Auroville Greenhouse Gas Emissions

Inventory Report

Financial Year 2018-19

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Acknowledgments

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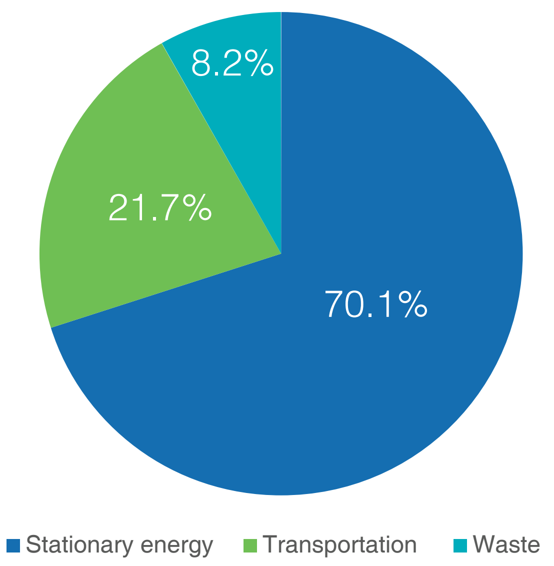
Key findings

In FY 2018-19, Auroville's residents and units produced **8,298.54 tCO_2e**. The sources of emissions are from Stationary Energy, Transportation and Waste.

The emissions from Stationary Energy include electricity consumption from residential buildings and facilities, income generating units and facilities and the manufacturing sector, and fuel combustion in a stationary apparatus such as a diesel generator. The emissions from Transportation come from on-road transport on two-wheelers, four-wheelers, buses and freight vehicles. The source of Waste sector emissions is from the treatment and management of solid waste and domestic wastewater.

The largest contributor to the total emissions, as shown in figure 1, is the Stationary Energy sector with 5,813.59 tCO_2e (70%), followed by Transportation with 1,803.58 tCO_2e (22%) and lastly Waste with 681.37 tCO_2e (8%).

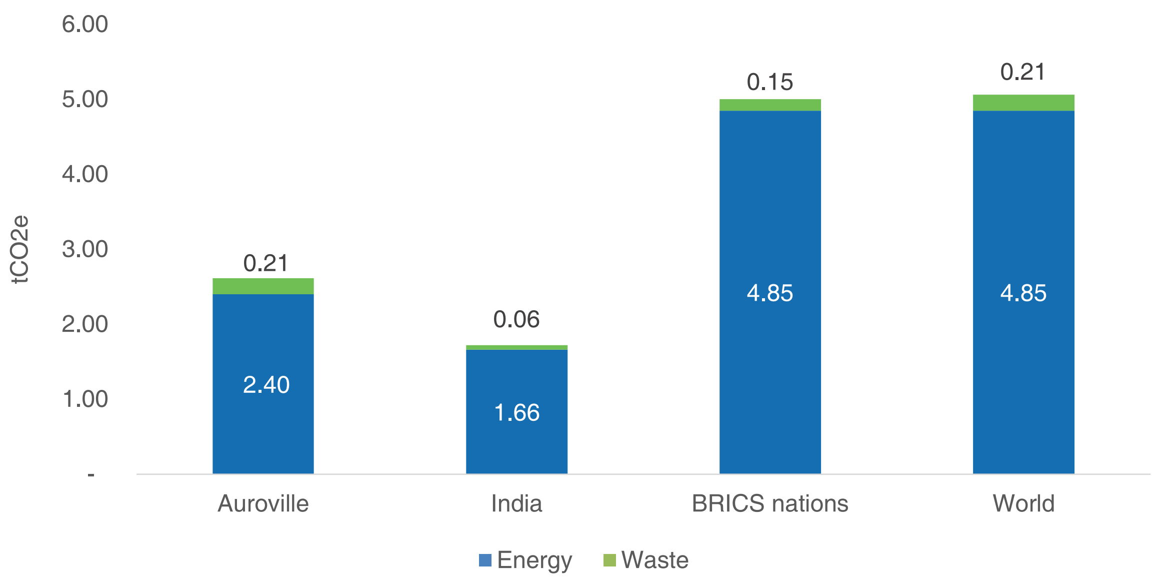
Figure 1: GHG emissions by sector (tCO_2e)



The emission intensity of Auroville is **2.62 tCO_2e** per person. In comparison to the world and the other emerging economies or BRICS nations (Brazil, Russia, India, China, South Africa), Auroville's per capita emission is moderate. In relation to the rest of India, which stands at 1.72 tCO_2e per capita, as shown in figure 2, Auroville's per capita is higher by 52%. Auroville's higher per capita emissions could be explained by a possibly higher average income per capita as compared to the average Indian and thus the higher proportion of consumption-based emissions.[1]

[1] *Hiding behind the poor, Greenpeace 2007*

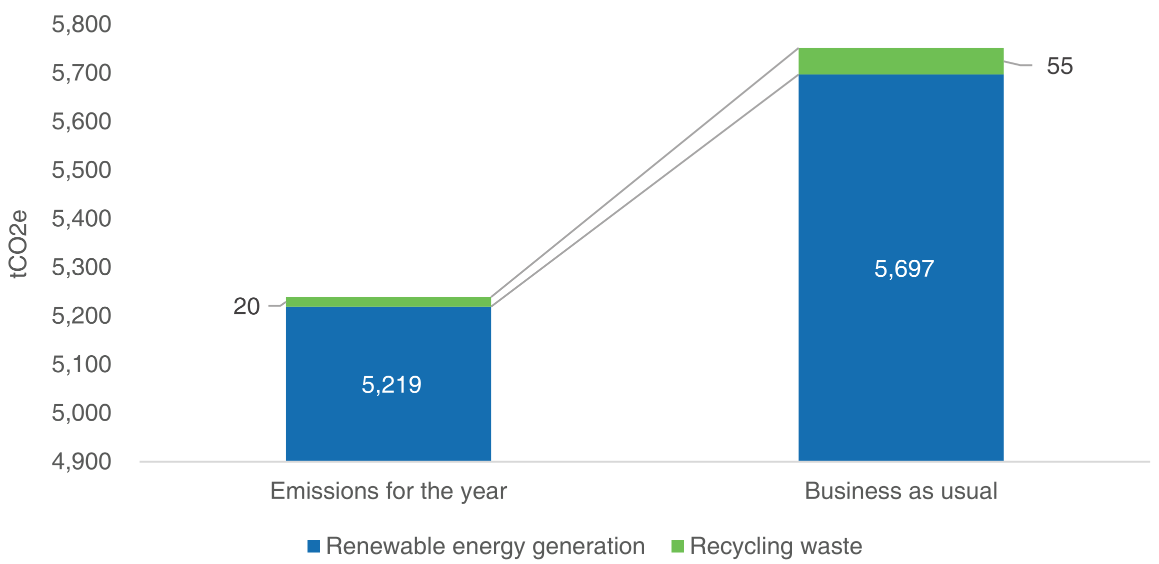
*Figure 2: Emissions per capita**



**Energy emissions include transportation; energy emissions for Auroville do not include flight data*
**Per capita emissions for India, BRICS and the World are from WRI Climate Watch 2016*

A number of sustainable practices by Auroville have contributed to a lower impact on the environment. The sustainable practices include generating renewable electricity through solar photovoltaics (PV) and a wind turbine, and recycling solid waste. If instead of producing solar power, Auroville had consumed electricity from the grid, it is estimated that an additional 478 tCO_2e would have been emitted. Similarly if Auroville had landfilled waste instead of recycling, the emissions would have increased by 35 tCO_2e. Thus Auroville avoided **513 tCO_2e** from being released into the atmosphere or 9% of the emission had these measures not been implemented (or in a business as usual scenario).

*Figure 3: Emissions avoided by Auroville**



**Does not include emissions saved from the wind turbine, e-vehicles and cycles and composting of organic waste*

The results presented here and expanded in the following sections are part of the first such exercise conducted within Auroville. The methodology adopted during the analysis forms part of a globally-recognised protocol for communities. This baseline report informs key decision makers on the strategies they need to develop and implement within the community in order to collectively achieve our global climate target.

The wish, in future reports, is to include emissions from **agriculture** and from the use of **industrial products** such as cement, lime and glass primarily used in construction and infrastructure development. In addition, carbon sequestration from **afforestation** activities in Auroville will also be included to give a deeper understanding of Auroville's net greenhouse gas emissions.

Contents

Background and purpose

Climate change is one of the most pressing challenges faced by planet Earth today. Human activities have contributed to a global temperature rise of over 1˚C from the pre-industrial era.[2] This rise of temperature can be attributed to the presence of 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.

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[3]. Article 4.1 of the 2015 Paris Agreement requires Parties to undertake the rapid reduction of emissions in accordance with the best available science.[4] India, one of its signatories, has pledged to reduce the emission intensity of its economy by 33-35% by 2030, compared to 2005 levels.[5] Since it is a developing country and heavily dependent on agriculture, it is particularly affected by climate change and the resulting changes in weather pattern.

Cities are particularly well-placed in helping their countries meet the national emissions targets. It is estimated that 70% of all energy-related GHGs occur within cities and it will likely grow as more people migrate to urban areas.[6] 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.

Auroville, a universal township in south India, has taken significant steps towards conscious and sustainable living since its inception over 50 years ago. These steps include research and implementation of climate responsive and green architecture, appropriate technologies in energy, waste and water management, organic farming and food production, and ecological restoration.

A conceivable next step in its evolution is to take inventory of its emissions in order to improve its ability to take effective action and monitor progress. The hope is that this report creates awareness in Auroville to help it create a robust roadmap with a reduction and mitigation strategy. Although consumption patterns for some sectors have been tracked by Auroville for many years, it is the first time that an emission inventory has been compiled. This report (for financial year 2018-19) may therefore serve as a baseline for similar exercises in the subsequent years. With the 2018-19 numbers as a baseline, Auroville will be able to design strategies and action plans towards emission reduction.

[2] IPCC special report Global Warming of 1.5 °C: https://www.ipcc.ch/sr15/
[3] Signing of the Paris Agreement: https://news.un.org/en/story/2016/04/527442-today-historic-day-says-ban-175-countries-sign-paris-climate-accord#.VxqAYGNpr-Y
[4] The Paris Agreement: https://unfccc.int/sites/default/files/english_paris_agreement.pdf
[5] Emissions intensity reduction plan: http://moef.gov.in/environment/climate-change/
[6] GHG protocol for community-scale GHG emissions inventories: https://ghgprotocol.org/sites/default/files/standards/GHGP_GPC_0.pdf

Methodology

The GHG emissions inventory of Auroville was calculated using the Global Protocol for Community-Scale Greenhouse Gas Emission Inventory (GPC). The GPC offers cities and local governments a globally-accepted framework to consistently identify, calculate and report on the city's greenhouse gas emissions.

In addition, the 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 sectors or emission sources that are covered in the inventory of Auroville forms part of the BASIC reporting of the GPC. The sectors include: a) stationery energy, b) transportation and c) waste. The sectors not included because of unavailability of data are industrial processes and product use (IPPU) and agriculture, forestry and other land use (AFOLU). The sectors and the sub-sectors that they are comprised of are shown in the table below.

Table 1: Sectors and sub-sectors of city GHG emissions

Stationery Energy
Residential buildings
Commercial and institutional buildings and facilities
Manufacturing industries and construction
Energy industries
Agriculture, forestry, and fishing activities
Non-specified sources
Fugitive emissions from mining, processing, storage, and transportation of coal
Fugitive emissions from oil and natural gas systems
Transportation
On-road
Railways
Waterborne navigation
Aviation
Off-road

Waste
Solid waste disposal
Biological treatment of waste
Incineration and open burning
Wastewater treatment and discharge
Industrial Processes and Product Use (IPPU)
Industrial processes
Product use
Agriculture, Forestry and Other Land Use (AFOLU)
Livestock
Land
Aggregate sources and non-CO_2 emission sources on land

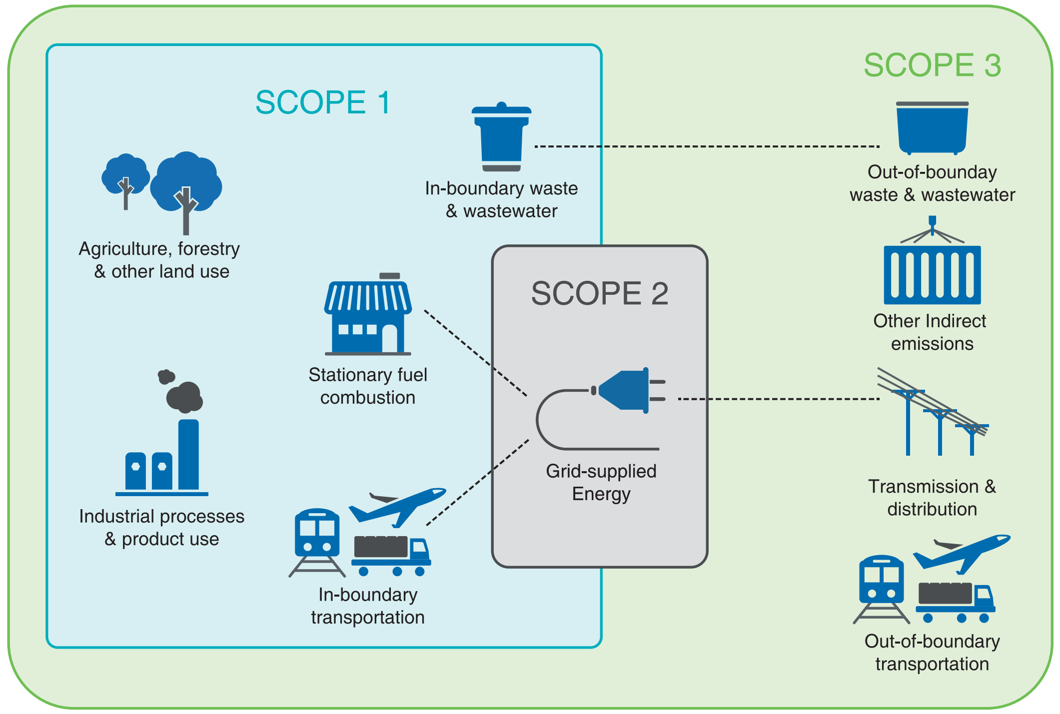
Every sectoral activity that takes place within a city can generate GHG emissions that occur both inside the city boundary as well as outside the city boundary. To distinguish among these, the emissions are grouped into the following three categories:

Table 2: Definition of scopes for city 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, figure 4 shows emission sources that occur within the geographic boundary, outside the geographic boundary and across the geographic boundary (emissions sources such as transmissions and distribution and industrial processes depicted here are not covered in this report).

Figure 4: 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)

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 (kgCO_2/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 (CO_2e).

The greenhouses gases covered by the GPC are carbon dioxide (CO_2); methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF_6) and nitrogen trifluoride (NF_3). 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. CO_2e 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.

The activity data in this report was gathered through a variety of sources including surveys amongst residents of the city (referred to interchangeably as community), and departments (or units of Auroville). The following sections explore the activities and emissions of each sector – Stationary Energy, Transportation and Waste – in detail. The report also highlights assumptions made during the analysis as a result of data gaps; the hope is that it serves to engage the community to improve mechanisms for data collection progressively.

Stationary Energy

Stationary Energy emissions are a result of:

1. **Fuel combustion** for generating heat or enabling a mechanical process and
2. **Fugitive emissions** occur at the point of extraction, processing, storage and transport of a fuel and includes unintentional releases such as equipment leaks, evaporation losses

The emissions under the Stationary Energy sector are categorised as per the scopes in the Table 3.

Table 3: Scopes for Stationary Energy

Scope	Description
1	Emissions from fuel combustion and fugitive emissions in the city; e.g. generators, power plants, fossil fuel exploration
2	Emissions from the consumption of grid-supplied electricity, steam, heating and cooling in the city
3	Distribution losses from grid-supplied electricity, steam, heating and cooling in the city

Fuel combustion

The combustion of **liquefied petroleum gas (LPG)** used as fuel for cooking, **diesel** for generators, land mowers or portable chainsaws and **petrol** for other equipment are the three fuels identified in Auroville and covered in this inventory.

The information on consumption of each fuel is typically gathered at the point of fuel use or is obtained by utilities or fuel providers.

Table 4: Stationary emissions by scope and sub-sector

Sub-sector	Scope 1			Scope 2
	LPG	Diesel	Petrol	Grid-supplied
Electricity				
Residential buildings and facilities	203	-	-	2,565
Income-generating unit and facilities	203	83	-	1,739
Institutional buildings and facilities	-	96	8	747
Manufacturing industries and construction	-	-	-	168
Total emissions (tCO_2e)	**407**	**180**	**8**	**5,219**

LPG

The data of the consumption of LPG used in households, restaurants and community kitchens, was provided by the Auroville Gas Service. Ideally the data is required to be disaggregated by the sub-sector that consumes the fuel but since that level of granularity is not available, the bulk of the consumption of the city is assumed to be consumed equally between the two consuming sub-sectors, i.e. residential buildings and income-generating units.

The monthly consumption of LPG cylinders, in their different volumes, helped derive the total consumption for the year. The annual LPG consumption for FY 2018-19 was 1,38,465 kg bringing the total emissions for LPG to **406.65 tCO_2e** as seen in Table 4.

Diesel

The data on consumption for both diesel and petrol was collected from the units in Auroville through a survey; the data received is compiled below in Table 5. The survey did not include residential communities because it was hard to collect data and it was assumed that they would hire the services of units for any machinery that they may need and therefore the consumption details will be covered in the responses of the units. However, this method overlooks any diesel generators that might be installed in residential communities.

Table 5: Stationary diesel consumption from sample

Data from 44 sample units	Diesel consumption (litres)	Diesel emissions (kg CO_2e)
Income-generating unit and facilities	11,232	30,102
Institutional buildings and facilities	16,571	44,411
Total	**27,803**	**74,513**

The annual financial turnover of 40 of the 44 units, which are listed as service and income-generating units, was used to ascertain the average emission intensity or kg CO_2e per INR. (The 4 units that were excluded are part of city services whose turnover details were not available). The average value was then multiplied by the total number of service and income-generating units to ascertain the total emissions from diesel consumption under Stationary Energy, which was estimated at **180 tCO_2e** as shown in table 4. The approach assumes that the spending on fuel is the same across all units regardless of their size and type of business operations.

Petrol

A similar methodology to that of diesel was followed for petrol emissions; the data gathered through the survey are compiled below in Table 6. After scaling up, the total emissions from petrol consumption for all institutional units are estimated at **8 tCO_2e** as shown in table 4.

Table 6: Stationary petrol consumption from sample*

Data from 44 sample units	Petrol consumption (litres)	Petrol emissions (kg CO_2e)
Institutional buildings and facilities	1,212	2,800
Agriculture, forestry and fishing activities	163	378
Total	**1,376**	**3,178**

*the data from agriculture, forestry and fishing activities was not scaled up because their turnover details were not available

Grid-supplied electricity

Electricity consumption is typically the largest source of scope 2 emissions for cities. It occurs when buildings and facilities in the city consume electricity from the public electricity grid. For some cities steam, heat and cooling is supplied though a small-scale distribution grid. Such a network is not available in Auroville, thus the only emission category for scope 2 is grid-supplied electricity consumption.

The data on grid-supplied electricity consumption of Auroville was provided by Auroville Electrical Service. The total consumption by sub-sector was put together with data on the annual meter reading and tariff type, which includes some facilities owned by Auroville outside its geographical boundary. Table 7 shows the total grid-supplied electricity consumption by each sub-sector, with the majority consumed by residential buildings and facilities. The total electricity consumed by Auroville in FY 2018-19 is 6,364.82 MWh – this number excludes locally-generated solar energy consumed behind-the-meter. Electricity sourced from the grid accounted for **5,219.15 tCO_2e** in FY 2018-19. These numbers are in line with the methodology recognised by the GPC. The rest of the section gives a more on-the-ground picture of electricity as a sector in Auroville with the push that it has given to renewable energy generation.

Table 7: Annual electricity consumption by sub-sector

Sub-sector	Total consumption (MWh)	Total emissions (in tCO_2e)
Residential buildings and facilities	3,128.05	2,565.00
Income-generating units and facilities	2,120.41	1,738.74
Institutional buildings and facilities	911.47	747.40
Manufacturing industries and construction	204.89	168.01
Grand total	**6,364.82**	**5,219.15**

Auroville's grid-supplied electricity comes from the following sources:

a) Electricity supplied by the state-owned electricity utility (TANGEDCO),
b) Electricity generated by Auroville's wind turbine located in a different geographical area and fed into the public grid, and
c) Electricity generated by the locally-installed distributed solar photovoltaic (PV) systems

Auroville owns and operates a **wind turbine** in Dharapuram, Tamil Nadu; the electricity it generates is wheeled to Auroville. Wheeling is a mechanism whereby credit (in kWh) is given at the point of consumption for the energy produced at the point of generation. This arrangement helps Auroville generate wind power which would not be possible within its boundary because of its geographical location and also enables the promotion of clean energy. As per the guidelines, renewable energy generated by Auroville's wind turbine will not be considered emission-free as it is supplied through the grid nor can it be subtracted from the total emissions. (However, the renewable energy generated helps lower the state's emissions). In FY 2018-19, 1,385.90 MWh was wheeled from the Auroville-owned wind turbine. Hence the total grid consumption of 6,364.82 tCO_2e and its linked emissions includes wind energy generation by the turbine.

The energy generated by the locally-installed **distributed solar PV systems** with a capacity of 260 kW (mostly rooftop solar systems) also serves to highlight the efforts towards sustainable development. Here, the electricity is first consumed by the building thereby reducing the amount of electricity that needs to be supplied by the electricity utility. Only the surplus solar not consumed by the building where the solar energy system is installed is exported to the grid - either the Auroville internal distribution network or the grid operated by the state utility. Most of this surplus solar energy is exported to the former and is consumed by the nearest load in the network. Assuming a capacity utilisation factor (CUF) of 17%, the gross solar energy generation for the FY 2018-19 is estimated at 387.13 MWh.

It may also be noted that Auroville has **stand-alone solar PV systems** (not supplied to the grid) with an aggregate installed capacity of 200 kW. The gross solar energy generation for FY 2018-19 at a CUF of 10% is estimated at 175.2 kWh.

Hence, the total consumption of electricity in Auroville including the local solar PV systems is estimated at 6,927.15 MWh. As shown in table 8, of the total consumption, the total renewable energy generated by Auroville is estimated at 1,948.23 MWh, which includes wheeled electricity. If the wheeled renewable energy was recognised to have zero emissions, the total emissions avoided by Auroville by not depending on the public grid is 1,597.55 (28% of what would have been 5,680.26 tCO_2e).

Table 8: Renewable energy capacity and production

Technology type	Installed capacity (kW)	Energy production in FY2018-19 (MWh)	Located in geographic boundary?	If outside the boundary, percentage of ownership by the city?
Wind energy generated in Dharapuram, Tamil Nadu	800	1,385.90	No	100%
Grid-connected solar PV systems	259.96	387.13*	Yes	-
Stand-alone solar PV system	200	175.20**	Yes	-
Total	1259.96	1,948.23		

*Estimated with the assumption of 17% CUF
**Estimated with the assumption of 10% CUF

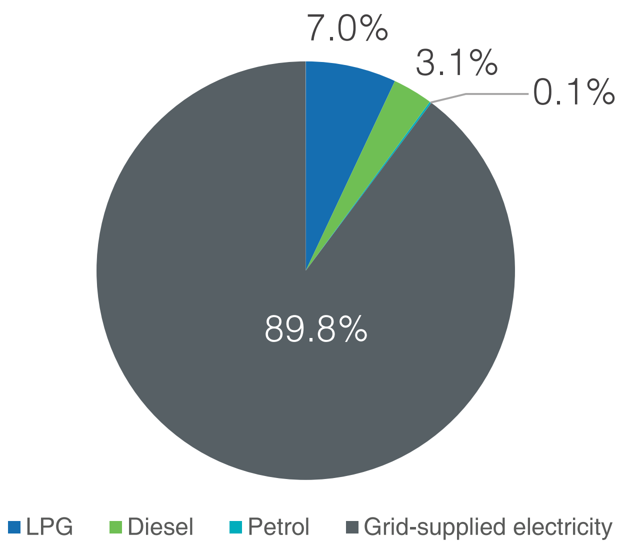
Fugitive emissions from fuel-related activities

A small portion of emissions from the energy sector arise as fugitive emissions, of which the two main sub-sectors are a) mining, processing, storage, and transportation of coal, and 2) oil and natural gas systems. Since Auroville does not have coal mines, the first sub-sector is not relevant to this report. Neither does Auroville produce, process and deliver natural gas and petroleum products, hence most emissions under the second sub-sectors also fall outside its purview. However, it is quite likely that there are equipment leaks, evaporation and other accidental releases that take place in Auroville but it was not possible to calculate these because of the isolated and undocumented nature in which these incidents may occur.

Results for Stationary Energy

The total GHG emissions for Stationary Energy was **5,813.59 tCO_2e**, of which 90% was through grid-connected electricity consumption, followed by consumption of LPG, diesel and petrol.

Figure 5: Share of Stationary Energy emissions



Transportation

The modes of transport that are sources of emissions include:

- On-road transportation
- Railway
- Water-borne transportation
- Off-road transportation

On-road transportation is the primary mode of transport in Auroville for the movement of both people and goods inside and to and from Auroville. On-road vehicles include passenger vehicles (motorbikes, cars, buses) and freight vehicles (trucks and tempos). **Off-road** vehicles adapted to travel on unpaved terrain are for example tractors, landscaping and construction equipment, and bulldozers. The activity data from off-road vehicles received were from the Auroville Road Service. As this qualifies as off-road transportation within construction sites and industrial premises, these have been reported under Stationary Energy as per the GPC. As other types of off-road activity data was unavailable, this mode of transport is excluded from the report. In addition, since there is no transport through **railways**, **waterborne** mediums and **airports** in Auroville, they do not come under the ambit of this report.

Unlike Stationary Energy emissions, Transportation emissions are mobile in nature hence it poses more challenges than others with respect to accounting the emissions accurately. The transportation emissions are categorised in the following scopes:

Table 9: Scopes for transportation

Scope	Description
1	Includes all GHG emissions from the vehicles within the Auroville boundary
2	Includes emissions from the electricity supplied from the grid for charging electric vehicles*
3	Includes all transboundary journeys and emissions from the vehicles which either originate or terminate within Auroville; and transmission and distribution losses**

** The amount of electricity used by electric vehicles is evaluated at the point of consumption. As this data was not available, Scope 2 has been excluded. However the absolute electricity consumption of Auroville, which includes electricity used to charge vehicles is accounted for in the Stationary Energy sector*
*** T&D losses cannot be calculated, as electricity consumption data for e-vehicles was not available*

Methodology for the sector

Due to variation in availability of data, purpose of inventory studies and existing transportation models, GPC does not prescribe a specific methodology for calculating emissions from road transport. Four common methods that provide guidance are described in Table 10 below.

Table 10: Transportation methodology options

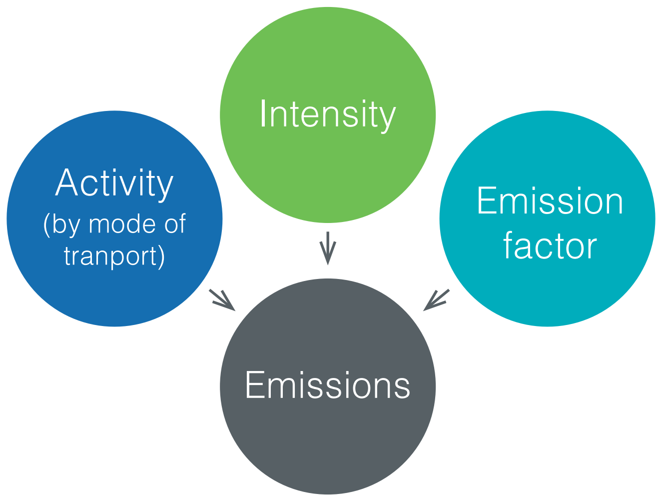
Number	Name of the method	Description
1	Fuel sales approach	Total fuel sold within the community; data collected from the fuel stations within the geographical boundary of the city
2	City-induced Activity	Based on the ASIF framework; includes all trips within the boundary, i.e. trips which either originate or end in the city; however, it excludes pass-through trips.
3	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.
4	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.

The **ASIF framework** referred to in Table 10 is described as per the following:

- **Activity (A)**: measured in terms of vehicle kilometre travelled (VKT) which is obtained from total number and length of trips
- **Mode share (S)**: gives the proportion of trips taken by different modes of transport (e.g. two-wheelers, four-wheelers, public bus, trucks.) In this study, total emissions are calculated separately for different types of vehicles/modes of transport hence, mode share (%) was not used in the formula. **Intensity (I)**: Reflects energy consumed per vehicle kilometre travelled. Energy intensity is a function of vehicle types, occupancy rate/load factor and represented as litres per passenger kilometre (l/pass/km).
- **Fuel factor (F)**: also known as emission factor and gives the carbon content of the fuel in grams per litre (g/l).

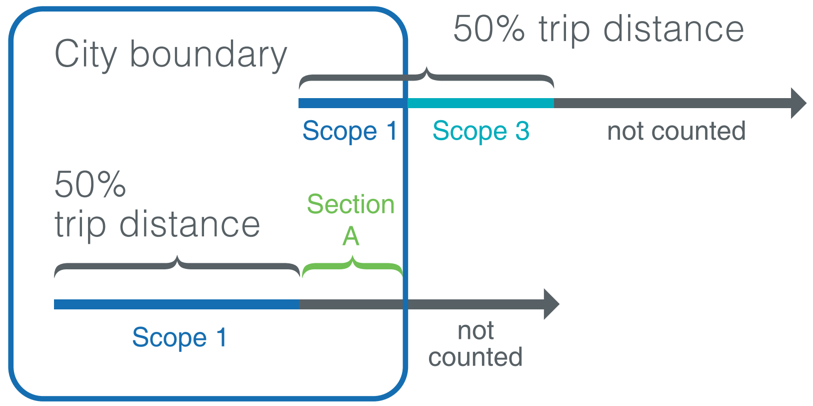
Thus as illustrated in Figure 6, the emissions (for particular vehicle type) = Activity (km) x Intensity (l/pass/km) x Emission factor (g/l).

Figure 6: ASIF framework as applied in this report



Transboundary trips referred to in Table 6 consider 50% of the trip as occurring within the city boundary and therefore scope 1 and the other 50% as occurring in scope 3. However, this poses a challenge which is illustrated in Figure 7. There may be a portion that indeed occurs within the boundary but is not reflected in scope 1.

Figure 7: Induced activity allocation



(Source: GPC)

One of the four methodologies as described in Table 10 is selected based on the quality and availability of data, and objectives of the inventory for the city. For example, the Fuel Sales method would be more preferable to show overall reduction in the fuel consumption of the city compared to the base year. The Activity methods provide a better picture about the transport system in the city, the preferred mode of transportation, the primary fuel used, the age of the vehicles, fuel efficiency of the vehicles on road and the role of electric vehicles in the system. These help to prioritize mitigation actions through proper policy measures. It is advisable to have consistency in the methodology or document it when it is changed while carrying out inventories because a change in method brings variations in the results in each method.

This inventory uses the **City-induced Activity method** to estimate GHG emissions from Transportation. 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% (although not required under BASIC reporting) in scope 3. And all pass-through trips are excluded even though they are inside the boundary since they are not induced by the city.

Results for Transportation

The best means of gathering activity data for Transportation was through interviews and surveys. The two major sections of the demography identified were:

a) **residents of Auroville** (with a population of 3,173) and
b) **units and city services** (or departments within Auroville that provide goods and services); in total 242 units

The data from 263 individuals and 45 units were compiled to calculate the actual emissions. Thereafter, an average from the sample data was used to scale up to all of Auroville.

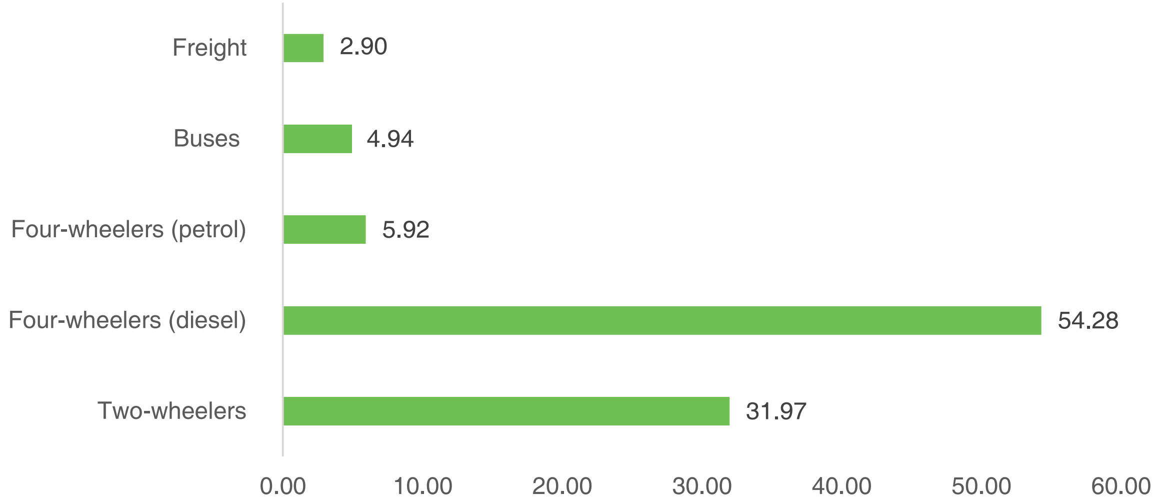
In total, for FY 2018-19, the activities related to Transportation in Auroville generated **1,803.5 tCO_2e**. This figure does not include GHG emissions from air travel or those generated by city services (the reasons for this are expanded later in this section below). The analysis of the scaled up emissions shows that four-wheel diesel vehicles contribute the majority of emissions followed by two-wheelers, four-wheel petrol vehicles, buses and lastly freight vehicles.

*Table 11: Total Transportation emissions by mode of transport**

On-road emissions	Fuel type	tCO_2e
Two-wheelers	Petrol	576.58
Four-wheelers	Diesel	978.90
Four-wheelers	Petrol	106.74
Buses	Diesel	89.02
Freight	Diesel	52.35
Total		**1,803.5**

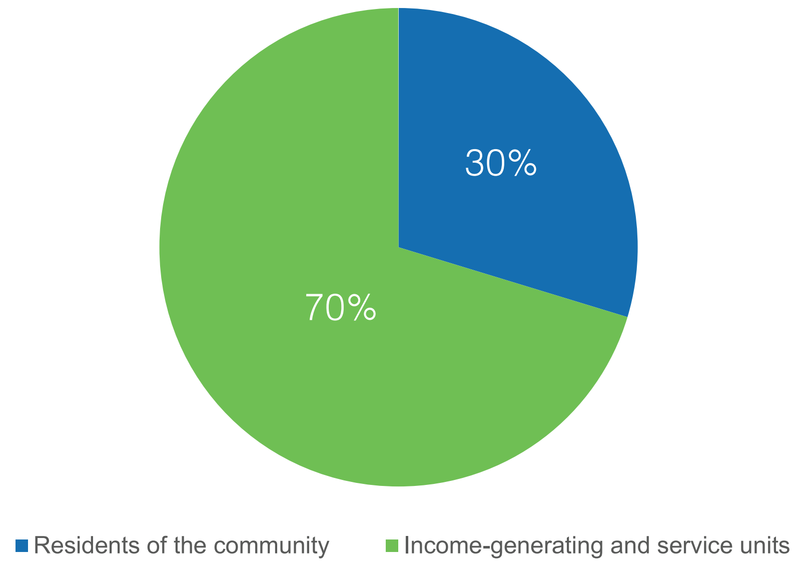
** Emissions from diesel four-wheelers include emissions from all taxi services provided by Auroville units. However, it do not include emission from external taxi service providers even though they may be within the geographical boundary.*

Figure 8: Transport emissions by mode of travel (%)



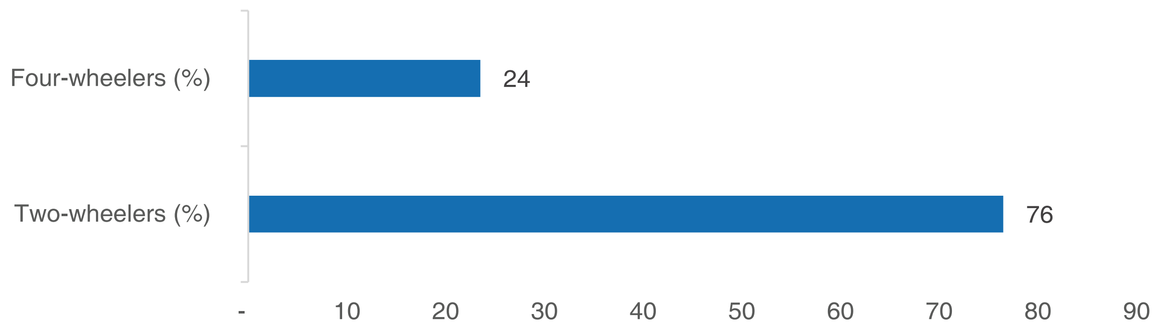
As seen in figure 9, a comparison of emissions between community members and units shows that 70% of all emissions comes from income-generating and service units, whereas only 30% is generated by the residents. The higher share of emissions from units is a result of more travel for work and official purposes.

Figure 9: Transport emissions from residents and units (%)



Furthermore, of the emissions from residents, 76.5% are contributed by two-wheelers and 23.5 % from four-wheelers (petrol and diesel combined).

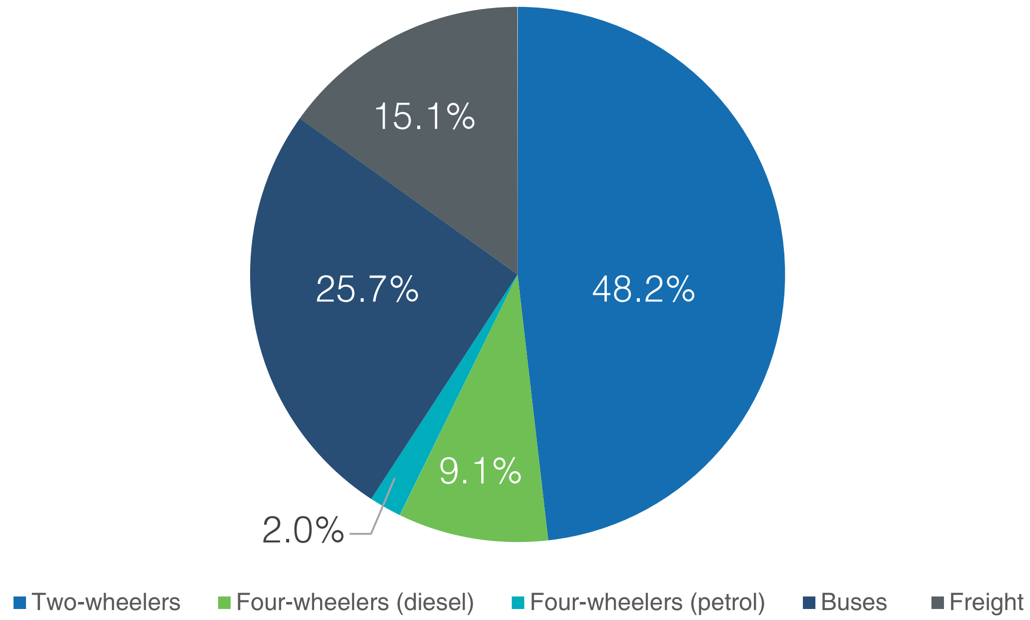
*Figure 10: Transport emissions from residents**



** This extraplation does not include data from taxis; as the complete data set for taxis was available, extrapolation was not needed*

A closer look at the emissions from Auroville units as seen in Figure 11 shows that the majority was contributed by two-wheelers, followed by buses, freight and four-wheelers diesel and petrol.

*Figure 11: Transport emissions from units (%)**



**This extraplation does not include data from taxis; as the complete data set for taxis was available, extrapolation was not needed*

As mentioned earlier, GHG emissions from aviation are not included in the inventory because Auroville does not have any airports inside its boundary. The sample data of flight emissions is reproduced in Table 12. The total emissions for both domestic and international flights amount to **476.6 tCO_2e/pass**. This has not been scaled up for the population because of lack of quality data.

The responses from units labelled city services have also not been scaled up because adequate data was not available; emissions from the sample of city services have also been listed in Table 12.

Table 12: Transport emissions not scaled up

Unscaled emissions	GHG emission	Unit
Flights	476.6	tCO_2e/pass
City services (including farms)	19.5	tCO_2e

Waste

The disposal and treatment of waste generates GHG emissions, primarily from aerobic and anaerobic decomposition. The sources of GHG emissions covered in this inventory under the Waste are from:

- municipal solid waste management and disposal,
- wastewater treatment and discharge, and
- incineration or open burning of waste

Under the BASIC reporting structure, the waste sector consists of the following scopes under the ambit of this report.

Table 13: Scope for Waste

Scope	Description
1	This includes all GHG emissions from treatment and disposal of waste within the city boundary
2	Not Applicable
3	This includes all GHG emissions from treatment of waste generated by the city but treated at a facility outside the city boundary

Auroville strives to achieve minimal waste by maximizing efforts towards prevention and treatment of waste. Its efforts are explored through the rest of this section.

Municipal solid waste management and disposal

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.

Solid waste in Auroville is managed by a unit called Ecoservice. The Ecoservice team collects segregated waste from households, communities, guest houses, restaurants and units, and processes it at a sorting shed. Waste is then either sold to recycling dealers, or landfilled at the Auroville landfill. Ecoservice collects the waste segregated by the communities into six broad categories namely – paper, plastic, glass, metal, sanitary and mixed waste. These six categories of waste are further segregated into 83 sub-categories at Ecoservice.

Ecoservice was established with the vision of reducing and reusing/recycling waste along with research in the field of waste management. Through its waste management practices, Ecoservice ensures minimum disposal of waste to the landfill.

Figure 12: Waste segregation bins in Auroville communities

Figure 13: Waste sorting in Ecoservice

The Methane Commitment (MC) model from the GPC protocol has been used to calculate methane emissions from solid waste disposal in Auroville. The MC model calculates emissions from the inventory year and is relevant for this baseline inventory. This choice is made by taking into consideration the unavailability of historic disposal data from Auroville landfills.

According to the MC model, the formula to calculate CH4 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

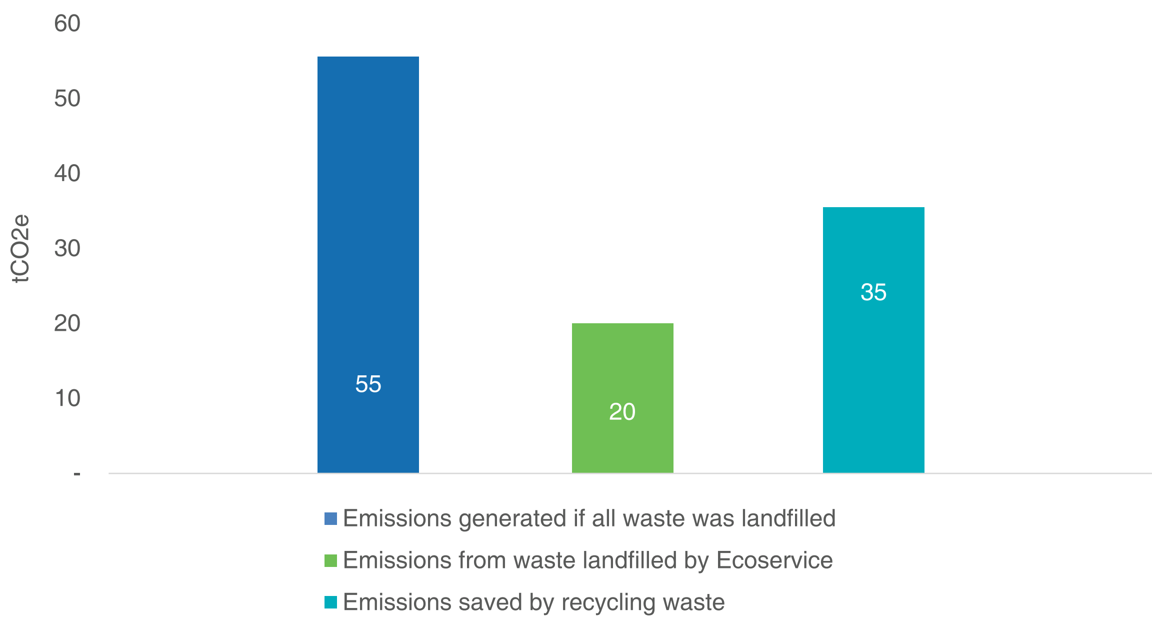
Using the equation above, the total emissions for solid waste disposal for FY2018-19 was 0.71 tonnes CH_4 or **19.75 tCO_2e**. Solid waste disposal consisted of 2.90% of the total GHG emissions by the Waste sector.

It's interesting to note that in FY2018-19, out of 109 tonnes of waste collected by Ecoservice, only 27 tonnes or 25% of waste was sent to the landfill. The rest is recycled or reused, resulting in an emission saving of 35 tCO_2e.

Table 14: Emissions saved through appropriate solid waste management

Description	Amount	Unit
Municipal solid waste collected	109.29	tonnes
Emissions generated if all waste was landfilled	54.84	tCO_2e
Emissions from waste landfilled by Ecoservice	19.74	tCO_2e
Emissions saved by recycling waste	35.10	tCO_2e

Figure 14: Emissions saved through waste management (tCO2e)



Wastewater treatment and discharge

For the treatment of domestic wastewater, Auroville has installed 97 integrated decentralised wastewater treatment systems (DEWATS) most of which are designed by the Auroville Centre for Scientific Research (CSR). As the majority of wastewater is treated through this system, an overview of the process is given below.

DEWATS consists of:

- a settler tank where the sludge is pre-treated with the help of bacteria which facilitate the initial digestion,
- primary treatment in a baffled tank where the wastewater is made to go through anaerobic bacteria blankets which further digest material to clean the water,
- secondary treatment in another tank where further anaerobic bacterial action on the wastewater is facilitated and finally the third treatment cycle often facilitated by a vortex system, which significantly reduces the biological oxygen demand (BOD) or the amount of oxygen required to remove waste organic matter from the wastewater. The water lastly, an optional measure, is led to a pond where natural ultra-violet (UV) exposure provides further biological treatment; plants and fishes are also introduced to prevent the breeding of mosquitoes.

The residual sludge after the treatment of the wastewater is removed from most septic tanks once a year by Pour Tous Water services and discarded in Fertile, Auroville.

Figure 15: An integrated DEWATS plant in Auroville

Wastewater is a potential source of CH_4 and N_2O emissions when it is treated or disposed off, as is the case for the DEWATS installations. 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. In Auroville, wastewater is not diverted to rivers, oceans or lakes hence N_2O is not considered. The equation used to estimate CH_4 emissions from domestic wastewater is:

$$CH_4 \text{ emissions} = \sum i\, [(TOWi - Si)\, EFi - Ri] \times 10^{-3}$$

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

The total emissions from wastewater treatment amounts to 23.63 tonnes CH_4 which is equivalent to **661.53 tCO_2e**. Wastewater treatment consisted of 97.09% of the total GHG emissions from the Waste sector.

Incineration and open burning of waste

Figure 18: Waste incinerator in Auroville Health Centre

In Auroville, only medical waste is incinerated. The only known site for incineration takes place at the Auroville Health Care Centre. The medical waste that it incinerates is composed of bandages, syringes, cotton, among others. It has a small chimney of a capacity of $1m^3$, which on average burns 2 kg of medical waste every week.

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. The equations for calculating the emissions are listed below.

$$CO_2 \text{ Emissions} = m \times \sum i\, (WFi \times dmi \times CFi \times FCFi \times OFi) \times (44/12)$$

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 W.

$$CH_4 \text{ Emissions} = \sum (IWi \times EFi) \times 10^{-6}$$

$$N_2O \text{ Emissions} = \sum (IWi \times EFi) \times 10^{-6}$$

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

Incineration of waste leads to 0.09 tCO_2, 2.5×10^-5 tCH_4 emissions and 6.3×10^{-6} tN_2O emissions which leads to a combined total of **0.094** tCO_2e from incineration, which accounts for 0.01% of the total GHG emissions from the Waste sector.

Biological treatment of solid waste

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. In Auroville, the biological treatment of waste is practiced in the form of composting. All of the organic waste produced in Auroville is composted and none of it is dumped at the landfill. Households and communities in Auroville usually have their own composting system. These include digging a common pit in the community and creating a Bokashi composting system to create rich compost. This compost is used to maintain the gardens of the residential complexes and that of the Matrimandir.

Due to the limited availability of data, emissions from composting have not been extrapolated and included in this inventory. However data from the sample have been given below along with the linked emissions by using the following equations:

$$CH_4 \text{ emissions} = \sum i \ (mi \times F\_\ CH_4 i) \times 10^{-3} - R)$$
$$N_2O \text{ emissions} = \sum i \ (mi \times EF\_N_2Oi) \times 10^{-3})$$

Where:

- m = Mass of organic waste treated by biological treatment type i, kg (user input)
- EF_ CH_4 = CH_4 emissions factor based upon treatment type i
- EF_ N_2O = N_2O emissions factor based upon treatment type i
- i = Treatment type: composting or anaerobic digestion (user input)
- R =Total tonnes of CH_4 recovered in the inventory year, if gas recovery system is in place

The emissions from 110 kg of waste generated 0.44 kg CH_4 and 0.03 kg N_2O amounting to **21.07 kg CO_2e**. The activity of composting saves CH_4 emissions. Had the 110 kg been landfilled, the residential complexes would have generated 1.97 kg CH_4 instead of 0.44 kg CH_4 essentially avoiding 12.32 kg CO_2e from being released into the atmosphere.

Table 15: Sample data of waste generated for composting

Organic waste generated in 2 days	Kilograms of waste	No. of residents
Residential complex 1	60	55
Residential complex 2	50	42
Total	110	97

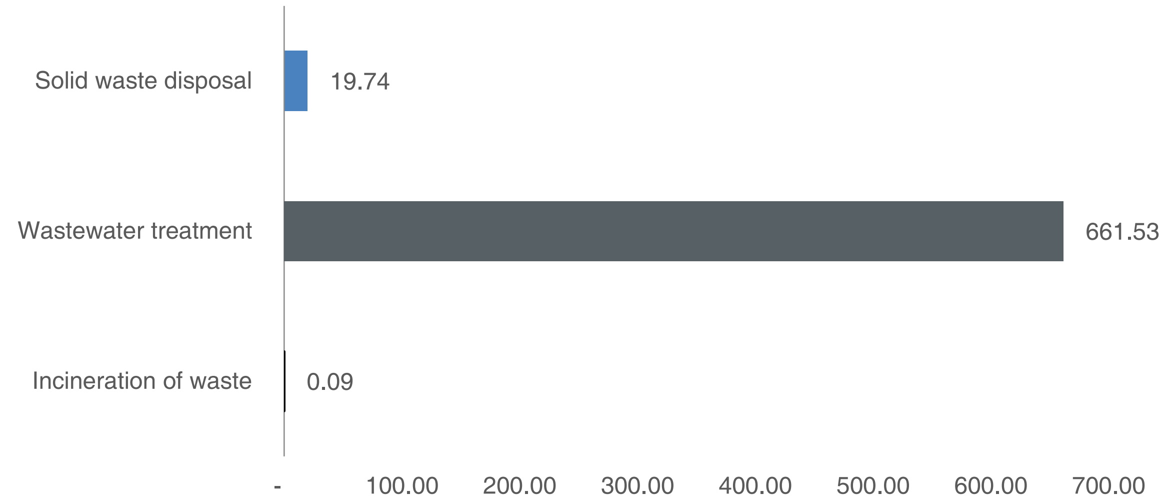
Results for Waste

In FY2018-19, the Waste sector in Auroville emitted a total of **681.37 tCO_2e**. The wastewater treatment contributed the most emissions with 97.09%, followed by solid waste disposal with 2.90% and incineration of waste with 0.01 %.

Table 16: Breakup of GHG emissions for Waste (tCO2e)

Waste category	Total emission in tCO_2e
Solid waste Disposal	19.74
Wastewater treatment	661.53
Incineration of waste	0.09
Total	681.37

Figure 19: Breakup of GHG emissions for Waste (tCO2e)



Conclusion

The Auroville greenhouse gas emissions inventory report for FY2018-19 is the first such exercise taken up by Auroville. It has helped to quantify emissions and identify opportunities for reduction. Some interventions that can be implemented are to increase locally-generated renewable energy, replace diesel generators with li-ion battery storage solutions, plan a community-wide public transportation system, increase the use of electric vehicles and employ carbon capture technologies during the processing of waste to create biogas.

A data collection process developed for such an exercise across all sectors will additionally help understand the community's emissions better. A list of assumptions and data gaps is listed below, which if addressed will help in that purpose.

The decision makers and sector experts in Auroville can play a big role in interpreting the data, filling the gaps, developing solutions and engaging the residents. The hope is that this report assists in giving an impetus to such a conversation to pave the way forward towards a sustainable future.

Assumptions and data gaps in the inventory report

- Auroville is a universal city in the making in south India:
  - emissions that occur outside the geographical master plan of the city have also been included if they are from sources owned and controlled by the Auroville Foundation;
  - Similarly emissions that occur within the master plan that are not owned and controlled by Auroville Foundation are excluded.
- Population - the population of Aurovillians and new comers for FY2018-19 was 3,173. Auroville has a large inflow of tourists and volunteers which have not be accounted for in this inventory for the transport and waste sectors.
- An uncertainty analysis of the data quality has not been made in this inventory
- Greenhouse gases – stationary fuel combustion and transportation emissions have been calculated in tCO_2e. A break up in CH_4, N_2O and other GHG emissions is not given because appropriate emission factors were not found
- Fuel consumption for stationary and mobile combustion -
  - an accurate number of units in Auroville, the industry they belong to, senior members/ executives of the units to talk/write to and details of their turnover will help collect accurate data for the sector
  - the survey was conducted in FY2019-20 and it assumes that consumption patterns were similar for the inventory period of FY2018-19
  - fuel efficiencies for vehicles have been assumed based on their observed engine capacities while age of vehicles have not been taken into account
  - the average distance travelled by each type of vehicle in a year is assumed to be same as that in a week
  - emissions are scaled up by assuming that the sample mean is the same as the population mean. First the average emissions of the pool sample (kg emissions / INR turnover) was derived; next the average was multiplied by the total turnover of income-generating and service units. This method assumes that the average spending on fuel per turnover unit and the average emissions caused thereby are the same across all units. It is expected that there is a certain amount of inaccuracy here since:
    - the sample data is not equally representative of all sectors (e.g. manufacturing, baking, consulting),
    - the sector mix is not equal to one another (equal number of bakeries, micro-industries for instance),
    - the units are not equal in size in terms of turnover
  - emissions are scaled up by assuming that the sample mean is the same as the population mean. First the average emissions of the pool sample (kg emissions / INR turnover) was derived;
  - on-road emissions was equally divided into scope 1 and scope 3 due to the lack of information on origin and destination of the travel by each type of vehicle
  - emission factor for domestic flights and international flights is assumed to be the same
  - overall, a larger pool of data must be available in the next inventory for greater confidence and precision on the estimated number
- Waste
  - Wastewater organics – the total wastewater treated from one DEWATs installation was obtained; with the limited sample set and with no knowledge of how many people it serviced, a national average had to be taken. The national average is based on income group which then informs the protein content in the wastewater per person. Since information on income groups in Auroville was not available, the entire population of Auroville has been considered rural based on the definition of rural India by National Sample Survey Organization. In addition, the exclusion of visitors underestimates the overall emissions; and there needs to be greater clarity on the fate of the sludge after the wastewater is treated to understand its linked emissions.
  - Municipal solid waste –
    - Ecoservice collects solid waste from 2/3rd of the Auroville population and 14 households from outside Auroville. The average waste per person was derived through that and extrapolated to account for the remaining 1/3rd. The assumption through the adopted methodology is that the waste management practices, i.e. segregation are the same for the 1/3 population. The next inventory must also verify that the waste generated by visitors has been accounted for through this methodology
    - The break-up of the components of waste sent to the landfill was computed based on 1 week's sample. The next inventory must take multiple samples to make sure it's representative of the entire year's landfill breakup
  - Biological treatment of solid waste – data on organic waste could only be obtained from 2 communities with limited sample sets; hence emissions were not extrapolated to the rest of the population

Annexure

Auroville GHG emissions report FY2018-19

Scope	GHG emissions source (By Sector and Sub-sector)	Tonnes CO_2e	Comments
	STATIONARY ENERGY		
	Residential buildings		
1	Emissions from fuel combustion within the city boundary	203.33	
2	Emissions from grid-supplied energy consumed within the city boundary	2,565.00	
	Commercial and institutional buildings and facilities		
1	Emissions from fuel combustion within the city boundary	391.12	
2	Emissions from grid-supplied energy consumed within the city boundary	2,486.14	
	Manufacturing industries and construction		
1	Emissions from fuel combustion within the city boundary	-	
2	Emissions from grid-supplied energy consumed within the city boundary	168.01	
	Energy industries		
1	Emissions from energy used in power plant auxiliary operations within the city boundary	-	Not occurring
2	Emissions from grid-supplied energy consumed in power plant auxiliary operations within the city boundary	-	Not occurring
1	Emissions from energy generation supplied to the grid	-	Not occurring
	Agriculture, forestry and fishing activities		
1	Emissions from fuel combustion within the city boundary	-	No data
2	Emissions from grid-supplied energy consumed within the city boundary	-	No data
	Non-specified sources		
1	Emissions from fuel combustion within the city boundary	-	Not found
2	Emissions from grid-supplied energy consumed within the city boundary	-	Not found
	Fugitive emissions from mining, processing, storage, and transportation of coal		
1	Emissions from fugitive emissions within the city boundary	-	Not occurring
	Fugitive emissions from oil and natural gas systems		
1	Emissions from fugitive emissions within the city boundary	-	No data
	TRANS PORTATION		
	On-road transportation		
1	Emissions from fuel combustion on-road transportation occurring within the city boundary	901.79	
2	Emissions from grid-supplied energy consumed within the city boundary for on-road transportation	-	No data
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	901.79	
	Railways		
1	Emissions from fuel combustion for railway transportation occurring within the city boundary	-	Not occurring
2	Emissions from grid-supplied energy consumed within the city boundary for railways	-	Not occurring
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	-	Not occurring
	Waterborne navigation		
1	Emissions from fuel combustion for waterborne navigation occurring within the city boundary	-	Not occurring
2	Emissions from grid-supplied energy consumed within the city boundary for waterborne navigation	-	Not occurring
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	-	Not occurring
	Aviation		
1	Emissions from fuel combustion for aviation occurring within the city boundary	-	Not occurring
2	Emissions from grid-supplied energy consumed within the city boundary for aviation	-	Not occurring
3	Emissions from portion of transboundary journeys occurring outside the city boundary, and transmission and distribution losses from grid-supplied energy consumption	-	Not occurring
	Off-road transportation		
1	Emissions from fuel combustion for off-road transportation occurring within the city boundary	-	No data
2	Emissions from grid-supplied energy consumed within the city boundary for off-road transportation	-	No data
	WASTE		
	Solid waste disposal		
1	Emissions from solid waste generated within the city boundary and disposed in landfills or open dumps within the city boundary	19.74	
3	Emissions from solid waste generated within the city boundary but disposed in landfills or open dumps outside the city boundary	-	Not found
1	Emissions from waste generated outside the city boundary and disposed in landfills or open dumps within the city boundary	-	No data
	Biological treatment of waste		
1	Emissions from solid waste generated within the city boundary that is treated biologically within the city boundary	-	No data
3	Emissions from solid waste generated within the city boundary but treated biologically outside of the city boundary	-	Not found

1	Emissions from waste generated outside the city boundary but treated biologically within the city boundary	-	No data
	Incineration and open burning		
1	Emissions from solid waste generated and treated within the city boundary	0.09	
3	Emissions from solid waste generated within the city boundary but treated outside of the city boundary	-	Not found
1	Emissions from waste generated outside the city boundary but treated within the city boundary	-	No data
	Wastewater treatment and discharge		
1	Emissions from wastewater generated and treated within the city boundary	661.53	
3	Emissions from wastewater generated within the city boundary but treated outside of the city boundary	-	Not found
1	Emissions from wastewater generated outside the city boundary but treated within the city boundary	-	No data

List of tables and figures

Tables

Figures

References

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