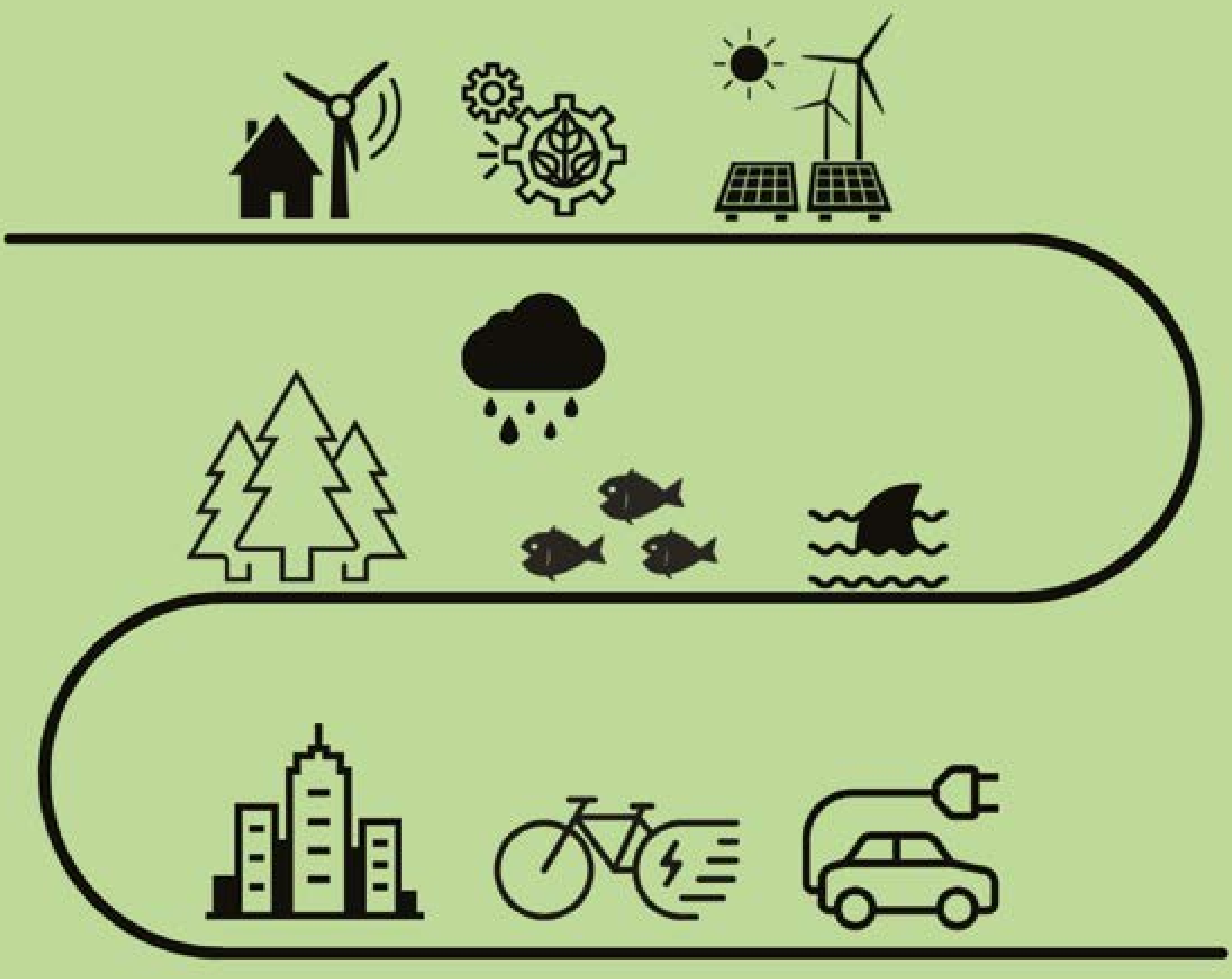
# BECOMING CARBON NEUTRAL

## A handbook for Local Self Governments in Kerala



## BECOMING CARBON NEUTRAL

'Becoming Carbon Neutral- A handbook for Local Self Governments in Kerala' is a comprehensive guide for local government bodies in the state of Kerala to achieve carbon neutrality. It is based on the concept of low-carbon development put forward by the United Nations Framework Convention on Climate Change (*UNFCCC*). The handbook explains in detail the concept of low-carbon/low-emission development, steps to integrate it into the development plans for local self governments and the ways to achieve carbon neutrality.

## FOREWORD

The negative consequences of Climate Change are staring at Kerala. Its vulnerability is not only due to its natural features like a long coastline and equally long mountain chain with a narrow strip of land in-between, criss-crossed by rivers with total dependence on the monsoons but also due to the care free consumerism of the society.

When the environmental movement began in the 1970s, it gained a lot of support particularly among the new generation. Strangely enough, the consciousness seem to have waned, best exemplified by the irrational but motivated and calculated emotional onslaught against the profoundly wise and commonsensical recommendations of the Gadgil Committee, which only sought to empower local communities in having the decisive say, in choosing sustainable livelihoods in harmony with nature, not out of idealism but in enlightened self-interest.

Now Thanal, a highly professional and committed NGO advocating sustainability in all aspects, particularly in relation to environment, has used the potential for local action through participatory planning which is the hallmark of Kerala's development in the last twenty five years to develop an excellent plan of action for achieving carbon neutrality at the level of a Village Panchayat. Contrary to the popular impression that climate change can be combatted only at the national and international level, it has proven through meticulous action research in Meenangadi Village Panchayat in Wayanad District that local planning and local remedial action is possible to mitigate Climate Change in a significant way, focussing on Carbon Neutrality.

Using the energies released by People's Planning, Thanal has done high quality professional work in developing a scientific but practical methodology investing a lot of effort in the Panchayat through a long process of experimentation and has developed a Hand Book which explains how detailed plans can be made to ensure Carbon Neutrality at the local level using empirical data.

This Hand Book is lucid. But naturally there are technical steps which can be conveyed to the elected representatives and local officials only through a specially designed training programme by the Kerala Institute of Local Administration which is already active in this field. To make it sustainable, it needs to become a people's movement through an alliance of concerned citizens, activists, experts and sensitive officials. This is one area where the famed concept of Voluntary Technical Corps (VTC) enunciated by no less a person than E.M.S.Namboodiripad himself, but so sadly neglected in the decentralized development process, after initial enthusiasm, needs to be revived. It would be easy to extend this across local governments by nurturing "resource" panchayats and municipalities into "schools of practice" and wider coverage achieved at speed through a hub and spoke model of replication.

**S.M.Vijayanand IAS**
**Chairman, Centre for Management Development Kerala**
**(Former Chief Secretary, Govt. of Kerala)**

# FOREWORD

Meenanngadi Panchayat happen to present this hand book for all Panchayaths. We printed the hand book for Kerala Panchayaths as we get several visitors from other panchayaths in Kerala and other states asking oru experience in exploring carbon neutral development planing in a local self government the rich discussion implementation of our plan and looking at IPCC frame work and Intended Nationally Determined Contribution (INDC) for further sharing at international level are broadly addressed by the hand book. Meenangadi Panchayat is happy to bring this joint publication with Thanal technical partner to our Carbon Neutral work.

K. E Vinayan
President,
Meenangadi Gramam Panchayat

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## UNITS

m - meter

sq. m – square meter

sq. km – square kilometer

ha – hectare

g - gram

kg – kilogram

Gg – Gigagram

t – tonne

kt – kilotonne

MWh – MegaWatt hour

TJ – Terra Joule

## ACRONYMS

AGB – Above Ground Biomass

BGB – Below Ground Biomass

COP – Conference of Parties

GHG – Greenhouse Gases

GWP – Global Warming Potential

IPCC – Intergovernmental Panel on Climate Change

KSEBL – Kerala State Electricity Board Limited

LSG – Local Self Government

LPG – Liquefied Petroleum Gas

MGNREGS - Mahatma Gandhi National Rural Employment Guarantee Scheme

NCV – Net Calorific Value

OPC – Ordinary Portland Cement

PPC – Portland Pozzolana Cement

UN – United Nations

UNFCCC – United Nations Framework Convention on Climate Change

$CO_2$ - Carbon dioxide

$CH_4$ – Methane

$N_2O$ – Nitrous oxide

$TiO_2$ – Titanium dioxide

# CHAPTER 1

# What is ‘Carbon Neutrality’ ?

## 1.1 Background

The world is currently going through a global crisis that affects the future of all living things on this planet- Climate Change. Even though the climate of the earth has been changing constantly for millennia, the change we witness today is the result of a multitude of human activities like deforestation, burning of fossil fuels, land use change and industrialized agriculture. Scientists found evidences for human-induced climate change in the later-half of the 20$^{th}$ century when they observed unnatural increase in global temperature over the last couple of centuries, since the First Industrial Revolution that started in the 1760s. Since then, the concentration of GHG in the atmosphere has increased drastically which resulted in 1.1$^{0}$ Celsius rise in global average temperature already since the pre-industrial levels. This signifies the anthropogenic nature of climate change which adversely affects the planet and its ecosystems. The gases that we emit from vehicles, industries, power plants, waste, etc. like Carbon dioxide ($CO_2$), Methane ($CH_4$), Nitrous oxide ($N_2O$), hydrofluorocarbons, perfluorocarbons and Sulphur hexafluoride has heat-trapping properties that prevent heat energy from escaping back into the space. This phenomenon is called the greenhouse effect and hence these gases are referred to as Greenhouse gases (GHG). The overwhelming amount of GHG in the atmosphere traps the majority of heat energy from the sun in the atmosphere thereby increasing the global temperature. This alarming rise in global temperature is called 'Global Warming' which in turn disrupts natural processes and causes the melting of glaciers, warming of oceans, rising sea-levels, etc.

The rapidly increasing temperature of the atmosphere also leads to disrupted ocean currents, which is the prime driver of earth's climate. Thus anthropogenic activities are the core reason for climate change that we face today. The climate is changing quickly so much so that most of the living things are unable to adapt to this change which can lead to their extinction.

Human-induced climate change affects our socio-economic-environmental systems adversely. It causes extreme weather events like storms, droughts, floods and heatwaves, increases the temperature and acidity of oceans and destroys the biodiversity and livelihood of people around the planet.

## 1.2 Carbon Neutral development

As there is mounting evidences for human-induced climate change, measures has to be taken to fight this global crisis. Carbon neutral / low-carbon development is a concept emerged in these circumstances which has its roots in the United Nations Framework Convention on Climate Change (UNFCCC). It refers to development with low GHG emissions to address climate change and integrate climate action in development strategies. Carbon neutral development, which is now often referred to as climate-resilient or climate-neutral development, is a pathway for countries to achieve net zero-emission. It focuses on mitigating our emissions while adapting to climate risks and build resilience among people to increase their capacity to face the adverse impacts of climate change. Adopting policies to mitigate and adapt to climate change and create climate-resilience is critical for the sustainable development of an economy. This change from a carbon-intensive economy to low-carbon development is an arduous task which can only be achieved with the participation of governments, civil society, private sector and individual citizens.

## 1.3 Kerala scenario

Kerala is one of the states in India which is highly vulnerable to climate change and its adverse impacts. Vulnerability to climate change can be considered to be high in state due to unique social, economic, environmental and physical conditions that amplify susceptibility to negative impacts and contribute to low capacity to cope with and adapt to climate related hazards *(Department of Environment and Climate Change, Govt. of Kerala, 2014)*. The state has high dependency on climate sensitive sectors like agriculture, fisheries and forests, long coastal line vulnerable to sea-level rise and erosion and fragile ecosystems like mangroves, backwaters and tropical forests. Kerala is the state with the highest population density in India with 859 persons per sq. km. All these factors increase the vulnerability of the state to climate change.

In 2018 Kerala witnessed unexpected floods due to heavy rainfall during the southwest monsoon season. The devastating floods and landslides affected 5.4 million people, displaced 1.4 million people, and took 433 lives (22 May–29 August 2018) *(KSDMA, 2018)*. During the southwest monsoon of 2019, another deluge had hit the state, wherein 1038 villages from 13 districts were notified as affected by floods and landslides and 125 lives were lost *(KSDMA, 2019)*. These recent events can be linked to the changing climate patterns experienced all around the planet as a result of human-induced global warming and climate change. As the state is witnessing such disastrous climate events, it is essential for the state to take necessary steps to move towards a climate-resilient, low-carbon state.

Achieving carbon neutrality is a laborious task for a state considering its area, population and potential to carry out interventions. However, climate-resilient development can be carried out efficiently at local self government (LSG) level especially because of the strong decentralized system of governance prevailing in Kerala.

## 1.4 LSG-level Carbon Neutral works in Kerala

The LSGs of Kerala generate significant quantities of GHG from energy usage, vehicles, industries, waste management, etc. Most of the LSGs are vulnerable to climate change impacts, especially coastal panchayats and the ones with fragile ecosystems. Hence it is critical for the local governments to take necessary measures to mitigate and adapt to the changing climate.

The adverse effects of climate change can result in the damage of properties, displacement of communities, unemployment, pandemics, destruction of ecosystem, and death. The two floods faced by Kerala consequently were wake-up calls for the state to take actions immediately to tackle this global issue and be responsive. The actions will be effective when it start from the local bodies, at a grass-root level. This is because involving communities is a major part in adapting to climate change and its impacts. Carbon neutral development is possible only with the participation of all levels of society.

In 2015, as a response to the revolutionary Paris Agreement *(See Infobox 1),* the then Finance minister of Kerala Dr. T. M. Thomas Isaac introduced the 'Carbon Neutral Wayanad' project to convert Wayanad district into the first carbon neutral district in Kerala. Following this, in 2017, a GHG emission profiling was done for Meenangadi grama panchayat in Wayanad and proposed suitable recommendations for the panchayat to achieve carbon neutrality by 2020.

As Meenangadi panchayat was found to be carbon-positive after GHG assessment, steps were taken to reduce its GHG emission and to increase its carbon sequestration. Together with the help of the community, Kudumbasree and MGNREGS, the panchayat was able to carry out various projects like planting trees, proper waste management, training in producing alternate products, installing compost parks and bins etc. all over the panchayat. The carbon-neutral development works in Meenangadi did not just fulfill the aims to reduce emissions and improve sequestration, but also helps in improving the economy of the farmers affected by climate change effects. The 'Shade Coffee' scheme implemented in the panchayat makes coffee cultivation, which is a major source of income for the people of Wayanad, more profitable. The 'Tree-banking' scheme provides incentives to people to plant and grow trees, essentially making trees a source of income for the people of Meenangadi. These admirable actions taken by Meenangadi panchayat is a model for all other LSGs in Kerala to move towards a low-carbon future.

## Infobox-1 Paris Agreement

To combat the climate crisis and reverse the warming of the planet, the member states of the United Nations *(UN)* signed a revolutionary treaty in 2015 at the 21st Conference of Parties *(COP)* held at Paris called the Paris Agreement. The Paris Agreements' central aim is to strengthen the global response to the threat of climate change by keeping the global temperature rise in this century well below 2 degrees Celsius above pre-industrial levels and to pursue efforts to limit the temperature increase even further to 1.5 degrees Celsius *(UNFCCC, 2020)*.

# CHAPTER 2 Carbon Neutral Development Framework

## 2.1 Carbon-Neutral Development in Kerala: A people-centered approach to Climate Action

The onset of anthropocene underscores the anthropogenic nature of climate change, exposing how human actions, both historic and contemporary, have led to the current climate crises *(Crutzen 2006)*. The looming threat from climate disruptions has flared global debates about a way out from this crisis. Such discussions can be broadly categorized into two: (1) neoliberal fixes promoting techno-managerial solutions, and (2) anti-capitalistic alternatives that reaffirm the need for a systemic change *(Clark and York 2005)*. Popularly referred to as "neoliberal environmentalism" or "market environmentalism," the approach aims to solve environmental problems through privatization, commercialization, and commoditization of natural resources *(Bakker 2005:544; Ciplet and Roberts 2017)*. These market-based solutions broadly aim to alleviate the fallouts of climate disruptions on capitalist growth, whereas the alternatives underscore the need to break away from an economic system that is based entirely on economic growth and profits. The divide between the two sides has been prominent surrounding the various strategies proposed for GHG emission reductions.

Adopting nature-based and people-centered solutions for development is essential for addressing human-induced climate change. This study for low carbon development in Kerala falls in line with the alternate solution where environment and people are in the forefront of development planning.

Being 'carbon-neutral' and 'climate-neutral' have gained momentum in the global policy discourse on climate action. 'Carbon-neutral,' as a carbon-specific concept, is being increasingly replaced by the term 'climate-neutral' that includes all GHG that are identified in the Kyoto Protocol. Developed as well as developing countries have started recognizing the importance of adopting climate-sensitive concepts in their policies. The president of the European Union, Ursula von der Leyen, stated that the EU envisions to be the world's first climate-neutral continent by 2050 *(EU 2020)*. Costa Rica follows the lead with a robust plan to achieve carbon-neutrality by 2021*(Flagg 2018)*.

'Carbon Neutral Wayanad' is a notable low carbon development project in Kerala that aims to achieve carbon neutral status for the district by balancing its emissions while enhancing the economy of the region and preserving its environment. This project in Wayanad joins the small club of countries that are striving to reduce GHG emissions. Quite distinct from other exemplars, the project is rooted in the principles of democratic decentralization and thus brings people to the center of planning and decision-making.

## 2.2 Striking a balance between Economy and Environment

The trade-off between economy and environment occupies the central stage of discussion surrounding initiatives to address climate change. The mainstream definitions of economic growth, conceived strictly in terms of GDP, preclude the negative environmental externalities created as a result of production and consumption. The Stockholm Conference in 1972 and the publication of the report *Limits to Growth* exposed the trade-off between economic growth and environment and explained how the world cannot embark on a journey of limitless economic growth on a planet with finite resources. Sustainable development was introduced as a resolution to this which sought to revise the idea of development by taking planetary limits into consideration *(World Commission on Environment and Development, 1987)*. Building on the concept of sustainability, low emission development approach for the state of Kerala underscores the need to balance development and GHG emissions. By combining initiatives that aim to curb emissions while boosting the local economy, the study illustrates the possibility of achieving economic development without compromising on environmental conservation. Moreover, the focus on the social, economic, and ecological well-being of the community highlights the need to move beyond traditional productivity definitions of economic growth.

## 2.3 Towards a decentralised model of Climate Action

Kerala model has received accolades for its ability to accomplish social development with limited economic growth. Apart from the strides in social indicators, the model has also been lauded for its sustainability *(Parayil1996; Véron 2001)*. And there remain many important questions about the next phase of this model, particularly considering the imminent dangers from climate change disruptions. It is in this context that this report proposes low carbon development as the next phase of Kerala model of decentralised planning and governance.

Climate change has been recognized as a critical constraint for Kerala's development. Detailing the need to integrate climate change strategies with Kerala's development planning, the Kerala State Action Plan on Climate Change (SAPCC) seeks to address the negative consequences of climate change and thereby reduce the risk associated with it *(DoECC 2014).* The active focus on climate change in development planning in the state is further elaborated in the approach paper to the Thirteenth Five Year Plan *(KSPB 2017)*. The Plan document explicates how climate change adaptation, mitigation, social vulnerability, and future risks should be assessed while formulating the state's development plan. Most importantly, drawing from the long lineage of decentralised governance, the state reaffirms the role of local government initiatives in climate change mitigation and adaptation (*KSPB 2017:53)*.

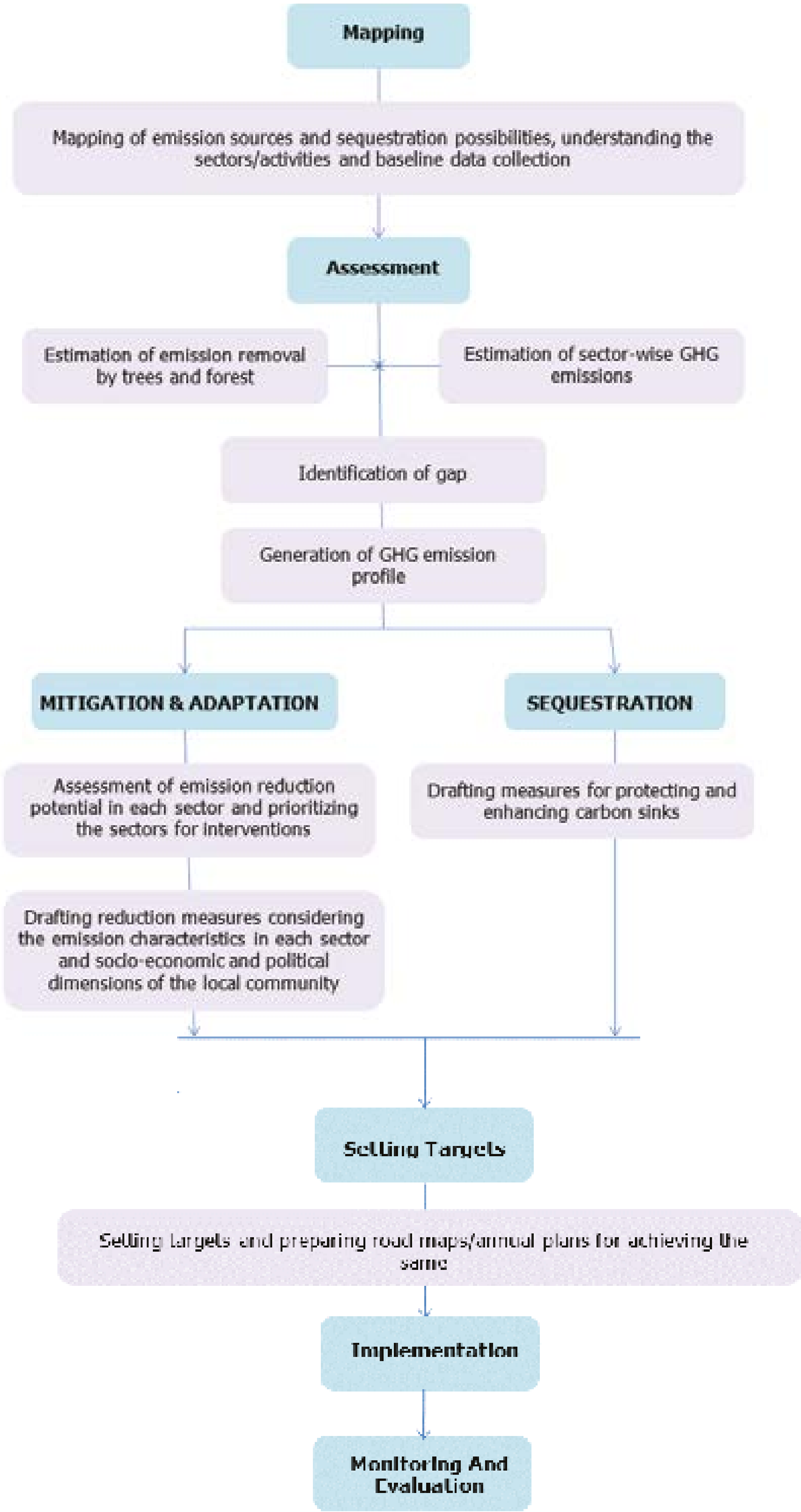
Following the path of the People's Campaign for Decentralised Planning, low carbon development projects in Kerala like 'Carbon Neutral Wayanad' emulates a people-centered approach in design and implementation. The campaign for decentralization in Kerala, hailed as a bottom-up alternative, sought to promote participatory democracy by "mandating structures and processes designed to maximize the direct involvement of citizens in planning and budgeting" *(Heller et al. 2007: 627)*. The agenda for decentralization was expected to facilitate local development by mobilising both people and resources *(Isaac and Harilal 1997; Kannan 2000).*

## 2.4 The Way Forward

The project reaffirms the need to bring climate change to the center of development planning. Climate change mitigation, adaptation, and resilience strategies must inform and underlie the development plans outlined for various sectors, including agriculture, industry, and service in India. In that respect, it is important to envision the goal to achieve carbon neutral status as an umbrella project that demands a coordinated effort from government departments, civil society, organizations and private sector. This assumes greater significance, considering the dominant framing surrounding the trade-off between environment and development in the existing literature. In this respect, the project stands as the next phase of the Kerala model development, where environmental sustainability is addressed by using the tools of people's planning. To conclude, the project seeks to propose 'low emission development' as just a beginning that opens a window to a new era of climate-centered development planning and decision making.

# CHAPTER 3 How can we achieve carbon neutrality?

Carbon neutrality can be achieved through a series of activities starting from the assessment and generation of GHG emission profile of the LSG, analyzing the emission reduction potential, to the drafting and implementation of low-carbon development strategies. The detailed step-by-step process to be carried out to achieve carbon neutrality for a LSG is given in the following flow chart and will be explained in the later parts of this chapter.

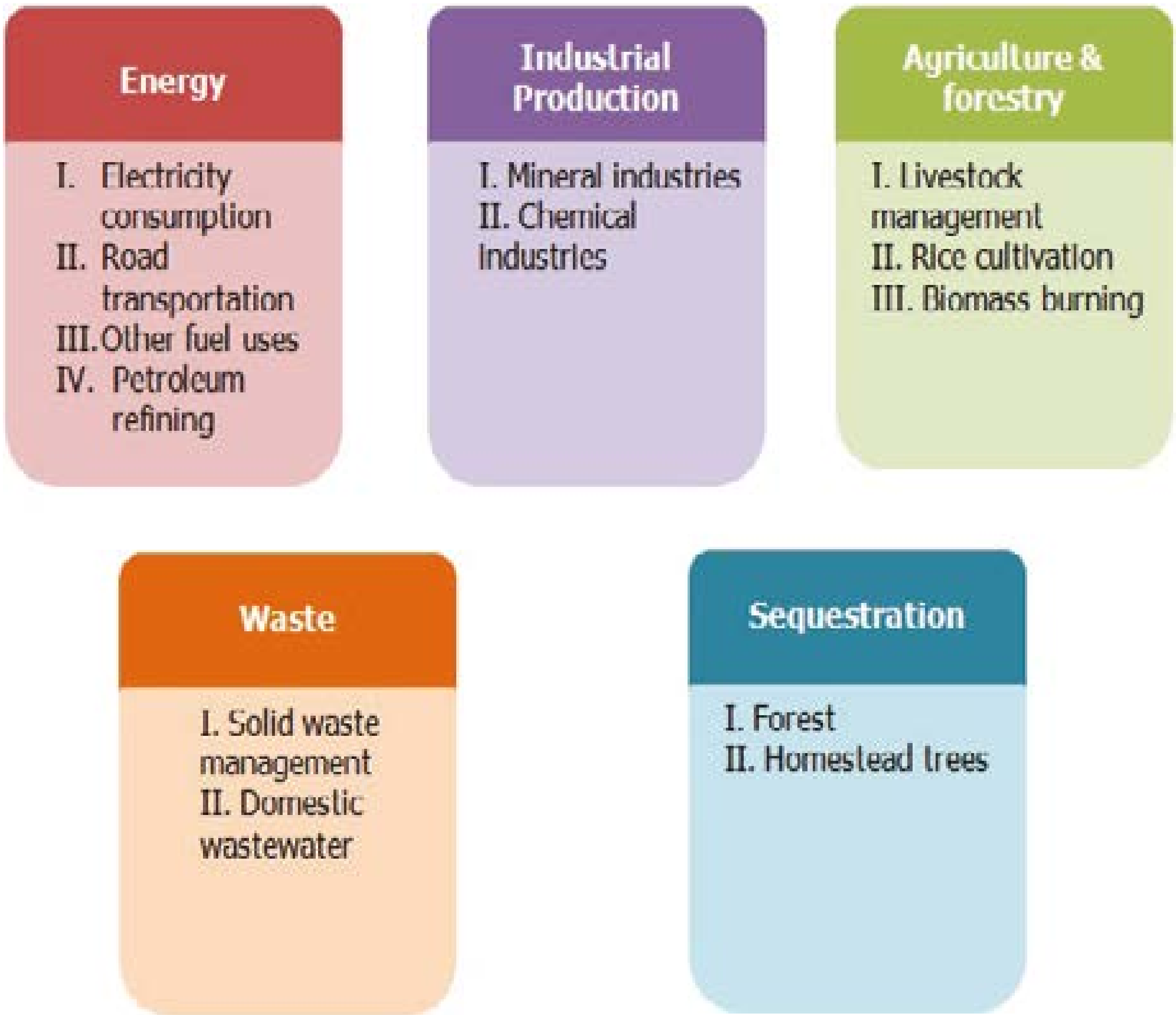

Mapping
Mapping of emission sources and sequestration possibilities, understanding the sectors/activities and baseline data collection
Assessment
Estimation of emission removal by trees and forest
Estimation of sector-wise GHG emissions
Identification of gap
Generation of GHG emission profile
MITIGATION & ADAPTATION
SEQUESTRATION
Assessment of emission reduction potential in each sector and prioritizing the sectors for interventions
Drafting measures for protecting and enhancing carbon sinks
Drafting reduction measures considering the emission characteristics in each sector and socio-economic and political dimensions of the local community
Setting Targets
Setting targets and preparing road maps/annual plans for achieving the same
Implementation
Monitoring And Evaluation

## 3.1 Mapping

The first step to achieve carbon neutrality is to estimate the GHG emissions and sequestration of the LSG. For this, all sources that emit GHG and all sinks that absorb GHG have to be identified. ‘Mapping’ is the initial stage for identifying and understanding all processes and activities that result in the emission and sequestration of GHG and to collect data for baseline emission profile generation of the LSG.

In this handbook, the sources and sinks of three major GHG- $CO_2$, $CH_4$ and $N_2O$- are provided as the emissions of other GHG are negligibly small at a regional level.

To make the mapping and data collection easier, all activities can be grouped into five major sectors that include similar or related sources and sinks, namely, Energy, Industrial Production, Agriculture and Forestry, Waste and Sequestration. The GHG sources in each sector and data to be collected for GHG estimation are explained in detail in the following section. All the activities in each sector included in this handbook are decided based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories and its refinement in 2019.



### 3.1.1 Energy

The Energy sector is comprised of activities that emit GHG by the burning of fuels for the production or conversion of energy. It is the major source of GHG in all economies. The sources of GHG included in the energy sector for the estimation of GHG at local body level are the following.

1. Electricity consumption
2. Road transportation
3. Other fuel uses
4. Petroleum refining
5. Water transportation

Among the above sources, electricity consumption, road transportation and other fuel uses are applicable for all LSGs to generate their emission profile. Petroleum refining and water transportation are limited to a few LSGs in Kerala and hence only needed to be taken into account for LSGs with these activities. Railways and aviation are not included in this handbook for GHG estimation as it does not come under the jurisdiction of any local self government bodies.

#### I Electricity consumption

Electricity can be generated from renewable and non-renewable sources. When it is generated at thermal power plants, coal or other fossil fuels are burned to produce energy to generate electricity which results in the emission of large quantities of $CO_2$. However, Kerala does not have a working thermal power plant but the electricity generated within the state, mostly from hydro-power stations and solar plants, does not meet the demand of the state and hence has to import it from other states and the national grid. According to Kerala State Electricity Board Limited (KSEBL), Kerala generates only 23% of the required electricity within the state and imports 77% from outside the state. The imported electricity is often generated from thermal power plants. Hence the total electricity consumption of each LSG is taken into account to calculate its corresponding GHG emission.

#### II Road transportation

GHG emission from road transportation occurs due to the burning of fossil fuels like petrol, diesel, compressed natural gas (CNG) and liquefied petroleum gas (LPG) in vehicles. $CO_2$ and $N_2O$ are the GHG emitted from vehicles during transportation. Even though vehicles travel within and between LSGs, for the ease of GHG estimation, vehicles registered in the particular LSG should be taken into account. This gives the total GHG emission the LSG is responsible for from road transport.

### III Other fuel uses

Burning of fuel in residential, commercial, institutional and industrial buildings and for agriculture and fishing purposes for energy is another major source of GHG in the energy sector. This includes the burning of kerosene, LPG and firewood in residences, kerosene, petrol and diesel in fishing boats and diesel and LPG consumption for industrial, commercial and institutional purposes which releases significant amount of $CO_2$, $CH_4$ and $N_2O$ into the atmosphere.

### IV Petroleum Refining

Petroleum refining is a major source of GHG because large quantities of fossil fuels are burned in the refineries for on-site electricity generation and heat, which result in the emission of significant amount of GHG. Since there is only a single petroleum refinery in Kerala, the LSG where it is built on should take it into consideration for the estimation of GHG.

### V Water transportation

Water transportation is a source of GHG because of the burning of fossil fuels. Boats in Kerala primarily use diesel engines and since there are extensive networks of water transportation system in Kerala due to the abundant backwaters and lakes, water transportation is a major source of $CO_2$, $CH_4$ and $N_2O$ in the state. However, this mode of transport exists only in a few LSGs and hence this sector is applicable only to those LSGs for the estimation of GHG. Emission from public water transportation and tourist boats are included in this sector.

## 3.1.2 Industrial Production

The Industrial Production sector includes GHG emission from various industrial processes where raw materials undergo chemical or physical change for the manufacturing of the product. Types of industries in Kerala that emits large quantities of GHG during the manufacturing of products are mineral, metal, and chemical industries. Some of the industries in the state that emits significant amount of $CO_2$ and/or $CH_4$ as byproducts are industries that produce Cement, Carbon black, Titanium dioxide and Silicon Carbide. The emission estimation for this sector is applicable only for LSGs with mineral and chemical industries within their local boundary as these industries could contribute significant amount to the total emission of the LSG.

### 3.1.3 Agriculture and Forestry

The Agriculture and Forestry sector includes GHG emission sources related to agriculture and forests. The GHG emission sources included in this sector are:

1. Livestock management
2. Rice cultivation
3. Biomass burning

All these sources are not applicable to all LSGs in Kerala. These sectors should be taken into account for GHG estimation of a LSG only if these activities exist in the LSG.

#### I Livestock management

Livestock such as cattle, sheep, goats, etc. emits $CH_4$ as a result of enteric fermentation and manure management. Livestock farming is one of the major livelihoods for the people of Kerala, especially the rural population. Hence emission from livestock is a key source of GHG in the agriculture sector.

#### II Rice cultivation

GHG emission from rice cultivation is due to the decaying of organic matter in flooded paddy fields. This process emits significant amount of $CH_4$. Since many areas in Kerala cultivate rice in flooded fields, rice cultivation is a major source of GHG in the state and will be a significant source for LSGs with extensive flooded paddy cultivation.

#### III Biomass burning

Biomass or organic matter emits $CO_2$, $CH_4$ and $N_2O$ during burning. The major source of GHG due to biomass burning is forest fire and burning of agricultural residue after harvest. Kerala faces forest fires annually during summer. Several LSGs in Kerala has extensive forest range that is vulnerable to fires and hence forest fires are significant sources of GHG emission in this sector.

In some parts of Kerala, burning agricultural residue after harvest, especially for rice cultivation, is a common practice and is another major source of GHG. Even though burning of rice residue emits $CO_2$, $CH_4$ and $N_2O$, it is assumed that the $CO_2$ is absorbed back through re-growth of the area thereby equaling the emission and removal of $CO_2$. Hence only non-$CO_2$ emissions are considered in this sector.

### 3.1.4 Waste

The Waste sector is comprised of GHG emitting sources like waste disposal sites, landfills, wastewater etc. where waste is either burned or let to decay. For this handbook, the sources taken into account for emission estimation are solid waste management and wastewater from domestic activities. Solid waste emits $CH_4$ due to the decomposition of organic matter whereas wastewater emits $CH_4$ and $N_2O$.

### 3.1.5 Carbon Sequestration

Carbon sequestration is the process in which atmospheric carbon or $CO_2$ is removed or absorbed by various carbon sinks. The major carbon sinks included in this sector are forest cover and trees outside forest (TOF). Trees absorb large quantities of $CO_2$ that can cause evident changes in the GHG emission profile of a LSG.

**Infobox 2** **Carbon sinks**

A carbon sink is any reservoir, natural or otherwise, that absorbs more carbon than it releases into the atmosphere, thereby reducing the atmospheric concentration of carbon. Forests and vegetation are the major carbon sinks on land that absorb significant quantities of $CO_2$.

### 3.1.6 Sources for data collection

The table given below shows the data to be collected for each sector to calculate its corresponding GHG emission. As GHG assessment will be carried out for a particular year, data should be collected for that particular baseline year which can be calendar year or financial year. The year of assessment should be decided based on the format of data availability, which is usually financial year for all government data.

Table 1 Sectors, sub-sectors and activity data for GHG assessment

| SECTOR | SUB SECTOR | ACTIVITY DATA |
|---|---|---|
| Energy | Electricity | Tariff wise electricity consumption |
| | Road transportation | Number of vehicles registered with vehicle category, engine type and fuel type |
| | Other fuel uses | LPG, kerosene and firewood consumption in residences<br><br>Petrol, diesel and kerosene consumption in fishing boats<br><br>Diesel and LPG consumption in commercial, industrial and institutional activities |
| | Petroleum refining | Annual crude oil consumption |
| | Water transportation | Annual diesel consumption |
| Industrial production | Mineral industries - cement | Annual production statistics / Annual raw material consumption for each products |
| | Chemical industries | Annual production statistics / Annual raw material consumption for each products |
| Agriculture and Forestry | Livestock – Enteric fermentation & Manure management | Livestock census |
| | Rice cultivation | Area of flooded rice cultivation |
| | Biomass burning | Area burnt during forest fire and quantity of crop production for agriculture residue burning |
| Waste | Solid waste management | Amount of solid waste generated and type of disposal measures |
| | Domestic wastewater | Amount of domestic wastewater generated and its treatment measures. |
| Sequestration | Forest | Area under forest cover |
| | Homestead trees | Number of trees in each species with age, height and width |

## 3.2 Assessment

Assessment is the stage where the GHG emission and sequestration in an LSG is estimated and an emission profile is generated. Data collected in the previous stage is analyzed and GHG emission and carbon sequestration is calculated in this stage to identify the gap to determine whether the LSG is carbon neutral or not. The following section provides detailed steps to assess the data collected to generate the emission profile of an LSG.

### 3.2.1 Basic equation for emission estimation

The methodology used for emission calculation in this handbook is developed by the Inter-governmental Panel on Climate Change (IPCC), which is based on a simple equation given below:

| Equation 1 |
|---|
| Emission estimate = Activity data x Emission factor |

Where,

**Activity data –** data on the magnitude of human activity resulting in emissions or removals taking place during a given period of time. It describes the annual, national magnitude of an activity (e.g. tonnes of coal mined nationally in a given year) *(IPCC, 2006).*

**Emission factor –** average emission rate of a given GHG for a given source, relative to units of activity. It is the mass of GHG emitted per unit of activity (e.g. $CH_4$ per tonnes of coal mined) *(IPCC, 2006).*

As mentioned before, only emissions of $CO_2$, $CH_4$ and $N_2O$ are considered in this handbook for the assessment. For the ease of representation, $CH_4$ and $N_2O$ are converted to the terms of $CO_2$, which is called the $CO_2$ equivalent ($CO_2$ eq.) emissions. To convert $CH_4$ and $N_2O$ emissions to $CO_2$ eq., they are multiplied with a standard value termed as the Global Warming Potential (GWP).

Table 2 Global Warming Potential of GHG

| Gases | Global Warming Potential (AR5) |
|---|---|
| $CO_2$ | 1 |
| $CH_4$ | 28 |
| $N_2O$ | 265 |

The GWP values are generated by IPCC and the values used in this handbook are the updated GWP values from IPCC Fifth Assessment Report (AR5), 2014.

### 3.2.2 Energy

The detailed steps to assess GHG emission from energy sector are given in the following section.

#### I Electricity Consumption

Emission from this activity is the sum of product of tariff-wise electricity consumption of the LSG in **MWh** and its emission factor. The emission factor used here was generated by the Central Electricity Authority (CEA) for all types of electricity generation in India. The equation for GHG estimation from electricity consumption is given below.

| Equation 2 |
|---|
| GHG Emission = ∑ (Electricity consumption in each tariff x Emission factor) |

Tariffs under which electricity consumption can be analyzed are:

- Domestic
- Commercial
- Industrial
- Agriculture
- Streetlights
- Other

Table 3 GHG emission factor for electricity *(Central Electricity Authority, 2018)*

| Emission factor | Unit |
|---|---|
| 0.82 | t $CO_2$/MWh |

#### II Road transportation

GHG emission from road transportation is the sum of the product of total number of each type of vehicles, emission factors for each fuel and vehicle type, its corresponding Annual Average Covered Distance (AACD) and GWP values. The general equation for the estimation of emissions from a vehicle is given below:

| Equation 3 |
|---|
| Total Emissions = ∑ Emissions from each category of vehicles |

For the accurate calculation of GHG emissions, vehicles are broadly classified into two wheelers, three wheelers, Light Motor Vehicles (LMVs), three-wheeled goods carriages, other goods carriages and buses. The number of vehicles in each category can be collected from the Motor Vehicles Department of Kerala (MVD) or from a survey. The detailed steps to estimate emission from each type of vehicle is explained in the following section.

| Equation 4 |
|---|
| Emissions from each type of vehicle = $CO_2$ emission + ($N_2O$ emission x GWP of $N_2O$) |
| $CO_2$ Emissions = No. of vehicles x AACD x $CO_2$ Emission factor |
| $N_2O$ emission = No. of vehicles x AACD x $N_2O$ Emission factor |

### i) Two wheelers

GHG emission from two-wheelers can be estimated using **Equation 4**, for which the AACD and emission factors for two wheelers are given in the table below.

Table 4 Coefficients for emission calculation from two wheelers *(WRI India, 2015), (Ramachandra & Shwetmala, 2009)*

| Sl. No | Category | Engine CC | Emission Factors | | AACD (km) |
|---|---|---|---|---|---|
| | | | $kgCO_2$/km@10uplift factor | g $N_2O$/km | |
| 1 | Motorcycle | <110 CC | 0.0368 | 0.19 | 6300 |
| 2 | Motorcycle | <500 CC | 0.0597 | | |

### ii) Three wheelers

GHG emission from three-wheelers can be estimated using **Equation 4** and the corresponding AACD and emission factors are given in the table below.

Table 5 Coefficients for emission calculation for three wheelers (*WRI India, 2015), (Ramachandra & Shwetmala, 2009)*

| Sl. No | Category | Emission Factors | | AACD (km) |
|---|---|---|---|---|
| | | kg $CO_2$/ km | g $N_2O$/ km | |
| 1 | Petrol | 0.1135 | 1.28 | 33500 |
| 2 | Diesel | 0.1322 | | |
| 3 | CNG | 0.10768 | | |

### iii) Light Motor Vehicles (LMV)

GHG emission from LMV can be estimated using **Equation 4** and the AACD and emission factors for the calculation are given in the table below.

Table 6 Coefficients for emission calculation for LMV *(WRI India, 2015), (Ramachandra & Shwetmala, 2009)*

| Sl. No. | Type of Car | Category | Fuel | Emission Factors | | AACD (km) |
|---|---|---|---|---|---|---|
| | | | | (kg $CO_2$/ km) with uplift factor | g $N_2O$/ km | |
| 1 | Small | <800 CC | CNG | 0.068 | 0.2 | 12600 |
| 2 | Small | <800 CC | LPG | 0.149 | | |
| 3 | Premium SUV | >3000 CC | Gasoline | 0.289 | | |
| 4 | Premium SUV | >3000CC | Diesel | 0.290 | | |

### iv) Goods Carriages

Emission from three-wheeler goods carriages can be estimated using **Equation 4**, for which the AACD and emission factors are provided in *Table 5* above.

GHG emission from goods carriages other than three-wheeled can also be estimated using **Equation 4** and the corresponding AACD and emission factors are given in the table below.

Table 7 Coefficients for emission calculation for goods carriages *(WRI India, 2015), (Ramachandra & Shwetmala, 2009)*

<table>
<tr><th rowspan="2">Sl. No.</th><th rowspan="2">Category</th><th colspan="2">Emission Factors</th><th rowspan="2">AACD<br>(km)</th></tr>
<tr><th>kg $CO_2$/km</th><th>g $N_2O$/km</th></tr>
<tr><td>1</td><td>LDV (<3.5T)</td><td>0.3070</td><td rowspan="3">1.3</td><td rowspan="3">63000</td></tr>
<tr><td>2</td><td>MDV (<12T)</td><td>0.5928</td></tr>
<tr><td>3</td><td>HDV (>12 T)</td><td>0.7375</td></tr>
</table>

v) **Buses**

GHG emission from buses can be estimated using **Equation 4** and the corresponding AACD and emission factors are given in the table below.

Table 8 Coefficients for emission calculation for buses *(Ramachandra & Shwetmala, 2009)*

| Emission Factors | | AACD |
|---|---|---|
| kg $CO_2$/km | g $N_2O$/km | (km) |
| 0.328 | 1.2 | 100000 |

### III Other fuel uses

GHG emission from fuel usage in other sectors can be calculated with the following general equation.

**Equation 5**

Total Emissions = $CO_2$ emission + ($CH_4$ emission x GWP of $CH_4$) + ($N_2O$ emission x GWP of $N_2O$)

Where,

$CO_2$ emission= fuel consumed in kt* x NCV$^{\#}$ x Emission Factor of $CO_2$

$CH_4$ emission = fuel consumed in kt x NCV x Emission Factor of $CH_4$

$N_2O$ emission = fuel consumed in kt x NCV x Emission Factor of $N_2O$

**kt – kilotonnes*

#NCV – Net Calorific Value*

Activity data for the estimation of GHG emission is annual consumption of each fuel and default emission factors for corresponding fuel type provided by IPCC can be used. The detailed steps to calculate GHG emission from each activity under other sectors is given in the following section.

### i) Residential fuel usage

GHG emission from residential usage of kerosene, LPG and firewood are considered in this section for the estimation of GHG emission using **Equation 5**. The emission factors for estimating the three different GHGs and NCV are given in the table below.

Table 9 Coefficients for emission calculation from Kerosene usage *(IPCC, 2006)*

| Coefficients for emission calculation | Value |
|---|---|
| NCV | 43.8 TJ/kt |
| Emission Factor for $CO_2$ | 71.9 tonnes/TJ |
| Emission Factor for $CH_4$ | 0.01 tonne/TJ |
| Emission Factor for $N_2O$ | 0.0006 tonne/TJ |

Table 10 Coefficients for emission calculation for LPG usage *(IPCC, 2006)*

| Coefficients for emission calculation | Value |
|---|---|
| NCV | 47.3 TJ/kt |
| Emission Factor for $CO_2$ | 63.1 tonne/TJ |
| Emission Factor for $CH_4$ | 0.005 tonne/TJ |
| Emission Factor for $N_2O$ | 0.0001 tonne/TJ |

Table 11 Coefficients for emission calculation for firewood usage

| Coefficient for emission calculation | Value |
|---|---|
| NCV | 15.67 TJ/kt |
| Emission Factor for $CO_2$ | 11.2 t/TJ |
| Emission Factor for $CH_4$ | 300 kg/TJ |
| Emission Factor for $N_2O$ | 4 kg/TJ |

### ii) Fishing Sector

GHG emission from the burning of kerosene, petrol and diesel in fishing boats can be calculated using **Equation 5**. The NCV and emission factors for each type of fuel for emission estimation are given in the table below.

Table 12 Coefficients for emission calculation in fishing sector *(IPCC, 2006)*

| Fuel | NCV (TJ/kt) | $CO_2$ (t/TJ) | $CH_4$ (kg/TJ) | $N_2O$ (kg/TJ) |
|---|---|---|---|---|
| Kerosene | 43.80 | 71.90 | 10.00 | 0.60 |
| Petrol | 44.30 | 69.30 | 10.00 | 0.60 |
| Diesel | 43.00 | 74.10 | 10.00 | 0.60 |

### iii) Miscellaneous fuel consumption

GHG emission from this sector includes burning of diesel in generators and LPG usage in industrial, commercial and institutional buildings which can be calculated with **Equation 5**. NCV and emission factors for emission estimation from miscellaneous diesel consumption are given in the table below. The coefficients for emission estimation from LPG usage are given in *Table 10* above.

Table 13 Coefficients for emission calculation from miscellaneous diesel consumption *(IPCC, 2006)*

| Fuel | NCV (TJ/kt) | $CO_2$ (t/TJ) | $CH_4$ (kg/TJ) | $N_2O$ (kg/TJ) |
|---|---|---|---|---|
| Diesel | 43.00 | 74.10 | 3.00 | 0.60 |

## IV Petroleum refining

In refineries, 6-10% of crude oil for refining is combusted for on-site purposes. So on average, 8% of crude oil consumed can be taken as activity data for the calculation of GHG emission from petroleum refining. Emission can be estimated using the following equation and the NCV and emission factors for the same are given in the table below.

| Equation 6 |
|---|
| Emissions = Crude oil combusted x NCV x Emission factor |

Table 14 Coefficients for emission calculation in Petroleum Refining *(IPCC, 2006)*

| NCV (TJ/kt) | Emission Factor ($t\ CO_2/TJ$) |
|---|---|
| 42.3 | 73 |

### V Water Transport

GHG emission from tourist boats and boats under the public water transportation system can be estimated with **Equation 7** given below. Total consumption of fuel in the baseline year in **kt** units is taken as the activity data.

| Equation 7 |
|---|
| Total Emissions = $CO_2$ emission + ($CH_4$ emission x GWP of $CH_4$) + ($N_2O$ emission x GWP of $N_2O$) |

Where,

$CO_2$ emission= fuel consumed in kt x NCV x Emission Factor of $CO_2$

$CH_4$ emission = fuel consumed in kt x NCV x Emission Factor of $CH_4$

$N_2O$ emission = fuel consumed in kt x NCV x Emission Factor of $N_2O$

Table 15 Coefficients for emission calculation for Water-borne Navigation *(IPCC, 2006)*

| Fuel | NCV (TJ/kt) | $CO_2$(t/TJ) | $CH_4$ (kg/TJ) | $N_2O$ (kg/TJ) |
|---|---|---|---|---|
| HSDO | 43.00 | 74.10 | 3.90 | 3.90 |

## 3.2.3 Industrial Production

Four major industrial productions in Kerala have been identified for the estimation of GHG- cement, Carbon black, Titanium dioxide ($TiO_2$) and Silicon carbide. Total GHG emission is the sum of product of activity data, emission factor and corresponding GWP values. The emissions from these can be estimated using the general equation given below.

| Equation 8 |
|---|
| Total Emissions =∑ ( (Production Quantity x $CO_2$ Emission factor) + (Production Quantity x $CH_4$ Emission factor x GWP of $CH_4$)* ) |

**$CH_4$ emission is only applicable for Carbon black and Silicon carbide.*

The list of activity data and emission factor for each type of industrial production is given in the table below.

Table 16 Activity data and Emission factors for GHG estimation in Industry sector

| Product | | Activity Data | Emission factors |
|---|---|---|---|
| Cement | Ordinary Portland Cement (OPC) | 0.95 of OPC produced in tonnes (which is the amount of clinker) | $CO_2$ = 0.52 tonne $CO_2$ / tonne of Clinker |
| | Portland Pozzolana Cement (PPC) | 0.75 of PPC produced in tonnes (which is the amount of clinker) | |
| Carbon Black | | Annual production in tonnes | $CO_2$ = 2.62 tonnes $CO_2$ / tonne of Carbon black<br>$CH_4$ = 28.7 kg $CH_4$ / tonne of Carbon black |
| Titanium dioxide(-$TiO_2$) | | Annual production in tonnes | $CO_2$ = 1.34 tonnes $CO_2$ / tonne of $TiO_2$ |
| Silicon carbide | | Annual production in tonnes | $CO_2$ = 2.62 tonne $CO_2$ / tonne of Silicon carbide<br>$CH_4$ = 11.6 kg $CH_4$ / tonne of Silicon carbide |

### 3.2.4 Agriculture and Forestry

Detailed method to calculate GHG emissions from livestock management, rice cultivation and biomass burning are explained in this section.

#### I Livestock management

Livestock management includes $CH_4$ emissions from enteric fermentation in livestock animals and $CH_4$ emissions from manure management of livestock animals and poultry. $CH_4$ emissions from both activities are the sum of product of the total number of livestock in the panchayat, its corresponding emission factors and GWP value of $CH_4$. The following equation can be used to estimate $CH_4$ emissions from livestock management.

**Equation 9**

Total Emissions =∑ ( (No. of Livestock x Enteric Fermentation Emission factor x GWP of $CH_4$) + (No. of Livestock x Manure Management Emission factor x GWP of $CH_4$) )

The emission factor for enteric fermentation and manure management are given in the table below.

Table 17 Coefficients for emission calculation for livestock *(IPCC, 2019)*

| Livestock | Enteric Fermentation emission factor kg $CH_4$/head/year | Manure Management emission factor kg $CH_4$/head/year |
|---|---|---|
| Cattle | 46 | 2 |
| Buffalo | 85 | 5 |
| Sheep | 5 | 0.21 |
| Goat | 5 | 0.22 |
| Swine | 1 | 6 |
| Poultry | - | 0.023 |

#### II Rice cultivation

$CH_4$ emission from flooded rice cultivation is the product of total area of flooded rice fields in the baseline year, its corresponding emission factor and the GWP value for $CH_4$. Emissions can be estimated using the equation given below:

| Equation 10 |
|---|
| Total Emissions = Area of flooded rice cultivation x $CH_4$ Emission factor x GWP of $CH_4$ |

Table 18 Coefficients for emission calculation for Rice cultivation *(IPCC, 2019)*

| |
|---|
| Emission Factor for $CH_4$ = 9 g/sq.m. |

### III Biomass Burning

Biomass burning includes sources that emit GHG like forest fires and burning of agricultural residue for rice cultivation. The methods to estimate GHG emissions are explained below.

#### i) Forest fire

GHG emission from forest fire is the sum of product of total area of forest burnt during fire in the LSG in the baseline year, mass of fuel available for combustion, combustion factor, emission factors of $CO_2$, $CH_4$ and $N_2O$ and their corresponding GWP values. The equation for emission estimation is as follows.

| Equation 11 |
|---|
| Total Emissions = $CO_2$ emission + ($CH_4$ emission x GWP of $CH_4$) + ($N_2O$ emission x GWP of $N_2O$) |

Where,

$CO_2$ emissions = Area x Mass of fuel available for combustion x Combustion Factor x $CO_2$ Emission factor

$CH_4$ emissions = Area x Mass of fuel available for combustion x Combustion Factor x $CH_4$ Emission factor

$N_2O$ emissions = Area x Mass of fuel available for combustion x Combustion Factor x $N_2O$ Emission factor

Table 19 Coefficients for emission calculation from forest biomass burning *(IPCC, 2019)*

| |
|---|
| Mass of fuel available for combustion = 13.12 t/ha |
| Combustion Factor = 0.36 |
| Emission Factor for $CO_2$ = 1670 g/kg |
| Emission Factor for $CH_4$ = 9 g/kg |
| Emission Factor for $N_2O$ = 0.11 g/kg |

### ii) Agricultural residue burning for rice

Burning of agricultural waste after harvest emits GHG which can be calculated using the following equation.

| **Equation 12** |
|---|
| Total Emissions = ($CH_4$ emission x GWP of $CH_4$) + ($N_2O$ emission x GWP of $N_2O$) |

Where,

$CH_4$ emission= quantity of crop produced x *a* x *b* x *c* x *d* x Emission factor of $CH_4$

$N_2O$ emission =quantity of crop produced x *a* x *b* x *c* x *d* x Emission factor of $N_2O$

Where:

a = residue to crop ratio,

b = dry matter fraction,

c = fraction burnt,

d = combustion factor

Table 20 Coefficients for GHG emission from agriculture residue burning for rice *(IPCC, 2019)*

| | |
|---|---|
| Residue to Crop Ratio | 1.50 |
| Dry Matter Fraction | 0.86 |
| Fraction Burnt | 0.08- 0.80 |
| Combustion factor | 0.89 |
| Emission factor for $CH_4$ | 2.7 g/kg |
| Emission factor for $N_2O$ | 0.07 g/kg |

## 3.2.5 Waste

Solid waste management and domestic wastewater are the major sources of GHG in the waste sector. The detailed steps to estimate GHG emissions from both sectors are given in the following section.

### I Solid waste management

Solid waste emits large quantities of $CH_4$ which can be estimated with the following equation. Annual generation of waste in the LSG in tonnes is taken as the activity data for emission estimation.

**Equation 13**

$$\text{Total Emissions} = SWM_{commercial} + SWM_{domestic}$$

**Equation 13a**

$$SWM_{commercial} = CO_2\ \text{Emission} + CH_4\ \text{Emission}$$

Where,

$CO_2$ emission = Annual waste generation x $CO_2$ emission factor

$CH_4$ emission = Annual waste generation x $CH_4$ emission factor x GWP of $CH_4$

| | |
|---|---|
| $CO_2$ emission factor | 0.165 kg of $CO_2$ / kg of waste |
| $CH_4$ emission factor | 0.013 kg of $CH_4$ / kg of waste |

Where,

| Equation 13b |
|---|
| $SWM_{domestic}$ = Annual waste generation x Emission factor |

Emission factor = 0.541 tonne $CO_2$ eq./ tonne of waste

### II Domestic wastewater

GHG emission from domestic wastewater can be calculated with the equations given below.

| Equation 14 |
|---|
| Total Emissions = ($CH_4$ emission x GWP of $CH_4$) + ($N_2O$ emission x GWP of $N_2O$) |

| Equation 14a |
|---|
| $CH_4$ Emissions = $\sum_{i,j} [(U_i \times T_{i,j} \times EF_j)] (TOW - S)$ |

Where,

Ui - fraction of population in income group i in inventory year

Ti,j - degree of utilization of treatment/discharge pathway or system 'j' for each income group fraction 'i' in inventory year

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

j - each treatment/discharge pathway or system

EFj - Emission factor, kg $CH_4$/kg BOD

S - Organic Component removed as Sludge in inventory year, kg BOD/year

Table 22 Coefficients for $CH_4$ emission from domestic wastewater

| Income group (i) | Treatment/discharge pathway or system (j) | Degree of utilization of treatment/Discharge pathway or system j, for each income group fraction i (Ti,j), 2011 | Emission Factor (EFj) |
|---|---|---|---|
| Rural | Septic Tank (uncollected) | 0.446 | 0.3 |
| | Latrine (uncollected) | 0.34 | 0.06 |
| | Public Latrine (Uncollected) | 0.012 | 0.3 |
| | Sewer (Open and closed drainage) | 0.099 | - |
| | Other & None (Uncollected) | 0.103 | 0.06 |
| Urban | Septic Tank | 0.567 | 0.3 |
| | Latrine | 0.218 | 0.06 |
| | Public Latrine | 0.009 | 0.3 |
| | Sewer | 0.143 | - |
| | Others/None | 0.063 | 0.06 |

TOW can be estimated using the equation shown below.

**Equation 14b**

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

Where,

P – Population of local body during the inventory year

BOD – Biochemical Oxygen Demand

I - correction factor for additional industrial BOD discharged into sewers

| Equation 14c |
|---|
| $N_2O\ \text{emissions} = N_{EFFLUENT} \times EF_{EFFLUENT} \times (44/28)$ |

Where,

$N_{EFFLUENT}$ - Nitrogen in the effluent discharged to aquatic environments, kg N/yr

$EF_{EFFLUENT}$ - Emission Factor for $N_2O$ emissions from discharged to wastewater, kg $N_2O$-N/kg N

44/28 - The factor is the conversion of kg $N_2O$-N into kg $N_2O$

Table 23 Coefficients for estimation of $N_2O$ emission from domestic wastewater

| Parameters | Urban | Rural |
|---|---|---|
| Annual Per capita protein Intake kg/person/year | 21.80875 | 21.097 |
| Fraction of Nitrogen in Protein (F FNPR) | 0.16 | 0.16 |
| Factor for Non Consumed Protein Added to Waste Water (F NON CON) | 1.4 | 1.4 |
| Factor for Industrial and commercial co-discharged protein into the sewer system (FIND-COM) | 1.25 | 1.25 |
| Nitrogen removed with sludge (N SLUDGE), kg N/year | 0 | 0 |
| Emission Factor for $N_2O$ emissions from discharged to waste-water (EFEFFLUENT), kg $N_2O$-N/kg N | 0.01 | 0.01 |

## 3.2.6 Sequestration

The amount of carbon stored annually is essential to generate the emission profile of an area. The same can be estimated by analysing the vegetation cover inside the urban local body.

### I Forests

The total forest cover inside the administrative boundary can be the base data for analysing the incremental growth in carbon stock of forest. The per hectare incremental growth obtained from the carbon stock values of alternate years (2013, 2015, 2017), published by Forest Survey India (FSI) can be used as the stock increment value to obtain obtain the annual carbon sequestration by forest.

| Equation 15 |
|---|
| Annual sequestration by forest cover = Area of forest cover X Annual increment in carbon stock |

Where,

Annual increment in carbon stock in Kerala forests = -13.7024 tonne $CO_2$/hectare

## II Homestead trees

Carbon sequestration in trees in homesteads can be estimated using **Equation 16** given below. The height and girth at breast height (GBH) or circumference at breast height (CBH) of each tree under each species is required for this estimation. Breast height of a tree is usually taken as 1.4 m above ground level.

| Equation 16 |
|---|
| Annual $CO_2$ Sequestration = ( (Total Biomass / 2) x 3.6663) / Age of tree |

Where,

Total biomass = Above Ground Biomass (AGB) + Below Ground Biomass (BGB)

AGB (in g) = volume of biomass (in cu. cm) x wood density (in g/cu. cm)

BGB (in g) = 0.26 x AGB (in g)

Volume of biomass (in cu. cm) = $\pi r^2 H$

H = height of the tree in cm

r = radius of the tree in cm [ radius 'r' can be obtained from the CBH value, which is $2\pi r$]

## 3.3 Mitigation and Adaptation measures

After the generation of GHG emission profile of the local self government, it will be clear whether it is carbon-positive, carbon-negative or carbon neutral. If the panchayat is carbon-positive, measures should be taken to reduce the emissions and increase sequestration to achieve carbon neutrality. In the case of carbon-negative and carbon-neutral panchayats, measures should be taken to maintain that state and to further prevent any rise in GHG emissions and to become a sustainable economy. Some of the measures to be adopted to achieve or to remain carbon neutral are explained in the following section.


Figure 1 Climate Mitigation measures

Table 24 Project ideas for GHG emission reduction

| Sl. No. | Project ideas to reduce GHG emission | GHG emission reduction |
|---|---|---|
| 1 | Roof top solar panels | Converting 1 MWh unit of electricity consumption to renewable sources can reduce 820 kg of $CO_2$ eq. |
| 2 | Wind energy harvesting | |
| 3 | Solar lights and equipments | |
| 4 | Replacing other bulbs with LED | |
| 5 | Using thermo boxes to cook | |
| 6 | Using star rated equipments | |
| 7 | Using solar water heaters | |
| 8 | Reducing electricity consumption and increasing efficiency | |
| 9 | Using electric two-wheelers | Reduce 0.082 kg$CO_2$ eq. per km of travel |
| 10 | Phase-out fossil fuel cars and use electric cars or other renewable fuels | Can reduce 0.28 kg$CO_2$ eq. per km of car travel |
| 11 | Avoid cars to travel short distance and use public transportation system | |
| 12 | Convert autorikshaws to electric or run on other renewable fuels | Reduce 0.4 kg$CO_2$ eq. per km. of travel |
| 13 | Convert buses to electric and other renewable options | Reduce 0.83 kg$CO_2$ eq. per km of bus travel |
| 14 | Promote local production to reduce goods transportation | Can reduce 0.86 kg$CO_2$ eq. per km of travel |
| 15 | Convert goods carriages to electric or run on renewable fuels | |
| 16 | Source level composting | Effective waste management reduces 530 kg$CO_2$ eq. per tonne of waste generated |
| 17 | Installing biogas plants | |

Along with mitigation measures, adaptation measures should also be carried out to tackle climate change. 'Climate Adaptation' refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. Some of the adaptation measures are:

- Increasing awareness among communities about climate change and its adverse consequences
- Training communities vulnerable to climate disasters to increase their resilience to extreme weather events and to face climate threats
- Allocating areas to host people affected by climate change effects prior to disasters
- Providing funds exclusively for disasters related to climate change effects to vulnerable communities
- Building flood defenses
- Setting up early warning systems for cyclones
- Switching to drought/flood-resistant crops
- Redesigning communication systems, business operations and government policies
- Climate Education


Figure 2 Climate Adaptation measures

All the mitigation and adaptation measures drafted to face human-induced climate change by becoming a carbon neutral society should be just, transparent, gender-responsive, participatory and inclusive.

## 3.4 Sequestration measures

Carbon sequestration measures are essential for achieving carbon neutrality. They complement the mitigation and adaptation measures by preserving and increasing existing/new carbon sinks to transform to a low-carbon economy. Adopting sequestration measures helps increase the carbon sequestration rate which thereby reduces the overall GHG emission of a region.

1. **Afforestation** – planting trees increases carbon sequestration. Some of the afforestation methods are avenue planting (planting trees along roads or streets), rooftop trees, urban forest (creating forest-like spaces in cities), planting more trees at home (homestead trees) and restoring degraded land and forest areas.
2. **Carbon farming** – farming practices to increase carbon sequestration. Eg. Managed bamboo forests – Bamboo has the highest rate of carbon sequestration. Planting bamboo forest increases carbon sequestration while also improving the livelihood of people by becoming a source of income. Matured bamboo can be cut and sold for various purposes and more bamboo can be planted again at its place.
3. **Multistrata agroforestry** – these are multi-layered agricultural systems with several types of crops and trees cultivated together to improve degraded soil system, prevent erosion and flooding, recharge groundwater table and increase biodiversity.
4. **Food forest** – these are agricultural systems that resemble forest but filled with food trees. Food forest increases carbon sequestration while also providing food materials for the region.
5. **Restoration and conservation of Mangroves –** as mangroves are one of the largest carbon sinks in the world, often termed as 'blue carbon', restoring mangrove forests increases carbon sequestration significantly. Kerala has many mangrove forest strips along its coastlines and restoring and conserving it not only helps in sequestration but also increases biodiversity and prevent sea encroachment and tides.

These measures create job opportunities for people, especially for women, to manage food forests, agroforests etc. Carbon sequestration measures have multiple benefits including carbon removal, acts as a source of income, ensures food security and improves ecosystem and biodiversity.

## 3.5 Setting targets

Once measures are drafted to reduce GHG emissions and improve carbon sequestration, targets has to be set to achieve carbon neutrality. Short-term, medium term and long-term goals can be formulated to achieve net-zero emission by incorporating it into the development plans.

An example to set target to achieve carbon neutrality is the 2030 Agenda for Sustainable Development and the Sustainable Development Goals (SDGs) by the United Nations. Based on the agenda, the world should reach sustainability by 2030 by eradicating poverty, hunger and inequalities. There are 17 goals and 169 targets associated with it set to achieve environmental and socio-economic sustainability by 2030. The LSGs can set their goals based on the SDGs and corresponding targets. The 17 SDGs range from reducing poverty to climate action. The following figure explains the 17 SDGs.


Figure 3 Sustainable Development Goals

Achieving carbon neutrality involves actions that directly respond to the 13th goal- Climate Action- while indirectly responds to many others like Goals 3, 5, 7, 8, 9, 10, 11, 12, 15 and 17. Climate action in energy efficiency can increase the access to energy and reduce energy expenditure (SDG 1, 7), can improve health (SDG 3), reduce pollution (SDG 11, 14, 12) and also improve economic productivity (SDG 8, 9). The reduced usage of fossil fuels in vehicles, energy industries and households helps to cut down emissions and provide us cleaner and fresher air. This can ensure improvement in quality of life (SDG 3). The LSGs should keep in mind that achieving carbon neutrality is a step to achieve sustainable development and hence setting targets that corresponds to these goals can aid immensely in achieving multiple goals with a few schemes.

## 3.6 Implementation

Implementation is the stage in which the finalized measures and targets are executed in the LSG to achieve the desired objectives. These can be performed through annual plans of the LSG with the help of public participation, stakeholder consultations, and inter-departmental coordination. Low carbon development should be given priority in the formation of action plans and development plans in the LSG. Each and every project of the LSG should be implemented only after carrying out an emission analysis to estimate the impact and GHG emission of the activity. For example, a plan to renovate a bus shelter should be carried out after analyzing its GHG emission to reduce its emission before and after construction. By looking at projects through a 'low-carbon lens', the LSG can integrate low carbon development in all its projects.

A **'Carbon Neutral Facilitation Centre'** (CNFC) can be created in the LSG to execute carbon neutral works. These bodies can include government representatives, professionals to provide technical assistance, Kudumbasree members, volunteers, students and civic society. Any work regarding carbon neutral development such as campaigns, surveys, classes, tree planting, etc. can be carried out through CNFCs.

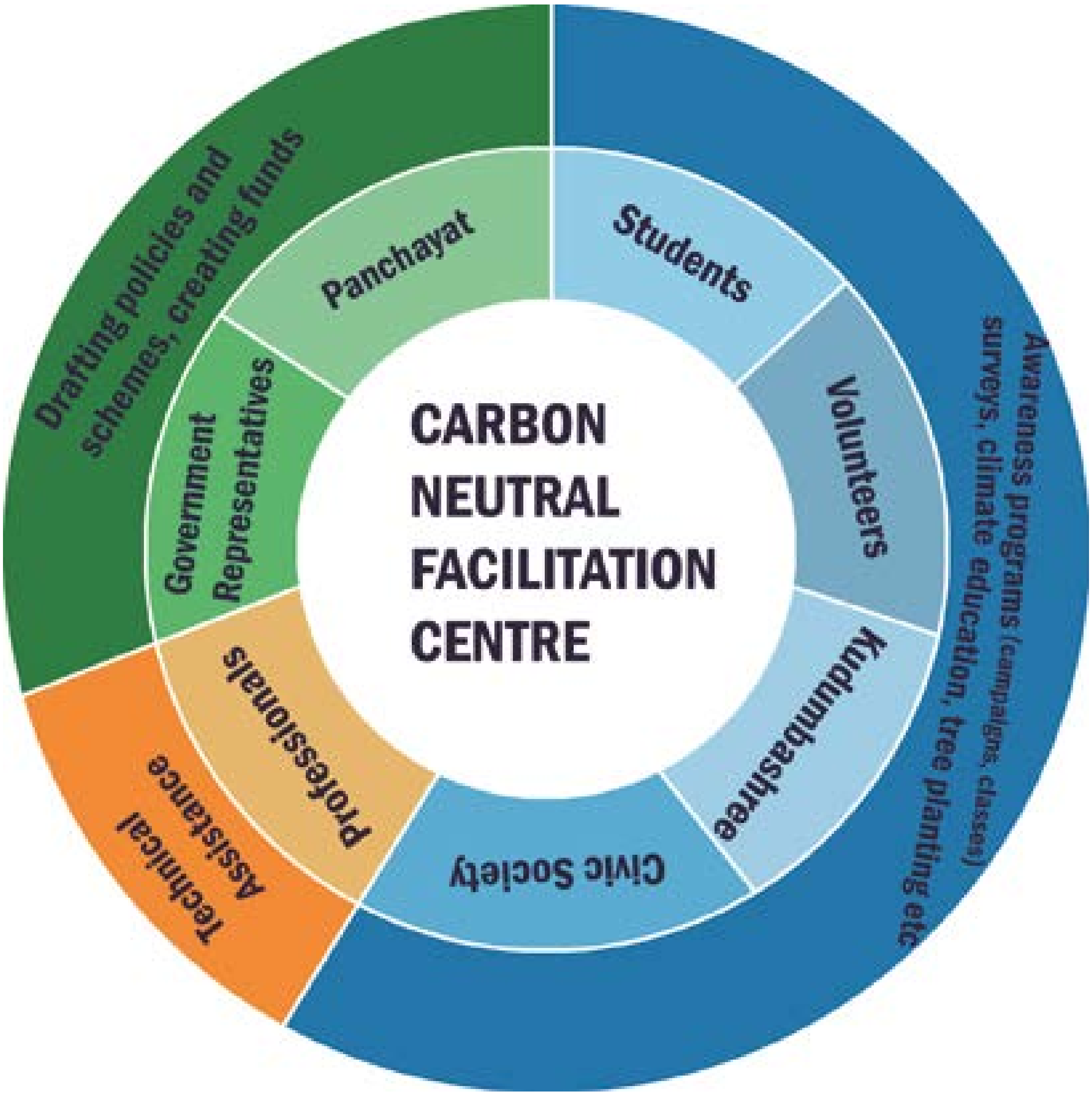



Figure 4 Carbon Neutral Facilitation Centre

For the implementation of projects, funds have to be allocated. A **'Carbon Neutral Development fund'** can be created for the LSG to carry out carbon neutral projects. Part of the fund can be taken from its own fund and other part can be obtained from interested individuals/organizations who want to offset their emission by investing in low-carbon development projects.

## 3.7 Monitoring and evaluation

Monitoring and evaluation is the final and integral part for a carbon neutral project. To assess the progress of the measures implemented and to check whether carbon neutrality is achieved, periodical monitoring of GHG emissions are essential. Continuous monitoring and evaluation increases the efficiency of the projects implemented to achieve carbon neutrality. Assessment of GHG emission and sequestration can be carried out annually or biennially to check whether there is an increase or decrease in emissions and sequestration. Periodical monitoring can make sure that projects are moving on the right path to reach the set targets for which annual roadmaps can be created.

A system has to be developed within the LSG to carry out the monitoring and evaluation process. A 'Carbon Neutral team' under the LSG can perform this process periodically to ensure the success of projects. The achievements can be made public to increase awareness among people.

# CHAPTER 4 For A Carbon Neutral Future Ahead

Adopting low-carbon/low-emission development strategies is critical for any economy in this current world ridden with floods, storms, droughts and pandemics. Nations around the world has realized that sustainability is the only way forward to combat this fatal threat. Our actions today affect the future of not only humanity but of all other living things on this planet. Reducing our GHG emissions, improving carbon sequestration, preserving biodiversity, protecting the environment, etc. are critical for the survival of all.

As countries across the globe are starting to address this and taking actions to tackle this crisis, Kerala should also step on to the right track to become a model state for low-carbon development and sustainable economy. For this, there is no other way but to start from the bottom- from people and community. Adopting low-carbon development strategies and nature-based solutions will help lead Kerala into a beacon of sustainable development which is equipped to face climate change and its adverse effects. The local self government bodies in Kerala have the opportunity to make this goal into a reality. The efficient decentralised governance system in Kerala has the capability to achieve this ambitious yet essential target.

'Becoming Carbon Neutral- A handbook for Local Self Governments in Kerala' is an attempt to assist the LSGs in achieving this goal of low-carbon development to combat climate change and develop a climate-resilient community. The various steps explained in this handbook will help LSG to assess their emission and draft measures to reduce it and mould it into a carbon neutral economy.

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