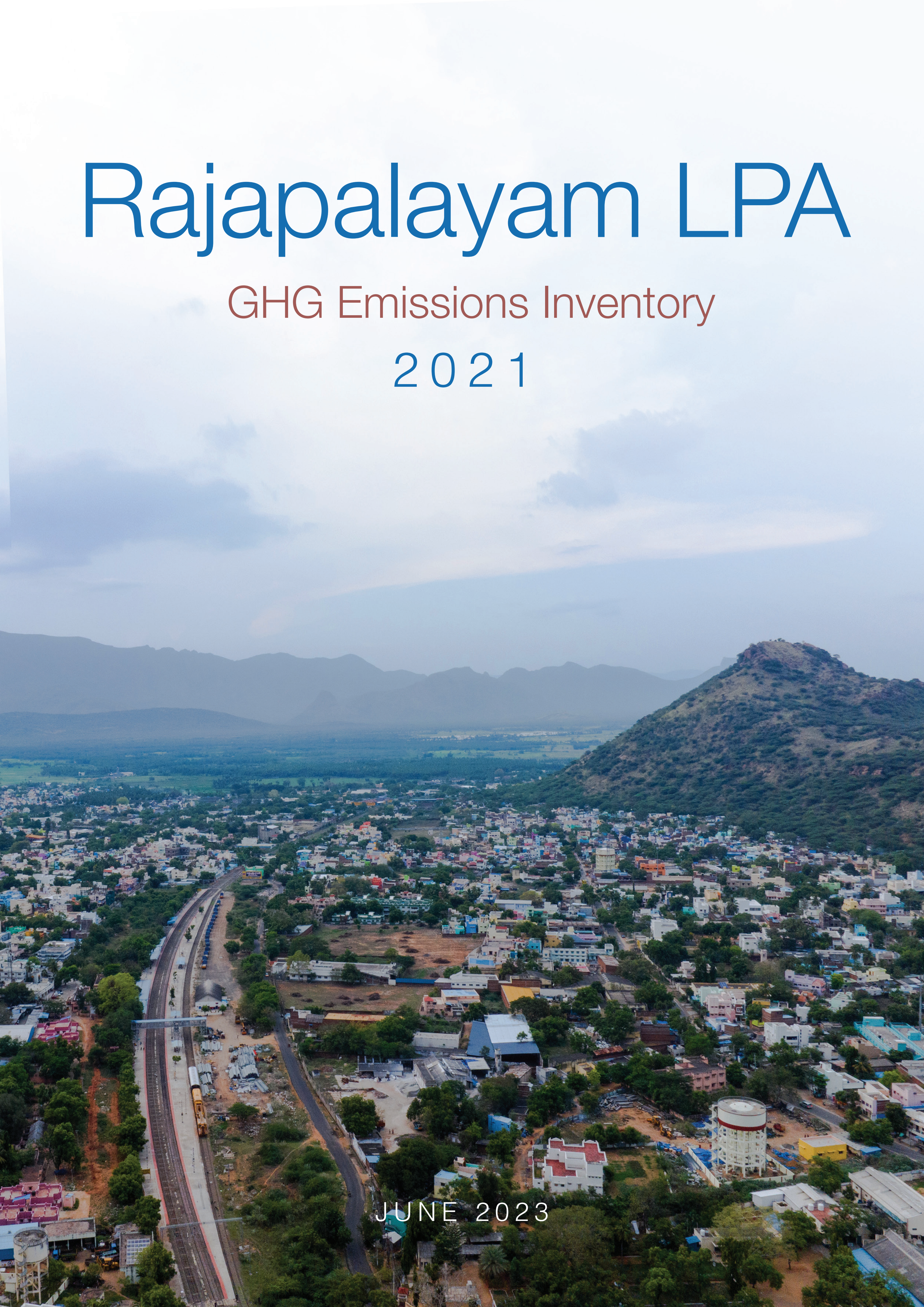
Rajapalayam LPA

GHG Emissions Inventory

2021



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Acknowledgements

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Foreword

Our future prosperity is completely intertwined with the state of our environment. We are all aware that climate change has started, as extreme weather events increase in frequency and severity. If we do nothing and allow the levels of greenhouse gases to increase at the current rate, our beautiful land of Tamil Nadu will become less and less habitable for future generations. The Hon. Chief Minister has impressively stepped forward and put our state at the forefront of the drive in India to become climate smart and carbon neutral. The goals have been set and as members of the wider community it is important that we motivate ourselves to find ways in which we can contribute to these goals and inspire our fellow citizens.

It is a long and complex task in front of us as we try to navigate the road to a sustainable future. The first part of this journey is the commitment to change and an openness to embrace new solutions. The next is to base our choices on sound data and scientific principles.

We need to create a clear baseline from which we can measure the effectiveness of our actions. This way we will learn from our efforts, so that in the future, others that follow us down this path will be able to do so more efficiently and reach the goal more effectively.

Innovative and smart thinking, alongside a willingness to support and drive new projects forward is the need of this moment. The demand for development and better standards of living are justified for any village, town, or city in India, so we need to find ways for the economy to prosper. However, at the same time we need to be clever and ensure our actions are not degrading the environment for future generations and that they also provide solutions that others are able to emulate and improve upon.

This document is the response to these needs as we look at the future growth and development of Rajapalayam, as it aspires to become the first climate smart town in Tamil Nadu.

Nirmala Raja
Chairperson, Ramco Community Services
Member, Tamil Nadu Governing Council on Climate Change

Key Findings

7,05,641.20 tCO2e/yr

Stationary Energy	Transportation	Waste	AFOLU
66.58%	**9.50%**	**12.38%**	**11.55%**

The total emissions of Rajapalayam LPA in the year 2021 were 7,05,641.20 tCO2e/yr with Stationary Energy contributing to 66,58% of emissions followed by waste at 12.38%. The emissions per resident of the town were found to be 14% higher than the average for India (2018) and 40% higher than Coimbatore (2021).

The total emissions of the town have an impact equal to a forest fire, **two times** the size of Sanjeevi Malai, every single day.

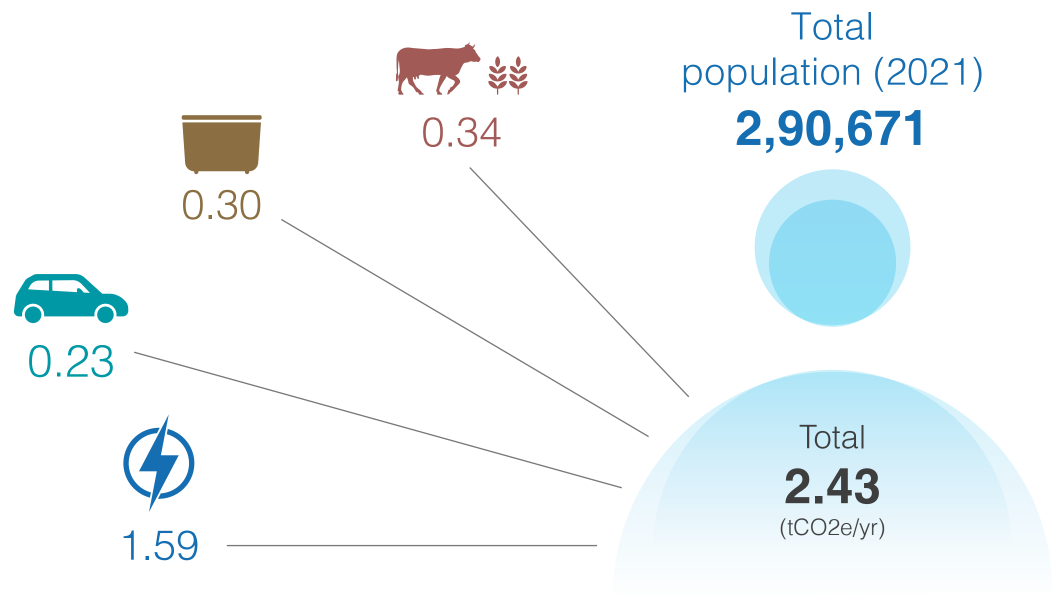
An installation of solar panels spanning 1.5 times the area of Sanjeevi Malai or **330 hectares** would be required to offset emissions from stationary energy.

The total transport related emissions equalled travelling in an Auto **around the world 3,000 times**, or once every 3 hours.

The total waste related emissions equalled **feeding 2 lakh 90 thousand people**, the entire population of the Rajapalayam Local planning area, once a day for 2 years.

The emissions released from activities in the Agriculture, Forestry and other Land Use sector equalled to reforesting an area 3 times the size of Sanjeevi Malai, every year, spanning around **600 hectares**.

Emissions per resident of Rajapalayam LPA



Comparing emissions per resident

Region	Per Capita Emissions (tCO_2e)	Per Capita emissions of Rajapalayam
India	2.12 (Global Data, 2021)	**14% higher** than India’s emissions in 2021.
Tamil Nadu	2.29 (GHGPI, 2018)	**6% higher** than Tamil Nadu's emissions in 2018.
Coimbatore	1.46 (ICLEI, 2021)	**40% higher** than Coimbatore's emissions during the same year, 2021.

The above average per-capita GHG emissions can be attributed to the highly developed industrial capacity of the town.

Contents

Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
BAU	Business as Usual
BOD	Bio-chemical Oxidation Demand
CH4	Methane
CO2	Carbon Dioxide
CO2e	Carbon Dioxide Equivalent
DG	Diesel Generator
EF	Emission Factor
EV	Electric Vehicle
GHG	Greenhouse Gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emissions Inventory
GPW	Global Warming Potential
ha	Hectare
HFC	Hydrofluorocarbons
HT	High Tension
IPPU	Industrial Processes and Product Use
kg	Kilogram
kL	Kilolitre
Km	Kilometre
kWh	Kilowatt Hours
L	Litres
LPA	Local Planning Area
LPG	Liquified Petroleum Gas
LT	Low Tension
MDF	Moderately Dense Forest
Mn	Million
Mt	Mega Tonne
N2O	Nitrous Oxide
NF3	Nitrogen Trifluoride
OF	Open Forest
PFC	Perfluorocarbons
RE	Renewable Energy
SEZ	Special Economic Zones
SF	Sulphur Hexafluoride
STP	Sewage Treatment Plant
t	Tonne
T&D	Transmission & Distribution
UNFCCC	United Nations Framework Convention on Climate Change
VDF	Very Dense Forest
yr	Year

Introduction 01

Climate change is one of the most pressing challenges faced by humanity today. Human activities have contributed to a global temperature rise of over 1˚ C from the pre-industrial era (IPCC 2023). This rise of temperature can be attributed to the increase in greenhouse gases (GHGs) in the atmosphere. The consequences can be seen in the form of extreme weather conditions, extinction of plant and animal species, rise in sea level, reduction in crop yields and scarcity of water, to name a few. India has been assessed as being particularly climate vulnerable. It is estimated that more than 80% of Indians live in districts vulnerable to climate risks (CEEW 2021). Tamil Nadu has been listed among the world's top 50 regions at high risk due to climate change (XDI 2023). The region is already routinely impacted by floods, droughts and cyclones that cause catastrophic economic loss. These climate impacts damage critical infrastructure, reduce agricultural yields and threaten livelihoods. For example, unprecedented rains in 2021 affected 31 of 38 districts and displaced 11,000 people (WRI 2022).

In order to combat climate change, 175 countries signed the UNFCCC Paris Agreement which aims to curb global temperature rise to well below 2˚ C (United Nations 2016). Article 4.1 of the 2015 Paris Agreement requires Parties to undertake the rapid reduction of emissions in accordance with the best available science (United Nations 2015). India, one of its signatories, has pledged to reduce the emission intensity of its economy by 45% by 2030, compared to 2005 levels. It also has pledged to reach net zero emissions by the year 2070 (MoEFCCC). 2022). The State Government of Tamil Nadu indicated that it aims at reaching net zero emissions before 2070.
Tamil Nadu is among the most industrialized and urbanized states in India. Cities are particularly well-placed in helping their countries meet the national emissions targets. It is estimated that 70% of all energy related GHG emissions occur within cities, and it will likely grow as more people migrate to urban areas (Greenhouse Gas Protocol. 2019). That being said, thousands of cities around the globe are developing new ways to implement climate-friendly solutions to accelerate the achievement of the long-term goals. Rajapalayam is among these cities and shows a high level of climate commitments.

Rajapalayam is the taluk headquarters of Rajapalayam Taluk, and an important town in the district of Virudhunagar within the State of Tamil Nadu. Rajapalayam LPA, which includes Rajapalayam town, 15 surrounding revenue villages and 2 reserved forests, has a total population of 2.16 lakh, as per the 2011 Census. In 2023, a master plan was formulated for Rajapalayam LPA, the master plan has a planning period till 2041. The master plan was meant to foster sustainable urban development, responsible land-use and resource efficiency and is expected to propel the town on a pathway towards decarbonization and inclusive growth. Rajapalayam is the first town in Tamil Nadu that has aspired to announce a GHG emission reduction target, it aims at achieving net zero emissions by the year 2041.

It is in this context that an emissions inventory for the town has been developed. The purpose of this GHG emissions inventory is to report on the sources and magnitude of GHG emissions. While this inventory provides us a broad understanding of today's emissions, consecutive reports on a yearly or bi-yearly basis can help improve the quality of the data and understand the progress of the activities undertaken by the LPA to reduce their impact on the surrounding environment.

Methodology 02

The Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC) helps create more targeted climate action plans and track progress over time, as well as strengthen opportunities for cities to partner with other levels of government and increase access to local and international climate financing.

The categories or emission sources that are covered in the inventory of Rajapalayam LPA are as per the BASIC+ reporting of the GPC. The categories include:

a) stationary energy,
b) transportation,
c) waste,
d) fuel,
e) industrial processes and products use (IPPU,)
f) agriculture, forestry, and other land use (AFOLU).

The categories and the sub-categories that they are comprised of are shown in Annexure 1.

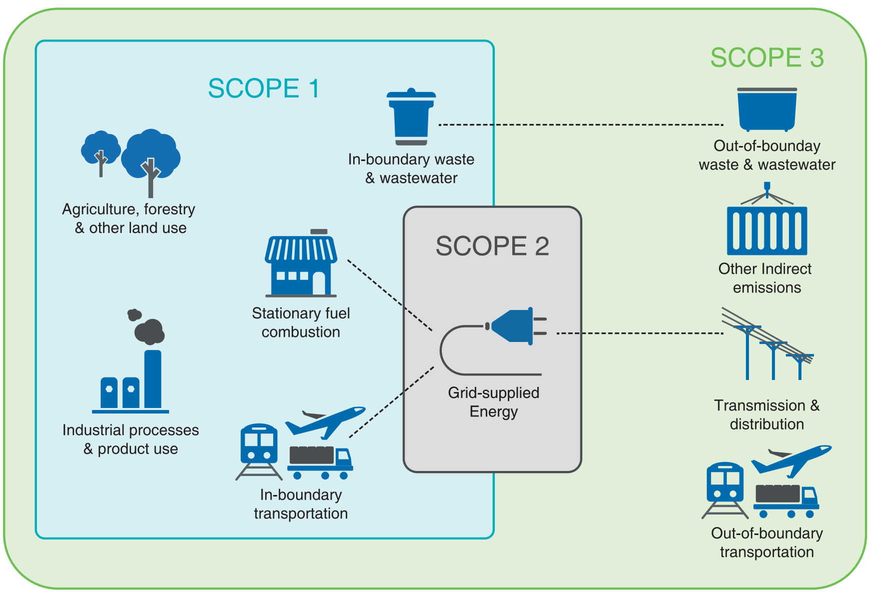
Every sectoral activity that takes place within a city can generate GHG emissions that occur both inside the city boundary as well as outside the city boundary. To distinguish among these, the emissions are grouped into the following three categories:

Table 2: Definition of scopes for inventories

Scope	Definition
Scope 1	GHG emissions from sources located within the city boundary
Scope 2	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
Scope 3	All other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary

To illustrate this, image 1 shows emission sources that occur within the geographic boundary, outside the geographic boundary and across the geographic boundary.

Image 1: Sources and boundaries of city GHG emissions



■ Inventory boundary (including scopes 1, 2 and 3) ■ Geographic city boundary (including scope 1)
■ Grid-supplied enegry from a regional grid (scope 2)

Source: GPC, 2014

For all emission sources, GHG emissions are estimated by multiplying activity data by an emission factor associated with the activity that is being measured. Activity data is a quantitative measure of an activity during a given period of time that results in GHG emissions (e.g., litres of diesel used, kilometres driven, and tonnes of waste sent to landfill). An emission factor is a measure of the mass of GHG emissions relative to a unit of activity. For example, data on electricity consumed to power a factory, measured in kilowatt-hours (kWh), is multiplied by the emission factor for electricity (kgCO2/kWh) to estimate the total amount of GHG emissions. GHG emissions data is reported in metric tonnes of each greenhouse gas emitted as well as carbon dioxide equivalent (CO2e).

The greenhouses gases covered by the GPC are carbon dioxide (CO2); methane (CH4), nitrous oxide (N2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3). Each GHG has different characteristics, the two most prominent ones for the purpose of measuring them are the amount of heat it absorbs and its lifespan. This is measured by the Global Warming Potential (GWP) which describes the warming potential of one unit of a given GHG relative to carbon dioxide.

As mentioned earlier, emissions from each activity are reported in metric tonnes of GHGs emitted as well as their carbon dioxide equivalent. CO2e is a universal unit that simplifies the accounting process by producing a single number to describe the impact of all the greenhouse gases; this is done by using the GWP of each GHG.

Points to note:
Data collection and analysis have been done on the basis of availability and subject to inaccuracies at source collection. All data sources and references have been cited with details provided under the ‘References’ section.

Detailed methodologies for each section have been provided in green boxes as per the GPC Protocol.

Industrial Processes and Product use (IPPU) refers to emissions arising from industrial processes that directly release Greenhouse Gases into the atmosphere. Industries in Rajapalayam LPA majorly consist of textile and agricultural produce manufacturing and do not consist of processes that directly release greenhouse gas emissions. Emissions for all other Industrial processes are covered under the Stationary Energy and Transportation sections.

Stationary Energy 03

The emissions from stationary energy make up 67.04% of the total emissions from Rajapalayam LPA. Grid-supplied electricity constitutes 80.13% of the emissions from the category. Electricity supplied by renewable sources have avoided 25.03% of stationary energy related emissions.

An installation of solar panels spanning 1.5 times the area of Sanjeevi Malai or 330 hectares would be required to offset emissions from stationary energy.

Stationary energy emissions are a result of:

- Fuel combustion
- Grid-supplied electricity
- Transmission and Distribution (T&D) losses
- Fugitive emissions

The total GHG emissions from stationary energy were 4,73,042.77 tCO2e/yr, of which 80.13% was from grid-supplied electricity, followed by emissions due to transmission and distribution losses from the grid-supplied electricity at 14.32%, and fuel combustion at 5.55%. Fugitive emissions were not considered due to lack of available data.

Figure 1: Percentage share of stationary energy emissions by sub-categories

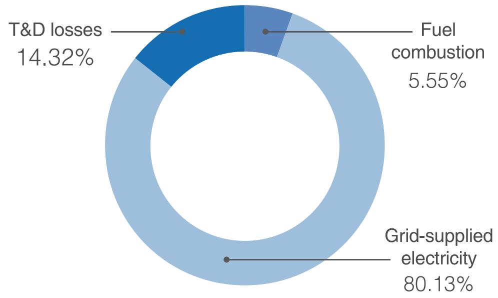


Table 2: Emissions from stationary energy

Stationary energy	Emissions (tCO2e/yr)
Fuel combustion	26,256.33
Grid-supplied electricity	3,79,054.02
T&D losses	67,732.42
Total	**4,73,042.77**

3.1. Fuel combustion

Fuel combustion amounted to 5.55% of emissions from stationary energy. Emissions from LPG contributed the highest to fuel emissions at 90.21%.

Fuel combustion consists of LPG, diesel and firewood emissions and each fuel type has been elaborated below.

Among all fuels, LPG emission contributed the highest with 23,685.59 tCO2e/yr at 90.21% of total fuel-based emissions, followed by diesel with emissions of 2,564.47 tCO2e/yr at 9.77%, and lastly firewood with 6.27 tCO2e/yr at 0.02% of the total fuel related emissions.

Figure 2: Percentage share of emissions from fuel combustion by category

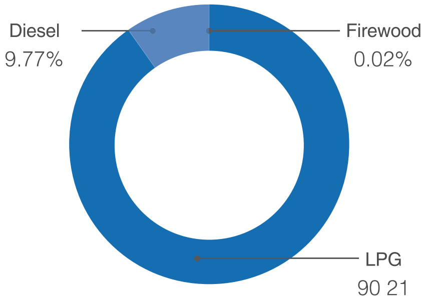


Table 3: Emissions from fuel combustion

Fuel category	Emissions (tCO2e/yr)
LPG	23,685.59
Diesel	2,564.47
Firewood	6.27
Total	**26,256.33**

Source: BPCL, 2021; IOCL, 2021; Tapasya Design Studio, 2021

LPG

Residential usage of LPG was the largest contributor of emissions with household consumption at 19,218.31 tCO2e/yr contributing to 81.14% of total LPG related emissions followed by commercial consumption with emissions of 4,467.28 tCO2e/yr at 18.86%.

Figure 3: Percentage share of LPG emissions by category

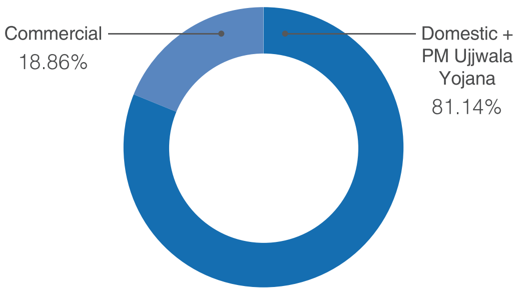


Table 4: Emissions from LPG

LPG category	Emissions (tCO2e/yr)
Domestic (14 kg)	19,218.31
Commercial (19 kg)	4,467.28
Total	**23,685.59**

Source: BPCL, 2021; IOCL, 2021; Tapasya Design Studio, 2021

Diesel

Emissions from industrial usage of diesel was 2,258.96 tCO2e/yr or 88.09%, followed by emissions related to the use of diesel by the agricultural sector at 305.51 tCO2e/yr or 11.91% of total diesel emissions.

Figure 4: Percentage share of diesel emissions by category

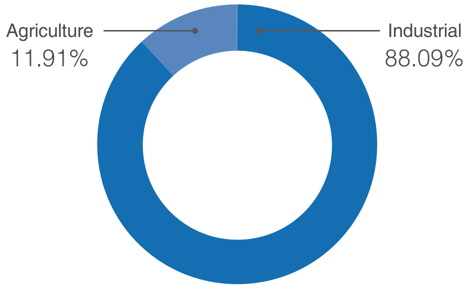


Table 5: Emissions from diesel

Diesel category	Consumption (kL/yr)	Emissions (tCO2e/yr)
Industrial	843.00	2,258.96
Agriculture	121.99	305.51
Total	**964.89**	**2,564.47**

Source: BPCL, 2021; IOCL, 2021; Tapasya Design Studio, 2021

Firewood

Firewood consumption data was only considered for residential usage as data for other usages was not available. The total residential firewood consumption is estimated at 93,651.34 kg resulting in 6.27 tCO2e/yr.

Table 6: Emissions from firewood

Firewood category	Consumption (kg/yr)	Emissions (tCO2e/yr)
Residential Usage	93,651.34	6.27

Source: Tapasya Design Studio, 2021

Methodology section for fuel combustion

LPG – Consumption data was obtained from BPCL and IOCL regional offices.

Diesel – Industrial consumption for diesel generators was obtained for one HT industry and extrapolated for the total consumption of industries in the LPA. Diesel consumed by tractors in agricultural activities was extracted from total diesel consumption by mode share and data was obtained from BPCL and IOCL regional offices.

Firewood - Usage data was obtained from a survey of 1000 households and extrapolated to the total number of households in the LPA.

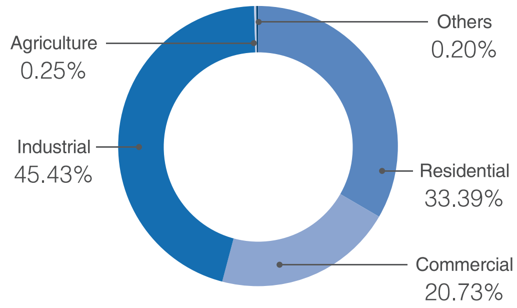
Fuel quantity x relevant emission factor= emissions in tCO2e/yr

3.2. Grid-supplied electricity

Grid-supplied electricity amounted to 80.13% of emissions from stationary energy. Emissions from the industrial sector contributed the highest to grid-supplied electricity at 45.43%. Electricity generated through wind and solar contributed to 29.41% reduction in the total electricity related emissions.

Industries account for the largest share related to grid-supplied electricity emissions at 1,72,201.39 tCO2e/yr or 45.43%. This is followed by consumption of the residential sector at 33.39%, commercial at 20.73%, agriculture at 0.25% and other zones at 0.20%.

Figure 5: Percentage share of grid consumption by categories



Grid-supplied electricity includes the following categories:

- Residential buildings include all households within Rajapalayam LPA.
- Commercial and institutional buildings and facilities include all commercial/ government buildings and educational institutions.
- Manufacturing industries include all manufacturing and warehousing facilities.
- Agriculture, forestry, and fisheries includes the consumption by agricultural connections.
- Non-specified sources include all the temporary connections provided by TNEB.

Table 7: Emissions from grid-supplied electricity

Consumer category	Grid-supplied electricity (MU)	Emissions (tCO_2e/yr)
Residential	154.34	1,26,558.80
Commercial	95.84	78,588.23
Industrial	210.00	1,72,201.39
Agriculture	1.14	934.80
Others	0.94	770.80
Total	**462.26**	**3,79,054.02**

Source: TNERC, 2021; TNEB, 2021, CEA, 2018; GPC, 2014; India GHG Program, 2015b: Tapasya Design Studio, 2021

Table 8: Emissions avoided

Electricity source	Supplied electricity (million kWh)	Emissions avoided in tCO_2e/yr
Wind	179.02	1,46,793.61
Solar	13.54	11,099.52
Total	**192.55**	**1,57,893.14**

Wind and solar integrated with the grid contributed to 29.41% of the total electricity consumption of the LPA. This amounts to 1,57,893.14 tCO_2e/yr avoided from the total electricity related emissions of the LPA.

Methodology section for grid-supplied electricity

The electricity consumed from the grid by consumers for all low-tension connections was received from TNEB Rajapalayam division, segregated by tariff codes.

Electricity consumed from the grid by consumers with high-tension connections was received by TNEB Rajapalayam, as total consumption and segregated into commercial and industrial.

Consumption x relevant emission factor= emissions in tCO_2e/yr

3.3. Transmission and Distribution (T&D) losses from grid-supplied electricity

T&D losses amounted to 14.32% of emissions from stationary energy. The industrial sector accounted for the highest emission share under the T&D losses at 45.43%.

Table 9: Emissions from T&D losses

Consumer category	T&D losses (million kWh)	Emissions for T&D losses (tCO_2e/yr)
Residential	23.63	19,376.15
Commercial	18.22	14,941.63
Industrial	40.43	33,153.51
Agricultural	0.17	143.12
Others	0.14	118.01
Total	**82.60**	**67,732.42**

Source: TNERC, 2021; TNEB, 2021, CEA, 2018; GPC, 2014; India GHG Program, 2015b: Tapasya Design Studio, 2021

Methodology section for T&D losses

Transmission and distribution losses for grid connected electricity are taken at 15.31% (TNERC, 2021) and calculated for each consumer category.

Consumption x relevant emission factor= emissions in tCO_2e/yr

3.4. Fugitive emissions from heating and cooling

Fugitive emission from heating and cooling processes by air conditioners, refrigerators and other related emissions are not considered due to lack of data.

Transportation 04

The emissions from transportation make up 9.36% of the total emissions from Rajapalayam LPA. On-road transportation constitutes to 56.63% of the emissions from the category.

The total transport related emissions equals travelling in an Auto around the world 3,000 times a year, or once every 3 hours.

In 2021, the activities related to transportation in Rajapalayam LPA generated 66,080.16 tCO2e/yr of which 56.63% was from on-road transportation followed by emissions from railways at 43.37%. This figure does not include GHG emissions from air travel, waterborne travel or those generated by city services.

Figure 6: Percentage share of transportation emissions by sub-categories

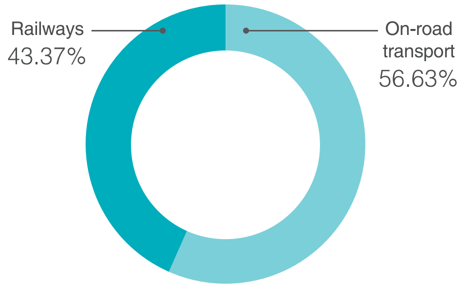


Table 10: Emissions from transportation

Sub-category	Emissions (tCO2e/yr)
On-road transport	37,424.39
Railways	28,655.76
Total	**66,080.16**

Source: India GHG Program, 2015a, 2015b; Tapasya Design Studio, 2021; Ministry of Railways, Govt. of India, 2021

On-road transportation and railways are the major modes of transport used in the Rajapalayam LPA for the movement of both people and goods inside and to and from the region.

4.1 On-road transportation

On-road transportation amounted to 56.63% of emissions from transportation. Emissions from two-wheelers contributed highest to emissions from on-road transportation with 79.90%.

Emissions from on-road transportation amounted to 37,424.39 tCO2e/yr and includes all passenger vehicles (two-wheelers, three-wheelers, four-wheelers, buses) and freight vehicles (trucks and tempos).

Figure 7: Percentage share of emissions from on-road transport

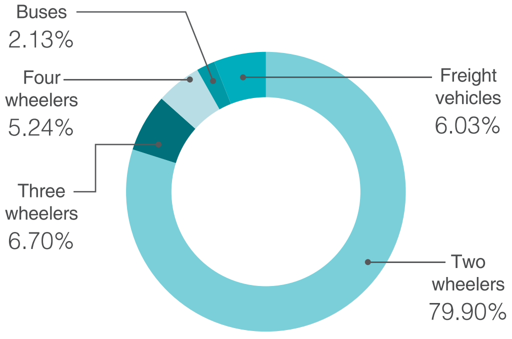


Table 11: Emissions from on-road transportation

Mode	Emissions (tCO2e/yr)
Two-wheelers	29,901.33
Three-wheelers	2,506.53
Four-wheelers	1,961.48
Buses	798.48
Freight	2,256.57
Total on-road transport emissions	**37,424.39**

As there are no public charging stations in the LPA, any emissions arising from charging Electric Vehicles (EVs) have been accounted for in the stationary energy sector under residential buildings. T&D losses have been calculated and accounted for in stationary energy under residential buildings

Methodology section for on-road transportation

The modes of transport that are sources of emissions include:

- On-road transportation
- Railways
- Water-borne transportation
- Aviation
- Off-road transportation

Four common methods that provide guidance are described in the table below.

Name of the method	Description
Fuel sales approach	Total fuel sold within the community; data collected from the fuel stations within the geographical boundary of the city
City-induced Activity	Based on the ASIF framework; includes all trips within the boundary, i.e. trips which either originate or end in the city; however, it excludes pass-through trips.
Resident Activity	Quantifies emissions through residents of the city. Information on resident vehicle kilometre travelled (VKT) is taken from vehicle registration records and surveys of resident travels. The non-city resident traffic is tracked by the origin-destination allocation approach.
Geographic or territorial	Quantifies emissions inside the boundary of a city. This is also based on ASIF model, but VKT confined to inside the city boundary. Additional surveys could be combined to report scope 3 emissions which are transboundary emissions.

This inventory uses the Fuel Sales approach to estimate GHG emissions from Transportation. The best means of gathering activity data for transportation was from fuel dispensing facilities and/or distributors, or fuel sales tax receipts. The fuel data was obtained from BPCL and IOCL regional offices.

Fuel quantity x relevant emission factor= emissions in tCO2e/yr

4.2. Railways

Emissions from railways amounted to 43.37% of the total emissions from transportation.

The total emissions from railways that are attributed to Rajapalayam LPA are 28,655.76 tCO2e/yr. The table below summarises the train routes with the distance each route covers in a year and its corresponding emissions for the year.

Table 12: Emissions from railways

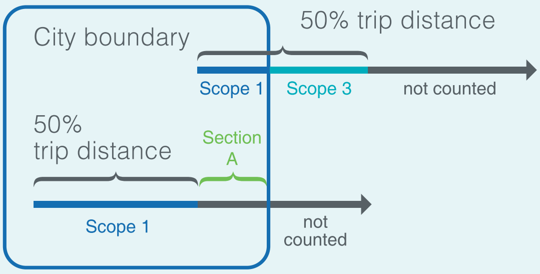
Train route	Distance travelled (km/yr)	Emissions (tCO2e/yr)
1	2,77,732	8,707.67
2	29,848	935.82
3	26,260	823.32
4	2,43,880	7,646.32
5	1,04,520	3,276.99
6	36,712	1,151.02
7	62,972	1,974.35
8	62,972	1,974.35
9	62,972	1,974.35
10	62,972	1,974.35
11	2,77,732	8,707.67
12	62,972	1,974.35
13	1,06,548	3,340.58
14	62,972	1,974.35
15	2,48,612	7,794.68
16	35,308	1,107.00
17	26,260	823.32
18	36,712	1,151.02
Total	**18,27,956**	**57,311.53**
50% attributed to Rajapalayam LPA	**9,13,978**	**28,655.76**

Source: Ministry of Railways, Govt. of India, 2021

Methodology section for railways

All trips within the boundary are considered in the scope 1 emissions. In addition, 50% of all transboundary trip distances are reported in scope 1 while the other 50% in scope 3 as per the BASIC+ reporting outlined by GPC. And all pass-through trips are excluded even though they are inside the boundary since they are not induced by the city.

Image 2: Induced activity allocation



Source: GPC, 2014

Train routes and schedules were obtained from the Indian Railways. Distance between source and destination for each of the 18 routes were taken from IRCTC, RailYatri, and Indian Rail Info official websites. The latter two were used for special fare trains.

The distance travelled for the year was calculated by obtaining the number scheduled trips per year multiplied by distance travelled in a day, and in turn, the emissions from each route giving the total emissions from railways. Of the total, 50% of the emissions are attributed to Rajapalayam LPA.

Total distance x relevant emission factor= emissions in tCO2e/yr

4.3 Waterborne navigation

Any fuel used for transport through waterborne mediums have been accounted for under total fuel consumption as accurate data was not available.

4.4 Aviation

As there is no airport present within the boundary of the LPA, all emissions arising from aviation would be accounted for in airports present outside the boundary of the LPA. Due to lack of data, aviation emissions have not been included in the inventory.

4.5 Off-road transportation

Off-road vehicles are adapted to travel on unpaved terrain, such as tractors. Off-road transportation within construction sites and industrial premises have been reported in the Stationary Energy category under agriculture, forestry, fishing, and other activities as per the GPC.

Waste

Emissions from waste make up 12.21% of the total emissions from Rajapalayam LPA. Wastewater treatment is the highest contributor to the category at 70.34%.

The total waste related emissions equals **feeding 2 lakh 90 thousand people**, the entire population of the Rajapalayam Local planning area, once a day for 2 years.

The disposal and treatment of waste generates GHG emissions, primarily from aerobic and anaerobic decomposition. The sub-categories of emissions are:

- Municipal solid waste management and disposal
- Wastewater treatment and discharge
- Incineration or open burning of waste
- Biological treatment of solid waste

In 2021, the emissions from the waste category of Rajapalayam LPA amounted to a total of 86,154.79 tCO_2e/yr of which wastewater treatment was the highest contributor amounting to 70.34% of the category, followed by solid waste disposal at 19.53%, biological treatment of solid waste at 10.13%, and incineration of waste at 0.001%.

Figure 8: Percentage share of emissions generated from waste by sub-categories

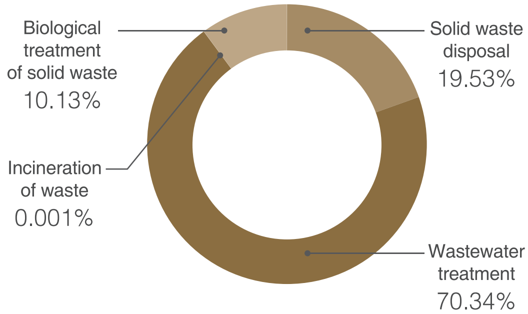


Table 13: Emissions from waste by category

Waste category	Emissions (tCO2e/yr)
Solid waste disposal	16,827.91
Wastewater treatment	60,601.42
Incineration of waste	0.47
Biological treatment of solid waste	8,725.00
Total	**86,154.79**

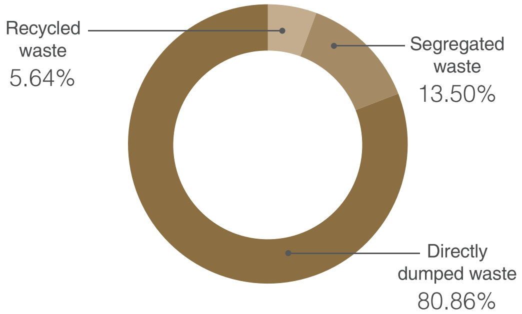
5.1. Municipal solid waste management

Municipal solid waste amounted to 19.53% of the emissions from waste. Emissions from directly dumped waste contributed highest to emissions from solid waste at 80.86%.

The disposal of municipal solid waste (MSW) generally refers to waste collected by municipalities or other local authorities. MSW typically includes food waste, paper and cardboard, wood, textiles, disposable diapers, rubber and leather, plastics, metal, glass.

Total emission from solid waste in the Rajapalayam LPA amount to 17,833.45 tCO2e/yr which is 19.53 % of the total emissions from the waste sector. Waste dumped directly in the landfill emits the most in the solid waste section amounting to 14,420.19 tCO2e/yr, followed by segregated waste at 2,407.71 tCO2e/yr, and recycled waste at 1,005.55 tCO2e/yr.

Figure 9: Percentage share of type of solid waste



Solid waste in Rajapalayam is managed by the municipality with the cooperation of the sanitary department. The team collects unsegregated solid waste from households through the door-to-door collection program and aggregated waste from the streets. This is then sent to the compost yard where the garbage is eventually burnt. Waste from markets and hotels are used to make compost.

Table 14: Emissions from solid waste

Solid waste category	Volume (kg)	Share (%)	Emissions (tCO2e/yr)
Recycled waste	20,04,040	5.64%	1,005.55
Segre-gated waste	47,98,539	13.50%	2,407.71
Directly dumped waste	2,87,39,219	80.86%	14,420.19
Total	**3,55,41,798**	**100.00%**	**17,833.45**

Source: City Sanitation Plan, 2014

Image 3: Waste collection though door-to-door collection program

Source: City Sanitation Plan, 2014

Image 4: Hotel and market waste at composting yard

Source: City Sanitation Plan, 2014

Methodology section for municipal solid waste management

The Methane Commitment (MC) model from the GPC protocol has been used to calculate methane emissions from solid waste disposal in Rajapalayam LPA. According to the MC model, the formula to calculate CH_4 emissions is:

CH_4 emissions = MSW × L0 × (1-frec) × (1-OX)

Where:

- MSW is mass of waste deposited (tonnes/yr)
- frec is the fraction of methane gas recovered from the landfill in the inventory year
- OX is the oxidation factor or the percentage of waste that gets converted into CH_4
- L0 is the methane generation potential of the waste potential of the waste

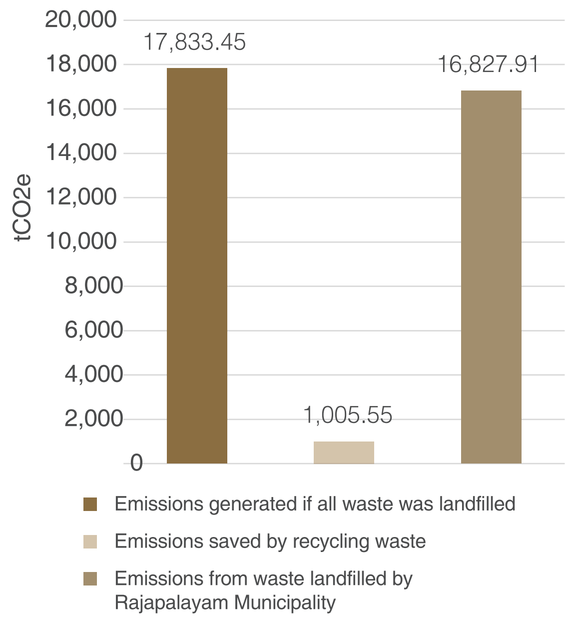
Using the equation above, the total emissions for solid waste were calculated in CH_4 and multiplied by GWP of CH_4 to get emissions in tCO_2e.

Table 15: Net emissions post appropriate solid waste management

Description	Amount	Unit
Municipal solid waste collected	35,541.80	tonnes
Emissions generated if all waste was landfilled	17,833.45	tCO2e/yr
Emissions saved by recycling waste	1,005.55	tCO2e/yr
Emissions from waste landfilled by Rajapalayam Municipality	16,827.91	tCO2e/yr
Total	**35,666.90**	**tCO2e/yr**

Source: Tapasya Design Studio, 2021

Figure 10: Emissions saved through waste management (tCO2e)



5.2. Wastewater treatment and discharge

Emissions from wastewater treatment make up most emissions from the waste category at 70.34%.

The total emissions from wastewater treatment amounts to 2,164.34 tCH_4 which is equivalent to 60,601.42 tCO_2e/yr. Wastewater treatment contributes to 70.34% of the total emissions from the waste category.

Wastewater is a potential source of CH_4 and N_2O emissions when it is treated or disposed of. The extent of CH_4 production depends primarily on the quantity of degradable organic material in the wastewater, the temperature, and the type of treatment system. N_2O is associated with the degradation of nitrogen components found in the wastewater and is calculated when it is discharged into natural water bodies. Since Rajapalayam does not have a sewage treatment plant in the LPA, the black water sewage are disposed of into open spaces or riverbanks. Also lacking desludging facilities, this practice is outsourced to private agencies.

Methodology section for municipal solid waste management

The equation used to estimate CH_4 emissions from domestic wastewater is:

CH_4 emissions = $\sum_i$ [(TOWi – Si) EFi – Ri] × 10-3

Where:

- CH_4 emissions is the CH_4 emissions in inventory year (kg)
- TOW is the total organics in wastewater in inventory year (kg BOD/yr)
- S is the organic component removed as sludge in inventory year (kg BOD/yr)
- i is the income group for each of the wastewater treatment system
- R is the amount of CH_4 recovered in inventory year (kg CH_4/yr)
- EFi is the factor kg CH_4 per kg BOD

Using the equation above, the total emissions for solid waste were calculated in CH_4 and multiplied by GWP of CH_4 to get emissions in tCO_2e/yr.

5.3. Incineration and open burning of waste

Incineration and open burning of waste contributed the least emissions to the category at 0.001%.

Incineration of waste amounts to a total of 0.47 tCO_2e which accounts for 0.001% of the total GHG emissions from the waste category.

Incineration of clinical waste leads to CO_2 emissions which can be estimated based on the mass of waste incinerated at the facility, the total carbon content in the waste, and the fraction of carbon in the solid waste of fossil origin. The non-CO_2 emissions – CH_4 and N_2O, are dependent on the technology used during the incineration and its conditions, both of which have been factored into the analysis.

Methodology section for incineration and open burning of waste

The equations for calculating the emissions are listed below:

CO_2 Emissions = m × $\sum_i$ (WFi × dmi × CFi × FCFi × OFi) × (44/12)

Where:

- m = Mass of waste incinerated, in tonnes
- WFi = Fraction of waste consisting of type i matter
- dmi = Dry matter content in the type i matter,
- CFi = Fraction of carbon in the dry matter of type i matter,
- FCFi = Fraction of fossil carbon in the total carbon component of type i matter,
- OFi = Oxidation fraction or factor i = Matter type of the Solid Waste

CH_4 Emissions = $\sum$ (IWi × EFi) × 10–6

Where:

- EFi = Aggregate CH_4 emission factor, g CH_4/ton of waste type i
- IWi = Amount of solid waste of type i incinerated or open-burned, tonnes

N_2O Emissions = $\sum$ (IWi × EFi) × 10–6

Where:

- EFi = Aggregate N_2O emission factor, g CH_4/ton of waste type i,
- IWi = Amount of solid waste of type i incinerated or open-burned, tonnes

5.4. Biological treatment of solid waste

Total emissions from biological treatment of solid waste contributed to 10.13% of the total waste category emissions.

The total emissions from biological treatment of waste amounted to 8,725.00 tCO_2e/yr, which is 10.13% of the total emissions from the waste category.

The biological treatment of waste refers to composting and anaerobic digestion of organic waste, such as food waste, garden and park waste, sludge, and other organic waste. Biological treatment of solid waste reduces overall waste volume for final disposal in landfill and reduces the toxicity of the waste.

Methodology section for biological treatment of solid waste

The practice of biological treatment of solid waste was followed by 224 households and the quantity of solid waste generated per day was recorded (City Sanitation Plan, 2014). This was then extrapolated using the total number of households to get the total quantity of waste generated.

The emissions from biological treatment of waste were calculated using the below equations:

CH4 emissions = ∑i (mi × F_ CH4i) × 10-3 - R)

N2O emissions = ∑i (mi × EF_N2Oi) × 10-3)

Where:

- m = Mass of organic waste treated by biological treatment type i, kg User input
- EF_ CH4 = CH4 emissions factor based upon treatment type, i
- EF_ N2O = N2O emissions factor based upon treatment type, i
- i = Treatment type: composting or anaerobic digestion User input
- R =Total tonnes of CH4 recovered in the inventory year, if gas recovery system is in place

Using the equation above, the total emissions for solid waste were calculated in CH_4 and multiplied by GWP of CH_4 to get emissions in tCO_2e.

Agriculture, Forestry, & Other Land-use

06

The total emissions from Agriculture, Forestry, and Other Land-Use (AFOLU) make up 11.39% of the emissions from Rajapalayam LPA. Agricultural produce constitutes to 83.74% of the emissions from the category.

The emissions released from activities in the Agriculture, Forestry and other Land Use sectors equals to reforesting 600 hectares every year, or 3 times the size of Sanjeevi Malai.

The sources of emissions from AFOLU are:

- Agricultural produce,
- Livestock rearing,
- Forestry,
- Waterbody management

In 2021, the net emissions from the AFOLU category amounted to a total of 80,363.48 tCO2e/yr of which agricultural produce was the highest contributor amounting to 83.74% of the category, followed by livestock rearing at 16.26%. Forest conservation and waterbody management together sequestered 2,071.56 tCO2e/yr.

Figure 11: Percentage share of emissions and sequestration in AFOLU

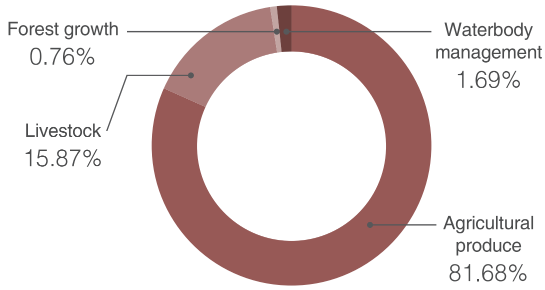


Figure 12: Percentage share of emissions from AFOLU by sub-categories

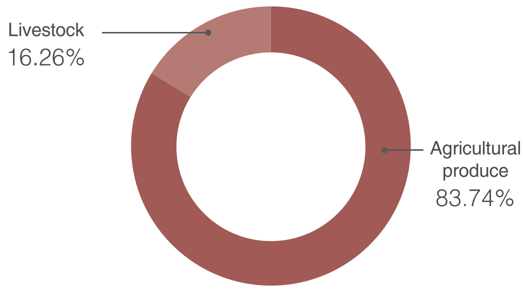


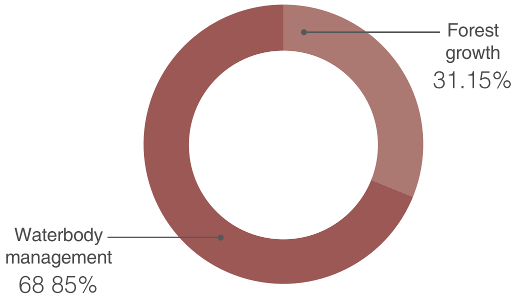
Table 16: Emissions from AFOLU

Category	Emissions (tCO2e/yr)
Agricultural produce	69,027.53
Livestock	13,407.51
Total	**82,435.04**

Table 17: Sequestration from AFOLU

Category	Area (ha)	Sequestration rate (tCO2e/ha)	Sequestration (tCO2e/yr)
Forestry	2,024	0.32	645.24
Water-body manage-ment	1,981	0.72	1,426.32
Total	**4,005**	**1.04**	**2,071.56**

Figure 12: Percentage share of sequestration from AFOLU by sub-categories



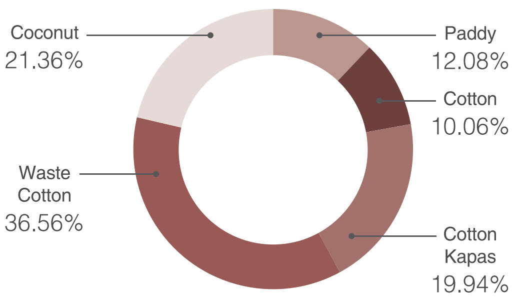
6.1 Agricultural produce

Agricultural produce amounted to 83.74% of emissions from AFOLU. Emissions from waste cotton contributed highest to emissions from agricultural produce at 36.56%.

Agricultural produce refers to the impact due to agricultural practices from growing produce used within the LPA boundary. Agricultural produce includes the main category contributors for emissions which are paddy, cotton, and coconut.

Total emissions from agricultural produce in Rajapalayam LPA amount to 69,027.53 tCO2e/yr which is 83.74% of the total emissions from the AFOLU category. Waste cotton emits the most amounting to 25,234.09 tCO2e/yr or 36.56%, followed by coconut at 21.36% and cotton kapas at 19.94%.

Figure 13: Percentage share of agricultural produce emissions by type



Methodology section for agricultural produce

Total agricultural produce was determined by the total consumption of fruits, vegetables and other agricultural goods within the LPA

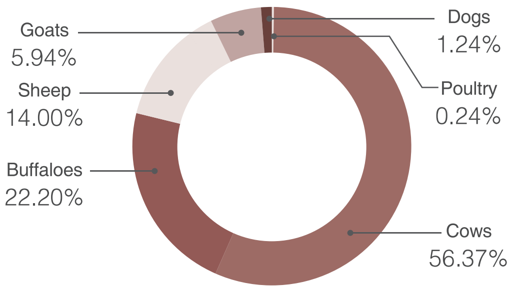
Table 18: Net emissions post appropriate solid waste management

Crop	Quantity Arrivals (in MT)	Emissions (tCO2e/yr)
Paddy	2,978.94	8,341.03
Cotton	5,469.34	6,946.06
Cotton Kapas	10,837.11	13,763.13
Waste Cotton	19,869.36	25,234.09
Coconut	5,036.80	14,743.22
Total	**44,191.55**	**69,027.53**

6.2 Livestock

Livestock rearing amounted to 16.26% of emissions from AFOLU. Emissions from cows contributed the highest to emissions from livestock at 56.37%

Figure 14: Percentage share of livestock emissions by type



Methodology section for livestock

The list of total livestock in the LPA were collected through a survey.

6.3 Forestry

Forestry sequestered 0.76% of all potential emissions in the AFOLU category.

Methodology section for forestry

Forestry related sequestration was estimated using some assumptions for the period of 20 years from 2021.

It is assumed that there is no deforestation or cutting of trees for development of the city over the next 20 years.

Within the next 20 years all land allocated as ‘Reserve Forest’ would be protected and turn into Very Dense Forests and ‘Eco-sensitive Zones’ would be protected and turn into Moderately Dense Forest.

6.4 Waterbody management

Waterbodies sequestered 1.69% of all potential emissions in the AFOLU category.

Methodology section for waterbody management

Area of the waterbodies within the town have been collected through a survey and found to be extremely polluted. The estimated sequestration rate for the waterbodies is based on the assumption that an active effort from the municipality to clean and restore the lakes will lead to a completely restored ecology within a 20 year period.

Conclusion

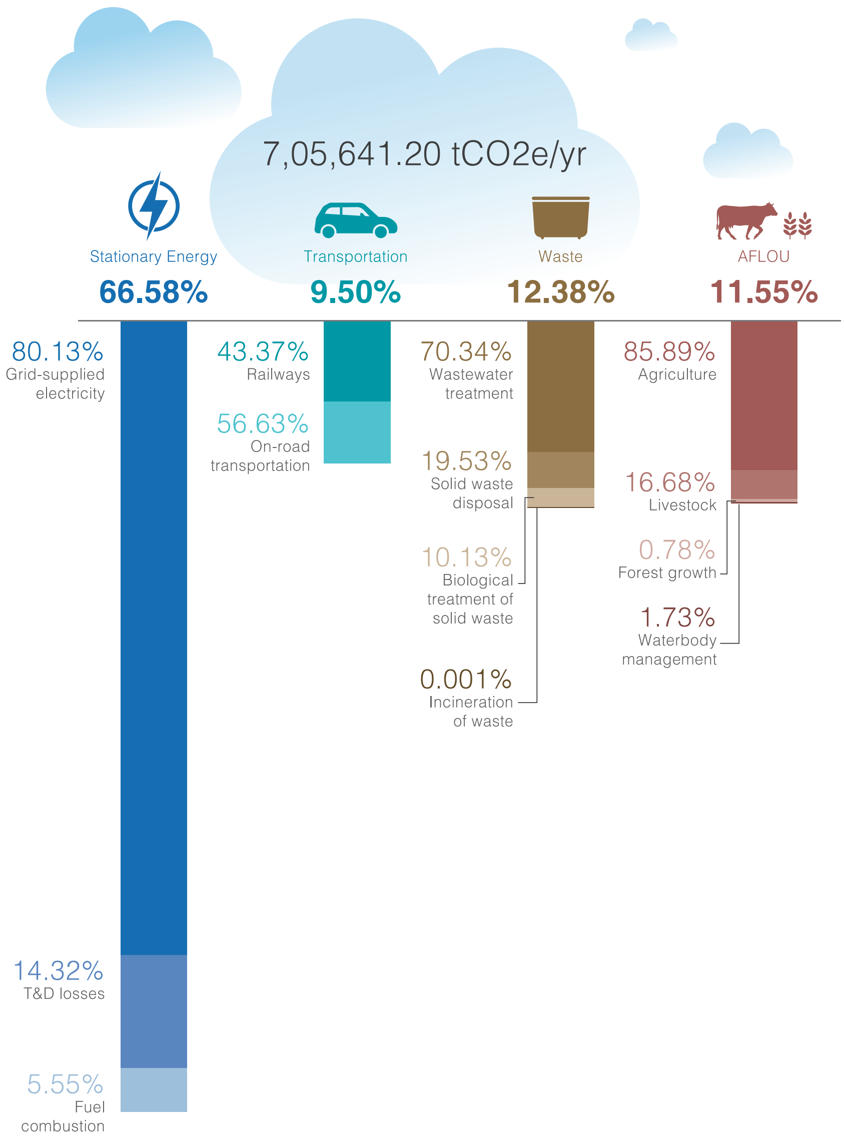
07

Rajapalayam LPA's GHG emissions for 2021 are estimated at 7,05,641.20 tCO2e/yr. The stationary energy category is the single largest emission source, accounting for 67.04% of total emissions in 2021 followed by waste at 12.21%.

A more detailed assessment of the reduction and sequestration potential for Rajapalayam LPA's key sectors will be needed. This will inform short and mid-term GHG reduction target setting, policy design interventions and the development of sector specific climate mitigation programs.

The Rajapalayam greenhouse gas emissions inventory report for 2021 is the first such exercise taken up by Rajapalayam LPA. It has helped to quantify emissions and identify opportunities for reduction.

Figure 15: Percentage share of total emissions by type



Annexure 1

Stationary Energy

Scope	Residential Buildings	Emissions (tCO2e/yr)
1	Emissions from fuel combustion within the city boundary	23,691.86
2	Emissions from grid supplied energy consumed within the city boundary	1,26,558.80
3	Emissions from transmission and distribution losses from grid-supplied energy consumption	19,376.15
	Commercial and Institutional Buildings and facilities	
1	Emissions from fuel combustion within the city	NA
2	Emissions from grid-supplied energy consumed within the city boundary	78,588.23
3	Emissions from transmission and distribution losses from grid-supplied energy consumption	14,941.63
	Manufacturing Industries	
1	Emissions from fuel combustion within the city	2,258.96
2	Emissions from grid-supplied energy consumed within the city boundary	1,72,201.39
3	Emissions from transmission and distribution losses from grid-supplied energy consumption	33,153.51
	Agriculture, Forestry and Fishing Activities	
1	Emissions from fuel combustion within the city	305.51
2	Emissions from grid-supplied energy consumed within the city boundary	934.80
3	Emissions from transmission and distribution losses from grid-supplied energy consumption	143.12
	Non-Specified Sources	
1	Emissions from fuel combustion within the city	NA
2	Emissions from grid-supplied energy consumed within the city boundary	770.80
3	Emissions from transmission and distribution losses from grid-supplied energy consumption	118.01
	Fugitive emissions from Mining, Processing Storage and Transportation of coal	
1	Emissions from fuel combustion within the city	NA

Transportation

Scope	On-road transportation	Emissions (tCO2e/yr)
1	Emissions from fuel combustion on-road transportation occurring within the city boundary	37,424.39
2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	NA
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	NA
	Railways	
1	Emissions from fuel combustion for railway transportation occurring within the city boundary	28,655.76
2	Emissions from grid-supplied energy consumed within the city boundary for railways	NA
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	NA
	Waterborne navigation	
1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	
2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	NA
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	NA
	Aviation	
1	Emissions from fuel combustion for aviation occurring within the city boundary	NA
2	Emissions from grid-supplied energy consumed within the city boundary for aviation	NA
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	NA
	Off-road transportation	
1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	NA
2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	NA

Waste

Scope	Solid waste disposal	Emissions (tCO2e/yr)
1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	16,827.91
3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	NA
1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	NA
	Biological treatment of waste	
1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	8,725.00
3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	NA
1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	NA
	Incineration and open burning	
1	Emissions from solid waste generated and treated within the city boundary	0.47
3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	NA
1	Emissions from waste generated outside the city boundary but treated within the city boundary	NA
	Wastewater treatment and discharge	
1	Emissions from wastewater generated and treated within the city boundary	60,601.42
3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	NA
1	Emissions from wastewater generated outside the city boundary but treated within the city boundary	NA

AFOLU

Scope	Category	Emissions (tCO2e/yr)
1	Emissions from livestock within the city boundary	13,407.51
1	Emissions from land within the city boundary	69,027.53
1	Emissions from aggregate sources and non-CO2 emission sources on land within the city boundary	NA

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