URBAN LEDS
URBAN LOW EMISSION DEVELOPMENT STRATEGIES

Rajshahi City, Bangladesh

Greenhouse Gas Emission Inventory Report 2017-18

Supported by

Jointly Implemented by

ICLEI Local Governments for Sustainability

UN-HABITAT FOR A BETTER URBAN FUTURE

Title: Rajshahi City, Bangladesh - GHG Emission Inventory Report 2017-18

Version 2.0 (March, 2021)

This document is prepared by: ICLEI - Local Governments for Sustainability- South Asia Secretariat under the "Accelerating climate action through the promotion of Urban Low Emission Development Strategies (Urban LEDS II) project with support from UN-Habitat and ICLEI - Local Governments for Sustainability – World Secretariat and funded by the European Commission.

Contributing Team from ICLEI South Asia:
Jubaer Rashid, Abdullah Kafy, Prateek Mishra, Bhaskar Padigala, Nikhil Kolsepatil, Soumya Chaturvedula

Acknowledgements:
The project team wishes to thank officials of Rajshahi City Municipal Corporation and all other government departments and stakeholders from the city and district for their support and contribution to the data collection and successful compilation of the document.

Contact:
ICLEI South Asia
C-3, Lower Ground Floor, Green Park Extension
New Delhi - 110016, India
iclei-southasia@iclei.org
http://southasia.iclei.org/

Contents

List of Figures

List of Tables

1 CITY PROFILE

The metropolitan city of Rajshahi is located on the bank of River Padma and is a key administrative division of Bangladesh. Rajshahi is a centre of excellence for education with a large number of educational institutions and is often called the Education City of Bangladesh. The city has one of largest universities of Bangladesh – University of Rajshahi, and also has Rajshahi University of Engineering and Technology, and Rajshahi Medical College. Divisional headquarters of various public departments are located in Rajshahi. Rajshahi city is also famous for its silk and mentioned as the Silk City. The city has taken notable efforts to reduce air pollution and is known as a Green and Clean City.

1.1 Location

Geographically Rajshahi is located within Barind Tract, 23 meters above the mean sea level. The city is located on the alluvial planes of River Padma, which flows through the southern side of the city. Rajshahi city is situated on the north bank of the River Padma, near the Bangladesh-India border, bound by Paba Upazila on all three sides. The city's area is 97.18 sq. km. and located between 24'20' and 24'24' north latitudes and in between 88'32' and 88'40' East longitudes. The city is well connected to the capital city of Dhaka, which lies at a distance of 256 km.

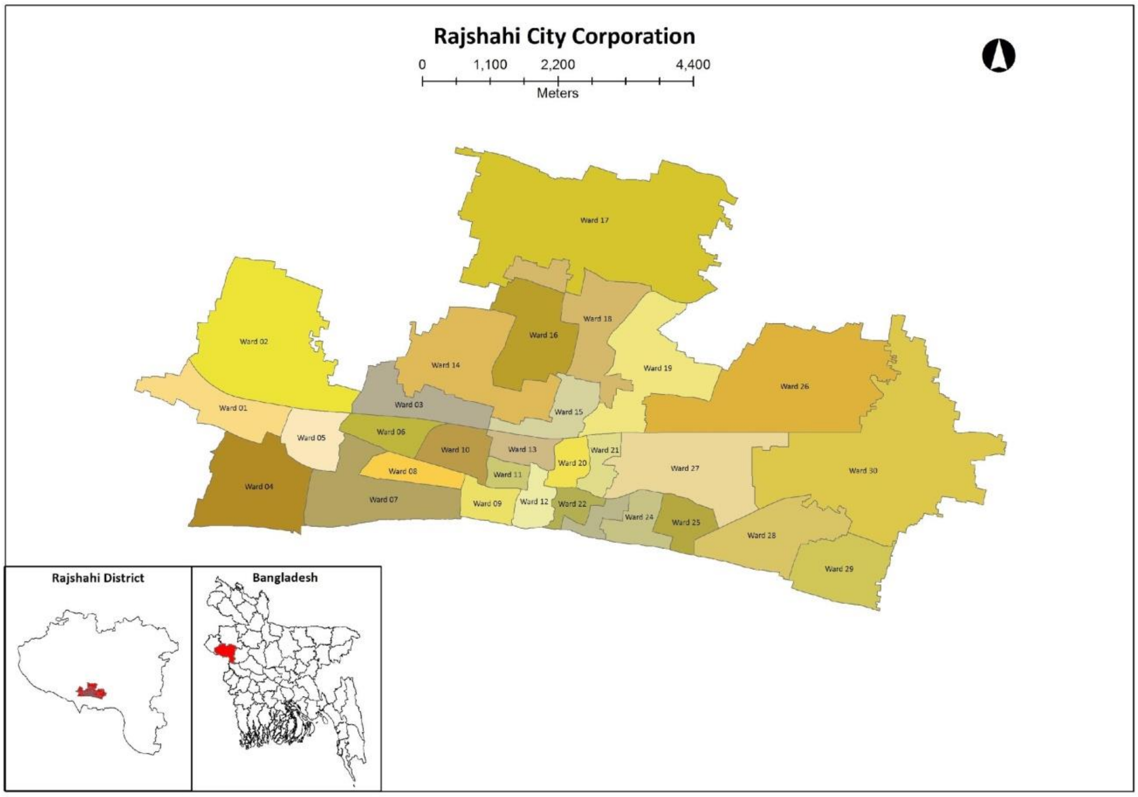


Figure 1: Location of Rajshahi City

1.2 Connectivity

Rajshahi is well connected by air, rail and road. There is a domestic airport named Shah Makhdum Airport located at Nowhata, 10 km away from the city. Domestic flights to and from Dhaka operate through this airport.

Rajshahi is well connected to the capital city of Dhaka and other cities in Bangladesh. The city has a central railway station and bus terminal as well. District buses and trains are also available from the city. Recently a direct and non-stop train service – Banalata Express has been launched and operates between Rajshahi and Dhaka. The Banalata Express train takes 4 hours to reach Dhaka from Rajshahi.

Though there is a river in Rajshahi, it does not play a significant role in transportation purpose, due to lack of navigability. The city's road and rail network is shown in Figure 2.

Figure 2: Road and Rail Network of Rajshahi

1.3 Demography

According to Bangladesh Bureau of Statistics (BBS) population census 2011, the population of Rajshahi City Corporation was 448,087 made up of 231,700 males and 216,387 females. The total number of households was 99,097. The density of population was 2,487 persons/sq. km. The population is distributed among 30 wards. Table 1 represents the ward wise population of Rajshahi City Corporation and the population density. The city's literacy rate is 73.96%.

Table 1: Ward-wise Area and Population of Rajshahi City Corporation, 2011

Ward No.	Area of Ward (Sq. km.)	Total Population	No. of Households	Population Density (Persons/sq. km.)
1	2.46	16032	3361	6517
2	7.62	17823	4134	2339
3	2.06	20132	4719	9773
4	4.11	13238	3109	3221
5	1.55	14128	3252	9115
6	1.32	15256	3456	11558
7	3.72	12942	2311	3479
8	1.07	11011	2227	10291
9	0.95	14232	2671	14981
10	1.44	11057	1986	3622
11	0.54	12294	2264	22767
12	0.91	11349	2107	12471
13	0.94	9845	2218	10473
14	4.82	22070	5122	2289
15	1.51	13700	3369	9073
16	3.20	16610	3775	5191
17	15.02	19951	4730	1328
18	2.75	14547	3516	3328
19	4.36	22929	5482	5259
20	0.81	7857	1725	9700
21	0.84	9927	2274	11818
22	0.68	8414	1855	12374
23	0.97	8654	2064	8922
24	0.65	14513	3489	22328
25	1.25	12752	2912	10202
26	8.73	18586	4346	2129
27	5.01	17856	4249	3564
28	3.37	21697	4990	6438
29	2.86	14239	3150	4979
30	11.66	26236	4234	2250
Total	97.18	449877	99097	241779

Land use data has been sourced from the land use survey conducted by Rajshahi Development Authority (RDA) in 2003 under the Structure Plan, Master Plan and Detailed Area Development Plans for Rajshahi Metropolitan City. Percentages of major land use for Rajshahi City Corporation area are – residential 33.46%, water bodies including river, pond, ditch 10.78%, agriculture 18.74%, vacant land 11.09%, roads 5.62%, educational and research land use covers 10.50%, industry and storage together comprise 0.81%, business and mercantile constitute 1.98% as seen in Figure 3[1].

[1] Source: Rajshahi Development Authority (RDA), 2003

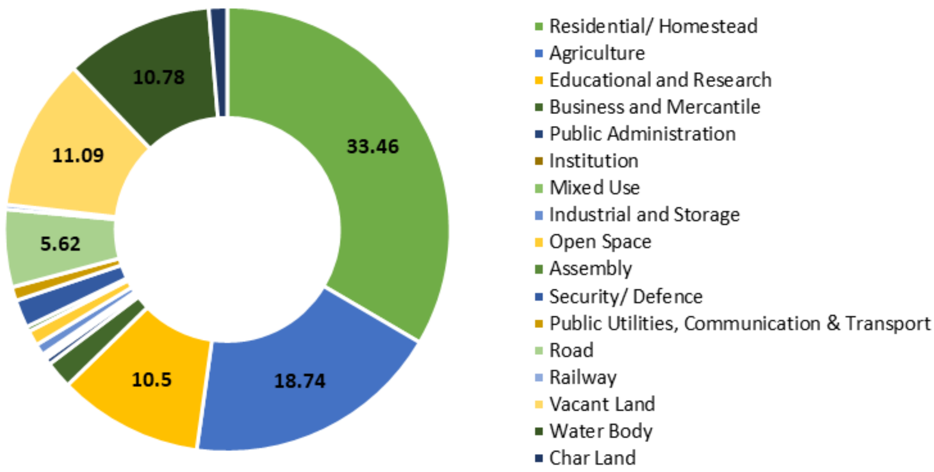


Figure 3: Land Use distribution in RCC Area

1.4 Economic Activities

A significant portion of the city's population engaged in the public and semi-public sector, banking, education, trading, and business. Rajshahi and its neighbouring regions are well suited to various crops such as mangoes, litchis, sugarcane, tomatoes and watermelons. In spite of being an important city and located on a riverbank, industrial development is limited. There is an industrial park under Bangladesh Small and Cottage Industries Cooperation (BSCIC) in Rajshahi, which mainly houses industries producing products of the famous Rajshahi silk. The head office of the regulatory board for sericulture, Bangladesh Sericulture Development Board, is based in the city. The city houses silk based factories, handcraft and boutique industries, food and fruits processing industries.

1.5 Local Government Bodies

Rajshahi was a municipality previously and was declared as a municipal corporation in 1991. Besides the City Corporation, the Rajshahi Development Authority (RDA) is responsible for planning and coordinates of all the development related work in the greater Rajshahi. The Rajshahi Water Supply and Sewerage Authority (WASA) is responsible planning and management of the water supply, sewerage and drainage system within the city area.

The Rajshahi City Corporation is under the Ministry of Local Government, Rural Development and Co-operatives. RCC is headed by a Chief Executive Officer (CEO) and who is the administrative head of the City Corporation and is responsible for the functioning of the corporation including tax collection, estates maintenance, projects, among others. The position of the CEO is an administrative cadre service post and appointed by the central government.

The political wing consists of an elected body headed by the Mayor and comprised of 30 Councilors. The Rajshahi City Corporation provides and maintains services which include water purification and supply, sewage treatment and disposal, garbage disposal and street cleanliness, solid waste management, building and maintenance of roads and streets, street lighting, maintenance of parks and open spaces, cemeteries and crematoriums, registering of births and deaths, conservation of heritage sites, disease control including immunization, and public corporation schools etc. The current organogram of RCC is depicted in Figure 4.

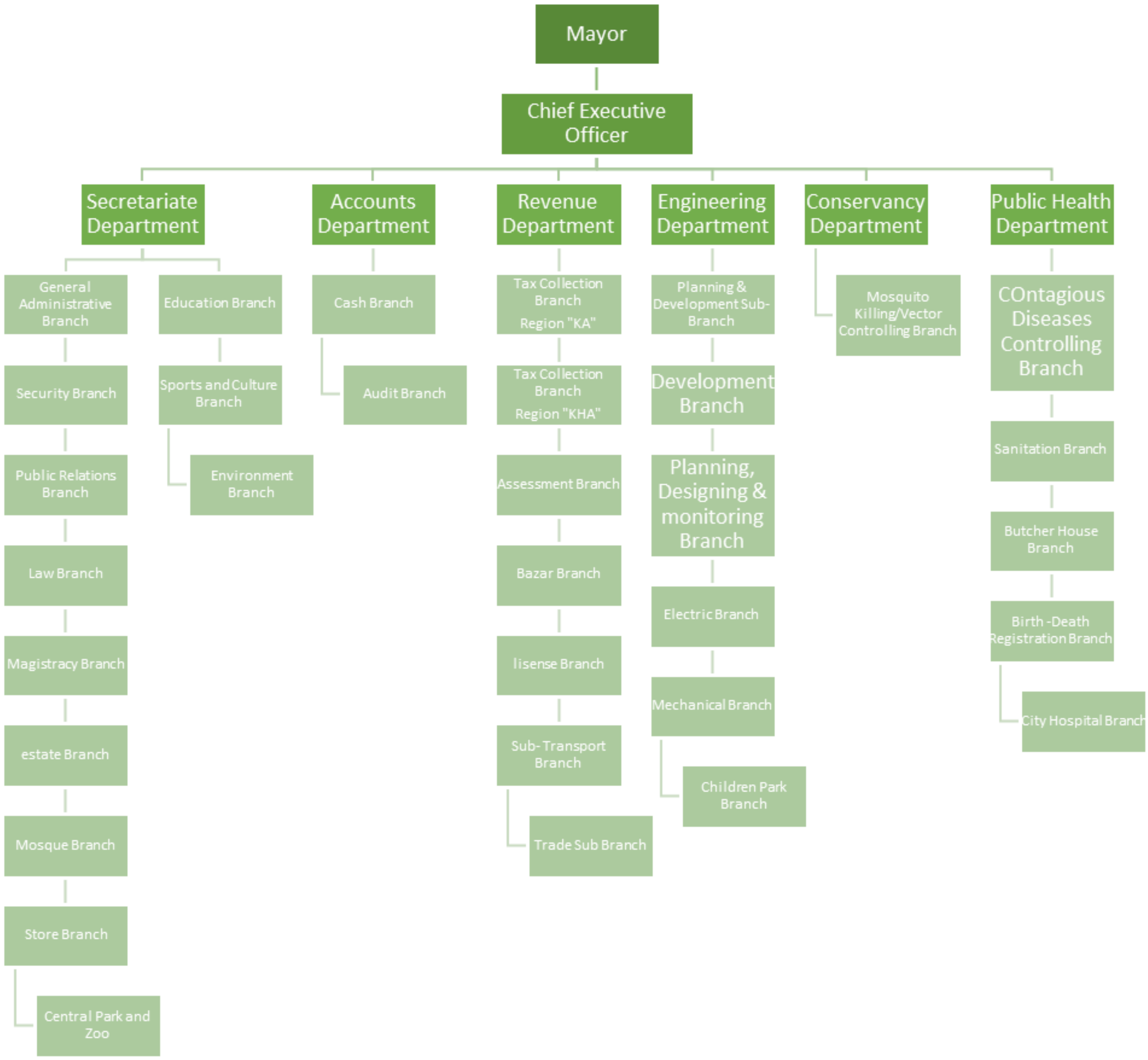


Figure 4: Rajshahi City Corporation Organogram

Other than the city corporation list of agencies involved in different development and planning schemes are:

a) **Rajshahi Development Authority** – responsible for preparing the city master plan, and other development policies.
b) **Rajshahi Water Supply & Sewerage Authority** – responsible for water supply & sewerage within the city corporation area
c) **Department of Public Health Engineering** – responsible for conducting surveys to find out the water contamination level of chemicals like arsenic and the relevant solutions for the same.
d) **Public Works Department** – Construction agency of Government of Bangladesh (GoB) responsible for the implementation of government construction projects. It also undertakes projects for autonomous bodies as deposit works.
e) **Department of Agricultural Extension** – promotes subsidy for the betterment of farmers, distributes fertilizer to the poor farmers, and often arranges training for farmers on modern techniques of cultivation.

f) **Forest Department** – responsible for forest extension, biodiversity and wildlife conservation.
g) **Roads & Highways Department** – responsible for the construction and maintenance of major regional roads and bridge networks.
h) **Water Development Board** – responsible for flood control, drainage and irrigation activities as well as to enhance water resource management.
i) **Power Development Board** – provide electricity to the residents, commerce and industrial establishment on the basis of their priority and capacity.

2 Baseline Assessment

2.1 GHG Emission Inventory

Rajshahi 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 a 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 Rajshahi City Corporation (RCC).

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 Table 2 below.

Table 2: 100 Year GWPs of the GHGs with respect to CO2

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 Rajshahi'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 RCC 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 3.

Table 3: Sources of the data used for GHG emission calculation

Fuel Type	Sector	Source of Data
Electricity	Residential	Northern Electricity Supply Company Limited (NESCO)
	Commercial/Institutional	Northern Electricity Supply Company Limited (NESCO)
	Manufacturing Industry and Construction	Northern Electricity Supply Company Limited (NESCO)
	Waterworks department – Water Supply	Rajshahi Water Supply and Sewerage Authority (RWASA)
	Street lights	NESCO

Diesel	Community Transport	Jamuna- Rajshahi; Meghna- Rajshahi
	Municipal Vehicles	Rajshahi City Corporation (RCC)
Petrol	Community Transport	Jamuna- Rajshahi; Meghna- Rajshahi
	Municipal Vehicles	Rajshahi City Corporation (RCC)
LPG	Residential	Jamuna- Rajshahi; Meghna- Rajshahi
	Commercial/Institutional	Jamuna- Rajshahi; Meghna- Rajshahi
Kerosene	Residential	Jamuna- Rajshahi; Meghna- Rajshahi
PNG	Residential	Pashchimanchal Gas Company Limited (PGCL)
	Commercial/Institutional	Pashchimanchal Gas Company Limited (PGCL)
	Manufacturing Industry and Construction	Pashchimanchal Gas Company Limited (PGCL)
Furnace Oil	Manufacturing Industry and Construction	Meghna- Rajshahi
Octane	Manufacturing Industry and Construction	Jamuna- Rajshahi; Meghna- Rajshahi
	Municipal Vehicles	Rajshahi City Corporation
Transport Sector		Rajshahi City Corporation
Solid Waste Management		Conservancy Department, RCC
Municipal Water Supply		Rajshahi Water Supply and Sewerage Authority (RWASA)
Municipal Street Lighting		Electrical Department- RCC

2.1.4 Economy-wide Trend of Energy Consumption and GHG Emissions

Economy-wide analysis of the data collected for GHG emissions inventory helped in determining the average growth or decline in energy consumption and GHG emissions from different sectors. Table 4 represents information on energy use by different sectors of Rajshahi city between the years 2013-14 and 2017-18. During the baseline year 2017-18, Rajshahi's total energy consumption stood at 5.92 Million Gigajoule (GJ), nearly double the energy consumption of 3.1 Million GJ in 2013-14.

Table 4: Sector-wise Energy Consumption

Sector	**Energy Consumption (GJ)**				
	2013-14	2014-15	2015-16	2016-17	2017-18
Residential Buildings	783,506	1,157,815	1,482,551	1,479,094	1,474,906
Commercial and Institutional buildings/facilities	160,533	167,105	207,472	226,554	201,818
Manufacturing Industries and Construction	614,332	930,358	972,103	1,758,391	2,095,008
Agriculture, forestry and fishing activities	1,080	1,260	1,260	1,224	1,080
Transport	1,548,138	1,485,395	1,715,404	1,907,828	2,151,409
Total	**3,107,589**	**3,741,932**	**4,378,790**	**5,373,091**	**5,924,222**

From Figure 5, it is evident that the total energy use by the city has increased significantly between the years 2013-14 and 2017-18 and at an annual average growth rate of 18.1%. Among the sectors, the average annual growth rate was observed to be the highest in the industrial sector at 48.2%, followed by the residential sector at 17.6%.

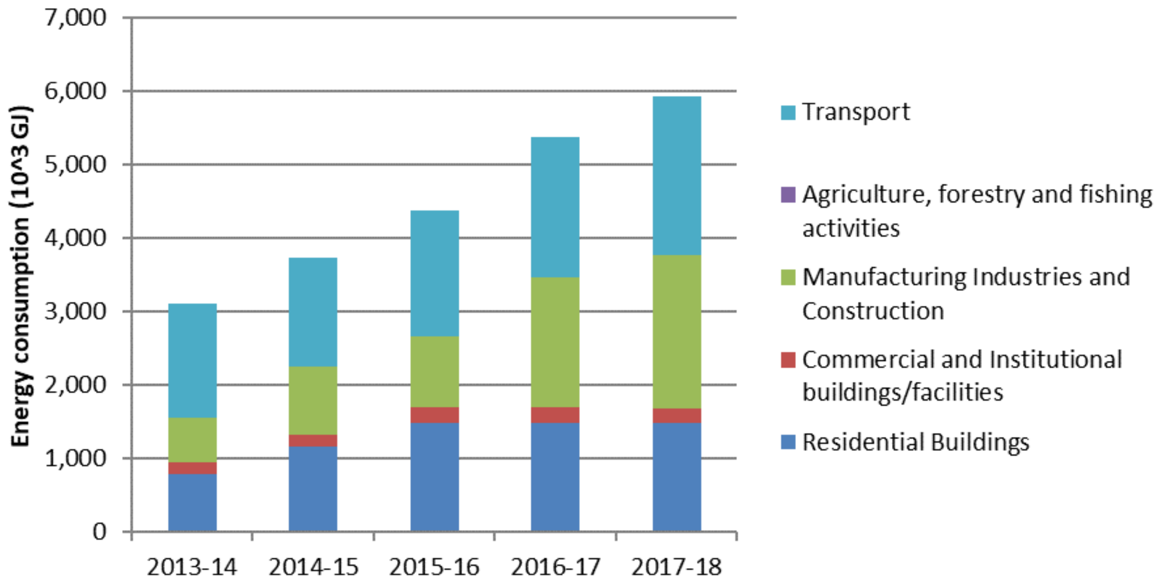


Figure 5: Trend of Energy Consumption from 2013-14 to 2017-18

The overall GHG emissions contribution from various sectors across the city's community is exhibited in Table 5 below. The total GHG emission for Rajshahi city in the year 2017-18 stood at 630,290 tonnes of CO_2 equivalent (tCO_2e), which translates to a per capita emission of 1.27 tCO_2e.

Table 5: Sector-wise GHG Emission

	GHG Emissions (tonnes of CO2e)				
Sector	**2013-14**	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Residential Buildings	94,058	119,398	141,763	142,707	148,564
Commercial and Institutional buildings/facilities	28,423	29,504	34,429	36,909	31,991
Manufacturing Industries and Construction	53,611	78,664	82,192	143,335	169,081
Agriculture, forestry and fishing activities	194	227	227	220	194
Transport	115,324	110,786	128,037	142,191	160,205
Waste	105,264	114,665	116,506	118,369	120,254
Total	**396,873**	**453,242**	**503,153**	**583,732**	**630,290**

Gas-wise emissions (CO_2, CH_4 and N_2O) along with notation keys for sectors and sources not considered in the inventory for the base year are available in a summary table in section 3 of this report.

Figure 6 depicts the sector-wise GHG emission trend in Rajshahi between 2013 and 2017. GHG emissions in the city have increased over the years, with an average annual growth rate of 11.8%. The highest increment in emissions was observed in manufacturing/construction sector, which experienced annual average growth of 43%, followed by residential, transport, waste sector &

commercial/institutional, with an average annual growth rate of 11.6%, 7.8%, 2.8% and 2.4%, respectively.

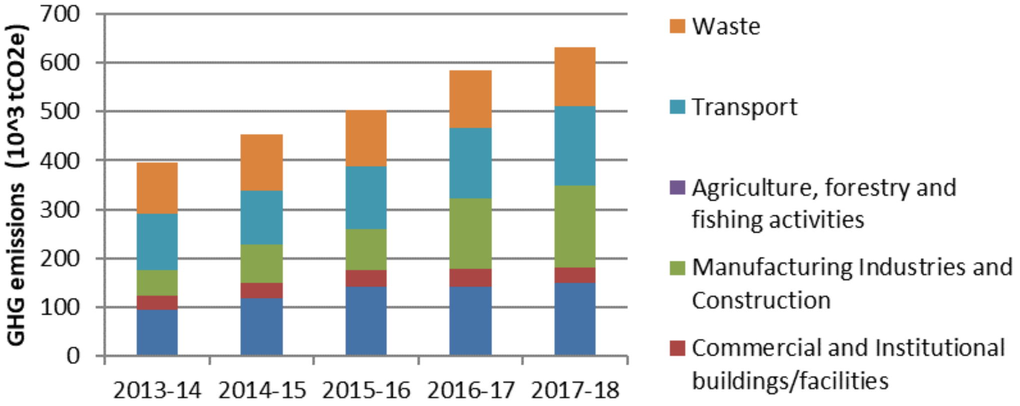


Figure 6: Trend of GHG Emissions from 2013-14 to 2017-18

2.1.5 Baseline Energy Consumption and Emissions

A baseline year is a historical reference point against which comparisons can be made 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 Rajshahi 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.

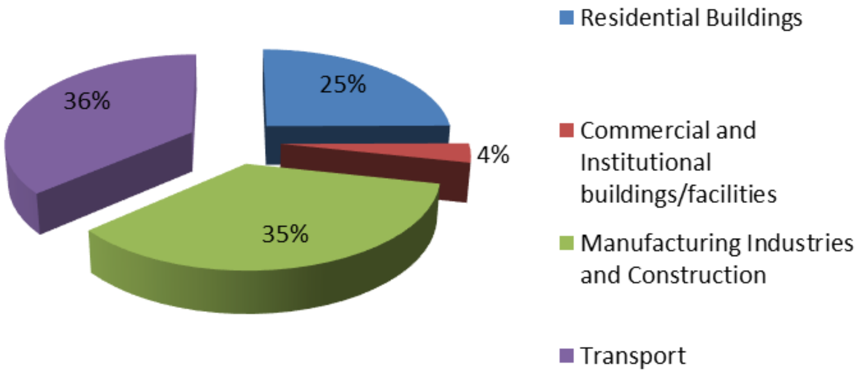


Figure 7: Sector-wise Share of Energy Consumption in 2017-18

Figure 7 suggests that the Transportation sector is the largest consumer of energy, with a share of 36% of the city's total energy. Manufacturing and construction sector with a 35.4% share in total energy consumption is the second-largest consumer of energy followed by the residential and commercial and institutional sector, which account for 24.9. % and 3.41% of energy use respectively. The energy consumed by the Agriculture, forestry and fishing activities is found to be negligible (around 0.02%) as compared to the other sectors and hence is not depicted in the above figure.

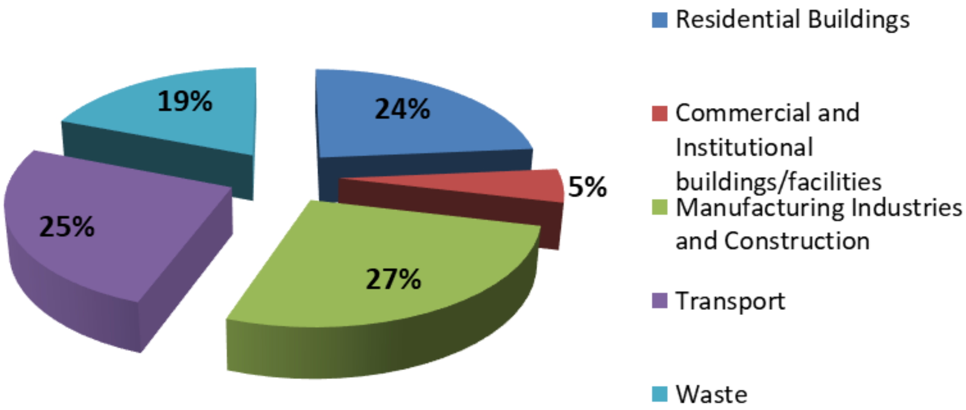


Figure 8: Sector-wise share of GHG Emissions in 2017-18

As exhibited in Figure 8, manufacturing industries and construction sector with a share of 26.8% is the highest contributor to the overall GHG emissions. This high contribution mainly results from the rapid industrialization in the city over the last few years. The transport sector is the second-highest contributor to GHG emissions in the city with share of 25.4% and is followed by residential, waste and commercial/institutional sector, with an emission share of around 23.6%, 19.1% and 5.1% respectively. The Agriculture, forestry and fishing activities sector contributes a negligible amount to the total GHG emission (0.03%) and is therefore not depicted in Figure 8.

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.

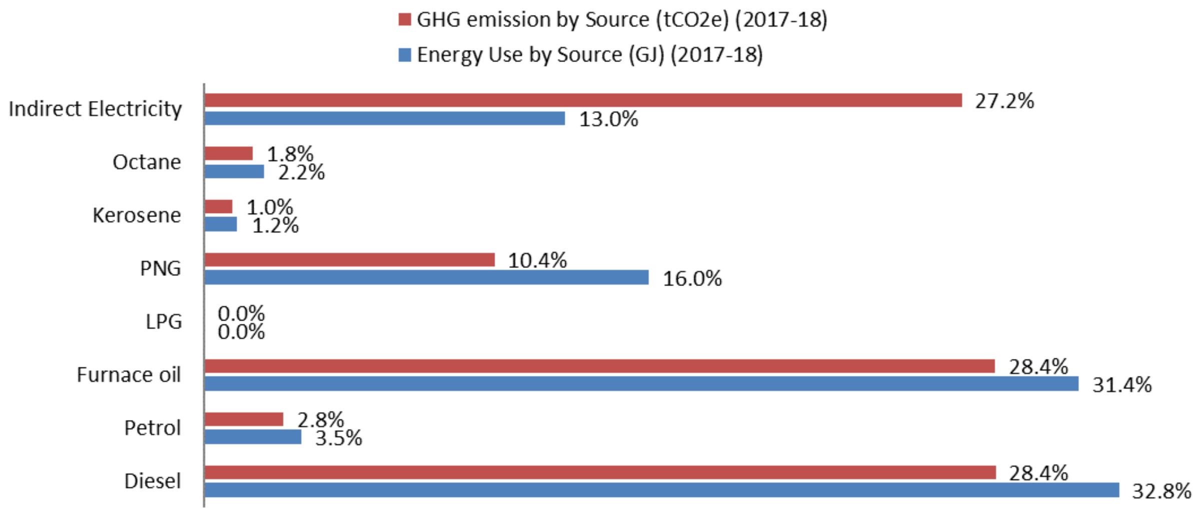


Figure 9 Share of Energy Consumption and GHG Emission by Energy Source in 2017-18

In terms of energy use, diesel is the main fuel source used, catering to about 32.8% of the total energy consumed in the city. Furnace Oil and PNG are the next major sources of energy with a contribution of 31.4% and 16.0% respectively in the energy use. Grid electricity is also a key contributor to GHG emissions, while catering to only 13% of the total energy demand.

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. Figure 10 depicts electricity consumption across key sectors. Electricity consumption in the city has steadily increased from 169 million kWh in 2013-14 to 213 million kWh in 2017-18.

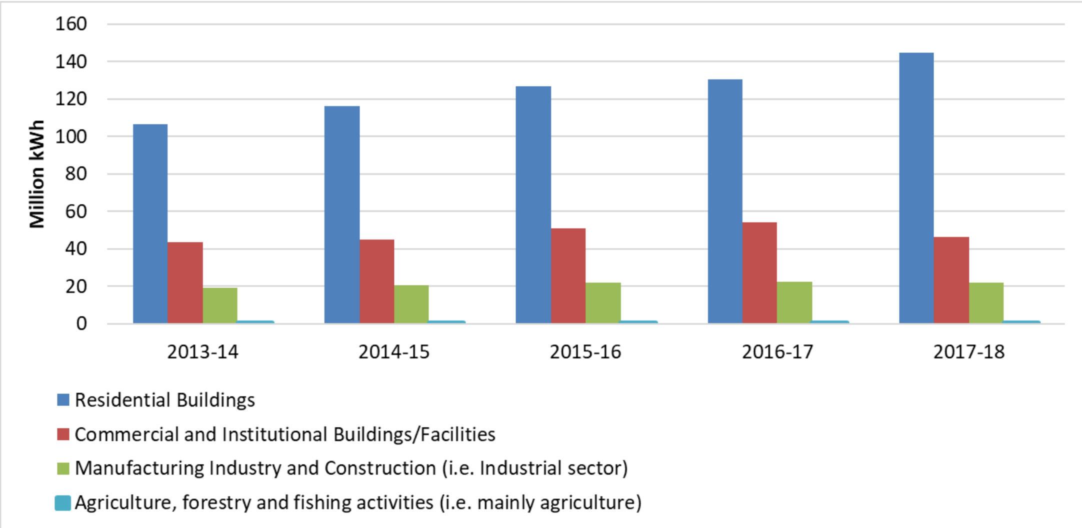


Figure 10: Sector-wise Trend of Grid Electricity Consumption at the community level

It can be seen that the electricity consumed by the Residential sector has increased substantially over the years, and is expected to further increase considering the population growth of the city. Variations in consumption pattern were observed for the other sectors. For instance, in the Commercial and Institutional sector, a growth in consumption was witnessed between 2013-14 and 2016-17, but then a decline was observed in the following year, i.e. in 2017-18. The reason for this was action taken by the city DISCOM to shut down illegal electricity connections in commercial areas.

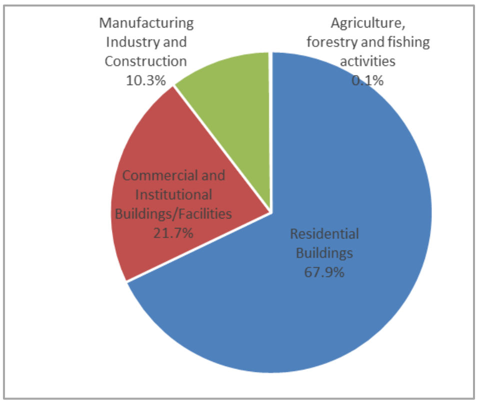


Figure 11: Sector-wise share of electricity consumption in 2017-18

As shown in 11, the main consumer of grid electricity at the community level is the Residential buildings sector with a share of over two-thirds in the city-wide consumption. The Commercial and

Institutional sector with a 21.71% 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 results in GHG emissions produced due to its generation. Based on the city and electricity grid structure, the generation facilities 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 at the community level. In the case of Rajshahi, electricity generation solely depends on thermal-based power units and supply is dependent on the regional grid.

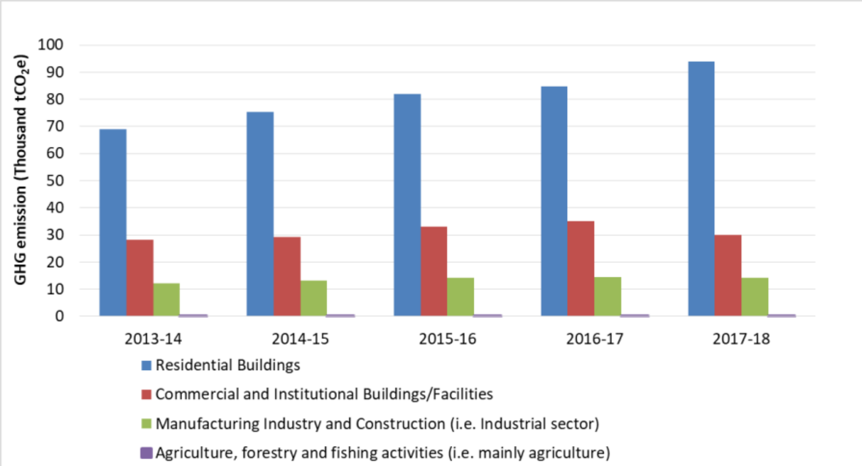


Figure 12: Sector-wise trend of GHG emissions due to Electricity Consumption

Figure 12 shows that the indirect emission due to grid electricity has increased uniformly between the years 2013-14 and 2017-18. This increase in the emission trend is driven mainly by high growth of electricity consumption in the Residential buildings sector sector.

The sector-wise contribution to the total indirect emissions follows the same trend as grid electricity consumption. The Residential buildings sector contributes the most followed by the Commercial and Institutional buildings/facilities sector (refer to Figure 13).

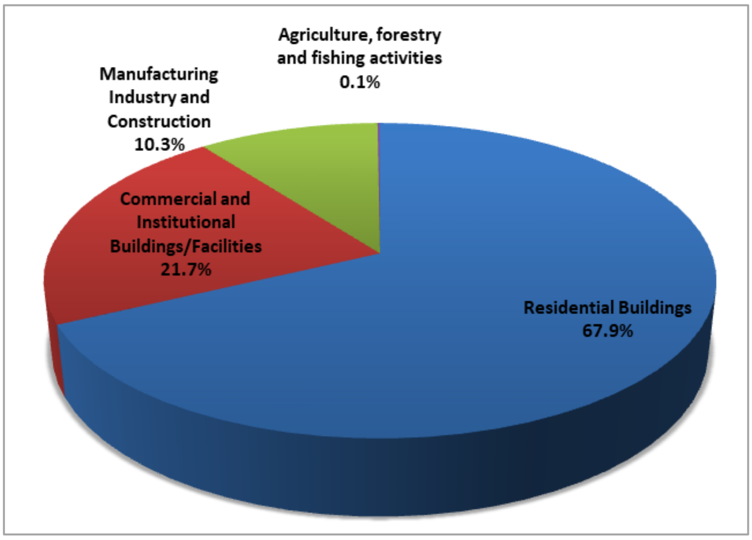


Figure 13: Sector-wise share of indirect GHG emissions at the community level in 2017-18

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

Rajshahi uses kerosene, liquefied petroleum gas (LPG) and piped natural gas (PNG) as the primary fuels to meet the energy requirements of heating, lighting and cooking in its Residential buildings. Kerosene is usually used for cooking in low-income households and for lighting in households without electricity. As shown in Figure 14, the energy consumption by kerosene and LPG has witnessed a decline in Rajshahi over the last five years. This is mainly because of the government's push towards the use of alternative cleaner fuel like PNG. PNG consumption increased consistently every year and reached 28.1 million cu. meter in the year 2017-18, up from 7.8 million cu. meter in 2013-14. While PNG consumption has also increased over the years, kerosene consumption decreased to 2,003 kilo Liters in 2017-18 from 4,481 kilo Liters in 2013-14.

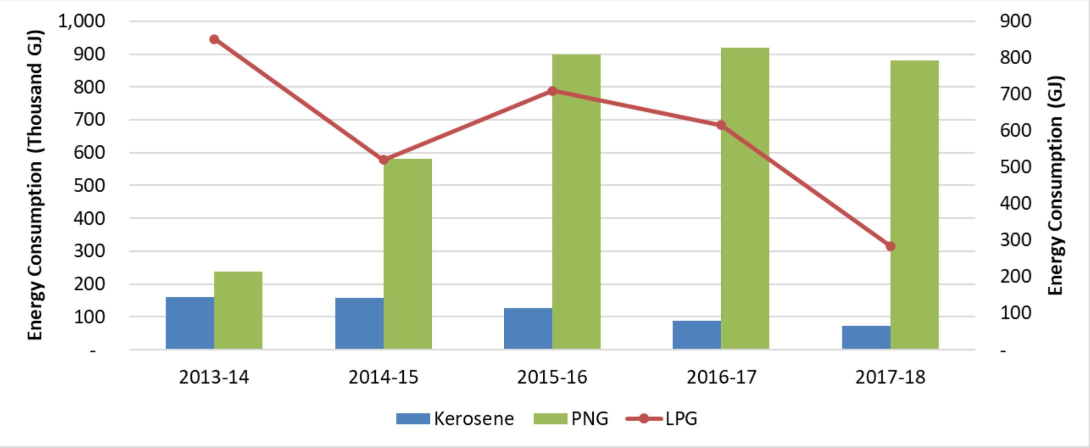


Figure 14: Trend of Energy Consumption by Fuel in the Residential sector

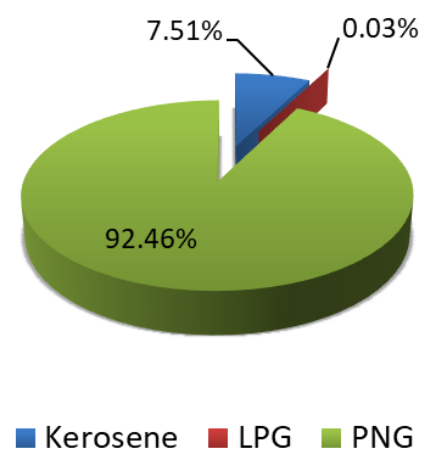


Figure 15: Share of energy use by fuel in the Residential sector, 2017-18

From Figure 15, PNG is observed to be the major stationary fuel in the Residential sector of the city and contributes to approximately 92.46% of domestic energy use. Interestingly, kerosene is the second major stationary fuel used in the residential sector of the city with a share of 7.51% of the total energy use and is way ahead of LPG, which has a share of just 0.03%. This exhibits that kerosene is still being used in the city, mainly in low-income households for cooking and lighting purposes, while LPG no longer holds any significance in domestic fuel use.

The GHG emissions from fuel use in Residential sector of the city have shown a rising trend, as seen in Figure 16. The total emission from stationary fuel use in the city stood at 25, 032 tCO_2e in 2013-14 while in 2017-18 it increased to 54,682 tCO_2e. However, a decline was recorded in the emission between 2016-17 and 2017-18. The reason for this decline is due to a decrease in the PNG consumption.

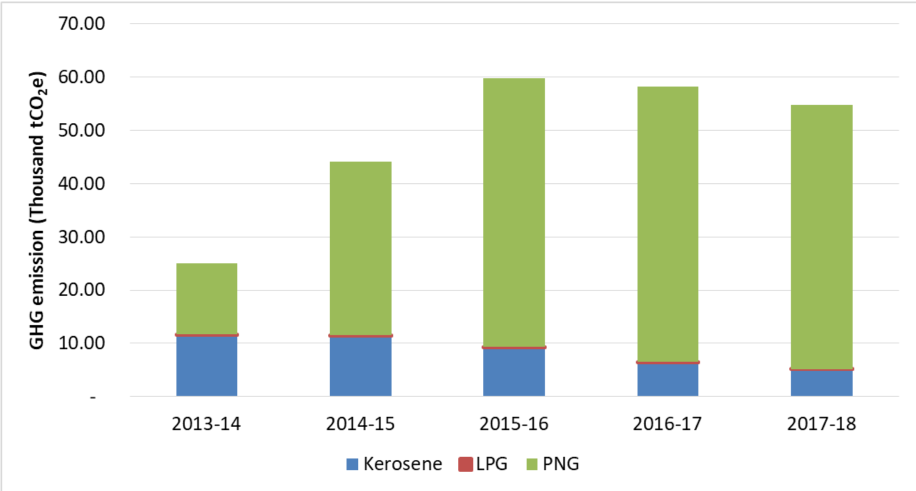


Figure 16: Trend of GHG emissions from fuel combustion in the Residential Sector

2.1.8.2 Commercial and Institutional buildings/facilities sector

LPG and PNG are the primary fuels consumed by the Commercial/Institutional sector end-users like hotels, shops, restaurants, malls, educational institutions, and office buildings. The LPG consumption stood at 6 metric tonnes in the year 2017-18, while PNG consumption amounted to 1.03 million cu. meter.

Figure 17 exhibits the trend of consumption of LPG and PNG in the commercial/institutional sector. The energy consumption by LPG has decreased considerably, while a significant rise can be observed in PNG consumption. This is due to the government's policy efforts to shift towards cleaner fuels in the city.

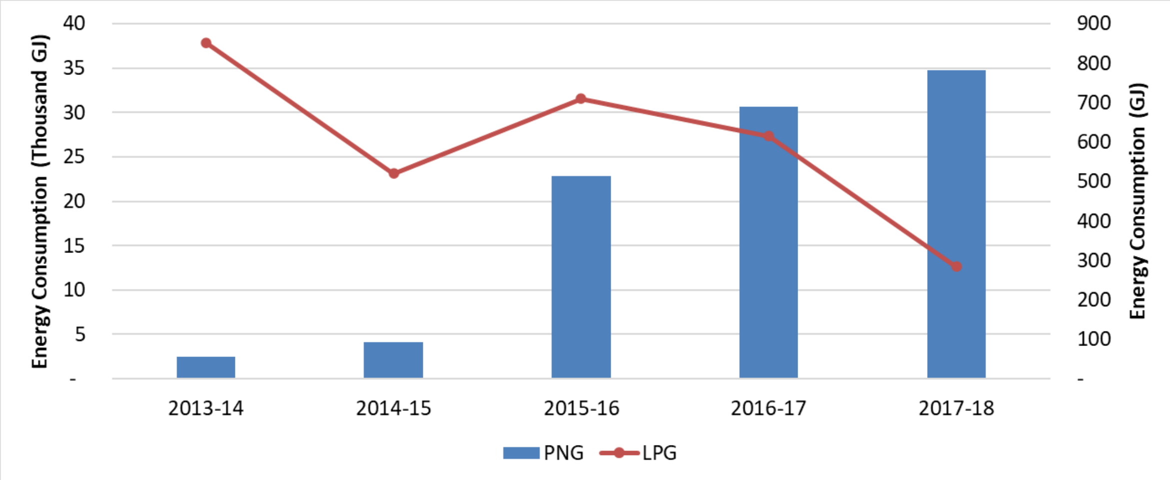


Figure 17: Trend of Energy Consumption by Fuel in Commercial/Institutional Sector

LPG consumption decreased at an annual rate of about 13.3% during the inventory period, while PNG consumption increased at an annual average growth rate of 257.4%. As can be seen from the Figure 18, PNG contributes to 99.22% of the total energy use, while LPG has a share of just 0.78%.

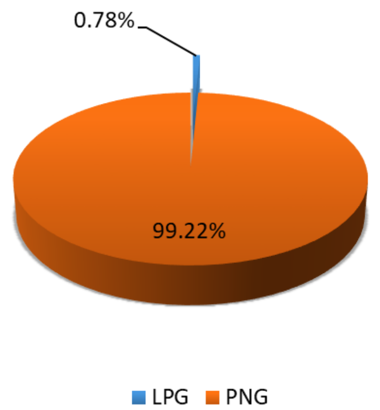


Figure 18: Share of stationary energy use by fuel in the Commercial/Institutional sector, 2017-18

GHG emissions from PNG and LPG consumption follow the same trend as that of energy consumption, as seen in Figure 19. The LPG consumption contributed to nearly 18 tCO_2e of the GHG emissions from fuel consumption in the commercial and institutional sector in the year 2017-18, falling from emissions of 54 tCO_2e in 2013-14. PNG consumption contributed to 1,951 tCO_2e of GHG emission in year 2017-18, a significant rise from emission of about 77 tCO_2e in 2013-14.

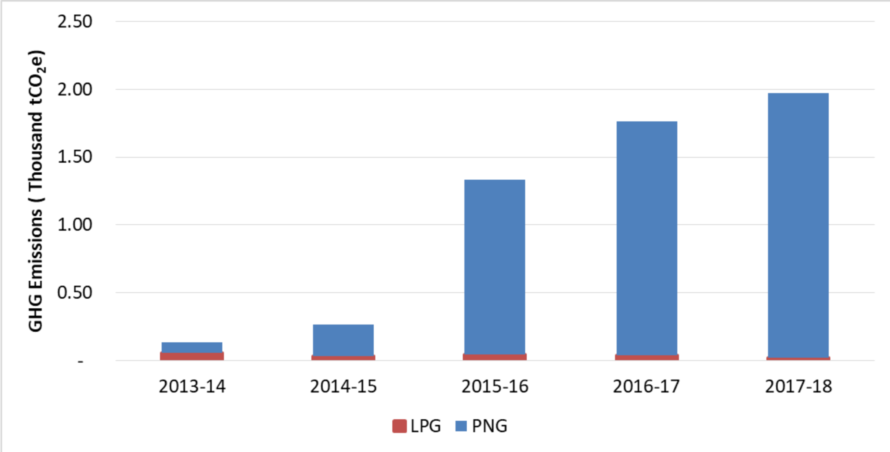


Figure 19: Trend of GHG Emissions from Fuel use in the Commercial/Institutional sector

2.1.8.3 Manufacturing Industries and Construction Sector

Furnace Oil, Octane, and PNG are the primary fuels used to meet the stationary energy demand in the Manufacturing industries and Construction sector of Rajshahi. Furnace oil is the main fuel consumed by the Industrial sector in terms of share in energy use. The total furnace oil consumption amounted to 51,674 kiloliters in the year 2017-18 as compared to 12, 479 kiloliters in 2013-14. A similar growth trend can be observed for both octane and PNG as well. While octane consumption increased to 3,165 kiloliters in 2017-18 from 1,836 kiloliters in 2013-14, PNG use increased to 869,389 cu. meter in 2017-18 from 671,225 cu. meter in 2013-14. The reason for this increase in fuel consumption is rapid industrialization in the city over the last few years.

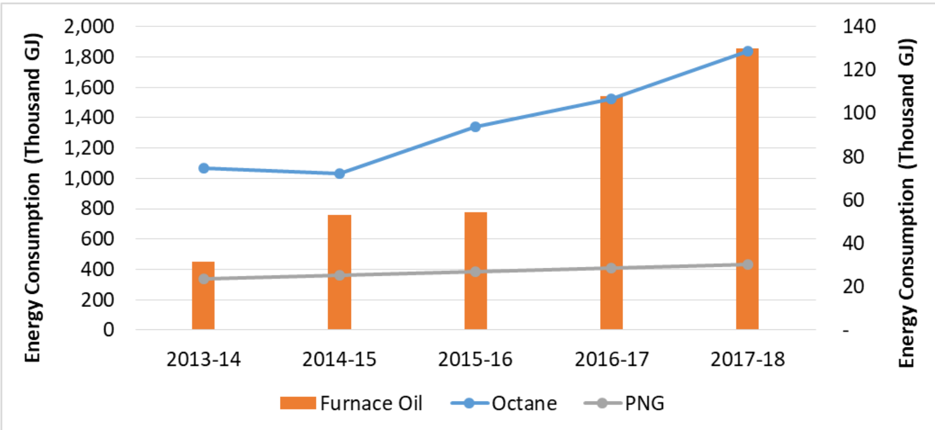


Figure 20: Trend of Fuel Consumption in Manufacturing Industries and Construction sector

Furnace oil with a share of 92.17% has the largest share, followed by Octane and PNG with a share of 6.38% and 1.45% respectively (see Figure 21).

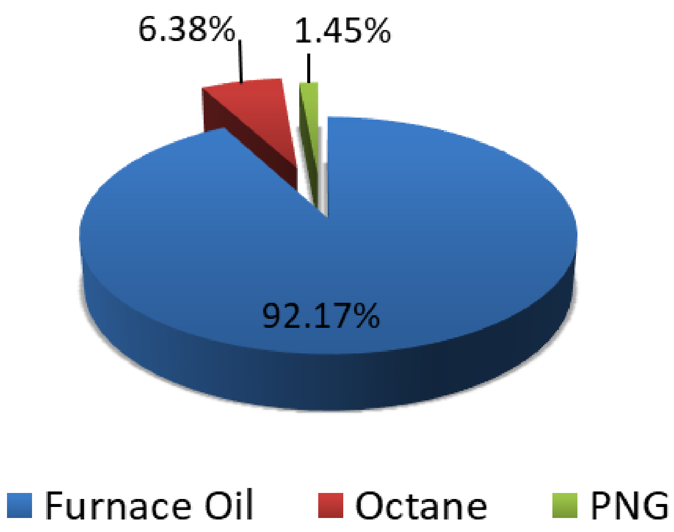


Figure 21: Share of energy use by fuel in the Manufacturing Industries and Construction sector, 2017-18

In the last five years, there has been a significant increase in the GHG emissions from stationary fuels consumed in Rajshahi's industrial sector, with emissions increasing from 41,305 tCO_2e in 2013-14 to 154,889 tCO_2e in 2017-18 (see Figure 22). Furnace Oil is the highest contributor to the GHG emissions, an obvious corollary to its highest share in energy use by the manufacturing/construction sector of the city.

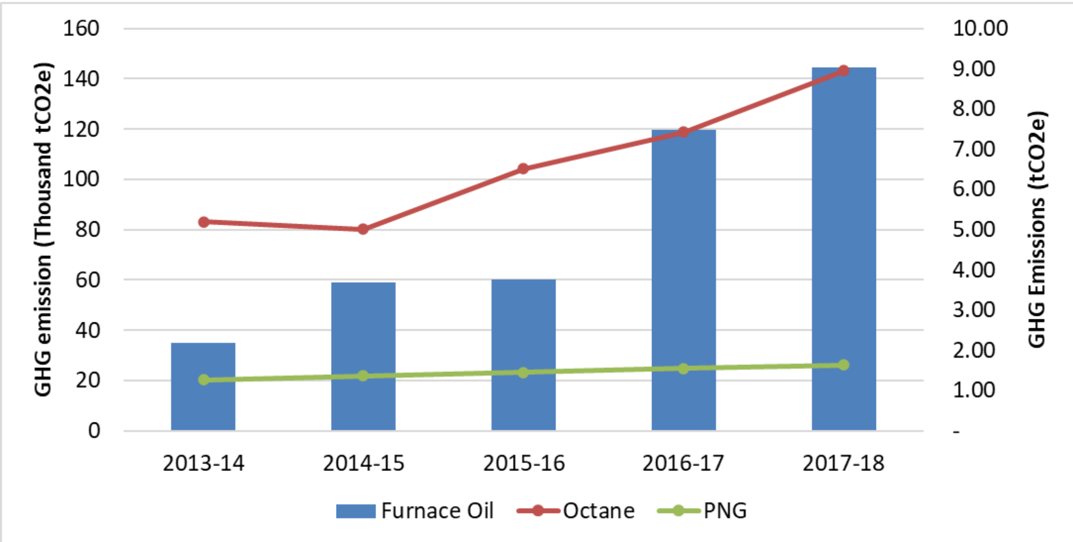


Figure 22: Trend of GHG Emission from Fuel use in the Manufacturing Industries and Construction Sector

2.1.8.4 Transportation

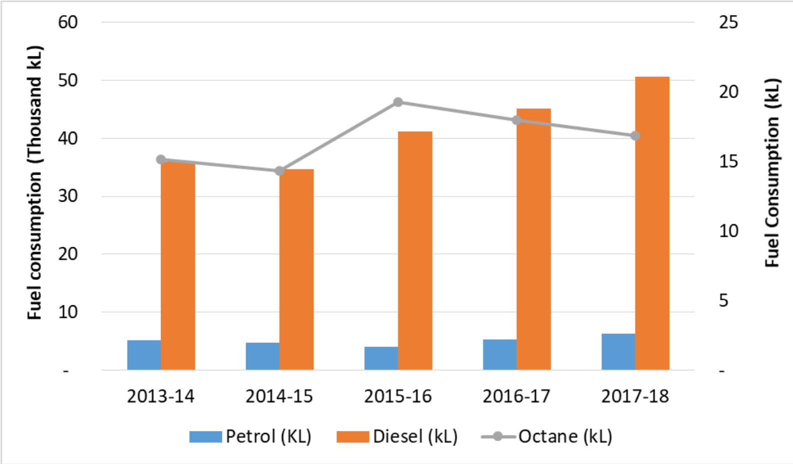


Figure 23: Trend of Fuel Consumption by Road Transportation Sector

Petrol, Octane and Diesel are the fuels used in the on-road transport in Rajshahi. 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 economic growth and rising population. By 2017-18, the diesel consumption in the city for transportation increased to 50,664 kiloliters. Meanwhile, petrol consumption increased to 6,290 kiloliters. Diesel consumption increased by almost 41% in 2017-18 as compared to that in year 2013-14. Based on discussions with the local fuel retailers, it was understood that the large infrastructure development projects were taken up in the city during this period. Also, the rapid industrialization of the city saw a large portion of the population from the nearby towns migrating to the city. This led to the increase in consumption of diesel by private vehicles as well as by heavy vehicles used for transportation activities in the city.

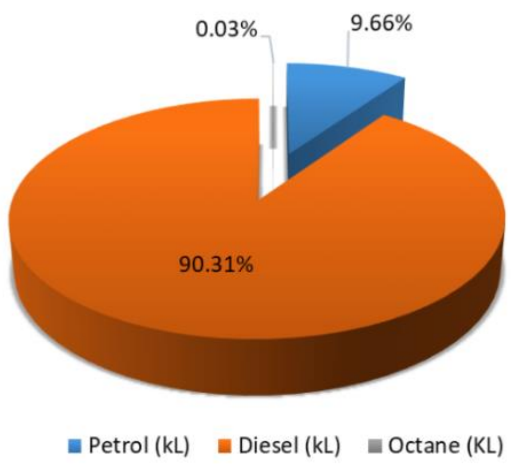


Figure 24: Share of Energy Use by Fuel in the Transportation sector, 2017-2018

The trend of use of octane has varied during the period of study and its share in the fuel mix of the transportation sector is negligible in the city as very few citizens opt for octane in place of petrol mainly due to its slightly higher price.

Rajshahi has one of the largest and most important railway stations in Bangladesh, which also serves as Western Zone Headquarter Bangladesh Railway. Several trains from Rajshahi Railway to Dhaka, North Bengal and South Bengal are operated daily through this station, including inter-city train services. These train services primarily use diesel powered locomotive. Passengers using rail as a mode of transport have increased year on year[2]. Emissions from passenger transport through railways amounted to 1240 tCO_2e in 2017-18, rising from 1035 tCO_2e in 2013-14. The total length of this rail network between Rajshahi to Dhaka & Khulna that comes under the city jurisdiction is 6.25 kms, and this track length was considered to estimate the GHG emissions.

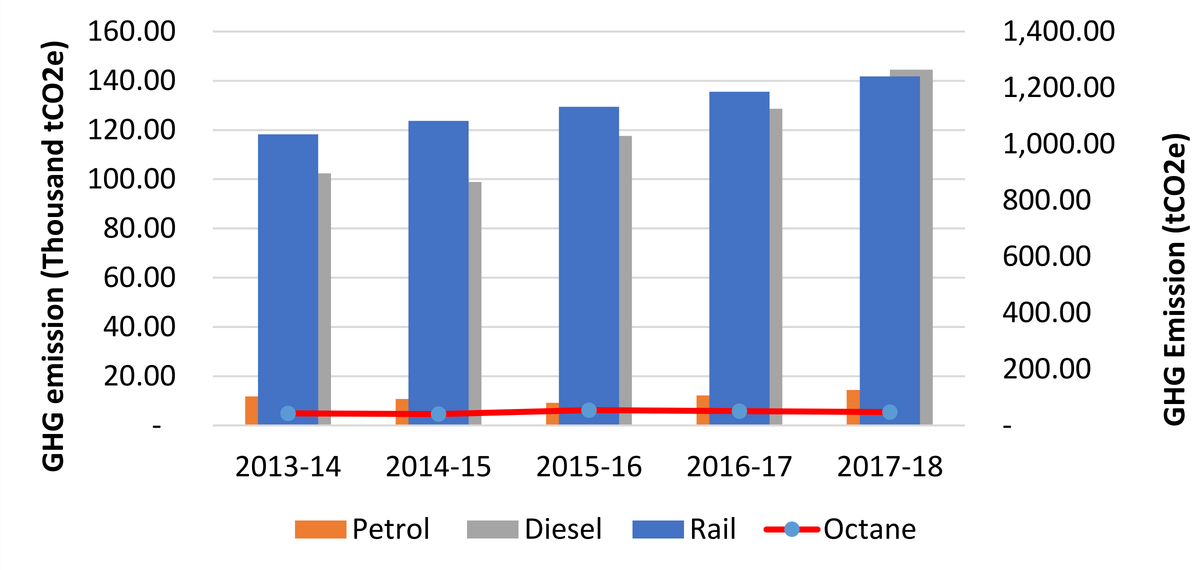
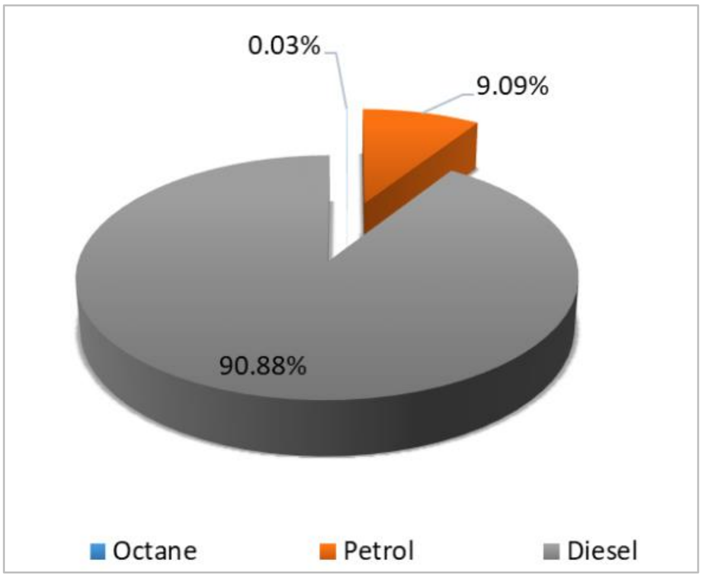


Figure 25: Trend of GHG emission from the Transportation sector

GHG emissions from the Transportation sector amounted to 160,205 tCO_2e in the year 2017-18, rising from 115,324 tCO_2e in 2017-18 (see Figure 25). Diesel alone contributes approximately 91% of the total emissions from the transportation sector, an outcome of its higher consumption in the sector. Petrol contributes to nearly 9% of the total emissions while Octane, as mentioned earlier, has a negligible share in the energy use and thereby in emissions.



[2] As per World Bank data on Railways, annual growth rate of passengers carried (million passenger-km) from 1995-2016 is around 4.43%. https://data.worldbank.org/indicator/IS.RRS.PASG.KM?locations=BD

Figure 26: Share of GHG emission by fuel in the Transportation Sector in 2017-18

2.1.8.5 Solid Waste treatment at the community level

Municipal solid waste (MSW) generally includes degradable matter (such as paper, textiles, food waste, and straw and yard waste), partially degradable matter (such as wood, disposable napkins, sludge) and non-degradable materials (such as leather, plastics, rubbers, metals, glass and electronic waste). Anaerobic decomposition of bio-degradable matter present in MSW generates GHG emission. CH4 emissions from solid waste disposal sites are the largest source of GHG emission in the Waste Sector.

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, considering the annual rainfall of Rajshahi which is more than 1400 mm, for the analysis. 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 uncategorized solid waste disposal site (SWDS).

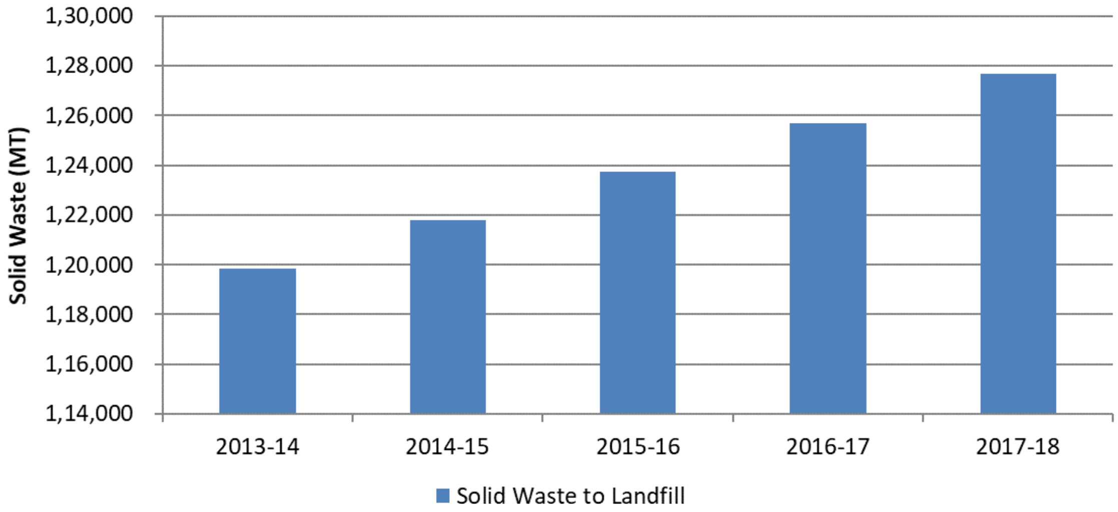


Figure 27 Trend of Solid Waste Generation in Rajshahi

The solid waste generation in the city has grown significantly from 2014-14 to 2017-18, amounting to 127,695 metric tonnes annually in 2017-18. The solid waste generated from the city is dumped directly into the disposal site. No processing facilities for composting, bio-methanation, waste incineration are available, leading to higher methane emissions. With increased waste generation and absence of processing infrastructure, the total GHG emissions from waste disposal have increased over the years and were estimated to be 110,456 tCO_2e in 2017-18.

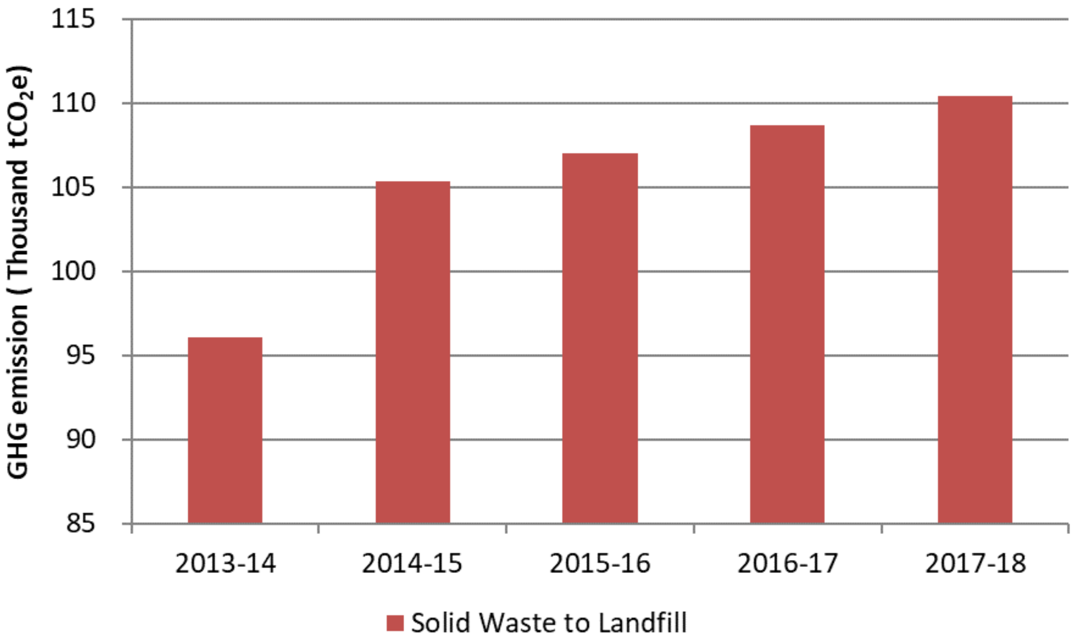


Figure 28: GHG emissions from Solid Waste Disposal at the community level

2.1.8.6 Domestic Waste Water management and associated emissions

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.

Rajshahi does not have a centralized covered sewage collection and treatment system. The city does have open drains through which sewage generated is discharge into rivers and nearby channels. Around 17% of the population is using pit latrines and 10% use septic tanks in the city. The total wastewater generated in the city is around 36.30 MLD, out of which 73% is discharged into the river without treatment. Based on the data from RWASA, the Biological oxygen demand (BOD)[3] value of the city's wastewater is about 70 mg/L.

CH_4 emissions associated with disposal are estimated to be 1,947 tCO_2e in 2017-18. Table 6 presents the GHG emission from different pathways for domestic wastewater treatment and disposal in Rajshahi.

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

---

[3] 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.

occurs on the disposal of domestic wastewater into waterways, lakes or sea. N_2O emissions from domestic wastewater in Rajshahi are estimated to amount to 7,850 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 Narayanganj city stood at 9,798 tCO_2e in 2017-18.

Table 6: GHG Emission from different pathways for Wastewater Treatment and disposal

Treatment/ discharge pathway or system	2013-14	2014-15	2015-16	2016-17	2017-18
Sewer (collected and aerobic treatment, not well managed)	-	-	-	-	-
Sewer (collected and not treated)	-	-	-	-	-
Others/ None (Sea Lake or river discharge without treatment) -	941.57	959.78	978.16	996.72	1,015.46
Septic system - Uncollected	644.91	657.38	669.97	682.69	695.52
Latrine - Uncollected	219.27	223.51	227.79	232.11	236.48
Domestic wastewater N_2O emissions	7,368.49	7,486.98	7,606.85	7,728.13	7,850.82
Total (Tonnes of CO2e)	**9,174.25**	**9,327.65**	**9,482.78**	**9,639.65**	**9,798.29**

The trend of emissions from wastewater generation has been portrayed in Figure 29. The emissions have witnessed growth annually from 2013-14 to 2017-18. Discharge of untreated waste into water bodies without any treatment has a higher contribution to the emissions than uncollected latrines.

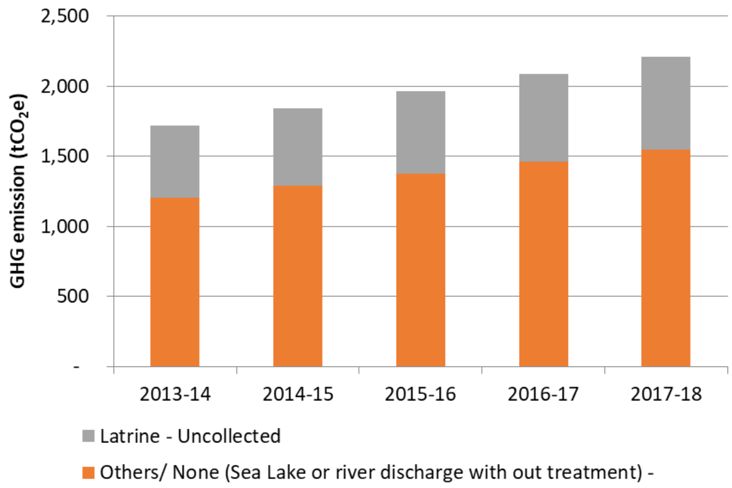


Figure 29: GHG Emission from Wastewater Treatment and disposal

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

RCC's energy consumption for its municipal services rendered to the city residents amounted to 46,804 GJ in 2017-18. Table 7 presents the energy consumption data of municipal buildings, services provided and transport.

From it can be noted that the total energy consumption of the city government has increased over the estimation period, driven mainly by an increase in electricity consumption for water supply in recent years. A similar trend can be observed in the transport used by the local government.

Table 7: Energy Use in Municipal Operations from 2013-14 to 2017-18

Sector	Energy Source/Activity	Energy Consumption (GJ)				
		2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Buildings		-	670	893	781	778
Facilities	**Water Supply (Electricity)**	27,576	29,556	31,536	33,480	35,460
	Street Lighting (Electricity)	2,077	2,160	1,296	1,296	1,296
Transport		5,141	5,351	7,156	7,369	9,271
Total		**34,794**	**37,737**	**40,881**	**42,926**	**46,804**

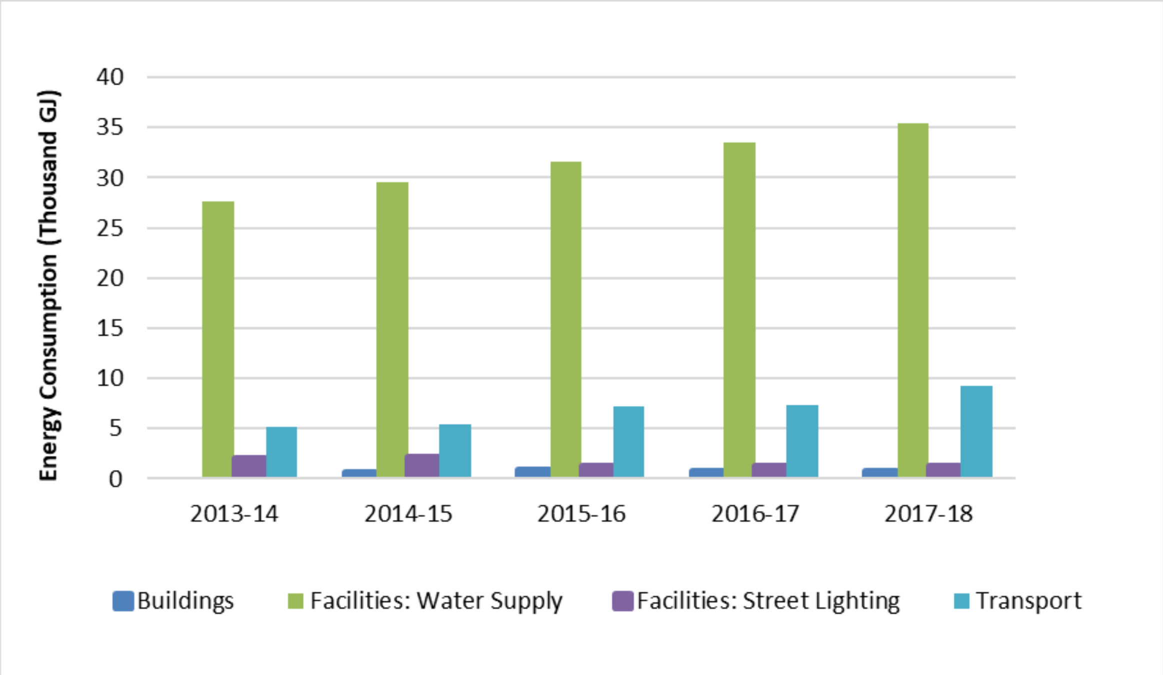


Figure 30: Trend of energy use by Municipal buildings and Services

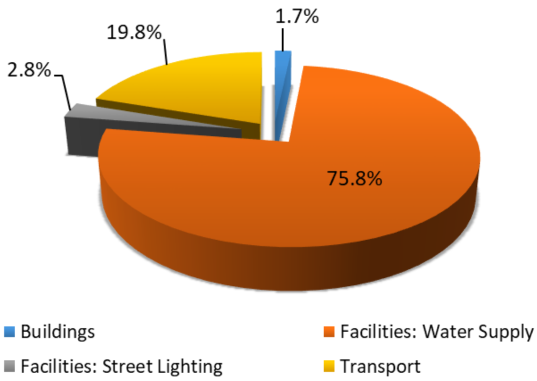


Figure 31: Share of Energy Consumption in Municipal Buildings and Services, 2017-18

The major share of the energy consumed by the municipal government is for the water supply service, contributing to 75.8% of RCC's energy use. The next key energy consumers are municipal transport which contributes about 19.8%, followed by street-lighting and government buildings having a share of 2.8% and 1.7% respectively/

The total GHG emissions from local government operations were estimated to be 7,440 tCO_2e in 2017-18.

Table 8: GHG emission from Municipal Operations from 2013-14 to 2017-18

Sector	Source/ Activity	GHG Emissions (tCO_2e)				
		2013-14	**2014-15**	**2015-16**	**2016-17**	**2017-18**
Buildings		-	121	161	141	140
Facilities:	**Water Supply**	4,964	5,320	5,676	6,026	6,383
	Street Lighting	374	389	233	233	233
Transport		377	393	526	543	684
Total		**5,715**	**6,223**	**6,597**	**6,943**	**7,440**

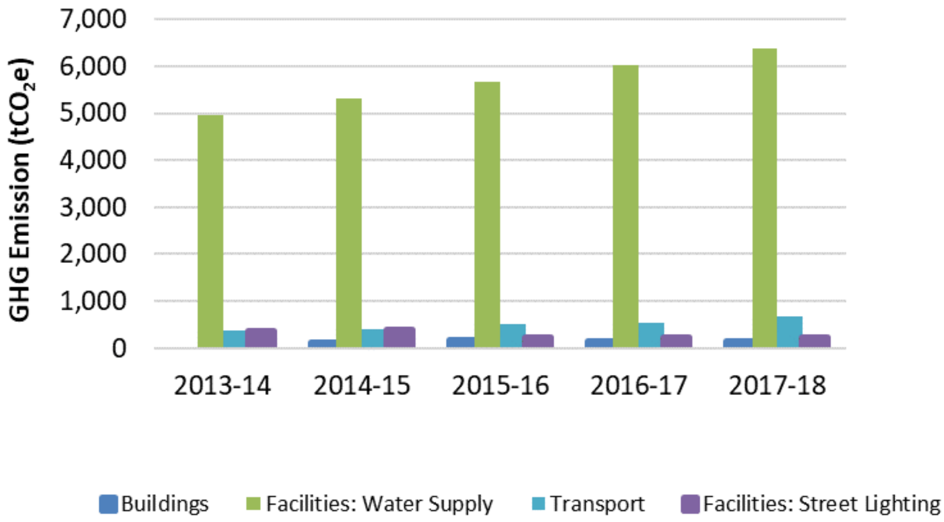


Figure 32: Trend of GHG emission from Municipal Operations

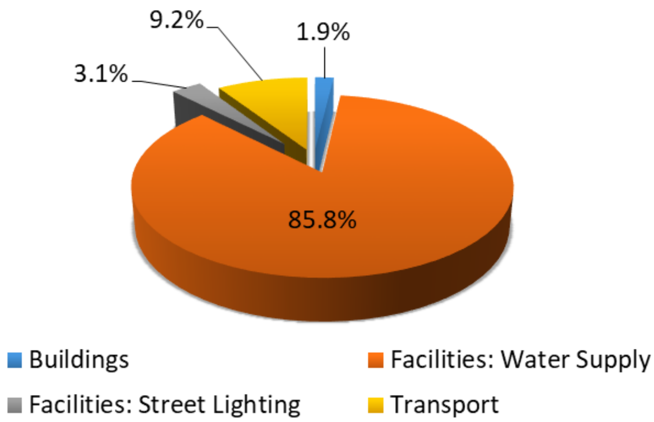


Figure 33: Distribution of GHG emission by source in Municipal Operations, 2017-18

From Figure 33 it is evident that water supply is the major contributor to municipal operations related emissions, a product of it being a major energy-consuming service in the city. It is followed by the municipal transport/vehicles which contribute around 9.2% of the emissions.

2.1.9.2 *Electricity Consumption by Municipal Buildings and Facilities*

RCC consumes grid electricity for providing municipal services like water supply, street lighting etc. and its annual electricity consumption was reported to be 10.4 million kWh in 2017-18. Figure 35 represents the trend of electricity consumption by the local government with respect to different services and facilities it provides to the city population.

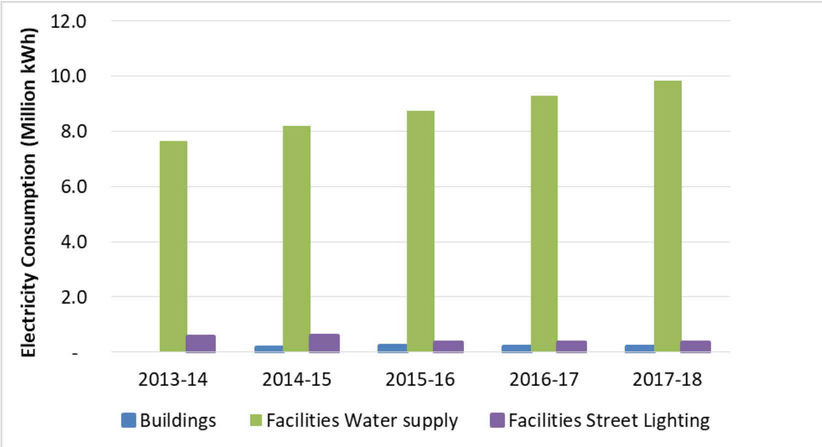


Figure 34: Trend of Electricity consumption in Municipal buildings and services

As can be seen from the Figure 34, the trend of electricity consumption by RCC is increasing. Electricity consumption by street-lights has declined after 2014-15 due to improvements in energy efficiency. RCC initiated replacement of conventional street-lights with LED street-lights in 2014-15. Through this initiative, a total of 0.72 Million kWh of electricity was saved in three years (between 2015-16 and 2017-18, with monetary savings of about BDT 4.5 million over the same period. Electricity consumed by the water supply service is significantly higher than that in street lighting and government buildings.

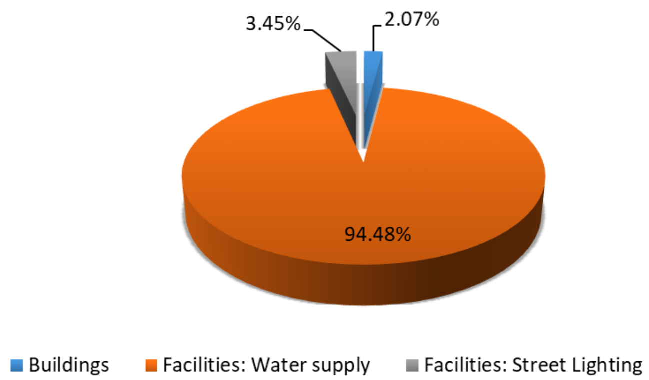


Figure 35: Distribution of Electricity Consumption in Municipal Buildings and Facilities, 2017-18

2.1.9.3 *Fuel Consumption by Municipal Vehicles*

RCC consumes fuels such as diesel, petrol and octane for its municipal vehicle fleet. RCC owns nearly 100 vehicles. This fleet includes vehicles such as cars and jeeps for work related commute and travel for its officers, solid waste management vehicles to transport waste to disposal site, fire tankers, boat, ambulances, other movable machinery. Diesel is the primary fuel used by municipal vehicles in Rajshahi, with a share of nearly 89% in fuel use (see Figure 37). Petrol and octane have a share of about 7% and 4% in the total fuel use respectively. Fuel consumption shows an increasing trend, given an expansion in the RCC's vehicle fleet, especially heavy machinery and trucks.

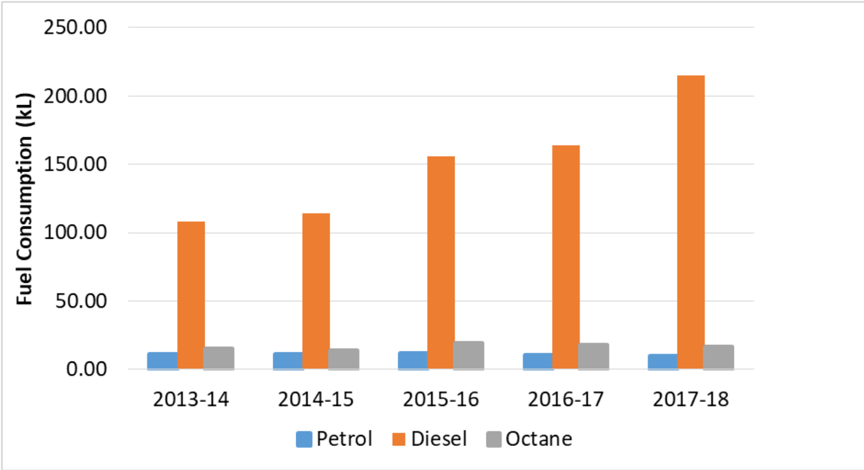


Figure 36: Trend of Fuel Consumption by Municipal Vehicles

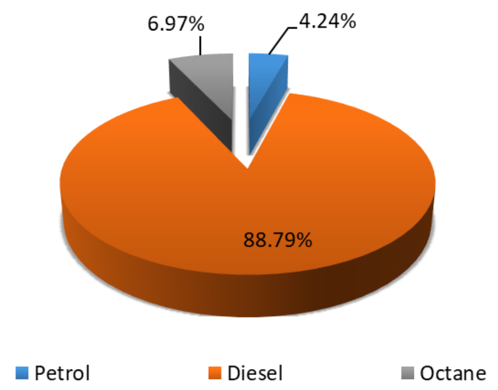


Figure 37: Fuel Wise Share of Consumption in Municipal Vehicles, 2017-18

2.1.10 Key Sustainability indicators for Rajshahi City

The key sustainability indicators for Rajshahi are provided in Table 9 below. These indicators can enable comparison of Rajshahi City with the other cities of Bangladesh as well as the cities around the globe. However, such comparison should be done with due caution since results may vary across cities, even amongst those located in the same country, on account of the different local context (in terms of socio-economic conditions and drivers), data availability and data management practices followed in the cities, and the overall methodology adopted for developing GHG inventory.

Table 9: Key Sustainability Indicators for Rajshahi

Sustainability Indicator	Unit of Measure	Rajshahi (2017 -18)
Per Capita Energy Consumption	GJ/capita	11.97
Per Capita GHG Emission	tCO_2e/capita	1.27
Per Household Energy Consumption	GJ/HH	57.59
Per Household GHG Emission	tCO_2e/HH	6.13
Per sq. km of Area Energy Consumption	GJ/sq. km	61,251.26
Per sq. km of Area GHG Emission	tCO_2e/sq. km	6,516.65

Per Capita Electricity Consumption	kWh/capita	431.27
Per Household Electricity Consumption	kWh/HH	2,074.43

3 GHG emissions inventory summary reporting output

City Information		Data Source
Official name of local government	Rajshahi City Corporation	N/A
Country	Bangladesh	N/A
Region	South Asia	N/A
Inventory year (specify months covered)	2017-18	N/A
Description of boundary and map	Rajshahi Municipal Corporation	
Resident population	4,49,756	District Statistics 2011 Rajshahi

Inventory Setup	
GWP (IPCC AR version used)	IPCC 2006
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	Description of activity/facility	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	93,882	-	Electricity		144.88	Million kWh	Electricity provider	93,882	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	5,167	-	Kerosene		2,003.00	kilolitres	Public fuel distribution office	5,149	tonnes of CO_2e	Fuel consumption	5.370842848	tonnes of CO_2e	Fuel consumption	12.80408935	tonnes of CO_2e	Fuel consumption		
		Direct	18	-	LPG		6.00	tonnes	Fuel/Oil supply companies	18	tonnes of CO_2e	Fuel consumption	0.007096626	tonnes of CO_2e	Fuel consumption	0.008459178	tonnes of CO_2e	Fuel consumption		
		Direct	49,497	-	PNG		2,62,33,425	cubic metre	Natural Gas Supply Companies	49,449	tonnes of CO_2e	Fuel consumption	22.036077	tonnes of CO_2e	Fuel consumption	26.26700378	tonnes of CO_2e	Fuel consumption		
	Commercial	Indirect	30,022	-	Electricity		46.33	Million kWh	Electricity provider	30021.84	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor		
		Direct	18	-	LPG		6.00	tonnes	Fuel/Oil supply companies	17.911884	tonnes of CO_2e	Fuel consumption	0.007096626	tonnes of CO_2e	Fuel consumption	0.008459178	tonnes of CO_2e	Fuel consumption		
		Direct	1,951	-	PNG		10,34,112	cubic metre	Natural Gas Supply Companies	1949.2598	tonnes of CO_2e	Fuel consumption	0.86865408	tonnes of CO_2e	Fuel consumption	1.035435663	tonnes of CO_2e	Fuel consumption		
	Institutional	IE		-															IE	Included under Commercial sector as no disaggregated data for this sub-sector
		IE		-															IE	Included under Commercial sector as no disaggregated data for this sub-sector
		IE		-															IE	Included under Commercial sector as no disaggregated data for this sub-sector
	Industry	Indirect	14,191	-	Electricity		21.90	Million kWh	Electricity provider	14,191	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor		

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	Description of activity/facility	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
		Direct	1,44,301	-	Furnace Oil		51,674	kiloliters	Fuel/Oil supply companies	1,43,830	tonnes of CO_2e	Fuel consumption	139.369805	tonnes of CO_2e	Fuel consumption	332.2576151	tonnes of CO_2e	Fuel consumption		
		Direct	8,948	-	Octane		3,165	kiloliters	Fuel/Oil supply companies	8,918	tonnes of CO_2e	Fuel consumption	6.4346349	tonnes of CO_2e	Fuel consumption	23.0102544	tonnes of CO_2e	Fuel consumption		
		Direct	1,640	-	PNG		8,69,389	cubic metre	Natural Gas Supply Companies	1,639	tonnes of CO_2e	Fuel consumption	0.73028676	tonnes of CO_2e	Fuel consumption	0.870501818	tonnes of CO_2e	Fuel consumption		
	Agriculture	Indirect	194	-	Electricity		0.3	Million kWh	Electricity provider	194.4	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	tonnes of CO_2e	Location-based using consumption and national grid emission factor	0	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	
Transportation	On-road	Indirect	NO	-																
		Direct	47.72	-	Octane		16.88	kiloliters	Fuel/Oil supply companies	48	tonnes of CO_2e	Fuel Sales method	0.03431602	tonnes of CO_2e	Fuel Sales method	0.122714087	tonnes of CO_2e	Fuel Sales method		
		Direct	14,450.41	-	Petrol		6,290.00	kiloliters	Fuel/Oil supply companies	14,398	tonnes of CO_2e	Fuel Sales method	15.5819025	tonnes of CO_2e	Fuel Sales method	37.14725556	tonnes of CO_2e	Fuel Sales method		
		Direct	1,44,466.79	-	Diesel		50,664.00	kiloliters	Fuel/Oil supply companies	1,43,974	tonnes of CO_2e	Fuel Sales method	145.7223338	tonnes of CO_2e	Fuel Sales method	347.4020438	tonnes of CO_2e	Fuel Sales method		
	Rail	Indirect	NO																NO	Electricity consumption for rail is not occuring as diesel locomotives are used as prime movers in trains
		Direct	1,240.45	-	Fuel (Diesel)		18,50,16,606	pass-km	Railway Department	1,240	tonnes of CO_2e	Passenger-km basis	0	tonnes of CO_2e	Passenger-km basis	0	tonnes of CO_2e	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	Airport is outside the city limit
		Direct	NO																NO	Airport is outside the city limit
	Off-road	Indirect	NO	-															NO	Electricity consumption for off-road transport is not occurring as these are using conventional combustion engines
		Direct	NO																NO	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	1,10,455.98	N/A	N/A		1,27,695	tonnes	Solid waste department, Rajshahi City Corporation	0	tonnes of CO_2e	Methane Commitment method	1,10,456	tonnes of CO_2e	Methane Commitment method	0	tonnes of CO_2e	Methane Commitment method		
	Biological treatment	Direct		N/A	N/A														NO	
	Incineration and open burning	Direct		N/A	N/A														NO	

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	Description of activity/facility	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
	Wastewater	Direct	9,798.29	N/A	N/A		927.36	tonnes of organics	Sewerage department, Rajshahi City Corporation	0	tonnes of CO_2e	Organic content based and population-based approach	1,947.46	tonnes of CO_2e	Organic content based and population-based approach	7,851	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	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Annexure 1

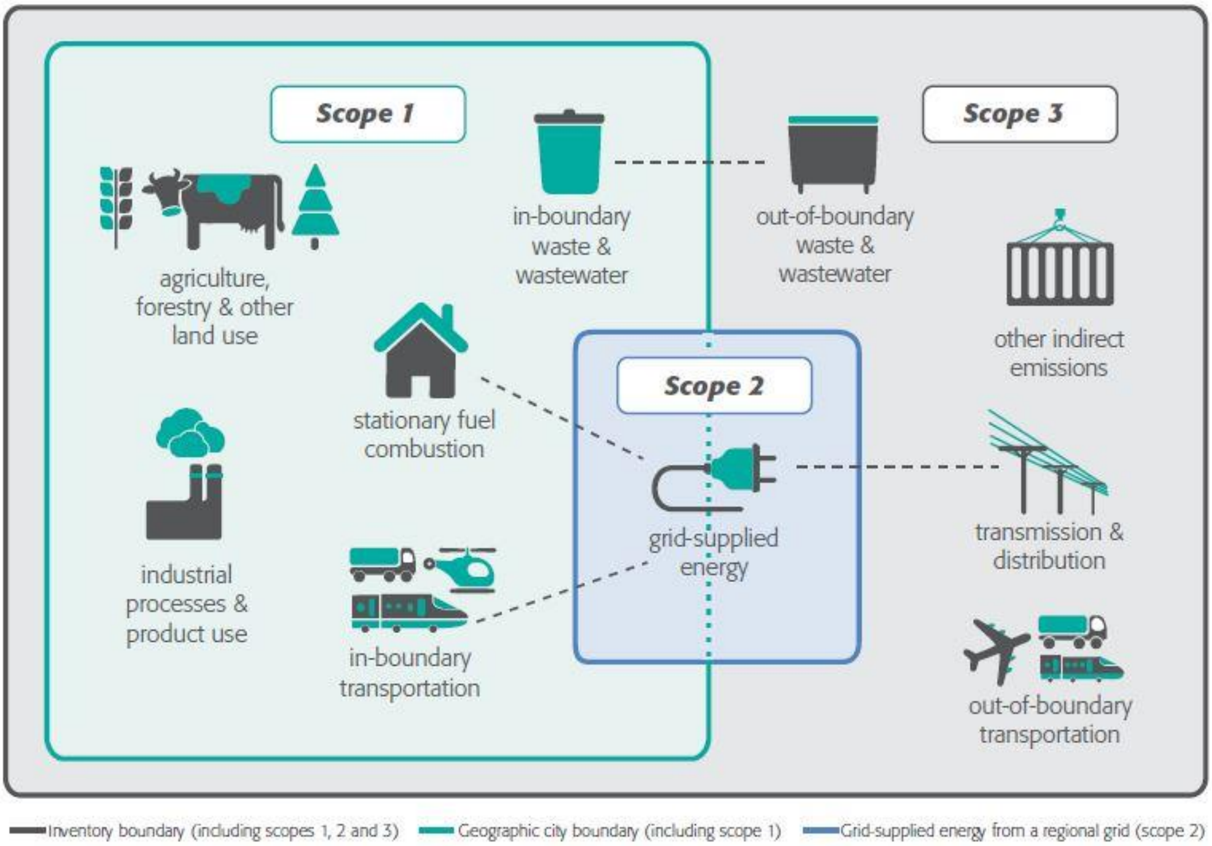


Figure 38: Sources of GHG Emission at the City-level as per GPC

Annexure 2

Key Assumptions in the Emission Estimation:

- **Population Projection:**

  The numbers have been taken from the District Statistics 2011 Rajshahi published in 2013. The document contains population figures from 1981 onwards. (http://203.112.218.65:8008/WebTestApplication/userfiles/Image/District%20Statistics/Rajshahi.pdf; refer page 19)

  Population figure has been projected by using arithmetic, geometric and incremental increase methods, considered average of all 3 methods for further analysis.

- **Electricity consumption –**

  Due to data limitation and unavailability of some information at the city level, several assumptions have been made for GHG emission calculations.

  For the residential sector, the energy use figures are available only for the Rajshahi Metropolitan areas. Hence, electricity use data has been apportioned/downscaled for the city, based on the number of consumers and the population of the metropolitan area against the city area.

  City-level electricity consumption for Commercial and Institutional Buildings/Facilities; Manufacturing Industry and Construction; and Agricultural sector has been calculated based on area ratio (%) and the difference in land use of Rajshahi metropolitan area against Rajshahi city area (source - Structure Plan, Master Plan and Detailed Area Development Plan for Rajshahi Metropolitan City, An Overview of Rajshahi City and Its Past Planning Efforts) and sectoral electricity consumption info received from DISCOM.

  Bangladesh's Grid emission factor i.e. 0.648 (tCO_2/MWh), has been used for calculation of emissions from electricity consumption.

  Source: https://www.adb.org/sites/default/files/institutional-document/296466/guidelines-estimating-ghg.pdf

- **Fuel** –

  Discrepancy in fuel consumption data (PNG consumption for Commercial and Industrial sector) was noted in data received from PGCL (commercial in 2013 and industrial in 2016 and 2017) - information for the mentioned years have been adjusted based on the previous year trends.

- **Fuel (Petrol and Diesel)**–

  Basic assumption has been made based on the market share of three companies (Padma, Jamuna and Meghana). Source: POCL (Padma Oil Corporation Limited) Annual Report. Weblink: http://pocl.gov.bd/wp-content/uploads/2019/01/POCL_Annual_Report_1718.pdf (refer page 29).

- **Waste Sector –**

  There is no concrete figure on daily waste generation for RCC available in the public domain. Based on discussions and documents shared by RCC, waste generation of 350 TPD has been considered for emission calculations. However, secondary literature indicates a higher generation of figure 400 TPD as of 2013. Based on the assumed waste generation figure of 350 TPD (info received from RCC) the per capita waste generation in RCC comes around to be 700 gm/per day/capita, which has been considered for calculating the solid waste generation in the city for subsequent years (also taken into account is the projected population in respective years).

  For GHG emission calculation using Methane Commitment method as per GPC, following conditions and assumptions have been considered:

  - Landfill type - Uncategorised Solid Waste Disposal Site

  - Landfill condition - Wet (as average rainfall is 1448mm per year as per City Resilience Strategy, Rajshahi City, Bangladesh, prepared by ICLEI SA under ACCCRN supported by the Rockefeller Foundation.

  - Physical composition of waste - considered from secondary literature (Halder, P. K., Paul, N., Hoque, M. E., Hoque, A. M., Parvez, M. S., Rahman, M. H., & Ali, M. (2014). Municipal solid waste and its management in Rajshahi City, Bangladesh: a source of energy. International Journal of Renewable Energy Research (IJRER), 4(1), 168-175)

- **Waste Water Treatment –**

  As per the information available in the public domain, there is no wastewater treatment facility in Rajshahi. All the wastewater generated in the city is directly dumped into the water bodies. The city has a network of open drains (these are stormwater drain which is also being used to collect and discharge WW into river/water body).

  Official figures on WW characteristics are not available, therefore results from secondary literature have been considered.

  # The first study

  https://www.researchgate.net/publication/237794645_Summary_Assessment_Baseline_Water_Quality_Survey_for_Rajshahi_Bangladesh/download.

  As per this study, the 5-day average BOD value is in the range of 22-112 mg/L.

  # The second study

  https://www.researchgate.net/profile/Md_Mohayminul_Islam/publication/331356584_A_Brief_Study_On_Water_Quality_Liable_for_Contaminating_the_River_Padma_Rajshahi/links/5c757953a6fdcc47159e5d18/A-Brief-Study-On-Water-Quality-Liable-for-Contaminating-the-River-Padma-Rajshahi.pdf.

  This research gives an average BOD value of 65 mg/L (5 days BOD) (as per sample taken from 10 sites).

  The average of both BOD values i.e. 70 mg/L has been considered for the wastewater emission calculations.

Most of the population uses septic tanks (80%), and around 20% population uses toilet connected to lined tanks and pits. Within that 80%, about 70% of the population's septic tanks are connected to open drains and 10% of the population uses septic tanks which are connected to soak pits, even though the specifications of the Bangladesh National Building Code (BNBC) state that it is not allowed to discharge the effluent of septic tanks into open water courses and a soak pit shall be installed. The Building Code also demands soil percolation tests to determine the soil and site suitability. The 20% of toilets connected to lined tanks and pits consists of: 12% of lined tanks with impermeable walls and open bottom, no outlet or overflow, 5% of lined pits with semi-permeable walls and open bottom, no outlet or overflow and 3% of lined tanks connected to an open drain or storm sewer

Source: https://www.susana.org/_resources/documents/default/3-3564-7-1552915661.pdf .

- **Rail Emissions**

Estimating country specific Rail Emission Factor- the proposed methodology relies mostly on publicly available data from India as relevant information is not available for Bangladesh. This method used country level railways annual data such as passenger kilometers, track length & occupancy rate at emission factors. Average diesel fuel consumption data has been used for calculations that are available in public domain.
For passenger transport, our assumption considered two types of train travel used by the passengers, Suburban (Intercity) and Non Sub-urban (Long distance). For this type of transport, the number of passengers carried and average distance travelled by each passenger were factored in.
The steps followed were: 1) Collecting fuel consumption data for passenger transport; 2) Collecting emission factor for fuels; 3) Deriving total emission from passenger transport; 4) Collecting passenger-km published by Railways and 5) Determining emission factor by dividing emissions with passenger km

Base data is used for year 2017-18. World Bank data on Railways, passengers carried (million passenger-km) annual growth rate was calaculated and used (1995-2016), which is around 4.43%. https://data.worldbank.org/indicator/IS.RRS.PASG.KM?locations=BD
This growth rate is broadly used to arrive at future values as well as claculate numbers for previous years.

- **Additional Comments**

  - **Emission Factors for Octane fuel:** Default values of Net Calorific values, carbon emission factor and oxidation factor from IPCC have been used to arrive at the final figure, which is at par with Diesel values in India.
  - **Energy Densities:** the values of energy densities for Natural Gas, Octane and FO have been compiled from the third NATCOM of Bangladesh. The values have been appropriately adjusted for measuring units based on their respective specific gravity.