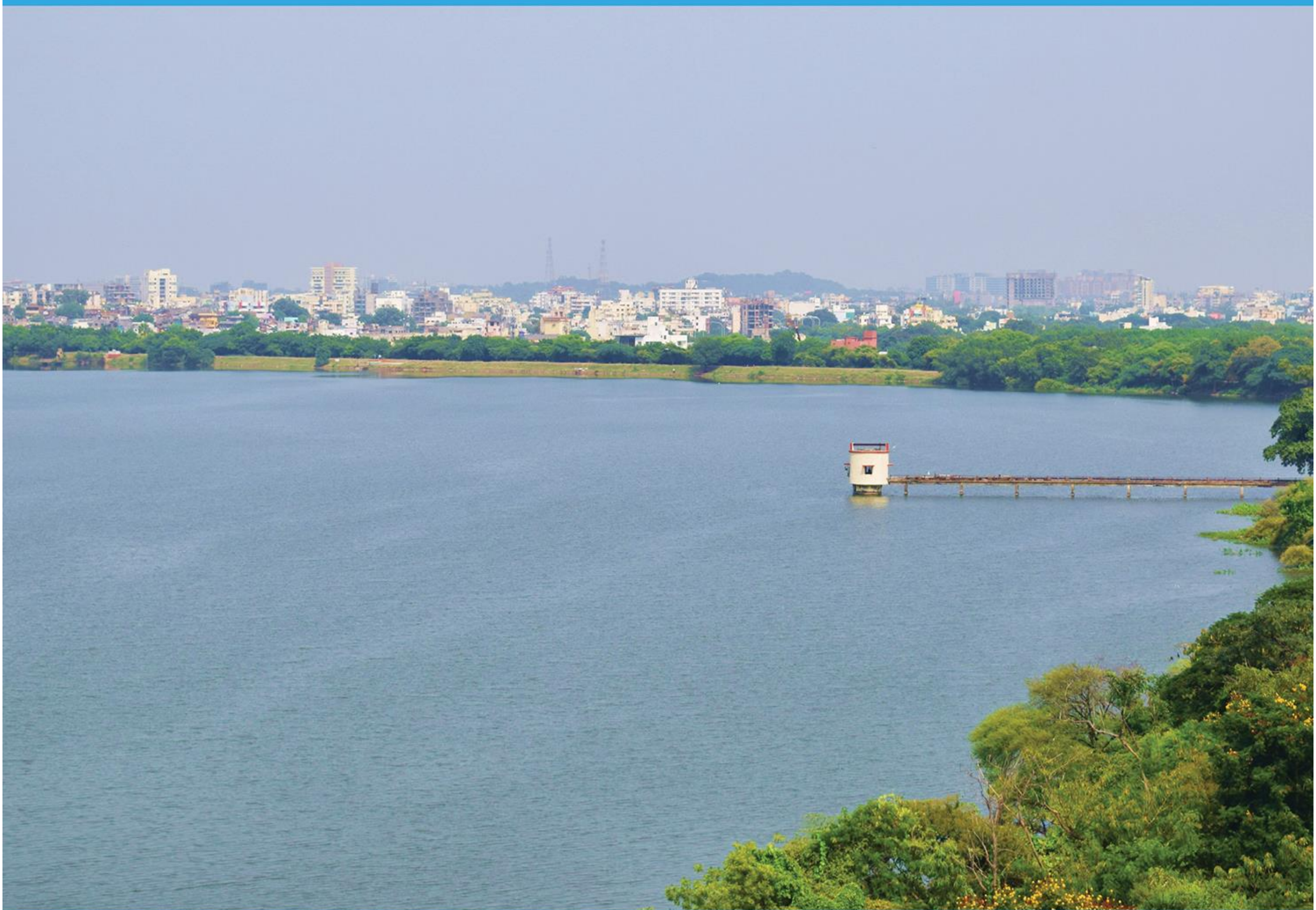
URBAN LEDS
URBAN LOW EMISSION DEVELOPMENT STRATEGIES

.nagpur

Nagpur City, India

Greenhouse Gas Emission Inventory Report 2017-18



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Urban LEDS II: GHG Emission Inventory for Nagpur, India
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Introduction

Nagpur is a central Indian city in the state of Maharashtra and is located at the exact geographical center of the Indian peninsula. Nagpur city aspires to be the growth nucleus of central India and an eco-city that provides adequate, equitable and sustainable access to urban services for all citizens. In order to achieve this the city has committed to various urban sustainability interventions such as reuse of treated wastewater for cooling purpose in thermal power plants, SCADA based 24*7 water supply project, replacing 137,000 odd streetlights with energy efficient LED ones, battery charging stations for taxis, rooftop solar photovoltaic (PV) systems on NMC owned buildings, e-Rickshaws for differently abled people, among others.

The city's local government, Nagpur Municipal Corporation (NMC), has also been working with various international development agencies such as the European Union and organizations under the United Nations. NMC is implementing projects like Urban NEXUS, Building Efficiency Accelerator (BEA), Mobilize Your City (MYC), International Urban Cooperation (IUC), and the URBAN LEDS II with the support of international organizations including United Nations Human Settlements Program (UN-Habitat), Agence Française de Développement (AFD), World Resource Institute (WRI), and ICLEI-South Asia.

The "Urban LEDS II (Accelerating climate action through the promotion of Urban Low Emission Development Strategies)" project aims at accelerating urban low emission development and climate resilience through multilevel governance approach towards urban climate action. The project is funded by the European Union and is jointly implemented by UN-Habitat and ICLEI – Local Governments for Sustainability (ICLEI). The regional offices of ICLEI and UN Habitat guide the model cities from target countries in developing comprehensive Urban Low Emission Development Strategies (Urban LEDS) and action plans based on specific city based studies and using ICLEI's GreenClimateCities process methodology.

In India, the Urban-LEDS II project will be implemented in the cities of Nagpur and Thane by ICLEI South Asia – the South Asian arm of ICLEI - Local Governments for Sustainability together with UN-Habitat. The implementing agencies would provide necessary institutional, technical and advisory services for on-ground implementation of the project, working closely with the nodal local governments and their associated agencies and departments in the cities of Nagpur and Thane. This report presents an inventory of Nagpur's GHG Emissions during the 5-year period between 2013 and 2018. The analysis of the inventory data helps in understanding the trends of energy and fuel use and corresponding GHG emissions across sectors in the city and helps in identifying specific emission mitigation actions.

1 Background Research

1.1 City Profile

1.1.1 Location

Nagpur city is the 3rd largest city in the Indian state of Maharashtra. It serves as the winter capital of the state, hosting the winter session of the state assembly and thereby is an important administrative center. Nagpur has a population of approximately 2.4 million persons (Census 2011) with a density of roughly 11,000 persons/sq. km and is projected to be the 5th fastest growing city in the world from 2019 to 2035 with an average growth rate of 8.41% according to an Oxford Economics report1.

1 *https://timesofindia.indiatimes.com/india/17-of-20-fastest-growing-cities-in-the-world-will-be-from-india/articleshow/66978406.cms*

The name Nagpur is derived from the Nag River which flows around the city. Nagpur is also known as the Orange City due to its prominent cultivation of orange fruit and is known to be one of the greenest cities in India. The city is located between 78°30‟ to 79°30‟E and 20°30‟ to 21°45‟N latitude which is at the exact geographical center of India and has low land features. It lies on the Deccan Plateau of the Indian Peninsula and has a mean altitude of 310.5 meters above sea level. Nagpur is classified as a city with tropical wet and dry climatic conditions. Nagpur experiences seasonal weather patterns with an annual average rainfall of about 1100 mm. Nagpur is known for its hot and dry summers where temperatures can go up to 48 ° C in the month of May.

1.1.2 Connectivity

Given its central location in India, Nagpur has the inherent advantage of distance and connectivity with all the important Indian cities through various modes of transport. The city is well placed to serve as a transport hub, connecting major Indian cities to each other and to international destinations.

Two important highways, the NH-7 (Varanasi - Kanyakumari) that connects north and south India and the NH-6 (Mumbai - Sambalpur – Kolkata) that connects the western and eastern parts of the country, pass through the city of Nagpur. An ultra-modern 701 km long, 120-meter-wide 8 lane expressway 'Maharashtra Samruddhi Mahamarg' is under construction which will connect the city of Mumbai and Nagpur. The city is also developed with arterial roads to improve connectivity with the Vidarbha region and inner and outer ring roads to help decongest the city traffic.

As is the case with the road network, Nagpur benefits from its strategic location at the intersection of nationally important broad gauge rail lines of the Central Railway Network and the South Eastern Railway network (Mumbai-Kolkata and Delhi - Chennai). The Nagpur Central Railway Station is thus an important railway junction and is connected to other major metro cities of India via a fully electrified broad gauge railway track.

Figure 1 Road and Railway Network of Nagpur2

Apart from these metropolitan regions, Nagpur is also connected to other major cities of India like Ahmedabad, Hyderabad, Pune, Jammu, Amritsar, Lucknow, Varanasi, Kochi, Thiruvananthapuram, Bangalore, Mangalore, Visakhapatnam through 160 trains that pass through the city. Within the city limits, there are smaller railway stations located at Ajni, Itwari, Kalamna, Kamptee, and Khapri. Figure 1 shows the rail network in Nagpur city.

2 Comprehensive Mobility Plan (CMP), Nagpur

Nagpur has an airport located near Sonegaon, 7.5 kilometers to the south west of Nagpur city which is connected to 37 other destinations within India. The airport also caters to international destinations including Saudi Arabia, Sharjah, Doha, Dubai, Singapore, and Bangkok. The airport is slated to expand under the Multimodal International Hub Airport (MIHAN) project that aims to make the airport an international passenger and cargo hub.

1.1.3 Demography

Nagpur city is spread over an area of 227.28 sq.km and with a population of 2.45 million, the average population density reaches 10,873 persons/sq. km. This is approximately 15% higher than the population density from the previous decade when it stood at 9400 persons/sq.km. Even though Nagpur's population has seen a steady increase since 1971 and has grown every decade, the decadal growth percentage has been on the decline. From Figure 2 it is evident that the last census (2001-11) saw the lowest growth in population as compared to previous. Further investigation revealed that during this decade, Nagpur had witnessed only the natural growth, and the addition of migration population was nominal.

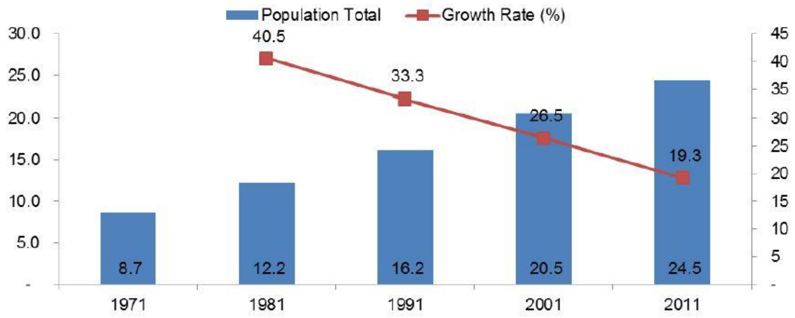
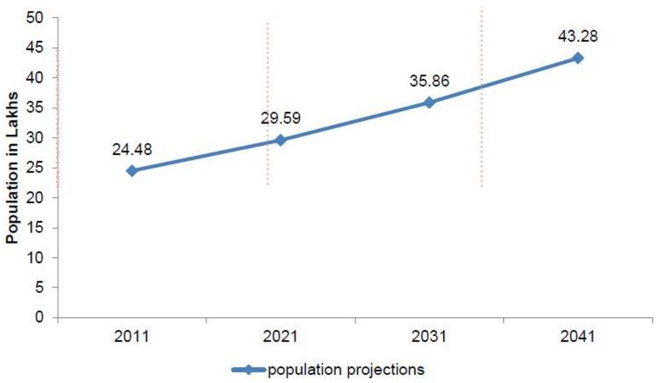


Figure 2 Population growth trend of Nagpur from 1971 - 20113

The declining growth rate in the population is attributed to the limited economic opportunities in the city. Although Nagpur is a base for various economic activities, and is home to the much-awaited MIHAN project, with potential for the future development of IT parks and industries, the economic growth potential has not been fully realized and has impacted the competitiveness of the city.

Nagpur city is the main hub of Vidarbha region for urbanization and caters as a growth center for neighboring districts. The trends show that the city has witnessed less in-migration during the period 2001-2011 which indicates that perhaps, Nagpur has been unable to provide adequate employment opportunities for the educated youth, which typically propel in-migration in an Indian context.



3 Census of India, 2011 and analysis by CRISIL

Figure 3 Population Projection for Nagpur till 20414

Based on the population trends during the last four decades and other factors, projections estimate that the city's population would increase to 2.96 million in 2021; 3.59 million in 2031 and 4.33 million in 2041 (see Figure 3). Looking at the decadal change in the population projection it is evident that the population growth is expected to be at around 20% in the upcoming decades.

According to the Census of India, 2011, the literacy rate of the total population of the city is at 92%. Male literacy stands at about 90%, whereas female literacy is at about 78%. The literacy rate has increased from 2001 to 2011 as a result of the increase in the enrolment of students in the schools.

1.1.4 Land Use

Majority of the land in Nagpur is developed for residential purposes (45%), followed by the land under public use (41%) as of 2011 (see Figure 4). Commercial and industrial developments occupy 6% of the city's land, and 8% of the land is under parks and gardens.

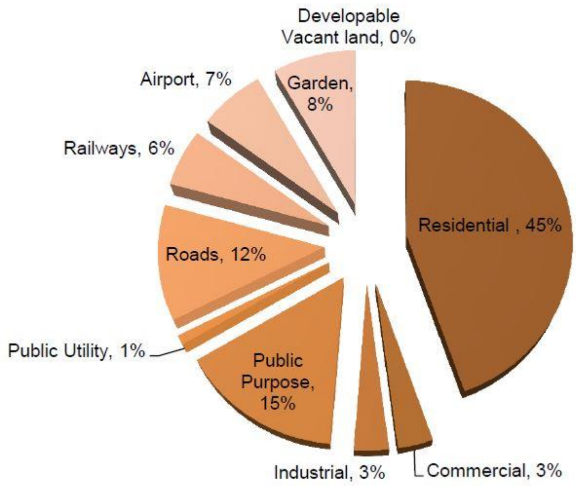


Figure 4 Existing Land use breakup of Nagpur, 2011 5

According to the Urban and Regional Development Plans Formulation and Implementation (URDPFI) guidelines, the existing break up of land use conforms to the guideline norms in the cases of land under residential use, commercial use and land under public use. The portion of land under industrial and recreational uses does not conform to the URDPFI guideline norms. Though land under recreational use is less than the established norms, this is adequately complemented by the large forest cover in the city.

Most of the development in the Nagpur Metropolitan Area (NMA) is either an outgrowth or expansion of Nagpur city. While Nagpur city's urban sprawl is happening horizontally, it is important to note that the transportation corridors are key drivers of this expansion as they not only facilitate the city's development but also connect urban growth centers. The fringes of the city bear most of the expansion happening along the transportation corridors. Corridors and the majority of the developed areas are sprawled outside the city on the south side close to the outer ring road.

4 City Development Plan. Nagpur, 2015

5 City Development Plan 2015

From the land use map (Figure 5) it is clear that most of the development is happening in the central areas. The peripheral areas of the city are relatively less developed. The open spaces available within city limits are less, with those available being scattered and in the form of large land parcels. This is attributed to factors such as houses having a smaller footprint, presence of 424 slums covering 25% of the city, and around 62% of the land falling under the category of undevelopable land.

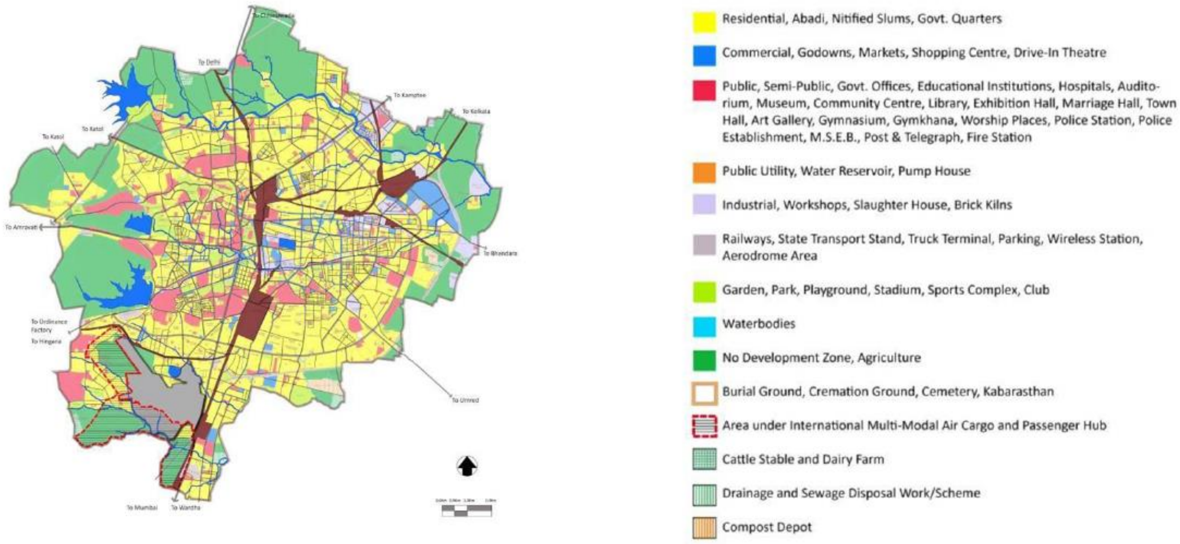


Figure 5 Existing Development Plan for Nagpur City6

Table 1 Proposed Land Use for Nagpur City 2021 and 20317

Sr.No.	Land use	2021			2031		
		Area in Hectares	% of developed area	% of total area	Area in Hectares	% of developed area	% of total area
1	Residential	6,706	44	**30**	7000	47	**32**
2	Commercial	501	3	**2**	700	5	**3**
3	Industrial	495	3	**2**	800	5	**4**
4	Public Purpose	2,312	15	**11**	2312	15	**11**
5	Public Utility	149	1	**1**	150	1	**1**
6	Roads	1,754	12	**8**	1800	12	**8**
7	Railways	873	6	**4**	900	6	**4**
8	Airport	993	7	**5**	1000	7	**5**
9	Garden	1,251	8	**6**	1300	9	**6**
10	Developable Vacant Land	0	0	**0**	0	0	**0**
	Total	**15,033**	**100**	**69**	**15,962**	**100**	**73**
11	Agriculture Land	5,774		**27**	4,846		**22**
12	Water Bodies & Nallahs	463		**2**	463		**2**
13	Non-Developable Land	0		**0**	0		**0**
14	Drainage & Sewage Disposal	141		**1**	141		**1**
15	Cattle Stable & Dairy Farm	212		**1**	212		**1**
16	Compost Depot	131		**1**	131		**1**
		6,723		**31**	**5793**		**27**
	Grand Total	**21,756**		**100**	**21,756**		**100**

Under the revised Development Plan published in 2015 by NMC, 235 square km (sq. km) of the area is considered of which 227.28 sq. km is under the jurisdiction of NMC and the remaining 7.72 sq km is located outside the NMC limits. As part of the plan, an area of 17.65 sq km is earmarked for sewerage and drainage disposal schemes and the entire development area has been divided into 7 planning zones for preparing the development plan. The newly merged census town located outside of the city

6 Nagpur Metropolitan Area Development Plan 2012 - 2032

7 City Development Plan for Nagpur, 2041

has an area of 7.72 sq. km and will be added to the NMC area for future development under the revised Development Plan, 2015.

1.1.5 Economic Activities

Primary sector: Nagpur district is mostly known for its agricultural land, with a cultivable area of 6440 sq. km out of 9892 sq. km. Nagpur district is moderately rich in minerals. Deposits of coal, manganese ore, dolomite, limestone, iron ore, clay, copper ore, chromite, tungsten ore, zinc ore, quartz, etc., are found in the district. Floriculture and fish farming are other prominent economic activities taking place in Nagpur district. The primary sector is not a key contributor to the city's economy as most of these activities happen outside the city.

Secondary sector: The peripheral areas of Nagpur city are home to various industries such as chemicals, cement, electrical, electronics, textile, ceramics, pharmaceuticals, food processing, wood & paper based industries. These industries contribute to the city's economy and support local economic development. The Multi-Modal International Hub Airport of Nagpur (MIHAN) project is an economic development project currently underway in Nagpur. The proposed MIHAN project is expected to spread over an area of 4,025 hectares at an estimated cost of INR 20,000 billion. Besides the airport, the proposed project involves a road-rail terminal, a special economic zone (SEZ) and other urban amenities which will boost the employment and thereby the economy of the city. As of March 2017, Nagpur region had 3,674 industrial units worth an overall investment of INR 160,570 million, working in the industrial area developed by Maharashtra Industrial Development Corporation (MIDC).

Tertiary: Markets (formal and informal) form an integral part of Nagpur's economic profile. Nagpur has a number of retail and wholesale markets with a variety of types of goods and services. These markets include small shops and hawkers. The Market department of the NMC is tasked for looking after such establishments and is responsible for providing services like land allocation, maintenance, and operation of markets, construction of new markets. The Market department also collects rents from the vendors, and shop owners. Nagpur has a few information technology (IT) industries within the limits of the city's jurisdiction and has the potential to accommodate more IT parks.

1.1.6 Local Government Body

The NMC is the democratically elected civic governing body of Nagpur and the primary agency responsible for its urban governance. The city is divided into 72 zones (known locally as *Prabhags*) which in turn are divided into 145 wards. The governing body of NMC comprises of the elected and the administrative wings. The elected political wing is headed by the Mayor and the administrative wing is headed by the Municipal Commissioner, who is the chief executive head and looks after the city administration. The politically elected representatives together constitute the general body of the Nagpur Municipal Corporation. Figure 6 gives the organizational structure of the NMC.

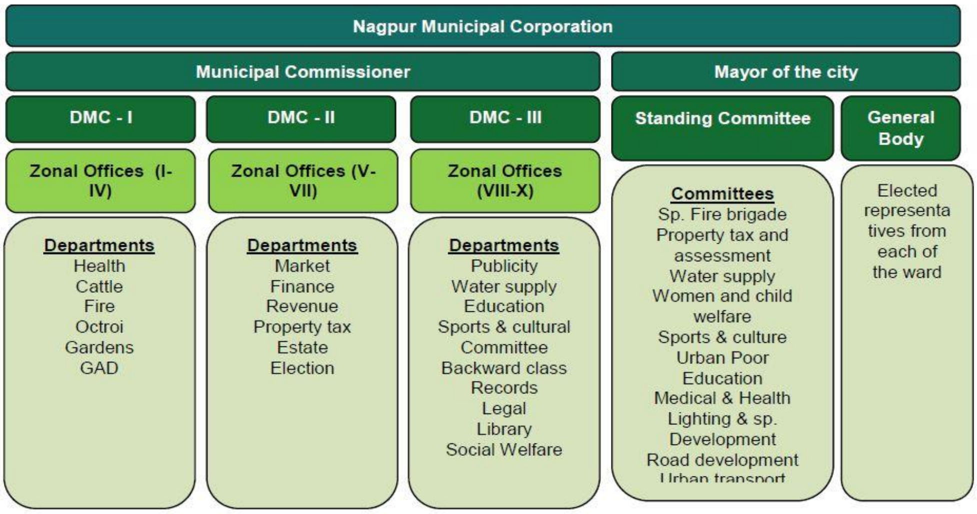


Figure 6 Organizational structure of Nagpur Municipal Corporation (NMC) 8

NMC is responsible for providing core urban services such as street lighting, construction and maintenance of roads, streets and flyovers, solid waste management sewage treatment and disposal, public hygiene, disaster management, maintenance of parks and open spaces, cemeteries and crematoria, registering of births and deaths, conservation of heritage sites, disease control and immunization, running of public municipal schools.

Nagpur Smart and Sustainable City Development Corporation Limited (NSSCDCL) is a Special Purpose Vehicle (SPV) established to implement the Smart City Mission in Nagpur. NSSDCL's main objective is to plan, design, perform technical and financial appraisals, construct, maintain and operate the projects envisaged in the Smart City proposal of NMC approved by the Government of India.

The Nagpur Improvement Trust (NIT) is the local planning authority that is responsible for development of the larger metropolitan area, including Nagpur city and its surrounding areas. NIT is responsible for carrying out the developmental works for improving civic infrastructure across the metropolitan area and for new urban areas coming up with the NMC's jurisdiction. NIT ensures conformity of new building development with the Development Control Regulations. In certain cases, wherein building layouts and schemes are developed by NIT itself, it also oversees planning and development of core civic functions such as water supply and construction of roads.

1.1.7 Major Urban Systems

1.1.7.1 Water Supply

Demographic growth, economic development and improved standards of living are driving rapid growth in demand for water in the city. The Water Works department of NMC oversees provision of water supply in Nagpur city and is carrying out various projects to achieve 24 x 7 water supply in the city.

Currently, water supply in Nagpur city is handled by a private operator, Orange City Water Services Ltd., under the public-private partnership (PPP) arrangement, that spans over a tenure of 25 years. The Kanhan River and the Pench dam are two major sources of water for the city. About 180 million liters per day (MLD) of water supply is provided through the Kanhan Water Supply Scheme. Three phases of the Pench project are operational at present and a fourth phase is currently being constructed. About 509 MLD of water supply in total is allocated through the Pench project at present.

8 General Administration Department (GAD), NMC, Nagpur

Table 2 Total supply of water from existing and proposed schemes and demand9

S No	Description		Year-wise supply and demand		
			2011	2021	2031
1	Existing Schemes	Pench project	396	396	396
		Kanhan water works	180	180	180
		Old Gorewada	16	16	16
2	Proposed Schemes	Pench Project. Phase-III, Stage- II	113	113	113
		Kochi Barrage on Kanhan Rivers	-	108	108
		Rehari Barrage on Kanhan Rivers	-	175	350
Total Supply (including distribution losses)			*695*	*978*	*1153*
Total Demand (within the NMC limits)			*532*	*709*	*934*
Total treated water demand including NMC limits, fringe area and special projects (CIDCO and MIHAN)			*558.72*	*738.38*	*987.8*
Total raw water demand including NMC limits, fringe area and the special projects (CIDCO and MIHAN)			*690 (252 mcm)*	*915 (334mcm)*	*1,222 (446 mcm)*

NMC has prepared a master plan to bridge the demand and supply gap in the water supply services up to 2031 from identified water sources (see Table 2). The Rahari barrage and Kochi barrage on Kanhan River are two key infrastructure projects proposed to be developed for ensuring adequate supply of water to the city by year 2031.

1.1.7.2 Sewerage

Nagpur city has a centralized sewerage network that covers about 85% percent of its households as of 2017-18 and the total wastewater generation is estimated to be around 532 MLD10.

Based on the topography of the city, it has been divided into three sewerage zones:

- North Sewerage Zone (NSZ);
- Central Sewerage Zone (CSZ) and
- South Sewerage Zone (SSZ)

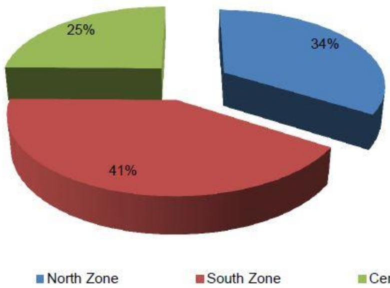


Figure 7 Zone wise sewerage generation11

As shown in Figure 7 wastewater generation in the South Zone is 41%, 34% in the North Zone, and 25% in the Central Zone respectively. The total wastewater treatment capacity in Nagpur is 230 MLD as of 2017-18, as against the cumulative wastewater generation of 532 MLD. The remaining wastewater from the three sewerage zones flow into the Nag River, Pili River, constructed drains and local water bodies without any treatment leading to high levels of pollution in the water bodies of Nagpur12.

At present, the urban areas growing around the fringes of the city are not serviced by a proper sewerage network. Among the three sewerage zones, the situation is most critical in the North zone

9 DPR on rehabilitation plan to implement 24*7 water supply project for Nagpur city, NMC

10 Calculated as 80% of the total volume of water supplied to the city

11 City Development Plan, Nagpur, 2015

12 Draft Development Plan for The Nagpur Metropolitan Area 2032

which worsens further during the monsoon season due to additional inflow of water. The National Environmental Engineering Research Institute (NEERI), a research institute focusing on water supply and wastewater disposal, reports that given the pollution, the quality of water flowing in Nag and Pilli rivers is not suitable for irrigation and is deteriorating day by day.

The NMC has a Sewage Treatment Plant (STP) located at Bhandewadi with an installed treatment capacity of 100 MLD. The STP consists of a conventional activated sludge plant (CASP) with sludge digestion tanks, with both sludge drying beds and mechanical sludge dewatering equipment. About 80 MLD of wastewater is collected and treated at the Bhandewadi STP. The volume of wastewater undergoing treatment is lower than the installed capacity, due to challenges faced in pumping adequate wastewater through the city's sewerage network.

In 2015, the NMC constructed and commissioned a second STP of 130 MLD capacity in association with MAHAGENCO under the Government of India's Jawaharlal Nehru National Urban Renewal Mission (JNNURM) scheme. Through this STP, NMC generates revenue by selling treated waste water to MAHAGENCO who then uses it in cooling towers of thermal power plants operational in the region, thus, reducing the burden of fresh water requirement in power generation plants.

In order to augment the waste water treatment capacity of the city, NMC has recently commissioned a 200 MLD wastewater treatment plant which started operating in August 2018. Following the same revenue model as the 130 MLD STP commissioned in 2015, NMC signed MOUs with MAHAGENCO and NTPC to supply the treated wastewater to thermal power plants operated by them. This is possible mainly due to the presence of the thermal power plants in the vicinity of the city and the mandate of state government to procure treated waste water for power plants. Due to the successful implementation of this model, other cities having similar conditions and potential are looking forward to implementing such projects.

1.1.7.3 Solid Waste Management

About 1200 tonnes of solid waste is collected within the Nagpur city on a daily basis. This municipal solid waste is transferred to the existing disposal site at Bhandewadi by a private agency. The Bhandewadi disposal site spans an area of 54 acres and is located at about 10 km from the center of the city. Currently, NMC treats 150-200 tonnes per day (TPD) of solid waste in a composting plant which is operated a private agency, Hanjar Biotech Energies Pvt. Ltd. As of now, NMC is carrying out bio-mining of the existing landfill site to segregate and dispose of the waste in a scientific manner. NMC along with Nagpur Smart City is going to establish 600 TPD centralized waste to compost plant 380 TPD of centralized MRF & RDF plant and 150 TPD of C&D waste treatment plant

NMC has successfully achieved 100% door-to-door collection of municipal solid waste by engaging a private company through a PPP agreement. Kanak Resources Management Limited has a fleet of 510 vehicles to collect, transport, and dispose waste at the Bhandewadi site. There are 10 temporary waste transfer stations in the city for secondary waste collection. Door-to-door collection happens through small trucks that carry waste to the 10 transfer points and the waste is further transferred to the disposal site through trucks having a higher waste carrying capacity. Kanak Resource's contract is over and NMC has appointed 2 separate agencies to collect and transport waste.

Source segregation of waste is a challenge in the city. To promote and instill the practice of waste segregation at source, NMC has been undertaking result-oriented initiatives such as awareness drives and free distribution of dustbins for segregation of waste under the Swachha Bharat Abhiyan (Clean India Mission). Recently NMC has proposed installation of 12 permanent waste transfer stations throughout the city to strengthen its waste management system. Also, under the Nagpur Smart City project, NMC has installed 10 smart trash bins in a pilot area with volume-based sensors and GPS through which these bins are continuously monitored and waste transfer vehicles trips are managed accordingly.

In terms of composition of municipal solid waste, it is seen that about 40% of total waste is organic waste followed by plastic (17.79%), paper (11.47%), wood (8.31%), inert materials (7.94%), cardboard (7.44%), and textiles (6.39%) (Refer Table 3).

Table 3 Composition of Municipal Solid Waste collected in Nagpur City[13]

S.No	Item	Site of Fresh Waste Dumpsite
1	Paper	11.47
2	Cardboard	7.44
3	Plastic	17.79
4	Textile	6.39
5	Organic	40.67
6	Inert	7.94
7	Wood	8.31
8	Thermocol	ND
9	Metals	ND
10	Glass	ND
ND- Non Detectable		

Vermicomposting:

A vermicomposting plant has been set up close to the dumping site at Bhandewadi. Food waste collected separately from commercial establishments such as hotels, restaurants, marriage halls amount to 8-10 tonnes daily and about one-third of it is converted into vermi compost. The vermi compost is used in NMC's gardens and the additional compost is sold in the market.

Management of Bio-Medical Waste:

A private agency has been contracted by NMC to treat and dispose of the bio-medical waste of Nagpur city. Apart from hospitals, dental clinics, dispensaries, blood banks, pathology laboratories, private Ayurvedic, and homeopathic colleges are catered to by the agency. A small land parcel of 0.25-acre belonging to the NMC, adjoining the existing landfill site at Bhandewadi has been allotted for the effective disposal of bio-medical waste.

1.1.7.4 Transportation

Nagpur is well connected to other major cities of India through major highways and railway lines that pass-through Nagpur. Given its good connectivity and central location in the country, the city has become a major trade and transportation center in the region. The city boasts an excellent road network, in terms of both quality and coverage.

The city has a distinct radial pattern and two ring roads. The total length of the roads is about 1,907 km, of which major roads account for 500 km. About 1,150 km of roads are within the jurisdiction of NMC. The city has a road density of 6.66 km per sq. km of its surface area. The road network in Nagpur is evolved with two national highways, one in north-south and another in the east-west direction, along with a radial pattern of roads formulated by two ring roads.

13 Results of waste characterization analysis conducted by NEERI for waste at dumpsite, April/May 2017

The total stock of vehicles in Nagpur city stands at about 1,610,500 as of 31st of March 2018. Due to the improving socio-economic conditions, personalized motor vehicles have been growing at the rate of 6% to 15% per annum in different cities across India. Similar trends are observed in Nagpur city, with an average annual vehicular growth rate of 12% in the recent years.

As is the case with most cities of India, a large chunk of Nagpur's total registered motor vehicles comprises of 2-wheelers. On an average, about 200-280 vehicles are being added every day, posing a challenge to expand the transportation infrastructure in the city at the same rate.

Figure 8 shows the number of new vehicles getting registered in Nagpur every year. It can be noted that new vehicle registration in the years 2016-17 and 2017-18 grew at 5.1% and 32.9% which is significantly higher compared to the previous years.

Figure 8 Number of Vehicles Registered Annually in Nagpur14

Public Transportation:

Nagpur has a bus-based public transport system with a fleet of 470 buses of varying capacities plying throughout the city every day. The Maharashtra State Road Transport Corporation (MSRTC), a state – owned agency, managed and operated the public transport system of Nagpur until 2007. Subsequently, the JNNURM scheme funded the procurement of new public buses in the city in 2010 and the responsibility of managing the public transport service for the city was taken over by NMC from MSRTC.

The Nagpur Mahanagar Parivahan pvt. Ltd. (NMPL), a special purpose vehicle (SPV) of NMC, was established to outsource the operations and maintenance (O&M) of Nagpur's public transport. A private operator, the Vansh Nimay Infra projects pvt. Ltd. (VNIL), was then selected by NMC for operating the city's public bus service for a period of ten years. It was agreed upon that during this period of engagement, VNIL can operate and maintain the bus service but the ownership of the buses will remain with the NMPL. This was supported by a revenue sharing model developed by NMC, wherein both NMPL and VNIL will share the revenues from advertisement while VNIL is obligated to pay royalty to the NMPL for providing the buses.

The bus-based public transport service has good coverage that reaches almost all areas within the city. There are about 174 routes which are operational at present and a total number of 254 buses currently in operation. This implies that more than 40% of the city's total fleet of 470 buses is not in operating condition/under maintenance. VNIL is responsible for planning activities like route planning, fare card, O&M of the public transport fleet, etc. but NMPL reserves the right to provide suggestions in terms of rationalization of the fares acting upon the interests of the citizens.

14 Updated Comprehensive Mobility Plan, Nagpur, 2018

Intermediate public transport (IPT) modes like autos, shared autos and taxis play an important role in meeting the travel demand of Nagpur's citizens. These IPT modes also function as a feeder service to the main mass transport systems and can provide accessible movement in predefined areas. The IPT modes compete directly with the road based public transport system for short trip lengths. The current share of Auto rickshaws is 19.8% in the transportation sector, which is observed to be more than that of public transport. The IPT in Nagpur is unorganized and is operated independently by the auto rickshaw drivers. The regulations on fares are often ignored by the auto rickshaw drivers which go unchecked, leading to challenges for passengers who depend on IPT modes for first and last mile connectivity.

Recognizing the increasing travel demand in the city, a mass rapid transit system in the form of a metro rail was envisaged in 2013 for the city of Nagpur. The Nagpur metro rail project, which is currently under construction, has a total length of 38.22 km and includes 36 stations. The entire stretch of this project will be divided into two corridors viz. North-South corridor of 19.66 km length with 17 stations and East-West corridor of 18.56 km length with 19 stations. The cost of this project is estimated at INR 86,800 million. A 12 km stretch on the Sita Buldi to Khapri route has been inaugurated and opened for the public in March 2019.

1.1.7.5 Electricity

The Maharashtra State Electricity Distribution Co. Ltd. (MSEDCL) is responsible for distribution of power within Nagpur city. Coal based thermal power dominates the mix of energy sources that generate power for Nagpur city and surrounding regions, owing to the rich coal deposits in Nagpur district and thermal power plants in the vicinity of the city. The electricity consumption by Nagpur city has been growing at an average annual rate of 3.23% in the recent years, with a total consumption of 1,822 Million kWh in the year 2017-18. The largest end-use consumer of electricity in Nagpur is the Residential Buildings sector with a share of about 59.8% in the city-wide consumption followed by the commercial sector with a 34.6% share in the year 2017-18 (Refer Figure 16 in Section 2.1.7). Table 4 gives the Total electricity consumption in the city during the years between 2013 and 2018.

Table 4 Year-wise Total Electricity Consumption for Nagpur City

Year	2013-14	2014-15	2015-16	2016-17	2017-18	Average Annual Growth Rate (%)
Total Annual Electricity Consumption (Million kWh)	1,527	1,659	1,735	1,758	1,822	3.23

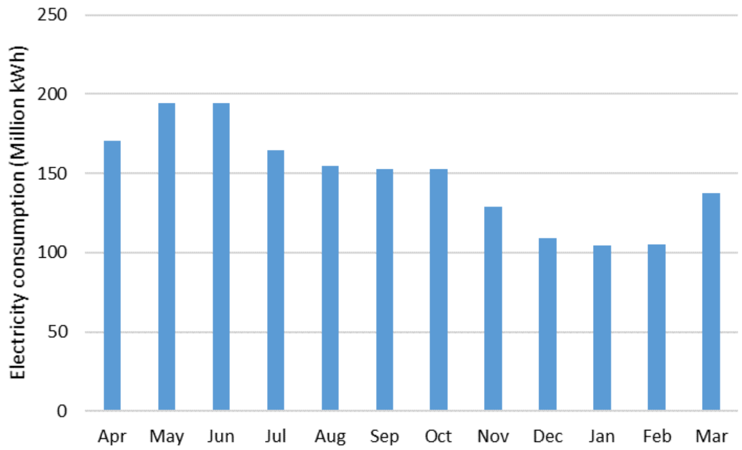


Figure 9 Monthly Electricity Consumption by Nagpur in 2017-18

Monthly energy consumption is useful in understanding minimum and peak consumption in the city and the seasonal variations therein. Figure 9 shows the monthly power consumption in Nagpur in the year 2017-18. It is evident that electricity consumption is increasing from March till June caused by the increasing cooling demand during the summer months which is hot and dry in Nagpur. The months of May and June record the highest electricity consumption of around 195 Million kWh which is almost double of the consumption during winter months.

2 Baseline Assessment

2.1 GHG Emission Inventory

Nagpur city's GHG emissions inventory is prepared based on the data collected for the years 2013 - 18. The inventory is in accordance with the approved principles and standards of the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC) created by a collaborative effort between World Resources Institute, C40 Cities Climate Leadership Group, and ICLEI – Local Governments for Sustainability. In particular, it complies with the BASIC level reporting which covers Scope 1 and Scope 2 emissions from stationary energy and transportation, as well as Scope 1 and Scope 3 emissions from waste (Refer Appendix).

The GHG emissions inventory consists of two analyses, one for the emissions within the community determined by the geographical boundaries of the city's municipal jurisdiction and the other for urban services provided by the NMC.

Community-level inventory is a useful tool to establish baseline status of GHG emissions and in developing mitigation actions for the entire city community. It includes emissions from community activities that occur within the municipal government's jurisdiction. This includes emissions due to activities such as residential buildings, commercial/institutional facilities, industrial units and processes, agriculture, forestry and land-use, and mobile transportation units.

Local Government inventory includes emissions from all local operations that the municipal corporation owns or controls. The various sectors considered for this inventory include local government buildings, facilities such as street lighting and traffic lighting, water, waste and sewage facilities, and municipal vehicle fleet. Based on the inventory data for the baseline year, the municipal government can develop innovative approaches to provide sustainable urban services and can demonstrate leadership in pursuing emission mitigation efforts that illustrate the possibilities of different mitigation actions to the community.

A city's GHG inventory is not just simply the sum of GHG emissions from its community-level activities and from the operations carried out by the local government body to provide basic urban services.

Usually, a major part of the emissions due to local government operations is a subset of the community level emissions. Often the community inventory data already accounts for the data pertaining to municipal government operations and so due care should be taken to avoid double accounting of emissions.

For example, the electricity consumption in municipal facilities for water supply, sewage treatment, and street lighting may already be accounted in the community-wide electricity consumption data based on relevant customer/end-user categories as prescribed under the electricity distribution and tariff arrangements. Adding the electricity consumption data from such facilities, obtained from the respective departments within the local government, to the community-wide data again will result in double accounting of the emissions and such overlaps have to be prevented by careful handling of data.

However, it is necessary to acknowledge that analyzing community-wide GHG emissions present its own challenges as the natural flow of energy and materials is typically most accurate at the national level. Reducing the spatial area of analysis, from national to sub-national and local levels result in a less accurate reflection of the material and energy flows. Therefore, a community level GHG emission accounting means that a combination of national and local area information is required in order to model the emissions. This report identifies the main energy carriers and the intensive GHG emitting sectors that contribute to the local carbon footprint and air pollution within the geographical boundary of Nagpur Municipal Corporation.

2.1.1 Methodology for GHG emission inventory

The GHGs considered in the GHG emission inventory are carbon dioxide (CO_2), methane (CH_4) and nitrogen oxide (N_2O), gases which account for nearly 99% of global GHG emissions.

The GHG inventory has been reported in terms of emissions of each individual GHG and the total carbon dioxide equivalent (CO_2e) emission. To arrive at the CO_2e, the global warming potential (GWP) of each gas for a 100-year timeline is factored. The GWP gives the climate change impact, in terms of the warming effect on the atmosphere, for each GHG with reference to CO_2. The GWP values based on the IPCC's Fourth Assessment Report are presented in the

Table 5 below.

Table 5 100 Year GWPs of the GHGs with respect to CO_2

Gas	Lifetime (years)	GWP for 100 years
CH_4	12	25
N_2O	114	298

Emissions Factors

For estimating the GHG emissions from the various activities or sources in a region, it is not feasible to carry out a direct physical measurement of GHGs emitted. The common methodology for estimating GHG emissions is by using the principle of emission factor and the relevant activity data to estimate the emissions.

$$GHG_A = EF_A \times D_A$$

where, GHG_A = GHG emissions resulting from activity A

EF_A = emission factor for activity A

D_A = data for activity A

The emission factor for a particular activity is dependent on the energy use and the direct emissions of GHGs resulting from the activity. As the emission factors are dependent on the energy use and the direct GHG emissions, they tend to vary over locations or even for different technologies. For example, the emission factor per kWh of electricity used would vary over countries or regions due to the varying energy mix, characteristics of fuel used and the efficiency of electricity generation. The emission factor per km travelled would vary depending on the fuel characteristics, the engine characteristics for the vehicle, the driving and traffic patterns prevalent. For accurately estimating a GHG inventory, it is thus important to use the emission factor best suited to the location.

For the present study, relevant emission factors as available in HEAT+ tool have been used to arrive at GHG emissions from activities in the region. HEAT+ contains numerous country specific emission factors and energy densities for a wide range of fuels, combustion technologies and waste types. HEAT+ uses these values to calculate the GHG emissions resulting from electricity usage, fuel consumption and waste decomposition.

2.1.2 Harmonized Emission Analysis Tool plus (HEAT+)

ICLEI's Harmonized Emission Analysis Tool *plus* (Heat+) is an online emissions accounting software package that helps local governments to account for GHG emissions and develop a comprehensive energy and carbon inventory of their respective cities. The tool helps them in making informed climate action decisions and was utilized to assist with the accounting of Nagpur's level of GHG emissions during the 5-year period of the inventory. The Heat+ tool incorporates the latest technical findings (IPCC, 2006) and is based on the International Local Government GHG Emissions Analysis Protocol (IEAP). It also incorporates the new international reporting requirements and standards outlined in the Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC).

HEAT+ is now GPC compliant. However, the government module is retained from the differentiation that was brought in with IEAP.

The Harmonized Emissions Analysis Tool (HEAT+) is a specialized online application designed to help local governments:

1. Create emissions inventory of GHGs as well as air pollutants such as nitrogen oxides, Sulphur oxides, carbon monoxide, volatile organic compounds, and particulate matter;
2. Forecast growth of these emissions for a future year;
3. Evaluate policies and measures to reduce emissions of these pollutants; and
4. Prepare action plans to reduce emissions.

While ICLEI designed HEAT+ as a GHG planning tool for its local government members to use while undertaking the five-mile stone process of the Cities for Climate Protection TM (CCPTM) Campaign, this tool has been substantially updated to support cities in the implementation of ICLEI's latest Green Climate Cities Program. Decision makers from other levels of governments as well as from the private sector and non-governmental organizations will also find the tool useful. With an easy to navigate interface, numerous built-in reports, extensive Intergovernmental Panel on Climate Change (IPCC) and country-specific emissions coefficient data sets, HEAT+ provides an unparalleled software environment for everything right from preparing city specific GHG inventories to evaluating the benefits of individual policies and measures for developing comprehensive action plans.

2.1.3 Data Sources and Collection

The baseline year for this study was the financial year of 2017-18 (i.e. April 2017-March 2018). A full GHG inventory includes emissions from energy, waste, agriculture, forestry, and land-use change. However, due to limited resources and data constraints, the direct emissions from agriculture, land-use change and forestry sectors were not included.

ICLEI South Asia and NMC staff members engaged through meetings and letters with a number of municipal, local and sub-national stakeholders to source the relevant energy consumption data focusing on the large carbon emitters within the municipal area. Supply and demand-side data were therefore collected and analyzed. The various sources of energy & other relevant data used in the report are elaborated in Table 6.

Table 6 Sources of the data used for GHG emission calculation

Fuel Type	Sector	Source of Data
Electricity	Residential	Maharashtra State Electricity Distribution Company Limited (MSEDCL)
	Commercial/Institutional	MSEDCL
	Manufacturing Industry and Construction	MSEDCL
	Municipal Buildings	Electrical department, Town Planning Department NMC
	Water works department – Water treatment plant and pumping stations	Water works department, NMC
	Drainage department – drainage pumping stations and sewage treatment plants	Pench Project Cell, NMC
	Street lights	MSEDCL
Diesel	Community Transport	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Manufacturing Industry and Construction	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Municipal Vehicles	Workshop Department NMC
Petrol	Community Transport	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Manufacturing Industry and Construction	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Municipal Vehicles	Workshop Department NMC
LPG	Residential	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Commercial/Institutional	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
	Auto LPG – Transportation	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
Kerosene	Residential	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
Furnace Oil	Manufacturing Industry and Construction	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
Light Diesel Oil	Manufacturing Industry and Construction	IOCL- Nagpur; HPCL-Nagpur, BPCL- Nagpur
Transport Sector		Regional Transport Office (RTO) – Nagpur
Solid Waste Management		Health Department (Sanitation)- NMC

Fuel Type	Sector	Source of Data
Municipal Water Supply		Water Works Department, NMC
Municipal Wastewater treatment		Pench Project Cell- NMC
Municipal Street Lighting		Electrical Department- NMC

2.1.4 Economy-wide Trend of Energy Consumption and GHG Emissions

Economy-wide analysis of the data collected for GHG emissions inventory led to determining the average growth or decline in energy consumption and GHG emissions from different sectors, classified based on their activities within the boundaries of the city under study. Table 7 presents the energy consumption by different sectors of Nagpur city between the years 2013-14 and 2017-18. Nagpur's total energy consumption stood at 19,044,340 Gigajoule (GJ) during the baseline year 2017-18.

Table 7 Sector-wise Trend of Energy Consumption in GJ per year

Sector	Energy Consumption (GJ)				
	2013-14	2014-15	2015-16	2016-17	2017-18
Residential Buildings	7,051,413	7,604,645	7,759,204	7,869,086	8,108,294
Commercial and Institutional buildings/facilities	2,113,844	2,176,699	2,401,017	2,667,922	2,858,715
Manufacturing Industries and Construction	910,477	936,768	1,017,666	1,068,395	1,038,318
Agriculture, forestry and fishing activities	2,376	1,764	2,448	2,304	2,664
Transport	4,685,594	4,861,691	5,668,627	6,182,962	7,036,350
Total	**14,763,704**	**15,581,567**	**16,848,962**	**17,790,669**	**19,044,340**

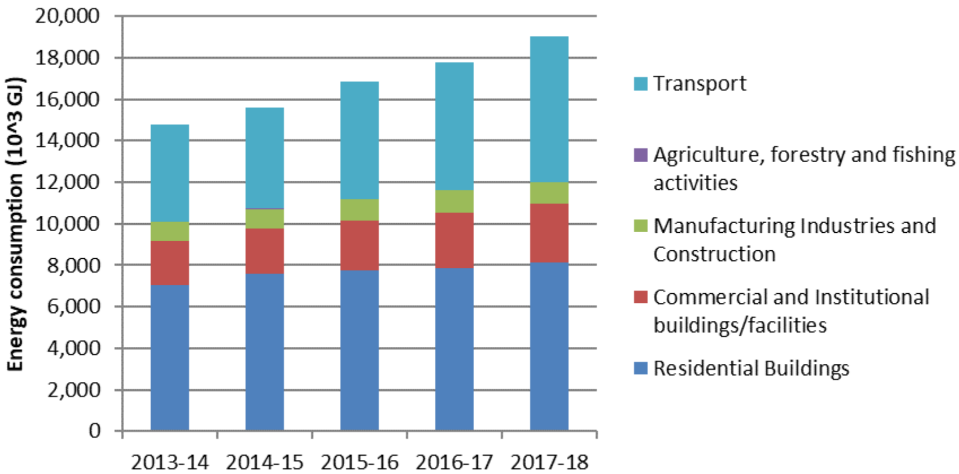


Figure 10 Trend of Energy Consumption in GJ from 2013 to 2018

From Figure 10 it is evident that the total energy consumption by the city is linearly increasing between the years 2013 and 2018 and at an annual average growth rate of 5.8%. Among the various sectors, the average annual growth rate is highest in the transportation sector at 10%, followed by the commercial and institutional sector at 7%. The lowest average annual growth rate in energy consumption was observed in the Agriculture, Forestry and fisheries sector at 2.4%.

The overall GHG emissions from various sectors across the city's community has been estimated based on the data collected and is presented in Table 8 below. The total GHG emission for Nagpur city in the year 2017-18 stands at 3.03 million tonnes of CO_2 equivalent (tCO_2e) which translates to a per capita emission of 1.13 tCO_2e.

Table 8 Sector-wise Trend of GHG Emission in tCO_2e per year

Sector	GHG Emissions (tCO_2e)				
	2013-14	2014-15	2015-16	2016-17	2017-18
Residential Buildings	976,655	1,071,603	1,106,456	1,117,635	1,161,452
Commercial and Institutional buildings/facilities	436,316	456,161	487,297	522,482	556,121
Manufacturing Industries and Construction	139,077	143,061	152,161	147,316	133,282
Agriculture, forestry and fishing activities	543	403	559	527	609
Transport	370,975	385,826	442,336	485,755	549,935
Waste	532,279	537,083	607,745	618,453	633,090
Total	2,455,845	2,594,136	2,796,554	2,892,168	3,034,489

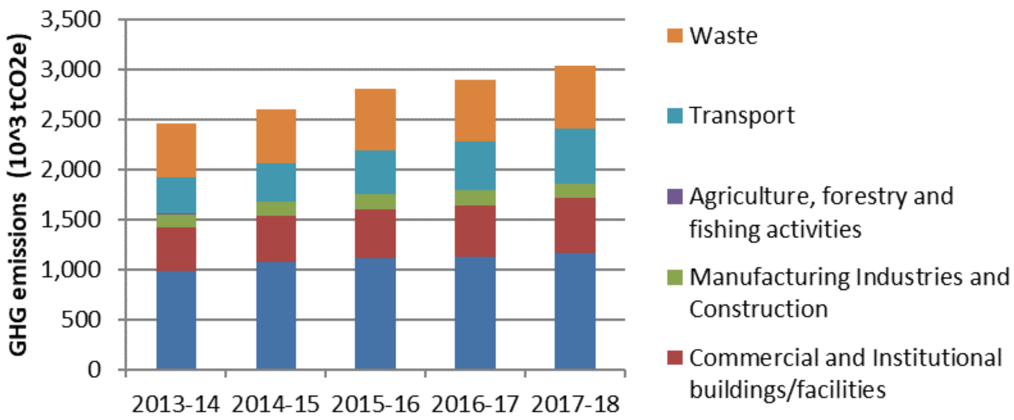


Figure 11 Trend of GHG Emissions in tCO_2e from 2013 to 2018

Figure 11 depicts the sector-wise GHG emission trend in Nagpur between 2013 and 2018. As can be seen from the graph, the GHG emissions are growing year by year with an average annual growth rate of 4.7%. The transport sector has the highest average growth rate at 9.6% followed by the commercial/institutional sector growing at a rate of 5.5%.

Note that the manufacturing/construction sector witnesses a decline in GHG emissions after the year 2015-16 even though the energy consumption of the sector keeps increasing until the year 2016-17 (Refer to Table 8). This contrasting trend could be ascribed to the significantly higher consumption of diesel and liquefied petroleum gas (LPG) in the year 2016-17 and the decline in the consumption of other types of fuel like furnace oil, petrol and light diesel oil (LDO) by the sector, leading to its lower contribution to the GHG emissions after the year 2015-16. The reasons for these variations in the energy consumption data are the variable demand of industries for specific type and quantity of fuels and the shutdown of operations in few industries within the NMC jurisdiction. It should also be noted that several manufacturing industries that require these fuels regularly operate are located outside the NMC's jurisdiction area and are not covered under the scope of this study.

2.1.5 Baseline Energy Consumption and Emissions

A baseline year is a historical point of comparison that can be used to measure changes in the past and current data values. This reference point in time helps track the effects of energy efficiency and emission targets set forth by climate action plans. 2017-18 was chosen as the baseline year for the GHG emission inventory prepared for Nagpur city. With the study significantly dependent on secondary data sourced from various government and private agencies, the base year is set as a financial year to align with most of the data accounting practices in these agencies. 2017-18 is also the latest year wherein requisite information was documented and available across all sectors. Data has also been collected for a time period of 5 years to understand the trends of energy use and GHG emission across sectors in the city.

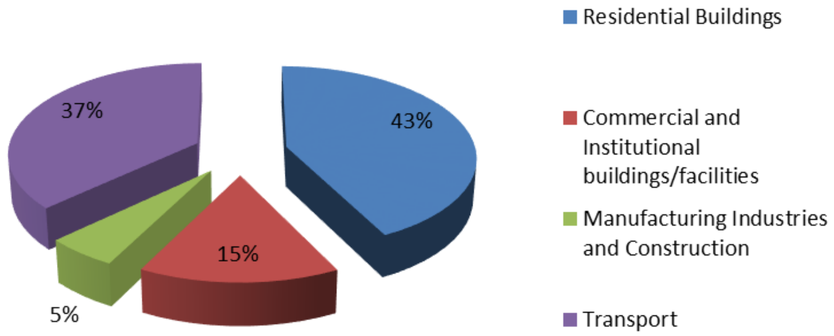


Figure 12 Sector-wise Energy Consumption in the baseline year 2017-18

Figure 12 suggests that the Residential Buildings are the largest consumers of energy, with a share of 43% of total energy consumed by Nagpur, even though the average growth rate in energy consumption is lower compared to other sectors. Transport sector with a 37% share in total energy consumption is the second largest consumer of energy followed by significant contributions from the Commercial and Institutional sector, and the Manufacturing industries and construction sector. The energy consumed by the agriculture, forestry and fishing activities is found to be negligible.

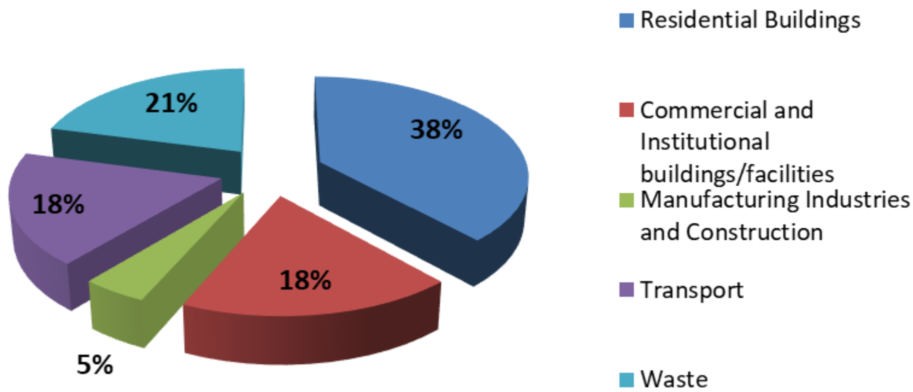


Figure 13 Sector-wise GHG Emission in the baseline year 2017-18

Based on Figure 13, the Residential sector with a share of 38% is the highest contributor to the overall GHG emissions, an obvious corollary to its highest share in energy consumption within Nagpur city. The significantly higher GHG emission contribution by the Residential sector is because grid electricity, which dominates the energy profile of the residential sector, is known to be produced from an energy mix dominated by thermal sources for supply to Nagpur. Also, the residential settlements cover more area than other sectors like commercial or manufacturing/industrial sectors and energy-intensive industries are settled outside the NMC's jurisdiction area as discussed earlier. Waste sector is the second highest contributor to GHG emissions with a 21% share and is followed by significant emissions from transportation (18%) and Commercial and institutional buildings/facilities sector (18%). The agriculture, forestry and fishing activities sector contribute a negligible amount to the total GHG emission (0.02%) and is therefore not depicted in Figure 13.

2.1.6 Supply Side Energy Consumption and Emissions

Primary and secondary energy sources supplied to the demand-side sectors for consumption are referred to as the supply-side sources. These include liquid, solid and gaseous fuels, electricity and renewable sources of energy. Demand-side energy refers to the energy end user, i.e. the sectors like residential, commercial, industrial users of energy within an urban jurisdiction. Grid electricity is the dominant energy type that is typically used in almost all sectors. Petroleum products form the second group and are used extensively for community transportation in the city and in the industrial sector.

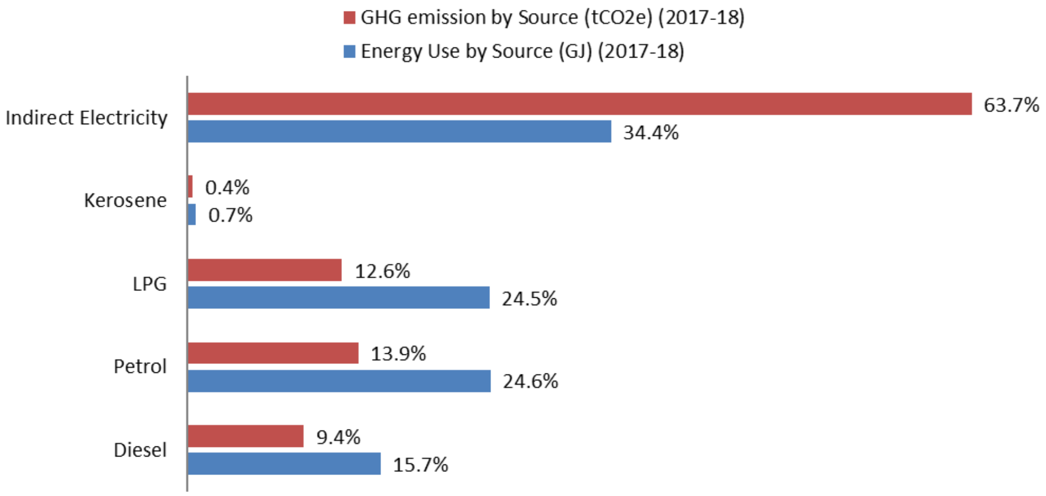


Figure 14 Share of Energy Consumption and GHG Emission by Energy Source

Electricity is the main form of energy used in Nagpur, catering to about 34.4% of the total energy consumed in the city. Petrol and LPG are the next major sources of energy with a contribution of 24.6% and 24.5% respectively to the energy supplied.

GHG Emission from grid electricity is the major contributor with a share of 63.7% in the overall GHG emissions from the city even though it caters to only 34.4% of the demand. This is because of the indirect GHG emissions from grid electricity produced by coal-based thermal power plants in the region.

2.1.7 Energy Indirect emissions from Grid electricity at the community level

2.1.7.1 Sector wise grid electricity consumption at the community level

At the community level, electricity is the most common form of grid-supplied energy across sectors and is used in almost all homes, offices, other buildings, and outdoor lighting. The cross-sectoral end-use electricity consumption pattern in Figure 15 can help inform us about the correlation between changes in the economic profile of the city and electricity consumption across key sectors. Figure 15 shows a growing trend in electricity consumption in the city which has steadily increased from 1527 million kWh in 2013-14 to 1822 million kWh in 2017-18.

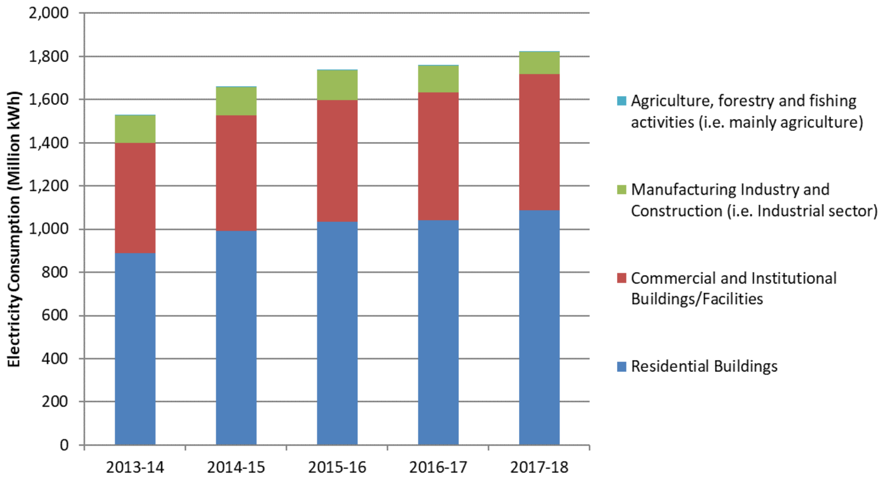


Figure 15 Sector-wise Grid Electricity Consumption at the community level

It can be seen that the electricity consumed by the Manufacturing industry and construction sector has increased until 2015-16 and then witnesses a decline from the 2016-17 period. The last 2 years of the study shows a significant decline in the electricity consumed by the sector. As mentioned earlier and from information received from oil marketing companies, a number of industries stopped their operations in the city temporarily or permanently thereby causing a reduction in energy consumption. Most of the industries now operate outside the city and in dedicated areas developed by Maharashtra Industries Development Corporation (MIDC) which do not come under the city government's jurisdiction.

On the other hand, energy consumption in the commercial sector shows steady growth, the primary reason being that few IT parks have started their operations in the city, along with major institutes like the Indian Institute of Management and retail outlets like Big Bazaar, hotels, cafes, etc. opening in the city. Recent developments like the Metro Rail project is expected to boost commercial developments in the vicinity, thereby driving an increase in the city's electricity demand in the near future.

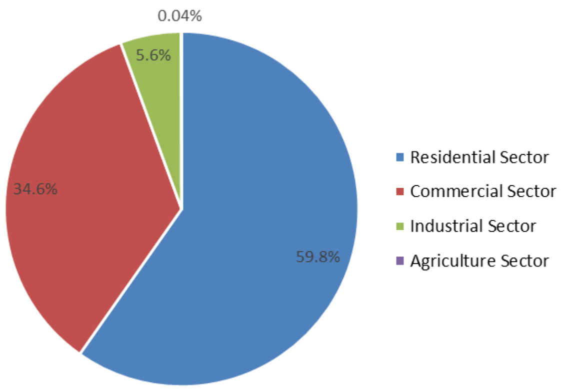


Figure 16 Sector-wise share of Electricity consumption in 2017-18

As shown in Figure 16, the main consumer of grid electricity at the community level is the Residential Buildings sector with a share of about 59.8% in the city-wide consumption. The commercial sector with a 34.6% share is the second largest consumer of grid electricity in the baseline year 2017-18.

2.1.7.2 Sector wise indirect GHG emissions from Grid Electricity consumption

Grid-supplied electricity entails emissions produced at generation facilities off-site from the consumption facilities. Based on the city and electricity grid structure, the energy generators can be located outside the geographic boundary at various locations tied to or exporting to the regional grid. Thus, the consumption of grid electricity contributes to indirect GHG emissions on the community level.

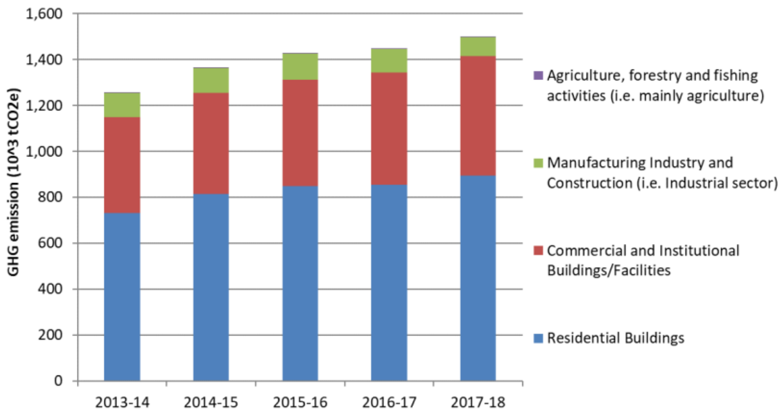


Figure 17 Sector-wise indirect GHG emissions due to Electricity Consumption

Figure 17 shows that the indirect emission due to grid electricity has an increasing trend between the years 2013 and 2018. It is interesting to note that despite the significant decline in electricity usage by the manufacturing/construction sector, there is a small increase in indirect GHG emissions from the year 2015-16 to 2016-17 contributed mainly by the higher growth of electricity consumption by other sectors.

As in the case of Nagpur, the grid energy is solely electricity supplied by the regional grid. Given the emission factor of 822.78 tCO_2e per million units of electricity, the sector-wise contribution to the total indirect emissions follows the same trend as grid electricity consumption. The Residential sector contributes the most followed by the Commercial and Institutional buildings/facilities sector (Refer to Figure 18).

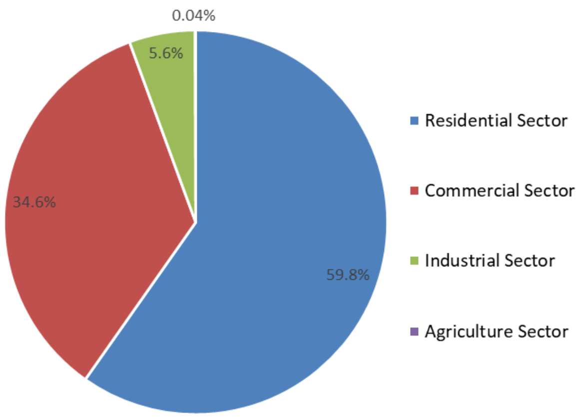


Figure 18 Sector-wise share of indirect GHG emissions at the community level

2.1.8 Direct Emission from Stationary Combustion at the Community Level

Direct emission from stationary combustion refers to the emissions from the intentional oxidation of fuels within a stationary apparatus that is designed for producing heat or mechanical work in a process (e.g. burning of kerosene and LPG for residential use, furnace oil for industries). It does not include fuel used for transportation. The quantity of direct GHG emission for stationary combustion depends on the volume and type of fuels used across sectors such as residential, commercial/institutional and industrial. It is estimated by multiplying the fuel consumption by the GHG emission factor for the specific fuel.

2.1.8.1 Residential buildings sector

Nagpur uses kerosene and LPG as the primary fuels to meet the energy requirements of the residential sector. Kerosene is usually used for cooking in low-income households and is distributed by the Public Distribution System (PDS)/fair price shops based on the central government's kerosene policy. LPG being a cleaner fuel has always been at the forefront of government's push towards modern cooking in Indian households. LPG is supplied majorly through gas cylinders using a distribution network established by the Public Sector Undertakings (PSUs) for distribution of LPG cylinders to residential homes. LPG consumption increased consistently every year and reached 85,867 metric tons in the year 2017-18 while Kerosene consumption decreased to 3540 kilo Litres from 5556 kilo litres in 2013-14..

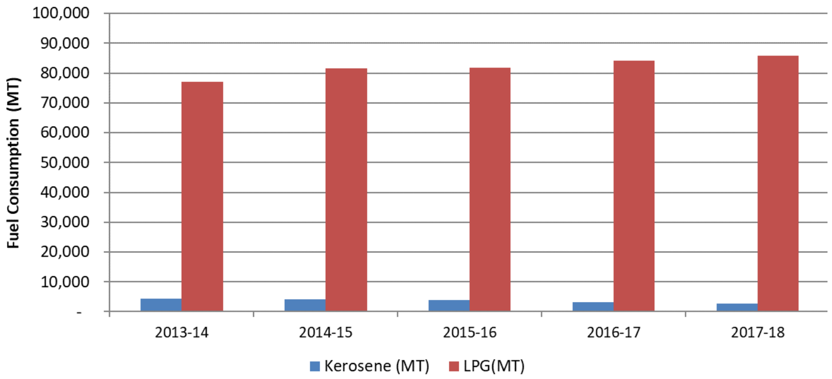


Figure 19 Trend of Fuel Consumption by Residential sector

From Figure 19 it is clear that the LPG consumption in the city has increased during the study period while kerosene consumption has been declining all along. Interestingly, there is a significant drop in kerosene consumption after the year 2015-16 which could be a direct impact of the central government's Prime Minister Ujjwala Yojana (PMUY), an initiative launched in May 2016 that aims to provide subsidized LPG connections to low-income households.

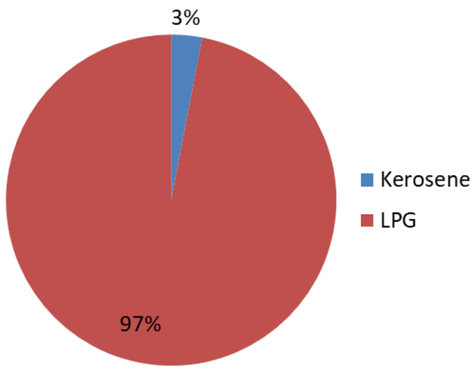


Figure 20 Share of stationary energy use by fuel in the Residential sector, 2017-18

The PMUY scheme led to an increase in new LPG subscribers and a shift towards LPG consumption after the year 2016, thereby reducing the share of kerosene in the stationary fuel use by residential sector. As of the year 2017-18, kerosene was found to have only a share of 3% in the stationary fuel consumption by Residential sector in Nagpur city (Refer to Figure 20). Even though the kerosene consumption was reduced as an impact of the scheme, it can be noted that the total GHG emissions from stationary combustion in the residential sector have been increasing all along (refer Figure 21) due to increased consumption of LPG propelled by subsidized LPG provision by the government.

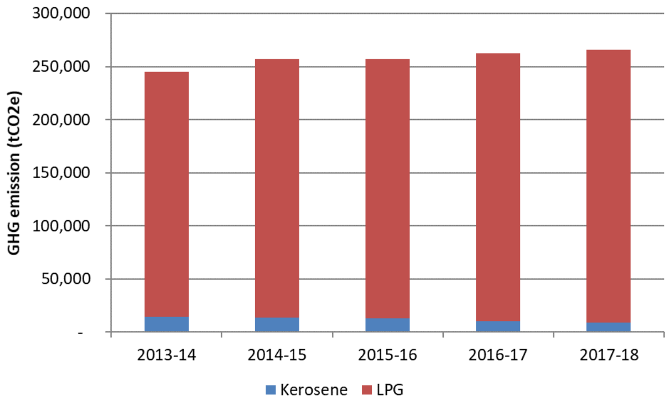


Figure 21 GHG emissions trend by Residential Sector

2.1.8.2 Commercial and Institutional buildings/facilities sector

LPG is the primary fuel consumed by the commercial/institutional sector end users like hotels, shops, restaurants, malls, educational institutions, office buildings, etc. The LPG consumed by the commercial sector of Nagpur stood at 12,427 metric tons by the year 2017-18.

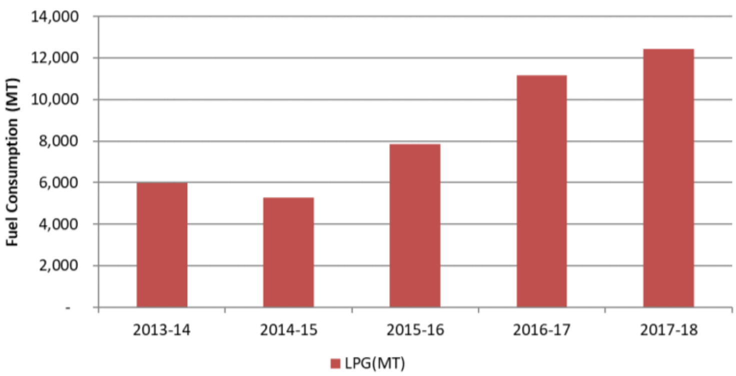


Figure 22 Trend of Fuel Consumption in Commercial/Institutional Sector

Figure 22 reveals that the LPG consumption decreased by about 12% in the year 2014-15 as compared to 2013-14 and then witnessed a sudden increase, by almost 48%, in the year 2015-16 as compared to 2014-15. Discussing the trend with PSUs supplying LPG, it was found that the lower consumption in the year 2014-15 was due to the cancellation of many illegal commercial connections and of multiple commercial connections in the name of a single owner. This was a result of the Direct Benefits Transfer for LPG (DBTL) Consumers Scheme that eliminated non-existent accounts by bringing in transparency in LPG supply chain and plugged LPG subsidy leakages. The sudden increase in 2015-16 can be ascribed to the new LPG consumers added during that period after implementation of DBTL scheme that eliminated unauthorized usage and improved availability of new LPG connections.

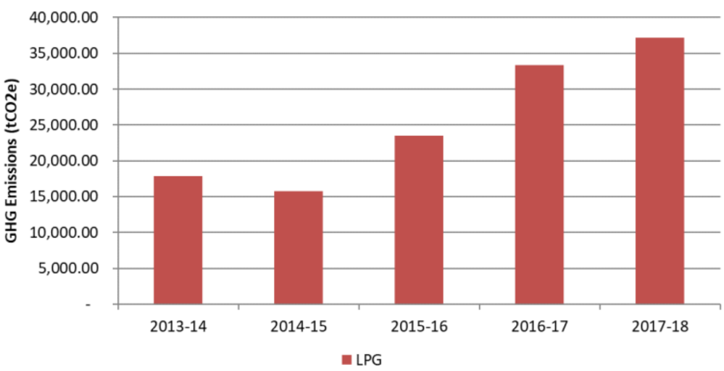


Figure 23 Trend of GHG Emissions by Commercial/Institutional sector

Figure 23 shows the GHG emission contributed by LPG consumed in the sector during the study period and follows the same trend as the quantity of LPG consumption. The LPG consumption by commercial sector alone contributed to 37,189 tCO_2e of the total GHG emission by the city in the year 2017-18.

2.1.8.3 Manufacturing Industries and Construction Sector

Petrol, diesel, furnace Oil, LDO, and LPG are the fuels used to meet the stationary energy demand in the Manufacturing and construction sector of Nagpur. It should be noted that very few industries operate within the NMC's jurisdictional area, and major fuel-intensive industries operate outside the NMC's jurisdiction. Diesel is the main fuel consumed by the industrial sector which far exceeds other fuels used in terms of quantity and its consumption reached 15,998 kilo Litres by the year 2017-18.

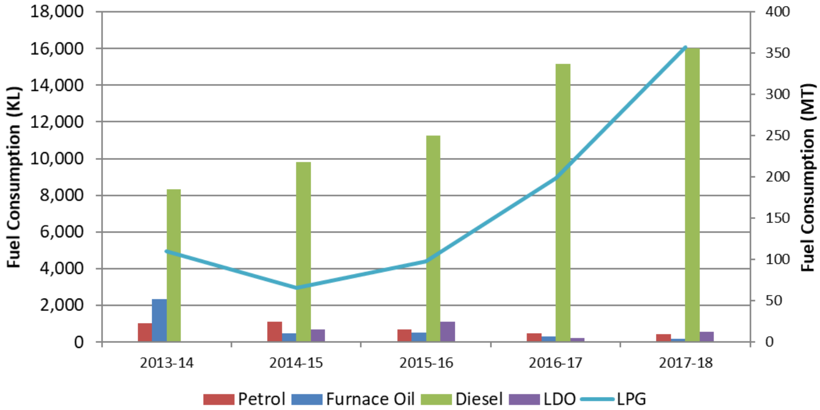


Figure 24 Trend of Fuel Consumption in Manufacturing and Construction sector

Figure 24 reveals that the Petrol and furnace oil consumption of the Manufacturing and Construction sector has a declining trend due to the many industries that have either stopped their operations or shifted outside the city limit. Diesel consumption on the other hand consistently increased each year as they are often used in Diesel Generators for producing power to be used as backup power or for peak hour consumption in Industries. Consumption of LDO and LPG does not have a clear trend as their demand is based on industry requirements and may not necessarily be constant every year. Figure 25 shows the GHG emission contribution by various fuels used in the industrial sector of Nagpur.

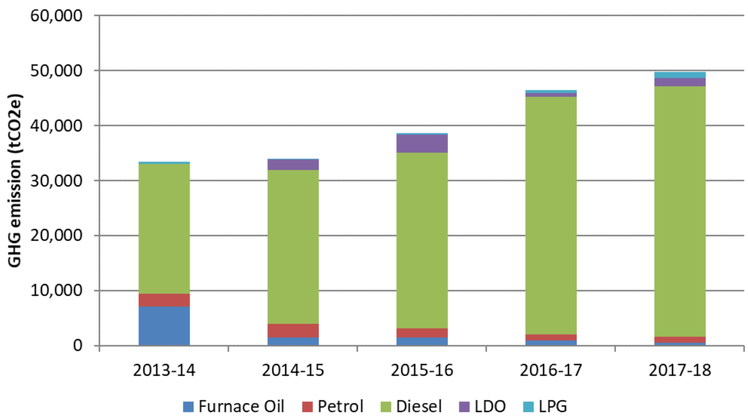


Figure 25 Trend of GHG Emission by Manufacturing and Construction Sector

2.1.8.4 Road transportation

Petrol, diesel, and Auto-LPG are the three fuels used in the transportation sector of Nagpur. Petrol is the major fuel used by two, three and four-wheeler motorists in the city followed by diesel, which is commonly used by only four-wheeler vehicles and heavy vehicles. The steady rise in consumption of petrol and diesel is due to the continuous increase in vehicle stock of the city fueled by the economic growth and rising population. By 2017-18, the petrol consumption in the city for transportation alone increased to 141,523 kilo litres. Although the use of Auto-LPG has been on the rise throughout the period of study, its share in the fuel mix of the transportation sector is negligible as there are very few retail outlets that sell Auto-LPG in the city.

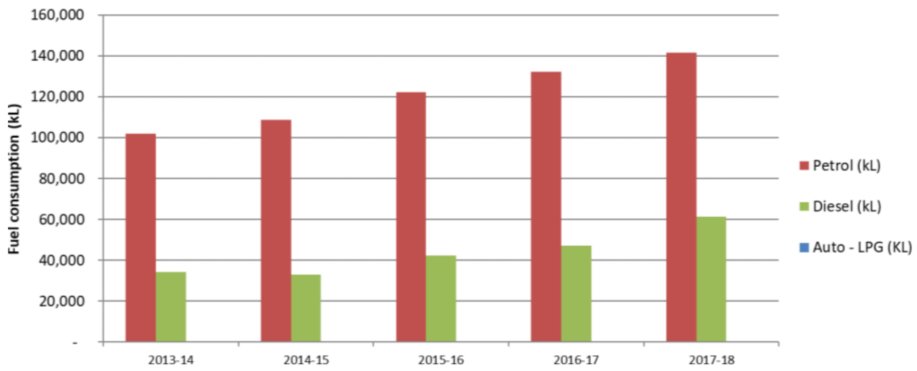


Figure 26 Trend of Fuel Consumption by Road Transportation Sector

From Figure 26, it is evident that diesel consumption increased by almost 30% in 2017-18 as compared to the year 2016-17. Based on discussions with the PSUs, it was understood that the large infrastructure development projects such as new road development, repairing/maintenance work, city metro rail projects, etc. were in progress in the city at the time. This necessitated the use of diesel generator sets for site operations and moving cement concrete making trucks for construction activities leading to the significant increase in diesel consumption witnessed in the year 2017-18.

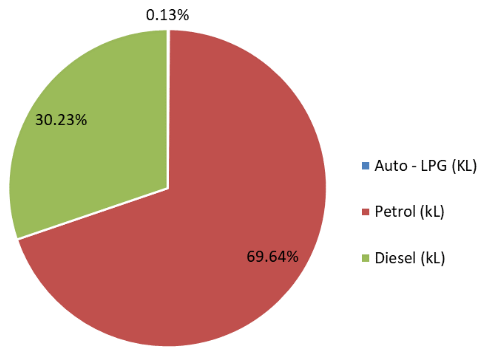


Figure 27 Share of Stationary Energy Use by Fuel in the Transportation sector, 2017-2018

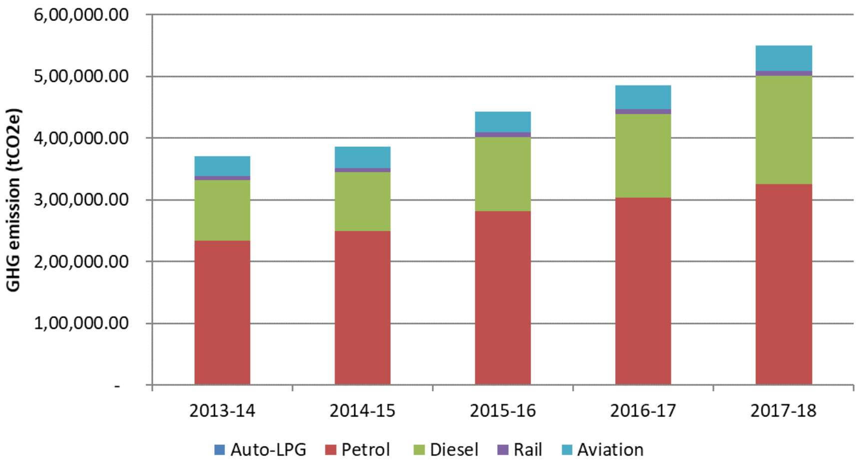


Figure 28 Trend of GHG emission by the transportation sector

Figure 28 shows that the GHG emissions from the Transportation sector alone stood at 549, 535 tCO_2e in the year 2017-18. Emission factor for diesel is higher than petrol but not significantly to have a notable difference between their share in fuel consumption and contribution to GHG emissions by the two fuels (Refer to Figure 27 and Figure 29). Rail emissions were estimated based on track length inside the city and approximate passenger ridership through rail transport within Nagpur city. For 2017-18, rail emissions stood at 7625.43 tCO2e. Aviation emissions were estimated based on number of take-off and landings (LTO) in the city with corresponding emission factors based on aircraft type and fuel required for LTOs. Aviation emissions were 41,636.59 tCO2e for year 2017-18. Auto LPG emissions are negligible hence not shown in chart.

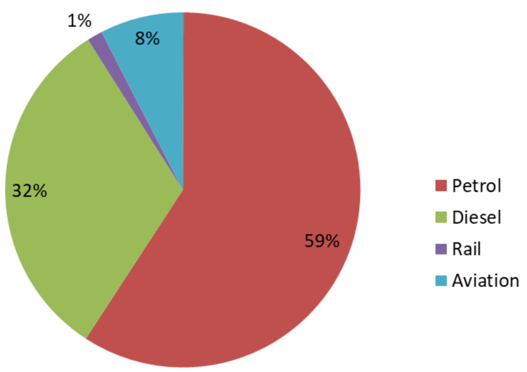


Figure 29 Share of GHG emission by fuel in the transportation sector

2.1.8.5 Solid Waste treatment at the community level

In order to estimate the GHG emissions from municipal solid waste based on the IPCC guidelines, the condition of the landfill site has been identified as wet for the analysis, considering the annual rainfall of Nagpur which is more than 1000mm. Given that the city's disposal site is not a scientific landfill, for the emission estimation, as per the IPCC guidelines the type of landfill site applicable is unmanaged disposal site, with a depth greater than 5m. Nagpur generated about 1215 tonnes per day of solid waste in 2017-18. About 200 tonnes per day of organic waste was processed in composting plant. It's a centralized composting plant located at Bhandewadi near to existing dumping ground. The remaining municipal solid waste is routed to the disposal site at Bhandewadi dumping site.

Municipal solid waste (MSW) consists of biodegradable organic matter, partially degradable matter and non-degradable materials. GHG emissions from anaerobic decomposition of bio-degradable matter present in the municipal solid waste, from treatment facilities and methane (CH_4) emissions from solid waste disposal sites are major sources of GHG emissions in the waste sector. The direct GHG emissions from solid waste can be estimated based on parameters such as the solid waste generation, its composition, type of technology used for treatment and management of the landfill site.

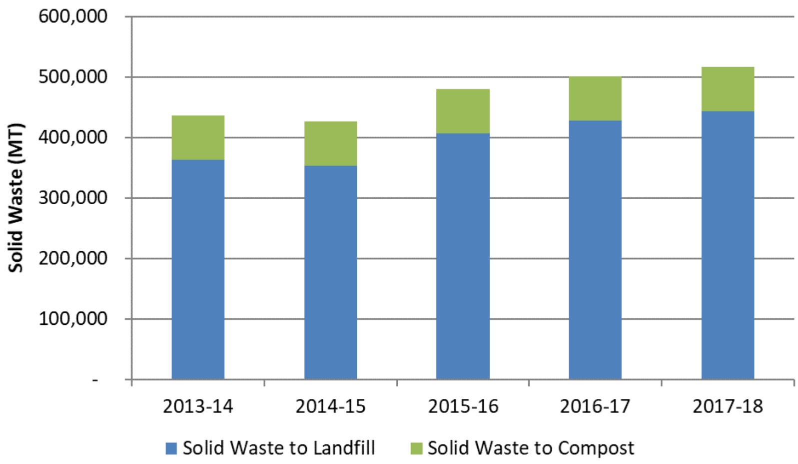


Figure 30 Trend of Generation and Processing of Solid Waste in Nagpur

The solid waste generation in the city can be seen to have a notable decline in the year 2014-15 compared to the year 2013-14 and then consistently increases. Based on a discussion with the Solid Waste Management department of NMC, the slightly higher trend in waste to landfill in 2013-14 is likely attributable to the high volumes of waste generated from cleaning and de-silting of Nag River and its surrounding areas. The solid waste generated from the project was dumped in the disposal site during the year 2013-14, thereby increasing the total solid waste generation in the city. As city's waste treatment capacity is inadequate hence landfill emissions were high and were 463565.77 tCO2e for year 2017-18. GHG emissions from composting were 12520.96 tCO2e for year 2017-18.

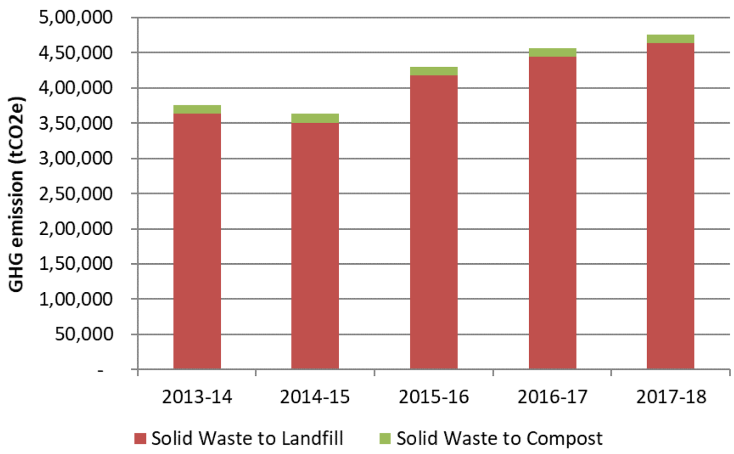


Figure 31 GHG emissions from Solid Waste Management at the community level

2.1.8.6 Domestic Waste Water management and associated emissions

Though the sewage network coverage within NMC limit is around 85%, large quantity of the collected raw wastewater is discharged into one of the rivers in Nagpur due to inadequate wastewater treatment capacity through STPs. Around 8.14% of the population is using septic tanks and about 1.2%

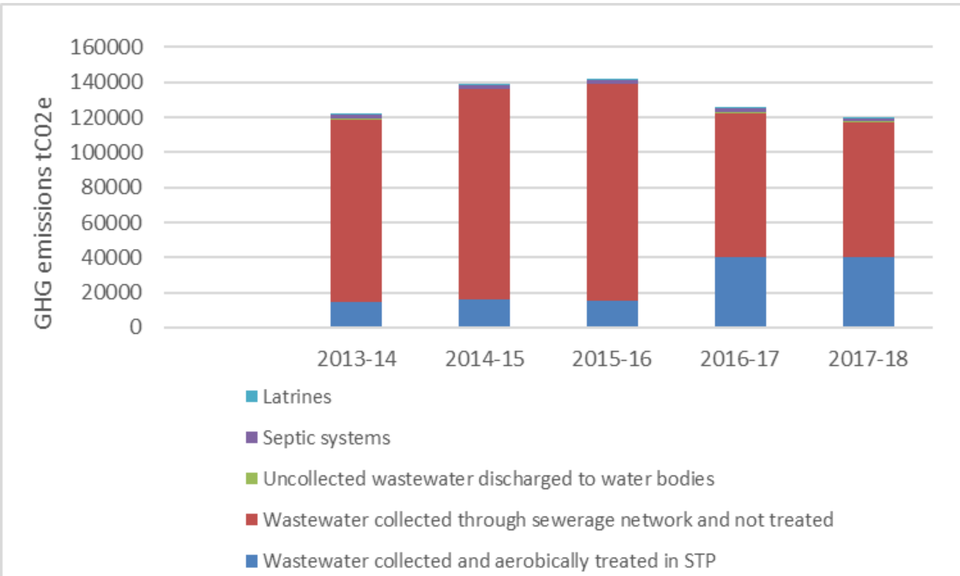
of the population is using pit latrines in the city. Based on the data from the Drainage department of NMC, the Biochemical oxygen demand (BOD)15 value of the city's wastewater is about 110 g/L.

Wastewater from domestic sources generates CH_4 emission on its treatment (on site, sewered to a centralized treatment plant or disposed of untreated into nearby areas or via an outfall) or disposal anaerobically. The extent of CH_4 emission from wastewater depends primarily on the quantity of degradable organic material in the wastewater, the volume of wastewater generated and the type of treatment system. As per 2006 IPCC Guidelines, CH_4 emissions are impacted by the type of treatment system or wastewater discharge pathway being used (such as sewers, septic tanks, latrines, centralized treatment plants, and direct discharge to sea, lake or river) and its corresponding methane generation potential, and the proportion of the resident population that uses these different wastewater treatment/discharge pathways or systems.

GHG emissions associated with waste water treatment and disposal are estimated to be 130,419 tCO_2e in 2017-18. Table 9 presents the GHG emission from different pathways for domestic wastewater treatment and disposal in Nagpur.

Table 9 GHG Emission from different pathways for Wastewater Treatment and disposal

Treatment/discharge pathway or system	GHG Emission from Domestic Wastewater (in tCO_2e)				
	2013-14	2014-15	2015-16	2016-17	2017-18
Wastewater collected and aerobically treated in STP	14,732.21	15,727.41	15,440.48	40,349.11	40,230.30
Wastewater collected through sewerage network and not treated	1,04,115.45	1,20,624.14	1,23,423.27	82,209.60	77,017.88
Uncollected wastewater discharged to water bodies	485.38	126.59	232.80	266.25	283.26
Septic systems	2,358.50	1,660.71	1,961.60	2,018.86	1,979.34
Latrines	98.10	61.39	65.71	65.85	58.56
Domestic N2O Emissions	34,784.29	35,435.41	36,093.91	36,759.97	37,433.78
Total	156,573.93	173,635.65	177,217.77	161,669.65	157,003.13



15 The primary factor in determining the CH_4 generation potential of wastewater is the amount of degradable organic material in the wastewater. BOD is a common parameter used to measure the organic component of domestic wastewater. Under the same ambient conditions, wastewater with higher BOD concentration will generally yield more CH_4 than wastewater with lower BOD concentration. The BOD concentration indicates only the amount of carbon that is aerobically biodegradable.

Figure 32 GHG Emission from different pathways for Wastewater Treatment and disposal

The emissions have risen by 2% annually from 2013-14 to 2017-18. Wastewater collected through the sewer network but not treated has the highest contribution, given that this pathway is prevalent due to extensive sewerage network but limited treatment capacity. Emissions from aerobic treatment of wastewater in STPs have the second highest contribution.

In addition, N_2O emission occurs from the degradation of the nitrogen present in domestic wastewater, which mainly results from human protein consumption. The degradation of nitrogen occurs on the disposal of domestic wastewater into waterways, lakes or sea. N_2O emissions from domestic wastewater in Nagpur are estimated to amount to 37,433.78 tCO_2e in 2017-18. The N_2O emissions have increased with rise in population from 2013-14 to 2017-18.

Thereby total GHG emissions, including CH_4 and N_2O emissions, from domestic wastewater in Nagpur city stood at 1,57,003.13 tCO_2e in 2017-18.

2.1.9 Emissions from Municipal operations and facilities

2.1.9.1 Sector wise Energy Consumption and GHG Emissions from Municipal Buildings and Facilities

NMC's energy consumption for its municipal services rendered to the city residents amounted to 643,455 GJ in 2017-18. Table 10 presents the energy consumption data of municipal buildings, services provided and transport.

Table 10 Trend of Energy Use at local government level for municipal buildings and services

Sector	Service	Energy Consumption (GJ)				
		2013-14	2014-15	2015-16	2016-17	2017-18
Buildings		6,746.8	6,973.8	7,042.1	7,503.4	9,110.0
Facilities	Waste Water Treatment	13,547.1	12,420.2	18,072.3	51,649.1	58,139.4
	Water Supply	352,865.5	361,016.6	384,344.8	367,910.8	351,626.8
	Street Lighting	166,068.0	172,260.0	193,788.0	197,244.0	193,212.0
Transport		27,037.4	26,463.9	27,629.4	29,934.1	31,367.0
Total		566,264.8	579,134.5	630,876.5	654,241.3	643,455.2

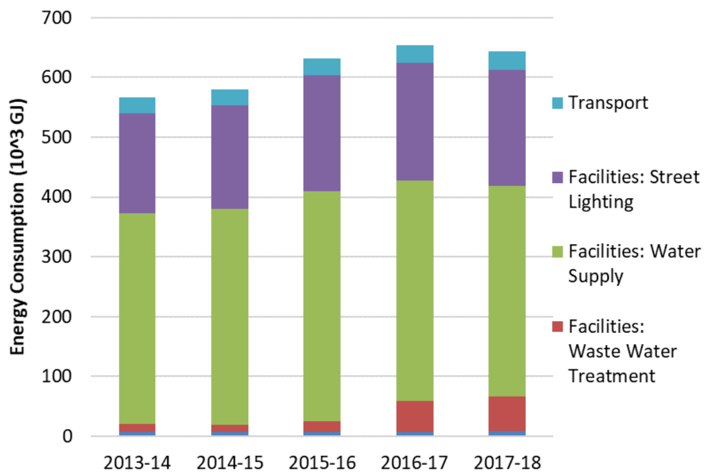


Figure 33 Trend of energy use by municipal buildings and services

From Figure 33 it can be noted that the total energy consumption of the city government increases until the year 2015-16 and then witnesses a decline. This is because diesel generators sets are not used often anymore for the water/wastewater facilities due to less frequent occurrence of power shutdowns. Also, the electricity consumption for water supply has reduced in the recent years (refer to Section 2.1.9.2).

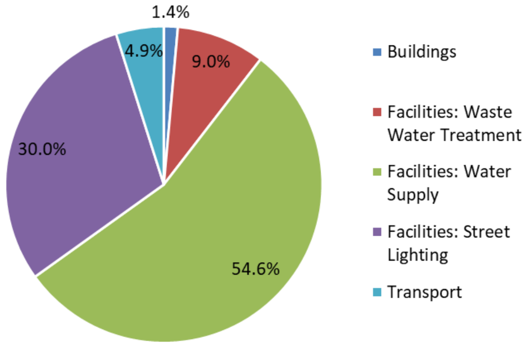


Figure 34 Sector-wise share of Energy Consumption in Municipal Buildings and Services, 2017-18

The major share of the energy consumed by the municipal government is for the water supply service. From Figure 34 it is evident that Water supply alone contributes to 54.6% of the municipal government's energy use. This could be due to the operation of energy intensive water pumps to transport water against heads for supply and storage. Water supply service is followed by street lighting which contributes about 30%, and wastewater treatment facilities having a share of 9% in the local government's total energy consumption. Mobile transportation of municipal vehicles consumes about 5% of energy.

The total GHG emissions from local government operations was estimated to be 142,201.8 tCO_2e in 2017-18. Table 11 gives the GHG emission contribution from each municipal service/facility in Nagpur.

Table 11 Trend of GHG emission (tCO_2e) per year for Local Government Operations (Buildings, Facilities, and Transport)

Sector	Service	GHG Emissions (tCO_2e)				
		2013-14	2014-15	2015-16	2016-17	2017-18
Buildings		1,542.0	1,585.2	1,601.1	1,701.2	2,069.0
Facilities:	Waste Water Treatment	3,096.2	2,838.7	4,130.4	11,804.5	13,287.8
	Water Supply	80,647.8	82,510.8	87,842.5	84,086.4	80,364.7
	Street Lighting	37,955.0	39,370.2	44,290.5	45,080.4	44,158.8
Transport		1,999.5	1,958.0	2,043.8	2,215.0	2,321.4
Total		125,240.6	128,262.8	139,908.2	144,887.4	142,201.8

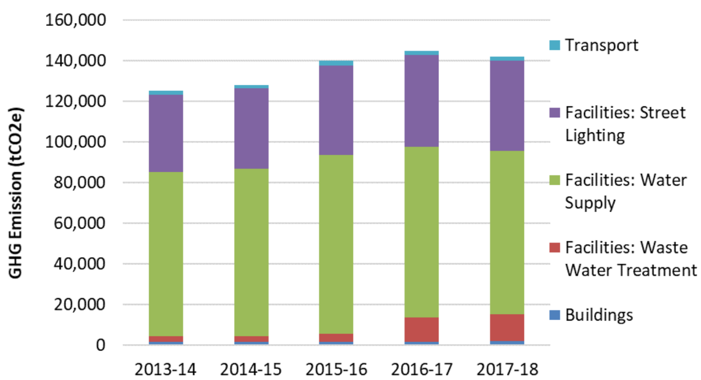


Figure 35 Trend of GHG emission (tCO_2e) for Municipal Buildings, Facilities, and Transport

Water supply and Street lighting are major contributors to emissions as evident from being the major energy consuming services. As stated earlier, the reduction in electricity consumption for water supply service has had a significant impact on the energy consumption in total and subsequently the GHG emissions associated with it (Refer to Figure 33 and Figure 35).

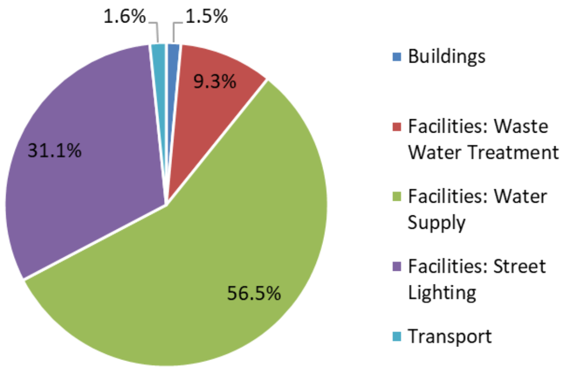


Figure 36 Sector wise Share in GHG emission by Municipal Buildings, Facilities, and Transport, 2017-18

2.1.9.2 Electricity Consumption by Municipal Buildings and Facilities

NMC consumes grid electricity for providing municipal services like water supply, street lighting etc. and its annual electricity consumption was reported to be 170 million kWh in 2017-18. Figure 37 represents the trend of electricity consumption by the local government with respect to different services and facilities it provides to the city population.

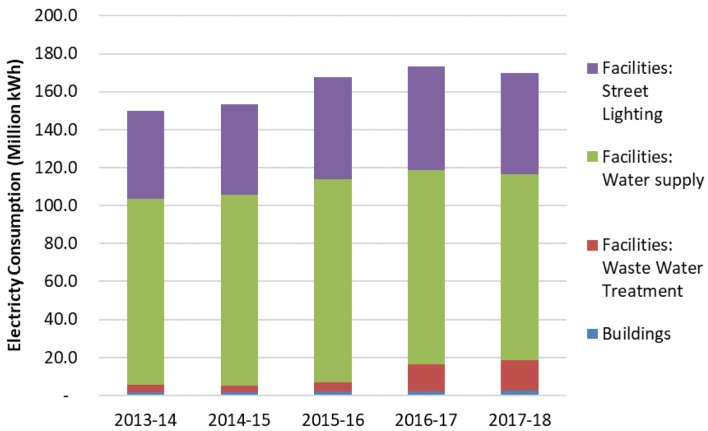


Figure 37 Trend of Electricity consumption by Municipal services

As can be seen from the figure, the trend of electricity consumption by NMC after 2015-16 is declining. This is due to the various efforts taken by the local government towards slope maintenance in its water supply infrastructure, the predominant power consuming service, which reduced the consumption of electricity in lifting water against heads.

Water is now supplied directly to households instead of being stored in elevated service reservoirs (water tanks) for local distribution of water. This led to the reduction in electricity consumption for pumping in the water supply network. Also, NMC has launched 24*7 water supply project which ensures a controlled and consistent supply of water. The project has been implemented in pilot areas and has helped to achieve positive results in terms of accountability of water usage. Implementation of Supervisory Control and Data Acquisition (SCADA) systems which continuously monitor the water distribution network in the city has helped realize reductions in water losses.

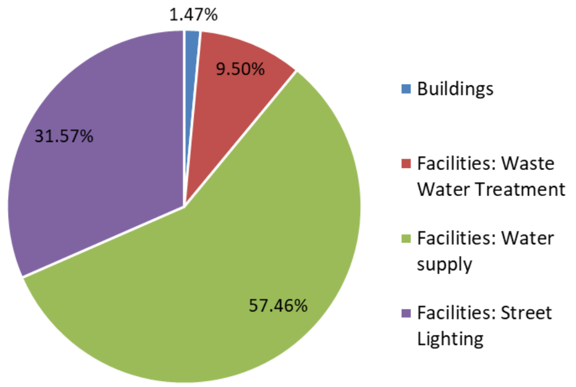


Figure 38 Sector wise Share of Electricity Consumption in Municipal Buildings and Facilities, 2017-18

Figure 38 clearly shows that the electricity consumed by the water supply service is significantly higher than other municipal services that consume electricity. Electricity consumption in street lighting is also significant, with a share of about 31.6% in 2017-18.

2.1.10 Key Sustainability indicators for Nagpur City

Sustainability Indicator	Unit of Measure	Nagpur (2017 -18)
Energy consumption per capita	GJ/capita	7.09
GHG emission per capita	tCO_2e/capita	1.13
Energy consumption per household	GJ/HH	32.31
GHG emission per household	tCO_2e/HH	5.15
Energy consumption per unit area	GJ/sq. km	83,748.20
GHG emission per unit area	tCO_2e/sq. km	13,344.28

3 GHG emissions inventory summary reporting output

City Information		Data Source
Official name of local government	Nagpur Municipal Corporation	N/A
Country	India	N/A
Region	South Asia	N/A
Inventory year (specify months covered)	April 2017 to March 2018	N/A
Description of boundary and map	City boundary representing jurisdiction of Nagpur Municipal Corporation (local government)	
Resident population	2,405,665	Population statistics for 2011 from National Census of India, 2011

Inventory Setup	
GWP (IPCC AR version used)	Fourth Assessment Report, 2007
Types of emissions factors (IPCC or LCA)	IPCC

Emission Sources and Emissions																			
Sector	Sub-Sector	*Direct (fuel combustion) or Indirect (grid energy) or Other (in separate rows)*	Total tCO_2e or Notation Key	ETS or non-ETS (in separate rows)	Type of Energy	Activity data			Emissions (CO_2 Gas)			Emissions (CH4 Gas)			Emissions (N20 Gas)			Notation keys (if no data to report)	
						Amount	Unit	Data source	Amount	Unit	Method	Amount	Unit	Method	Amount	Unit	Method	Notation key	Explanation
Stationary Energy	Residential	Indirect	895,757	-	Electricity	1,089	Million kWh	Electricity supplier	892,726	tonnes of CO_2e	Location-based using consumption and national grid emission factor	217.74	tonnes of CO_2e	Location-based using consumption and national grid emission factor	2,813.55	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	9,132	-	Kerosene	3,540	kiloliters	Public fuel distribution office	9,100	tonnes of CO_2e	Fuel consumption	9.49	tonnes of CO_2e	Fuel consumption	22.63	tonnes of CO_2e	Fuel consumption		
		Direct	256,563	-	LPG	85,867	tonnes	Fuel/Oil supply companies	256,340	tonnes of CO_2e	Fuel consumption	101.56	tonnes of CO_2e	Fuel consumption	121.06	tonnes of CO_2e	Fuel consumption		
	Commercial	Indirect	518,991	-	Electricity	631	Million kWh	Electricity supplier	517,235	tonnes of CO_2e	Location-based using consumption and national grid emission factor	126.15	tonnes of CO_2e	Location-based using consumption and national grid emission factor	1,630.14	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	37,131	-	LPG	12,427	tonnes	Fuel/Oil supply companies	37,098	tonnes of CO_2e	Fuel consumption	14.70	tonnes of CO_2e	Fuel consumption	17.52	tonnes of CO_2e	Fuel consumption		
	Institutional	Indirect	IE	-														IE	Included under Commercial sector as no disaggregated data for this sub-sector
		Direct	IE	-														IE	Included under Commercial sector as no disaggregated data for this sub-sector
	Industry	Indirect	83,471	-	Electricity	101	Million kWh	Electricity supplier	83,189	tonnes of CO_2e	Location-based using consumption and national grid emission factor	20.29	tonnes of CO_2e	Location-based using consumption and national grid emission factor	262.18	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	542	-	Furnace Oil	181	kiloliters	Fuel/Oil supply companies	540	tonnes of CO_2e	Fuel consumption	0.52	tonnes of CO_2e	Fuel consumption	1.25	tonnes of CO_2e	Fuel consumption		
		Direct	1,027	-	Petrol	447	kiloliters	Fuel/Oil supply companies	1,023	tonnes of CO_2e	Fuel consumption	1.11	tonnes of CO_2e	Fuel consumption	2.64	tonnes of CO_2e	Fuel consumption		
		Direct	45,618	-	Diesel	15,998	kiloliters	Fuel/Oil supply companies	45,462	tonnes of CO_2e	Fuel consumption	46.01	tonnes of CO_2e	Fuel consumption	109.70	tonnes of CO_2e	Fuel consumption		
		Direct	1,557	-	Diesel Oil (light)	546	kiloliters	Fuel/Oil supply companies	1,552	tonnes of CO_2e	Fuel consumption	1.57	tonnes of CO_2e	Fuel consumption	3.74	tonnes of CO_2e	Fuel consumption		
		Direct	1,067	-	LPG	357	tonnes	Fuel/Oil supply companies	1,066	tonnes of CO_2e	Fuel consumption	0.42	tonnes of CO_2e	Fuel consumption	0.50	tonnes of CO_2e	Fuel consumption		

Emission Sources and Emissions

Sector	Sub-Sector	*Direct (fuel combustion) or Indirect (grid energy) or Other (in separate rows)*	Total tCO_2e or Notation Key	ETS or non-ETS (in separate rows)	Type of Energy	Activity data			Emissions (CO_2 Gas)			Emissions (CH4 Gas)			Emissions (N20 Gas)			Notation keys (if no data to report)	
						Amount	Unit	Data source	Amount	Unit	Method	Amount	Unit	Method	Amount	Unit	Method	Notation key	Explanation
	Agriculture	Indirect	609	-	Electricity	1	Million kWh	Electricity supplier	607	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0.15	tonnes of CO_2e	Location-based using consumption and national grid emission factor	1.91	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	Agriculture activity is limited and no fuel use occuring within city limits.
	Fugitive	Direct	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	Activities such as coal and oil extraction & processing leading to fugitive emissions are not occuring within the city limits
Transportation	On-road	Indirect	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No electric transport within the city, hence no significant indirect emissions.
		Direct	388	-	Auto-LPG	257	kiloliters	Fuel/Oil supply companies	388	tonnes of CO_2e	Fuel Sales method	0.15	tonnes of CO_2e	Fuel Sales method	0.18	tonnes of CO_2e	Fuel Sales method		
		Direct	325,128	-	Petrol	141,523	kiloliters	Fuel/Oil supply companies	323,942	tonnes of CO_2e	Fuel Sales method	350.59	tonnes of CO_2e	Fuel Sales method	835.80	tonnes of CO_2e	Fuel Sales method		
		Direct	175,157	-	Diesel	61,427	kiloliters	Fuel/Oil supply companies	174,559	tonnes of CO_2e	Fuel Sales method	176.68	tonnes of CO_2e	Fuel Sales method	421.20	tonnes of CO_2e	Fuel Sales method		
	Rail	Indirect	4,829	-	Electricity	417,032,064	passenger-km	City Development Plan, Mobility Plan, Indian Railways office	4,829	tonnes of CO_2e	Passenger-km basis	-		Passenger-km basis	-		Passenger-km basis		
		Direct	2,796	-	Fuel (Diesel)	417,032,064	passenger-km	City Development Plan, Mobility Plan, Indian Railways office	2,796	tonnes of CO_2e	Passenger-km basis	-		Passenger-km basis	-		Passenger-km basis		
	Waterborne	Indirect	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No water transport within the city
		Direct	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No water transport within the city
	Aviation	Indirect	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	Aviation modes are not using electricity for the journeys. Electricity consumption in Aviation buildings is included in Commercial buildings
		Direct	41,637	-		16,879	No. of landings and take-offs	Airport Authority of India statistics	41,123	tonnes of CO_2e	Landing & Take-off Emissions	29.39	tonnes of CO_2e	Landing & Take-off Emissions	484.50	tonnes of CO_2e	Landing & Take-off Emissions		
	Off-road	Indirect	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	Electricity consumption for off-road transport is not occurring as these are using conventional combustion engines
		Direct	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	IE	Emissions are included in On-road transport, due to unavailability of reliable disaggregated fuel consumption data for off-road vehicles.
Waste	Solid waste disposal	Direct	463,566	N/A	N/A	443,430	tonnes of waste	Solid Waste Department, Nagpur Municipal Corporation	-	tonnes of CO_2e	Methane Commitment method	463,565.78	tonnes of CO_2e	Methane Commitment method	-	tonnes of CO_2e	Methane Commitment method		

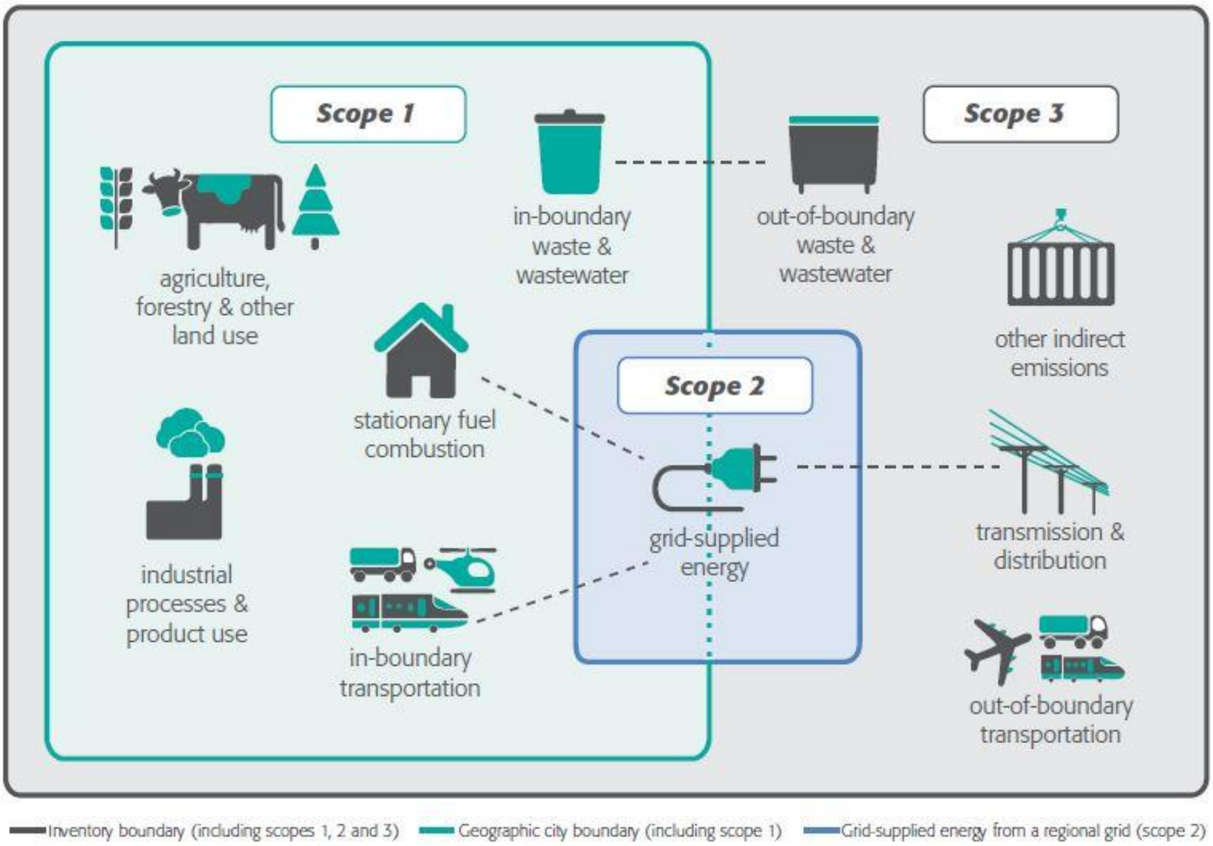
Emission Sources and Emissions																			
Sector	**Sub-Sector**	***Direct (fuel combustion) or Indirect (grid energy) or Other (in separate rows)***	**Total tCO_2e or Notation Key**	**ETS or non-ETS (in separate rows)**	**Type of Energy**	**Activity data**			**Emissions (CO_2 Gas)**			**Emissions (CH4 Gas)**			**Emissions (N20 Gas)**			**Notation keys (if no data to report)**	
						Amount	**Unit**	**Data source**	**Amount**	**Unit**	**Method**	**Amount**	**Unit**	**Method**	**Amount**	**Unit**	**Method**	**Notation key**	**Explanation**
	Biological treatment	Direct	12,521	N/A	N/A	73,000	tonnes of waste	Solid Waste Department, Nagpur Municipal Corporation	-	tonnes of CO_2e	Amount of waste composted	7,300.00	tonnes of CO_2e	Amount of waste composted	5,220.96	tonnes of CO_2e	Amount of waste composted		
	Incineration and open burning	Direct	NO	N/A	N/A	-	-	-	-	-	-	-	-	-	-	-	-		
	Wastewater	Direct	157,003	N/A	N/A	25,886	tonnes of organics	Sewerage Department, Nagpur Municipal Corporation	-	tonnes of CO_2e	Organic content based and population-based approach	119,569.35	tonnes of CO_2e	Organic content based and population-based approach	37,433.78	tonnes of CO_2e	Organic content based and population-based approach		
IPPU	Industrial process	Direct	NE	N/A	N/A													NE	Not estimated due to absence of data
	Product use	Direct	NE	N/A	N/A													NE	Not estimated due to absence of data
AFOLU	Livestock	Direct	NE	N/A	N/A													NE	Not estimated due to absence of data
	Land use	Direct	NE	N/A	N/A													NE	Not estimated due to absence of data
	Other AFOLU	Direct	NE	N/A	N/A													NE	Not estimated due to absence of data

Energy Generation																		
Sector	**Inside or outside city boundary (in separate rows)**	**Total tCO2e**	**ETS or non-ETS (in separate rows)**	**Type of Energy**	**Activity data**			**Emissions (CO2 Gas)**			**Emissions (CH4 Gas)**			**Emissions (N20 Gas)**			**Notation keys (if no data to report)**	
					Amount	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**	**Notation key**	**Explanation**
Electricity-only generation	Inside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No power generating facilities within the city boundary
	Outside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No power generating facilities within the city boundary
CHP generation	Inside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No grid supplied CHP within city limits
	Outside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No grid supplied CHP within city limits
Heat/cold generation	Inside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No heating or cooling networks exists
	Outside city boundary	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NO	No heating or cooling networks exists
Local renewable energy generation	N/A	NE	-	-	-	-	-	-	-	-	-	-	-	-	-	-	NE	Reliable information on activity data not available

Emission Credits																	
Category	**Sold or purchased**	**Total tC2Oe or Notation Key**	**Allocation to sector**	**Sub-category**	**Date of sale/ purchase**	**Activity data**			**Emissions (CO2 Gas)**			**Emissions (CH4 Gas)**			**Emissions (N20 Gas)**		
						Amount	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**	**Amount**	**Unit**	**Data source**
Offset credits generated in the city	*Sold*	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Credits purchased from outside	*Purchased*	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Purchase of certified green electricity	*Purchased*	NO	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Appendix

Figure 39 Sources and Boundaries of city GHG Emissions16



16 Global Protocol for Community-Scale GHG Emission Inventories. Available at *https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities*