



GOVERNMENT OF PUDUCHERRY
DEPARTMENT OF SCIENCE, TECHNOLOGY AND ENVIRONMENT
PUDUCHERRY CLIMATE CHANGE CELL

CLIMATE SCHOLAR RESEARCH SERIES

Report No. 03/2026

**“ASSESSMENT OF CARBON FOOTPRINTS IN MAHE, UNION TERRITORY
OF PUDUCHERRY – AS A RESPONSE TO CLIMATE CHANGE”**



Published by
Puducherry Climate Change Cell (PCCC)
Department of Science, Technology and Environment
Government of Puducherry
August 2026

PUBLICATION INFORMATION

Climate Scholar Research Series

Report No. 03/2026

Title

Assessment of Carbon Footprints in Mahe, Union Territory of Puducherry – as a Response to Climate Change

Region

Mahe Region, Union Territory of Puducherry

Authors

- 1. Vismaya. V**, I year, M.Sc. (Botany)
Department of Botany
Mahatma Gandhi Govt. Arts College, Chalakkara, Mahe
- 2. Keerthana K Krishna**, I year, M.Sc. (Botany)
Department of Botany
Mahatma Gandhi Govt. Arts College, Chalakkara, Mahe

Faculty Mentor

Dr. K. Sasikala, Assistant Professor,
Department of Botany
Mahatma Gandhi Govt. Arts College, Chalakkara, Mahe

Publisher

Puducherry Climate Change Cell (PCCC)
Department of Science, Technology and Environment
Government of Puducherry

Publication Date

August 2026

Programme Details

The Climate Scholar Award Programme is a student research initiative of the Puducherry Climate Change Cell (PCCC), Department of Science, Technology and Environment, Government of Puducherry. The programme promotes region-specific climate research in higher educational institutions and supports the generation of locally relevant knowledge for climate adaptation, resilience planning and sustainable development in the Union Territory of Puducherry.

This publication forms part of the Climate Scholar Research Series, which disseminates selected research outputs generated under the programme.

Suggested Citation

Vismaya V and Keerthana K Krishna (2026), *Assessment of Carbon Footprints in Mahe, Union Territory of Puducherry – as a Response to Climate Change*, Climate Scholar Research Series No. 03/2026, Puducherry Climate Change Cell (PCCC), Department of Science, Technology and Environment, Government of Puducherry.

Abstract

Mahe (Mayyazhi) is a small district of the Union Territory of Puducherry, covering an area of 9 km², bordered entirely by Kannur and Kozhikode districts of Kerala. It consists of four regions, namely Chalakkara, Palloor, Pandakkal and Mahe town. Chalakkara and Pandakkal are riverine residential localities within Mahe, closely linked to the Mahe River and the Arabian Sea. The region experiences a tropical climate with high humidity, warm temperatures and heavy monsoonal rainfall. Climate change is one of the most global challenges of the present century, with significant implications for human health, lifestyle and environmental stability. Coastal and riverine regions are particularly vulnerable to climate-related impacts due to their geographic sensitivity.

This study focuses on understanding the relationships between climate change and carbon emissions from human activities in this region. The study is based on primary data collected through direct interaction with local residents using a structured questionnaire survey. By focusing on household-level data, the research emphasises how everyday energy consumption contributes to broader environmental challenges, underscoring the importance of sustainable lifestyle practices and climate-sensitive planning in vulnerable coastal regions.

Data to be collected include household electricity consumption, fuel usage for cooking and transportation, vehicle ownership and usage, and the number and type of electrical appliances such as fans, lights, refrigerators, and other commonly used devices. These parameters were used to calculate household-level carbon emissions using standard Carbon Footprint estimation methods. The analysis will help to identify patterns of energy consumption and assess how daily lifestyle choices contribute to overall carbon emissions. Sector-wise evaluation of the emissions revealed a clear dominance of electricity consumption as the primary contributor to household carbon emissions. The overall analysis revealed that the total carbon emission generated from the surveyed households amounted to 266,400.24 kg CO₂ per year, which is equivalent to 266.40 tons of CO₂ annually. This magnitude of emission indicates that domestic activities constitute a substantial share of localized carbon emissions in the Mahe region.

Keywords: Climate change, carbon footprint, Mahe, Puducherry

Contents

Abstract	1
Introduction	3
Objectives	4
Study Area	5
Review of Literature	8
Methodology	11
Results and Discussion	13
Mitigation Measures	18
Conclusion	21
References	22
Annexure I	24
Annexure II	25
Annexure III	27

Introduction

Climate change is one of the most serious environmental challenges of our time that impacts our society in many ways. It is defined as a change in temperature, weather, and climatic conditions over a long period of time, mainly caused by human activities, such as burning fossil fuels, deforestation, industrialization and improper disposal of waste. The enhanced greenhouse effect has led to global warming, sea-level rise and imbalance in the ecosystems. The impact of climate change has been particularly pronounced on coastlines, and it has become a critical concern.

"Carbon Footprint" is a term that refers to the total amount of greenhouse gases, in particular carbon dioxide, emitted directly or indirectly by human activities, such as emissions from the use of electricity, fuels used for cooking such as LPG, fuels used for transportation such as petrol and diesel, and generation of waste materials. Measuring the carbon footprint is important for understanding the impact of human activities and lifestyles on the environment.

The need for this study has arisen from growing concern about climate change and the lack of localized data on carbon emissions in Mahe. Though global and national-level data are available on carbon emissions, it is important to assess carbon emissions at the regional and community level to make proper planning and development. This study will conduct surveys in various places in Mahe and obtain data on electricity bills, LPG usage, petrol consumption, and waste management to determine the amount of carbon dioxide emitted in the region.

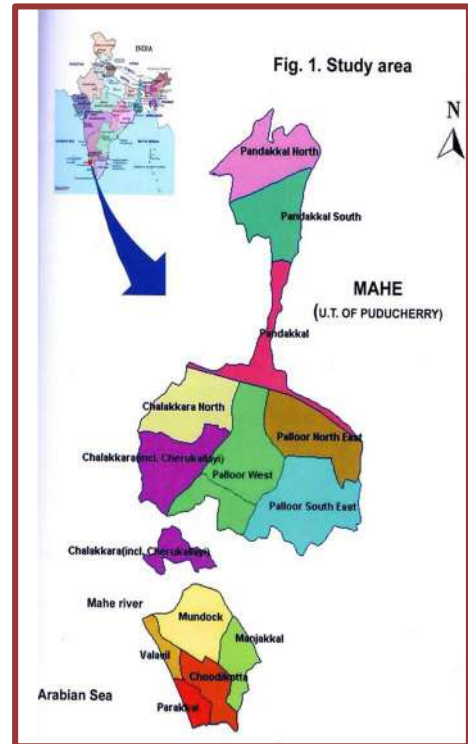
This research will also assist in the identification of the major carbon emission contributors in Mahe, as well as to raise awareness among the residents of Mahe regarding the impact of carbon emissions on the environment. Moreover, it can also assist in providing guidelines on the reduction of carbon footprints through the implementation of energy conservation measures, as well as development of appropriate waste management strategies. The ultimate goal of this project is to assist in the mitigation of climate change.

Objectives of the study

- To estimate household carbon footprints in the Mahe area.
- To identify major emission sources (transport, electricity, LPG, etc.)
- To analyse and calculate total Carbon Footprint emissions in Mahe
- To assess awareness about climate change among residents.
- To suggest mitigation strategies for reducing Carbon Footprint.

Study area

Mahe, Union Territory of Puducherry, is situated on the West Coast of the Indian Peninsula between $11^{\circ}42'$ and $11^{\circ}43'$ North Latitude and $75^{\circ}31'$ and $75^{\circ}33'$ Eastern Longitude, just between Vatakara and Thalassery, 65 kilometers from Kozhikode and 28 kilometers from Kannur in Kerala state (**Fig. 1**). This former small French Town, covering an area of 9 sq. kilometers, is 650 kilometers away from its Administrative Head Quarters, Puducherry. National Highway 17 (Mangalore-Edappally) and Mangalore-Shornur railway lines are passing through Mahe. The entire area, even though in three segments, is well connected through a network of paved roads. Mahe consists of 3 parts namely Mahe proper, Kallayi and Naluthara enclaves. Mahe proper, a small town lies on the river Mahe. The Naluthara enclave lies between the Ponniyam River on the north and Kozhikode-Thalassery Road in the south and Kallayi is situated between these areas. The entire region covers an area of 9 sq. km.



Physiography

The study area falls in the costal physiographic zone of Kerala. The region has got highly undulating terrain with hillocks and valleys. The general slope is towards southwest.

Soil

Soil of this area varies in depth, texture, internal drainage and degree of erosion. The salient attributes of the soils occurring in different physiographic regions are as given below:

- Texture : Clay, gravelly clay
- Depth : Very deep
- Drainage : Imperfectly drained to well drained
- Erosion status : Slight to moderate.

(Harilal, C. C., Kumar, G. P., & Ravindran, C. P. 2007) [8].

Population

Mahe comprises 14 wards. The total population, as per 2011 census, is 41,934. (Department of Agriculture, Government of Puducherry) [2]. The population density of the Municipal area is estimated to be 4,092 persons / sq.km (**Table I**).

The total number of households is 6054. The density is much higher than other areas of Puducherry. (Directorate of Census Operations, Puducherry, 2014) [5].

Table - I Estimated population of Mahe (2000 - 2011)

Sl. No.	Year	Population	Density/sq.km
1	2000	36471	4052
2	2001	36828	4092
3	2002	37184	4131
4	2003	37544	4171
5	2004	37907	4211
6	2005	38274	4252
7	2006	38645	4293
8	2007	39019	4334
9	2008	39396	4376
10	2009	39777	4419
11	2010	40162	4461
12	2011	41934	4659

Land use

The area exhibits two broad land use patterns. They are:

1. Settlements with mixed crops / trees
2. Dense built-up area.

Settlements with mixed crops/trees are predominantly seen in Pandakkal and Palloor segments, and the densely built-up area is seen in Mahe town. Of the two land use categories, the former, i.e., settlements with mixed crops / trees covers from the greater part (>50%) of the area.

(Harilal, C. C., Kumar, G. P., & Ravindran, C. P. 2007) [8].

Climate

The area enjoys tropical humid climate with summer from March to May and mild winter from December to February. The region receives South-West Monsoon (June - September), North - East Monsoon (October - December), winter rain (January to February) and summer rain (March - May). **Table - II** depicts the details of season-wise rainfall or the past ten years.

Table - II Details of season-wise rainfall in Mahe (2003 - 2018)

(Source: Department of Agriculture, Government of Puducherry. Rainfall Statistics) [3]

Sl. No.	Year	S.W Monsoon period	N.E Monsoon period	Winter period	Hot weather	Total
		In mm	In mm	In mm	In mm	In mm
1	2003-2004	2268	210	-	829	3307
2	2004-2005	1967	353	21	144	2485
3	2005-2006	2196	431	10	784	3421
4	2006-2007	2404	410	-	467	3281
5	2007-2008	3477	311	3	453	4244
6	2008-2009	2036	486	-	273	2794
7	2009-2010	2694	519.6	30	391.2	3634.8
8	2010-2011	2263.4	566.8	-	174.4	3004.6
9	2011-2012	2737.4	464	-	-	3201.4
10	2012-2013	2028.6	231.2	25.6	338.8	2624.2
11	2013-2014	2771	354.6	2.6	367.8	3496
12	2014-2015	2537	300.2	-	324.6	3161.8
13	2015-2016	2131	421.8	0	313.6	2866.4
14	2016-2017	1854.4	38.2	12.4	166.6	2071.6
15	2017-2018	2165.2	160.6	4.8	539.8	2870.4

The region has a tropical monsoon climate, with high rainfall and humidity. The region is mostly urban/semi-urban, with limited industrial activity. Household electricity consumption, LPG usage, fuel consumption in transportation, and waste generation contribute to carbon emissions in the region, making it suitable for carbon footprint analysis.

Review of Literature

A lot of studies on carbon Footprints emission was carried by various workers. Gao, Liu and Wang (2014) [7] conducted a comparative study focusing on the research methods and procedures used in carbon footprint studies. The study compared different carbon footprint assessment standards to identify their similarities, differences, and limitations. They analyzed the goals, principles, system boundaries, calculation approaches, and data selection used in organizational and product carbon footprint assessments. The authors highlighted that the selection of greenhouse gases, system boundaries, quantification methods, data sources, and treatment of specific emissions are critical elements in carbon footprint assessment.

Zhang, Luo and Skitmore (2015) [15] provided a comprehensive analytical review of household carbon emission (HCE) research. The study emphasized that rising living standards and economic development have significantly increased household energy consumption, leading to higher greenhouse gas emissions. The authors reviewed previous studies on the measurement methods, influencing factors, and mitigation strategies of household carbon emissions. Key quantification approaches identified include input–output analysis, life cycle assessment, and emission coefficient methods. The review also highlighted various factors influencing household emissions such as income, household size, age, education level, gender, location, and rebound effects. Additionally, the study discussed mitigation measures at policy, technological, and consumer levels and suggested future research directions to better understand and reduce household carbon emissions.

Yan et al. (2018) [14] investigated the carbon footprint of urban residential buildings using a household survey-based approach. The study aimed to quantify household carbon emissions by examining energy consumption patterns and lifestyle behaviors in urban households. By collecting primary data through surveys, the researchers estimated emissions associated with electricity use, heating, transportation, and other daily household activities. The findings highlighted that household consumption patterns and energy usage significantly influence the overall carbon footprint of urban residential buildings. The study emphasized the importance of improving energy efficiency, promoting low-carbon lifestyles, and implementing sustainable urban policies to reduce residential carbon emissions. Peng, Yang and Scheffran (2021) [12] proposed a life-cycle assessment (LCA) framework for quantifying the carbon footprint of rural

households using survey data. The study emphasized the need to consider the entire life cycle of household activities, including production, consumption, and waste management, to accurately measure emissions. The framework integrates household survey data with LCA methods to estimate both direct and indirect carbon emissions associated with rural household consumption. The authors highlighted that this approach can provide more comprehensive and reliable carbon footprint estimates and can help policymakers design effective strategies for reducing rural household emissions.

Rukhsana and Molla (2020) [13] assessed the carbon footprint of urban households in Kolkata, India, to understand the contribution of household activities to urban carbon emissions. The study examined different components of household consumption such as electricity usage, transportation, cooking fuel, and waste generation. The findings indicated that variations in income level, lifestyle, and consumption patterns significantly influence household carbon footprints. The research highlighted the importance of adopting sustainable consumption practices and improving energy efficiency to reduce urban household emissions.

Bera, Bose and Nag (2022) [1] examined the carbon footprint of both rural and urban households to understand differences in emission patterns. The study compared energy consumption, lifestyle practices, and resource utilization in rural and urban communities. The results showed that urban households generally produce higher carbon emissions due to greater energy consumption and more carbon-intensive lifestyles, while rural households have relatively lower emissions but still contribute significantly through traditional energy sources. The study emphasized the need for targeted mitigation strategies that address the specific characteristics of rural and urban communities. Jiang, Motose and Ihara (2023) [10] estimated the carbon footprint of household activities in Japan using a time-use perspective. The study analyzed how daily household activities such as cooking, commuting, leisure, and household chores contribute to carbon emissions. By combining time-use data with emission factors, the researchers quantified emissions associated with different activities. The results showed that lifestyle patterns and time allocation significantly affect household carbon footprints. The study highlighted the importance of behavioral changes and efficient energy use in reducing emissions from household activities. Nautiyal et al. (2023) [11] conducted a comprehensive assessment of the carbon footprint of Indian households and explored potential emission reduction pathways. The study analyzed

household consumption patterns, energy use, and socio-economic factors influencing carbon emissions across India. The findings revealed that household activities such as electricity consumption, transportation, and food consumption are major contributors to carbon emissions. The study also proposed strategies such as improved energy efficiency, adoption of renewable energy, and promotion of sustainable lifestyles to reduce household carbon footprints in India.

Dey, Gautam and Devi (2024) [4] estimated the carbon footprint of households in the Kalyani subdivision of Nadia district in West Bengal, India. The study focused on evaluating emissions generated from household energy use, transportation, and other daily consumption activities. The findings indicated that electricity consumption, cooking fuel, and transportation were the major contributors to household carbon emissions in the study area. The research emphasized the need for awareness programs, energy-efficient technologies, and policy interventions to reduce household carbon footprints in the region.

Du et al. (2024) [6] presented a comprehensive review of household carbon footprint research, focusing on measurement methods, evolution of research trends, and emission assessment approaches. The study analyzed the development of carbon footprint methodologies and compared various techniques used to quantify household emissions. It also examined the key drivers influencing household carbon footprints and highlighted the importance of integrating technological, behavioral, and policy measures to reduce emissions. The review identified research gaps and suggested future directions for improving the accuracy of household carbon footprint estimation and supporting sustainable development strategies.

Methodology

A survey of the 70 household Carbon Footprints in the Mahe region was undertaken across four localities from February 2026 to March 2026. During the survey, monthly consumption of electricity, LPG and Fuel were recorded. The data were used to calculate the annual consumption and then multiplied by appropriate carbon equivalent emission factors to obtain the annual carbon footprint for each household from different energy sources (IPCC, 2006 *Guidelines of National Greenhouse Gas inventories*) [9]. The data were analyzed and the results obtained were compared among the areas and mitigation measures were suggested.

Selection Process

Selection of households for the present study has been done by using a stratified random sampling method. This method has been used to ensure an adequate representation of households from different regions of Mahe. Mahe comprises different areas, such as Mahe town, Palloor, Pandakkal and Chalakkara. To get a balanced and unbiased dataset, about 70 households have been proportionately selected from each of these areas. Initially, a list of residential houses was prepared during the visits to the respective areas.

Only permanent residential households were included in this study. Other commercial establishments and temporary residences were excluded. One responsible adult member of each household above 18 years of age was interviewed using a structured questionnaire (**Annexure I**). Prior consent was obtained from the interviewee before data collection.

Data Analysis Process and Carbon Footprint Calculation

During the household survey, responsible adult members in all 70 households were interviewed on the following:

- i) The average monthly consumption of electricity as recorded on their electricity bill in kWh,
- ii) The types and quantities of fuel (litres) used monthly for cooking and other purposes
- iii) The types and quantities of Fuel (litres) used monthly for a personal vehicle

All the recorded energy consumption was primarily used to calculate the annual consumption and then multiplied by their appropriate carbon equivalent emission factors to obtain the annual carbon

footprint for each household from different energy sources (IPCC, 2006 *Guidelines of National Greenhouse Gas inventories*) [9]. Furthermore, after the data were correctly entered and computed, a summation of all the emissions from different sectors was made at the final stage, showing the overall carbon footprint at the household level per year. The calculations have been carried out in MS Excel Spreadsheets by extracting data from 70 interview schedules (**Annexure II**).

The carbon Footprint was calculated by multiplying the activity data by its corresponding emission factor (Dey, M., Gautam, R.K. and Devi, A.B., 2024) [4].

Carbon Footprint = Activity Data $\times$ Emission Factor

Activity Data = Activity Data means the quantity of fuels, energy, or materials consumed or produced by a process relevant for the Greenhouse Gas (GHG) emission calculations.

Emission Factor = An Emission Factor (EF) is a coefficient that represents the amount of greenhouse gas (GHG) emissions released per unit of activity. It is used to convert activity data (such as electricity consumption, fuel use, or LPG usage) into Carbon dioxide equivalent (CO_{2e}) emissions (Table III)

Table III: Carbon Equivalent Emission factor

SOURCE	EMISSION FACTOR UNIT (INDIA)
ELECTRICITY	0.82 kgCO ₂ /KWh
LPG	42 kg CO ₂ /Cylinder (14.2 kg)
PETROL	2.31 kgCO ₂ /L
MUNICIPAL SOLID WASTE	0.2 – 0.6kg CO ₂ /kg

Results and Discussion

The present investigation was undertaken to assess the household carbon footprint in selected regions of Mahe, namely Pandakkal, Palloor, Chalakkara and Mahe town based on primary data collected from 70 households. The analysis considered major domestic emission sources, including electricity consumption, LPG usage for cooking, petrol consumption for transportation, and household waste management practices. The collected data were systematically compiled in Excel Spreadsheet format, and carbon emissions were estimated using standard emission factors widely applied in greenhouse gas accounting studies (**Annexure III**).

The overall analysis revealed that the total carbon emission generated from the surveyed households amounted to 266,400.24 kg CO₂ per year, which is equivalent to 266.40 tonnes of CO₂ annually. This magnitude of emission indicates that domestic activities constitute a substantial share of localized carbon emissions in the Mahe region. When this emission was distributed across the surveyed households, the average household carbon emission was estimated to be 3,805.72 kg CO₂ per year, demonstrating that routine energy consumption and transportation activities at the household level collectively generate considerable greenhouse gas emissions. Furthermore, when adjusted for household population, the average per capita emission was estimated at 1,019.26 kg CO₂ per year, which provides an indicator of individual-level contribution to domestic carbon emissions within the study region (**Table – IV**).

Table IV – Total Carbon Footprint Emission from the Households of Mahe region

Sl. No.	Survey	Value
1	Total household surveyed	70
2	Total Emissions (kgCO ₂ /Year)	266400.24
3	Total Emissions (t CO ₂)	266.400
4	Average Household Emission (kgCO ₂ /Year)	3805.72
5	Average Per Capita Emission(kgCO ₂ /Year)	1019.26

Sector-wise evaluation of emissions revealed a clear dominance of electricity consumption as the primary contributor to household carbon emissions (**Fig.2**). The result indicated that electricity accounted for 82.96% of the total carbon emissions recorded in the dataset (**Table V, Fig. 3**). This

finding highlights the heavy dependence of households on electrical energy for various domestic purposes, such as lighting, refrigeration, operation of electrical appliances, and thermal comfort devices including air conditioners and fans. In the Indian context, where electricity generation largely relies on fossil fuel-based thermal power plants, particularly coal, increased electricity demand directly results in elevated carbon dioxide emissions. Therefore, the high contribution of electricity-related emissions observed in this study reflects both the growing energy demand of modern households and the carbon-intensive nature of the existing power generation mix.

The second major contributor identified in the analysis was LPG consumption, which accounted for 8.78% of the total household emissions (**Table V, Fig.4**). Liquefied petroleum gas is widely adopted as a primary cooking fuel in urban and semi-urban households due to its efficiency, cleanliness, and ease of use compared to traditional biomass fuels. However, despite its advantages, LPG combustion releases carbon dioxide as a by-product, thereby contributing to greenhouse gas emissions. The proportion of emissions attributed to LPG consumption in the present study indicates that cooking-related energy use remains a notable component of the household carbon footprint, particularly in areas where alternative low-carbon cooking technologies are not widely adopted.

Transportation-related emissions derived from petrol consumption contributed 8.26% of the total emissions (**Table V, Fig. 5**). These emissions primarily arise from the use of personal vehicles, such as motorcycles and cars for commuting, shopping and other daily mobility requirements. Although the percentage contribution of petrol consumption is comparatively lower than the electricity-related emissions, it still represents a significant source of carbon release due to the combustion of fossil fuels in internal combustion engines. Increasing dependence on private vehicles, particularly in rapidly urbanizing regions, can substantially elevate household-level carbon emissions, if sustainable transportation alternatives are not implemented.

Table V Sector-wise contribution of Carbon Footprint emission from all regions of Mahe

Sl. No.	Sector-wise contribution of Carbon Footprint Emission	Area				%
		Mahe	Chalakkara	Pandakkal	Palloor	
1	Electricity (kWh)	56481.6	61913.28	62749.68	39852	82.96
2	LPG (litres)	6216	6888	6552	3738	8.78
3	Petrol (litres)	4684.68	8620.92	6042.96	2661.12	8.26

Fig. 2 Sector-wise contribution of household carbon emissions in Mahe

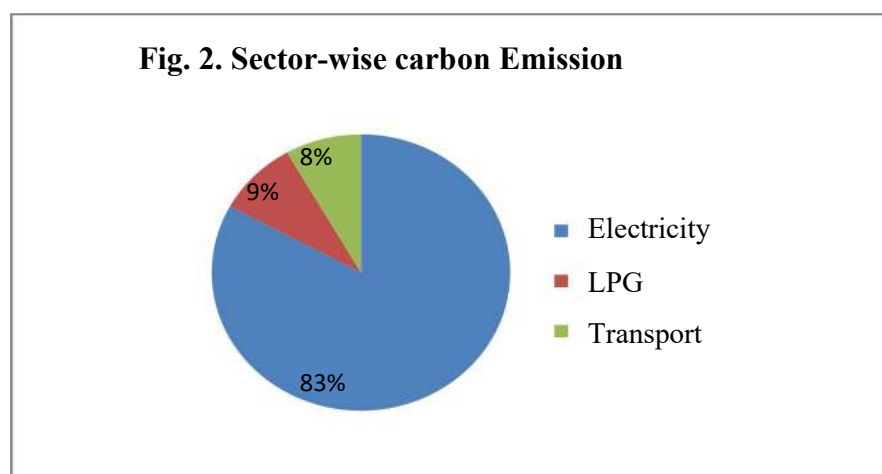


Fig. 3 Area wise Carbon emission break down - Electricity

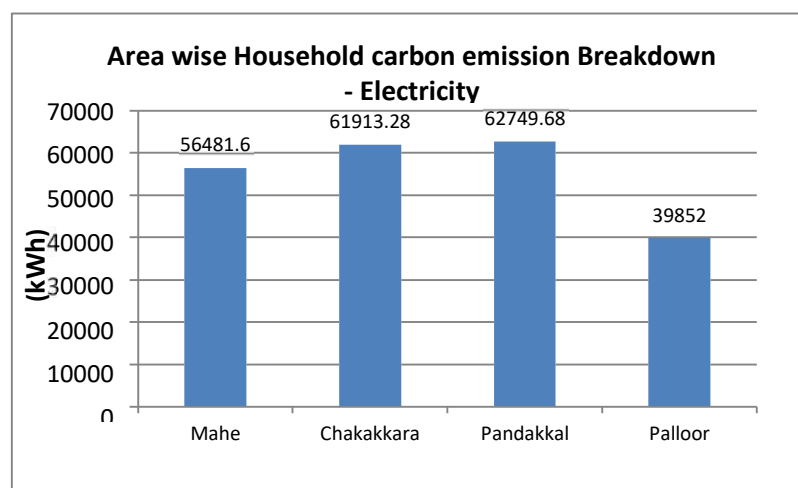


Fig. 4 Area wise Carbon emission break down - LPG

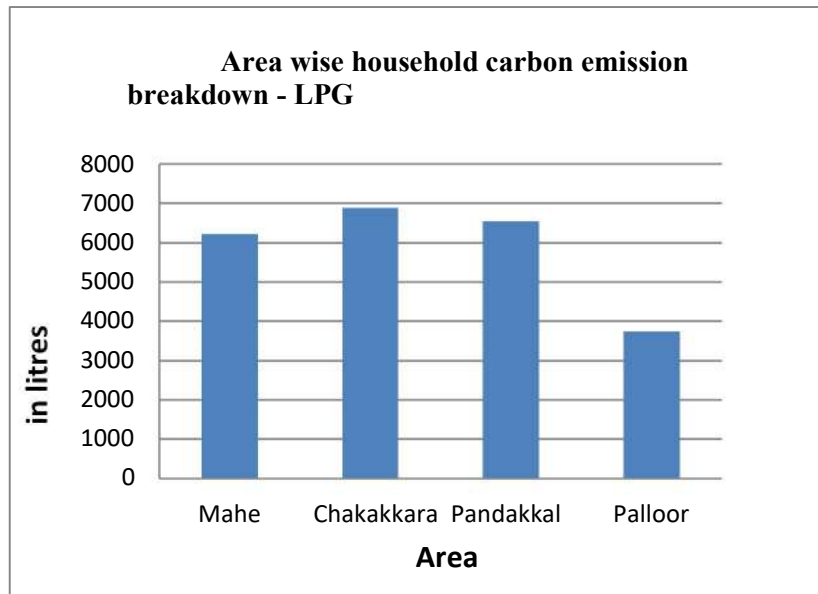
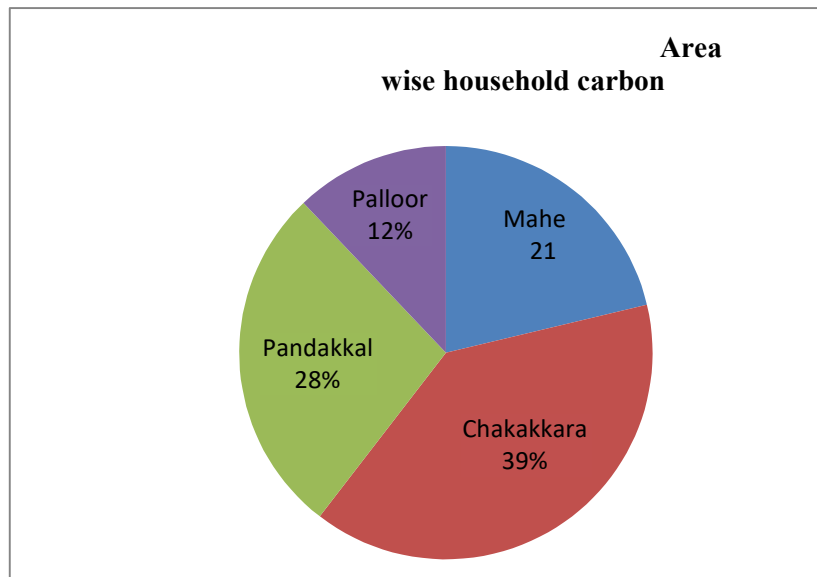


Fig. 5 Area-wise carbon emission break down - Petrol



In addition to sector-wise emission estimates, the spatial distribution of resource consumption across the surveyed areas further explains variations in household carbon emissions. The dataset indicates that Pandakkal and Chalakkara exhibited relatively higher electricity consumption, reflecting a greater reliance on electrical appliances and cooling devices.

In contrast, Palloor showed comparatively lower electricity usage, which may be associated with differences in household energy demand and appliance ownership. Similarly, variations in LPG consumption among the study areas can be attributed to differences in household size, cooking patterns and lifestyle practices. Petrol consumption patterns also varied across regions, reflecting differences in vehicle ownership and commuting behaviour among households.

Waste management practices in the surveyed households were largely dependent on municipal waste collection systems. Organized waste disposal through municipal services reduces the likelihood of uncontrolled burning or open dumping of waste, both of which can release greenhouse gases, such as carbon dioxide and methane. Although emissions from waste management were not a dominant component in the present household-level calculations, efficient waste handling systems still play an important role in minimizing indirect environmental impacts associated with domestic waste generation.

Overall, the results of the present study clearly demonstrate that household energy consumption patterns are the primary determinants of domestic carbon emissions in the Mahe region. Among the evaluated sectors, electricity consumption emerged as the dominant contributor, followed by LPG usage and petrol consumption. The total estimated emission of 266.40 tonnes of CO₂ annually from 70 households highlights the cumulative environmental impact of routine domestic activities. These findings emphasize the importance of promoting energy-efficient appliances, adoption of renewable energy sources, improved public transportation systems, and increased environmental awareness among households as key strategies for reducing carbon emissions at the community level.

The present assessment therefore provides a localized understanding of household carbon emission dynamics in Mahe, contributing valuable baseline information for environmental planning and climate mitigation strategies. Such household-scale carbon footprint studies are essential for identifying priority sectors for emission reduction and for supporting the development of sustainable energy policies and community-level climate action initiatives in the region.

Mitigation Measures

It is very essential to protect and restore the natural ecosystems in order to mitigate climate change because conserving biodiversity is a global concern. The protection of forests, wetlands, mangrove ecosystem, National Parks, Biosphere reserves, Wildlife Sanctuaries, Sacred groves are to be conserved for better management of climate change. The Sustainable Resource management need to be adopted and it can be done by the people's participation, in the form of action committees and protest against mafias.

The findings of the present study indicate that household energy consumption, particularly electricity use, LPG consumption and transportation fuel use are the primary contributors to carbon emissions in the Mahe region. Since these emissions contribute to the accumulation of greenhouse gases in the atmosphere and intensify climate change, the adoption of effective mitigation measures at the household and community levels becomes essential. The following are the strategies that can significantly reduce the household carbon emissions and promote environmentally sustainable living.

1. Energy Efficiency in Household Electricity Use

Since electricity consumption contributes the largest share of household emissions, improving energy efficiency can significantly reduce carbon footprints. Households can adopt energy-efficient appliances, such as LED lighting, inverter-based air conditioners, and energy-rated refrigerators, which consume less electricity compared to conventional devices. Additionally, reducing unnecessary electricity usage, switching off appliances when not in use, and maximizing natural lighting and ventilation can lower energy demand. The installation of solar rooftop systems can further reduce dependence on fossil fuel-based electricity generation and promote the use of renewable energy sources.

2. Sustainable Cooking Practices

Although LPG is considered a relatively cleaner fuel compared to traditional biomass, its combustion still produces carbon dioxide. Households can reduce cooking-related emissions by adopting energy-efficient cooking practices, such as using pressure cookers, minimizing heat loss during cooking, and ensuring proper maintenance of LPG stoves for efficient combustion. In the long term, the promotion of electric induction cooking powered by renewable energy or biogas-based cooking systems could provide sustainable alternatives to LPG usage.

3. Sustainable Transportation

Transportation-related emissions arising from petrol consumption can be reduced by encouraging sustainable mobility practices. Households can minimize vehicle use by adopting public transportation, carpooling, cycling, and walking whenever feasible. The transition to electric vehicles (EVs) powered by renewable electricity can also significantly reduce fossil fuel emissions from transportation. Promoting shared transportation systems and improving local public transport infrastructure can further contribute to lowering household transportation emissions.

4. Improved Waste Management Practices

Proper waste management plays an important role in reducing indirect greenhouse gas emissions. Households should adopt waste segregation at the source, separating biodegradable and non-biodegradable waste materials. Organic waste can be managed through composting or biogas generation, which reduces methane emissions from landfill decomposition. Recycling of plastic, paper and metal waste can also help reduce the environmental impact associated with resource extraction and waste disposal.

5. Promotion of Environmental Awareness

Climate change mitigation at the household level requires greater public awareness and behavioral changes. Educational campaigns and community-based environmental programs can encourage residents to adopt energy-saving habits and sustainable lifestyles. Awareness regarding carbon footprints and their environmental impacts can motivate households to make environmentally responsible decisions in daily life.

6. Policy Support and Community-Level Initiatives

Local governments and community organizations can play an important role in promoting climate change mitigation. Policies that encourage renewable energy adoption, energy-efficient housing, improved public transportation systems, and sustainable waste management infrastructure can significantly reduce community-level carbon emissions. Incentive programs such as subsidies for solar installations or energy-efficient appliances can further support household-level emission reduction.

7. Afforestation

Afforestation is one of the effective ways of mitigating the impacts of climate change. Trees absorb the carbon dioxide from the environment during the process of photosynthesis. They store the absorbed carbon dioxide in the trunk, branches, leaves, and soil. Since carbon dioxide is one of the major greenhouse gases responsible for global warming, the more trees we plant, the less the level of carbon dioxide will be. Afforestation play a critical role in the mitigation of climate change. By planting trees along the roadside, at home, and other degraded land, it is possible to mitigate climate change. Thus, tree planting is an effective way of mitigating climate change.

8. Promotion of Renewable Energy Sources

Renewable energy is considered to be an effective strategy to mitigate the effects of climate change through the reduction of greenhouse gases that contribute to global warming. Renewable energy refers to energy produced from natural resources that can be refilled over time, including solar energy, wind energy, water energy, and biomass energy. Unlike fossil fuels like coal, oil, and natural gas, renewable energy resources produce very little or no carbon dioxide during energy production. Using renewable energy resources can help to reduce the use of fossil fuels that contribute to carbon emissions. For instance, individuals can use solar panels or solar water heaters to produce electricity or to warm water using solar energy. Using renewable energy resources can reduce the carbon footprint associated with electricity consumption at the community or individual level. Promoting the use of renewable energy resources can provide an effective mitigation strategy to mitigate the effects of climate change.

9. Social and Community-Based Climate Action:

Climate change mitigation involves the active participation of communities and society in general. Social awareness, environmental education, and social engagement programs are critical in promoting social behavior change and encouraging responsible energy consumption. Community-based initiatives such as environmental campaigns, climate change awareness campaigns, waste segregation campaigns may encourage people in their homes to adopt environmentally responsible practices.

Conclusion

The present study assessed the household carbon footprint in selected regions of Mahe, namely Pandakkal, Palloor, Chalakkara and Mahe town, based on primary data collected from 70 households. The analysis revealed that domestic activities contribute a considerable amount of carbon emissions in the region. The total annual carbon emission estimated from the surveyed households was 266.40 tonnes of CO₂, indicating that everyday household energy consumption plays a significant role in contributing to greenhouse gas emissions at the local level. The sector-wise analysis showed that electricity consumption is the largest contributor to household carbon emissions, accounting for the majority of the total emissions, followed by LPG consumption for cooking and petrol usage for transportation. These findings demonstrate that modern lifestyle patterns and increasing dependence on energy-intensive appliances and private vehicles are important factors influencing household carbon emissions. From a climate change perspective, the accumulation of greenhouse gases such as carbon dioxide in the atmosphere leads to global warming and alters regional climate systems. In coastal regions such as Mahe, climate change impacts may include rising temperatures, increased flooding events, coastal erosion and changes in rainfall patterns. Therefore, understanding household-level carbon emissions is important for identifying the sources of emissions and implementing effective mitigation strategies. The results of this study highlight the need for energy conservation, adoption of renewable energy sources, sustainable transportation practices and improved waste management systems to reduce household carbon emissions. In addition, increasing public awareness about environmentally responsible lifestyles can play an important role in promoting community-level climate action. Overall, the present study provides a baseline assessment of household carbon emissions in the Mahe region, contributing valuable information for environmental planning and climate change mitigation. Reducing household carbon footprints through sustainable energy use and behavioral changes can significantly contribute to long-term climate stability and environmental sustainability. The findings will be useful to the stake holders, policy makers, NGO's, Academicians, environmentalists and to various departments such as Agro forestry, wetland development agencies, Forest and Agriculture and forms a basis for further research work.

References

- [1]. Bera, M., Bose, P. and Nag, P.K., 2022. Household carbon footprint: rural and urban community. *J of Ecol and Nat Resour*, 6, p. 2.
- [2]. Department of Agriculture, Government of Puducherry. Population Statistics. Government of Puducherry. Available at : <https://agri.py.gov.in/pop.html>
- [3]. Department of Agriculture, Government of Puducherry. Rainfall Statistics. Government of Puducherry. Available at: agri.py.gov.in
- [4]. Dey, M., Gautam, R.K. and Devi, A.B., 2024. Estimation of carbon footprint of Indian households in Kalyani subdivision of district Nadia, West Bengal, India. *The holistic approach to environment*, 14(3), pp.78–90.
- [5]. Directorate of Census Operations, Puducherry. (2014). District Census Handbook, Mahe (Part A: Village and Town Directory), Census of India 2011. Office of the Registrar General & Census Commissioner, India. Retrieved from Census of India.
- [6]. Du, J., Zhong, Z., Shi, Q., Cao, Y., Yang, C. and Wang, L., 2024. A review of household carbon footprint: measurement methods, evolution and emissions assessment. *Carbon Footprints*, 3(3), pp. N–A.
- [7]. Gao, T., Liu, Q. and Wang, J., 2014. A comparative study of carbon footprint and assessment standards. *International Journal of Low-Carbon Technologies*, 9(3), pp. 237–243.
- [8]. Harilal, C. C., Kumar, G. P., & Ravindran, C. P. (2007). Quantification, Characterization and Management of Solid Waste from Mahe, Union Territory of Pondicherry. Department of Science, Technology and Environment, Government of Pondicherry.
- [9]. IPCC, 2006 *Guidelines of National Greenhouse Gas Inventories*.
- [10]. Jiang, Y., Motose, R. and Ihara, T., 2023. Estimating the carbon footprint of household activities in Japan from the time-use perspective. *Environmental Science and Pollution Research*, 30(9), pp. 22343–22374.
- [11]. Nautiyal, S., Goswami, M., Kishan, R. and Premkumar, A., 2023. Household carbon footprint of India: A comprehensive assessment and prospecting for emission reduction pathways. *Centre for Ecological Economics and Natural Resources, Institute for Social and Economic Change*, Bengaluru.

- [12]. Peng, Y., Yang, L.E. and Scheffran, J., 2021. A life-cycle assessment framework for quantifying the carbon footprint of rural households based on survey data. *MethodsX*, 8, p. 101-411.
- [13]. Rukhsana and Molla, M.F., 2020. Assessment of the Carbon Footprint Across Urban Households in Kolkata. In: *Habitat, Ecology and Ekistics: Case Studies of Human-Environment Interactions in India* (pp. 115–131). Cham: Springer International Publishing.
- [14]. Yan, X., Cui, S., Xu, L., Lin, J. and Ali, G., 2018. Carbon footprints of urban residential buildings: a household survey-based approach. *Sustainability*, 10(4), p. 1131.
- [15]. Zhang, X., Luo, L. and Skitmore, M., 2015. Household carbon emission research: an analytical review of measurement, influencing factors and mitigation prospects. *Journal of Cleaner Production*, 103, pp. 873–883.

Annexure I - Questionnaire

1. Area/Ward in Mahe.
2. Number of family members.
3. Average Monthly Electricity Consumption in Units
4. Which of the following appliances do you use?
5. Number of Air conditioners (if any)
6. Do you use Solar Panels?
7. Type of cooking fuel used
8. Number of LPG Cylinders used per year
9. Vehicles owned
10. Types of fuel used
11. Average Monthly fuel used for transportation
12. Do you segregate household waste?
13. Method of Waste Disposal
14. Are you aware of climate change?
15. Have you observed any of the following in Mahe?
16. Are you willing to adopt eco-friendly practices to reduce carbon footprint?
17. Which sustainable practices do you follow?
18. Suggestions to reduce Carbon emissions.

Annexure II - Raw data collection of electricity bills, LPG & Petrol of Mahe region

Sl. No.	Area	Number of Members	Monthly Electricity Consumption (KwH)	LPG Cylinders Per Year	Petrol (Litres per month)	Number of A/C	Waste Disposal Method
1	Mahe	2	150	4	0	0	Municipal Collection
2	Mahe	4	165	8	0	0	Municipal Collection
3	Mahe	6	339	9	0	0	Municipal Collection
4	Mahe	3	480	12	10	2	Municipal Collection
5	Mahe	6	160	12	25	2	Municipal Collection
6	Mahe	9	595	10	20	2	Municipal Collection
7	Mahe	9	330	12	15	0	Municipal Collection
8	Mahe	5	185	6	20	0	Municipal Collection
9	Mahe	4	240	6	0	1	Municipal Collection & Discharge into Sea
10	Mahe	8	1008	5	8	2	Municipal Collection & Discharge into Sea
11	Mahe	4	184	5	10	0	Municipal Collection
12	Mahe	3	182	5	8	1	Municipal Collection
13	Mahe	4	150	4	0	0	Municipal Collection
14	Mahe	7	105	5	12	0	Municipal Collection
15	Mahe	2	89	6	0	1	Municipal Collection
16	Mahe	3	225	9	0	0	Municipal Collection
17	Mahe	2	20	5	7	2	Municipal Collection
18	Mahe	3	223	5	9	1	Municipal Collection
19	Mahe	4	520	11	15	1	Municipal Collection
20	Mahe	3	390	9	10	0	Municipal Collection
21	Chalakkara	2	160	6	0	1	Municipal Collection
22	Chalakkara	5	150	6	0	1	Municipal Collection
23	Chalakkara	8	350	7	45	0	Municipal Collection
24	Chalakkara	2	320	12	30	2	Municipal Collection
25	Chalakkara	4	120	7	20	0	Municipal Collection
26	Chalakkara	5	800	12	0	1	Municipal Collection
27	Chalakkara	4	75	10	0	0	Municipal Collection
28	Chalakkara	4	350	10	50	2	Municipal Collection
29	Chalakkara	4	300	6	40	1	Municipal Collection
30	Chalakkara	5	190	6	30	2	Municipal Collection
31	Chalakkara	7	310	12	20	1	Municipal Collection
32	Chalakkara	5	405	12	15	1	Municipal Collection
33	Chalakkara	5	450	6	5	2	Municipal Collection
34	Chalakkara	8	600	12	0	0	Municipal Collection
35	Chalakkara	6	150	7	10	2	Municipal Collection
36	Chalakkara	1	22	0	7	1	Municipal Collection

Sl. No.	Area	Number of Members	Monthly Electricity Consumption (KwH)	LPG Cylinders Per Year	Petrol (Litres per month)	Number of A/C	Waste Disposal Method
37	Chalakkara	4	480	10	14	0	Municipal Collection
38	Chalakkara	2	240	6	0	0	Municipal Collection
39	Chalakkara	5	620	12	20	1	Municipal Collection
40	Chalakkara	2	200	5	5	0	Municipal Collection
41	Panthakkal	2	640	6	40	1	Municipal Collection & Compost
42	Panthakkal	4	280	6	20	1	Municipal Collection
43	Panthakkal	1	180	2	5	1	Municipal Collection
44	Panthakkal	5	260	8	10	1	Municipal Collection
45	Panthakkal	6	320	7	12	0	Municipal Collection
46	Panthakkal	4	337	12	8	1	Municipal Collection
47	Panthakkal	4	85	6	5	0	Municipal Collection
48	Panthakkal	4	60	12	10	0	Municipal Collection
49	Panthakkal	5	610	12	20	2	Municipal Collection
50	Panthakkal	4	480	10	14	1	Municipal Collection
51	Panthakkal	4	550	11	16	1	Municipal Collection
52	Panthakkal	6	710	14	22	0	Municipal Collection
53	Panthakkal	2	220	6	5	0	Municipal Collection
54	Panthakkal	3	260	7	6	1	Municipal Collection
55	Panthakkal	4	310	8	8	0	Municipal Collection
56	Panthakkal	2	180	5	4	1	Municipal Collection
57	Panthakkal	3	290	7	5	0	Municipal Collection
58	Panthakkal	1	150	4	3	0	Municipal Collection
59	Panthakkal	4	275	8	0	1	Municipal Collection
60	Panthakkal	2	180	5	5	0	Municipal Collection
61	Palloor	5	600	12	18	1	Municipal Collection
62	Palloor	4	520	11	15	0	Municipal Collection
63	Palloor	3	380	9	10	0	Municipal Collection
64	Palloor	4	500	10	15	0	Municipal Collection
65	Palloor	2	260	7	0	0	Municipal Collection
66	Palloor	4	450	10	9	1	Municipal Collection
67	Palloor	3	270	7	5	0	Municipal Collection
68	Palloor	2	180	5	4	0	Municipal Collection
69	Palloor	6	650	12	20	1	Municipal Collection
70	Palloor	3	240	6	0	1	Municipal Collection

Annexure III - Emission Calculation of Carbon Footprints of Mahe region per Year

Sl. No.	Area	Electricity Emission (Kg CO2/ Year)	LPG Emissions (Kg CO2/ Year)	Petrol Emissions (Kg CO2 / Year)	Total Household Emissions (Kg CO2 / Year)	Total Household Emissions in Tonnes	Per Capita Emission (Kg CO2 /Year)
1	Mahe	1476	168	0	1644	1.644	822
2	Mahe	1623.6	336	0	1959.6	1.9596	489.9
3	Mahe	3335.76	378	0	3713.76	3.71376	618.96
4	Mahe	4723.2	504	277.2	5504.4	5.5044	1834.8
5	Mahe	1574.4	504	693	2771.4	2.7714	461.9
6	Mahe	5854.8	420	554.4	6829.2	6.8292	758.8
7	Mahe	3247.2	504	415.8	4167	4.167	463
8	Mahe	1820.4	252	554.4	2626.8	2.6268	525.36
9	Mahe	2361.6	252	0	2613.6	2.6136	653.4
10	Mahe	9918.72	210	221.76	10350.48	10.35048	1293.81
11	Mahe	1810.56	210	277.2	2297.76	2.29776	574.44
12	Mahe	1790.88	210	221.76	2222.64	2.22264	740.88
13	Mahe	1476	168	0	1644	1.644	411
14	Mahe	1033.2	210	332.64	1575.84	1.57584	225.12
15	Mahe	875.76	252	0	1127.76	1.12776	563.88
16	Mahe	2214	378	0	2592	2.592	864
17	Mahe	196.8	210	194.04	600.84	0.60084	300.42
18	Mahe	2194.32	210	249.48	2653.8	2.6538	884.6
19	Mahe	5116.8	462	415.8	5994.6	5.9946	1498.65
20	Mahe	3837.6	378	277.2	4492.8	4.4928	1497.6
21	Chalakkara	1574.4	252	0	1826.4	1.8264	913.2
22	Chalakkara	1476	252	0	1728	1.728	345.6
23	Chalakkara	3444	294	1247.4	4985.4	4.9854	623.175
24	Chalakkara	3148.8	504	831.6	4484.4	4.4844	2242.2
25	Chalakkara	1180.8	294	554.4	2029.2	2.0292	507.3
26	Chalakkara	7872	504	0	8376	8.376	1675.2
27	Chalakkara	738	420	0	1158	1.158	289.5
28	Chalakkara	3444	420	1386	5250	5.25	1312.5
29	Chalakkara	2952	252	1108.8	4312.8	4.3128	1078.2
30	Chalakkara	1869.6	252	831.6	2953.2	2.9532	590.64
31	Chalakkara	3050.4	504	554.4	4108.8	4.1088	586.97
32	Chalakkara	3985.2	504	415.8	4905	4.905	981
33	Chalakkara	4428	252	138.6	4818.6	4.8186	963.72
34	Chalakkara	5904	504	0	6408	6.408	801

Sl. No.	Area	Electricity Emission (Kg CO2/Year)	LPG Emissions (Kg CO2/Year)	Petrol Emissions (Kg CO2 /Year)	Total Household Emissions (Kg CO2 /Year)	Total Household Emissions in Tonnes	Per Capita Emission (Kg CO2 /Year)
35	Chalakkara	1476	294	277.2	2047.2	2.0472	341.2
36	Chalakkara	216.48	0	194.04	410.52	0.41052	410.52
37	Chalakkara	4723.2	420	388.08	5531.28	5.53128	1382.82
38	Chalakkara	2361.6	252	0	2613.6	2.6136	1306.8
39	Chalakkara	6100.8	504	554.4	7159.2	7.1592	1431.84
40	Chalakkara	1968	210	138.6	2316.6	2.3166	1158.3
41	Panthakkal	6297.6	252	1108.8	7658.4	7.6584	3829.2
42	Panthakkal	2755.2	252	554.4	3561.6	3.5616	890.4
43	Panthakkal	1771.2	84	138.6	1993.8	1.9938	1993.8
44	Panthakkal	2558.4	336	277.2	3171.6	3.1716	634.32
45	Panthakkal	3148.8	294	332.64	3775.44	3.77544	629.24
46	Panthakkal	3316.08	504	221.76	4041.84	4.04184	1010.46
47	Panthakkal	836.4	252	138.6	1227	1.227	306.75
48	Panthakkal	590.4	504	277.2	1371.6	1.3716	342.9
49	Panthakkal	6002.4	504	554.4	7060.8	7.0608	1412.16
50	Panthakkal	4723.2	420	388.08	5531.28	5.53128	1382.82
51	Panthakkal	5412	462	443.52	6317.52	6.31752	1579.38
52	Panthakkal	6986.4	588	609.84	8184.24	8.18424	1364.04
53	Panthakkal	2164.8	252	138.6	2555.4	2.5554	1277.7
54	Panthakkal	2558.4	294	166.32	3018.72	3.01872	1006.24
55	Panthakkal	3050.4	336	221.76	3608.16	3.60816	902.04
56	Panthakkal	1771.2	210	110.88	2092.08	2.09208	1046.04
57	Panthakkal	2853.6	294	138.6	3286.2	3.2862	1095.4
58	Panthakkal	1476	168	83.16	1727.16	1.72716	1727.16
59	Panthakkal	2706	336	0	3042	3.042	760.5
60	Panthakkal	1771.2	210	138.6	2119.8	2.1198	1059.9
61	Palloor	5904	504	498.96	6906.96	6.90696	1381.392
62	Palloor	5116.8	462	415.8	5994.6	5.9946	1498.65
63	Palloor	3739.2	378	277.2	4394.4	4.3944	1464.8
64	Palloor	4920	420	415.8	5755.8	5.7558	1438.95
65	Palloor	2558.4	294	0	2852.4	2.8524	1426.2
66	Palloor	4428	420	249.48	5097.48	5.09748	1274.37
67	Palloor	2656.8	294	138.6	3089.4	3.0894	1029.8
68	Palloor	1771.2	210	110.88	2092.08	2.09208	1046.04
69	Palloor	6396	504	554.4	7454.4	7.4544	1242.4
70	Palloor	2361.6	252	0	2613.6	2.6136	871.2