.nic.in). In Union Territory of Puducherry, the Department of Science, Technology and Environment" (http://dste.puducherry.gov.in) is authorized as the promoter and regulator of GHG assessment, adoption, policy planning and mitigation on climate change. In tune with these national and regional initiatives, this study was carried out by the researcher by involving multiple stakeholders, like the World Bank officers, in association with various government departments, researchers from Pondicherry University and NGOs. Hence , it is considered as a pioneering work and the same is discussed in this Chapter (GHG-I) and Chapter 5 (action plan for mitigation and adaptation).

## 4.2 Theoretical Setup

"Recent climate change is proved to have widespread impacts on human and natural systems. Anthropogenic greenhouse gas emissions have increased since the pre-industrial era, driven largely by economic and population growth, and are now higher than ever before" (IPCC, 2014; http://climatechange.procon.org). "It was estimated that 70% of the world's energy related GHG emissions are coming from cities, and this number is on the rise, as two thirds of all people are expected to live in urban areas by mid-century" (http://ghgprotocol.org). "The ever increasing urbanization and overall growth of the world's population is projected to add 2.5 billion people to the urban population by 2050, with nearly 90% of the increase concentrated in Asia and Africa, simultaneously, the proportion of the world's population living in urban areas is expected to increase, reaching 66% by 2050 (http://esa.un.org). According to the results, India ranks $5^{th}$ in aggregate GHG emissions in the world, behind USA, China, EU and Russia in 2007". (http://envfor.nic.in).

"By 2050, the urban population is predicted to pass 6.7 billion (UNDESA, 2014), out of the 7.1 billion people alive today" (Gouldson et al., 2015). "Forecasts suggest that the vast majority of this urban population live in low and middle-income countries is increasing by 1.2 million people per week (WHO, 2014). When compared to the body of research done on international or national climate strategies, the available literature on the links between cities and GHGs emissions is relatively small" (Gouldson et al., 2015). Recent initiatives by the government sectors, have sought to advance and standardize the ways in which urban GHG-I are prepared.

Based on the above predictions, cities are anticipated to be a major source of GHG emissions and also a major source of innovative climate solutions, it has an integral part in tackling the global challenge of climate change, by evolving various action plan on climate change through GHG-I. “Already many, cities are designing and implementing groundbreaking solutions to mitigate climate change, because urban areas are a logical setting for implementing and measuring climate action” (http://ghgprotocol.org). “Regional level planning for GHG emission reduction however requires a thorough estimation of the inventory and benchmarking against which mitigation measures can be strategized” (Nimkar et al., 2015; Hoek et al., 2015).

“Regional planning for climate action begins with developing a GHG-I, because, a city’s ability to take effective action on mitigating climate change and monitoring progress, depends only on having access to good and reliable data on GHG emissions. GHG-I will enable the cities to understand the emissions contributing to different activities within the community, and also allows the cities to determine where to best address the direct mitigation efforts, create a strategy to reduce GHG emissions, and track their progress. Since, the lifestyle characteristics of the cities have an impact on resource consumption and GHG emission (Kalmykova et al., 2015), GHG emission baseline is considered as an important component of an inventory program” (http://www.ipcc-nggip.iges.or.jp). “Many cities have already developed GHG-I, and use them to set emission reduction targets, inform their climate action plans, and track their performance, in addition, helping the cities meet legal and voluntary requirements to measure and report GHG emissions data” (http://ghgprotocol.org).

## 4.3 Methodology

“Based on the available body of literatures, IPCC indicates that, many risks constitute particular challenges for the least developed countries and vulnerable communities, with limited ability to cope. People who are socially, economically, culturally, politically, institutionally marginalized are especially vulnerable to climate change” (https://www.ipcc.ch). According to the sources, although GHG-I is prepared at the national level, no initiatives has been undertaken to down scale it at the regional level. Hence, in this study, ‘GHG-I’, the standard that is provided by Intergovernmental Panel on Climate Change by 2006 and recommended by the Ministry for Environment Forest and Climate Change (http://www.ipcc-nggip.iges.or.jp; http://envfor.nic.in; http://www.moef.nic.in) was adopted. The IPCC 2006 guideline suggests “a three tier approach for estimation of GHG emission (http://www.ipcc-nggip.iges.or.jp; http://envfor.nic.in; http://www.moef.nic.in):

- ***Tier I:*** In this approach, the activity data are relatively coarse, for example, nationally or globally available estimates of deforestation rates; agriculture production statistics and global land cover maps, etc. are used.

- ***Tier II:*** This approach uses the same methodological approach like that of Tier 1, but along with it, the emission factors and activity data, which are defined by the country, are applied.

- ***Tier III:*** This approach applies higher order methods, including models and inventory measurement systems tailored to address national circumstances, repeated over time, and driven by disaggregated levels.

The uncertainties in estimation however, are reduced when it moves up the tier ladder. For the purpose of GHG emission estimation at Union Territory of Puducherry, the following three GHGs are considered: Carbon dioxide ($CO_2$); Methane ($CH_4$); Nitrous oxide ($N_2O$) (see *Table 4.1*, for the formula, lifetime, radiative efficiency, etc.) (https://www.ipcc.ch)

***Table 4.1. Lifetimes, radiative efficiencies and direct GWPs relative to CO2 (except for CH4)***

***(Source: https://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch2s2-10-2.html)***

| Industrial Designation or Common Name (years) | Chemical Formula | Lifetime (years) | Radiative Efficiency ($W\ m^{-2}\ ppb^{-1}$) | SAR‡ (100-yr) | 20-yr | 100-yr | 500-yr |
|---|---|---|---|---|---|---|---|
| **Carbon dioxide** | $CO_2$ | See [a] | [b]$1.4x10^{-5}$ | 1 | 1 | 1 | 1 |
| **Methane**[c] | $CH_4$ | 12[c] | $3.7x10^{-4}$ | 21 | 72 | 25 | 7.6 |
| **Nitrous oxide** | $N_2O$ | 114 | $3.03x10^{-3}$ | 310 | 289 | 298 | 153 |

**Note:**

“[a] The $CO_2$ response function used in this table is based on the revised version of the Bern Carbon cycle model used in IPCC report, using a background $CO_2$ concentration value of 378 ppm.

[b] The radiative efficiency of $CO_2$ is calculated using the IPCC (1990) simplified expression as revised in the TAR, with an updated background concentration value of 378 ppm and a perturbation of +1 ppm.

[c] The perturbation lifetime for methane is 12 years as in the TAR. The GWP for methane includes indirect effects from enhancements of ozone and stratospheric water vapor”.

When it comes to tourism sector, since currently there is no systematic approach for estimating $CO_2$ emissions associated with the tourism industry, Lin (2010) adopted “two approaches, namely top-down and bottom-up as recommended by several notable workers - Go¨ssling et al. (2005); Peeters (2005); Becken& Hay (2007) and the same is adopted in this study. Where the top-down method approximates the percentage of CO2 emissions for tourism in the entire coordination (i.e., a country or region specific) even as the bottom-up approach investigate data for tourists arriving at the respective destinations”.

The data collection is done through Puducherry Tourism and Transport Development Corporation (PT&TDC), Transport Department, Local Administrative Department (LAD), Hospitality Industry and Hydrology Department either through personal contact or by referring their respective web sites. Evaluation of CO2 emission from transport, solid waste generation, wastewater generation is done based on the recommendations given by IPCC guidelines (2006).

## 4.4 GHG-I at UTP

The Adaptation Policy Frameworks for Climate Change (UNDP, 2005) and the National Programs of Action are programs, that provided a guideline for the developing countries to identify priority activities that respond to their urgent and immediate needs with regard to adaptation to climate change (UNFCCC, 2007; de Bruin et al., 2009), one such activity is GHG-I which is being adopted widely (GHG Protocol, 2014; Andy Gouldson et al., 2015). "Most developing countries have reports no more than two annual emission inventories over the past two decades" (Aldy, 2012; 2015) "and in tune with this, the researcher use this as a starting point" (John and Malcolm, 2006) to categorize sector wise GHG-I and to evolve action plan for mitigation strategies. This pioneering effort enabled us "to provide more accurate and comparable quantification of GHG sources as suggested by several workers" (Karjalainen and Kellomaki, 1995; Braatz et. al., 1995) at our UTP. The methodological approach in this paper is categorized for $CO_2$ and $CH_4$, under Part-A and Part-B as follows:

- **GHG-I at UTP - Part-A:** This part deals with the Carbon dioxide emission inventory from domestic sector, transportation sector and industrial sector, followed by $CH_4$ emission inventory from municipal solid waste and municipal wastewater, in addition to enteric fermentation, manure management, rice cultivation from agriculture and animal husbandry sector. Finally, also with the inclusion from $CO_2$ emission from stationary fossil fuel consumption.

4.4.1. Emission of Carbon dioxide

Domestic Sector
Transportation sector
Industrial sector

4.4.2. Emission of Methane

Urban Sector
Municipal solid waste disposal
Domestic wastewater disposal

4.4.3 Agriculture and Animal Husbandry Sector

Enteric fermentation
Manure management
Rice cultivation

4.4.4. Estimation of Carbon-dioxide emission from stationary fossil fuel consumption

- **GHG-I at UTP - Part-B:** This part deals with the Carbon dioxide emission inventory from

4.4.5. Tourism Sector
Emission from transport sector associated with the tourist
Emission from municipal wastewater generated by tourist
Emission from municipal solid waste generated by tourist

### 4.4.1 Emission of Carbon-dioxide

The study includes emission calculation of $CO_2$ from domestic, transport and industry.

**Domestic Sector:** The boundary of domestic emission includes the jurisdiction boundary of the Union Territory (UT) including all the four regions (Puducherry, Karaikal, Yanam, Mahe). Basis of emission includes consumption of electricity, kerosene and LPG by domestic users. Use of biomass for cooking is not considered for the purpose of GHG-I. The GHG emission from domestic sector was estimated by multiplying the total amount of electricity, kerosene and LPG consumed by the domestic users with respective emission factors (*Table 4.2*).

***Table 4.2. Energy consumption and type with specific GHG emission factors Domestic sector of Puducherry Compared with India's emission factor***

| Energy Type | Consumption (Metric Tonne/ year) | Emission Factor (tonnes of $CO_2$e/TJ) |
|---|---|---|
| **LPG** | 33,074.00 | 63.10 |
| **Kerosene** | 12,276.00 | 71.90 |
| **Southern Regional Grid Emission Factor** | 578 (Million units) | 0.91 (t$CO_2$e/MWh) |

**Transportation sector:** Transport sector emission includes UT wide emission from road transport including all the four-jurisdiction boundary of the UT regions. For the transport sector, the GHG emission is estimated based on the total diesel and petrol sold in the UT multiplied by emission factor (Case I). In Case I, the total fuel being sold is used to estimate the GHG inventory was considered. But by considering the fact, that a considerable proportion of the petroleum products sold to the transportation sector in UT, were also used by vehicle of adjacent state Tamilnadu (due to the lower price of the fuel oil) and also by tourist vehicles the per capita based approach (i.e. Case II) is adopted. The energy type and emission factor for transport sector is highlighted in *Table 4.3*.

***Table 4.3. Energy consumption and specific GHG emission factors for different energy source used in transport sector***

| Energy Type | Consumption (Metric Tonne/ year) | Emission Factor (tonnes of $CO_2$e/TJ) |
|---|---|---|
| **Petrol** | 83,971.00 | 69.30 |
| **High Speed Diesel** | 354,002.00 | 74.10 |

Because of the low price of the diesel/petrol in the UTP, vehicles from adjacent states buy the fuel from the UT. However, due to the lack of information with regard to the distances travelled by the vehicle across all the four regions of UT, the national per capita emission from the transportation sector is adopted and multiplied to the population of the UT to arrive at the emission figure (Case II). As per the publication by MOEF (2010) "INCCA: Indian Network for Climate Change Assessment, the total emission from road transportation sector is 123554.00 (thousand tons) of $CO_2$e in 2007. Considering the population of 1.15 billion, the per capita GHG emission from transportation sector is estimated to be 0.107 t $CO_2$ e/ capita/ annum. Considering current population of Puducherry, the total emission of GHG from transport sector is 0.134 million tonnes of $CO_2$e".

**Industry Sector:** For estimation of GHG-I from industry sector, fossil fuel and electricity consumption, the number of industries located in Puducherry is considered. The GHG estimation from fossil fuel consumption by the industries is done on the projected fuel consumption information provided by the industries to the Puducherry Pollution Control Committee relating to their production capacity. For industry sector, estimation of fossil fuel consumption is not done based on actual production, but based on the projected production capacity and specific fossil fuel consumption (since collection of actual data is not available and also would require more time). GHG-I for electricity consumption by industries is calculated based on the information provided by the Electricity Department on the cumulative amount of energy consumed by the industries.

***Table 4.4. Energy consumption and Specific GHG emission factors for different energy source used in industry sector***

| Energy Type | Consumption (Metric Tonne/ year) | Emission Factor (tonnes of $CO_2$e/TJ) |
|---|---|---|
| **Coal** | 489,600.00 | 95.81 |
| **Diesel** | 31.69 | 74.10 |
| **Furnace Oil** | 26,127.69 | 77.40 |
| **Electricity** | 1,523 (million units) | 0.91 |

The GHG-I from industry sector includes emission due to energy consumption only. Electricity, coal, diesel, furnace oil, etc. are being used in the industries and the GHG-I was done based on the total quantum of each fuel type multiplied by respective GHG emission factors as available in 2006 IPCC Guidelines for National Greenhouse Gas Inventories, Chapter I (IPCC, 2006) and $CO_2$ Baseline Database, Version 8.0 published by CEA (2011) and the emission factors are highlighted in *Table 4.4*.

### 4.4.2 Emission of Methane

"Methane is a powerful greenhouse gas, with a Global Warming Potential (GWP), far greater than that of carbon dioxide, particularly over the time horizon of the first few decades following emission" (Robert et. al., 2011). "The comparative impact of $CH_4$ on climate change is over 20 times greater than $CO_2$ over a 100-year period" (Nandhivarman et. al., 2015; www.epa.gov). The main GHG emitted from waste management sector is methane that is produced and released into the atmosphere as a by-product of the anaerobic decomposition of solid waste, whereby methanogenic bacteria break down organic matter in the waste. Similarly, wastewater becomes another source of methane emission when treated or disposed anaerobically.

**Urban Sector:** For waste sector (municipal solid waste and sewage), the equation as per UNFCCC "Tool to determine methane emissions avoided from disposal of waste at a solid waste disposal site" Version 5 (UNFCCC Methodology ACM0001, 2013) given below is adopted:

$$BE_{CH4,\,SWDS,\,y} = \varphi.\,(1-f).\,GWP_{CH4}.\,(1-OX).\,\frac{16}{12}.\,F.\,DOC_f.\,MCF.\sum_{x=1}^{y}\sum_j W_{j.x}.\,DOC_j.e^{-k_j(y-x)}.(1-e^{-kj})$$

Where:

"$BE_{CH4,\,SWDS,\,y}$ - Methane emissions avoided during the year y from preventing waste disposal at the solid waste disposal site (SWDS) during the period from the start of the project activity to the end of the year y ($tCO_2e$)

$\varphi$ - Model correction factor to account for model uncertainties

f - Fraction of methane captured at the SWDS and flared, combusted or used in another manner

$GWP_{CH4}$ - Global Warming Potential of methane, valid for the relevant commitment period

OX - oxidation factor (reflecting the amount of methane from SWDS that is oxidized in the soil or other material covering the waste)

F - fraction of methane in the SWDS (volume fraction)

$DOC_f$ - fraction of DOC that can decompose

MCF - methane correction factor

$W_{j,x}$ - amount of organic waste type j prevented from disposal in the SWDS in the year x (tons)

$DOC_j$ - fraction of DOC in the waste type j

$k_j$ - decay rate for the waste type j

j - waste type category (index)

x - year during the crediting period: x runs from the first year of the first crediting (x = 1) to the year y for which avoided emissions are calculated (x = y)

y - year for which methane emissions are calculated".

GHG emission from municipal solid waste and sewage water, whether industrial or domestic, contributes considerably to the GHG emission in the UTP. The waste, comprising mainly of organic components result in the emission of CH4 which has a GWP of 21 times that of $CO_2$. For the purpose of estimation of net GHG-I, the waste generated from the domestic sector is only considered (whereas for the tourist sector it is discussed under GHG-I at UTP – Part-B, in the subsequent section). The GHG sources categorized for the estimation in waste sector are:

4.4.2.1.1. Municipal solid waste disposal
4.4.2.1.2. Municipal wastewater disposal

**Domestic solid waste disposal (municipal): "**Organic food wastes which are diverted to landfill produce methane through decomposition along with other adverse gases" (Nandhivarman et. al., 2015; Muthu, 2017). "Landfill gas produced through solid waste disposal is approximately 40–60% $CH_4$, followed by $CO_2$ along with varying amounts of nitrogen, oxygen, water vapor, hydrogen sulphide, and other contaminants. The other contaminants make up for less than 1% of landfill gas and are commonly known as non-methane organic compounds (NMOC), which includes toxic chemicals such as chloroform, benzene, toluene, vinyl chloride, and carbon tetrachloride" (Nandhivarman et. al., 2015). "The lifetime of $CH_4$ in the atmosphere is much shorter than $CO_2$, but $CH_4$ is more efficient at trapping radiation than that of $CO_2$. The comparative impact of $CH_4$ on climate change is over 20 times greater than $CO_2$ over a 100-year period" (Nandhivarman et. al., 2015; www.epa.gov). Emission due to municipal solid waste disposal is calculated based on the total population of the UT as 1247953 (as per 2011 census) and solid waste generation at the rate of 0.00045 tonne/capita/day. Average GHG emission is estimated to be as 88725 tonnes of $CO_2e$ per annum.

**Municipal wastewater disposal: "**With 2598 persons per square km, UTP is currently placed among the towns with highest population density in the country" (GOI Census, 2011). "Because of rapid urbanization and increasing population there is an unprecedented pressure on water resources" (Golda et al., 2015; Golda, 2017). "Wastewater is a significant and growing problem, especially in urban areas of both the developed and developing world" (Golda et al., 2014, 2015& 2017) emitting various GHG's.Emission due to sewage is calculated based on the total methane emitted from wastewater due to anaerobic treatment or disposal of it. Wastewater originating from a variety of domestic, commercial and industrial sources has significant contribution in GHG emissions of the UTP. The GHG emission from sewage for the UTP is collectively considered for both domestic and industrial wastewater generated. Further, emissions from domestic wastewater handling are estimated for both urban and rural centres. Emission due to sewage is estimated considering the above-mentioned population and wastewater generation potential of 120 litre/capita/day, and the annual GHG emission is estimated at 92779 $tCO_2e$.

**Agriculture and Animal Husbandry Sector**

"Agriculture sector is the second largest contributor of anthropogenic GHG emissions after the energy sector" (Patra, 2014). "Livestock constitutes an integral component of Indian agriculture sector and also a major source of GHG emissions" (Chhabra et al., 2012). "A life cycle assessment of GHG emissions done by FAO indicated that livestock contributes about 18% to the global anthropogenic GHG emissions accounting for 37% of anthropogenic methane and 65% of anthropogenic nitrous oxide" (FAO, 2006) and "dairy cattle sector 4% of total anthropogenic GHG emissions" (FAO, 2010). "Concerns over the contribution of the livestock farming to the global warming/ climate change paved way for a number of studies to improve the scientific knowledge regarding the GHG emissions at national/ local levels" (Gerber et al., 2011; Ji and Park, 2012; Bellarby et al., 2013; Patra, 2014) and "mitigation strategies" (Patra, 2012a; Bellarby et al., 2013; Patra, 2014). "Various estimates of GHG emissions from Indian livestock had been reported using various approaches in different years" (Singhal et al., 2005; Swamy and Bhattacharya, 2006; Chhabra et al., 2009; Patra, 2012b; Patra, 2014). "The agricultural sectors constitutes to about 17% of the net CO2e emissions" (http://envfor.nic.in). The purpose of this chapter is to analyze the current trends and projected estimates of GHG emission from the livestock of Puducherry through enteric fermentation and manure management followed by rice cultivation.

The present study presents a detailed inventory of GHG country-specific emission coefficients based on IPCC guidelines (IPCC, 2006; Abha Chhabra et. al., 2012) at state level from different age groups, indigenous and exotic breed of different livestock categories estimated using the recent Census (2007) in the UTP. When it comes to agricultural sector, tthough soil carbon and field burning of agricultural residues are sources of agricultural emission, they are however eliminated from calculations. Specific emission factor used for national GHG-I was considered for the estimation of inventory for the agriculture sector.

**Enteric Fermentation:** "Apart from the fact that, the livestock accounts for about 18% of the global GHGs emissions including the emissions such as $CH_4$ from enteric fermentation, $N_2O$ from manure and fertilizer, and $CO_2$ from land-use, agriculture also plays substantially in the climate change through energy use (FAO 2006) directly and indirectly. Livestock sources contribute as a major anthropogenic source of methane emission from agriculture sector. The methane emissions from livestock have principally two components, i.e. emissions from 'enteric fermentation' and 'manure management'. About 37% of anthropogenic methane is attributed to enteric fermentation by ruminants as part of their normal digestive processes. Livestock manure management is also a significant source of methane with global emissions accounting to 9.3 Tg/ year" (Scheehle and Kruger 2006; Abha Chhabra et.al., 2013), "whereas livestock also contributes a small but significant emission of nitrous oxide ($N_2O$) from animal waste management systems" (Dwarakanath et al., 2016; World Bank Report, 2013).

"The second potent GHG 'methane' is produced in herbivores as a by-product of enteric fermentation, a digestive process by which carbohydrates are broken down by micro-organisms into simple molecules for easy absorption and assimilation through the bloodstream. The amount of methane that is released depends on the type of livestock, digestive tract, age, weight of the animal, followed by quality and quantity of the feed consumed. Ruminant livestock (e.g., cattle, sheep) are major sources of methane with moderate amounts produced from non-ruminant livestock (e.g., pigs, horses). The ruminant gut structure fosters extensive enteric fermentation of their diet. The specific emission factor was calculated by NATCOM as a part of preparing the GHG inventory towards national submission is used for calculation of UT specific sectoral emission (*Table 4.5*) (Since, the latest statistics present for the livestock population was based on 2007 census in UT, the same is used for calculation)" (Dwarakanath et al., 2016; CTRAN, 2013):

***Table 4.5. Livestock population and Specific emission factors for different livestock (Source: Dwarakanath et al., 2016; CTRAN, 2013)***

| Category of livestock | Number of livestock | Emission Factor (kg $CH_4$/head/year) – Enteric Fermentation |
|---|---|---|
| **Dairy cattle - Indigenous** | 6,134 | 28±5 |
| **Dairy cattle - Cross-bred** | 79,062 | 43±5 |
| **Dairy buffalo** | 3,325 | 50±17 |
| **Sheep** | 4,694 | 4±1 |
| **Goat** | 69,567 | 4±1 |
| **Horses and ponies** | 32 | 18 |
| **Donkeys** | 60 | 10 |
| **Pigs** | 728 | 1 |

*Table 4.5* highlights "the total population of livestock in each category and the specific emission factor pertaining to enteric fermentation, the total methane emission is calculated at 4036 $tCH_4$/year (84768 $tCO_2e$/year)" (Dwarakanath et al., 2016).

**Manure management: "**Livestock manure management is also a significant contributor of CH4 (anaerobic decomposition of animal waste) with global emission accounting to 9.3 Tg/ year" (Scheehle and Kruger, 2006) and "small yet significant amount of $N_2O$" (Abha Chhabra et al., 2012). "The emission of CH4 however depends on the rate of waste production per animal, the number of animals, and on how the manure is managed" (Dwarakanath et al., 2016). "Various research studies indicated that, when manure is stored or treated as a liquid (e.g. in lagoons, ponds, tanks, or pits), it decomposes anaerobically producing significant quantity of CH4. Apart from this, the temperature and the retention time of the storage unit greatly affect the amount of CH4 produced. When manure is handled as a solid (e.g., in stacks or piles) or when it is deposited on pastures and rangelands, it tends to decompose under more aerobic conditions, hence less methane is produced. Methane emission estimates from manure management are based on methane emitted during the storage and treatment of manure. Methane emission factors in manure management are required for estimation of total methane emissions by each type of animals (Amlan Kumar Patra, 2014), because methane emissions from manure management systems are highly temperature dependent, the average annual temperature for all countries in the world, where manure is managed, was adopted" ( http://www.weatherbase.com). The IPCC (2006) "default values of CH4 emission factors in manure management for all species of livestock in each annual average temperature of all countries were used for estimation of methane emissions". In India according to a study done by Amlan Kumar Patra (2014), "between the years 1960 to 2010, the annual manure CH4 emission increased from 0.52 million tonnes to 1.1 million tonnes with an annual growth rate of 1.57%".

***Table 4.6. Specific emission factors for different livestock***

| Category of livestock | Emission Factor (kg $CH_4$/head/year) – Manure Management |
|---|---|
| **Dairy cattle - Indigenous** | 3.50±0.20 |
| **Dairy cattle - Cross-bred** | 3.80±0.80 |
| **Dairy buffalo** | 4.40±0.60 |
| **Sheep** | 0.30 |
| **Goat** | 0.20 |
| **Horses and ponies** | 1.60 |
| **Donkeys** | 0.90 |
| **Pigs** | 4.00 |

"The specific emission factor was calculated by NATCOM as a part of preparing the GHG inventory towards national submission is used for calculation of UTP specific sectoral emission (*Table 4.6*). *Table 4.6* highlights the total CH4 emission in manure management, which was estimated, based on the total population of livestock in each category and the specific emission factor pertaining to manure management. The total CH4 emission is calculated at 354 $tCH_4$/year (or 7,452 $tCO_2e$/year)" (Dwarakanath et al., 2016).

**Rice Cultivation**: "Since, rice cultivation in India is majorly done through water logging; CH4 is emitted from the cultivation of rice mainly due to anaerobic decomposition of the organic matter. The emission of CH4 pertaining to rice cultivation however depends upon the type of irrigation and the type of application of water. The country specific coefficient emission factor provided by India's Initial National Communication (NATCOM), published by Ministry of Environment and Forests (MoEF, 2004) was adopted for preparing the GHG-I towards the calculation of UTP sectoral emission" (Dwarakanath et al., 2016; CTRAN, 2013):

***Table 4.7. Specific Methane emission from different water application (Dwarakanath et al., 2016; CTRAN, 2013)***

| Type of irrigation | Type of water application | Specific Methane emission (kg$CH_4$/ha) |
|---|---|---|
| **Irrigated** | Continuously flooded | 162.00 |
| | Single aeration | 66.00 |

| Type of irrigation | Type of water application | Specific Methane emission ($kgCH_4/ha$) |
|---|---|---|
| | Multiple aeration | 18.00 |
| **Rain-fed** | Drought prone | 66.00 |
| | Flood prone | 190.00 |
| **Deep water** | Deep water | 190.00 |

***Table 4.8. GHG emission from Agriculture sector***

***(Dwarakanath et al., 2016; CTRAN, 2013)***

| Category | Total Emission ($tCH_4$ /year) | Total Emission ($tCO_2e$/year) |
|---|---|---|
| **Enteric Fermentation** | 4,036.00 | 84,768.00 |
| **Manure Management** | 354.00 | 7,452.00 |
| **Rice Cultivation** | 1,900.00 | 39,901.00 |
| **Total** | **6,290.00** | **1,32,121.00** |
| **Total Equivalent GHG emission** | | **0.132 million $tCO_2e$** |

"Based on the total 20926 ha of land area under paddy cultivation in the Puducherry region, with 80% of land under irrigation (considering single aeration) and 20% of the area under non-irrigated (flood prone area) the total methane emission is calculated at 1900 $tCH_4$/year (39901$tCO_2e$/year). The inventory of GHG emission from agriculture sector" is presented in *Table 4.8* (CTRAN, 2013; Dwarakanath et al., 2016)

### 4.4.3 Estimation of Carbon-dioxide emission from stationary fossil fuel consumption

The product of activity data and corresponding emission factor is used to determine the emission of GHG. The emissions of the GHGs thus obtained were then multiplied with the corresponding Global Warming Potential (GWP) to express the emission in terms of $CO_2$ equivalent ($CO_2$-eq). The basic equation involved in estimating the emission is:

$$\text{Emission } j = \sum AD_i * EF_{ij}$$

Where, AD is activity data of $i^{th}$ activity and
EF is emission factors of $i^{th}$ activity for $j^{th}$ GHG emission.

- **GHG-I at UTP - Part-B: "**The GHG emission intensity of tourism sector has not been determined separately, since tourism is not measured as an economic sector in the national accounts" (Perch-Nielsen et al., 2010). "While for tourism-reliant countries like India where the growth rate (2015) of the tourism sector increased to 17.3% than the previous year (http://business.mapsofindia.com), it would be useful to know the GHG emission" (Perch-Nielsen et.al., 2010) through inventory analysis. "The Union Territory of Puducherry is one of the most popular tourist destinations in South India. Being a French colony until 1954, and since, this coastal town retains a number of colonial buildings, churches, temples, mosques, ashram, monuments, statues, museum, parks, lakes and systematic town planning, as well as urban architecture of the local Tamil style. The town with blossoming bougainvilleas, crumbling cathedrals on leafy boulevards and 18th-century colonial buildings colouring the former French colony, along with the neighbouring International city Auroville draws tourists from across the world and it is a popular weekend destination that can be reached easily from the nearby metropolitan cities". The number of incoming tourists is increasing not only the revenue for the government and livelihood for the locals but also their GHG emission foot print at UTP associated with transport, solid waste and liquid waste. Hence, this sector is given a special attention for GHG-I and grouped under Part B in this Chapter. This part deals with the $CO_2$ emission inventory from

4.4.5. Emission from Tourism Sector
Transport sector associated with the tourist
Municipal wastewater generated by tourist
Municipal solid waste generated by tourist

### 4.4.4 Tourism Sector

"The fifth assessment report of IPCC, indicates that global warming observed many unprecedented changes since 1950's, such as global increase in ocean temperature by 0.11 [0.09 to 0.13] °C, and atmosphere temperature by 0.85 [0.65 to 1.06] °C, over the period 1880–2012; and melting of snow and ice over the period 1901–2010, global mean sea level rose by 0.19 [0.17 to 0.21] m and increased concentration of greenhouse gases(GHGs) have exceeded the pre-industrial levels by about 40% of CO2; 150% CH4; and 20% N2 respectively" (IPCC, 2013), "where travel and tourism, excluding aviation, is responsible for about 3% of GHG emissions, with anticipated growth rate at 2.5% per year until 2035" (WEF, 2009). "These figures highlights that, tourism also contributes to climate change through the emission of GHGs through transport, accommodation and other tourist related activities" (Perch-Nielsen et al., 2010). "As a result, the tourism industry has a growing self-interest and is under increasing pressure to act on climate change" (Scott et al., 2008; Perch-Nielsen et al., 2010).

According to research carried out by UN-World Tourism Organization (UNWTO) in association with the United Nations Environment Programme (UNEP) and the World Meteorological Organization (WMO), "$CO_2$ emissions from international tourism including all forms of transport accounted for just fewer than 5% of the world total or 1307 million tonnes in

2005". According to Mishev and Mochurova (2008), "transport accounts for 75% of all emissions by the tourism sector, with aviation making up about 40% of all tourism emissions, road transport 32%, accommodation represents about 21% and other forms of transport 3%, of total tourism sector emissions as indicated in the website - http://sdt.unwto.org/sites. Comparatively, with its estimated 5% share of the total world emissions, tourism ranks far below agriculture (15% of global emissions) and on a par with the chemical manufacturing industry".

"Across the globe, the tourism industry both consumes energy and emits $CO_2$" (Lin, 2010; Perch-Nielsen et.al, 2010). "With the introduction of Tourism Satellite Accounts (TSA) (WTO, 1999) that measure tourism's economic contribution to national economies, the significance of tourism started to be acknowledged" (Becken and Patterson ,2006). "The World Tourism Organization (WTO) has predicted that $CO_2$ emissions will become increasingly significant as the number of international travelers increases" (WTO, 2001; Lin, 2010) "since the international tourism is growing at a rate of about 4% annually worldwide with an estimated 763 million international arrivals in 2004" (WTO, 2005; Becken and Patterson, 2006) "India showed a considerable increase -7.1 million foreign tourist arrived in 2015" (January to November) (http://www.ibef.org). "For example, the energy consumed by the tourism industry accounts for 60% of the state's total consumption" (Tabatchnaia et al., 1997). "Previous investigations on energy and $CO_2$ emissions have generally divided the tourism industry into three sections, namely transport, accommodation and activities" (Becken et. al., 2003; Go¨ssling et al., 2005; Lin, 2010; Perch-Nielsen et al., 2010). "In addition to its economic significance, this sector is a major source of environmental impacts and resource consumption too" (Becken and Patterson, 2006). "For instance, buses and private cars consume massive amounts of fossil fuels, along with electricity consumption via air conditioning, lighting and heating water for travelers. Transport for tourism activities consumes fossil fuels, whereas the operation of tourism locations consumes electricity and other associate energy and resources, there by generating various types of waste (solid and liquid) resources also. This fossil fuel, electricity consumption and waste generation can be translated into CO2 emissions using the guidelines established by Intergovernmental Panel on Climate Change (IPCC, 1996) based on country-specific emission factors" (Lin, 2010).

Several workers have indicated that transport accounts for a significant proportion of the energy consumption and $CO_2$ emissions by the tourism industry. Gossling (2000& 2002) and Lin (2010) stated that "since transport accounts for the largest amount of energy consumed and GHGs emitted by leisure activities, it should be linked with the Høyer's (2000) concept of sustainable transport within sustainable tourism". Additionally, in developing countries like India air travel consumes the most energy in the tourism industries. For instance, Becken (2002a & 2002b) found that “flights by international tourists in New Zealand account for 6% of national energy usage. A survey on the Western coast of the South Island in New Zealand found that transport accounts for 65–73% of the energy consumed by local and international travelers”. Whereas, Dubois and Ceron (2006) “predicted that France would see its GHG emissions from transportation in its tourism industry rise by 90%, and its total passenger-kilometers increase by 200%, by 2050”. Peeters et.al., (2007) “predicted that $CO_2$ emissions from transportation associated with the tourism sector in Europe will rise by 90% by 2020. Hence, a carbon tax for international flights has been proposed” (Mayor &Tol, 2007; Tol, 2007; Lin, 2010).

“There are many case studies focused on countries or region specific relationship between $CO_2$ emissions and transport (Lin, 2010), such as Lebanon (El-Fadel&Bou-Zeid, 1999), the U.K. (Kwon, 2005), Australia (Lenzen, 1999) and Mumbai, India (Yedla et.al., 2005) and also various workers have specifically examined $CO_2$ emissions from transport in the tourism industries in Norway (Høyer, 2000), France (Dubois &Ceron, 2006), the Western coast of the South Island in New Zealand (Becken, 2002b), Rocky Mountain National Park in the US, Amsterdam, the Netherlands, borders of France, the Seychelles and Val di Merse in Italy” (Go¨ ssling et al., 2005). In the recent study, Lin (2010) also indicated that, “$CO_2$ emissions of different tourist locations within a single country have rarely been compared”. To compare the GHG and $CO_2$ emissions of individual tourist, this investigative research study revolves around UTP using Statistics from various sources like Tourism Department, Hospitality sectors, Local Administrative Department, etc.

**GHG-I for tourist Sector at UTP**

Although greenhouse gas (GHG) inventory is prepared at the national level no initiatives has been undertaken to down scale it at the regional level. Hence, in this study, GHG-I is carried out through standard IPCC approach. For the purpose of GHG emission estimation the following three GHG are considered, namely carbon dioxide ($CO_2$), methane ($CH_4$) and nitrous oxide ($N_2O$). The key sectors such as energy, wastewater, and solid waste relevant to UTP were selected and emission across the tourism sector is determined. According to Tourism Department, Puducherry, around 10.2 lakh domestic and 50000 foreign tourists arrive in UTP and the region wise tourist arrival since 2001-2015 is given in *Table 4.9*. The tourists contribute more to the revenue generation at UTP by way of transportation, hospitality industry and by various consumer products purchased during their stay along with the associated GHG emission. In this study, an attempt is made to inventorize GHG emission from transportation, coupled with wastewater and municipal solid waste generation due to tourism.

***Table 4.9. Domestic and International Tourist Arrivals in Puducherry***

| Year | Domestic tourist | Foreign tourist | Total | Growth (%) |
|---|---|---|---|---|
| **2001** | 476804 | 22,115 | 498919 | - |
| **2002** | 480519 | 20,094 | 500613 | 0.34 |
| **2003** | 500139 | 25,559 | 525698 | 5.01 |
| **2004** | 558445 | 32,053 | 590498 | 12.33 |
| **2005** | 574011 | 36,009 | 610020 | 3.31 |
| **2006** | 652245 | 46,273 | 698518 | 14.51 |
| **2007** | 798528 | 57,682 | 856210 | 22.58 |
| **2008** | 827799 | 60,306 | 888108 | 3.73 |
| **2009** | 851192 | 54,038 | 905230 | 1.93 |
| **2010** | 835872 | 50,964 | 886836 | -2.03 |
| **2011** | 897986 | 52,298 | 950284 | 7.15 |
| **2012** | 981714 | 52,931 | 1034645 | 8.88 |
| **2013** | 1,068,184 | 61,516 | 1129700 | 9.19 |
| **2014** | 1,188,093 | 83,291 | 1271384 | 7.50 |
| **2015** | 1,247,192 | 1,06,513 | 1353705 | 6.47 |

**Emission from transport sector associated with the tourist**

Transportation vehicles have different requirements such as fossil fuels (petrol or diesel) and electricity with different energy efficiency rates (energy consumed rises with increasing distance traveled). Every unit of different energy sources generates different amounts of CO2 emissions, however, previously $CO_2$ emission evaluation based on vehicle volumes, related to tourists, is difficult to estimate, but data including departure destinations and transport modes used by tourists can yield considerable amount of inventory analysis. Therefore, this GHG-I study concentrates on tourists to facilitate estimates and evaluations of CO2 emissions, by considering one and half days and four days for domestic and foreign tourists respectively. On the other hand, kilometer travelled by domestic and foreign tourist is assumed as 25 kilometer per person per day (km/p/d) with average mileage of the four-wheeler as 20 kilometer per litre (kmpl). The above-mentioned figures were arrived based on the random survey done at hospitality sector and from the recommendation provided by PT&TDC. “The total $CO_2$ emissions (kg-CO2) by different vehicles (Lin, 2010) from the tourism sector can be determined through Distance-Based Method (DBM), by the following equation” (http://www.ghgprotocol.org):

Emission from Transport = Fuel Consumption x Emission Factor ---- (1)

*Table 4.10. Emission of $CO_2$, $CH_4$ and $N_2O$ from Transport Sector*

| Year | Domestic tourist nos. | Foreign tourist nos. | Emission by Domestic Tourists | | | | Emission by Foreign Tourists | | | | Total $CO_2$ Equivalent by Tourists (tonnes/Year) | Per capita of Co2 Equivalent (Tonne/ per person/ Year) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | $CO_2$ Emission by Domestic Tourists Tonnes/Year | $CH_4$ Emission by Domestic Tourists Tonnes/Year | $N_2O$ Emission by Domestic Tourists Tonnes/Year | Co2 Equivalent (tonnes/Year) | $CO_2$ Emission by Foreign Tourists Tonnes/Year | $CH_4$ Emission by Foreign Tourists Tonnes/Year | $N_2O$ Emission by Foreign Tourists Tonnes/Year | $CO_2$ Equivalent (tonnes/ Year) | | |
| 2001 | 476804 | 22115 | 35331176 | 1859.5356 | 1859.536 | 35931806 | 1638722 | 86.2485 | 86.2485 | 1666580 | 37598386 | 0.005429 |
| 2002 | 480519 | 20094 | 35606458 | 1874.0241 | 1874.024 | 36211768 | 1488965 | 78.3666 | 78.3666 | 1514278 | 37726045 | 0.005393 |
| 2003 | 500139 | 25559 | 37060300 | 1950.5421 | 1950.542 | 37690325 | 1893922 | 99.6801 | 99.6801 | 1926119 | 39616444 | 0.005465 |
| 2004 | 558445 | 32053 | 41380775 | 2177.9355 | 2177.936 | 42084248 | 2375127 | 125.0067 | 125.0067 | 2415504 | 44499752 | 0.005512 |
| 2005 | 574011 | 36009 | 42534215 | 2238.6429 | 2238.643 | 43257297 | 2668267 | 140.4351 | 140.4351 | 2713627 | 45970924 | 0.005552 |
| 2006 | 652245 | 46273 | 48331355 | 2543.7555 | 2543.756 | 49152988 | 3428829 | 180.4647 | 180.4647 | 3487119 | 52640107 | 0.005613 |
| 2007 | 798528 | 57682 | 59170925 | 3114.2592 | 3114.259 | 60176831 | 4274236 | 224.9598 | 224.9598 | 4346898 | 64523729 | 0.005623 |
| 2008 | 827799 | 60306 | 61339906 | 3228.4161 | 3228.416 | 62382684 | 4468675 | 235.1934 | 235.1934 | 4544642 | 66927326 | 0.005627 |
| 2009 | 851192 | 54038 | 63073327 | 3319.6488 | 3319.649 | 64145574 | 4004216 | 210.7482 | 210.7482 | 4072287 | 68217861 | 0.005558 |
| 2010 | 835872 | 50964 | 61938115 | 3259.9008 | 3259.901 | 62991063 | 3776432 | 198.7596 | 198.7596 | 3840632 | 66831695 | 0.005539 |
| 2011 | 897986 | 52298 | 66540763 | 3502.1454 | 3502.145 | 67671956 | 3875282 | 203.9622 | 203.9622 | 3941162 | 71613117 | 0.005519 |
| 2012 | 981714 | 52931 | 72745007 | 3828.6846 | 3828.685 | 73981673 | 3922187 | 206.4309 | 206.4309 | 3988864 | 77970537 | 0.005486 |
| 2013 | 1068184 | 61516 | 79152434 | 4165.9176 | 4165.918 | 80498026 | 4558336 | 239.9124 | 239.9124 | 4635827 | 85133853 | 0.005514 |
| 2014 | 1188093 | 83291 | 88037691 | 4633.5627 | 4633.563 | 89534332 | 6171863 | 324.8349 | 324.8349 | 6276785 | 95811117 | 0.005607 |
| 2015 | 1247192 | 106153 | 92416927 | 4864.0488 | 4864.049 | 93988015 | 7865937 | 413.9967 | 413.9967 | 7999658 | 1.02E+08 | 0.005055 |

DBM can be used when vehicle activity data is in the form of distance travelled but fuel economy data is not available. In this case, the first step is to collect data on distance travelled by vehicle type and fuel type and in the second step convert distance estimate to $CO_2$ emissions by multiplying results from step 1 by distance based emission factors. The emission Factor for $CO_2$ is 74.1 tonnes/TJ, whereas jointly for $CH_4$ and $N_2O$ is 3.9 kg/TJ (IPCC, 2006) while the density of diesel as 0.832 kg/L is considered. Based on the total no of domestic and foreign tourist, the emission of $CO_2$, $CH_4$ and $N_2O$ from the associated transport sector were given in the emission of $CO_2$, $CH_4$ and $N_2O$ from the associated transport sector were given in the *Table 4.10* and comparison is represented in *Figure 4.1*, *Figure 4.2*(for $CO_2$) and *Figure 4.3*($CH_4$).

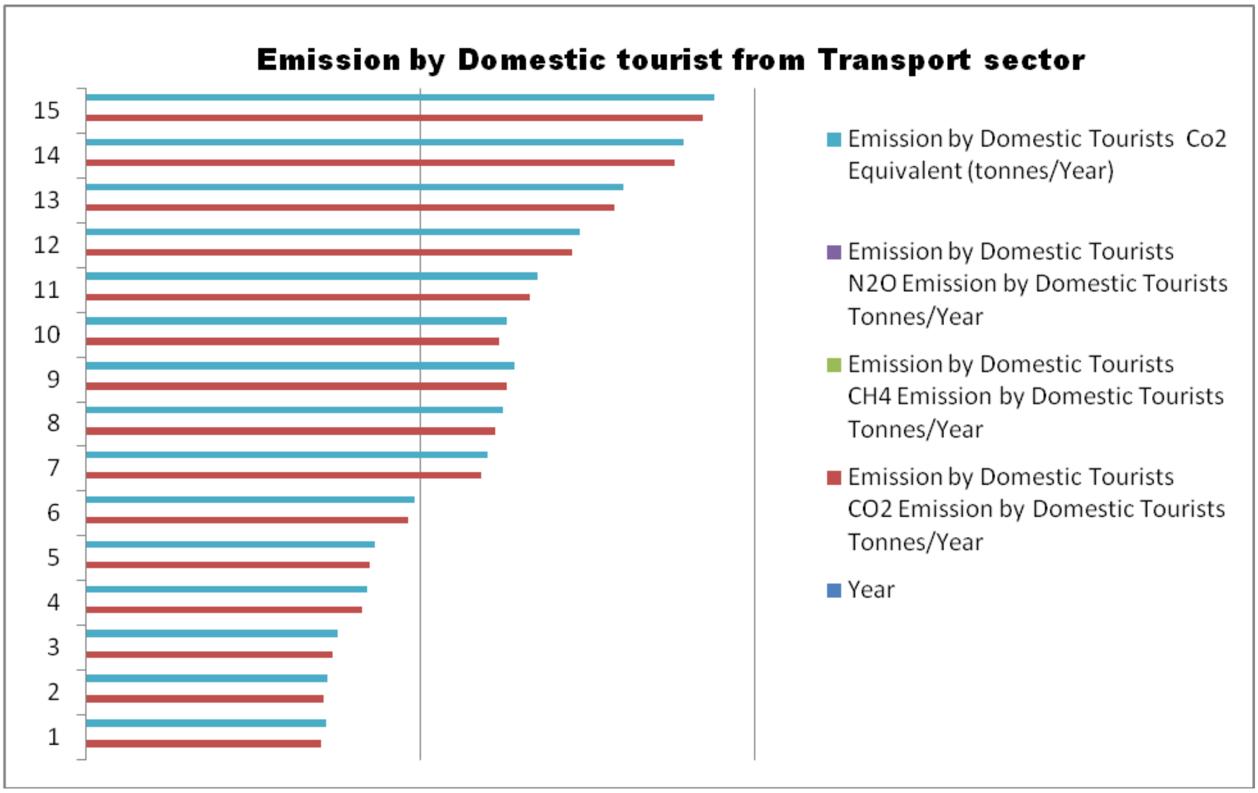



***Figure 4.1. Emission by Domestic tourists from the Transport sector (tourism sector)year 2001-15***

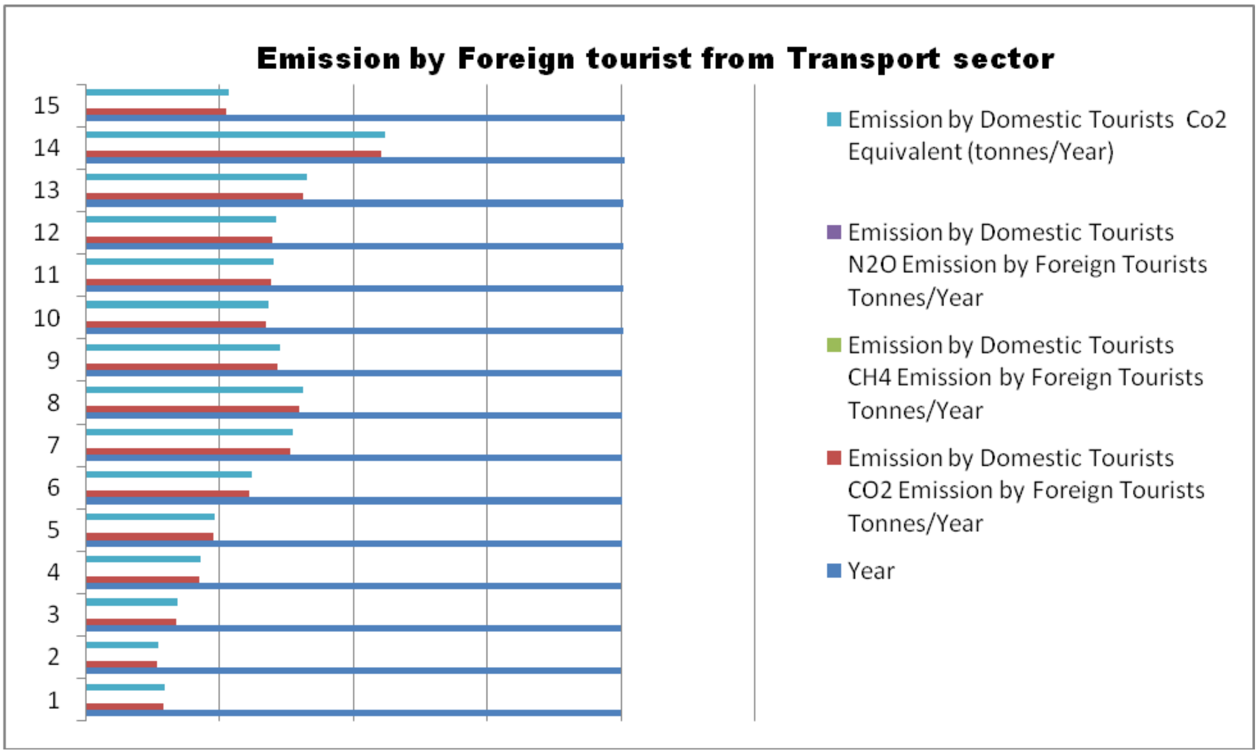



***Figure 4.2. Emission by Foreign tourist from the Transport sector (tourism sector) year2001-15***

**Emission from municipal wastewater generated by tourist**

In this part of inventory analysis for methane emission from wastewater associated with tourism, was considered based on their stay for one and half days and four days for domestic and foreign tourists respectively. Assuming wastewater generation as 80% with the water supply rate of 180 liters per capita per day (lpcpd), the wastewater generated by domestic and foreign tourist is 144 lpcpd. The calculation was arrived using the IPCC (2006) guidelines:

"As per IPCC (2006) guidelines for GHG inventories: Chapter 6 of wastewater treatment and discharge (pg. 6.11)

Equation 6.1 of total $CH_4$ emissions from domestic wastewater ($CH_4$ Emissions)

Table 6.5 : India, Ui = 0.06 (fraction of population), Ti,j = 0.67 (urban high income, sewer), EFj = 0.3 (Table 6.2 and 6.3)

Equation 6.3 of total organically degradable material in domestic wastewater (TOW)
P = domestic and foreign tourist population, BOD = 34 g/person/day (Table 6.4: country specific per capita BOD), 0.001 = conversion from gms to kg of BOD, I = 1.25 (default value correction factor)

Assumption: (organic component removed as sludge in inventory year, S = 0) and (amount of $CH_4$ recovered in inventory year, R = 0)
The general equation to estimate $CH_4$ emissions from domestic wastewater is as follows:

$$CH_4\ Emissions = \left[\sum_{i,j} \left( U_i \bullet T_{i,j} \bullet EF_j \right)\right] \left( TOW - S \right) - R$$

Where:

$CH_4$ Emissions = $CH_4$ emissions in inventory year, kg $CH_4$/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

$U_i$ = fraction of population in income group *i* in inventory year, See Table 6.5.

$T_{i,j}$ = degree of utilisation of treatment/discharge pathway or system, *j*, for each income group fraction *i* in inventory year, See Table 6.5.

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

$EF_j$ = emission factor, kg $CH_4$ / kg BOD

R = amount of $CH_4$ recovered in inventory year, kg $CH_4$/yr

$CH_4$ emission factor for each domestic wastewater treatment/ discharge pathway or system

$$EF_j = B_o \bullet MCF_j$$

Where:

$EF_j$ = emission factor, kg $CH_4$/kg BOD

j = each treatment/discharge pathway or system

$B_o$ = maximum $CH_4$ producing capacity, kg $CH_4$/kg BOD

$MCF_j$ = methane correction factor (fraction), See Table 6.3.

Total organically degradable material in domestic wastewater

$$TOW = P \bullet BOD \bullet 0.001 \bullet I \bullet 365$$

Where:

TOW = total organics in wastewater in inventory year, kg BOD/yr

P = country population in inventory year, (person)

BOD = country-specific per capita BOD in inventory year, g/person/day, See Table 6.4.

0.001 = conversion from grams BOD to kg BOD

I = correction factor for additional industrial BOD discharged into sewers (for collected the default is 1.25, for uncollected the default is 1.00.) ,,

*Table 4.11. Emission of $CO_2$ & $CH_4$ from Wastewater Generated by Domestic and foreign Tourist*

| Year | Wastewater generated by Domestic tourists (lit/year) | Wastewater generated by Foreign tourists (lit/year) | (TOW) Total organics in wastewater generated by domestic tourists (kg BOD/year) | (TOW) Total organics in wastewater generated by foreign tourists (kg BOD/year) | $CH_4$ Emissions by domestic tourists (kg $CH_4$/year) | $CH_4$ Emissions by foreign tourists (kg $CH_4$/year) | Emissions by Domestic Tourists in $CO_2$ Equivalent (kg/year) | Emissions by Foreign Tourists in $CO_2$ Equivalent (kg/year) | Total Emissions in $CO_2$ Equivalent (kg/year) | Per capita of $CO_2$ Equivalent (Kg/ per person/Year) |
|---|---|---|---|---|---|---|---|---|---|---|
| **2001** | 102989664 | 12738240 | 30396.26 | 3759.55 | 366.578835 | 45.340173 | 9164.4709 | 1133.5043 | 10297.98 | 0.02064 |
| **2002** | 103792104 | 11574144 | 30633.09 | 3415.98 | 369.43502 | 41.1967188 | 9235.8755 | 1029.918 | 10265.79 | 0.02051 |
| **2003** | 108030024 | 14721984 | 31883.86 | 4345.03 | 384.519367 | 52.4010618 | 9612.9842 | 1310.0265 | 10923.01 | 0.02078 |
| **2004** | 120624120 | 18462528 | 35600.87 | 5449.01 | 429.346477 | 65.7150606 | 10733.662 | 1642.8765 | 12376.54 | 0.02096 |
| **2005** | 123986376 | 20741184 | 36593.2 | 6121.53 | 441.314007 | 73.8256518 | 11032.85 | 1845.6413 | 12878.49 | 0.02111 |
| **2006** | 140884920 | 26653248 | 41580.62 | 7866.41 | 501.462262 | 94.8689046 | 12536.557 | 2371.7226 | 14908.28 | 0.02134 |
| **2007** | 172482048 | 33224832 | 50906.16 | 9805.94 | 613.92829 | 118.259636 | 15348.207 | 2956.4909 | 18304.7 | 0.02138 |
| **2008** | 178804584 | 34736256 | 52772.19 | 10252.02 | 636.432566 | 123.639361 | 15910.814 | 3090.984 | 19001.8 | 0.02140 |
| **2009** | 183857472 | 31125888 | 54263.49 | 9186.46 | 654.417689 | 110.788708 | 16360.442 | 2769.7177 | 19130.16 | 0.02113 |
| **2010** | 180548352 | 29355264 | 53286.84 | 8663.88 | 642.63929 | 104.486393 | 16065.982 | 2612.1598 | 18678.14 | 0.02106 |
| **2011** | 193964976 | 30123648 | 57246.61 | 8890.66 | 690.394086 | 107.22136 | 17259.852 | 2680.534 | 19940.39 | 0.02098 |
| **2012** | 212050224 | 30488256 | 62584.27 | 8998.27 | 754.766266 | 108.519136 | 18869.157 | 2712.9784 | 21582.14 | 0.02086 |
| **2013** | 230727744 | 35433216 | 68096.73 | 10457.72 | 821.246564 | 126.120103 | 20531.164 | 3153.0026 | 23684.17 | 0.02097 |
| **2014** | 256628088 | 47975616 | 75740.93 | 14159.47 | 913.435601 | 170.763208 | 22835.89 | 4269.0802 | 27104.97 | 0.02132 |
| **2015** | 269393472 | 22929048 | 79508.49 | 6767.254 | 958.872389 | 81.6130802 | 23971.81 | 2040.327 | 26012.14 | 0.01922 |

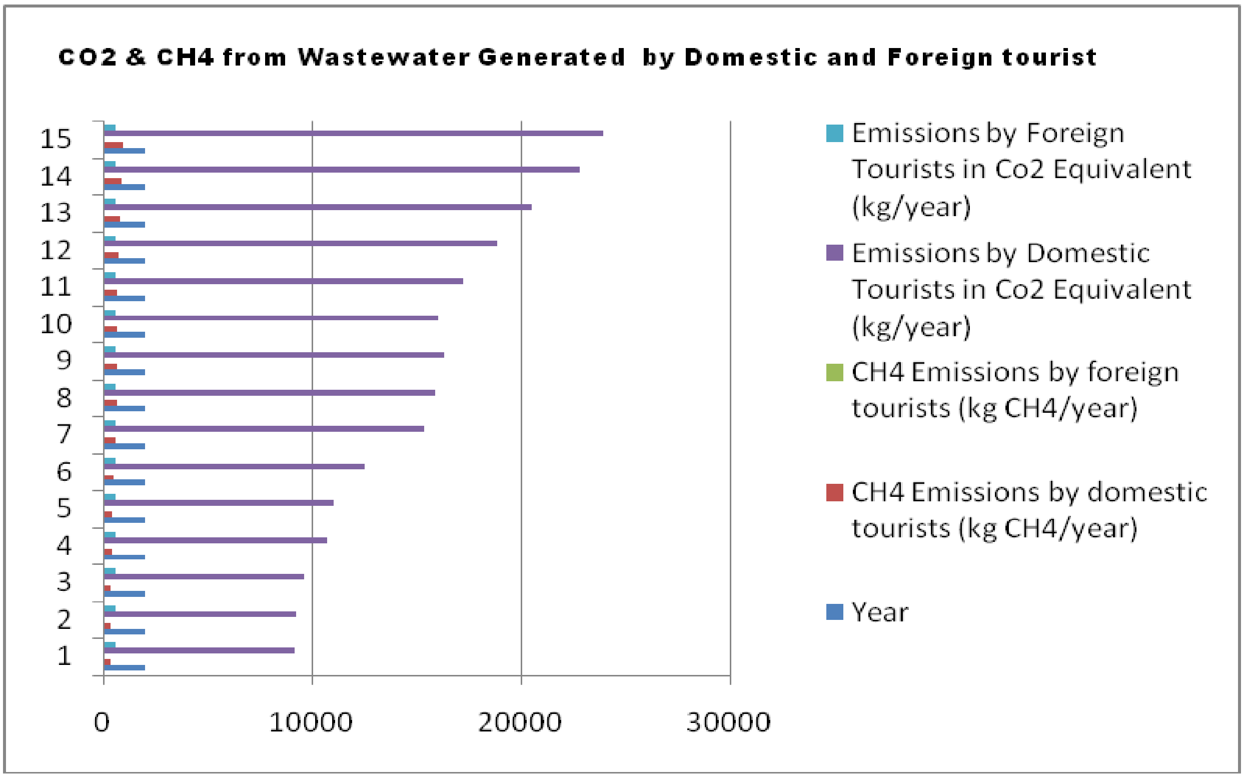



*Figure 4.3. $CH_4$ emission from wastewater*

**Emission from municipal solid waste generated by tourist**

"Based on the structured and semi structured interview with the concerned officials and staff of LAD, and Puducherry Pollution Control Committee (PPCC), the municipal solid waste generation by domestic and foreign tourist was estimated as 400 gms/cap/day, and the emission calculation was done by IPCC guidelines as follows:

CH4 generated = (as per *Table 4.12* recommended default methane generation rate (k)values under tier 1)-->tropical zone---> for moist and wet condition = 0.4

Assuming Recovered methane (Rt) = 0 and oxidation factor (OX) is assumed as unmanaged and uncategorized SWDS = 0 (From *Table 4.12*)

Type of waste - rapidly degrading waste (food/sewage waste)

$CH_4$ emission from SWDS

$$CH_4\ Emissions = \left[\sum_x CH_4\ generated_{x,T} - R_T\right] \bullet (1 - OX_T)$$

Where:

$CH_4$ Emissions = $CH_4$ emitted in year $T$, Gg

T = inventory year

x = waste category or type/material

$R_T$ = recovered $CH_4$ in year $T$, Gg

$OX_T$ = oxidation factor in year $T$, (fraction)

The $CH_4$ recovered must be subtracted from the amount $CH_4$ generated. Only the fraction of $CH_4$ that is not recovered will be subject to oxidation in the SWDS cover layer.

”

***Table 4.12. Emission of CH4 from Solid Waste Sector***

| Year | Solid waste generation by Domestic tourists (Gg/year) | Solid waste generation by Foreign tourists (Gg/year) | CH4 Emissions by Domestic tourist (Gg/year) | CH4 Emissions by Foreign tourist (Gg/year) | Emissions by Domestic Tourists in Co2 Equivalent (Gg/year) | Emissions by Forign Tourists in Co2 Equivalent (Gg/year) | Total Emissions in Co2 Equivalent (Gg/year) | Per capita of Co2 Equivalent (Gg/ per person/Year) |
|---|---|---|---|---|---|---|---|---|
| **2001** | 0.28608 | 0.03538 | 0.0056739 | 0.00070 | 0.119145309 | 0.01473645 | 0.13388176 | 2.68344E-07 |
| **2002** | 0.28831 | 0.03215 | 0.0057178 | 0.00064 | 0.120073625 | 0.01338974 | 0.13346337 | 2.666E-07 |
| **2003** | 0.30008 | 0.04089 | 0.0059513 | 0.00081 | 0.124976334 | 0.01703137 | 0.14200771 | 2.70132E-07 |
| **2004** | 0.33507 | 0.05129 | 0.0066451 | 0.00102 | 0.139546024 | 0.02135868 | 0.16090471 | 2.7249E-07 |
| **2005** | 0.34441 | 0.05761 | 0.0068303 | 0.00114 | 0.143435706 | 0.02399478 | 0.16743049 | 2.74467E-07 |
| **2006** | 0.39135 | 0.07404 | 0.0077612 | 0.00147 | 0.162985068 | 0.03083425 | 0.19381932 | 2.77472E-07 |
| **2007** | 0.47912 | 0.09229 | 0.0095018 | 0.00183 | 0.199538732 | 0.03843670 | 0.23797543 | 2.7794E-07 |
| **2008** | 0.49668 | 0.09649 | 0.0098501 | 0.00191 | 0.206853063 | 0.04018522 | 0.24703828 | 2.78163E-07 |
| **2009** | 0.51072 | 0.08646 | 0.0101285 | 0.00171 | 0.212698581 | 0.03600850 | 0.24870708 | 2.74745E-07 |
| **2010** | 0.50152 | 0.08154 | 0.0099462 | 0.00162 | 0.20887037 | 0.03396013 | 0.24283049 | 2.73817E-07 |
| **2011** | 0.538792 | 0.08368 | 0.0106853 | 0.00166 | 0.224391615 | 0.03484904 | 0.25924066 | 2.72803E-07 |
| **2012** | 0.589028 | 0.08469 | 0.0116816 | 0.00168 | 0.245313836 | 0.03527085 | 0.28058468 | 2.71189E-07 |
| **2013** | 0.64091 | 0.09843 | 0.0127105 | 0.00195 | 0.266921236 | 0.04099151 | 0.30791274 | 2.72562E-07 |
| **2014** | 0.712856 | 0.13327 | 0.0141374 | 0.00264 | 0.296884481 | 0.05550139 | 0.35238587 | 2.77167E-07 |
| **2015** | 0.74832 | 0.06369 | 0.0148406 | 0.00126 | 0.311652328 | 0.02652585 | 0.33817818 | 2.49883E-07 |

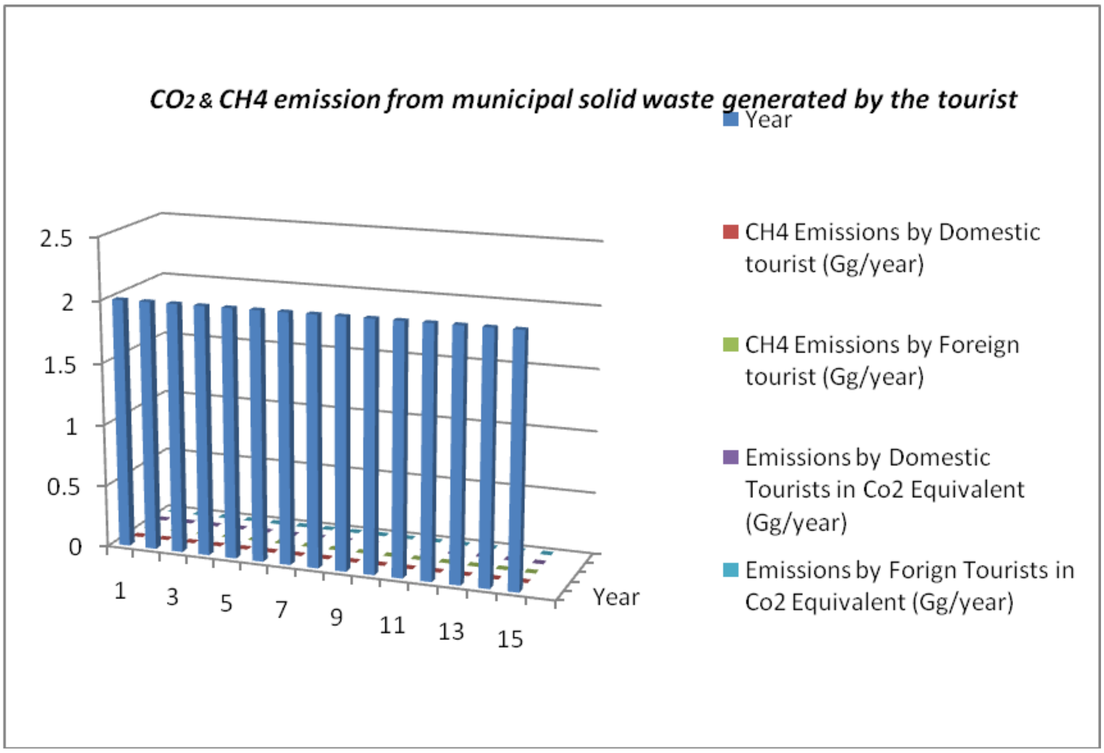



***Figure 4.4. $CO_2$ & $CH_4$ emission from municipal solid waste generated by the tourist***

## 4.5 Result and Discussion

### Part-A

According to the Fourth Assessment Report of the IPCC (2007), "the increased concentration of anthropogenic GHG's in the atmosphere caused dramatic rise in temperature and the global climate change" (IPCC, 2007). "China, USA, European Union (27 countries), Russia, India are the main contributors of GHG emissions (excluding LULUCF: Land use, land-use change and forestry) which in 2005 correspondingly as accounted for 19.1%, 18.3%, 13.3%, 5.2% and 4.9% of the emission profile respectively" (http://cait2.wri.org). According to the results, "India ranks 5$^{th}$in the GHG emissions in the world, behind USA, China, EU and Russia in 2007" (http://envfor.nic.in). "India had already announced its intent to further reduce the emissions intensity of our GDP by 20-25% between 2005 and 2020 even as we pursue the path of inclusive growth" (http://envfor.nic.in).

"Evolving a high quality GHG-I is an important step to GHG emissions action plan and mitigation. The inventory quality is estimated by means of the uncertainties analysis, where the level of uncertainties depends on the reliability of active data and parameters used" (Nina et. al., 2014). The estimation of major industrial, domestic, agriculture, transport and waste management sectors are made using Tier 1 methodology as per IPCC (2006) Guidelines and available data. The emissions of industry sector were calculated based on installed capacity of the industry sector, since the credible data on plant availability, plant utilisation, and production efficiency were not available.

"These assumptions might have resulted in slight over-estimation than the actual. It is thus necessary that this estimation process may be carried forward along the IPCC tier ladder for a more accurate GHG estimation. For completeness, estimation of emissions from other sectors may also be considered to be incorporated. The results of the estimates were further recalculated into $CO_2$ equivalent based on the GWPs" (Houghton et. al., 1996).

In the domestic sector, emission was calculated on the basis of total kerosene, LPG and electricity consumed whereas in case of the transport sector, it was calculated on the basis of actual fuel sold through retail selling of petroleum products. The emission estimation from municipal solid waste and sewage was done on basis of total population and not on actual generation due to unavailability of data.

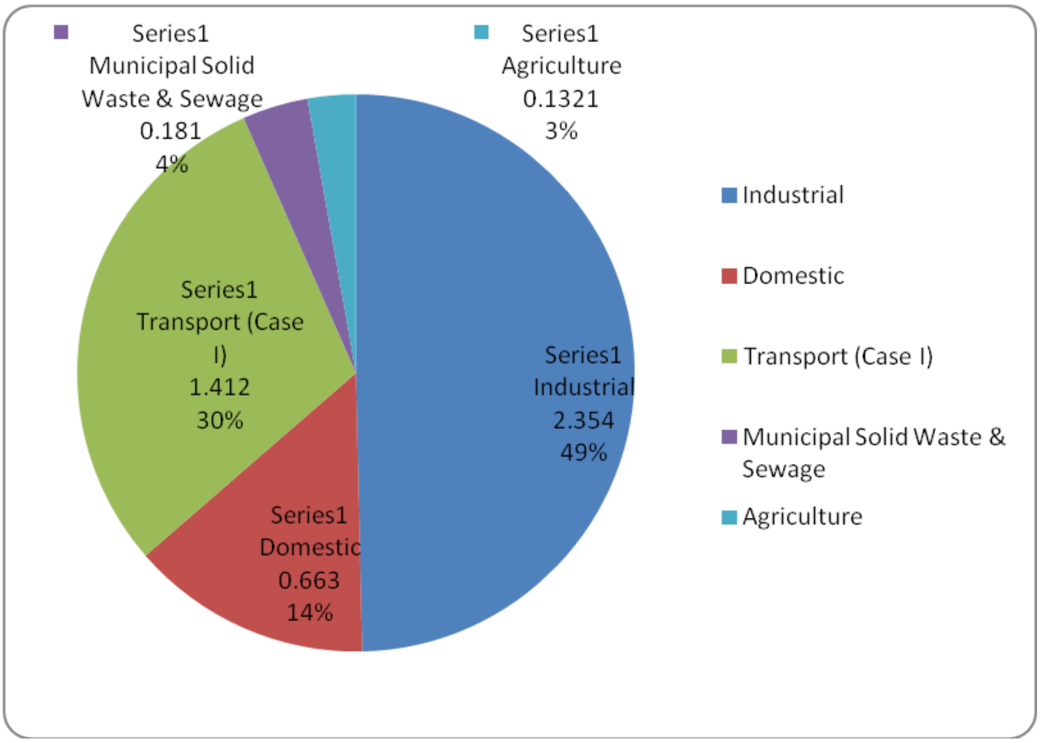



***Figure 4.5. Sector wise GHG emission with Case I emission from transport sector***

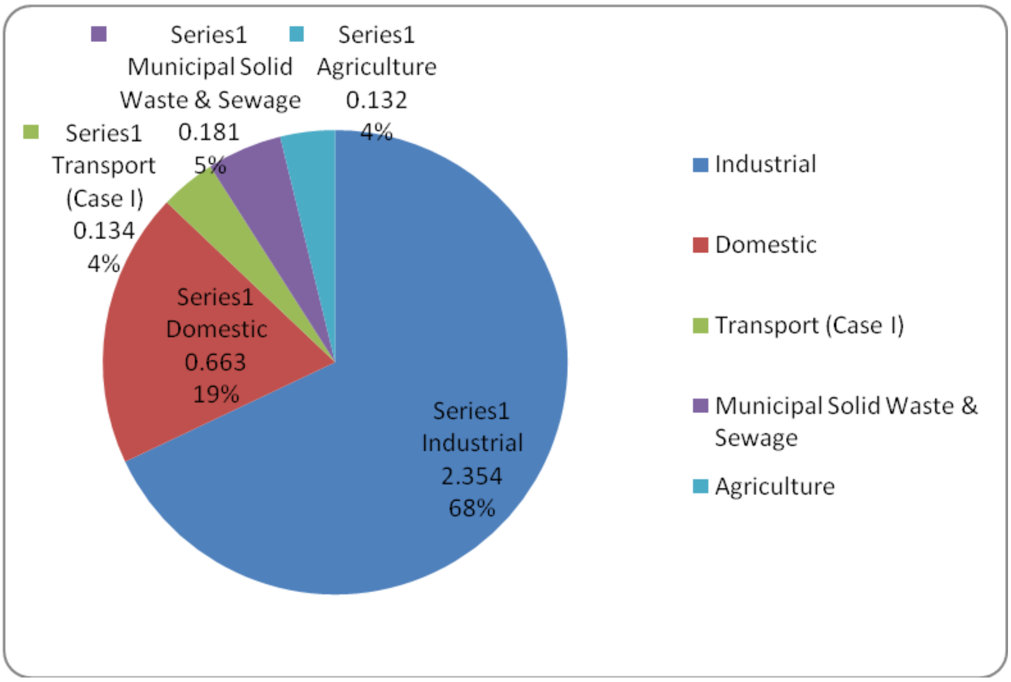



*Figure 4.6. Sector wise GHG emission with Case II emission from transport sector*

The sector wise GHG emission is represented in *Figure 4.5* and *Figure 4.6* with two cases of emission from transportation sector (Case I: GHG emission estimated for the transportation sector was based on net fuel oil sold net of the consumption from industry and Case II: GHG emission from transportation sector was estimated based on per capita GHG emission from transportation sector in 2007 across India. However for case II estimation emission from road transportation was considered).

When it comes to agriculture, since the credible data on plant availability, plant utilization, and production efficiency were not available, the estimation of agriculture sector (enteric fermentation, manure management and rice cultivation) was done using the Tier 1 methodology as suggested by IPCC (2006) guidelines. The inventory of GHG emission from agriculture sector based on the available data is presented in *Table 4.13*:

***Table 4.13. GHG emission from agriculture sector (Source: CTRAN, 2013)***

| Category | Total Emission ($tCH_4$/year) | Total Emission ($tCO_2e$/year) | $CO_2e$ emission (Million Tonnes of $CO_2e$/year) |
|---|---|---|---|
| **Enteric Fermentation** | 4,036.00 | 84,768.00 | 0.0848 |
| **Manure Management** | 354.00 | 7,452.00 | 0.0075 |
| **Rice Cultivation** | 1,900.00 | 39,901.00 | 0.0399 |
| **Total** | **6,290.00** | **1,32,121.00** | **0.1321** |

The total emission ($tCH_4$ /year) through enteric fermentation, manure management and rice cultivation are 4,036.00; 354.00 and 1,900.00 respectively. Whereas carbon dioxide equivalent ($CO_2e$) emission (Million Tonnes of $CO_2e$/year) computed through enteric fermentation, manure management and rice cultivation are 0.0848; 0.0075 and 0.0399 respectively. Even though these assumptions might have resulted in slight over-estimation than the actual, it is thus necessary that this estimation process may be carried forward along the IPCC tier ladder for a more accurate GHG estimation in the near future or phase II.

**Part – B**

The total $CO_2$ equivalent by the total tourist (domestic and foreign) associated with the transport, wastewater and solid wastes were 69719.76 (Tonnes/year); 265088.68 (Kg/year); and 3.446360774(Gg/year) respectively (*Table 4.14*). When it comes to the per capita of $CO_2$ equivalent associated with the transport, wastewater and solid wastes by the individual tourist: the $CH_4$ emission by domestic tourist was 0.08249 (Tonne/ per person/Year), 0.31366 (Kg/ per person/Year) and 4.07777E-06 (Gg/ per person/Year) respectively, whereas for foreign tourist it was calculated as 16.22(Kg/TJ), 0.002(Kg) and $6.39*10^{-7}$(Gg) respectively (*Table 4.14*).

***Table 4.14. GHG Emissions by the Total Tourist and per capita of Co2 Equivalent in UTP***

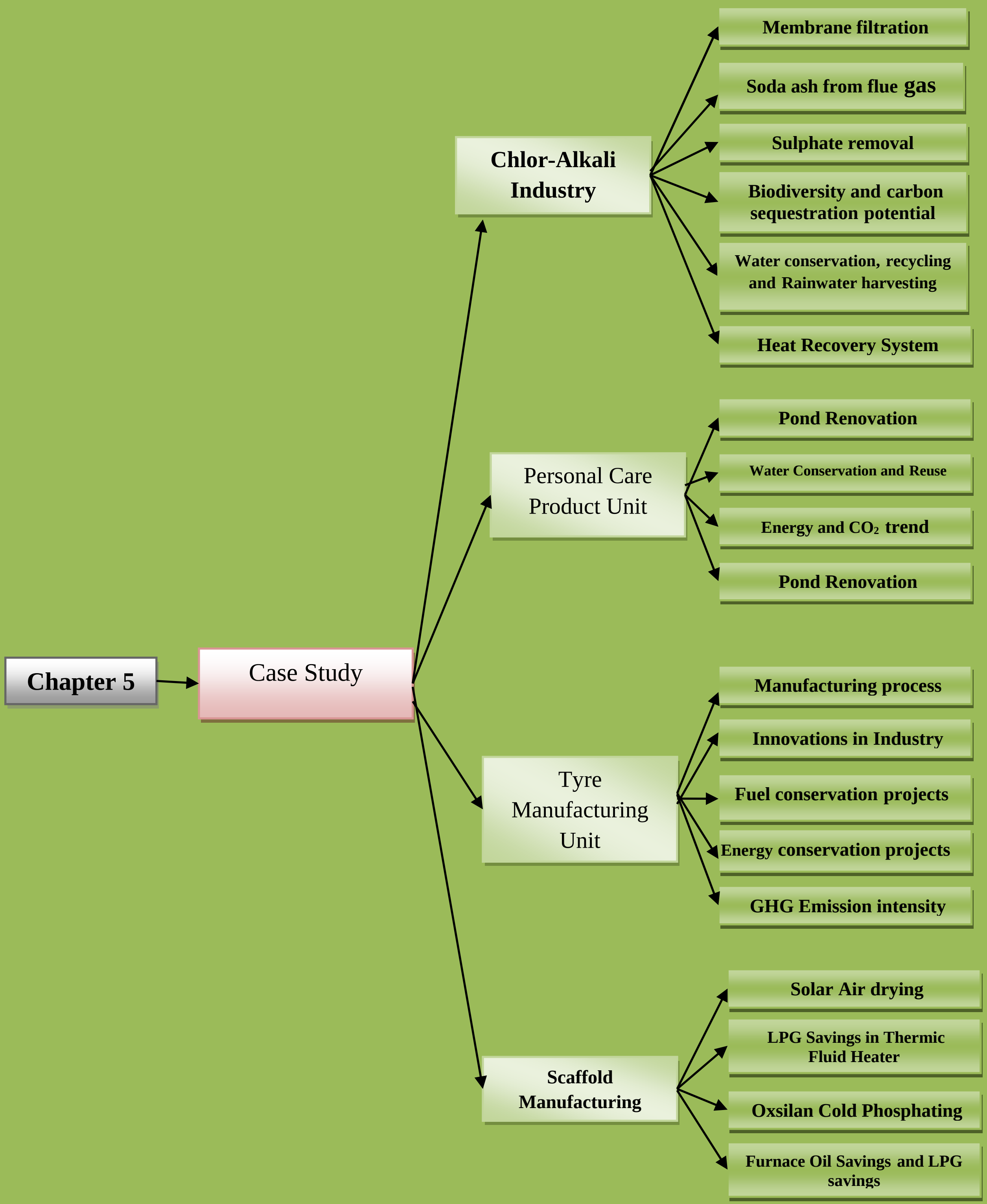
| Year | Domestic Tourist nos. | Foreign Tourist nos. | Sector | Total $CO_2$ Equivalent by Tourists | Per capita of $CO_2$ Equivalent |
|---|---|---|---|---|---|
| **2001-2015** | 1247192 | 106513 | Transport | 69719.75958 (tonnes/Year) | 0.08249 (Tonne/ per person/Year) |
| | | | Wastewater | 265088.68 (kg/year) | 0.31366 (Kg/ per person/Year) |
| | | | Solid waste | 3.446360774 (Gg/year) | 4.07777E-06 (Gg/ per person/Year) |

## 4.6 Limitations of the Study

"The focus of this study is to evaluate the GHG emissions from various sectors at the state /UT level. Since, global/ regional data are not always available, extrapolations have been necessary" (Malmodin, et. al. 2010). For example, data from industrial countries such as the United States, Sweden, and other European countries, with different studies and different scope were referred and sited, hence extrapolations to global data is needed. However, the quantitative data used in this study, do give an indication of the order of magnitude that could be expected in a macro scale study, and also some of the data that have a high uncertainty have a limited contribution to the overall result, thus adding only a limited uncertainty to the total result. GHG emissions are just one environmental impact, and other impacts, environmental as well as social, need further study on national /global scales to get a better understanding of the sectors.

# CHAPTER 5

# 5 PUDUCHERRY CLIMATE CHANGE ACTION PLAN



## 5.1 Introduction

### 5.1.1 Puducherry Climate Change Action Plan

Puducherry climate change action plan identifies and prioritizes strategies that simultaneously advance the UTs development goals, while yielding co-benefits of climate change mitigation and adaptation effectively. The greenhouse gases inventory done for the Puducherry has identified the crucial sectors in which various activities need to be taken up. In line with the national missions identified under National Action Plan for Climate Change, the activities to be taken up have been categorized under the relevant missions. Accordingly, the following mission activities emerged:

“ 1. Solar Mission
2. Mission on Enhanced Energy Efficient
3. Mission on Sustainable Habitat
4. Mission for a green Puducherry and Sustainable Agriculture
5. Water Mission
6. Mission on Strategic Knowledge on Climate Change
7. Coastal Mission”

In each mission, the crucial activities that are to be taken up have been identified. Baseline data in respect of the ongoing projects under the mission has also been gathered.

***Table 5.1. Baseline data of the ongoing projects***

| Action Plan | Mission | Key Priorities | Corresponding strategies |
|---|---|---|---|
| 1 | **Solar Mission**<br>“Enhancement of the solar energy share in the total energy mix has been identified as key element for the mitigation and adaptation programme. This is emerged based on discussions with the concerned stakeholders. Accordingly, the following key priorities have been identified under the solar mission” | 1. “Harnessing renewable energy potential scenario of the UT by Assessment of Solar energy potential across the UT & preparation of solar potential map<br>2. Mandatory use of solar water heating systems in domestic sector through policy action and demonstration<br>3. Promotion and facilitation of Renewable energy application in Govt. schools & central kitchens of UT.<br>4. Enhancement of solar lighting application in public places through demonstration projects<br>5. Strengthening technical competency of | “For taking up implementation of climate change action plan the high priorities have been considered. The priorities have been further categorized into mitigation and adaptation and short, medium and long term. Accordingly, the following activities are identified for implementation. Under solar mission 9 number of high priorities and 6 number of medium |

| | | | |
|---|---|---|---|
| | (CTRAN, 2013) | various stakeholders of RE technology including O&M service providers, technicians, installers, manufacturer & others<br><br>6. Promotion of Solar water heating system application in health sectors<br><br>7. Mandatory use of Solar Water Heating system in hotel sectors<br><br>8. Promotion of grid interactive solar power generation in PPP/IPP mode through policy measures and facilitating setting up of 20 MW rooftop and small solar power plants of up to 2 MW capacity.<br><br>9. Promotion of solar application in public buildings for lighting and hot water generation through demonstration project of 50 kW solar power and 1000 LPD SWH installation in two govt. buildings" (World Bank Report, 2013). | priorities identified for implementation under mitigation.<br><br>Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 10 short term, 14 medium term and one long term activities" (World Bank Report, 2013). |
| 2 | **Mission on Enhanced Energy Efficiency**<br><br>"Enhancing energy efficiency is one of the key challenges faced by the Union Territory. In order to improve energy efficiency and address the energy security concerns, National Productivity Council (NPC) had conducted a study focused on estimation of the total electricity consumption and saving potential in | **1.** "Provisioning of LED/CFL distribution to household and replacing incandescent lamp<br><br>**2.** Development and promotion of Policy measures towards up-gradation of existing production/manufacturing process across the industrial facilities to energy efficient one.<br><br>**3.** Enforcing Energy Audit and its implementation across the industrial facilities<br><br>**4.** Incorporate conditions as a part of building permit to adopt star rated energy efficient electrical appliances and use of CFL | "For taking up implementation of climate change action plan the high priorities have been considered. The priorities have been further categorized into mitigation and adaptation and short, medium and long term.<br><br>Accordingly, the following activities are identified for implementation. Under Enhancing energy efficiency 9 number of high priorities, 2 |

| | | | |
|---|---|---|---|
| | different sectors (e.g. agriculture, industry, domestic, municipalities, etc.) of Puducherry as per the guidelines of Bureau of Energy Efficiency (BEE). Accordingly, the following key priorities have been identified under the Enhanced Energy Efficiency" (World Bank Report, 2013) | **5.** Institution of Energy Conservation Award<br>**6.** Enforcement towards use of Energy Efficient Lighting in all Govt. & commercial building<br><br>**7.** Facilitating energy audit across all large (in terms of energy consumption) government offices and retrofitting of existing energy inefficient system with efficient and star rated products.<br><br>**8.** Promoting and Adapting Energy Efficient technology measures and practices in new building<br><br>**9.** Creation of Green Corpus fund" (World Bank Report, 2013) | medium priorities and 6 number of low priorities identified for implementation under mitigation.<br><br>Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 8 short term, 6 medium term and 3 long term activities"(World Bank Report , 2013). |
| 3 | **<u>Mission on Sustainable Habitat</u>**<br>"Developing a sustainable habitat faces significant challenges due to climate change. Climate change impacts range from increase in extreme weather events, natural calamities, flooding to high temperatures leading to public health concerns. The impacts potentially have serious consequences on human health, livelihood and socio-economic assets, especially for the urban poor, informal settlements and other | **1.** "Adopting ECBC code for residential apartments and commercial centers<br><br>**2.** Wastewater recycling & Strengthening/ modifications of exiting STPs<br><br>**3.** Promotion of Green buildings and green building certificate<br><br>**4.** Integrated Municipal solid waste management<br><br>**5.** Establishment of modern slaughter house within Puducherry Municipality<br><br>**6.** Capacity building programs of Urban Local Bodies (ULBs)/ stakeholders of the coastal towns on potential climate change impacts (Tsunami, cyclone, flooding of low-lying coastal areas, land loss and displacement) and additional preparedness requirements.<br><br>**7.** Construction of Flyover and laying of | "For taking up implementation of climate change action plan the high priorities have been considered. The priorities have been further categorized into mitigation and adaptation and short, medium and long term.<br><br>Accordingly, the following activities are identified for implementation. Under Enhancing energy efficiency 17 number of high priorities, 17 medium priorities and 15 numbers of low priorities identified for implementation under mitigation. |

| | | | |
|---|---|---|---|
| | vulnerable groups. Considering the fact that it is a coastal city it faces multi-hazard scenario from shoreline change, sea level rise to tsunami. As the urban regions of this Union Territory are highly dynamic systems that face unique climate impacts, their adaptation must be location specific and should be tailored to local circumstances. The high priorities identified are based on cost effectiveness, cost-benefit, feasibility, ease of implementation and overall sustainability. Within the sustainable habitat sector, five key priorities are put under the transport infrastructure sector and eighteen priority actions are under sustainable urban development sector" (CTRAN, 2013). | bypass road<br><br>**8.** Providing/ renewing underground sewerage systems to urban areas<br><br>**9.** Promotion of eco-friendly road construction methods and capacity building of stakeholders<br><br>**10.** Climate friendly transport management and promotion of Public transport<br><br>**11.** Promotion of use of cooking gas from kitchen waste in bio-digester" (World Bank Report, 2013) | Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 12 short term, 32medium term and 5 long term activities. " (World Bank Report, 2013) |
| 4 | **<u>Green Puducherry mission and Sustainable Agriculture</u>**<br><br>"To reduce the climate change stresses on the sector and enhance the | 1. "Enhancing productivity through introduction of genetically superior seedlings<br><br>2. Eco-restoration of coastal areas by bio shelter plantations<br><br>3. Wildlife and biodiversity | "Accordingly, the following activities are identified for implementation. Under Green Puducherry mission and Sustainable Agriculture, 17 |

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| | adaptive capacity as well as resilience of the sector and livelihood of the people dependent on the sector. Accordingly, the following key priorities have been identified under the Green Puducherry mission and Sustainable Agriculture" (CTRAN, 2013)<br>. | conservation by insitu & exsitu methods<br><br>4. Enrichment of existing forest density<br><br>5. Promotion of farm forestry and agro forestry<br><br>6. Consolidation and protection of forests<br><br>7. Watershed development through vegetative means<br><br>8. Development of ecotourism and involving local communities<br><br>9. Identification and propagation of adaptive species through modern nurseries<br><br>10. Study on REDD & REDD + Feasibility for Afforestation in Puducherry<br><br>11. Capacity building of staff<br><br>12. Protection of Mangrove forests<br><br>13. Monitoring critical faunal habitats [turtles/ littoral birds]to assess impact of climate change<br><br>14. Drip Irrigation for 30% of land area under Horticulture<br><br>15. Promotion of solar pumps for irrigation purpose by replacing 5 nos. diesel pumps with solar pump<br><br>16. Educating farmers on better cropping systems, drought resistance crop, minimization of chemical fertilizer and encouraging organic farming and | numbers of high priorities, 17 medium priorities and 15 number of low priorities identified for implementation under mitigation.<br><br>Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 12 short term, 32 medium term and 5 long term activities" (World Bank Report, 2013) |

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| | | soil reclamation program<br><br>17. Replacing existing pumps by foot valve motor pumps in Karaikal region" (World Bank Report, 2013). | |
| 5 | **<u>Water Mission</u>**<br>"The water resources continue to be undervalued and overused without regard to current costs and future requirements. Traits of growing economy like urbanization and industrialization are taking toll on the water bodies causing large-scale pollution. Government of Puducherry is acting on climate change issues through national policies via local regulations, urban services and programme administration. The following action points have emerged out of several rounds of discussions among the working group members under Water Mission. The key priorities have been identified with a focus on conservation of water to meet the rapid increase in demand and consumption along with wastage of water" (CTRAN, | **1.** "Rain water harvesting pond creation of 10% of land area by 2013 and 50% by pipeline irrigation by 2015<br><br>**2.** Desiltation of all the temples and village/ farm ponds by 2015<br><br>**3.** Channelizing storm water into village pond or ground water recharge by 2015<br><br>**4.** Promotion of percolation pits in housing colonies and in urban areas<br><br>**5.** Rainwater harvesting for all type of new and existing buildings (Residential, Commercial and Industrial buildings) by 2013 and 2015 respectively" (World Bank Report, 2013) | "Under Water Mission, 6 numbers of high priorities, 9 medium priorities and 3 numbers of low priorities identified for implementation under mitigation.<br>Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 7 short term, 10 medium term and 1 long term activities" (World Bank Report, 2013)<br>. |

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| | 2013) | | |
| 6 | **<u>Mission on Strategic Knowledge on Climate Change</u>**<br>"Measures to generate strategic knowledge should carefully include perspectives, knowledge and understanding of the population, policy makers, decision makers and stakeholders. The knowledge strategy developed should be comprehensible and executable by the stakeholders at large. The knowledge networks should operate in a hub-and-spoke model with nodal institutions linked to a wider range of knowledge partners linking to both intra-mural and extra mural research support system. This should minutely address the issues and at the same time support the need for economic and livelihood growth of the UT" (CTRAN, 2013). | **1.** "Creating awareness on water and energy conservation, composting, source segregation of House hold waste, plantation Rain water harvesting pond creation of 10% of land area.<br><br>**2.** Educating farmers on better cropping systems, drought resistance crop, minimization of chemical fertilizer and encouraging organic farming and soil reclamation programme. Channelizing storm water into village pond or ground water recharge.<br><br>**3.** Advocating clean development mechanism, resource conservation and waste minimization through seminar/ workshop Rainwater harvesting for all type of new and existing buildings (Residential, Commercial and Industrial buildings)<br><br>**4.** Capacity building on mitigation/adaptation of Greenhouse Gases among the officers and establishment of a climate change cell<br><br>**5.** Inventorisation of GHG generation from industries and other sectors<br><br>**6.** Setting up of Energy Bench Mark for all government buildings/ institutions<br><br>**7.** Establishing a network of knowledge institutions, location specific research on climate science, setting up of an effective mechanism for data sharing and access and organizing conferences/ workshops on climate change and related issues<br><br>8. Evaluation of action plan programs | "Under strategic knowledge on climate change, 8 numbers of high priorities and 3 medium priorities identified for implementation under mitigation.<br>Accordingly, Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 5 short term, 5 medium term and 1 long term activities" (World Bank Report, 2013)<br>. |

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| | | and providing budget support to implementing departments/ authorities" (World Bank Report, 2013) | |
| 7 | **<u>Coastal and Disaster Management</u>**<br>"The climate change action plan assesses the vulnerability of the coastal community in light of the projected variation in climate, weather variability and climate extremes and strategizes measures towards effective disaster risk reduction and promotes the concept of disaster resilience. The adaptive measures planned under the CCAP on one hand is intended to enhance the coping capacity and resilience of the vulnerable coastal communities so that they can respond promptly and effectively as well as quickly recover from the crisis situation. The actions proposed under the missions is so planned that it integrates preparedness and proactive measures towards disaster risk reduction as reactive measures are widely | 1. "Demarcation of HTL or LTL along the coastal stretches and preparation of revised coastal Zone Management Plan<br><br>2. Integrated Coastal Zone Management Plan Preparation<br><br>3. Flood Mapping and Development of Climate change projection Model and its impact on coastal ecosystem in Puducherry<br><br>4. Assessment of Erosion prone Area with the help of Digital elevation model and strengthen coastal protection method through improved technology<br><br>5. Study on Micro level vulnerability assessment due to climate change on coastal ecosystem<br><br>6. DPR on flood shelters, multipurpose cyclone shelters in vulnerable location in Coastal line and construction of flood shelters, multipurpose cyclone shelters and climate resilient buildings that can withstand multiple hazards<br><br>7. Development of a techno legal regime for construction of Disaster resilient housing and public infrastructure<br><br>8. Integration of Climate change risk in the disaster Management policy of the UT<br><br>9. Establishment of an integrated training and Capacity building protocol and knowledge management for better assessment of climate risks and best | "Under strategic knowledge on climate change, 12 number of high priorities and 3 medium priorities identified for implementation under mitigation. Accordingly Short term, medium term and long term activities- the detailed discussion and formulation of action plan has revealed that 9 short term, 5 medium term and 1 long term activities" (World Bank Report, 2013). |

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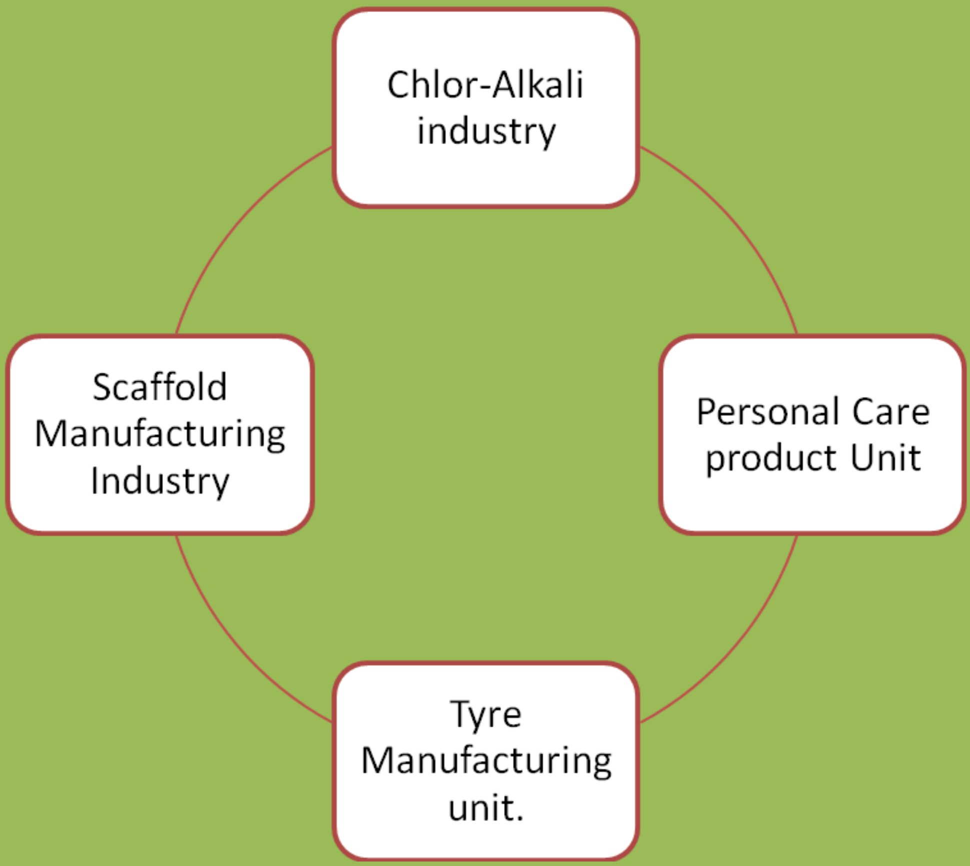
| | covered under existing Disaster management programme” (CTRAN, 2013). | management practices<br><br>10. Study on Impact of Climate change on Marine Biodiversity with special emphasis on Flagship species and coastal flora and fauna<br><br>11. Strengthening, delivering and monitoring system and preparedness in disaster prone coastal area<br><br>12. GIS based mapping along the selected vulnerable coastal area of Puducherry<br><br>13. Development of Sustainable aquaculture” (World Bank Report, 2013) | |

# CHAPTER 6

# 6 CASE STUDIES OF INDUSTRIES IN PUDUCHERRY



## 6.1 Introduction

This chapter deals with four specific industrial Case studies. In each industry, an attempt has been made to estimate GHG emission, introduce new initiatives to reduce emissions and the resultant impact on net GHG emission. As the industrial sector contributes to the maximum for the GHG in the UT as per the inventorisation done, the same have been chosen for case study. The following are the four industrial case studies chosen (major industries in the UTP) for collaborative research.

1. Chlor-alkali industry,
2. Personal care products industry,
3. Tyre manufacturing industry and
4. Infra structure manufacturing industry.

The studies selected are based on the following criteria:

- High power and fuel consuming Industries.
- Having commitment towards Sustainable Development.
- Willingness to co-operate for the study.
- Having adequate technical resource persons to document and provide data etc.

The industries generally have the potential of Green House Gasses Emission because of the following activities. Fuel consumption, the consumption of power in various process, water heating for steam generation or for hot water requirement, heating and cooling needs etc., It has been observed that lot of potential exist in the manufacturing industries on these activities which consume lot of energy and fuel. Hence, the industries are selected on this basis, besides, their willingness to co-operate and other factors.

In addition, the following factors of implementation of various activities which will reduce the Green House Gasses emission like modification of existing process, waste water treatment and re-use, rain water harvesting and using the same, renewable energy usage development of green belt and Solid Waste Management etc. The selection of Industries for the case study was based on these criteria. There were certain common activities which are in all the four industries and there were certain industry specific activity which gives scope for quantification of reduction of Green House Gas Emission.

The *Table 6.1* depicts the factors, which are common to all the four industries and also industry specific activities.

***Table 6.1. Common factors to all the four industries and industry specific activities***

| S.no. | Industry selected for case study | Common mandated sustainable industrial initiatives | Industry specific strategic mitigation strategy for GHG emission (direct & indirect) |
|---|---|---|---|
| 1 | Chlor-Alkali industry | • Water conservation<br>• Effluent treatment<br>• Waste heat recovery method<br>• Dry cooling tower<br>• DM water<br>• Rainwater harvesting<br>• Fire hydrant system<br>• Chlorine stock level monitor<br>• Windsocks are provided<br>• Automated weather monitor | • Membrane chloroalkali technology<br>• Recovery of barium sulphate from solid waste<br>• Ultrafiltration membrane system for brine clarification<br>• Ultrafiltration technology for recycle of cylinder pit washings<br>• Membrane system for sulphate removal<br>• Electro deionisation technology for the production of DM water<br>• New hydrochloric plant with heat recovery unit<br>• Recovery of sodium sulphate from the rejects f sulphate removal unit<br>• Developed soda ash from flue gas |
| 2 | Personal Care product Unit | • Regeneration of waste water using boiler ash cooling<br>• Push type taps is used to reduce water consumption<br>• Fire hydrant system<br>• RO backwash water<br>• Steam condensate is used<br>• Rain water harvesting<br>• Upgradation of motors<br>• Steam recovery<br>• LED Lighting for power saving<br>• LP compressors<br>• Solar freezers<br>• Solar lighting<br>• ETP sludge<br>• Solid and liquid waste management<br>• Vermicomposting<br>• E-waste management | • Renovation of 8 traditional ponds<br>• Biomass Briquette fired boiler for energy saving and $co_2$ emission reduction |

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| 3 | Tyre Manufacturing unit. | • Dust collector & fume extractor with bag filters<br>• Wet scrubber<br>• Steam atomized burner<br>• FO centrifugal sludge separator<br>• Acoustic insulated compressor<br>• Impervious flooring in fuel storage yard<br>• Oil skimmer<br>• Salt generation from softener<br>• Ball floats fixed in cooling towers<br>• Closed loop radiator cooling from engine<br>• Rainwater harvesting<br>• solar LED type street lights has installed<br>• Solar powered traffic lamps<br>• Turbo ventilation by natural air draft<br>• Fuel reduction method has implemented<br>• Power consumption has implemented<br>• Green belt<br>• Solar water heaters | • Biomass Briquette fired boiler in furnace oil fired boilers |
| 4 | Scaffold Manufacturing Industry | • Solar Air drying<br>• Energy Saving in Lightings<br>• Led street lightings & T8 led fixtures | • LPG Savings in Thermic Fluid Heater<br>• Oxsilan Cold Phosphating for Pre-Treatment Process<br>• VFD based compressor<br>• LPG Gas Manifold System For Thermic Fluid Heater |

"The industries are one of the world's largest contributors of GHGs. Chemical products and technologies are used in almost every area of the world economy and in 2008, total sales exceeded $3 trillion. As the global economy grows, it increases the demand for the chemical industry's products, which stimulates product innovation, resulting in new products every year while striving to improve production processes and resource use more efficiently" (ICCA, 2009).

In the face of sustainability concerns, rising energy costs and competitive pressures, the chemical and petrochemical industry investigates that, the catalytic processes can contribute to further, increasing the sector's efficient use of energy usage and emissions reductions.

"At present, global energy demand for the chemical industry is 15 EJ per year (EJ/yr) (excluding feedstock) and 42 EJ/yr (including feedstock) and accounts for approximately 10% of the global energy demand or 30% of the total industrial energy demand worldwide" (IEA, 2012). In addition, "the chemical industry generates 5.5% of CO2 emissions (i.e. 7% of global GHG emissions) and is responsible for 17% of industrial CO2 emissions (i.e. 20% of the industrial GHG emissions). In 2005, the global GHG emissions across the chemical industry were 3.3 GtCO2-eq (+/- 25%), with 2.1 Gt from the manufacture of products and 1.2 Gt from extraction of feedstock/fuel and disposal phases" (ICCA, 2009).

Ren et al., (2006) reported that, "the steam cracking for olefin production is the most energy-consuming process in the chemicals industry; accounting for emissions of about 180 MtCO2/year and that significant reduction are possible". Whereas Worrell et al., (2000a) stated that, "the chemical industry is highly diverse, with thousands of companies producing tens of thousands of products in quantities varying from a few kilograms to thousands of tonnes. Because of this complexity, reliable data on GHG emissions is not available. The majority of the $CO_2$- eq direct emissions from the chemical industry are in the form of $CO_2$, the largest sources being the production of ethylene and other petrochemicals, ammonia for nitrogen-based fertilizers, and chlorine". On the other hand, according to Galitsky and Worrell (2004), "pharmaceutical manufacture uses relatively little energy, most of which is used in the buildings that house industrial facilities".

According to ICCA (2009) report, "Chemical products have a twofold effect on GHGs: firstly the GHGs are emitted in the manufacturing of chemical products, secondly, at the same time the use of many of these products enables significant reduction in global emissions. Hence, the emissions reduction while using these products can be far in excess than the amount of GHGs emitted during production. As explained in this report, the best illustration of this impact is insulation. High-performance foam insulation of a house significantly reduces the heating required, thereby reducing energy consumption and GHG emissions"**.**

"By 2002, the Japanese chemical industry reduced unit energy consumption to 90% of the 1990 fiscal year level – eight years ahead of target. By 2006, further improvements meant that the performance achieved was 82% of the 1990 level; on the other hand, since 1974, the U.S chemical industry has reduced its fuel and power energy consumed per unit of output by nearly half".

"The chemical industry's incremental abatement (composed of both own emissions and product savings) between the above two scenarios is 4.7 $GtCO_2$. This corresponds to 12% of the 38 $GtCO_2$ abatement opportunity identified in the GHG abatement cost curve published by McKinsey & Company in February, 2009. This number assumes, of course, that all opportunities for abatement within the sector are met, while, all the other opportunities for abatement across the sectors were realized. But within the context of these two conditions, the study underlines the important role of the chemical industry in global GHG reductions" (McKinsey & Co, 2009).

"The chemical sector is also the producer of some of the most potent GHGs, notably refrigerants. These GHG as chemical products are outside the battery limit of this study, since, they are not emitted by the chemical industry. Generally, they form part of a product sold to the consumer (e.g. a fridge) and are released at the end of the lifetime if proper recycling procedures are not adhered to. Strictly speaking, urea also falls into this category, since $CO_2$ is released" (IEA, 2012).

The GHG inventorisation done by the DST&E, Government of Puducherry in collaboration with the consultant World Bank (2013) "had revealed that 3.46 million tonnes of $CO_2e$ is emitted annually, which is 2.7 tonnes equivalent to per capita emissions (based on the 2011 Census). As per the GHG report, industrial sector contributes to 2.35 million tonnes $COs_2$ equivalent per annum. This is almost 78% of the total GHG emission from industrial sector".

"The Clean Development Mechanism (CDM), established under the Kyoto Protocol, is the primary international offset program in existence today. It offsets through investments in GHG reduction, avoidance, and sequestration projects in developing countries. These offset credits, called Certified Emission Reduction credits (CER), represent a reduction in one metric ton of carbon dioxide ($CO_2$) emitted to the atmosphere. Developed countries can use CER to cost-effectively achieve their Kyoto Protocol's GHG emission reduction targets. Even though, the United States is not a signatory to Kyoto Protocol, several U.S. state GHG programs, including the Regional Greenhouse Gas Initiative and the Western Climate Initiative, had also proposed that CER can be used in their programs by firms for compliance purposes" (Antinori et al., 2007).

"Apart from providing a cost-containment mechanism for developed countries to meet their Kyoto Protocol emission reduction targets, the CDM may play a critical role in providing private sector financing for low carbon technology in developing countries. At the Climate Conference in Copenhagen (COP 15), 2009, the U.S. Secretary of State, Hillary Clinton pledged that developed countries would mobilize \$100 billion by 2020 from both public and private sources for climate mitigation and adaptation in the developing world. The CDM has already channeled \$2.7 billion of private sector financing to developing countries, and there is the potential that the United States and other developed countries can capitalize on this experience to help meet the \$100 billion goal"(Au Yong, 2009).

Jiarong (2010) reported, "The sustainable development of chemical industry must be based on the attempts of controlling the emissions of all poisonous pollutions, as well as accelerating the emission reduction of GHG to protect the global climate. Up to 2010, the chemical production in US reduced 43 billion US dollar, which is 12.4% less than the estimation without emission reduction requirement. Chemical facilities with high energy cost, such as bases, fertilizer and chemical mining, will be affected seriously. Exportation of chemical produced will decrease 27% while the import will increase 11%. The chemical industry in US will reduce 120-150k staffs".

## 6.2 Case Study-1-Chlor-Alkali industry

### 6.2.1 Background

The Chlor-Alkali industry is one of the oldest and important industries of the country in the inorganic chemical industry. "The Chlor-Alkali industry in India forms an important component of basic chemical industry, comprising around 74% of the basic chemical production in India. It comprises of caustic soda, liquid chlorine and soda ash. These products are commonly used in various applications such as finishing operations in textiles, manufacture of soaps and detergents, Aluminium smelting, Dyes and dye stuff industry, paper and pulp, control of pH (softening) of water, pharmaceuticals, electroplating , adhesives and additives, general cleansing and bleaching etc. The demand for the two sub-segments-caustic soda and soda ash, ash increased significantly registering a compound annual growth rate (CAGR) of 5.6% and 4.7% respectively, over the past five years" (Research and Markets 2011)

"Globally the size of the Chlor-Alkai industry is 170 million tones. The size of the Indian Chlor-Alkali sector is at 7 million tones. Despite its large size and significant global contribution, Indian Chlor-Alkali sector represents only 4 % of world market" (Mathur 2013).

A case study of the unit presently considered is the first membrane Chlor-alkali plant in India. This technology was successfully demonstrated in Indian conditions, which led Government of India to take a policy decision that all the new Chlor-alkali plants will be of membrane-based technology. The total energy savings is around 30 % compared to the conventional mercury based chlor-alkali process.

### 6.2.2 Applications

"Chlorine, by-product of caustic soda industry is very important for manufacturing of Poly Vinyl Chloride (PVC), one of the five major Thermoplastic commodity plastics. Besides this, it is used in infection of drinking water, pharmaceutical industry and various other chemical industries. Use of chlorine is very important for the countries like India especially in case of floods. 85% of the pharmaceuticals rely on chlorine chemistry including medicines that treat heart disease, cancer, AIDS and many other life threatening diseases. Chlorine tablets are also used by public health workers in rural areas.

Chlor-Alkali industries are increasingly working towards reducing energy intensity of their operations, adopting latest technologies, minimizing emissions, and increasing the share of recyclable products in their portfolio" (Research and Markets 2011)

### 6.2.3 Highlights of processes for Chlor-Alkali/Caustic soda

"The Chlor-Alkali process is an industrial process for the electrolysis of sodium chloride solution (brine). Depending on the method, several products besides hydrogen can be produced. If the products are separated, chlorine and sodium hydroxide (caustic soda) are the products. By mixing, sodium hypochlorite or sodium chlorate is produced, depending on the temperature".

"There are three basic processes for the electrolytic production of chlorine, the nature of the cathode reaction depending on the specific process. These three processes are (i) the diaphragm cell Process (Griesheim cell, 1885), (ii) the mercury cell process (Castner–Kellner cell, 1892), and (iii) the membrane cell process (1970). Each process represents a different method of keeping chlorine produced at the anode separate from the caustic soda and hydrogen produced, directly or indirectly, at the cathode.

The basic principle in the electrolysis of a sodium chloride solution is the following:

- At the anode, chloride ions are oxidised and chlorine ($Cl_2$) is formed.

- At the cathode, in the mercury process, a sodium/mercury amalgam is formed and hydrogen ($H_2$) and hydroxide ions ($OH^-$) are formed by the reaction of the sodium in the amalgam with water in the denuder. In membrane and diaphragm cells, water decomposes to form hydrogen ($H_2$) and hydroxide ions ($OH^-$) at the cathode.

For all processes, the dissolving of salt, sodium chloride, is:

$$NaCl \rightarrow Na^+ + Cl-$$

The **anode** reaction for all processes is:

$$2\ Cl^-(aq) \rightarrow Cl_2(g) + 2\ e^-$$

The **cathode** reaction is:

$$2\ Na^+(aq) + 2\ H_2O + 2e^- \rightarrow H_2\ (g) + 2\ Na^+(aq) + 2\ OH^-(aq)$$

The **overall** reaction is:

$$2\ Na^+(aq) + 2\ Cl^-(aq) + 2\ H_2O \rightarrow 2\ Na+(aq) + 2\ OH^-(aq) + Cl_2(g) + H_2(g)$$

Hence, an attempt is made to analyze and explore the options / scope for the present emission of GHG emission and its reduction by appropriate interventions".

### 6.2.4 Process Description

Three types of Electrolytic Cells namely Diaphragm, Mercury and Membrane Cells are in use for the above process. The first two, i.e. Diaphragm and Mercury Cells involve use of Asbestos and Mercury, which are pollutants. In the case of Membrane Cells, no pollutants are involved.

This Membrane Cell Technology is the process adopted in the unit using Bipolar Electrolysers. The main raw material is Raw Salt. The salt is dissolved with weak brine and recycled water to get a saturated brine solution at the Saturator. The Brine Solution contains impurities such as Ca, Mg, $SO_4$ and insoluble impurities. The impurities are precipitated in the Reactor, settled in a Clarifier, filtered in Filter Press, packed and this non-hazardous solid waste is sent to our Salt field for embankment of saltpan bunds. Clarifier overflow brine is filtered in Anthracite Filter and Ultra Filter to bring down the impurity in brine to ppm level.

For the Membrane Cell process, the requirement is ultra-pure brine (with Ca, Mg, put together less than 20 ppb). Hence, the filtered brine is passed through Ion Exchange Resin

Column. The Brine coming out of the Ion Exchange Resin Column will have a total hardness of less than 33 ppb. This brine is sent to Electrolysers. Brine is fed in the Anodic compartment and weak Caustic is circulated in the cathodic compartment of Electrolysers. Chlorine and the depleted brine flows out of the anodic compartment. Caustic and hydrogen flows from the cathodic compartment.

Chlorine is separated from Depleted Brine (weak Brine) from Electrolysers. The heat of the Chlorine is removed by Brine and then it is cooled, washed / filtered. A portion of chlorine is taken to Hydrochloric Acid Plant and burnt along with Hydrogen in a furnace to produce Hydrochloric Acid and the remaining Chlorine is chilled, dried, compressed and liquefied. The Liquid Chlorine at -7°C is taken to Chlorine storage Tanks. To ensure safe operation, these tanks are provided with double safety valves with rupture disc with level and weight indicators, pressure and level alarms.

The Depleted Brine is stripped off Chlorine by air/ vacuum system, which removes the residual Chlorine, and the same is sent to Sodium Hypochlorite plant for absorption in Caustic Soda and rendering it air free of chlorine, before letting out to the atmosphere through the stack. Chlorine stripped weak Brine is sent back to the Saturator.

Apart of the Caustic coming out of the Cells is recycled after dilution with Demineralized water (DM) water and the balance is taken as product. Some of the hot product caustic is sent to Concentration Plant where it is heated by a Thermic Fluid heater using Hydrogen / Furnace Oil as fuel to concentrate product Caustic from 33% to 48%. Hydrogen is sent for bottling, for HCL production and for heating Thermic Fluid as fuel.

As a redundancy measure, Sodium Hypo plant is connected with Uninterrupted Power Supply (UPS) system to ensure the continuous running of pump and blower even in case of power failure and failure of DG set (redundancy), thus eliminating the failure of absorption. Instruments like pH / Redox meters and conductivity meters are installed for the reliability of scrubbing unit.

Liquid effluent generated during hand washing and maintenance is sent to Effluent Treatment Plant (ETP) for neutralization of pH and settling for further discharge to marine outfall.

### 6.2.5 Membrane technology

In the 1970s, the development of ion-exchange membranes enabled a new technology to produce chlorine: the membrane electrolysis process. The first ion exchange membranes were developed at the beginning of the 1970s by Du Pont (Nafion), followed by Asahi Glass (Flemion) which installed the first industrial membrane plant in Japan in 1975 due to the pressure of Japanese environmental regulations. Non-chlor-alkali related mercury pollution in Minamata drove the authorities to prohibit all mercury processes and Japan was the first country to install the membrane process on a massive scale in the mid-1980s.

"Since 1987, practically 100% of the new chlor-alkali plants worldwide apply the membrane process. The replacement of existing mercury and diaphragm cell capacity with membrane cells is taking place at a much slower rate because of the long lifetime of the former and because of the high capital costs of replacement. In this process, the anode and cathode are separated by a water-impermeable ion-conducting membrane. Brine solution flows through the anode compartment where chloride ions are oxidized to chlorine gas. The sodium ions migrate through the membrane to the cathode compartment, which contains flowing caustic soda solution. The demineralized water added to the catholyte circuit is hydrolyzed, releasing hydrogen gas and hydroxide ions. The sodium and hydroxide ions combine to produce caustic soda, which is typically brought to a concentration of 32-35% by reticulation, the solution before it is discharged from the cell" (IPCC 2010).

The membrane prevents the migration of chloride ions from the anode compartment to the cathode compartment; therefore, the caustic soda solution produced does not contain salt as in the diaphragm cell process. Depleted brine is discharged from the anode compartment and resaturated with salt. If needed, to reach a concentration of 50% caustic soda, the caustic liquor produced has to be concentrated by evaporation (using steam).

"The cathode material used in membrane cells is either stainless steel or nickel. The cathodes are often coated with a catalyst that is more stable than the substrate and that increases surface area and reduces over-voltage. Coating materials include Ni-S, Ni-Al, and Ni-NiO mixtures, as well as mixtures of nickel and platinum group metals. The anodes used are metal.

The membranes used in the chlor-alkali industry are commonly made of perfluorinated polymers. The membranes may have from one up to three layers, but generally consist of two layers. One of these layers consists of per-fluorinated polymer with substituted carboxylic groups and is adjacent to the cathodic side. The other layer consists of perfluorinated polymer with substituted sulphonic groups and is adjacent to the anodic side. To give the membrane mechanical strength, the membrane is generally reinforced with PTFE fibers. The membranes must remain stable while being exposed to chlorine on one side and a strong caustic solution on the other. The general economic lifetime of Chlor-Alkali membranes is approximately three years, but ranges between 2-5 years" (Euro Chlor report, 1997).

"Whereas the conventional brine treatment system in a Chlor-Alkali industry comprises of media filter and pre-coat filters in order to sufficiently reduce the suspension matter and protect the ion-exchange resin from damage" (Hoang *et al.*,2012).

Membrane cells have the advantage of producing a very pure caustic soda solution and of using less electricity than the other processes. Disadvantages of the membrane process are that the caustic soda produced may need to be evaporated to increase concentration and, for some applications, the chlorine gas produced needs to be processed to remove oxygen. Furthermore, the brine entering a membrane cell must be of a very high purity, which often requires costly additional purification steps prior to electrolysis.

Membrane cells can be configured either as monopolar or bipolar. As in the case of the diaphragm cell process, the bipolar cells have less voltage loss between the cells than the monopolar cells. However, the number of cells connected together in the same circuit is limited.

For membrane process, essentially high purity brine is required as the unwanted impurities ($Ca^{2+}$, $Mg^{2+}$ and $SO^{4-}$ ) deteriorate membrane performance, therefore, purification of brine, settling, filtration, acidification, de-chlorination are auxiliary processes for the quality and efficient production of such alkalis. Brine purification helps to precipitate most of the raw salt contained impurities.

Ultrafiltration technology is best explained as a membrane technology capable of rejecting particles of size of micro level. The ultrafiltration membrane for brine application has a pore size of 0.05 microns. The ultrafiltration system replaces pre-coated filters thus providing the most efficient system in terms of particle removal, power consumption and maintenance. In the process of brine treatment, the impurities in the salt such as calcium and magnesium are transformed to insoluble impurities. Majority of the precipitated impurities will settle at the clarifier and remaining escapes in the overflow. The suspended solids in the brine overflow are trapped due to elimination of alpha-cellulose in a series of filter to render the brine suitable for electrolysis. Alpha cellulose is an excellent particle for retention, so that the brine quality not gathers specification of the amalgam cell but also in membrane electrolyzer.

### 6.2.6 Brine purification

The brine purification process consists of a primary system for mercury and diaphragm technologies and an additional secondary system for membrane technology. This operation is needed to avoid any undesirable components (sulphate anions, cations of Ca, Mg, Ba and metals) that can affect the electrolytic process.

In the above said brine purification system, because of energy conservation, it has resulted in 13.2 MT $CO_2$e. Further, in the process of elimination of alpha cellulose, resulted in savings 73.3MT $CO_2$e per annum during the year 2008-2014.

### 6.2.7 Proposed Production of soda ash from flue gas

"Soda ash or sodium carbonate is one of the raw materials in chlor-alkali industry, which is used for the treatment of brine. Impurities such as calcium salts are precipitated out by the addition of sodium carbonate. A technique for the production of sodium carbonate from the flue gas emanating from Thermic Fluid heater stack was developed and optimized. The sodium carbonate thus produced is being used for the treatment of brine thus eliminating the purchase of soda ash from the market" (Ullmann's Encyclopedia1996, Research and Markets 2011). Every year, it is estimated that 600 Mt of $CO_2$e will be reduced once the project is implemented which is expected after taking all necessary approvals.

#### 6.2.7.1 Membrane technology for sulphate removal and recovery of sodium sulphate – Elimination of chemicals

The unit has been in the forefront of water conservation in the chlor-alkali sector. Its specific water consumption is the lowest among the chlor-alkali sector in India. Various innovative technologies and schemes have been in practice for the reduction and recycle of wastewater. An innovative technique like conventional mercury technology, recycling and conservation of water and elimination of barium salts for manufacturing has resulted in savings of 71540cum of water/ annum. This resulted in the reduction of 121.6 MT $CO_2$e / annum.

### 6.2.8 Biodiversity and carbon sequestration potential of plantation activities of Carbon stock

Chlor-alkali industry campus is spread over 37 acres. The green belt covering area of 25 acres has grass lawns, flowering plant, ornamental plants, shrub and trees. The total number of trees is 37,000. An attempt was made to estimate the carbon sink and other co-benefits including the biodiversity from the plantation activities carried out by the unit since its inception. The carbon stock from the plantation activities with in the unit premises is estimated at 6625MT $CO_2$e. The CERs generated annually through plantation activities within the premises was 390 MT $CO_2$e.

### 6.2.9 Water Conservation, Recycling and Rainwater harvesting

Rivers, lakes and ground water are all secondary sources of water. At present, the unit depended on any one of these sources. Puducherry gets a rainfall of 1.392.2 mm on an average and the number of rainy days in the city range from 45-50 days in a year. The unit has carried out an ambitious programme on rainwater harvesting and every year, sizable quantity of water is being charged into the aquifer. In 2015, a total amount of 103089 (cu.m) of rainwater has harvested in this techniques.

### 6.2.10 Hydrochloric Acid Plant with Heat Recovery System

Hydrochloric acid plant, wherein the hydrogen and chlorine, upon combustion, form HCl gas which is absorbed in water to produce dilute hydrochloric acid. It has been proven very economical and reliable operation. In this process, the chlorine is produced as a by-product or where hydrogen chloride or hydrochloric acid is required.

Considerable heat is generated during the process, which is normally absorbed by the cooling water. In this plant, about 50% heat is converted to steam, which is used in the caustic concentration plant. This improved process aids in energy recovery, reduced water consumption and reduction in the carbon footprint.

- GHG reduction equivalent to the reduction in energy consumption: 4600 MT$CO_2$E.
- GHG reduction equivalent to the reduction in water consumption: 21.42 MT$CO_2$E.

### 6.2.11 Conclusion

All industries are moving towards more efficient and low or zero emission processes due to economic benefit, regulation, and concern for health and the environment. New materials and process technologies are playing an increasing role in emission treatment and byproduct utilization. This study examined the GHG reduction and sustainable solutions in this chemical industry (Chlor-alkali industry) in Puducherry region. The result shows that, the Membrane technology is an environment friendly and energy efficient technology process used to treat wastewater and process streams. The GHG reduction made in the elimination of alpha cellulose 73.3MT $CO_2$and the greenhouse reduction for the last 5 years is 121.6 MT $CO_2$e / annum. The unit has carried out rainwater harvesting system for ground water recharge. Therefore, the study reveals that, this chemical industry could achieve the GHG reduction and sustainable solutions by using various advanced, innovative technologies and also by implementing cleaner processes and pollution prevention measures which yielded both economic and environmental benefits.

## 6.3 Case Study-2- Personal Care Product Unit

### 6.3.1 Introduction

"Carbon dioxide is the most important and abundant gas among all GHGs which have the highest contribution in global warming phenomenon. Thus, finding promising approaches to mitigate $CO_2$ emissions is the priority of studies to subside the threat of climate change. Improving energy efficiency, modernizing production and changing consumption patterns would have a large impact on future GHG emissions" (Kotov, 2002).

The low-temperature detergents case describes the combined $CO_2$ impact of modern surfactants and laundry enzymes. Both components of modern washing agents have contributed to the effect that modern washing leads to excellent results at much lower temperatures than in the past and therefore reduces energy consumption and $CO_2$ emissions. Compared to soap-based systems for which the washing temperature is typically 60°C or higher, the temperature can be reduced to 30°C if modern washing agents are applied. This reduces the energy demand per washing cycle from ~1 kWh to ~0.6 kWh. Considering the $CO_2$ intensity of power, this translates into $CO_2$ savings of 321 $gCO_2$/ load.

Apart from the in-use phase, modern detergents also have a lower $CO_2$ footprint than soaps. For modern detergent systems, life cycle emissions of 65 $gCO_2$/dosing were estimated, compared to 309 $gCO_2$/dosing for soap. This difference is largely driven by the fact that modern detergents are more efficient and require only one third of the amount of soap.

"Worldwide, modern detergents are applied in about 158 billion washing cycles every year. There are, however, regions where washing laundry at room temperature is a common practice irrespective of the use of soap or modern detergents. Taking such regional differences into account, the use of modern washing agents leads to a global net $CO_2$ abatement of ~80 $MtCO_2$per year" (ICCA 2009)

"In recent years, climate policy analysts have explored the links between consumption device and greenhouse gases (GHGs) by developing methods to estimate life-cycle emanation connected with different categories of consumption, e.g., a carbon 'footprint' or a 'consumption-based' GHG inventory" (Minx *et al.* 2009; Dawkins *et al.* 2010; Wiedmann2008; Jones and Kammen 2011; Weber *et al.* 2010; Davis and Caldeira 2010; Peters *et al.*2011). "Implicit in many of the studies is the notion that shifts in consumption patterns might escort to reductions in global emissions. Supplementary time, analysts have pointed out limitations in production-based GHG accounting. One prominent critique is that it may give a misleading impression of national progress in curbing GHG emissions, as decreases (or increases) in national emissions may be due to the shift in activities (such as manufacturing) to (or from) another country, without decreasing (or increasing) total global emissions" (Wiedmann 2008; Peters and Hertwich 2008; Peters *et al.*2011; Carbon Trust 2011). "As an alternative, several authors have suggested utilization based emissions accounting, which includes the emissions embodied in trade and insist therefore, in principle, account for such carbon leakage effects, whether due to climate policy or instead to broader economic trends" (Peters 2008).

"Consumption-based accounting can also emphasize the GHGs associated with different product types, ranging from food and libation, to clothing and appliances. Highlighting the emissions associated with products can help erect sustain for new opportunities to reduce global GHGs, such as consuming fewer high-GHG stuff and other strategies collectively referred to as sustainable consumption" (Oregon DEQ, 2007).

At the level of the entire globe, consumption and production-based emissions would be identical. However, for most countries, the difference between production- and consumption-based emissions is significant.

The greenhouse gases inventorisation done by the Government of Puducherry in 2013 has revealed that 3.46 million tonnes of Carbon dioxide equivalents are emitted annually. This is 2.7 tonnes equivalent per capita emissions based on the 2011 Census. As per the greenhouse gases inventorisation report, industrial sector contributes to 2.35 million tonnes $COs_2$ equivalent per annum. This is almost 78% of the total GHG emission from industrial sector. The personal care product, industry was considered for selection because of the following reasons.

### 6.3.2 Personal Care product Unit

The industry had presence in India for more than 75 years. They have 40 manufacturing locations across India etc., the Unit selected for the case study started its operation in Puducherry in 1995. A number of products are manufactured namely, Non Soap Detergent Personal Wash bars (PW), Distilled Fatty acid (DFA), powder plant, VIM bar polycot, powder package and Nominal Mineral Bar plant. The unit employed about 230 technical and 215 non-technical staff besides about 210 contractual staff.

***Table 6.2. Plant name and capacity (tonnes/annum)***

| S.No | Name of the plant | Capacity Tonnes/annum |
|---|---|---|
| 1 | Hydro Chloric acid plant | 1,10,000 |
| 2 | PW plant | 5000 |
| 3 | DFA plant | 35000 |

As on 2014, the total volume of installed capacity of all the products is to the tune of 1,33,340 Metric Tonne per annum.

This study aims to assess the efforts taken at the unit to transforming lives by empowering communities for sustainable future. The initiatives include Water conservation, waste minimization, sustainable sourcing, gender ratio in work place, enhancing women's life skills, introduction and implementation of successful models.

### 6.3.3 Water sustainability project of pond renovation

A detailed long-term plan was conceived to cover 30 villages and 3000 farmers, targeting 30 ponds in all (Fig. 6.6).

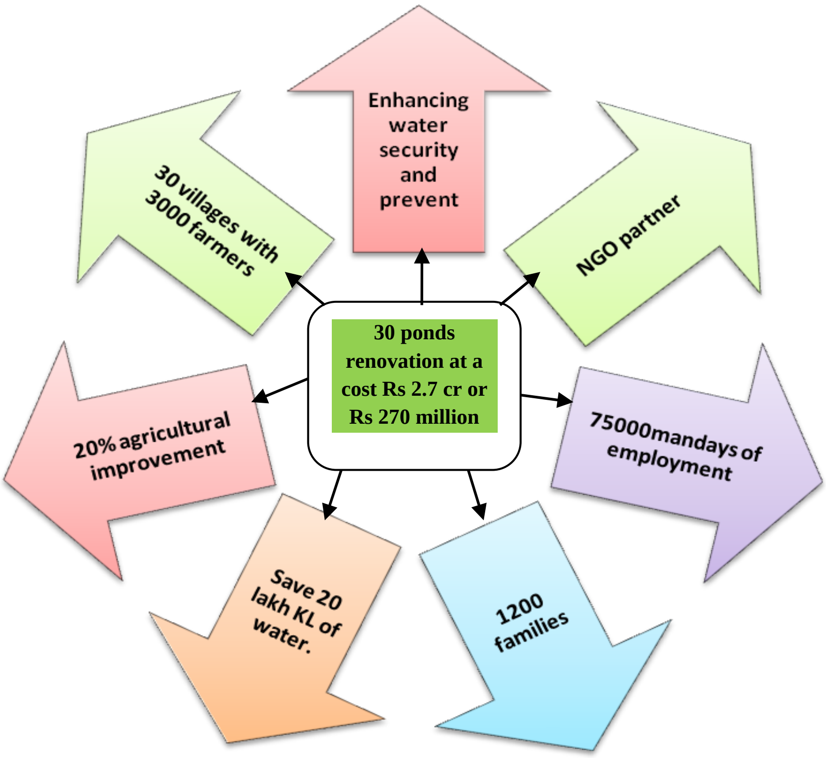


***Figure 6.1. Approach of water sustainability project of pond renovation***

### 6.3.4 At community level in the vicinity

In this study, a careful investigation was done to analyze and quantify the GHG emissions due to the interventions not only the increase was about 39%, but the quality of water was also restored, ensuring water for cattle and human beings for 4 to 6 months of the year. More importantly, it provided irrigation security to the largely farming community. During the year 2008-09, eight ponds were filled with debris and solid wastes from the surrounding areas, which has significantly reduced their storage capacity. Even the little water collected was impure and was renovated. The details of the ponds and water collection are given in *Table 6.3*.

***Table 6.3. Renovation of ponds and storm water collection in Pondicherry region***

| Sl.No. | Name of the Pond | Present water storage in $m^3$ (after renovation) | Additional water storage created in $m^3$ | Net increase (%) | Water availability in months |
|---|---|---|---|---|---|
| 1. | Alakkaraikuttai | 2025.24 | 525.24 | 74.1 | 4 |
| 2. | KondanKoilkulam | 2840.00 | - | 100 | 4 |
| 3. | Palakuttai | 2481.00 | 881.00 | 76.58 | 3 |
| 4. | Marikulam | 4418.75 | 2768.75 | 37.34 | 3 |
| 5. | Kottaikulam | 6840.00 | 3040.00 | 55.55 | 5 |
| 6. | Salakuttai | 1080.00 | 810.00 | 25 | 3 |
| 7. | Ooralkulam | 3753.75 | 1253.75 | 66.60 | 6 |
| 8. | Odaikulam | 1662.50 | 512.50 | 69.17 | 4 |
| | Total | **25101.24** | **9791.24** | | **-** |
| | | | **Average** | | **4** |

### At the Industry Level

The industry has taken a number of initiatives, since 2010 and reduced water consumption per tonne of product manufactured. A careful evaluation of their water consumption during the period from 2010-15 has revealed that the annually average water consumption per tonne of product manufactured has reduced from 0 .845 kilo liter per tonne in 2010 to 0.606 kilo liter in 2015.

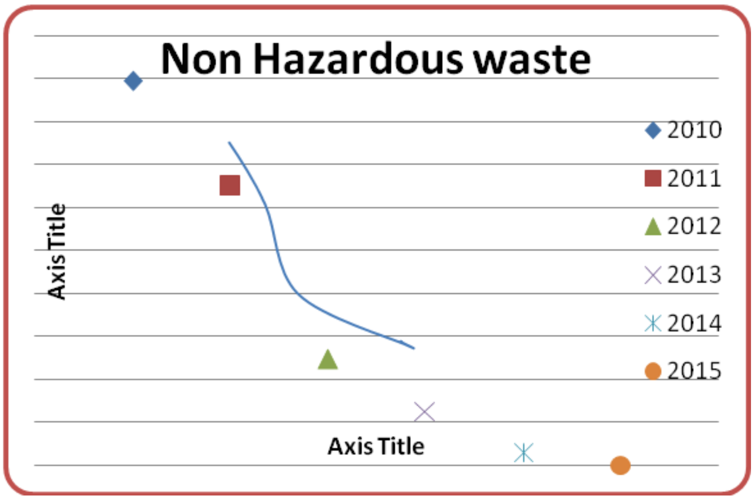


*Figure 6.2. Trend in the water consumption per tonne of product manufactured*

**Water Conservation and Reuse**

During the study period, a number of activities were critically looked into and policy interventions had been delineated and discussed at various levels for water reduction in the plant they include De-Mineralized plant-regenerated water. All water dispensing with a tap effective control of pipes leakage RO backwash water, reuse of stream condensate etc.

*Table 6.4. Reveals the extent of water reduction due to policy interventions*

| Sl.No. | Activity | Intervention | Savings |
|---|---|---|---|
| 1. | DM plant regeneration wastewater | Reuse for boiler ash cooling | 3 KLD |
| 2. | Normal water taps in canteen wash room and plant hydrant stations | Push type taps | 50% of water consumption reduction |
| 3. | Fire Hydrant pipe leakage underground hydrant lands | Rerouted above the ground | Resulted in water waste. |
| 4. | RO back wash water | Reused in toilet flush | 12 KLD saving |
| 5. | Stream condensate from plants | Recycling for cooling tower make up and boiler feed | 16500 KL per annum |
| 6. | DO wastes let off in the drain? | RO regenerator recycled into boiler feed water and feed for second stage regenerator is used with cooler tower/gardening | Reuse of 24000 KLD per annum |

**Energy and $CO_2$ trend Graph**

**Energy Trend in the last 5 years**

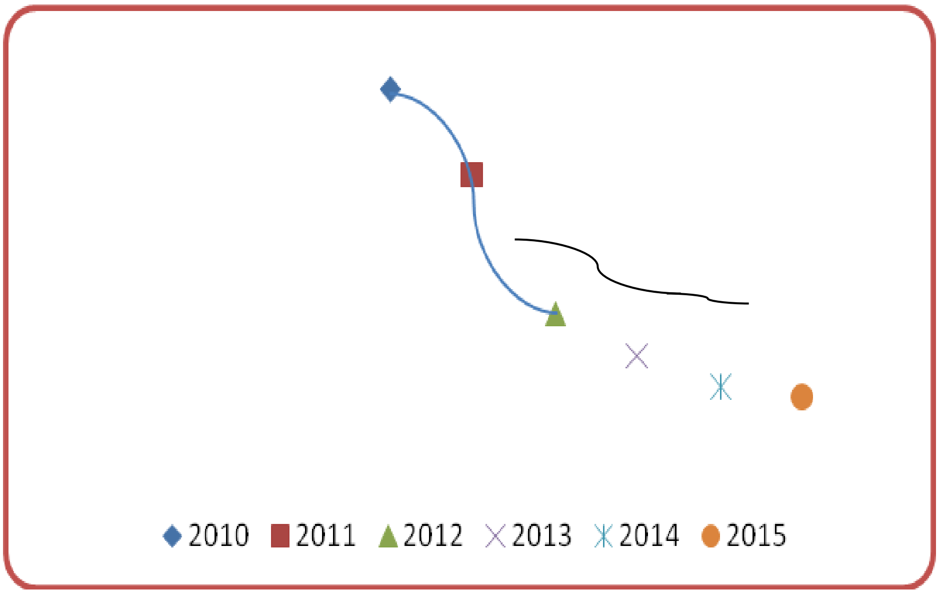


*Figure 6.3. Energy Trend in the last 5 years*

The energy consumption for the last 5 years from 2010 was critically analyzed. It has revealed that from 2010 -2015, the industry had achieved 35% specific energy reduction. In 2010, the industry was consuming 1.581 GJ/Ton, which has come down to 1.028 GJ/Ton in 2015. This is a unique and significant achievement because of the fact that certain product expansion and activity as taken place during this period.

**$CO_2$TREND reduction**

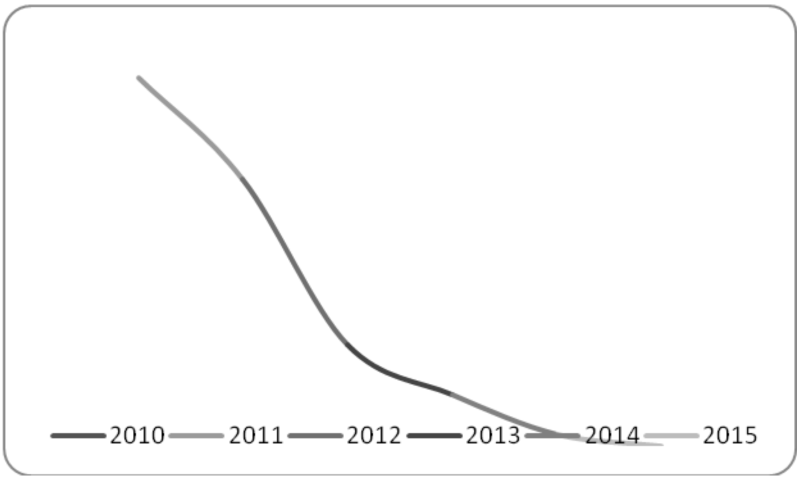


*Figure 6.4. $CO_2$ Trend reduction*

The energy consumption reduction is directly transferred into 36% $CO_2$ emission reduction during the same period. Critical analysis of the specific emission trend has revealed that 162.38 kg /Ton in 2010, which over a period has been reduced to 104.36 kg/Ton in 2015.

**Non-hazardous waste**

The industry produced non-hazardous waste in the form of boiler ash, laminate and corrugated boxes, plastic drums, canes, metal scrap, wood scrap HDPE, poly bags, e-waste etc. In 2010, it was observed that the unit was generating 1.792 KG/Ton of product manufactured. The Fig-6.10 shows the trend in reduction of non-hazardous wastes in the unit in the last five years.

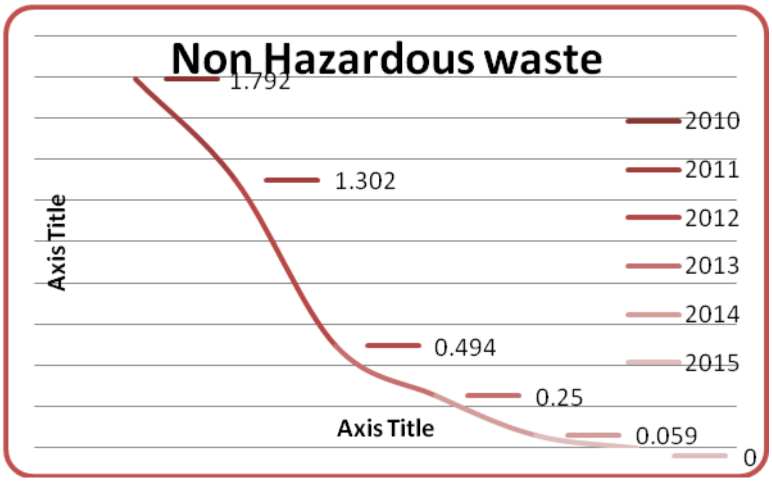


*Figure 6.5. Non-hazardous waste disposed trend*

*Table 6.5. Summary of the achievements with GHG reduction*

| S.No | Description | Savings | UOM |
|---|---|---|---|
| 1 | Water Reuse | 24,000 | KL/Annum |
| 2 | Water Recycle | 16,500 | KL/Annum |
| 3 | Water Conservation through wastage reduction | 4,500 | KL/Annum |
| 4 | Rain water recharge capacity – In house | 114 | KLD |
| 5 | Power saving through energy conservation projects | 31,13,734 | KW/Annum |
| 6 | $CO_2$ reduction | 11,884 | TPA |
| 7 | Green Energy generation | 4,000 | KW/Annum |

### 6.3.5 Conclusion

The unit proposes to use low water raw materials and evolving new formula, which will require less process water. This resulting in reduction of 4000 GH of energy consumption and 970 tons of $CO_2$ emission reduction per month. This is expected to reduce 64 KLD of water consumption with the assessment of all the sustainable initiatives taken by the unit. It had resulted in significant amount of energy consumption of power and thereby reduction of greenhouse gas emission directly, besides water conservation measures, rainwater harvesting and pond renovation undertaken by the industry has proved adequately that the unit is trying hard towards achieving the goal of development through environment sustainability.

## 6.4 Case Study- 3 - Tyre Manufacturing Unit

### 6.4.1 Introduction

"Emissions from tyre manufacturing industry are one of the major contributors in global warming and climate change" (India's Greenhouse Gas Emissions 2007). A large automobile tyre-manufacturing unit is functioning in Puducherry since 1998. The unit manufactures two-wheeler and four wheeler automobile tyres including scooter, motor cycle, Passenger & truck radials and very large OTR tyres. Automotive passenger car radial tyres and truck radial tyres are manufactured. The unit is situated in about 77 acres with a built up area more than 1.0 lakh sq m of land. The unit has employed about 2200 persons directly and 1000 persons indirectly. The facility can manufacture 15,300 automotive tyre radials per day. The unit is certified for OHSAS and EMS and ISO / TS 16941. It supplies to many Original Equipment Manufacturers in the automobile industry across the globe.

An in-depth analysis of the company reveals that the unit is committed to maintain healthy, safe & environmentally responsible work conditions in its manufacturing plants. To achieve this goal, the unit has taken the following initiatives:

- Minimising the impacts of the manufacturing activities on the employees' health, safety, environment and society.
- Complying with all applicable legal, statutory, regulatory and customer specific requirements.
- Optimising the consumption of resources.
- Continuous monitoring and upgrading of machinery and technology.
- Continuously monitoring and improving work conditions and performance.
- Periodical training of all employees to perform their activities efficiently.

To achieve these, the unit strives to adopt the latest technology for manufacturing, R&D with world-class system. In the present study, efforts have been made to analyze the steps involved in the manufacturing of tyres, pattern of consumption of resources, various initiatives taken by the unit to reduce energy, resource consumption and resultant GHG reduction.

### 6.4.2 Manufacturing process

In the unit, Natural rubber is the basic elastomeric used in tyre making. Styrene-butadiene co-polymer (SBR) is a synthetic rubber which is often substituted in part for natural rubber based on the comparative raw materials cost. Polybutadienes used in combination with other rubbers because of its low heat-build up properties. Halo-butyl rubber is used for the tubeless inner liner compounds, because of its low air permeability. The halogen atoms provide a bond with the carcass compounds, which are mainly natural rubber. Carbon black forms a high percentage of the rubber compound. This gives reinforcement and abrasion resistance. Silica is used together with

carbon black in high performance tyres, as low heat buildup reinforcement. Sulphur crosslinks the rubber molecules in the vulcanization process. Vulcanizing accelerators are complex organic compounds that speed up the vulcanization. Activators assist the vulcanization. The main component is zinc oxide. Antioxidants prevent sidewall cracking due to the action of sunlight and ozone.

**Compounding and Mixing**

Incorporating carbon black and various chemicals into rubber in a heavy-duty machine called Banbury mixer does this. Banbury mixer consists of an enclosed chamber with two rotating rotors inside which sheer rubber and the material against the inside the chamber. The rotors are rotated by high power DC motor. The rubber and the materials are loaded into the chamber with the help of an automatic feeding system. The chamber temperature is controlled using tempered water. The mixed rubber compound is sheeted out from a two-roll mill and is used in the subsequent process.

**Fabric treatment**

The strength required for the tyre is provided by fabric reinforcement. Generally, Nylon, Rayon and Polyester are used for the same. In steel radial Tyres, steel cords are used as reinforcement. The textile fabric reinforcement used is to be chemically treated for bonding the same with rubber, which is very essential for the life of tyre. The fabric is then hot stretched and thermally stabilized so that the tyre maintains its dimensional parameters. These two treatments are done in dip unit. The fabric is first jet through an adhesive emulsion and is dried, stretched at high temperature and subsequently stabilized.

**Fabric calendaring**

The treated fabric/steel cords are then embedded in rubber compound in a process called calendaring. The processed fabric/steel-cords are sandwiched between two thin films of rubber compound in a multi roll calendar. The coated fabric is subsequently cooled and wound in liners for further processing.

**Preparation of tread and side wall**

Tread is the patterned rubber mass on the circumference of the tyre, which makes contact with the road surface. It is the wearing portion of the tyre and hence is the heaviest component in the tyre assembly. A process called extrusion manufactures this component. The rubber compound after warming on tow roll mills is forced through a dye with the help of heavy-duty screw extruder to get a pre-designed shape. This tread is then cooled and cut to the required size for the tyre. Sidewall is a thin sheet of rubber on both sides of the tyre and protects the textile reinforcement from external damages, degrading agents etc. This compound is made in a similar way as of tread.

**Bead**

The fabric reinforcement in the Tyre is tied around two steel rings on either side of the tyre. These steel rings called the beads, forms the rigid portion of the tyre, which seats on the rims of the vehicle. The steel rings are made of steel wires coated with rubber compounds and wound on forms of required diameter. The rubber coating is done with the help of extruder.

**Fabric**

The continuous length calendared fabric is cut to design the angle and width for the respective Tyre called plies on a bias cutter and is then spliced into a continuous sheet. Additional layer of rubber film called squeegee is applied on this sheet.

**Assembling of green tyres**

Various compound mentioned above viz. coated fabric piles, tread, sidewall, beads etc. are assembled to a Green Tyre on an assembly machine. This machine essentially has a cylindrical shaped collapsible drum mounted on a rotating shaft. The coated fabric in the required numbers of layers is serviced on to this drum with the help of a servicer. Beads are applied on to the coated plies from the sides of the drum and the same is locked in position by turning the fabric around it.

After requisite number of fabric layers is assembled on the drum the tread is applied and consolidated followed by sidewall. The Green Tyre so formed is removed by collapsing the drum.

**Molding Tyre**

The assembled Green Tyre, after suitable treatment, is molded in heavy-duty tyre curing presses. The process essentially consists of a fixed bottom frame, which holds the bottom half of the mold and a movable top frame holding the top half of the mold. At the centre of the bottom mold, an inflatable barrel shaped rubber bladder, with suitable arrangement for lifting and lowering the same is provided. The molding process essentially consists of pre-shaping the cylindrical shaped green tyre into a toroidal shape by placing over the bladder and administering steam into the bladder. The two half of the mold are then closed over the green tyre and locked in with high closing force. The green tyre is then molded against molds by administering high-pressure steam and hot water into the bladder. Tyre is heated both from inside as well as from outside to harden (care) the rubber compounds. Tyre is removed by opening the mold and releasing the bladder and is subsequently cooled under pressure condition on post cure inflators. The tyre so made with suitable finishing is ready for use.

### 6.4.3 Inspection & Testing

**Primary stage inspection:**

Tyres are inspected by human eyes for numerous visual defects such as incomplete mold fill, exposed cords, blisters, blemishes, and others.

**Final stage inspection:**

Tyre uniformity measurement is a test where the tyre is automatically mounted on wheel halves, inflated, run against a simulated road surface, and measured for force variation. Tyre balance measurement is a test where the tyre is automatically placed on wheel halves, rotated at a high speed and measured for imbalance, uniformity and balancing. After final inspection, the tyres are sent to the warehouse.

### 6.4.4 Innovation in the manufacturing

The unit has introduced “Silica based passenger car radial tyres in selected segments called as Green Tyres”. The gains are:

- 35% reduction in carbon black consumption per tyre.
- 10% reduction in fuel consumption.
- reduction in rolling resistance.
- Silica is more compatible soil than carbon black.

All these have reduced air pollution on roads, decreased wear and tear of the tyre, and indirectly decreased the fuel consumption per km travelled. In other words, has resulted in reducing GHG emissions.

**Innovations at the Industry Level**

(i) Power saving through introduction of alternative energy source.
(ii) Preface of energy saving appliance.
(iii) Turbo ventilation by natural air draft of about 4.5 lakhs sq.ft.
(iv) Setting up of solar panel.
(v) LED street lights, to reduce power consumption including traffic lamps

During the period 2008-2009 to 2013-2014, a remarkable reduction of fuel consumption in liters per MT of the product manufactured has been achieved. From 270 MT the unit has reduced the fuel consumption to 160 MT/lit during the period.

Similarly, the unit has consistently attempted to reduce power consumption/ MT of product manufactured by energy conservation measures. During the period, 2009-10 to 2012-13, the unit has achieved reduction from 1304 units/ MT in 2009-10 to 1210 units/ MT in the year 2012-13. This has resulted in, 11 % reduction of power consumption in units per tonne of product manufactured. During the same period, the unit has made improvement through automotive power factor control. In the year 2010-11, the unit had 0.95-power factor, which over the year has improved to 0.98 in the year 2013-14. The sum of the projects implemented for power reduction has been studied. The unit has done a number of green belt initiatives the total landscaping had increased to 2.00 lakhs sq.ft. The number of saplings increased to about 2200 in 2015.

In this study, besides quantification of these initiatives an attempt has been made to analyze, greenhouse gas inventorisation from various sources. The sources include scope 1, 2 and 3 emissions.

- Scope 1 emissions are direct emissions, which result from the activities within the organization control. These include fuel consumption for process, company vehicles transportation process emission, fugitive emission.

- Scope 2 emission includes indirect emission from electricity heat or stream, which is purchased and used. Scope 3 emissions is an optional reporting category that includes all other indirect emissions viz. transport raw material supply, business for product, commuting, waste disposal and for the production of purchased materials.

A careful attempt and close evaluation of records scrutinized and verified revealed the following:

**For the year 2009-2010**

**Scope 1 emissions:**

- from boiler it has been estimated to be 25,740 tonnes of $CO_2$ equivalent.
- From DG set 10,903 tonnes of $CO_2$ equivalent.
- Company vehicle 220 tonnes of $CO_2$ equivalent.

Total 36,863 tonnes of $CO_2$ equivalents.

**Scope 2 emission** included electricity purchased 22,777 tonnes of $CO_2$ equivalent.

***Table 6.6. Scope three emissions***

| **Sl. No** | **Source** | **Tonnes of $CO_2$ equivalent** | **% of $CO_2$ equivalent** |
|---|---|---|---|
| 1 | Daily commuting transportation | 485 | 4.85 |
| 2 | Business travel | 2 | 0.02 |
| 3 | Raw material | 1129 | 11.29 |
| 4 | Product delivery | 10182 | 101.82 |
| 5 | Waste disposal | 2 | 0.02 |
| | TOTAL | 11800 | 118.00 |

Grand total of 1, 2 & 3 is 71440 tonnes of $CO_2$ equivalent.

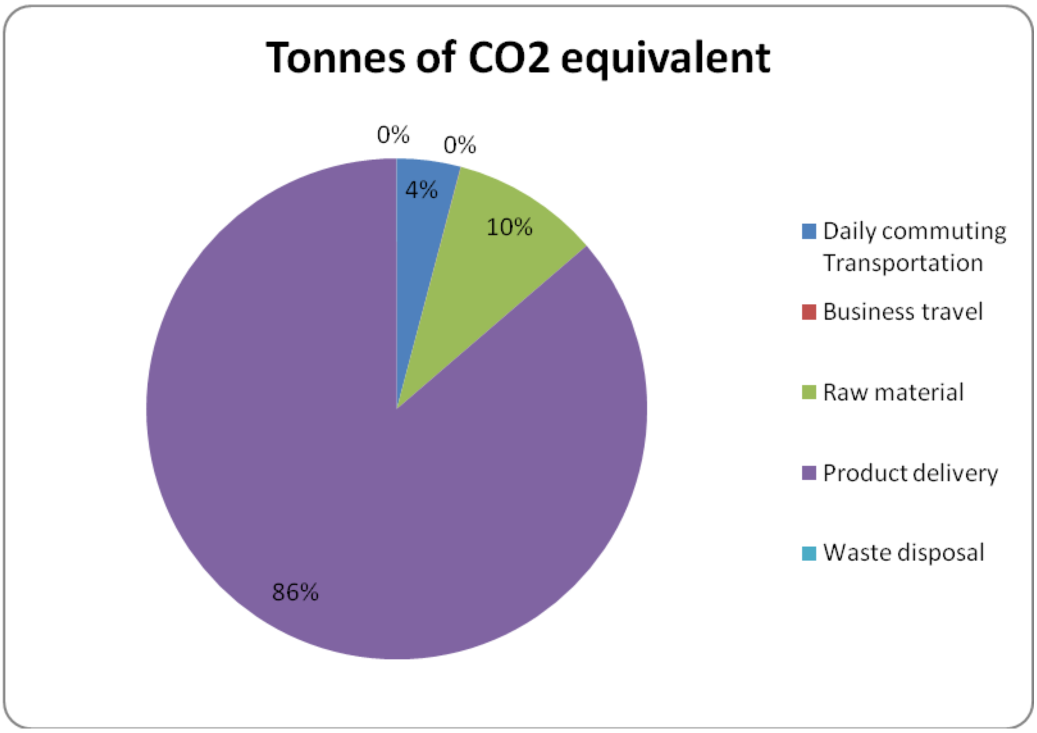


*Figure 6.6. $CO_2$ equivalent (Tonnes)*

*Table 6.7. Overall scope and tCO2 equivalent*

| Sl. no | Scope | $tCO_2$ equivalent |
|---|---|---|
| 1 | Scope 1 | 36,863 |
| 2 | Scope 2 | 22,777 |
| 3 | Scope 3 | 11800 |
| | Total | 71440 |

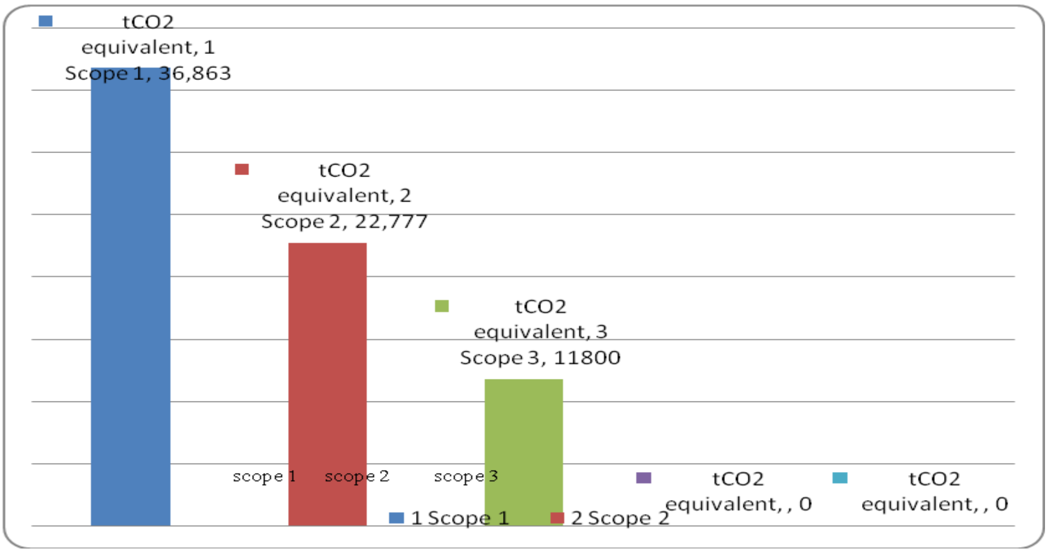


*Figure 6.7. Overall emission ($tCO_2$ equivalent)*

Besides, the unit had initiated a number of initiatives like biomass-fired boiler instead of furnace oil, solar street lighting instead sodium vapor lamps, provision solar water heaters in canteen, reduction in power consumption by preventing air leaks in the compressor. Change of calendar heating medium from steam to hot water, replacing of modified and new style gasket to all ball float trap.

### 6.4.5 Fuel conservation projects

The industry has mainly focused on fuel conservation projects from the year 2012-2015. There are 21 different projects has initiated in the unit. The detailed list of projects and FO saved are given below:

***Table 6.8. Fuel conservation projects and savings***

| Sl.no | Year | Fuel conservation projects | FO saving/ year-liters |
|---|---|---|---|
| 1 | 2012-2013 | 36” & 48” calendar heating medium changed from stream to hot water | 170100 |
| 2 | 2012-2013 | Deaerator makeup water storage tank changed from underground open sump to insulated 6 KL storage tank with level controller | 58800 |
| 3 | 2012-2013 | Optimizing the hot water recovery time to 0.3 min in light truck sizes to avoid hot water tank overflow | 38000 |
| 4 | 2012-2013 | Trap gasket modified and new style-54 type gasket changed to all the ball float trap to avoid trap passing due to gasket failure | 247500 |
| 5 | 2012-2013 | Per-heated air used for boiler combustion air- truck ( air from IR screw compressor to boiler) | 16200 |
| 6 | 2013-2014 | Top platen and platen cover insulation with ceramic paper 15 presses | 25632 |
| 7 | 2013-2014 | Tyre repair area condensate connected to cond. Ret. Header near bladder press | 56960 |
| 8 | 2013-2014 | Air preheating in boiler by utilizing the waste heat from screw compressor-passenger plant | 35600 |
| 9 | 2013-2014 | Auxiliary line trap replacement from ball float to venture type in all presses- truck plant | 78320 |
| 10 | 2013-2014 | Blow down venting steam recovery by installing heat exchanger in the blow down line | 35600 |
| 11 | 2013-2014 | 78” dome press insulation | 3560 |
| 12 | 2014-2015 | Temperature reduction from 165°C to 60°C in platen top and bottom side by insulating with ceramic wool fibre blanket-70 presses | 151886 |
| 13 | 2014-2015 | Curing blow down flash steam recovery by installing heat exchanger-passenger plant | 35550 |
| 14 | 2014-2015 | Curing blow down flash steam recovery by installing additional heat exchanger-passenger plant | 20900 |
| 15 | 2014-2015 | Providing O separator-3 Nos to improve furnace oil quality | 22200 |

| | | | |
|---|---|---|---|
| 16 | 2014-2015 | Water spray in curing BD line-10 nos | 5950 |
| 17 | 2014-2015 | Boiler feed water temperature increase from 106°C to 110°c by installing additional heat exchanger in curing BD-truck plant | 53200 |
| 18 | 2014-2015 | Trap condensate recovery improvement by providing 4" header in place of 3" | 17775 |
| 19 | 2014-2015 | Water spray in curing BD line- 15nos to recover flash steam | 15525 |
| 20 | 2014-2015 | Curing blow down tank over flow to be connected to heat exchanger circulation | 10450 |
| 21 | 2014-2015 | Installation of FO purifier-1 No | 13300 |

During 2012-2013, the unit has saved 247500/lit of FO in Trap gasket modified and new style-54 type gasket project. This particular project has changed the ball float trap to avoid trap passing due to gasket failure in the unit. All these initiatives had resulted in the reduction of the GHG emission from the unit. The *Table 6.9* summarizes the reduction of GHGs by implementing the above initiatives.

***Table 6.9. Total fuel saved & Total GHG emission reduction in $tCO_2$***

| **Sl. No** | **Year** | **Total fuel saved** | **Total GHG emission reduction in t $CO_2$** | **% $CO_2$ reduction** |
|---|---|---|---|---|
| 1 | 2012-2013 | 530600 | 1576 | 15.76 |
| 2 | 2013-2014 | 235672 | 700 | 7.00 |
| 3 | 2014-2015 | 346736 | 1030 | 10.30 |
| | Total | 11,13,008 | 3306 | 33.06 |

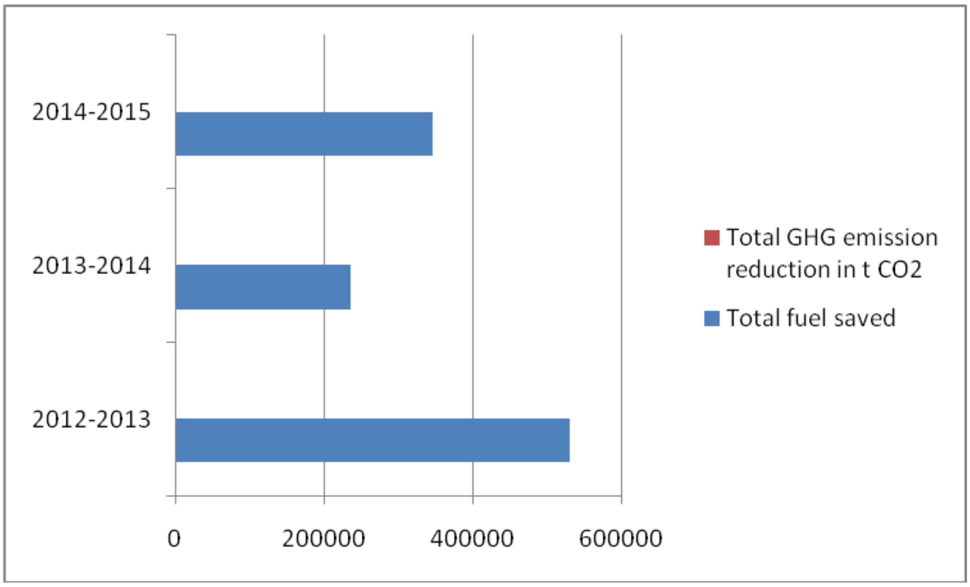


***Figure 6.8. Total fuel saved & Total GHG emission reduction in $tCO_2$***

In this table shows that, the unit has saved 11,13,008/lit of FO during 2012-2015 projects and total GHG emission reduction was 3,306 t $CO_2$ during 2012-15.

### 6.4.6 Energy conservation projects

The industry has attempt on power consumption in Energy conservation projects during the year 2012-2015. There are 48 different projects has initiated in the unit. The detailed list of power conservation projects are given below:

***Table 6.10. Power conservation projects and unit of power saved in a year***

| **Sl. no** | **Year** | **Power conservation projects** | **Units saving/ year-lit** |
|---|---|---|---|
| 1 | 2012-2013 | 400 watt high bay fitting replaced with 50 watt LED in Zone-1 | 120960 |
| 2 | 2012-2013 | Lights at truck curing aisle stopped with transparent sheet ( 16X4 No.s) | 184320 |
| 3 | 2012-2013 | Truck chiller efficiency improvement by relaying of the AHU duct at VMI II | 36000 |
| 4 | 2012-2013 | Street lighting converted to LED lighting | 72000 |
| 5 | 2012-2013 | Truck zone 3 trench conveyor stopped if no tyre available | 8640 |
| 6 | 2012-2013 | TUO auto sequence modified to stop 3 conveyors if machine is idle | 6480 |
| 7 | 2013-2014 | MB Banbury, stopping of mill motors, when current fall below the set value in MB Banbury | 4550 |
| 8 | 2013-2014 | FB Banbury, main motor idle stoppage | 41250 |
| 9 | 2013-2014 | MB Banbury, stopping of ‘K’ blower | 25000 |
| 10 | 2013-2014 | Banbury, 400 Wlight fitting to be replaced with 165 W LED lights | 39170 |
| 11 | 2013-2014 | Zone-1, to provide timer switch control system for shop floor lighting | 11900 |
| 12 | 2013-2014 | Zone-2, 150w low bay fitting replacement with 40w LED fittings in VM pass area | 180000 |
| 13 | 2013-2014 | CPP, shutting of fuel booster unit for furnace oil | 30000 |
| 14 | 2013-2014 | MB Banbury, Mill 1, 4 & 5 primary cooling pump motor size to be de-rated from 22 KW to 15KW due to conversion of 3 state to 2 stage pump | 6000 |
| 15 | 2013-2014 | MB Banbury, Mill 2 & 3 primary cooling pump motor size to be de-rated from 22 KW to 15KW due to conversion of 3 state to 2 stage pump | 12000 |
| 16 | 2013-2014 | 36” calendar cracker mill motor, pile up sensor to stop the mill, when stock is not in the rolls | 4500 |
| 17 | 2013-2014 | MB Banbury, 3 mill option selection from SCADA | 12000 |
| 18 | 2013-2014 | MB Banbury, stopping of group ABO fans when ABO conveyor is not running | 9000 |
| 19 | 2013-2014 | MB Banbury, providing VFD for dust collector motor to run at variable speed, as recommended for process | 26200 |
| 20 | 2013-2014 | K7 Banbury, providing VFD for dust collector motor to run at variable speed, as recommended for process | 30000 |
| 21 | 2013-2014 | 48” calendar cracker mill motor, pile up sensor to stop the mill, | 4500 |

| | | | |
|---|---|---|---|
| | | when stock is not in the rolls | |
| 22 | 2013-2014 | K7 Banbury, main motor stops along with its auxiliaries | 8500 |
| 23 | 2013-2014 | MB Banbury, 3 mill option selection from SCADA | 12000 |
| 24 | 2013-2014 | K7 Banbury, stopping of group ABO fans when ABO conveyor is not running | 4500 |
| 25 | 2013-2014 | Providing automatic switching system for shop floor lighting in Zone 1 | 10404 |
| 26 | 2013-2014 | 400W light fitting to be replaced with 90W LED lights in zone-3 area | 72000 |
| 27 | 2013-2014 | Provide transparent sheet in shipping area to avoid darkness and to stop the light | 42631 |
| 28 | 2013-2014 | Provide a closed loop drive control in hot water make up pump system in truck plan | 28800 |
| 29 | 2013-2014 | Provide auto stop system for avoid ideal running of trench conveyor motor | 3456 |
| 30 | 2014-2015 | In HVAC system, sprinkler pump speed is reduced from 2930 to 2300rpm | 54000 |
| 31 | 2014-2015 | Interlinking Mill-1, 3 & 5 cooling pumps in master batch banbury | 43200 |
| 32 | 2014-2015 | Additional chiller circulation pump 11 KW to be switched off after studying the pressure at all AHU inlets | 28800 |
| 33 | 2014-2015 | Zone -1 400W light fitting to be replaced with 200W induction lights | 151740 |
| 34 | 2014-2015 | Auto cleanout when DCV top and bottom chamber is empty and transport line pressure reaches 120 and below for 5min | 30000 |
| 35 | 2014-2015 | Triplex& Duplex extruder, switching off the TCU when machine not scheduled for production & with auto start | 68400 |
| 36 | 2014-2015 | FB/MBB/K7 Banbury, 400W light fitting replaced with 200W induction lights | 180000 |
| 37 | 2014-2015 | FB Banbury, providing VFD for compressor-5 motor to run at optimized speed | 36000 |
| 38 | 2014-2015 | FB Banbury, providing VFD for fume extractor motor to run at optimized speed | 36000 |
| 39 | 2014-2015 | Duplex -2 extruder, to replace 4 nos of 7.5 kw motor with single 22 kw motor & VFD control | 15120 |
| 40 | 2014-2015 | HFE, to provide interlock to switch-off of the mill cooling primary and secondary pump | 39600 |
| 41 | 2014-2015 | Zone -1 400W light fitting to be replaced with 200W induction lights | 28800 |
| 42 | 2014-2015 | Avoid ideal running of chill water pump by control the pump on/off through recipe base | 12000 |
| 43 | 2014-2015 | Separate cooling line for mill # 3 when running belt cushion & RCB. So that mill #1 &mill # 2 cooling pump can be stopped. | 31200 |
| 44 | 2014-2015 | In chillers unit cooling tower fan motor control through closed loop ( circulation water temperature) | 16500 |
| 45 | 2014-2015 | Closed loop control for hydraulic pump # 1 based on pressure feedback | 53400 |
| 46 | 2014-2015 | Closed loop control for hot water circulation pump in trench # 3 based on pressure feedback | 23100 |
| 47 | 2014-2015 | To avoid idle running of fill line pump in trench # 1& 2 based on curing step function | 138000 |

| | | | |
|---|---|---|---|
| 48 | 2014-2015 | Zone – 3 400W light fitting to be replaced with 200W induction lights | 95040 |

From the above, it is revealed that the activity of lighting modification in the trucks curing aisle alone resulted in the highest saving of power consumption to the tune of 1,84,320 units/year of power in the year 2012-2013 alone.

***Table 6.11. Total power saved and Total GHG emission reduction in $tCO_2$***

| Sl. No | Year | Total units saved | Total GHG emission reduction in $tCo_2$ | % $CO_2$ reduction |
|---|---|---|---|---|
| 1 | 2012-2013 | 428400 | 370 | 3.70 |
| 2 | 2013-2014 | 606361 | 523 | 5.23 |
| 3 | 2014-2015 | 1054900 | 916 | 9.16 |

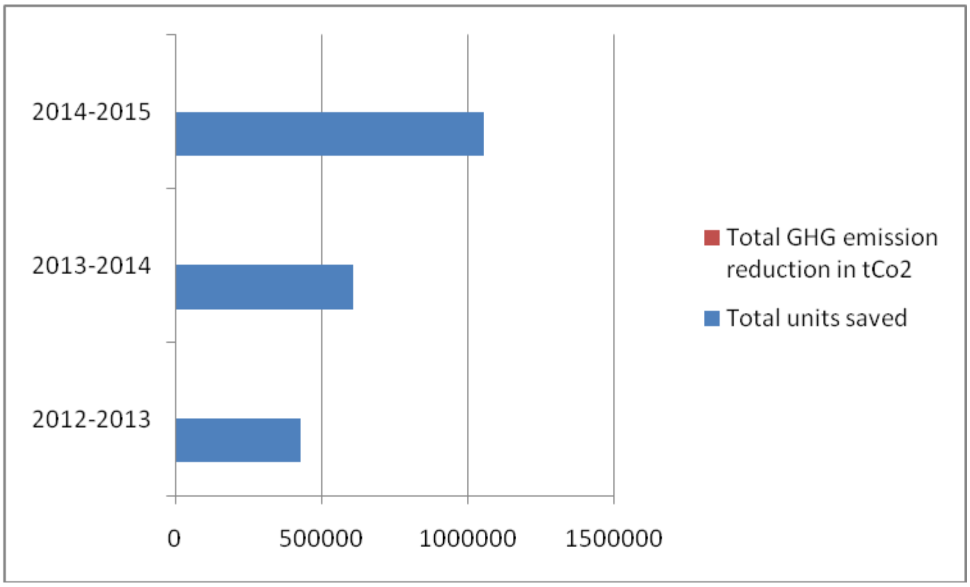


***Figure 6.9. Total power saved and Total GHG emission reduction in tCO2***

### 6.4.7 GHG Emission intensity

Emission intensity is the average emission rate of a given pollutant from a given source relative to the intensity of a specific activity. During the year 2009 to 2015, the GHG emission intensity has decreased intensity in product manufactured from1.53 $tCo_2$/MT to 1.38 $tCo_2$/MT in scope 1 & 2 categories.

***Table 6.12. Emission intensity***

| Unit | Scope category | Emission intensity | | | |
|---|---|---|---|---|---|
| | | 2009-10 | 2012-13 | 2013-14 | 2014-15 |
| $tCo_2$ for the reporting period | | 59481 | 80318 | 85446 | 89752 |

| | | | | | |
|---|---|---|---|---|---|
| $tCo_2$/MT product manufactured | Scope 1 & 2 | 1.53 | 1.39 | 1.39 | 1.38 |
| $tCo_2$/No. of product manufactured | | 0.016 | 0.020 | 0.021 | 0.020 |

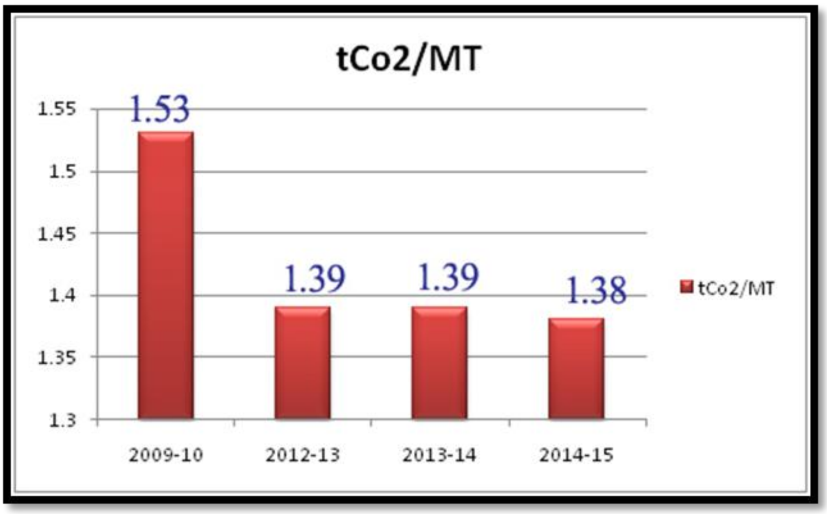


***Figure 6.10. Emission intensity status***

### 6.4.8 Conclusion

The energy consumption has been increased rapidly with its growth. Under this situation, the activities on the energy conservation have been carried out positively in every step. Approximately, 11 % reduction of power consumption in units per tones of product manufactured has been achieved. Due to effective management plans followed by the unit, the pollutant load has not resulted in any significant impact on the environment.

## 6.5 Case study-4- Scaffold Manufacturing Industry

### 6.5.1 Introduction

The unit is involved in the manufacturing of scaffoldings. In the manufacturing process, large quantity of furnace oil is being used for air heating purpose. The unit had initiated a number of steps towards sustainable Development and energy consumption. Some of the initiatives include:

- Oxsilan-Cold phosphating process implemented in Paint shop for pre treatment
- Solar air drier 135 sq.mtr for paint shop component surface dry.
- Using LPG instead of FURNACE OIL in thermic fluid heater.

- Implementation of LED lamps instead HPSV which saved 7928 KWH
- Implementation of solar street lights which saved 473 KWH
- Introduced VSD based compressor, which result in 30% saving from the previous standard compressor.

All these initiatives had resulted in substantial reduction of consumption of power, energy, furnace oil etc. In this paper an attempt has been made to analyze, quantify and summaries the initiatives taken by the unit in terms of GHG emission reduction.

**Formwork Facts in India**

- Formwork completed 420 million sq.m. (Year 2002-03) per annum (based on cement consumption).
- Formwork done using system formwork / engineered formwork- 5% -10% of the above - 21- 40 million sq.m.
- Formwork cost constitutes 25% of the cost of concrete but involves 60% of the time.
- Advancements in formwork technology are limited as compared to concreting & reinforcement.
- Formwork governs- i) Quality ii) Cost and iii) Time

**Governing Topics**

- Concept of formwork - methodology
- Requirement of materials for formwork
- Design
- Erection
- Inspection and
- Release or striking

**Factors - Formwork Design & Detailing**

**Loads**

- Lateral Pressure
- Vertical Loads
- Horizontal Loads
- Impact
- Incidental/Other loads

**Requirements**

- Safety
- Strength and stability
- Erection and release
- Shape, size and finish
- Reuse
- Tolerances
- Top Forms
- Construction Joints

**Others**

- Permissible stresses
- Condition of materials at site
- Site Conditions
- Methodology of Construction
- Uncertainties of loading and skill of workmanship

The formwork designer should have specialist knowledge and experience not only in design, but also in detailing of the formwork. Attention to be paid to the detailing of connections to ensure that any local failure does not lead to a progressive collapse involving the entire false work.

**International Standards**

- ACI 347-94 - guide to formwork for concrete.
- ACI SP-4 - formwork for concrete.
- OSHA - Occupational Health and Safety Act standards
- American Society of Civil Engineers Standards Development.
- Construction Industry Research and Information Association (CIRIA) reports on concrete pressure on formwork, striking times, recommendations etc.,
- BS 5975 - British Standards for formwork

- CAN/CSA - S269.3 - Canadian standard on formwork
- SAA 1509 - 1974 - Australian standards for Formwork.
- DIN 4420 - German standards for Formwork.

The above standards covers all topics in detail, including lateral pressure of concrete, superimposed loads like P&M heaps, bang loads and environmental loads like wind loads etc.

**Checks before Concreting**

The Australian Formwork Code - SAA 1509 -74 highlights "the common construction deficiencies leading or contributing to form failures

- Inadequate lateral and diagonal bracing of shores;
- Use of prop on prop;
- Lack of bracing at joints in shores;
- Out-of plumb shoring;
- Locking devices on metal shoring not locked, defective, extemporized or missing;
- Unstable soil under shore foot plates;
- Failure to provide adequately for lateral pressures on forms;
- Inadequately tightened or secured form ties;
- Failure to check tightness of reshores on floors below;
- Failure to inspect formwork during and after concrete placement to detect abnormal deflections or other signs of incipient failure which could be corrected;
- Are bolts and wedges secure against loosening due to vibration?"

**Checks during Concreting**

- Experienced form watcher should be present to deal site problems during concreting.
- Extra materials should be available in case of emergency.
- Keep a close watch on fastenings and wedges as it may loosen due to vibration.

**Indian Standards**

IS - 14687 - 1999, Indian Standard - False work for Concrete Structures - Guidelines is available.

The other code available for reference "IRC 87 - 1984 - Guidelines on design and erection of formwork for road bridges" is derived from the British and American codes.

The above codes do not deal in detail above the design factors and special applications.

**Formwork Scenario in India**

- Low technology
- Labor intensive
- Labor-unskilled, migratory, traditional and family oriented
- Low value projects-large number
- No industry - institute linkage
- Negligible trade prequalification
- Absence of monitoring body.

### 6.5.2 Emerging Trends in Formwork

**Present Scenario**

- Involving low investment cost.
- Low plant/ equipment requirements for handling.
- Labor intensive systems are not considered as a disadvantage
- Time required for execution/ completion of projects

**Transition Towards**

- Large value and fast track projects necessitating high technology products.
- Mechanization such as pumping of concrete constrain the use of engineered formwork and systems to ensure timely implementation with safety.

**Emerging Trends in the Industry**

- Infrastructure projects of large value have commenced.
- Involvement of foreign consultants/ JV partners in various forthcoming projects.
- Transition towards fast track projects.
- Move towards mechanization
- Globalization of the Indian market/ entry of foreign construction companies.
- Funding of projects by global financing institutions.

**Precedents**

- Usage of system formwork specified by **MSDRC (Maharasthra State Road Dev. Corporation).**
- Usage of internationally accepted system formwork or steel formwork specified by **National Capital Territory- Delhi Public Works Department**.
- Usage of system formwork specified by **M/s.Bechtel at Enron Power Project - Dabhol.**
- Standards for formwork place out by Nuclear Power Corporation and stringent implementation of the same.
- Patronage of system formwork specified by DMRC **(Delhi Metro Rail Corporation).**

**Need for system formwork**

**Specification by:**

- Foreign Design Consultants Like Sverdrup, Dar, Kajima , Mott Mcdonalds, Ramboll , Fluor & Daniel etc.,
- Foreign Project Management Consultants Like Bechtel, Bovis Lend Lease Holdings, Foster Wheeler , etc.,

**Entry of :**

- Multinational Construction Companies like Dywidag, Hochtief, Skankska, Ballast Nedam, Mitsui., etc.,
- Indian companies today are wishing to emulate their Global counterparts in quality & productivity standards.

### 6.5.3 System Formwork

'System' implies a fully compatible arrangement of formwork with a minimum of individual components with reusable elements intended to solve each forming task thereby rationalizing the forming work.

Various International codes specify a excess of checks that need to be done before concreting. These are inherently built in the System formwork due to high degree of standardization.

1) Formwork is the mold for construction of Housing projects, High-rise buildings, commercial building, Bridges etc. Formwork consists of Wall components, Beam components, Deck components and Supporting structures. Separate systems are developed to construct wall, beam, deck, high rise buildings, Pier, Pylons for bridges and these formwork systems can take care of shape of the concrete elements, quality of concrete, finish of the concrete and reduce the construction time and cost.

2) In detail wall components will have wall panels, corner panels, adjustable panels, which consist of frames with top sheet as plywood and MS or Aluminium sheet, and accessories kicker, rocker, starter blocks, vertical corners, pivot blocks, Aluminium legs.

3) Beam components will have beam side panels, beam soffit panels, which consist of mild steel standard section or Aluminium extrusions as frames with top sheet as plywood and aluminium sheet, props for soffit, aluspan, beam splice bar, beam prop head.

4) Slab components will have slab panels consist of Mild steel standard tubular or Aluminium extrusions as frames with top sheet as plywood and Aluminium sheet, props, span, slab prop head, slab corners & horizontal corners.

5) In detail column components will have panels, corner angles, which consist of mild steel channel sections with plywood sheeting member or Aluminium frames with top sheet as plywood and Aluminium sheet and steel frames with top sheet as plywood, universal walers and corner connector.

6) Supporting steel components are stub pins, wall ties, tie rods, bracing angles, steel brackets, platforms, adopters, frami clamps, frami hooks, frami clips etc.,

7) Prop is one of the supporting components in Formwork systems. Prop is made out of tubes and base plates and this is used in construction of concrete floor slabs, wall shutters alignment, concrete beams etc.,

### 6.5.4 Aluminium Formwork

The basic element of Aluminium Formwork technology is the panel which is a framework of extruded aluminium sections, welded to an Aluminium sheet. The panels are made from a high strength Aluminium alloy, with the face or contact surface of the panel, from 4mm thick plate, which is welded to a framework of specially designed extruded sections, to form a robust component. It can be reused over 250 times; the initial cost appears high; however, the ultimate cost per sqft of forming area is less when compared to traditional methods.

**System Formwork Advantages**

- Flexible system
- Lesser overall stock
- Rapid assembly
- Reduced cycle time, labor savings.
- Virtually self-aligning
- Dimensional accuracy.
- International safety Standard
- Built in safety features
- Excellent aesthetics
- Consistent high quality, lines, surface finish.
- Overall Economy
- Versatile and recurring productive usage netting large savings

**Process Flow – System Formwork**

- Preparation of shell plan drawing-Concrete element drawings
- Preparation of Formwork scheme drawing
- Preparation of detailing, Bill of Quantity & Costing
- Preparation of Material procurement details
- All Formwork items made out of steel processed in saw cutting for tubular sections & Aluminium extrusions , shearing of plates, gas cutting (for heavy sections), sawing of timber and plywood.
- Holes punching using tool and die.
- Drilling of holes.
- Blanking, flattening of tubes, forming of plates
- Fabrication & welding - Bend removal, fit up & welding using jigs & fixtures.
- QA & C - Inspection.
- Pretreatment – Degreasing, De-rusting, preconditioning and painting.
- Mockup assembly at Factory.
- Packing and dispatch.

- Formwork assembly at site.

**Basic Safety Requirements**

The basic safety requirement is the responsibility of each entrepreneur, as far as is reasonably practicable, to protect every employee from injury and ill health at the workplace.
This aim of providing a 'safe place to work' is achieved by adopting safety guidelines including the following:

- Risk assessment and control, before work starts
- Safe Work Procedure for every activity at the workplace, which may involve risk.
- Work Permit System for all hazardous activities such as work at height.
- In a worksite, every open side or opening into or through which a person is liable to fall shall be covered or guarded by effective guardrails, barriers or other equally effective means to prevent fall.

**Hazards in Formwork**

'Hazards' are potential dangers. Hazardous activities in formwork design, erection, use and dismantling are as follows:

- Incorrect or incomplete formwork design
- Erecting frames and bracing
- Erecting bearers and joists
- Placing deck and beam formwork
- Moving around on formwork during rebar placement, concreting, and curing
- In erection, use and dismantling phases, most actions engross following common hazards:
- Climbing up to or down from formwork, usually by ladders
- Working at height with unprotected edges on platforms
- Tripping and falling at level
- Falling through gaps and holes in formwork
- Falling from incomplete or badly designed formwork
- Hit by formwork components
- Carrying heavy loads
- Struggling with awkward shapes
- Fitting damaged connections and components
- Handling sharp objects and corrosive materials

- Working in harsh (sunny, cold, wet, windy, dusty, noisy etc.) environments
- Uneven, sloping and cramped work surfaces
- Overloading of formwork

Working at height has been the most hazardous activity all over the world and continues to attract the maximum number of accidents and the maximum number of fatalities. There are many ways in which safety may be ensured while working at height as follows:

A. Guardrail and toe board
B. Work restraint, attachment to lifeline
C. Retractable lifeline
D. Auxiliary scaffolding
E. Safety net below
F. Safety harness

In providing risk control against falling from height, collective control for all workers (A, D, or E) is better than individual control (B, C, or F); fall prevention (A, B, C, or D) is better than 'fall arrest' (meaning termination of a fall before hitting the base) to reduce the effects of fall impact after one has fallen (E or F).

## 6.6 Solar energy

### 6.6.1 Solar Air drying

"The unit has two nos of hot air ovens. One for Water Drying and another one for Paint Curing, which consume 12 lit/hr and 14.25 lit/hr furnace oil respectively. The company has devised an innovative solar air heating system in 2010.To reduce the Fuel consumption & Environment friendly heating method they have installed 135m$^2$ solar collector with 4000KCAL /Hour Heat output" ( State planning commission, 2013).

**Salient Features of the installed system includes:**

- A 135 m$^2$ Solar panel divided into 3 compartments. A south facing support frame with cement sheet has been installed. The Solar panel unit has been formed using aluminium extrusions, high absorption aluminium V- corrugated absorber, 4mm thick toughened glass (partially double), mineral wool insulation of thickness 75 mm, silica sealant and EPDM rubber.

- ❖ Fresh air is sent from below through the special V corrugated aluminium, so that the collector will deliver hot air in the range of 60 – 95°C depending upon solar radiation. Insulated metal duct draws the solar heated air through a suitable blower with necessary Controls and delivers it to the inlet point of the driers. Switch over arrangement from solar to conventional heating mode is also provided for the other lean period.

- ❖ This alone has saved 50T of furnace oil per annum resulting in 1.4 lakh of co2e. This in other words has resulted in saving of 4.9lakh m2 of forest required for the co2 absorption.


***Plate 6.1. A view of Solar Air Dryer***

**Renewable Energy Usage:**

- ❖ Solar 1.5KW SPV lighting system implemented during 2008 for Diesel Generator & Compressor Room Lightings.
- ❖ So far Energy Produced from Solar 43000 KWH.
- ❖ Emergency Locations identified and Introduced Standalone individual 36w CFL Street lighting system during the period of 2009.
- ❖ 15nos of 150w panel with 120Ah Batteries with 36w CFL luminaries fixed around factory in 15 locations.

Another innovative initiative done by the unit include Furnace Oil Savings in Thermic Fluid Heater during the period 2010 to 2014. The details are given in the *Table 6.13*.

*Table 6.13. Shows that total consumption and cost saved*

| As per calculation | Actual production/Annum MT | Average Production/Month | Average production by Solar heater/ Month | Burner running hrs/Month | Average production by solar heater per annum (10 Months) | Burner running hrs per annum (10 Months) | Furnace oil consumption per annum | Remarks |
|---|---|---|---|---|---|---|---|---|
| 2010-11 | 12469 | 1586 | 198 | 36 | 1983 | 361 | 16237 | |
| 2011-12 | 18428 | 1536 | 192 | 35 | 1920 | 349 | 15721 | |
| 2012-13 | 13165 | 1097 | 137 | 25 | 1371 | 250 | 11231 | |
| 2013-14 | 8458 | 705 | 88 | 16 | 881 | 160 | 7216 | |
| Total FO consumption saved 2010 to 2014 | | | | | | | 50405 | |
| Total FO cost saved (if Fo cost Rs. 45/Kg) | | | | | | | 22 Lakhs | |
| LPG System implementation | | | | | | | | |
| 2014-15 | 11326 | 944 | 118 | 21 | 1180 | 215 | 9662 | 1kg of Furnace oil= 0.73kg of LPG |
| 2015-16 | 7420 | 618 | 77 | 14 | 773 | 141 | 5627 | |

This alone resulted in 1.64 lakh KG of $CO_2$ equivalent. In other words, this has saved 4.9lakh $m^2$ of forest that would have been required to absorb the $Co_2$ emitted.

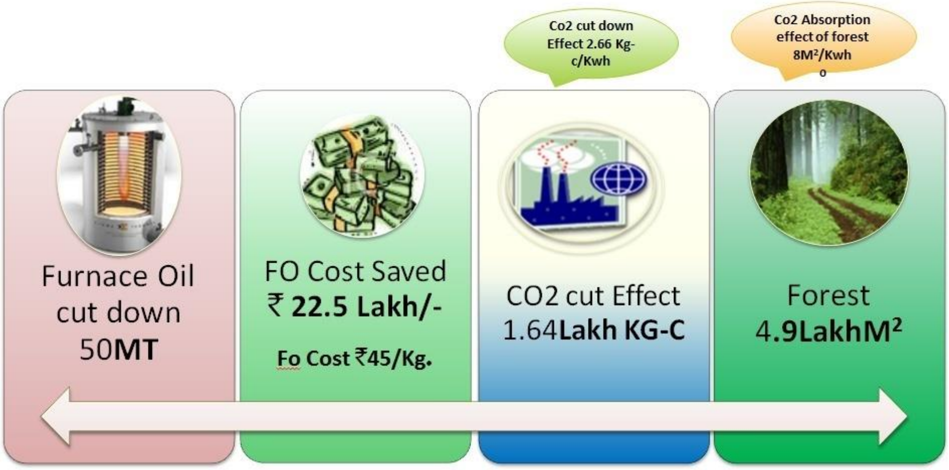


*Figure 6.11. Furnace oil cut down*

### 6.6.2 LPG Savings in Thermic Fluid Heater During 2014-2016:

The unit during the period, 2014-2016, introduced LPG based heating also for the heating in the thermic fluid heater. This has further reduced furnace oil consumption 11 $m^2$ of MT of furnace oil saved. This alone has reduced $Co_2$ emissions by 0.39 lakh kg equivalent. In other words, 1.2 lakh forest would have been additionally required for the absorption of the emitted $CO_2$.


*Figure 6.12. LPG cut down*

### 6.6.3 Oxsilan Cold Phosphating for Pre- Treatment Process:

"In the paint shop, during the pre-treatment process, existing, hot phosphating is used for Component painting. In this process, hazardous sludge is generated and its Handling & Disposal poses a problem. Besides, the Furnace oil consumption is 8Lts/hr for Operation, which is on the higher side" (Chemetall 2009).

In order to overcome the above process, the unit introduced an innovative method of Cold Oxsilan Process in 2010. The process has the following advantages:

- Oxsilan products are optimized with respect to substrate and application.
- Nanoscale: an ultra-thin organic coating is formed compared to conventional techniques where crystal layers are deposited.
- The si-o-si-bond is very strong and therefore highly stable.

**Working Principle:**

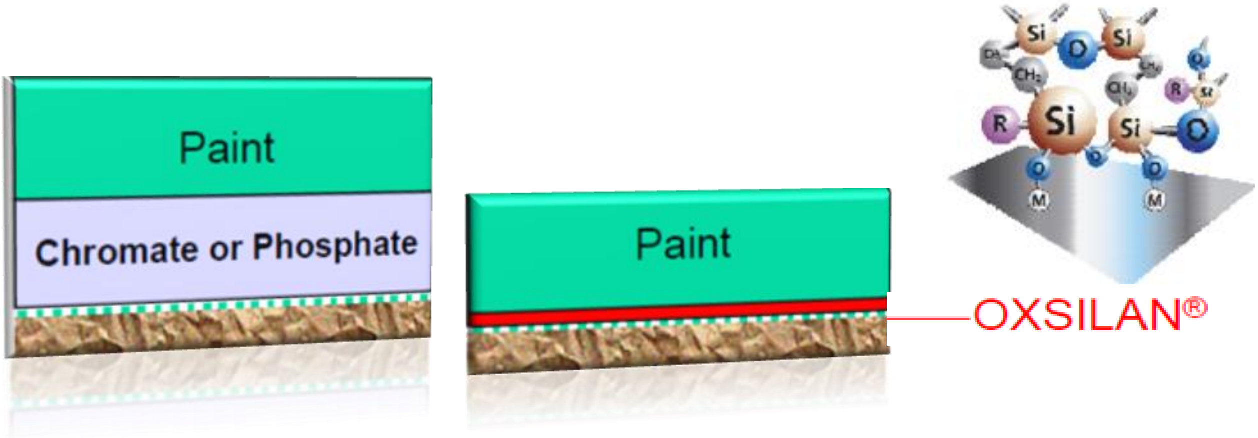


*Figure 6.13. Working Principle of Paint*

- ❖ Complimentary of hazardous metals and sludge less process
- ❖ Power savings ( fuel & power)
- ❖ Effortless to handle and simple bath control
- ❖ Ensure Greenhouse Gases (GHGs) and hence reduces global warming.

In the above process alone, the energy & cost savings during the period 2010-2016 is depicted below:

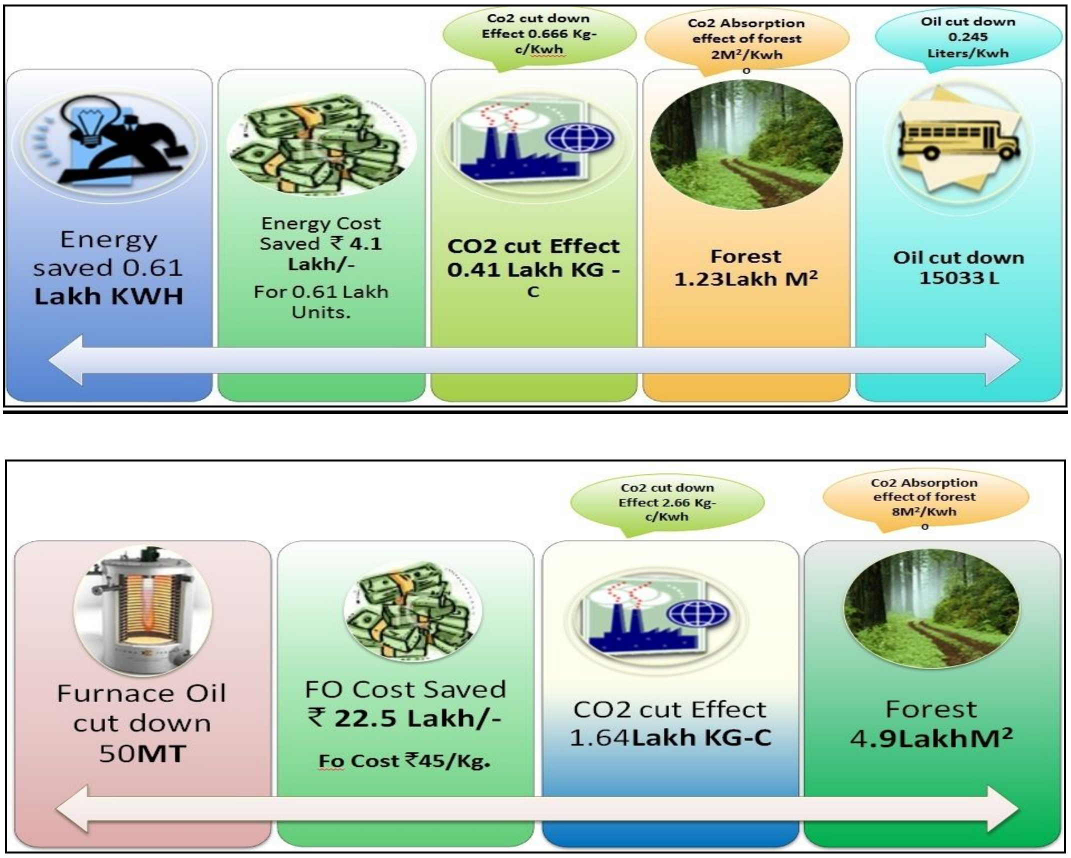


*Figure 6.14. Furnace oil Saving & Cost saving Details (2010-2014)*

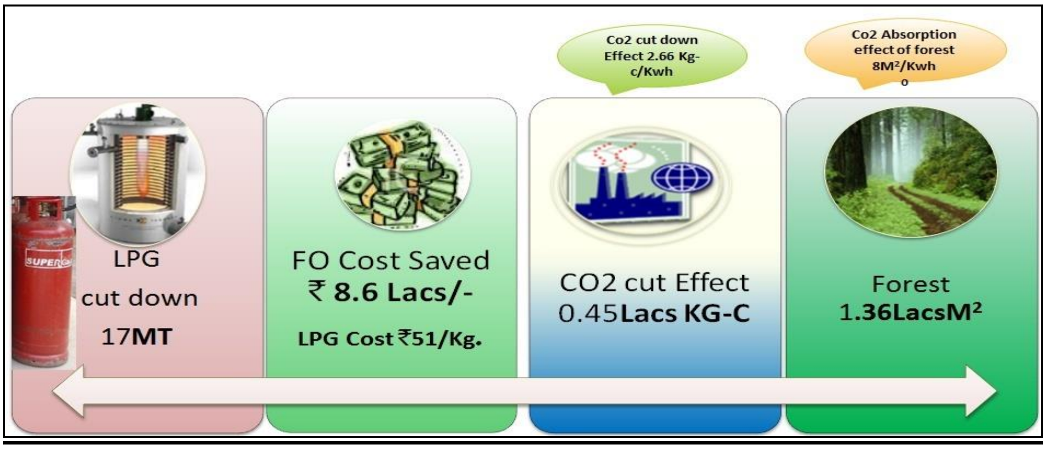


*Figure 6.15. LPG Saving & Cost saving Details (2014-2016)*

### 6.6.4 Energy Saving in Lightings

Lighting is an essential service in all the industries. The power consumption by the industrial lighting varies between 2 to 10% of the total power depending on the type of industry. Innovation and continuous improvement in the field of lighting, has given rise to tremendous energy saving opportunities in this area.

In this Lighting Scheme, Direct Lighting is Suited for Factories and indoor applications. For **INDOOR** Lighting, two types of basic light control system where in the unit is using, specular reflection system.

**T5 Lighting Implementation Weld shop**

T5 lamps are fluorescent lamps that are 5/8" of an inch in diameter. Differences in length and socket pin design versus conventional fluorescent lamps prevent any problems with electric circuits or human factors. The unit has changed all the lighting in the weld shop area into T5 systems from the earlier, T8 systems.

- ❖ First time introduced T5 technology in the working premises.
- ❖ Besides, due allowing of clear Day light in Welding bay helped in easy identification of Components.
- ❖ Colour Reading index is good compared with HPSV lamps.
- ❖ No glare in welding bay areas.
- ❖ This alone has saved 7500KWH/Annum of energy.

**T5 Lighting Implementation Shop Floor**

In Shop floor, earlier, the unit had used 250w/400w HPSV lamps earlier. However, they replaced the same with T5 lightings to reduce energy consumption and saved 9600KWH/Annum.

**Induction lighting for lighting mast**

- Induction light is a gas discharge lamp in which the power required to generate light is transferred from outside the lamp envelope to the gas inside via an electric or magnetic field.
- It contrasts with a typical gas discharge lamp that uses internal electrodes connected to the power supply by conductors that pass through the lamp envelope.

The internal electrode less lamp or induction light is a gas discharge lamp first time introduced in the unit premises itself. Existing lamps of 6*2*400w HPSV luminary for Lighting masts were replaced with 300w*5nos of induction Luminary. This alone resulted in the energy saving of 10500KWH /Annum.

### 6.6.5 LED street lightings and T8 led fixtures

Continuous Improvement in Energy Conservation Activities was attempted by the unit. LED Street light Luminaries & LED 18w lamps used for pathway lightings (Ahmed Mohamed Ibrahim et al., 2013). In the formwork section of the unit, the following activities had been implemented:

- Maximize sunlight use through transparent roof sheets, north light roof, etc.
- The unit had replaced conventional magnetic ballasts by more energy efficient ballasts, with due consideration to life and power factor apart from watt loss.
- Further, the interior colors are selected for maximum light reflection, modified the layout of the section for optimum lighting.
- Following electrical fittings are replaced for maximum efficiency:
    a. On / off type voltage regulation type (for luminance control)
    b. Group control switches / units
    c. Occupancy sensors
    d. Photocell controls
    e. Timer operated controls

Further, the unit had installed, input voltage regulators / controllers for energy efficiency as well as for longer life expectancy for lamps where higher voltages, fluctuations are expected. Replaced energy efficient displays, like LED's in place of lamp type displays in the control panels/ instrumentation areas, etc. This has resulted in 17035 KWH of saving.

### 6.6.6 Introduced VFD based compressor

"The unit had introduced/ replaced its compressors in to Variable frequency drive (VFD) based ones. This type of compressor uses a special drive to control the speed (RPM) of the unit, which in turn saves energy compared to a fixed speed equivalent" (Snehal Bhende, 2014).

The most common form of VSD technology in the air compressor industry is a variable frequency drive, which converts the incoming AC power to DC and then back to a quasi-sinusoidal AC power using an inverter switching circuit. The benefits of this technology included reducing power cost, reducing power surges (from starting AC motors), and delivering a more constant pressure. This has resulted in the power saving of 8052 KWH. This alone has reduced power consumption by 30% lesser than the conventional ones.

**Waste segregation system implementation**

- It enables more of the waste to be recycled which reduces the drain on resources and energy when new stuff is being produced.
- It reduces the amount of stuff that has to go to landfills, which is also environmentally good.
- The unit had introduced for the first time in the working premises waste segregation shed which resulted in helping the workers to easily identify and segregate the waste separately and send for disposal in safe manner.
- Category wise segregation helps to maintain cleanliness in the surrounding & in the environment where it is stored.
- Waste can further sent to approved recyclers as per the norms.
- Various alternatives can be designed to minimize the waste generation.

**Process implementations**

- The unit plan to execute the Auto loading system in section shearing machine.
- Major difficulty and hazard presently is handling Heavy weight materials.
- Requires Skilled Labor for Material movement

The unit plan to fix the above difficulty by introducing the simple chain link mechanism.

**Advantages**

- Workmen fatigue reduced and productivity increased.
- Manual lifting required 04 persons, but in auto loading required only two Persons.
- Avoid major accidents and ensure the safe work place.

### 6.6.7 LPG Gas Manifold System For Thermic Fluid Heater during the period 2014-2016

Thermic fluid heater is a heat-generating unit, which is available in LPG/LDO/FO / WOOD / Husk as fuel for firing. In construction, it has double coil three pass construction and fitted with modulated pressure jet burning system. The thermic fluid, which acts as a heat carrier, is heated up in the heater and circulated through the process tanks wherein it transfers heat for the process through a heat exchanger and then returned to the heater.

**Problem faced with furnace oil during process in Thermic fluid heater**

- Every Turn on – Off time the Excess heat go to stack, Every process 5Deg loss identified using of Furnace Oil .
- 6KW *2Nos of Heater Used in Service Tank & Pre-Heating Tank to improve the Viscosity of furnace oil for Easy Flow and Rapid firing purpose.
- Nozzles can clog with dirt even though they have a bronze screen. Every Time Cleaning to be done and change the nozzle periodically.
- Oil furnaces need to be regularly cleaned and the fuel filters must be changed.
- $CO_2$ Emissions.
- Combustion problem due to oil poor burning property.

**LPG Advantages:**

- No soot, burners have a longer life - so maintenance is low
- Clean Burning
- No spillage as it vaporizes at atmospheric temperature and pressure.
- Effects of corrosion are greatly reduced
- Instantly controllable flame temperature
- Avoids scaling and decarburizing of parts
- Environmentally friendly fuel, with minimal sulphur content and sulphur- free emissions
- Very high efficiency with direct firing system

- Instant heat for faster warm-up and cool-down
- A high calorific value of 11,900 Kcal/Kg results in high efficiency heat output.
- Pilferage, Spillage, Adulteration is nil.
- Production rate is higher
- Greenhouse gas & $Co_2$ emission is 40% less than LDO.

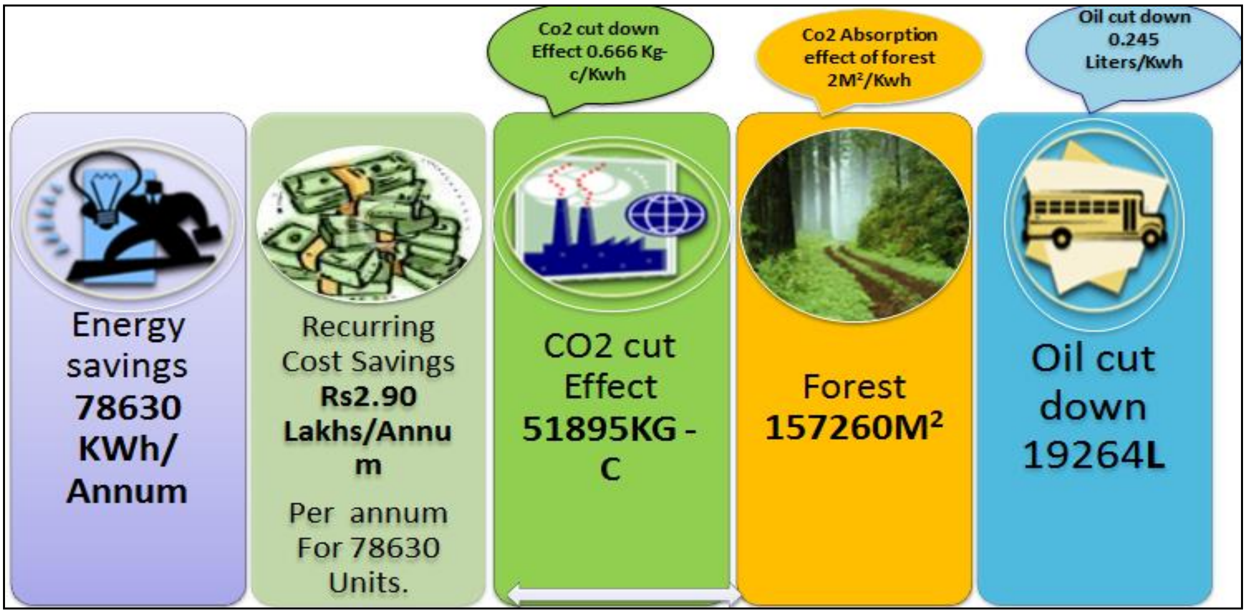


***Figure 6.16. LPG Manifold - Energy saving for the Period 2014 to 2016***

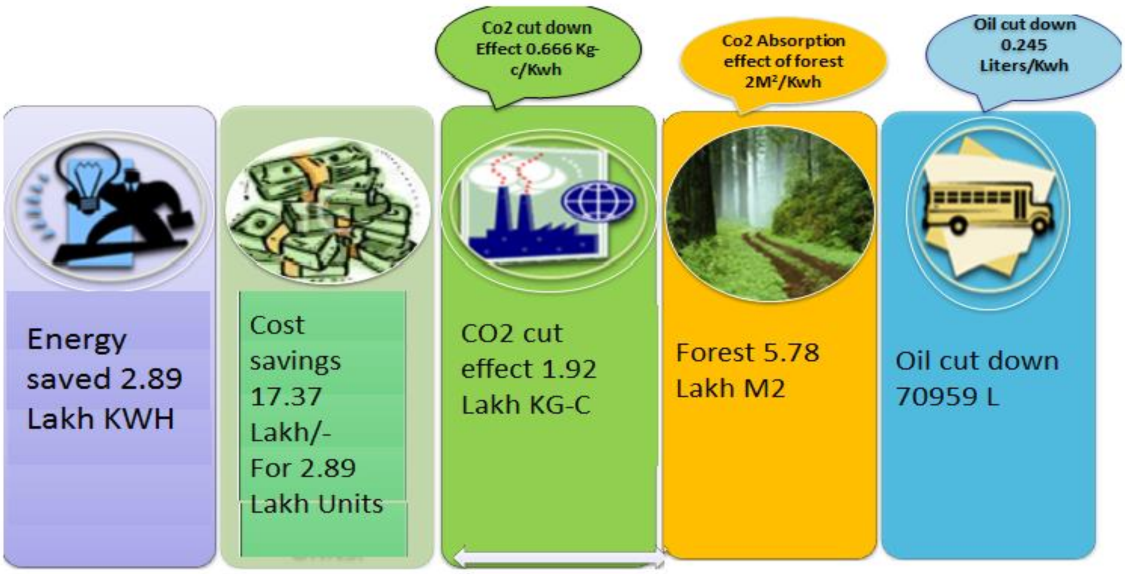


***Figure 6.17. Overall Energy Savings for the Period of 2009-2016***

### 6.6.8 Summary Furnace Oil, LPG and Energy Savings

***Table 6.14. Furnace Oil Savings and LPG savings***

| **Sl. No** | **Technology using L &T industry** | **Furnace oil cut down** (MT) | **Year- 2010 to 2014** | | | **LPG cut down** (MT) | **Year- 2014 to 2016** | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | **Furnace oil Cost saved** (Lakh) | **$CO_2$ cut effect** (Lakh Kg- C) | **Forest** (Lakh - $M^2$) | | **Furnace oil Cost saved** (Lakh) | **$CO_2$ cut effect** (Lakh Kg- C) | **Forest** (Lakh - $M^2$) |
| 1 | Furnace Oil Savings and LPG savings in Thermic Fluid Heater | 50 | 22.5 | 1.64 | 4.9 | 11 | 5.6 | 0.39 | 1.2 |
| 2 | Furnace oil Saving & Cost saving Details | 50 | 22.5 | 1.64 | 4.9 | 17 | 8.6 | 0.45 | 1.36 |

***Table 6.15. LPG Manifold- Energy saving***

| **Sl. No** | **Technology using L & T industry** | **Energy saved** (Lakh kwh) | **Year- 2010 to 2014** | | | | **Year- 2009 to 2016** | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | **Energy cost saved** (Lakh) | **$CO_2$ cut effect** (Lakh Kg- C) | **Forest** (Lakh $M^2$) | **Oil cut down** (L) | **Energy cost saved** (Lakh) | **$CO_2$ cut effect** (Lakh Kg- C) | **Forest** (Lakh $M^2$) | **Oil cut down** (L) |
| 1 | LPG Manifold | 0.61 | 4.1 /- | 0.41 | 1.23 | 15033 | 17.37 | 1.92 | 5.78 | 70959 |
| 2 | | 78630 | 2.9 | 5189 | 15726 | 19264 | | | | |

### 6.6.9 Conclusion

The mitigation of greenhouse gas emissions to acceptable levels is arguably the greatest environmental challenge these days. With increasing population and industrial sector contributes more GHGs emissions in Puducherry region. GHG emissions are becoming one of the most significant environmental issues facing industries. In today's world situation, it is very much necessary to find out the solution for the global impact of pollution for the survival of life. The

Intergovernmental Panel on Climate Change (IPCC) claimed that greenhouse gases generate impact large enough to change global climate. Some industries are beginning to reduce carbon emissions from their designs and manufacturing processes in order to comply with IPCC recommendations around the world. In the future, energy efficiency is potentially the most important and cost-effective means for mitigating greenhouse gas emissions. An attempt is made on impact of policy intervention of the emission of GHGs in a large Scaffold Manufacturing Industry.

**Case Study-1-Chlor-Alkali industry**

From this case study, it may be concluded that the membrane technology is an environment friendly and energy efficient technology. The estimated annual GHG reduction in the elimination of alpha cellulose and energy conservation were73.3MT $CO_2$e (0.733% of alpha cellulose has eliminated) and 13.2MT $CO_2$e, (0.132% of energy saved) respectively. The GHG reduction from sulphate removal and recovery of sodium sulphate was121.6 MT $CO_2$e / annum. Biodiversity and carbon sequestration potential of plantation activities of carbon stock was estimated at 6625MT $CO_2$e and annual Certified Emission Reduction Certified Emission Reductions (CERs) generated through plantation activities was 390MT $CO_2$e. The GHG reduction equivalent to the reduction in energy and water consumption in HCL heat recovery system were 4600MT $CO_2$and 21.42MT $CO_2$respectively. This amounts to a total GHG reduction of 208.10 MT $CO_2$e/annum.

**Case Study-2- Personal Care Product Unit**

The study revealed that, the unit has adopted to use low water raw materials and evolved anew formula which required less process water. The energy consumption for the last 5 years from 2010 was carefully analyzed. From 2010 -2015, the industry had achieved 35% specific energy reduction. In 2010, the industry was consuming 1.581 GJ/Ton, which has come down to 1.028 GJ/Ton in 2015.The energy consumption reduction was directly transferred into 36% $CO_2$ emission reduction during the same period. The specific emission was 162.38 kg /Ton in 2010, which over a period has been reduced to 104.36 kg/Ton in 2015. This culminated in reduction of 4000 KW/Annum GHG due to reduced energy consumption and about 970 Tons of $CO_2$ emission reduction per month. The specific emission trend has revealed that 162.38 kg /Ton was observed in 2010, which over a period has resulted to 104.36 kg/Ton in 2015. This amounts to a total of GHG reduction 11,884 Tonnes/annum has saved.

**Case Study- 3 - Tyre Manufacturing Unit**

The unit has saved 11,13,008/lit of FO during 2012-2015 projects and total GHG emission reduction was 3,306 $tCo_2$ during 2012-15. Power consumption from the unit is 1,84,320 units/year of power in the year 2012-2013.The GHG emission intensity has decreased in product manufactured from 1.53 $tCo_2$/MT to 1.38 $tCo_2$/MT in scope 1 and2 categories. Approximately, 11 % reduction of power consumption in units per tonne of product manufactured has been achieved. This amounts to a total of GHG reduction in fuel and power saved that amounts to 5,115$tCo_2$.

**Case study-4- Scaffold Manufacturing Industry**

The reduction in the furnace oil consumption cut down the emission of 1.64 lakh KG of $CO_2$ equivalent and saved 4.9lakh $m^2$ of forest that would have been required to absorb the $CO_2$ emitted. The thermic fluid heater reduced furnace oil consumption and resulted has saved 11 $m^2$ of MT of furnace oil. This alone has reduced $CO_2$ emissions by 0.39 lakh kg equivalent. In other words, 1.2 lakh $m^2$ forest area would have been additionally required for the absorption of the emitted $CO_2$. The unit saved 10500KWH /Annum of energy.VFD based compressor has resulted in the power saving of 8052 KWH. This alone has reduced power consumption by 30% lesser than the conventional compressor.

This case study clearly indicates the hidden potential in major industries to reduce GHG emission by making raw-material substitution, process changes, machinery changes, loss of heat / steam, rain water harvesting, waste water treatment and its re-use, increasing the green power and thereby increasing the carbon Sequestration. It is essential to make the other such industries in the region to realize these potentials and motivate them to adopt these innovative techniques as in any case they could not only save money and enhance their profits by adopting them, but also can boost up their corporate image on environmental/social responsibility. Government and regulatory authorities shall also create more sensitization programmes for other industries and supervise and monitor them to successfully implement these projects.

This can be effectively aligned with /dovetailed to the ongoing/proposed programmes such as Corporate Environmental Responsibility , Corporate Social Responsibility, (CSR), AMRUT Scheme ,smart city , JNNRUM, Green India Mission (GIM), National Adaptation and Mitigation Programs under Climate Change Action Plan, Perform, Achieve and Trade (PAT) scheme , Renewable Energy Certificate Scheme, National Clean Development Mechanism (CDM) UNIDO Green Industry Initiative., etc.

***The END ***

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# ANNEXURE

## ANNEXURE - A: LIST OF DEPARTMENT

### SOLAR MISSION

1. Health department
2. Renewable Energy Agency Puducherry
3. Adidravidar welfare dept.
4. Department of industries & Commerce
5. Forest Department
6. Town & Country Planning Dept.
7. Public Work Department

### ENHANCED ENERGY EFFICIENCY

1. Renewable Energy Agency Puducherry
2. Town & Country Planning Department
3. Regional Planning Authorities (RPAs)
4. Public Work Department
5. Agriculture Department

### SUSTAINABLE HABITAT MISSION

1. Town & Country Planning Department
2. Local Administration Department
3. Public Work Department
4. Transport Department
5. Puducherry Pollution Control Committee
6. Project Implementing Agency
7. Dept. of Revenue & Disaster Management
8. Department of Science, Technology & Environment

### WATE MISSION

1. Agriculture Department
2. Regional Planning Authority
3. Land Acquisition and Development
4. Public Work Department

### COASTAL DISASTER MISSION

1. Dept. of Revenue & Disaster Management
2. Public Work Department
3. Project Implementing Agency
4. Puducherry Water Resources Organisation

5. Department of Science, Technology & Environment
6. Forest Department

**GREEN MISSION**

1. Department of Industries and Commerce
2. Department Of  Forest and Wildlife
3. Local Administration Department
4. Town & Country Planning Department

## ANNEXURE - B: PUDUCHERRY CLIMATE ACTION PLAN (TEMPLATE – 1)

### A. List of activities identified in the Draft SAPCC

| Type[1] | Response Activity Title[2] | Organizations[3](P) | Organizations[4] | Ref. No.[5] |
|---|---|---|---|---|
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### B. List of additional activities proposed[6]

| Type | Response Activity Title | Organizations(P) | Organizations | Ref. No. |
|---|---|---|---|---|
| | | | | |
| | | | | |
| | | | | |
| | | | | |

[1]Indicate whether it is Mitigation or Adaptation or Both

[2]Describe the Response activity

[3]List the organizations to be primarily responsible

[4]Other closely Related Departments for the activity

[5]Provide a department reference number, e.g. FOR/CAP/1 for the Forest Department's Activity 1.

[6]Consider policies and schemes under planning & implementation by the respective departments.

(Considering both the Central and State Government schemes along with the prevailing practices in the associated sector)

## ANNEXURE - C: PUDUCHERRY CLIMATE ACTION PLAN (TEMPLATE - 2)

Name of the Authorized representative:
(Note: to be completed for all identified activities included in Template 1)

A. Reference No. :
B. Response Activity Title :
C. Objective of the response activity :
D. Type of Activity (Mitigation or Adaption) :
E. Scale of Activity
(state-wide or district-wide or particular area) :
F. Nature of Activity :
(Research Study/Policy Action/ Pre-investment Study/ Demonstration Project/ Investment Project/ Capacity Building/Regular Operation & Maintenance)
G. Importance of Activity (High/Medium/Low) :
(Consider the extent of climate/livelihood proofing, extent of mitigation, higher significance for adaptation action.)
H. Barrier/constraints (None/Minimal/Large) :
(consider technology, operational and financial constraints)
I. Overall priority level (High/Medium/Low) :
J. Organization involved:
K. Description of stages/sub-activities :
L. Monitoring & Evaluation :
1. Process indicators
2. Results/Outcome indicators
M. Timeframe(Short-term, i.e. 1-2 years/
Medium-term, i.e. 3-5 years): Short term :
N. Indicative Budget :

K. Source of funding, if identified :

Signature of Representative
Name:
Designation: