Transitions Research

Panaji, Goa :

Greenhouse Gas Inventory Report

Transitions Research is a social science collective driving radical transitions at the intersection of technology, society, and sustainability. We aim to ensure these transitions are just, inclusive, and empower people while protecting the planet. Our work focuses on discovering sustainable pathways by generating anticipatory knowledge, co-creating solutions, and building capacities for societal action.Our initiative, PULL (People's Urban Living Lab) works to co-create, test and implement equitable climate solutions in mid-sized Indian cities. Through PULL: Net Zero, we are working to discover net-zero solutions for Indian cities that leave nobody behind

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Disclaimer:

The opinions and arguments presented herein are solely those of the Transitions Research team and do not necessarily reflect the official views of the organisations interviewed.

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City Overview

Panaji, the capital of Goa and the district headquarters of North Goa, with an area of 8.12 sq km and a population of 40,017, is a prominent tourist hub, hosting 600,000 domestic and 88,000 international tourists (Office of the Registrar General & Census Commissioner, 2011 annually. As of 2019, the GDP of Panaji was INR 1,510 crore with a growth of 3.2 per cent each year, and a per capita income of INR 4,66,000. With 30 administrative wards, the city encompasses 17,807 households (Directorate of Planning, Statistics & Evaluation, 2021). Industrial and manufacturing activities are minimal within the city boundaries and no significant agricultural activities are found inside the city. The city is a major commercial and administrative centre in Goa, where 98 per cent of the working population is engaged in the service sector (CRISIL, 2015).

Demography, economic drivers, and consumption patterns

Panaji is experiencing steady urban and economic growth, with its population increasing annually at a rate of 1.9 per cent (Census of India, 2011). This demographic expansion, coupled with a city GDP growth rate of 3.2 per cent and a per capita income growth rate of 2 per cent per year (GIZ, 2023), has been shaping the city's evolving consumption and development patterns. The economy is primarily driven by tourism and allied services such as hospitality, retail, and local transport. These activities, along with rising residential development, continue to push up energy demand across sectors.
The city's electricity consumption ranges across residential, commercial, and industrial users. Growing neighbourhoods have increased household demand, while hotels, offices, and shops significantly add to the city's load. Though small, the industrial sector also comprises a portion of overall electricity use.

Road transport is the dominant mode of transportation in Panaji, covering 5.45 per cent of the city's land area (CRISIL, 2015), and serving both intracity and interstate connectivity needs. Public transport remains underutilised, as the majority of travel demand is met by private and commercial vehicles. Two-wheelers are the most common, comprising 67 per cent of registered vehicles, followed by four-wheelers (cars and taxis). In 2020, the city added 5,634 new registrations to its vehicle fleet, contributing to rising energy consumption. Freight transport is primarily handled by light goods vehicles (2.5%), while medium and heavy goods vehicles play a minimal role (Parivahan Analytics & Reporting, n.d.).

Liquefied petroleum gas (LPG) remains the primary cooking fuel in Panaji, meeting 77 per cent of the city's demand across both residential and commercial users. However, a portion of the population continues to rely on kerosene (2%) and traditional biomass such as firewood (21%), especially in areas where access to LPG is inconsistent (GIZ, 2023).

Over the years, Panaji has built a strong foundation in decentralised waste management. As per available data, Panaji generates waste amounting to around 43 tonnes per day (TPD) – 17 TPD dry and 26 TPD wet waste (UNDP, 2023). Panaji has achieved an impressive 99 per cent waste segregation rate, with households practising primary segregation using two or four bins. In 2021, the city advanced to implementing 16-way segregation at source, a transformative step that positioned Panaji as a zero-landfill capital (Banerjee, Shankar, , et al., 2021).

Meanwhile, construction activity in the building sector continues to rise, driven by both residential and commercial demand. This growth is contributing to an increase in operational energy use for lighting, cooling, and appliances, as well as embodied emissions from construction materials. Commercial buildings, particularly in the tourism and retail sectors, remain major electricity consumers, especially during peak hours.

Panaji's annual energy demand is approximately 148 GWh, as of 2020 (Central Electricity Authority, 2025.). Currently, much of Panaji's electricity is sourced from neighbouring states and central grids dominated by fossil-fuel-based generation. Sectors such as residential, commercial, industrial, and transport also rely heavily on other fossil fuels, compounding the city's emission intensity. Recognising this, the Government of Goa is pushing for self-reliance through a dedicated renewable energy transition plan for Panaji, decarbonising electricity use across all sectors and reducing dependence on conventional fuels.

Complementary policies targeting green buildings, electric mobility, decentralised waste management, and urban greening are also being advanced, together forming a cohesive framework to achieve net zero and become a solar city.

Sectoral emissions

People's Urban Living Lab (PULL) is supporting Panaji's net zero by 2050 and solar city goals by co-creating contextual, actionable climate solutions across buildings, mobility, and waste, with a strong focus on equity. In Panaji, we are driving integrated planning, fostering stakeholder collaboration, and leveraging digital tools to turn climate ambition into implementation.

In Panaji, emissions come from both direct and indirect sources. Direct (Scope 1) emissions primarily arise from transport, waste, and cooking fuels, while indirect (Scope 2) emissions result from the city's dependence on grid electricity, which is predominantly fossil-fuel-based. As Panaji charts its course to achieving net zero by 2050 and becoming a solar city, understanding and addressing Scope-2 emissions from purchased electricity is a critical step. The city's heavy reliance on grid electricity, makes Scope 2 a significant contributor to its overall emissions. A detailed emission baseline of current emission levels, covering both Scopes 1 and 2–activities causing emissions and usage of purchased electricity–will help policymakers to better identify the emission sources and to make informed decisions to reduce emissions.

Methodology

PULL's emissions inventory for Panaji provides sector-wise estimates of emissions across residential, industrial and commercial, transport, and waste sectors. The city-level emissions are estimated using electricity and fuel consumption in the respective sector. FY 2020–21 was taken as the baseline year for the emissions inventory.

Industrial and commercial (I&C) sector

Residential sector

Transport sector

Municipal solid waste sector

Industrial and commercial (I&C) sector

Electricity is the primary energy source consumed in Panaji's I&C sector. The share of electricity consumed by the I&C sector in Panaji is derived from the Report on Twentieth Electric Power Survey of India (Volume III): Mega Cities. Emissions have been calculated using the applicable grid emission factor as provided by the Central Electricity Authority. Figure 1 illustrates the methodology followed for estimating all emissions from the I&C sector. While the sector also uses fuels such as heavy oils and liquid fuels for heating, cooling, and transport, these have been excluded from the current analysis due to limited data availability and to prevent double counting.

View of a busy Calangute Market, lined with shops selling clothes, accessories, snacks, and beach items.

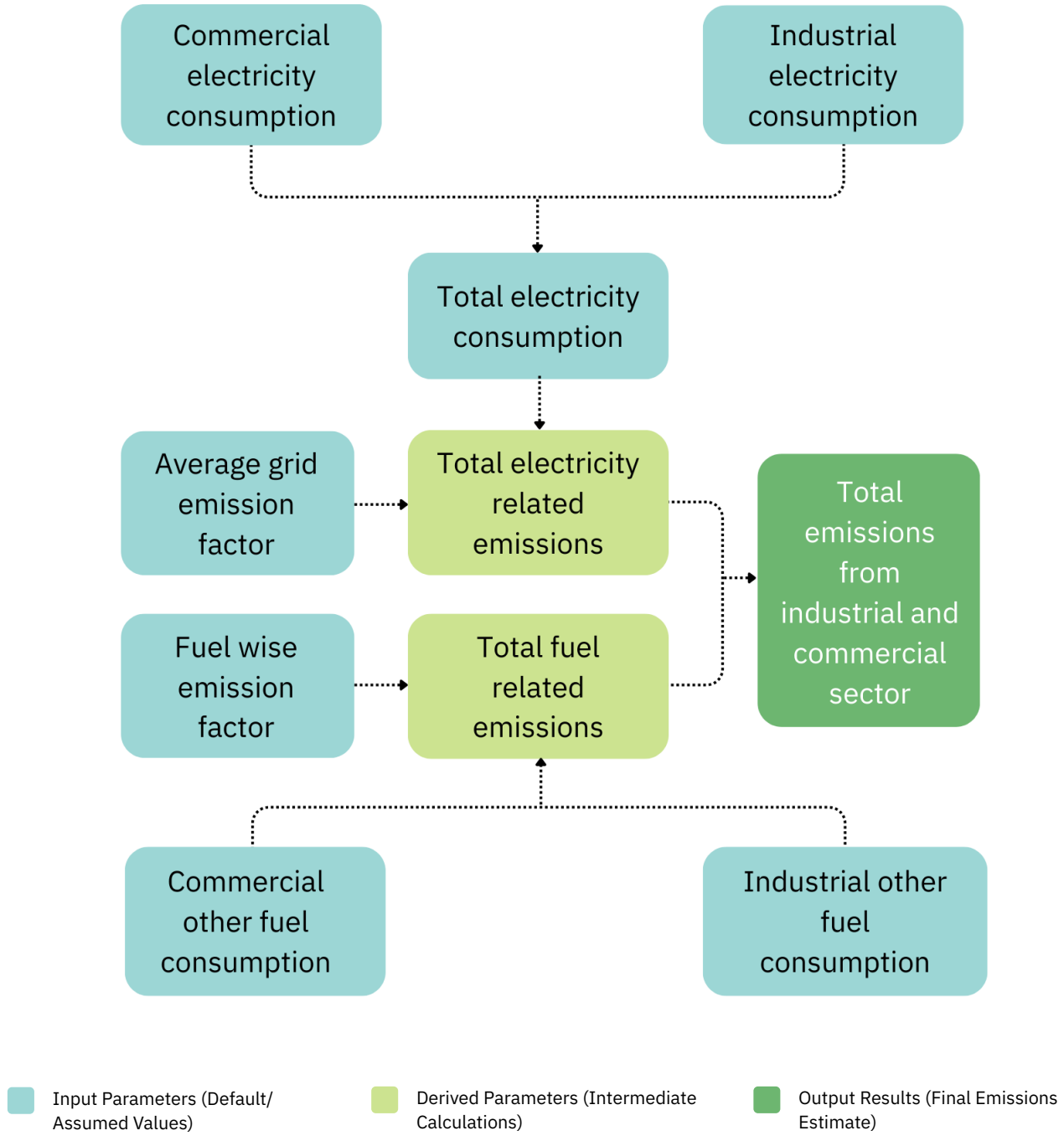

Figure 1: Methodology for estimating emissions from commercial and industrial sector

Residential sector

Electricity consumption and cooking fuels are the primary sources of emissions in Panaji's residential sector. Residential electricity demand is estimated using per capita electricity consumption in conjunction with population data. Cooking fuels such as liquefied petroleum gas (LPG), kerosene, and traditional biomass contribute significantly to overall residential emissions. While LPG has achieved near-universal coverage in Panaji, the use of traditional biomass remains relatively high. The fuel mix for cooking energy comprises 77 per cent LPG, 2 per cent kerosene, and 21 per cent traditional biomass (GIZ, 2023). Emissions from use of energy for cooking are accounted for in the city's overall emissions inventory. Residential emissions from electricity use are calculated using the average grid emission factor. The methodology for estimating all emissions from the residential sector is illustrated in Figure 2. On account of limited data and confining the current estimation to Scope 2, building and life cycle material emissions were excluded, which could be a part of the next phase of the study.

Building demolition in Panaji, Goa, as part of residential redevelopment activities.

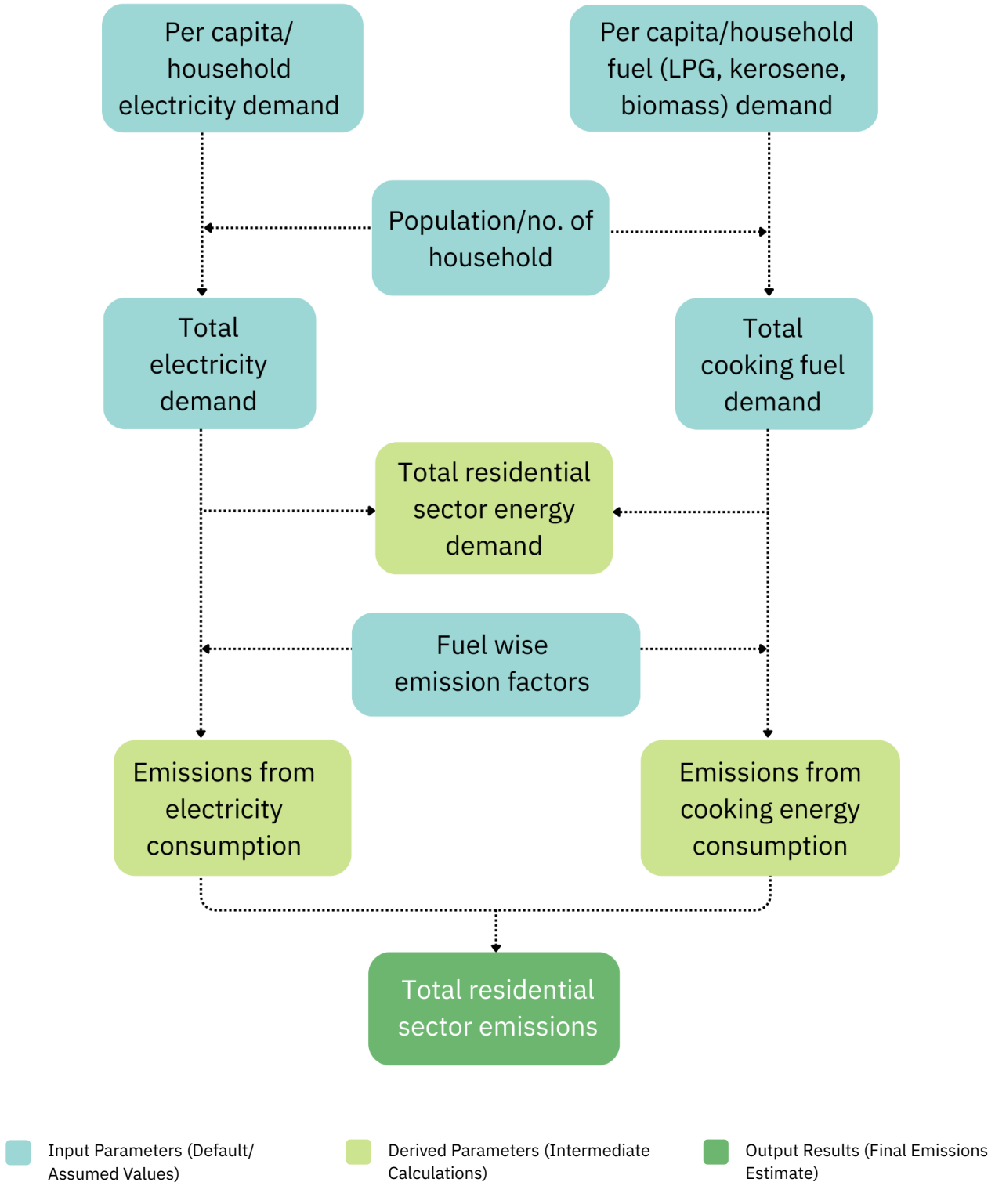

Figure 2: Methodology for estimating emissions from the residential sector

Transport sector

Emissions from Panaji's transport sector are estimated using the Activity, Share, Intensity, Fuel (ASIF) framework outlined in the Greenhouse Gas Protocol's Accounting and Reporting Standard for Cities (Version 1.1). Transport energy demand is disaggregated by vehicle type – passenger vehicles (2W (two-wheeled), 3W, 4W, and buses) and freight vehicles (light, medium, and heavy goods vehicles). Vehicle registration data is sourced from the Goa Economic Survey 2024–2025, while fuel-type distribution is derived from the Parivahan Analytics & Reporting portal. The emissions analysis for this sector is limited to the jurisdiction of Panaji, as the vehicular activity considered in the inventory pertains only to the city's administrative boundaries. Passenger transport emissions are calculated using passenger-kilometre (pkm) demand, while freight transport emissions are based on ton-kilometre (tkm) demand. Fuel consumption and emissions are derived using fuel-specific emission factors from India-Specific Road Transport Emission Factors (Gajjar & Sheik, 2015). The methodology followed is illustrated in Figure 3.

Traffic near schools in Panaji, Goa, during peak hours.

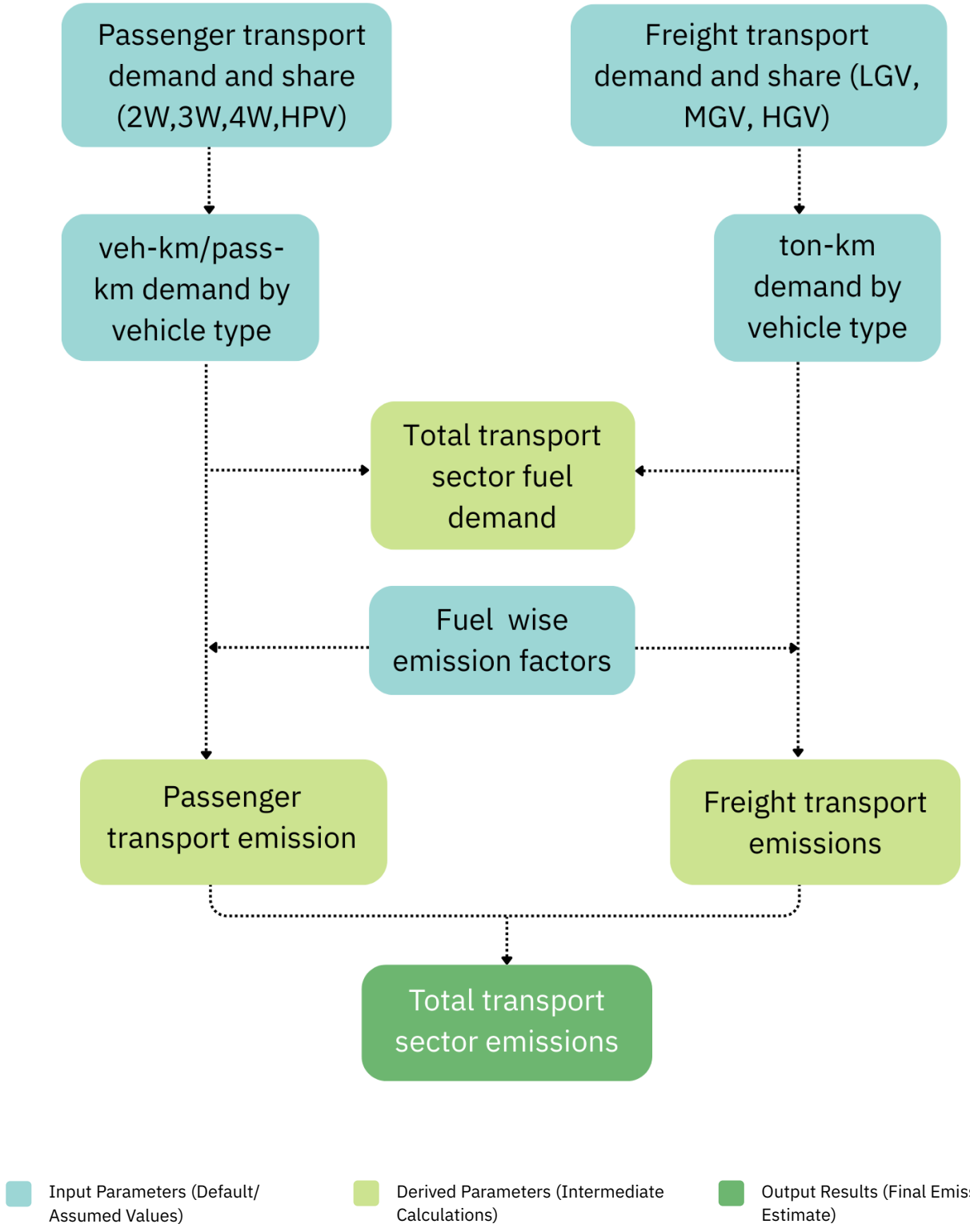

Figure 3: Methodology for estimating emissions from the transport sector

Municipal solid waste sector

Panaji is recognised as one of India's leading cities in efficient municipal solid waste (MSW) management. The city segregates collected waste into 16 distinct categories, enabling targeted processing. Wet waste is directed to biodigesters and composting facilities, while dry non-recyclables are sent to cement kilns for incineration.

Emissions from these processes – including composting, anaerobic digestion, and incineration – are estimated using the IPCC Waste Sector methodology (IPCC, 2006). The city also operates a well-organised transport system to ensure effective waste collection and delivery from multiple sources to appropriate processing units.

The annual growth in waste generation is estimated by factoring in population growth, the elasticity of per capita waste generation with respect to income, and the per capita income growth rate. The emissions inventory accounts for methane (CH_4) emissions from solid waste disposal sites, nitrous oxide (N_2O) emissions from composting, and emissions from incineration of dry waste and non-recyclables. Figure 4 illustrates the methodological framework used to estimate municipal solid waste emissions.

Recyclable waste sorted and baled at a material recovery facility in Panaji, Goa.

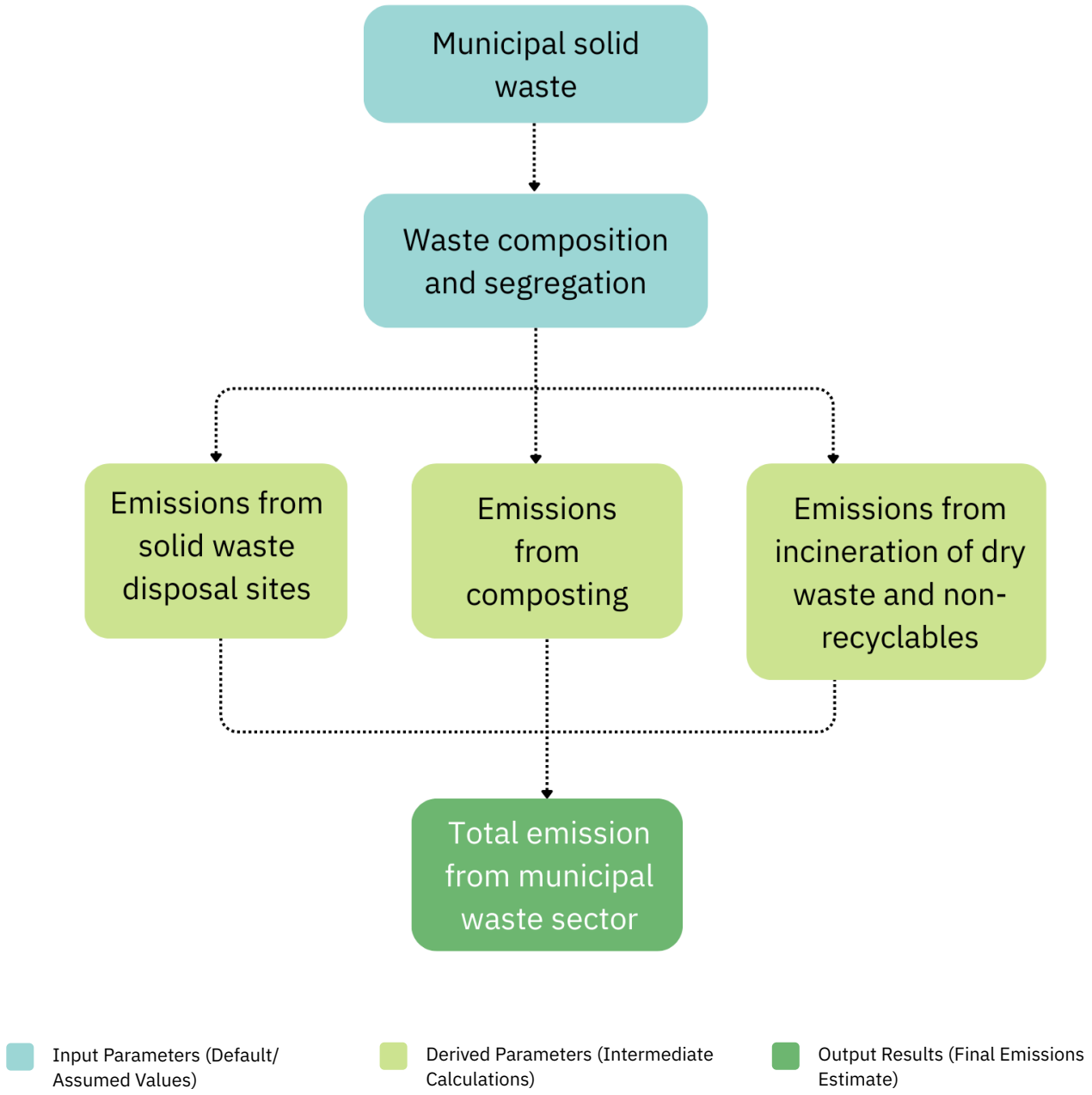

Figure 4: Methodology for estimating emissions from the waste sector

Emissions overview

As one of the fastest growing cities in India and a thriving tourist destination, Panaji's emissions are largely driven by four key sectors – residential, commercial and industrial, transport, and waste.

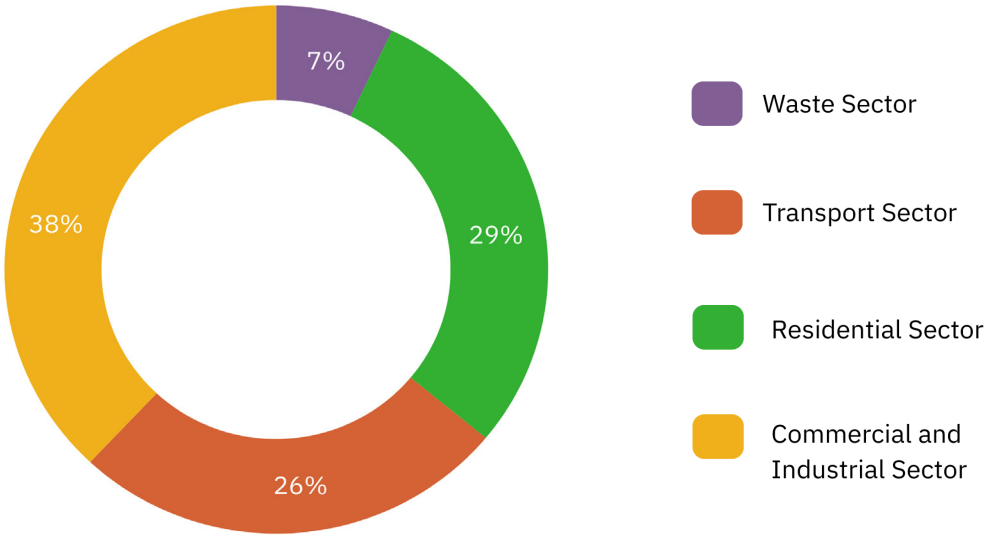

Figure 5: Sectoral emissions for Panaji

The commercial and industrial sectors are the largest contributors, together accounting for 38 per cent of Panaji's total emissions. To cater to the year-round influx of tourists and to support local employment and services, these sectors consume significant amounts of electricity, much of it sourced from fossil-fuel-based power sourced from the national grid. The high dependency on coal-dominated electricity generation results in substantial emissions.

The residential sector is responsible for 29 per cent of total emissions. These arise primarily from household electricity use and cooking fuels. While most households in Panaji rely on LPG, traditional biomass is still used, particularly in lower-income areas. Additionally, households without reliable electricity or LPG access often use firewood and other biomass for both cooking and lighting, adding to the sector's overall emissions. In 2020, biomass consumption in homes resulted in an estimated 14,208 tCO_2 emissions.

Panaji has one of the highest per capita vehicle ownership rates in India, with approximately 0.8 vehicle for every resident, according to state government statistics. Without targeted interventions, the rising population and growing tourist influx are expected to significantly increase vehicle density in the city. The transport sector currently contributes around 26 per cent of total emissions and remains a critical area of concern due to its direct reliance on fossil fuel combustion. These emissions span both passenger and freight movement and are expected to rise if there is no intervention.

The waste sector contributes 7 per cent of Panaji's emissions, stemming from emissions released during composting, anaerobic digestion, incineration, and from disposal sites. The city has implemented a structured waste management system, collecting wet waste from residential, commercial, and industrial areas and treating it through composting or biodigesters. Non-recyclable dry waste is sent to cement kilns or incinerators, where it is used as an energy source, which also results in emissions.

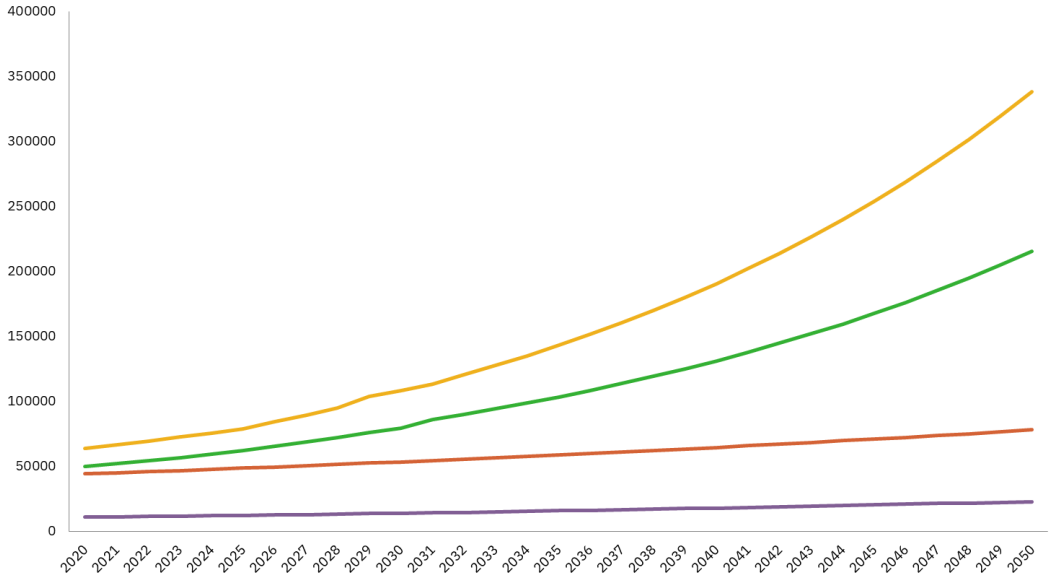

Figure 6: Sectoral emissions trend for Panaji

The baseline emissions pathway for Panaji until 2050 reveals a rising trend that continues upwards across all major sectors. Figure 6 illustrates the emissions trend under a Business-as-Usual (BAU) scenario, where existing policies persist without further intervention. In 2020, the city's total emissions stood at approximately 1,69,493 tCO_2e. From this base year, emissions follow a steady upward trend, and by 2050 they are projected to reach nearly 6,55,364 tCO_2e. This represents an almost fourfold increase, reflecting the cumulative impact of rising energy demand and urban activity.

The sectoral trends within this pathway illustrate how different parts of the economy contribute to this growth. The commercial and industrial sector emerges as the primary driver of future emissions growth. By 2050, the commercial and industrial sector is projected to reach around 3,39,171 tCO2e, accounting for nearly 52 percent of total emissions. The residential sector also shows a strong upward trend, contributing 33 percent of emissions by mid-century as household energy demand expands. The transport sector is projected to reach nearly 79,847 tCO_2e, representing 12 percent of the total, while the waste sector rises to 23,262 tCO_2e, contributing around 3 percent.

This baseline scenario provides a critical reference point for policy and planning. It highlights both the magnitude of change underway and the relative weight of sectoral contributions, offering a clear basis for prioritisation of mitigation strategies.

Conclusion

This sector-wise emissions inventory for Panaji breaks down the source of emissions for policymakers and consumers to comprehend the necessity and focus areas that need changes in policy initiatives. It demonstrates both the magnitude of change underway and the relative weight of sectoral contributions, offering a structured basis for prioritising mitigation. Besides aiding policymakers, inventories also establish behaviour patterns towards energy consumption, which in turn can be used to bring about changes in their lifestyle pattern through schemes, subsidies, and technologies.

Future works to improve emissions inventory for Panaji would essentially require addressing data gaps in various sectors to establish a holistic and detailed assessment. Data collection through household surveys in the city in subsequent quarters would help in revising the inventory and challenges in data gaps.

Importantly, the emissions inventory offers a clear basis for prioritisation of mitigation strategies and the analysis underscores the need for targeted interventions across sectors in the city. The ***Compendium of Net Zero Solutions for Panaji, Goa*** have outlined a wide set of options to support such interventions. Building on this foundation, subsequent efforts will focus on translating broad strategies into actionable interventions that can reverse the rising trends and position Panaji firmly on the pathway to net zero.

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Appendix: Data sources

Sector	Variable	Details	Source
Residential sector	Electricity consumption		(GIZ, 2023)
	Fuel consumption	Residential LPG consumption	(Ministry of Petroleum & Natural gas, GOI, 2020)
		Residential kerosene consumption	(GIZ, 2023)
		Residential traditional biomass consumption	(GIZ, 2023)
	Emission factor	kgCO2/MWh or kgCO2/TJ	(Central Electricity Authority, 2024)
Commercial and industrial sector	Electricity consumption		(Central Electricity Authority, 2023)
	Emission factor	kgCO2/MWh	(Central Electricity Authority, 2024)
Transport sector	Vehicle stock	No. of vehicles in each category	(Economic Survey Reports and Parivahan Analytics & Reporting Portal)
	Vehicle utilisation rate	Average distance travelled by a vehicle in a day	(GIZ, 2023)
	Occupancy	No. of occupants for a vehicle	(GIZ, 2023)

Sector	Variable	Details	Source
	Emission factor	Distance-based emission factor	(Gajjar & Sheik, 2015)
Commercial and industrial sector	Wet waste	Kitchen waste, biodegradable waste, fallen leaves, wet waste from hotels and industries	(Ministry of Housing and Urban affairs, 2020)
	Dry waste	Newspapers, magazines, office paper, cardboard boxes, plastic bottles and containers, glass bottles and jars, metal cans and packaging, textiles, wood waste, and construction materials	(Ministry of Housing and Urban affairs, 2020)
	Waste collection vehicles	Municipal waste collection vehicles for door-to-door collection	(Ministry of Housing and Urban affairs, 2020)
	Waste emission factor	kg CO_2eq/ton MSW or kgCO2/km/ton MSW	(Kristanto & Koven, 2019)

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