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Greenhouse Gas Emissions Inventory
For the City of Johannesburg

Global Protocol for Community-scale Greenhouse Gas Emissions (GPC)

1. Introduction

1.1 This report provides an estimate of the City of Johannesburg's greenhouse gas emissions inventory. The work was undertaken by Siemens through the C40 Measurement & Planning initiative. It is the first city-wide inventory produced for the city and uses the global protocol for community scale greenhouse gas emissions (GPC) methodology. The GPC was developed by C40 and ICLEI in close consultation with local governments and also the World Resources Institute and the joint work programme of the Cities Alliance between World Bank, UNEP and UN-Habitat. Johannesburg is the first African C40 City to use the GPC to estimate its emissions.

1.2 This report gives an overview of Johannesburg's greenhouse gas emissions and the methodology used to collect the estimate them. In addition this report sets out some of the challenges in data collection and makes recommendations on how data collection can be improved going forward.

1.3 All cities face challenges with collecting and reporting data related to their greenhouse gas emissions and Johannesburg is no exception. It is the first and most important step in understanding the City's emissions and how to improve its measurement.

1.4 Producing a city-wide baseline allows the City to examine where its emissions are coming from, but it also allows them to understand areas where data is not adequate or available, or where further information is needed to help them make decisions about programmes or policies they might wish to put in place. Cities should continue year on year to scrutinise their own data and identify ways in which they can improve the measurement of the city's emissions.

1.5 High quality data is the cornerstone to developing deliverable and measurable strategies and programmes. Importantly it also allows cities and its citizens to track progress against targets and understand how well programmes are performing.

Ultimately high quality data gives confidence and reduces risks to policy makers and financiers when making decisions about city policies, programmes and infrastructure.

1.6 The GPC provides an important platform for cities to report their emissions in a consistent and replicable way and allowing for comparison.

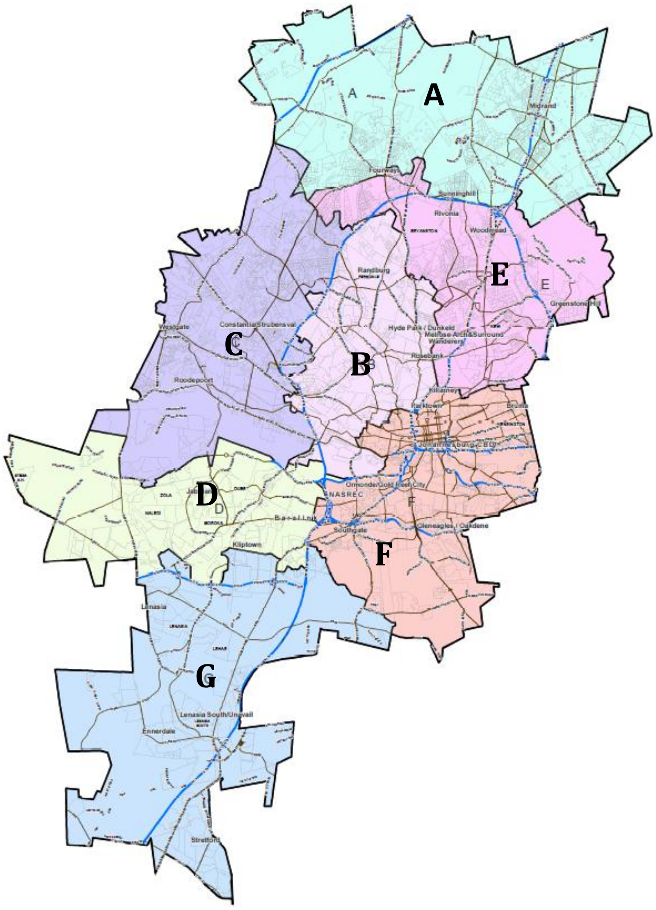
2. Johannesburg: a world class African city

2.1 Johannesburg is South Africa's largest and fastest growing city. Johannesburg is located in the province of Gauteng, which is also home to South Africa's capital Pretoria - 62 km north east of Johannesburg. The metropolitan area of Johannesburg was formed in 2000 by the merger of five previously independent municipal areas. The city covers 1,644 km^2 with an average density of 1,963 persons per km^2.

2.2 The city has 4.4 million residents living in 1.4 million households. Between 2001 and 2011 the population has increased by an average of 121,000 every year. 43,000 new homes have also been added every year over the same period. The City is forecast to double in size by 2040[i]. Johannesburg is also a young city with 42% of the population is under 24 years of age.

2.3 The City is divided into seven administrative regions as shown in Figure 1.

Figure 1: City of Johannesburg regions



Region A: Diepsloot & Midrand
Region B: Northcliff & Randburg
Region C: Roodeport
Region D: Greater Soweto
Region E: Sandton & Alexandra
Region F: Inner City
Region G: Ennerdale & Orange Farm

2.4 Johannesburg is the financial centre of South Africa, the city is home to the headquarters of mining companies, financial institutions and many other multinational corporations. It has the headquarters of 70% of South Africa's businesses. In 2009, the province of Guateng had a gross domestic product of 624 billion rand (£34.4 billion), of which Johannesburg contributed 47.6 per cent[ii]. Table 1 shows the composition of Johannesburg's economy. The vast majority of the City's GVA comes from the tertiary and secondary sectors. Finance & business services accounts for over 28 per cent of the economy. Other important sectors include community services (20.27 percent), manufacturing (19.83 percent) and wholesale and retail trade (15.4 percent).

Table 1: Johannesburg's economy by GVA and employment

	2006	2007	2008

Sector	Share of GVA (%)	Employment (%)	Share of GVA (%)	Employment (%)	Share of GVA (%)	Employment (%)
Financial & Business Services	27.12	23.11	28.46	23.66	28.16	24.52
Community Services	20.45	15.3	20.11	15.27	20.27	14.64
Wholesale and Retail Trade	16.76	15.58	16.04	15.1	15.4	15.27
Transportation and Communication	7.81	6.03	7.38	5.67	6.88	5.42
Sub-total Tertiary Sector	**72.14**	**60.02**	**71.99**	**59.7**	**70.71**	**59.85**
Manufacturing	19.36	22.24	19.26	23.16	19.83	22.63
Construction	3.51	6.49	3.75	6.23	4.04	6.08
Electricity, Water and Gas	2.47	0.98	2.4	0.95	2.42	0.93
Sub-total Secondary Sector	**25.34**	**29.71**	**25.41**	**30.34**	**26.29**	**29.64**
Mining and Quarrying	2.18	0.76	2.22	0.68	2.6	0.69
Agriculture	0.35	0.58	0.38	0.54	0.4	0.56
Sub-total Primary Sector	**2.53**	**1.34**	**2.6**	**1.22**	**3**	**1.25**

Source: Source: Annual Economic Review 2009, City of Johannesburg

2.5 Table 1 shows the composition of Johannesburg's economy. The vast majority of the City's GVA comes from the tertiary and secondary sectors. Finance & business services accounts for over 28 per cent of the economy. Other important sectors include community services (20.27 percent), manufacturing (19.83 percent) and wholesale and retail trade (15.4 percent).

3. The Global Protocol for Community-Scale Greenhouse Gas Emissions

Why develop the GPC?

3.1 The World Resources Institute (WRI) is developing a GHG inventory standard to guide city and community-scale GHG accounting practices worldwide. WRI has partnered with ICLEI – Local Governments for Sustainability (ICLEI), C40 Cities Climate Leadership Group (C40), the World Bank, UN-HABITAT, and United Nations Environment Program (UNEP) to develop the **Global Protocol for Community-Scale Greenhouse Gas Emissions (GPC)**.

3.2 The GPC recognizes the importance of cities to climate change. Cities now account for 50% of global population and by 2050 75% of people will live in them. In addition cities are responsible for two thirds of global energy consumption and 70% of emissions of greenhouse gases[iii]. Cities are central to tackling climate change. In order to reduce their emissions cities need to be able to track their emissions and understand the impact of their policies and programs on them. In addition to secure financing, funders must be confident that the projected outputs from their programmes and projects are robust.

3.3 Cities need to learn from each other. An important step in that process is ensuring that cities are reporting in the same formats and to the same methodology. As well as helping cities to share their data, adopting the same methodology and standardizing inventories will give the finance more confidence in climate related projects and allow for better scrutiny of the performance of our cities.

3.4 The GPC serves as the global framework for accounting and reporting city and community-scale GHG emissions that covers scope 1, scope 2, and some scope 3 emission sources.

GPC Reporting standards

3.5 In May 2012, the partners released the GPC Pilot Version 1.0, which is currently being tested in over 30 cities around the world. The release of final version is expected in 2014. This version and its associated guidance has been used in developing this inventory.

3.6 The GPC methodology has three levels - Basic, Basic+ and Expanded. Box 1 gives an overview of the three levels and also explains the different scopes of emissions collected by the methodology. The sources and scopes reported in each level of the GPC is set out in Table 2.

Box 1: GPC three inventory levels and GHG Emissions Scopes

BASIC
Covers all Scope 1 and Scope 2 emissions of stationary units, mobile units, wastes, and Industrial Processes and Product Use (IPPU), as well as Scope 3 emissions of waste sector.

BASIC+
Covers GPC 2012 BASIC as well as agriculture, forestry and land use (AFOLU) and *scope 3* emissions for mobile units.

Expanded
Covers in addition to Basic+ all scope 3 emissions from consumption based emissions including from the importing and exporting of all goods and services.

GHG Emissions Scopes

GHG emissions in geographic areas are categorized into three scopes

Scope 1 emissions
All direct GHG emissions sources from activities taking place within the city boundary – for example the use of fuels such as gas to provide heating in buildings

Scope 2 emissions

Table x The GPC Scopes and Sources covered by Basic, Basic+ and Expanded levels

Table 2: Sources and scopes of GHG emissions covered by each GPC reporting level.

Sources	Scope 1	Scope 2	Scope 3		
	Basic			Basic+	Expanded
STATIONARY UNITS					
Residential Buildings	X	X			
Commercial/Institutional Facilities	X	X			
Energy Generation	X	X			
Industrial Energy Use	X	X			
Fugitive Emissions	X	X			
MOBILE UNITS					
On-Road Transportation	X	X		X	
Railways	X	X		X	

Water-Borne Navigation	X	X		X	
Aviation	X			X	
Off-Road	X	X			
WASTE					
Solid Waste Disposal	X		X		
Biological Treatment of Waste	X		X		
Incineration and open burning	X		X		
Wastewater Treatment and discharge	X		X		
INDUSTRIAL PROCESSES AND PRODUCT USE (IPPU)	X				
AGRICULTURE, FORESTRY, AND LAND USE (AFOLU)	X*				
OTHER INDIRECT EMISSIONS					X
TOTAL BY SCOPE	SCOPE 1	SCOPE 2	SCOPE 3		
TOTAL BY SOURCE	BASIC				
	BASIC+				
	EXPANDED				

3.7 The GPC pilot methodology is attached as an Appendix 1 to this report. The sources of information and emission factors used are contained within the model. A detailed explanation of the methodology used to calculate the emissions inventory is contained in Appendix 2.

4. Johannesburg Greenhouse Gas Emissions

Baseline

4.1 The baseline for the City of Johannesburg's emissions inventory is 2007. This year was selected as it had the most comprehensive data sets available at the time of production. However in some instances 2007 data was not available. In these situations the latest available data was used (where emissions appear to be fairly consistent year on year) or estimates for 2007 were back-cast from the latest available dataset. The limitations of the Inventory are set out in Section 5 and Appendix 2.

4.2 As the quality of the dataset improves Johannesburg should look to revise the baseline in accordance with improved information or methods of back-casting data

City-wide Emissions Summary

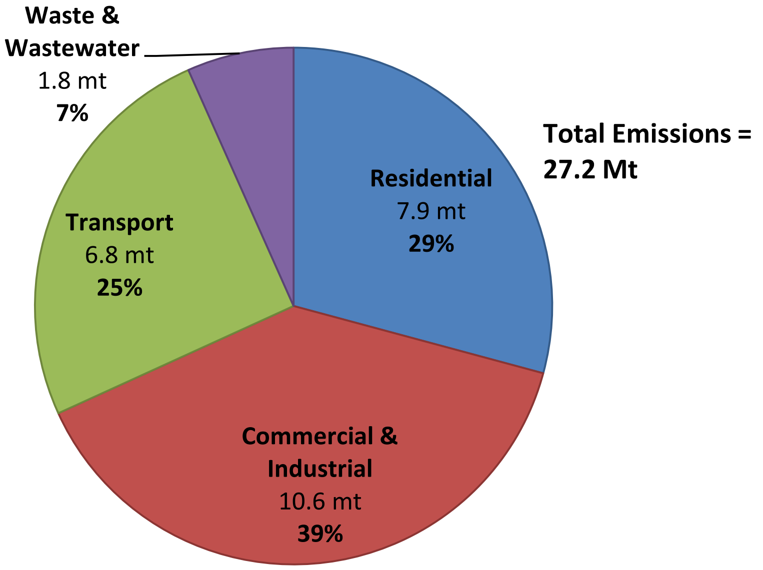
4.3 Table 3 sets out the City of Johannesburg's estimated emissions for 2007. In total 27.2 million tonnes of CO_2e were emitted. The largest contributor is the Commercial & Industrial sector which accounted for 10.6 million tonnes of CO_2e (39%), followed by the Residential sector with 7.9 million tonnes (29%), the Transport sector with 6.8 million tonnes (25%) and Waste and Wastewater sector with 1.8 million tonnes (7%). No estimates of emissions for the Industrial Processes and Product Use (IPPU) or Agriculture Forestry and Other Land Use (AFOLU) was included in the inventory due to a lack of data.

Table 3: Johannesburg emissions inventory summary by sector and GHG gas

Sector	CO_2 (tonnes)	CH_4 (tonnes)	N_2O (tonnes)	CO_2e (tonnes)
Residential				
Direct Emissions Scope 1	246,488	68	662	453,179
Energy Indirect Emissions Scope2	7,490,289			7,490,289
Residential sub-total	**7,736,777**	**68**	**662**	**7,943,468**
Commercial & Industrial				
Direct Emissions Scope 1	84,714	6	0	84,895
Energy Indirect Emissions Scope2	10,526,275			10,526,275
Commercial & Industrial sub-total	**10,610,989**	**6**	**0**	**10,611,171**
Mobile Units				
On-Road Transportation	5,583,122	296	71	5,611,185
Railways	246,900	0	0	246,901
Aviation	973,839	26	31	983,977
Mobile Units sub-total	**6,803,861**	**321**	**101**	**6,842,063**
Waste and Wastewater				
Solid Waste Disposal		85,057		1,786,193
Biological Treatment of Waste		231	17	10,205
Incineration	72	24	22	7,520
Wastewater Treatment and discharge			35	10,718
Waste and Wastewater sub-total	**72**	**85,311**	**74**	**1,814,636**
Industrial Processes and Product Use (IPPU)				
Direct Emissions from Industrial Processes	Not estimated			0
Direct Emissions from Product Use	Not estimated			0

Agriculture, Forestry, and Land Use (AFOLU)				
Direct Emissions from AFOLU	Not estimated			0
Total	**25,151,699**	**85,706**	**838**	**27,211,337**

Figure 2: CO_2e emissions by sector (Million tonnes CO_2e)

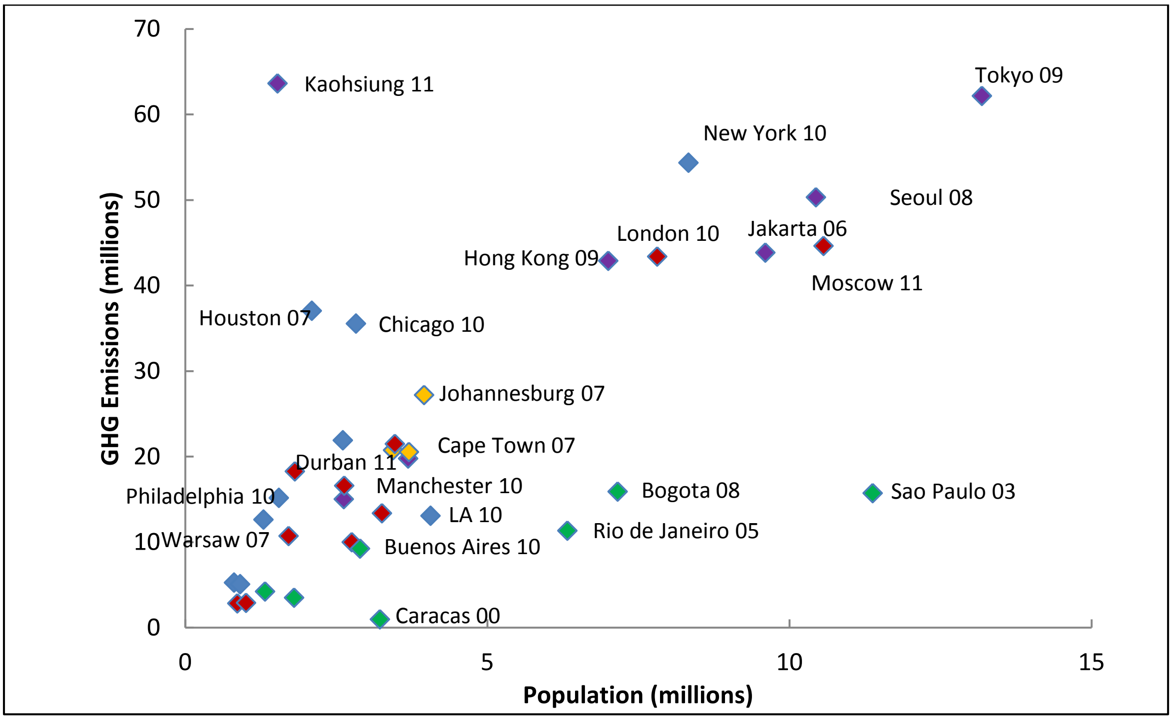


City Comparison

4.4 Direct comparison of emissions inventories should be undertaken with some caution. This is due to the different ages of inventories and the different methodologies applied from city to city. For example one City may include emissions from aviation from all airports servicing the city another may not. However Figures 2 and 3 give an indication of Johannesburg's emissions against other large cities. Figure 2 shows the emissions for a number of cities plotted against their population. The chart also displays the age of each inventory.

4.5 Johannesburg's emissions per head were 6.89 tonnes in 2007. This is broadly comparable with other African Cities (highlighted yellow) in Figure 3. Emissions in Cape Town were 5.54 tonnes per head and 6.19 tonnes per head in Durban. However no evaluation of the methodologies for those cities has been made. Figure 3 also illustrates that most North American cities (highlighted blue) tend to have larger carbon footprints per head. South American (highlighted green) and Asian cities tend to have the lowest footprints (highlighted purple).

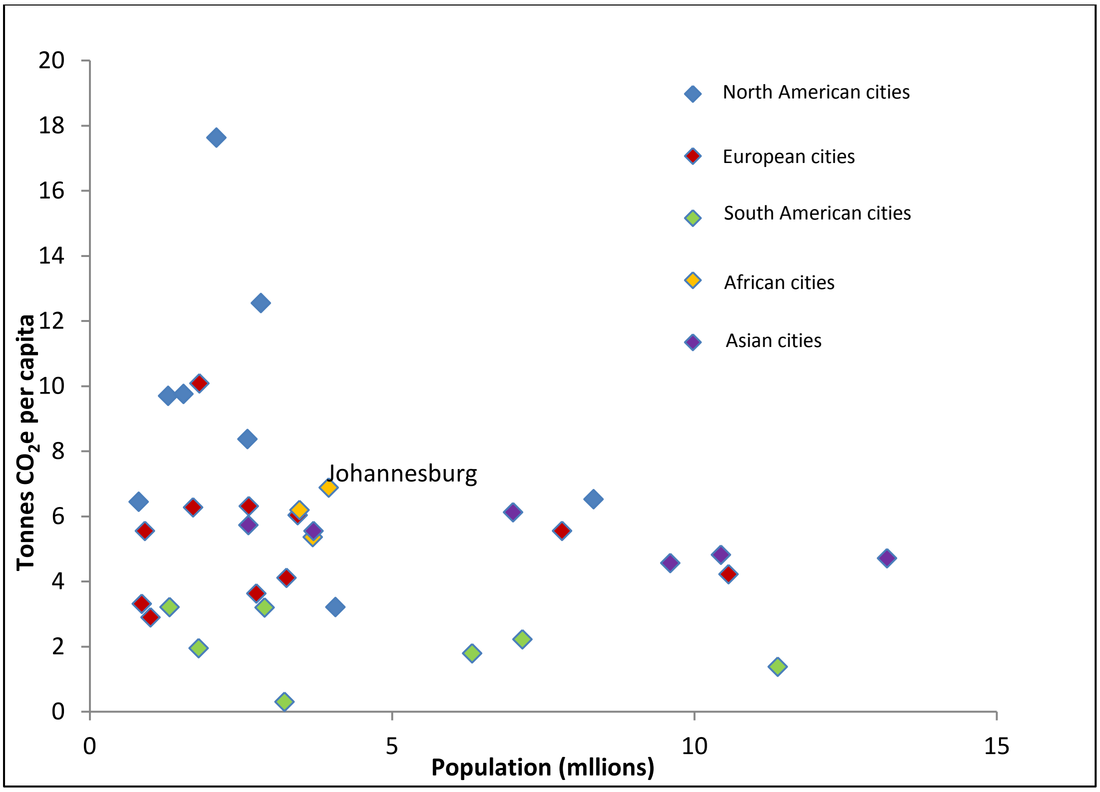
Figure 2: CO_2e emissions and population of selected global cities



Source: CDP Cities

Note: the number after the city indicates the inventory year

Figure 3: CO_2e emissions per head of population of selected global cities



Source: CDP Cities

Emissions by greenhouse gas and scope

4.6 Table4 shows that the vast majority of Johannesburg's CO_2e emissions are CO_2 (92.4 per cent). 6.6% of Johannesburg's CO_2e emissions are from methane (CH_4), largely from the disposal of waste in landfill sites.

Table 4: Johannesburg's emissions by greenhouse gas

	Emissions (tonnes)	Emissions CO_2e (tonnes)	Percentage of CO_2e emissions
CO_2	25,151,699	25,151,699	92.4%
CH_4	85,706	1,799,823	6.6%
N_2O	838	249,097	0.9%
Total		27,211,337	

4.7 The majority (67%) of Johannesburg's emissions are scope 2, from the consumption of electricity within the city. Scope 1 activities including heating and cooling of buildings, the use of fuel in transportation and the disposal of the City's waste accounts for 29% of the emissions. Just fewer than 4% of emissions were scope 3. This was made up of emissions from inter-city rail transport and aviation.

Table 5: Johannesburg emissions by scope

Emissions Scope	CO_2e (tonnes)
Scope 1	7,963,896
Scope 2	18,262,653
Scope 3	984,789

4.8 Table 6 shows the CO_2e emissions by energy type. Electricity is the largest single source of energy used in Johannesburg, accounting for 63,833 TJ (38.77%). Electricity was also the largest contributor to CO_2 emissions from energy (72.45%). The emissions from electricity are so significant because of the carbon intensity of the South Africa's electricity supply. South Africa relies almost entirely on coal for the generation of electricity. In addition electricity is the main source of heating and cooling in residential and commercial buildings within the city.

4.9 Petrol and diesel combined to account for 48.36% of energy use in the City and 22.26% of the city's emissions from energy. Petrol accounted for 58,584 TJ and diesel 21,040 TJ of energy use.

4.10 16,630 TJ of Jet fuel and aviation fuel were also consumed by Johannesburg which produced just under 4% of the emissions. LPG, natural gas, furnace oil, paraffin and coal accounted for the remainder of the energy use and emissions but made up a small proportion of emissions from energy use in the city.

Table 6: Energy use and CO2e emissions by energy type

Energy source	Terajoules (TJ)	Terajoules (TJ %)	CO_2e (000's tonnes)	CO_2e (%)

Electricity	63,833	38.77	18,263	72.45
Petrol	58,584	35.58	3,965	15.73
Diesel	21,040	12.78	1,647	6.53
Natural Gas	1,451	0.88	87	0.34
LPG	76	0.05	4	0.02
Paraffin	1,922	1.17	133	0.53
Coal	1,023	0.62	119	0.47
Furnace Oil	76	0.05	6	0.02
Jet Fuel	16,564	10.06	980	3.89
Aviation Fuel	66	0.04	4	0.02
	164,635	-	25,207	

Figure 4: Johannesburg's energy sources by fuel type

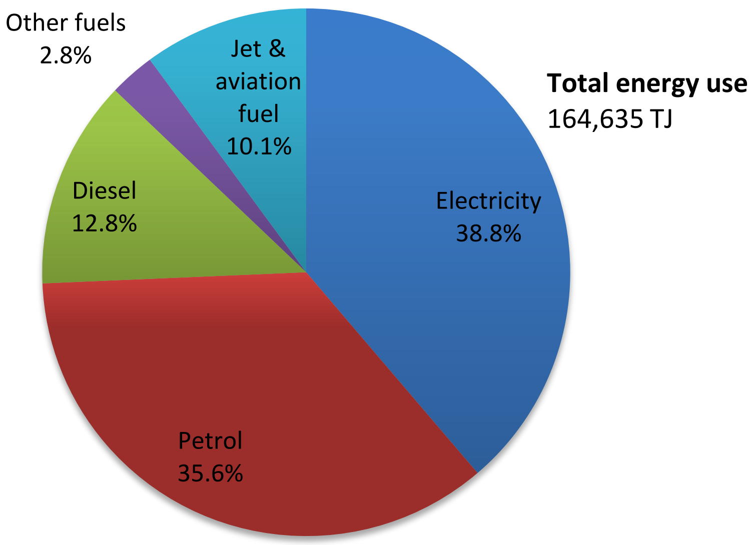
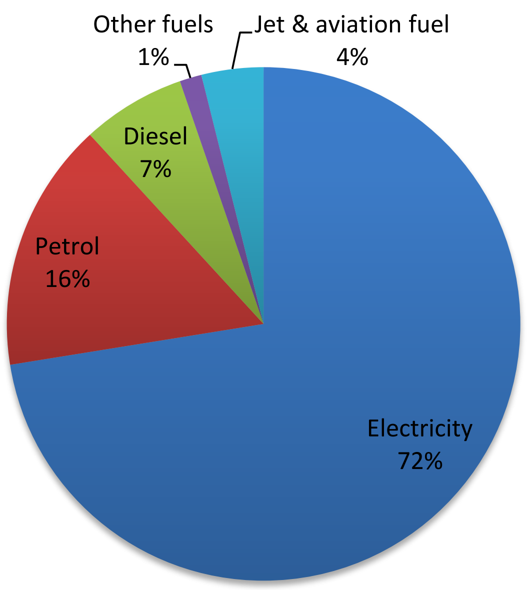


Figure 5: Johannesburg's GHG emissions by fuel

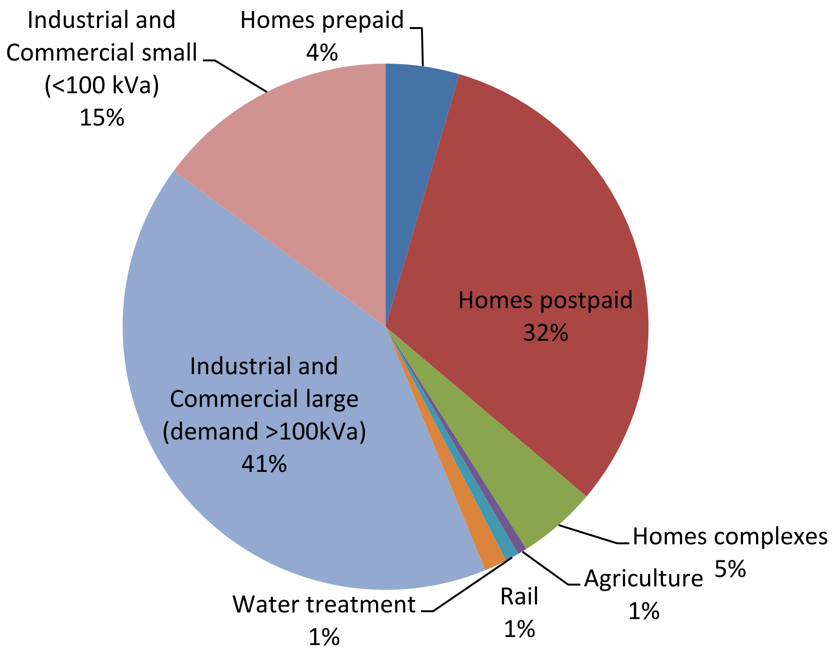


Electricity

4.11 Electricity is the primary source of energy and CO_2 emissions in Johannesburg. The vast majority of the Johannesburg's power is provided via City Power. City Power is the Electricity Distribution Service Provider to the Service Authority, Johannesburg Council. Its role is to purchase, distribute and sell electricity within its geographical footprint of business. The National Energy Regulator of South Africa (NERSA) granted City Power a license to trade in 2001. The City of Johannesburg is the sole Shareowner of the company.

4.12 City Power operates six independent networks which were the former Municipal Transmission Systems and provides electricity to over 385,000 points of delivery (82% of the City's electricity is provided through City Power). The majority (93%) of these delivery points are to domestic consumers. The majority of this power is purchased from Eskom one of the largest electricity companies globally and the remainder from the Kelvin Power Station. Eskom generates 95% of South Africa's electricity and nearly half of the electricity consumed in Africa. Eskom also provide electricity directly to 323,000 customers within the municipal boundaries of the City of Johannesburg. 96% of these customers are domestic and are spread north to south along the western boundary of the metropolitan area of Johannesburg.

Figure 6: Electricity consumption by sector



Electricity in homes

4.13 A total of 16.18 terra watt hours (TWh) of electricity were consumed by Johannesburg in 2007. Homes accounted for 6.7 TWh or 41% of the electricity consumption. The majority of domestic electricity consumption (77%) was by conventionally billed customers. 11% of electricity was consumed through pre-paid domestic meters and 12% to residential complexes. Table 7 below shows that electricity is the major source of energy used in homes for cooking (82%), heating (77%) and lighting (87%).

4.14 Nine out of ten households in Johannesburg now have access to electricity and there is a rolling programme of electrifying households, in 2012/13 a further 3,307 homes were connected to the electricity grid[1]. The City also continues to grow rapidly. The combined effect of a growing population and of increasing levels of electrification is likely to result in an increasing demand for electricity and place a greater strain on existing infrastructure.

[1] http://www.joburg.org.za/index.php?option=com_content&view=article&id=9014:increased-access-to-basic-services&catid=88:news-update&Itemid=266

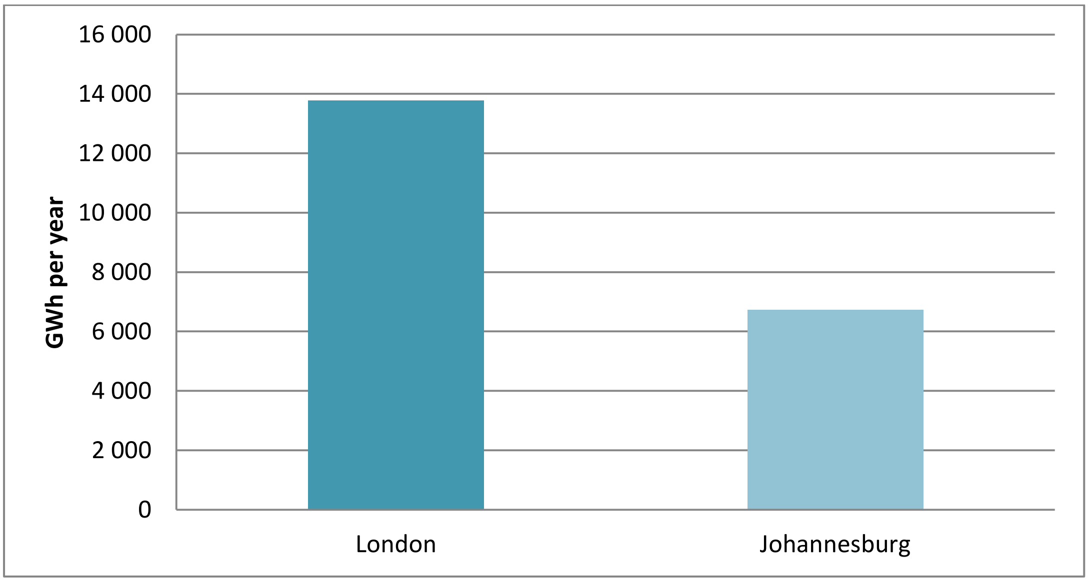
Table 7: Estimated energy source used for cooking, heating and lighting in Johannesburg

Energy type	Number of households					
	Cooking	**%**	**Heating**	**%**	**Lighting**	**%**
Electricity	1,039,541	82%	973,647	77%	1,097,130	87%
Gas	39,499	3%	83,656	7%	-	-
Paraffin	137,483	11%	101,345	8%	18,710	1%
Wood	11,636	1%	50,857	4%	-	-
Coal	6,124	0%	25,797	2%	-	-
Solar	-	-	-	-	1,534	0%
Candles	7,043	1%	2,948	0%	123,914	10%
Other	22,352	2%	25,428	2%	22,390	2%

Source: Adapted from the SA Statistics General Household Survey, 2012

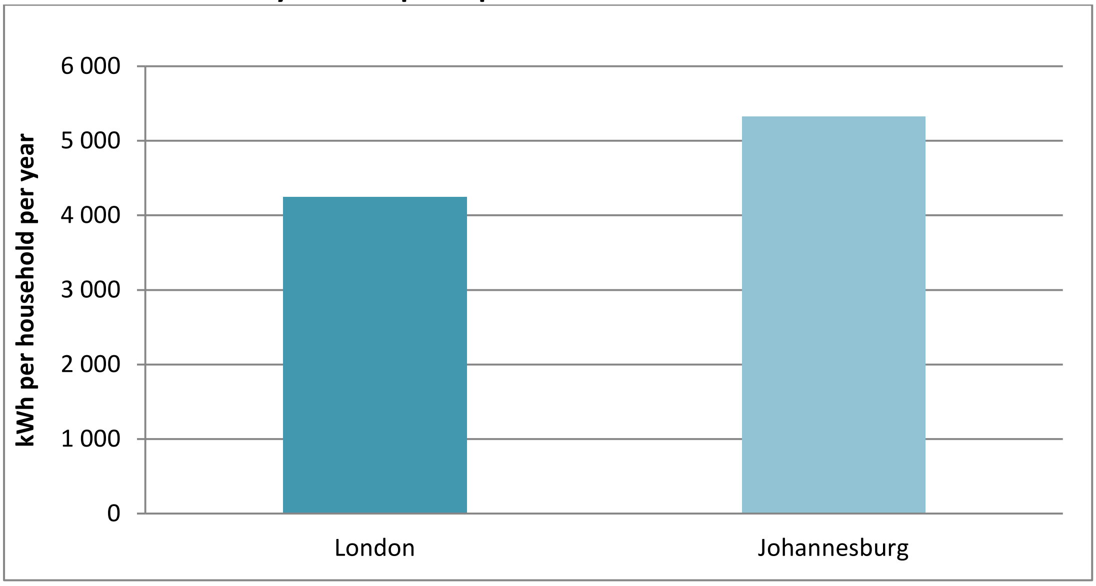
4.15 Figures 7, 8 and 9 show the consumption of electricity in Johannesburg in comparison to London. Figure 7 shows the total amount of electricity consumed by London's households was twice as much as Johannesburg. This of course is principally a reflection of the greater number of households in London. London's 3.2 million homes consumed a total of 13,776 GWh of electricity a year compared with Johannesburg's 1.2 million homes which consumed 6,730 GWh.

Figure7: Total electricity consumption in homes



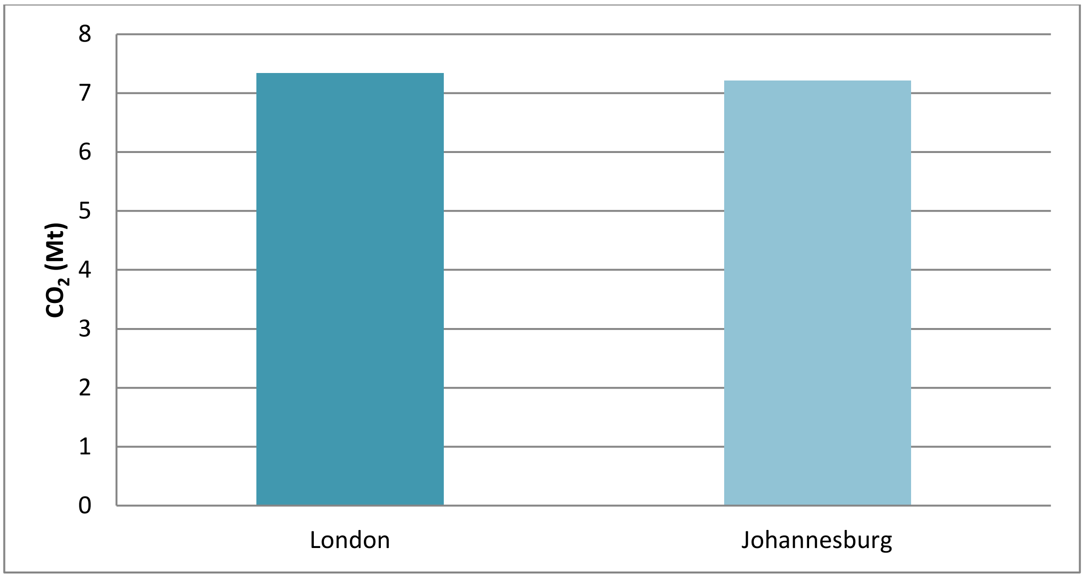
4.16 Figure 8 shows that when electricity use per household is compared, Johannesburg uses 5,326 kWh per household. This is slightly higher than electricity consumption per household in London which was 4,247 kWh per year. This reflects the greater reliance on electricity within Johannesburg for cooking and heating. Around four out of five homes use electricity for cooking and heating in Johannesburg. Most London households use gas for cooking and heating (which in turn account for 80% of energy use in London's homes). London's total residential consumption of gas was 44,701 GWh, over three times its use of electricity.

Figure 8: Domestic electricity consumption per household



4.17 Figure 9 shows that despite the total electricity use in Johannesburg being less than half of London's the CO_2 emissions of both cities is equivalent, with both producing just over 7 million tonnes. This illustrates the importance of reducing emissions from electricity in Johannesburg.

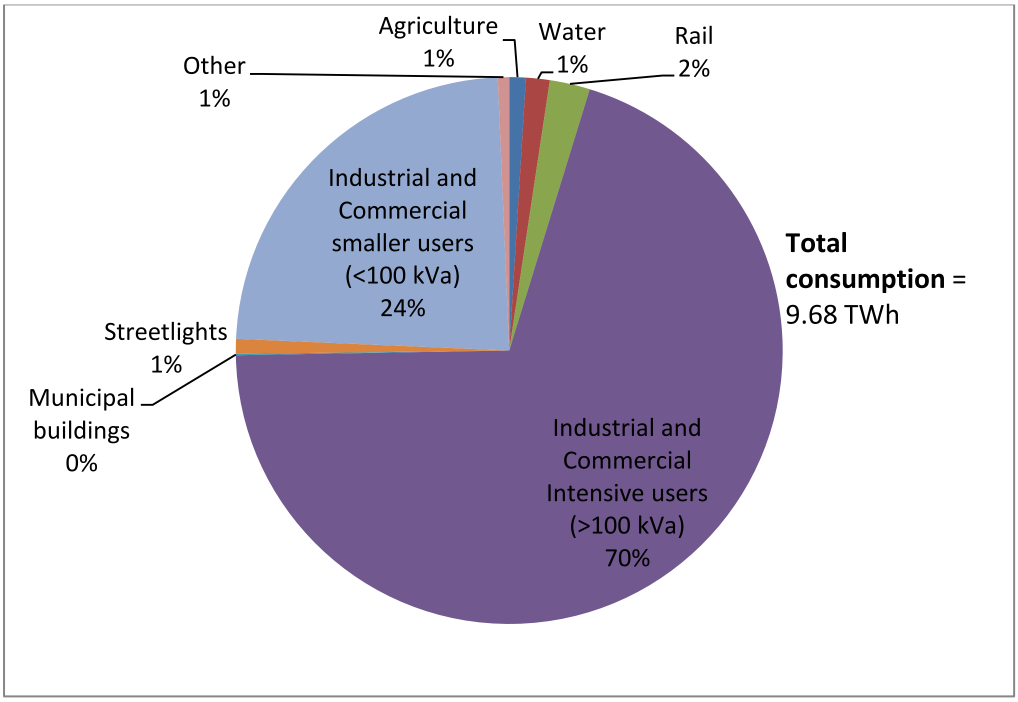
Figure 9: CO_2 emissions from domestic electricity consumption



Electricity in the commercial and industrial sector

4.18 The majority (59%) of Johannesburg's electricity consumption was from the commercial and industrial sector. In total Johannesburg's businesses and industry consumed 9.68 TWh of electricity in 2007. The largest proportion was used by high demand (>100 kVa) users of electricity (70%). Smaller commercial and industrial users (<100 kVa) used 24% of the sectors total electricity. Water treatment accounted for 1% and the City's Metrorail and Inter-city rail services 2%. The City's streetlights[iv] (account for around 1% of commercial and industrial electricity use.

Figure 10: Commercial and industrial electricity consumption



Other fuels in stationary applications

Paraffin

4.19 Table 7 shows that after electricity, paraffin is the second most prevalent source of energy for cooking and heating. Over 100,000 homes are estimated to use paraffin for both cooking and heating. A small proportion of households also use paraffin for lighting. Despite the health and safety risks, paraffin tends to be used by lower-income households as it is readily available and relatively cheap fuel source.

4.20 An estimated 1,922 TJ of paraffin is consumed in Johannesburg's homes, accounting for over 1% of energy and 0.5% of CO_2 emissions.

Natural Gas

4.21 Egoli Gas is the only company delivering natural gas to households, businesses and industry in Johannesburg via a distribution network. The company serve around 7,500 domestic, commercial and industrial customers in the City[v]. In 2006/07 97,000 gigajoules of energy were used by individual households and 142,000 gigajoules in multiple occupancy dwellings. In addition 1,451,000 gigajoules of gas were consumed by the industrial/commercial sector.

Coal

4.22 There was very limited information available on the use of coal in Johannesburg. Coal is still used by some households for their energy needs in parts of Johannesburg. Using the 2012 General Household survey it was estimated that almost 26,000 homes use coal for heating and just over 6,000 for cooking. It is estimated that 42,000 tonnes of coal were used in homes in the City in 2007 and that it accounted for 1,023 terajoules of energy.

4.23 No reliable information was available for coal use within the commercial and industrial sector, so it has not been included in the inventory.

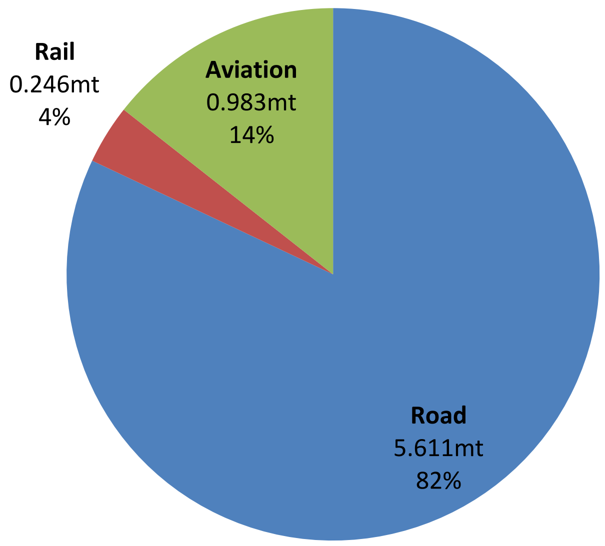
Other stationary fuels

4.24 Estimates were made of furnace oils and LPG use in the commercial and industrial sector. This estimate was based on fuel sales records. However both were not significant, accounting for 76 terajoules of energy each (0.05%) and 0.02% of emissions from energy.

Transport

4.25 The majority of Johannesburg's transport emissions come from road transportation (82%) – the majority of fuel use is estimated to be from private cars and minibus taxis within the City. Aviation accounts for 14% and rail 4% as set out in Figure 11.

Figure 11: Transport emissions by type (CO_2e million tonnes)



Road transportation

4.26 2.3 billion litres of diesel and 4.23 billion litres of petrol were sold in Gauteng in 2007[vi]. Johannesburg's fuel sales in 2007 were not available. Fuel sales in 2007 were estimated based on the proportion of sales in Gauteng that were within Johannesburg in 2010. Using this method it is estimated that in 2007 Johannesburg purchased 1.713 billion litres of petrol and 615 million litres of diesel.

4.27 Fuel sales data was used to estimate emissions in the City as no reliable transport survey data was available for travel distance, routes, vehicle modes or types to make a travel distance estimate of emissions. In addition no survey data was available to determine the proportion of in-boundary, cross-boundary and regional trips, so no split between scopes 1 and 3 was made.

4.28 Overall emissions from road transport were estimated to be 5.58 million tonnes of CO_2e. Of which 3.96 million tonnes were from petrol and 1.65 million tonnes from diesel.

4.29 Figure 12 shows the number of registered vehicles in Johannesburg in 2013. The majority of the 1.5 million registered vehicles were cars (68%). Using HBEFA estimates of vehicle mileage and fuel efficiency per vehicle type, suggests that cars could be responsible for around 43% of the fuel consumed in road transportation. Despite the small proportion of minibus taxis registered (3%) they could account for 14% of fuel consumption. Heavy load vehicles account for around 3% of registered vehicles and are estimated to account for almost 25% of fuel consumption. These figures need to be treated with caution as they are estimates, but they do illustrate the potential scale of impact of different vehicle categories in the City.

Figure 12: Licensed vehicles in Johannesburg 2013

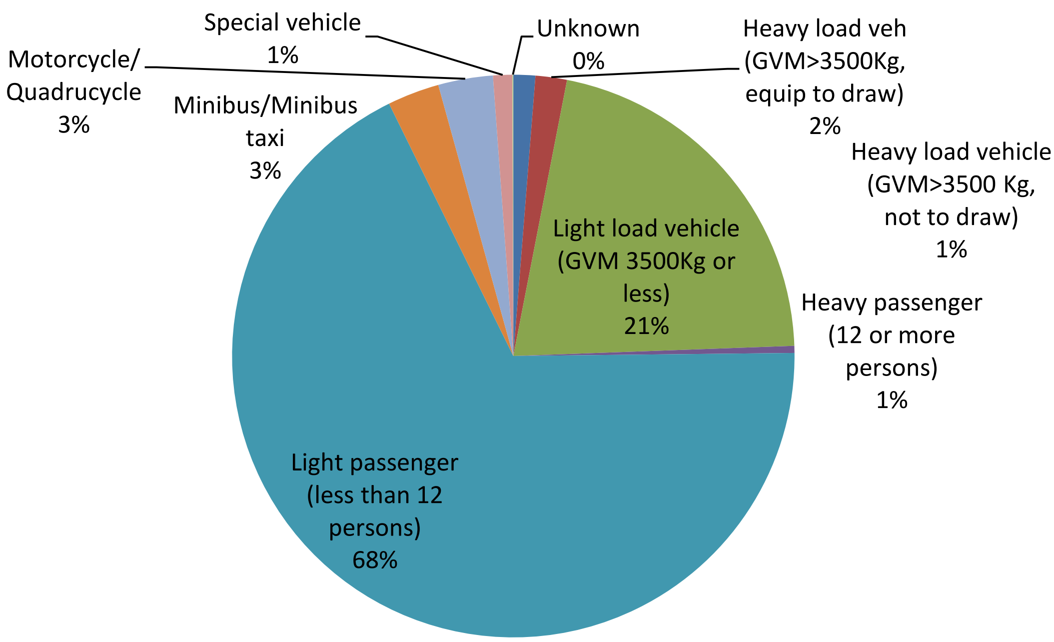
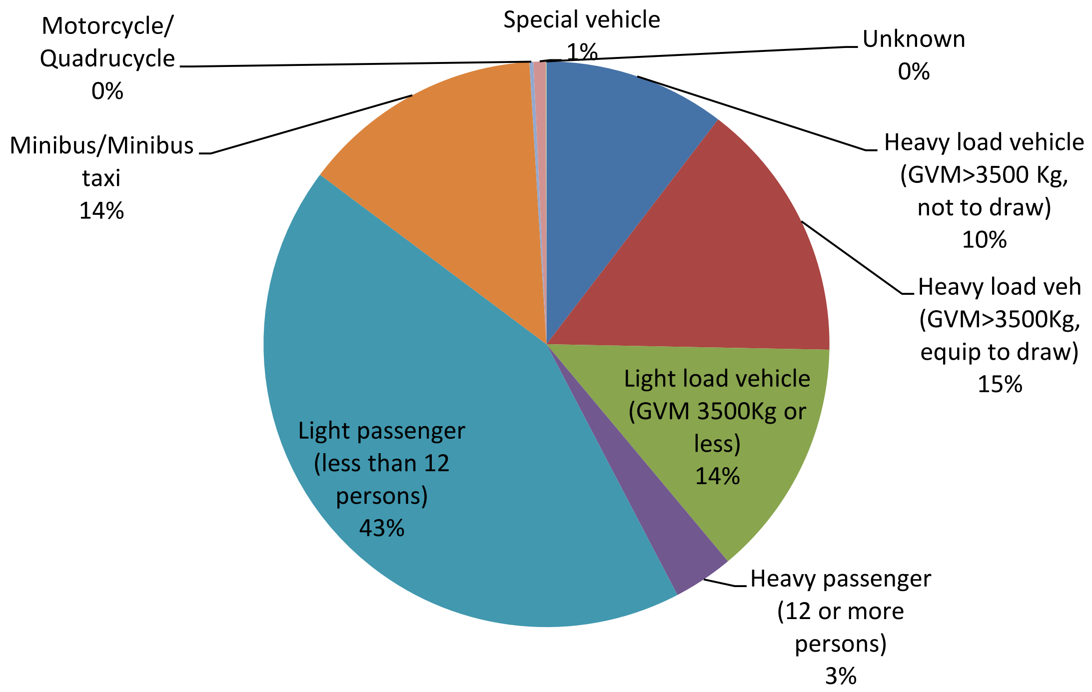


Figure 13: estimated fuel use in Johannesburg in 2013



Aviation

4.30 In line with the GPC methodology, emissions from airports within the boundary of the City were calculated. This means that no estimation was made of emissions from the OR Tambo International Airport, which lies just beyond the city's boundaries but serves Johannesburg. Emissions were calculated for Lanseria Airport on the western boundary of the city.

4.31 Lanseria Airport is a privately operated airport, which flies inter-city services. Around 36 flights to and from both Cape Town and Durban arrive every day. Based on sales of jet and aviation fuel within Johannesburg emissions from aviation were estimated to be 983,000 tonnes of CO_2e.

Rail

4.32 The intra-city services (Metrorail) accounted for the majority of rail emissions. Metrorail operates twelve corridors. Over 243,000 trips were made within the year with a total distance of 10,283,435 km. All Metro-rail corridors within Johannesburg are electrified. Metrorail services accounted for 246,089 tonnes of CO_2e.

4.33 In addition Inter-city services run to and from Cape Town, Durban, Port Elizabeth, East London, Komatipoort and Musina. Just under 50 services arrive or depart from Johannesburg weekly. All lines are electrified, with the exception of a small portion of the route between Johannesburg and Port Elizabeth, where trains operate on diesel. The total vehicle km travelled in 2007was estimated to be 2,518,496 km, of which 2,428,016 km were powered by electricity and 90,480 by diesel. Johannesburg's apportionment of emissions was based on the number of stops within the city versus the total number of stops per route. 812 tonnes of CO_2e were allocated to Johannesburg on this basis.

Waste and wastewater treatment

Waste management

4.34 Municipal Waste in Johannesburg is managed through the City's waste agency Pikitup, which – like other utility services - is established as a separate company under the Municipal Systems Act. The City government has entered into a Service Delivery Agreement (SDA) with each of these companies to operate specific municipal services in the city. This SDA includes the entity's functions and obligations, service standards, five-year business plan, and performance and development targets.

4.35 In 2007 Pikitup managed a total of 1.803 million tonnes of municipal waste. 1.745 million tonnes (97%) were disposed in one of the city's four landfill sites, Robinson Deep, Ennerdale, Goudkopies and Marielouise. In addition 400 tonnes were incinerated at the City's Springfield/Robinson Deep incinerator, which was decommissioned in September 2009. Pikitup also composted 57,664 tonnes of green waste in 2007/08, accounting for 3% of the waste managed in the City.

Table 9: Waste management in Johannesburg 2007

Management method	Tonnes
Robinson Deep landfill	510,417
Ennerdale landfill	185,153
Goudkopies landfill	308,179
Marielouise landfill	741,758
Landfill sub-total	**1,745,507**
Incineration	**400**
Composting	**57,664**
Total	**1,803,571**

4.36 In 2007 no methane gas from the landfills was captured either for flaring or energy generation. Emissions from the four landfills were calculated based on the tonnes of waste buried in 2007. The calculation includes an estimate of emissions from that waste in future years (future downstream commitment). Landfill accounted for 99% of CO_2e emissions from waste management. The total calculated emissions from landfill were 1.786 million tonnes of CO_2e. In total 1.803 million tonnes of CO_2e were generated from waste management.

Wastewater treatment

4.37 Water is managed by Johannesburg Water an independent company formed in 2002. The City of Johannesburg is the sole shareholder of the company. Johannesburg Water operates in six regions with ten network depots and six wastewater treatment plants. The company supplies water and sanitation to approximately 750,000 domestic, commercial and industrial customers and serves an estimated consumer base of 3.8 million people. It reticulates water to consumers through a water network of about 11,000 km of distribution pipes and over 100 reservoirs and water towers. Johannesburg Water also collects wastewater through an 11,000 km wastewater network[vii].

4.38 In 2007 Johannesburg Water treated 331,021 mega liters of water at its six treatment works. The electricity consumption from wastewater treatment is accounted for in the electricity section of this report. Details of the six wastewater treatment plants are contained in Appendix 2. Wastewater treatment was responsible for 10,717 tonnes of CO_2e.

5. Moving forward – improving Johannesburg's Citywide inventory

5.1 This section explores some of the challenges around the City's greenhouse gas inventory. It identifies some priority areas for focus and some recommended actions to improve the quality of the greenhouse gas emissions inventory.

5.2 No city inventory is perfect. All cities have gaps in their data and have to make estimations of parts of their emissions inventories. The process of improving data quality and information can take time. Cities need to understand the weaknesses in their data to begin the process of addressing them.

5.3 This section sets out four broad areas of focus for Johannesburg in its efforts to improve its inventory. These are set out below and discussed in more detail in the section.

1. Establish good governance arrangements for data collection within the city
2. Identify and engage the right stakeholders
3. Identify resources to support the inventory
4. Prioritise improving data in the most significant sectors

Establish good governance arrangements for data collection within the city Establish governance arrangements for data collection in the City

5.4 The City should decide how it intends to lead the collection and publication of a city-wide inventory in the future. The following actions should be considered

a. A lead officer with responsibility for producing the City's greenhouse gas emissions inventory should be identified. This person would be responsible for ensuring that systems are in place to collect and produce an annual assessment of the City's emissions.
b. Johannesburg should ensure that there is senior support for the initiative to ensure that barriers to gathering and using data are overcome. This was particularly important in pulling together this Inventory in such a short period of time.
c. The City should commit to reporting its emissions annually to either the City Manager, or a senior body to ensure that progress towards tackling emissions is mainstreamed within the City. This would align with Climate Change being a key theme of Johannesburg 2040 Growth and Development Strategy.
d. Establish a small group of named officials within City departments, City utilities and other relevant bodies with responsibility for producing clear and agreed datasets that feed into the inventory and to an agreed timetable.
e. Review existing data sets and reporting cycles and identify an appropriate annual cycle for producing the Inventory.
f. Identify key projects and programmes that the City and other stakeholders manage that need to be reported as part of the Inventory. Establish and agree data that should be collected annually in relation to these programmes.

Identify and engage the right stakeholders

5.5 There are a number of players with an interest in improved data within Johannesburg and the Guateng region. These include

i. Guateng Provincial Government
ii. South Africa Government – Department for Energy, Department for Environmental Affairs
iii. Statistics South Africa
iv. University of Johannesburg

v. CDP
vi. Trade associations e.g. SAPIA
vii. Utilities

5.6 The City should develop a stakeholder map of all relevant organisations that could input into the citywide inventory. They should continue to have discussions with stakeholders to ensure there buy-in and agree their roles in the process.

5.7 As part of this engagement the City should explore opportunities for the improved pooling of data and information or the possibility of jointly commissioning of research to support common goals and share the costs. The City should also explore the possibility of partnering with academic institutions and their student faculty to support specific research to improve data quality.

Identify resources to support the inventory

5.8 The City of Johannesburg should consider how it can secure resources to support additional research and development in areas where existing data is not available or insufficient. The City could consider leading a bid for support from an appropriate funding pot such as the SA Green Fund, managed by the Department for Environmental Affairs.

Prioritise improving data in the most significant sectors

5.9 This section deals with areas where no information is currently available and also areas of the Inventory where data has been estimated but needs to be improved further.

a. Missing data

5.10 The Johannesburg inventory has some gaps in data that the City should look to address over time. Three main areas were not included in the Inventory due to a lack of information. There are three major gaps in information discussed below

- Industrial Process and Product Use (IPPU)
- Agriculture, Forestry and Other Land Use (AFOLU)
- Commercial coal use

1. Industrial Process and Product Use (IPPU)

5.11 IPPU captures emissions from non-energy related industrial activities and product use.

<u>Industrial Processes</u>

5.12 In terms of industrial processes the major industrial processes which generate non-energy related emissions are set out below in Table 10. As an example cement production produces CO_2 as a consequence of the chemical conversion process used in the production of clinker, a component of cement, in which $CaCO_3$ is converted to lime (CaO). Manufacturing accounts for 20% of GVA in Johannesburg. Emissions from IPPU are therefore likely to be a significant source of emissions which are not accounted for.

5.13 To address IPPU emissions the City should identify if any of the activities described in Table 10 occur within the City's boundaries. A starting point may be through working with CDP to identify significant players in these industries. Alternatively the City could work with relevant Industry Associations or the Johannesburg Development Agency. National government departments may also hold data related to industrial activity at the local level.

5.14 Actual or estimated activity data (amount of material manufactured/produced) will be needed to estimate the GHG emissions from processes. Useful summaries of the calculation methodologies for most of these sectors are available through the GHG Protocol website (set out below).

Table 10: Manufacturing processes producing significant non-energy GHG emissions

Sector	Process	Calculation tools and methods	Possible sources
Mineral products	Cement production	http://www.ghgprotocol.org/calculation-tools/cement-sector+	SA Department of Mineral Resources, Association of Cementitious Materials Producers (ACMP)
	Lime production	http://www.ghgprotocol.org/calculation-tools/lime-sector	SA Department of Mineral Resources
	Glass production	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_2_Ch2_Mineral_Industry.pdf	SA Department of Mineral Resources
Chemical Industry	Ammonia production	http://www.ghgprotocol.org/calculation-tools/ammonia	
	Nitric Acid production	http://www.ghgprotocol.org/calculation-tools/nitric-acid	

	Adipic Acid production	http://www.ghgprotocol.org/calculation-tools/adipic-acid	UN Stats Division
	Petrochemical and Carbon Black production	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_3_Ch3_Chemical_Industry.pdf	SA Calcium Carbide, SAPIA
Metal Production	Iron and steel production	http://www.ghgprotocol.org/calculation-tools/iron-and-steel-sector	South Africa Iron and Steel Institute, SA Department of Mineral Resources
	Aluminium production	http://www.ghgprotocol.org/calculation-tools/aluminum	SA Department of Mineral Resources
	Magnesium production and casting	http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/3_Volume3/V3_4_Ch4_Metal_Industry.pdf	SA Department of Mineral Resources

Product Use

5.15 As well as emissions from the manufacture of particular materials and products, the use of products in non-energy use applications can result in significant GHG emissions in cities. Some of the main contributors are set out in Table 11.

5.16 There is currently no estimate of emissions from product use within the South Africa Greenhouse Gas Inventory. This is often used by cities to make an estimate of their apportionment of these emissions. The City should explore working with national departments and other interested local government departments to commission research to estimate emissions from product use.

Table 11 Sources of non energy related emissions from product use

Product	Uses
Lubricants	Transportation and industry
Paraffin waxes	Candles, corrugated boxes, paper coating, board sizing, adhesives, food production and packaging
Bitumen, road oil and other petroleum dilutants	Transportation
White spirit, kerosene and other	Painting, dry cleaning

aromatics as solvents	
Nitrous oxide	Propellant in aerosol products, medical applications

2. Agriculture, Forestry and Other Land Use (AFOLU)

5.17 No estimate has been made of emissions and removals from AFOLU. AFOLU accounts for anthropogenic GHG emissions and removals by sinks in six managed land categories.

- Forest land
- Cropland
- Grassland
- Wetlands
- Settlements
- Other lands

5.18 Johannesburg should work with South Africa Department of Environment Affairs to acquire activity data obtained from the country's national inventory, in order to calculate AFOLU emissions.

3. Commercial Coal Use

5.19 No estimate of coal consumption in the commercial and industrial sectors were calculated in the inventory. Johannesburg should look to identify potential partners such as trade associations or government to develop an estimate of coal used in the city.

b. Improving the quality of data

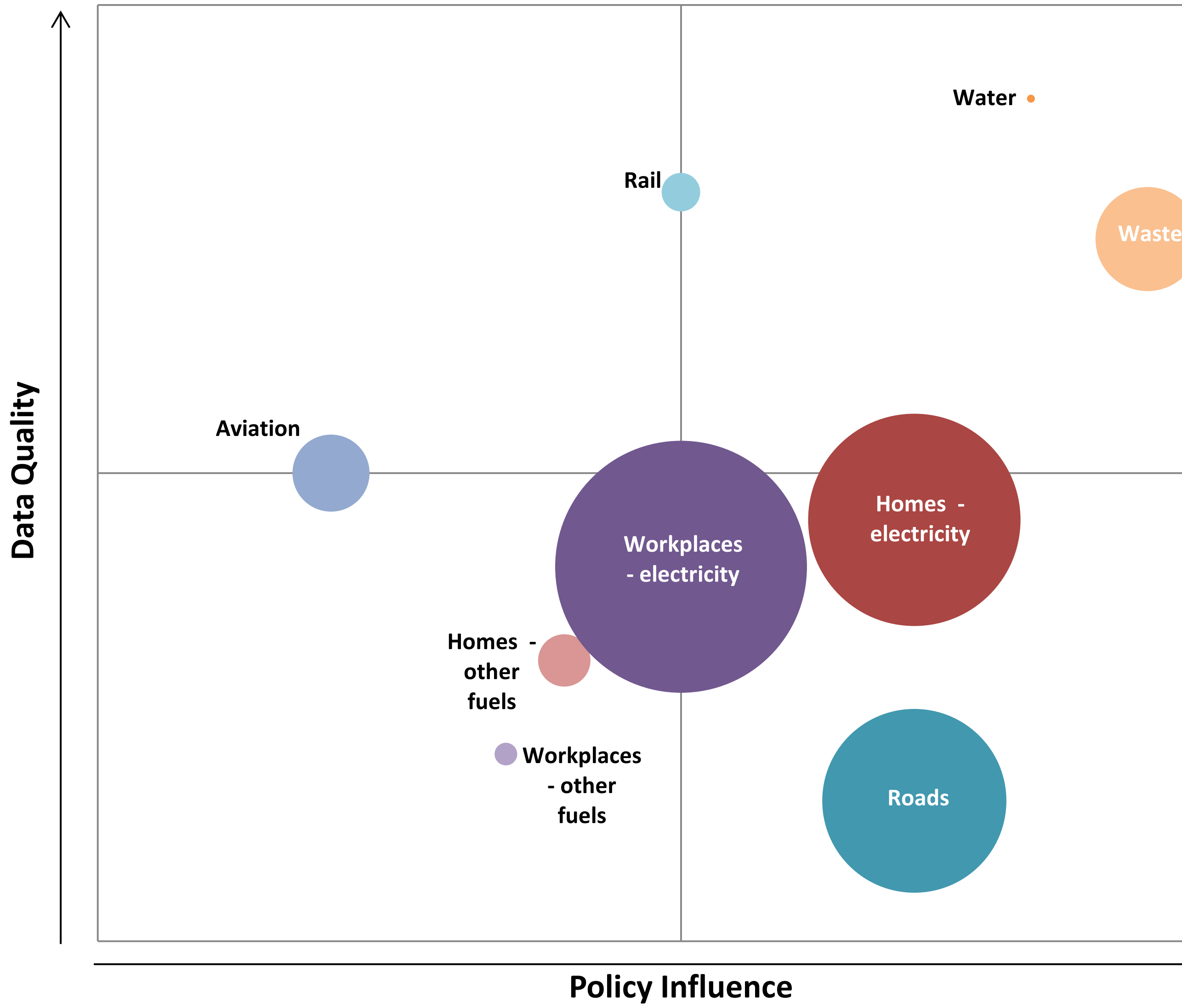
5.20 Figure 14 indicates the importance of different sectors to Johannesburg's total CO_2 emissions. The size of the circle represents the tonnes of CO_2e from each sector. The sectors are mapped against data quality and the City's ability to influence through policy and programmes the sector. This gives an indication of the sectors where improvements in data quality would have most impact.

5.21 On this basis there are three main priority areas for immediate focus of data improvement

i. emissions from electricity in homes
ii. emissions from electricity in workplaces
iii. and emissions from road transport.

5.22 Improving data quality in these areas will enable a greater understanding of the sources of emissions and ways in which they can be reduced.

Figure 14: Greenhouse gas emissions by sector, data quality and policy influence in Johannesburg



Electricity activity data

5.23 As electricity accounts for over 72% of Johannesburg's reported GHG emissions, the priority focus should be on improving the consistency of data collected, its quality and the depth of information available. Activity data for electricity was gathered from City Power and Eskom. The majority of the cities electricity is provided by City Power.

Technical losses from electricity transmission and distribution

5.24 The estimates of technical losses provided by City Power and Eskom are significantly different. Eskom estimated the technical losses to be 4% whilst City Power's estimate is 9%. The City should work with City Power and Eskom, to examine why the estimates of technical losses vary so greatly between the two organisations. The City should encourage the two companies to adopt a similar methodology for calculating their losses in the City of Johannesburg.

Non-technical losses

5.25 No estimate of non-technical losses was made in the Johannesburg Inventory. However this is identified as in issue in the City. Non-technical losses are generally caused by human elements. These include consumption losses, where energy is consumed but missing from billing systems or billing losses as a result of incorrect metering data. Illegal connections to the electricity network are the main source of non-technical losses[viii]. City Power and Eskom should ensure that these losses are accounted for in their annual reporting and reported separately within the data set.

Reporting sub-sectors

5.26 Both Eskom and City Power report electricity consumption by different sub-sectors as set out in Table 12. The City should work with its partners to agree a consistent and useful sub-sets of consumption data. In addition The City and its electricity suppliers should work together to try and provide greater detail of significant electricity users within the commercial and industrial sector. Having this level of detail will help the City identify sectors and businesses it could prioritise in any city-wide reduction plans.

Table 12: Electricity consumption sub-sectors

City Power electricity consumption sub-categories	Eskom electricity consumption sub-categories
Time of Use Tariff (Medium Voltage)	Commercial
Time of Use Tariff (Low Voltage)	Industrial
Large power users (Medium Voltage) => 100 kVa	Mining
Large Power Users (Low Voltage) => 100kVa	Public lighting
Commercial conventional billing	Agricultural
Commercial prepaid	Traction
Agricultural	Internal sales
Commercial Complexes	Domestic conventional billing
Domestic Complexes	Domestic prepaid
Domestic conventional billing	
Domestic prepaid	

5.27 Additionally the City should work with its electricity suppliers to further understand how electricity is used within Johannesburg's housing stock and commercial buildings.

Electricity generation

5.28 As more and more micro-generation is installed in the City, it will become increasingly important to include this within the inventory. The City should discuss with Eskom and City Power how it might capture this data in future years.

Road Transport

5.29 Road transportation is a significant source of emissions in Johannesburg, accounting for as much as 22% of the City's reported emissions. It is also an area that the City has direct influence over. It already has a number of initiatives in place to increase the use of public transport in the city.

5.30 Fuel sales data was used to estimate the emissions from Johannesburg's road transport. No data was available for vehicle kilometres travelled by vehicle class or for the age. In addition no survey data was available to determine the number of in-city boundary trips and cross-boundary trips. This creates the following challenges and issues

- It assumes ALL fuel purchased within the City's boundaries is consumed within the boundaries of the City
- It does not account for consumption within the City by vehicles making fuel purchases outside of the City.
- The estimate of fuel consumption by vehicle class is not actionable
- No differentiation in scope 1 and scope 3 emissions was possible.

5.31 The GPC outlines four methodological approaches to estimating CO_2 emissions from transport. These are set out below.

Table 13: Different methods for assessing GHG emissions from transport

Method	Description	Benefits	Disbenefits	Comments
Travel Distance Approach	Emissions calculated based on travel distances of all relevant trips	• Detailed and Actionable • Assign via scopes	• Requires transport demand model and data. • Costs	Most accurate. It requires surveys to obtain data on travel distance, routes, vehicle modes, and vehicle

			• Resource intensive • High level of technical capacity	types.
Fuel sales approach	Estimates made based on the amount of fuel sold in the city.	• Costs • Less time consuming • Low technical capacity	• Less accurate in allocating emissions by Scope • Data less actionable	• Fuel sale data Require surveys to determine the proportion of in-boundary, cross-boundary trips, and regional transits
Resident traffic approach	Calculate emissions based on the total vehicles garaged within the city boundary	• Costs • Less time consuming Low technical capacity	• Less accurate in allocating emissions by Scope • Data less actionable	• Total vehicles by type garaged in the city boundary (this can be obtained through road tax data or household surveys) • Travel distance or fuel consumption of each type of vehicles Surveys to determine the proportion of in-boundary and cross-boundary trips
Vehicle Ownership Approach	Calculate emissions based on where the vehicles are registered/purchased	• Costs • Less time consuming Low technical capacity	• Less accurate in allocating emissions by Scope • Data less actionable	• Total vehicles by type registered in the reporting city • Travel distance or fuel consumption of each type of vehicles Surveys to determine the proportion of in-boundary and cross-boundary trips

5.32 The City of Johannesburg should look to explore opportunities to develop a travel distance approach with the Johannesburg Road Agency and other transport agencies in the Guateng region.

5.33 In the meantime the following improvements could be made to the fuel sales approach adopted.

5.34 The City should look to work with other authorities to determine the proportion of in-boundary, cross-boundary trips, and regional transits. This should ideally be captured by vehicle type. The City could look to commission work jointly with other interested parties such as the Guateng Provincial Government and other City/Regional Governments in the province. Without such survey data it is not possible to estimate the scope 1 and scope 3 split of emissions from fuel use.

5.35 The City should ensure that it report consistently on public transport emissions in Johannesburg. Varying levels of information where available for different public transportation services. The best example of good quality data was from the Rea Veya (BRT), which included the following information.

a. Routes
b. Number of buses
c. Age of buses, engine type and fuel type
d. Fuel economy of Artic buses and complimentary/feeder buses
e. Kilometers travelled per week
f. Liters of fuel used per year

5.36 As the Reya Vaya was rolled out after 2007, this data was not used in the Inventory. However efforts should be made to ensure a similar level of information is collected for other bus services. Whilst good levels of data were available for routes and kilometers travelled, no data related to fuel consumption, fuel efficiency or engine types, vehicle age were provided. Similar data should be collected for other municipal services provided by the City or its agencies where they have significant vehicle fleets (such as Pikitup or Johannesburg Water).

6. Conclusion

6.1 There is an appetite within the City of Johannesburg and many of its agencies to calculate the emissions within the city and develop a method for data collection and capture.

6.2 This provides an opportunity to formalise arrangements for data collection across government and non-government agencies. Formalising these arrangements will also lead to improvements in data, as weaknesses can be identified.

6.3 Having a method for collecting data, senior support and a programme of identified and agreed actions to improve data quality will bring a number of benefits to the City

- Greater confidence in data and impacts of activities the City are undertaking.
- The ability to develop programs and policies to tackle major sources of emissions
- The ability to monitor the impact of existing programs and review their performance
- Greater confidence for decision makers and funders in the impacts of projects and programs.

- Improvements in communicating with residents and businesses in the City around climate change and associated programs.

Appendices

Appendix 1: GPC draft Guidance

To be included

Appendix 2: Johannesburg Methodology Report

Figure A2.1 shows how the Johannesburg greenhouse gas emissions inventory workbook has been structured. Worksheet tabs are colour coded in the workbook - the following colour coding is used in the spreadsheet.

Yellow tab	=	GHG Emissions Summary
Red tab	=	Background information, assumptions and emission factors
Blue tab	=	Sector and Activity worksheets

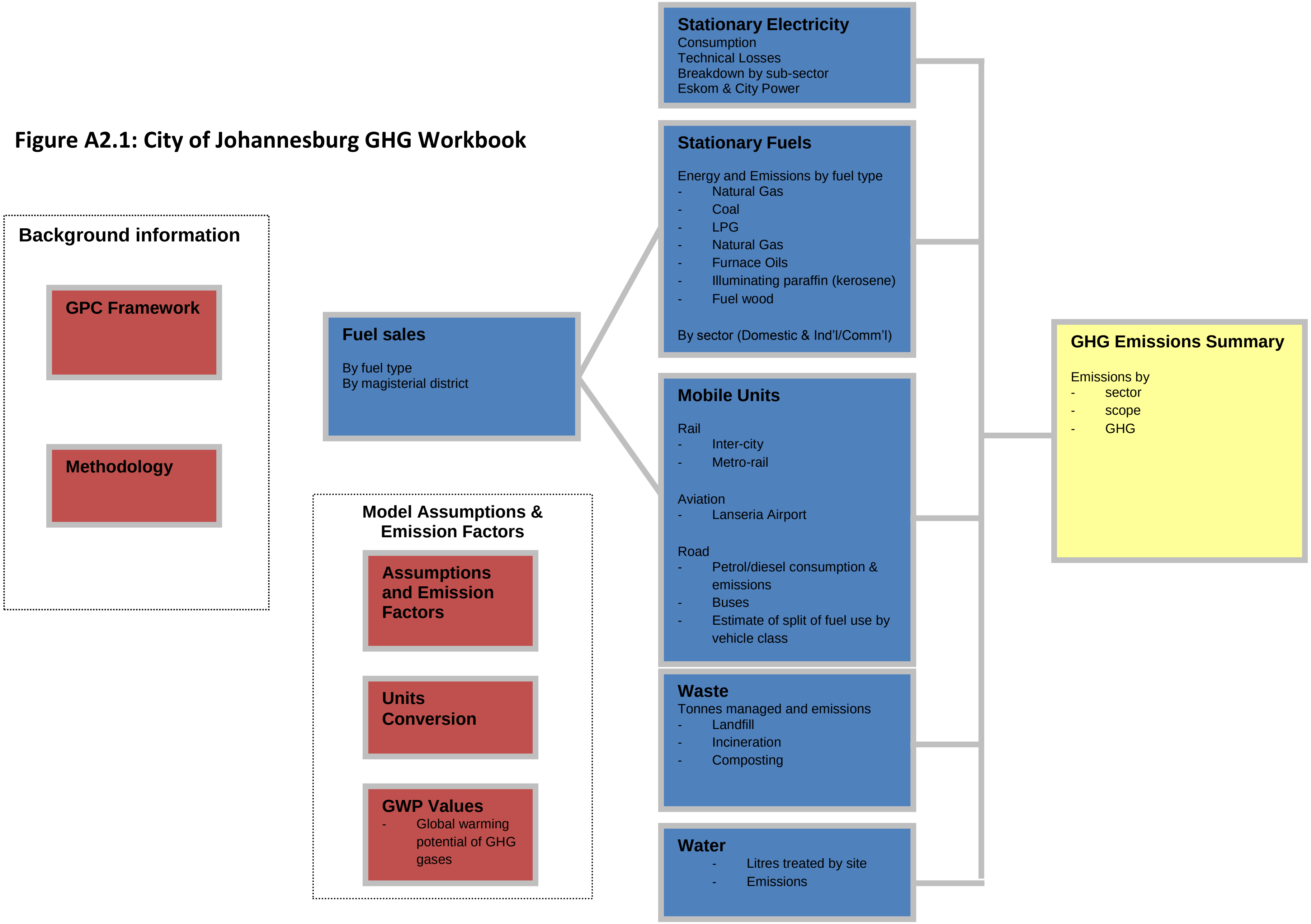


Figure A2.1: City of Johannesburg GHG Workbook

Reporting Level

Reporting Level	**BASIC** or **BASIC+**
Why choosing this level?	**BASIC+** The decision was made based on the data available. Enough transport information was available on aviation and rail to make this possible. This coupled with good information on fuel sales (but a low understanding of cross-boundary trips) made Basic + more appropriate (as it captures scopes 1,2 & 3 for transportation). However not all aspects of the GPC were reported on due to a lack of data in some areas (AFOLU and IPPU).
Emission factors	All emission factors used within the model are contained within the 'Assumptions & Emission Factors' Spreadsheet within the model. Unit conversions are set out in the 'Units conversions' spreadsheet All assumptions spreadsheets (including the GWP for different GHG's) are marked with a red tab within the spreadsheet.
Structure of model	The overall CO2 emissions by sector, by GHG gas, by scope for the City are summarized in the spreadsheet 'GHG Emissions Summary' which is coded with a yellow tab. The summary also converts all GHG gases into CO2 equivalent (CO2e). The 'GHG Emissions Summary' spreadsheet is driven by the following spreadsheets highlighted with a blue tab in the workbook • Stationary Fuels • Electricity • Waste • Wastewater • Mobile Units • Fuel Sales

I. Stationary Units

I.1 Residential Buildings

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	The following fuels were accounted for in residential buildings • Fuel wood • Coal • Natural gas • Illuminating paraffin **<u>Fuel wood</u>** As emissions from fuel wood are biogenic, in line with GPC guidance they are not included in the Emissions Inventory for the City. However for completeness an estimate of fuel wood used as a source of energy has been made for the City – but the emissions have not been included. The estimation of firewood used was based on the '*Assessment of the Gauteng Firewood Market and the Origin of Protected Tree Firewood Products Sold 2007'* The energy content of fuelwood was calculated based on work undertaken by http://www.sparknet.info/ an interdisciplinary interactive Knowledge Network focusing on energy for low-income households in Southern and East Africa. **<u>Coal</u>** An estimate of the number of households using coal for cooking and heating was made based on the Stats SA 2011 Community Survey for Guateng. The same proportion of homes using coal for heating and cooking was then applied to the City of Johannesburg. Coal use per home was assumed to be 136kg per month, based on data from the Department of Minerals and Energy collected as part of the Basa Njengo Magogo (BNM) project. 2012 Defra GHG Conversion factors (https://www.gov.uk/government/publications/2012-greenhouse-gas-conversion-factors-for-company-reporting) for domestic coal was used to calculate emissions of CO_2, N_2O and CH_4. **<u>Natural Gas</u>** Natural gas (Sasol gas) is distributed in Johannesburg via the Egoli gas reticulation system. Egoli gas is the sole licensed provider delivering to around 7,500 customers in the City. No gas consumption data was provided by Egoli gas. However gas data was provided for 2006/07 for the City of Johannesburg State of Energy Report 2008. These consumption figures were used in the Inventory. 2012 Defra GHG Conversion factors for natural gas were used to calculate emissions of CO_2, N_2O and CH_4. **<u>Illuminating Paraffin (kerosene)</u>** An estimate of the number of households using Illuminating paraffin for cooking and heating was made based on the Stats SA 2011 Community Survey for Guateng. The same proportion of homes using Illuminating paraffin for heating and cooking was then applied to the City of Johannesburg. Estimates of litres of fuel used per home were based on ERDC work into Energy in low income homes 'Energy Services in low-income urban South Africa: A quantitative assessment, ERDC, 1996'. 2012 Defra GHG conversion factors were used for calculating CO_2, N_2O and CH_4 emissions.

Scope 2	Electricity consumption data was made available from City Power and Eskom. The data for households was provided broken down by - Pre-pay customers - Conventional payment customers - Residential complexes Eskom data was made available for 2009, 2010, 2011, 2012, 2013. Electricity consumption for those years was fairly similar. 2009 figures were used as a proxy for 2007. City Power provided annual energy consumption data for 2003 to 2011. A breakdown by sub-sector was provided for 2011. The same sub-sector breakdown was assumed for 2007. Eskom provided figures for their technical losses which were 4%. Technical losses for City Power were taken from City Power's Business Plan 2011-2016 and were 9%. Total electricity was calculated as consumption plus technical losses. A carbon intensity figure of 1.03 kg per kWh of electricity (Eskom 2001 Annual Report) was applied to the Total electricity figure. No estimate was made for non-technical losses (such as theft).

I.2 Commercial/Institutional Facilities

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	The following fuels were accounted for in commercial and institutional facilities. Industrial emissions were also aggregated with these as data was not sufficiently robust to breakdown further. • LPG • Natural gas • Furnace Oils • **<u>Coal</u>** No estimate for coal has been made in the inventory, as no reliable data could be identified to support an estimate. **<u>LPG</u>** SAPIA published fuel sales for the region of Guateng in 2007 including LPG. The estimate of Johannesburg's use of LPG was based on Fuel sales data for 2010, available from SA Department of Energy. Fuel sales are provided by magisterial district for the whole of SA. Both aggregated fuel sales for Guateng and Johannesburg were calculated. Johannesburg calculated from the magisterial districts of Johannesburg, Randburg and Roodepoort. 23% of the area of the Vereeniging magisterial district is also within the city boundaries. In the case of Vereeniging 23% of fuel sales were

	attributed to Johannesburg. The percentage of Guateng's fuel sales of LPG within Johannesburg in 2010 was calculated. The same proportion was then applied to estimate LPG sales in Johannesburg for 2007. 2012 Defra GHG Conversion factors for LPG were used to calculate emissions of CO_2, N_2O and CH_4. **<u>Furnace Oils</u>** SAPIA published fuel sales for SA in 2007. This was not broken down further. However the SA Department of Energy published data by magisterial district for 2010. The same methodology used for LPG was applied to estimate fuel use in Guateng and Johannesburg in 2007. The proportion of national fuel sold in Guateng and Johannesburg in 2010 was assumed for 2007. 2012 Defra GHG Conversion factors for Furnace Oils were used to calculate emissions of CO_2, N_2O and CH_4. **<u>Natural Gas</u>** Commercial gas use data was not provided by Egoli gas. However data was available for 2006/07 in the City of Johannesburg State of Energy Report 2008. 2012 Defra GHG Conversion factors for Furnace Oils were used to calculate emissions of CO_2, N_2O and CH_4.
Scope 2	Electricity consumption data was made available from City Power and Eskom (as set out in 1.1). Industrial electricity consumption was also included in this estimate, as the data provided did not allow for it to be broken day easily into commercial users and industrial users. The data for commercial/institutional and industrial electricity consumption was broken down into the following sub-sectors • Large Industrial and Commercial Users (demand of greater than 100kVa) • Wastewater treatment • Agriculture • Local authority buildings • Small Industrial and Commercial Users (demand less than 100kVa) Eskom data was made available for 2009, 2010, 2011, 2012, and 2013. Electricity consumption for those years was fairly similar. 2009 figures were used as a proxy for 2007. City Power provided annual energy consumption data for 2003 to 2011. A breakdown by sub-sector was provided for 2011. The same sub-sector breakdown was assumed for 2007. Eskom provided figures for their technical losses which were 4%. Technical losses for City Power were taken from City Power's Business Plan 2011-2016 and were 9%. Total electricity was calculated as consumption plus technical losses. A carbon intensity figure of 1.03 kg per kWh of electricity (Eskom 2001 Annual Report) was applied to the Total electricity figure.

	No estimate was made for non-technical losses (such as theft).
Scope 3	**N/a.** GPC Basic+ calculated.

I.3 Energy Generation

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	None in 2007.
Scope 2	None in 2007.
Scope 3	N/a. GPC Basic+ calculated.

I.4 Industrial Energy Use

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Included in 1.2 Commercial and Institutional Emissions. Data was not sufficient to breakdown further.
Scope 2	Included in 1.2 Commercial and Institutional Emissions. Data was not sufficient to breakdown further.
Scope 3	N/a. GPC Basic+ calculated.

I.5 Fugitive Emissions

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	**Not calculated.**
Scope 2	**Not calculated.**
Scope 3	**N/a**

II. Mobile Units (Transportation)

(Chapter 5 in Methodology Guide)

II.1 On-Road Transportation

Methodology Description

<table>
<tr><th colspan="2">Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences</th></tr>
<tr><td>Scope 1</td><td>Survey data was not available to obtain data on travel distance, routes, vehicle modes, and vehicle types.
Fuel sales data was available for diesel and petrol in Guateng in 2007. Johannesburg fuel sales data was available at the magisterial district level for 2010. Johannesburg was calculated from the magisterial districts of Johannesburg, Randburg and Roodepoort. 23% of the area of the Vereeniging magisterial district is also within the city boundaries. In the case of Vereeniging 23% of fuel sales were attributed to Johannesburg. The proportion of all fuels sales in Gauteng in 2007 that were in Johannesburg was calculated. This proportion was applied to the 2007 data for Guateng.

No survey data was available to determine the proportion of in-boundary, cross-boundary trips, and regional transits, so no estimate of scope 1 / 3 split made.

Registered vehicle data was made available for 2013 by the Johannesburg Road Agency. And some vehicle registration data available for 2009. For HGV's, HGV's equipped to draw and LGV's only 2013 was available. In these cases the 2009 registrations were estimated. The % difference in other vehicle categories between 20013 and 2009 was applied to these categories.

Fuel economy and km travelled for each vehicle class was calculated using the HBEFA handbook estimates for vehicles in Africa. Fuel use by vehicle class was estimated by dividing total mileage per vehicle class by fuel consumption. The proportion of fuel use by vehicle class was then used to estimate the use of fuel per vehicle class.

Johannesburg Bus Fleets
Detailed data on distance, routes and no. of trips were available from the JRA through the Transport Information Registry. This was also made available for the Rea Vaya (including type of vehicle and fuel consumption by vehicle). This data was used to estimate fuel use in the bus fleet (excluding bus services not operating in 2007 such as Rea Vaya).

2012 Defra GHG Conversion factors for petrol and diesel were used to calculate emissions of CO_2, N_2O and CH_4.</td></tr>
</table>

Scope 2	N/a
Scope 3	Included in scope 1. No data was available for trans-boundary trips.

II.2 Railways

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	N/a
Scope 2	Metro-rail data was provided by PRASA for 2013 and this was used as a proxy for 2007. The data included km travelled, number of services and electricity consumed by each line. The Guatrain was removed from the data as it came into service in 2012. The following services were calculated Johannesburg - Pretoria Johannesburg - Leralla Johannesburg - Naledi Germiston - Kwesine George Goch - Vereening (Midway) Germiston - Vereeniging (Meyerton) Johannesburg - Randfontein Johannesburg - Springs Germiston - Booysens (New Canada) Springs - Nigel Johannesburg - Oberholzer Daveton - Dunswart It was assumed that all electricity was via feeders in Johannesburg as the vast majority of services and stations are within the City boundaries. Electricity supply was direct from Eskom, therefore the transmission losses estimates from Eskom (4%) were applied to electricity consumed by Metro-Rail. A carbon intensity figure of 1.03 kg per kWh of electricity (Eskom 2001 Annual Report) was applied to the total electricity figure to calculate total emissions.
Scope 3	Inter-city rail services Emissions were calculated for Shosholoza Meyl, Blue train & Premier Classe inter-city train services. The following services were measured

Depart	Arrive	via
Johannesburg	**Cape Town**	Klerksdorp, Kimberley, Beaufort West, Worcester, Bellville
Cape Town	**Johannesburg**	Bellville, Worcester, Beaufort West, Kimberley, Klerksdorp
Johannesburg	**Cape Town**	Klerksdorp, Kimberley, Beaufort West, Worcester, Bellville
Cape Town	**Johannesburg**	Bellville, Worcester, Beaufort West, Kimberley, Klerksdorp
Johannesburg	**Cape Town**	Klerksdorp, Kimberley, Beaufort West, Worcester, Bellville
Cape Town	**Johannesburg**	Bellville, Worcester, Beaufort West, Kimberley, Klerksdorp
Johannesburg	**Durban**	Germiston, Newcastle, Ladysmith, Pietermaritzburg
Durban	**Johannesburg**	Pietermaritzburg, Ladysmith, Newcastle, Germiston
Johannesburg	**Durban**	Germiston, Newcastle, Ladysmith, Pietermaritzburg
Durban	**Johannesburg**	Pietermaritzburg, Ladysmith, Newcastle, Germiston
Johannesburg	**Port Elizabeth**	Vereeniging, Kroonstad, Bloemfontein, Colesburg, Cradock
Port Elizabeth	**Johannesburg**	Cradock, Colesburg, Bloemfontein, Kroonstad, Vereeniging
Johannesburg	**Port Elizabeth**	Vereeniging, Kroonstad, Bloemfontein, Colesburg, Cradock
Port Elizabeth	**Johannesburg**	Cradock, Colesburg, Bloemfontein, Kroonstad, Vereeniging
Johannesburg	**East London**	Vereeniging, Kroonstad, Bloemfontein,Burgersdorp, Queenstown
East London	**Johannesburg**	Queenstown, Burgersdorp, Bloemfontein, Kroonstad, Vereeniging
Johannesburg	**Komatipoort**	Pretoria, Witbank, Middelburg, Nelspruit, Kaapmuiden
Komatipoort	**Johannesburg**	Kaapmuiden, Neslpruit, Middleburg, Witbank, Pretoria
Johannesburg	**Musina**	Pretoria, Hammanskraal, Mokopane, Polokwane, Louis Trichardt
Musina	**Johannesburg**	Louis Trichardt, Polokwane, Mokopane, Hammanskraal, Pretoria

Distance for each journey was calculated using the online rail-freight distance calculator http://www.spoornet.co.za:70/CalculateDistance.asp

Timetables for services were available via PRASA for all services.

All services are electrified with the exception of Johannesburg to Port Elizabeth, where trains use diesel between Bloemfontein & Nouport (diesel).

For electrified lines transmission losses estimates from Eskom (4%) were applied and a carbon intensity figure of 1.03 kg per kWh of electricity (Eskom 2001 Annual Report)

	was applied to the total electricity figure to calculate total emissions. No data was available on the locomotive and carriage stock per route. Energy and diesel consumption was calculated using ATOC's 2007 'Baseline energy statement – energy consumption and carbon dioxide emissions on the railway'. The energy and diesel consumption of UK's 96/97 rail stock was used in the assumptions. 2012 Defra, GHG conversion factors were used to calculate emissions from non-electrified parts of the line between Johannesburg and PE. No data was available to assess the number of passengers starting or finishing journeys in Johannesburg, nor the total number of passengers using the inter-city services. Therefore total emissions from each inter-city service were calculated. Emissions from each railway line. The contribution from Johannesburg was calculated based on the proportion of stops within the city boundary against the total number of stops for the entire railway line.

II.3 Water-borne Navigation

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	**N/a**
Scope 2	**N/a**
Scope 3	**N/a**

II.4 Aviation

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences

Scope 1	None.
Scope 2	N/a
Scope 3	Johannesburg is served by two airports. The OR Tambo International Airport, located beyond the city boundaries and the Lanseria Airport in west Johannesburg. In line with the GPC methodology only emissions from airports within the city's boundaries were calculated. Emissions from the OR Tambo were therefore excluded from the calculation. The GPC recommends Scope 3 emissions from the cross-boundary trips that powered by direct fuel combustion are allocated based on distance travelled, number of passengers, amount of goods, fuel loaded, or number of stops. SAPIA fuel sales data for 2007 contained details of the amount of aviation gasoline and jet fuel sold in SA. 2010 data by magisterial district was available from the SA Department of Energy for the entire nation. The same proportion of total fuel sales within Johannesburg in 2010 was then applied to the 2007 data.

II.5 Off-Road

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Not calculated. Included in On-road transportation estimates
Scope 2	N/a
Scope 3	Not calculated. Included in On-road transportation estimates

III. Waste

(Chapter 6 in Methodology Guide)

III.1 Solid Waste Disposal

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Methane Commitment Method Used to calculate emissions from waste sent to landfill. Tonnages of waste landfilled at Johannesburg's four landfill sites were provided by the waste agency Pikitup. Over 1.7 million tonnes of waste were sent to landfill in 2007. **Calculating degradable organic content of waste** The composition of the waste stream was based on a waste composition study in Cape Town in 2008. Degradable organic content, total carbon content, fossil carbon fraction in % of total carbon and dry matter content calculated for Johannesburg's waste stream are set out below for its municipal waste stream (Table 1). The DOC was calculated as **DOC = (0.15 x A) + (0.2 x B) + (0.4 x C) + (0.43 x D) + (0.24 x E) + (0.15 x F)** *A = Food* *B = Garden waste and plant debris* *C = Paper* *D= Wood* *E= Textiles* *F = Industrial waste* *G= Plastics* **Table 1 Johannesburg's municipal waste emission factors** **Degradable Organic Content** — **0.162** **Total carbon content** — **0.421** **Fossil carbon fraction in % of total carbon** — **0.232** **dry matter content** — **0.505** For each individual waste types (e.g. paper) default IPCC emission factors were used for the DOC, Total carbon content, fossil carbon content and dry matter content (as set out below in Table 2).

Table 2 Johannesburg waste stream by material and default emission factors from IPCC

	% of waste stream collected by municipality	Waste to landfill (tonnes)	DOC in % of wet waste	Total carbon content in % dry weight	Fossil carbon fraction in % of total carbon	Dry matter content in % of wet weight
Garden waste	17	303,718	20	49	0	40
Plastic	17	300,227	0	75	100	100
Paper	13	223,425	40	46	1	90
Food waste	13	218,188	15	38	0	40
Cardboard	9	157,096	40	46	1	90
Glass	7	115,203	0	0	0	100
Textiles	6	99,494	24	50	20	80
Soil	4	73,311	0	49	0	40
e-waste	4	73,311	0	0	0	90
Cans	4	62,838	0	0	0	100
Books	2	34,910	40	46	1	90
Other	5	83,784	0	3	100	90

Methane Generation Potential (MGP)

The following formula was used to calculate the MGP. The MGP was calculated as 0.0541433
The landfill sites operated by Pikitip are well managed. A factor of 1 was applied in line with IPCC guidance. For the fraction of methane in landfill gas and the proportion ultimately degraded, IPCC default values were used.

$$L_0 = MCF*DOC*DOC_F*F*16/12$$

MCF	*Methane Correction Factor*
DOC	*Degradable Organic Content*
DOC_F	*Fraction of DOC ultimately degraded*
F	*Fraction of methane in landfill gas*
L_0	*Methane generation potential*

	Factor	Assumptions/ source
Methane Correction Factor	**1.000**	**Managed landfill site**
Degradable Organic Content	**0.162**	
Fraction of DOC ultimately degraded	**0.500**	**IPCC default value**
Fraction of methane in landfill gas	**0.500**	**IPCC default value**

Methane Generation Potential	**0.0541433**

	Calculating GHG emissions from municipal waste The following equation was used to calculate GHG emissions. In 2007 no landfill gas was recovered at Johannesburg's landfill sites either by flaring or energy generation. The oxidation factor was set at 0.1, the IPCC default for well managed sites. **$CH_4=M_{waste}*L_0*(1-f_{rec})*(1-OX)$** *Mwaste* — *Tonnes MSW disposed to landfill* *L0* — *Methane Generation Potential* *Frec* — *Methane recovered or flared* *OX* — *Oxidation factor* ***Assumptions*** — ***Landfill gas recovered in 2007 = 0%*** ***OX = 0.1 (well managed landfill sites)***
Scope 2	None
Scope 3	**Not applicable. All waste managed is within City of Johannesburg borders.**
Scope 3	

III.3 Biological Treatment of Waste

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	**57k tonnes of waste composted.** **For methane emissions** **CH_4 Emission s =** $\sum_i (M \cdot EFi\ ) \cdot 10^{-3} - R$ Where *i* = composting or anaerobic digestion *M* = Mass of organic waste treated by biological treatment type *EF* = emission factor for treatmentCH4/kg waste treated R = total amount of CH_4 recovered in year Gg CH_4

	For Nitrogen dioxide emissions **N_2O emissions =** $\sum_i (\boldsymbol{M} \cdot \boldsymbol{EFi}\ ) \cdot \mathbf{10^{-3}}$ Where *i* = composting or anaerobic digestion *M* = Mass of organic waste treated by biological treatment type *EF* = emission factor for treatment N_20/kg waste treated IPCC standard emission factors were used for CH_4 (4.0) and N_20 (0.3)
Scope 2	**N/a**
Scope 3	**All waste managed within the City of Johannesburg borders**
Description of activity data, data sources, and data collection methodologies	

III.4 Incineration and Open Burning

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	400 tonnes of municipal waste were incinerated at Robinsons Deep incinerator in 2007. Data provided by Pikitup Emission factors were taken from the IPCC 2006. Methane emission factor = 60 (batch type stoker incineration of MSW) N2O Emission factor = 56 (batch type incineration) Oxidation factor = 1 For CO_2 emissions $CO_2\ Emissions = m \times \sum_i (WF_i \times dm_i \times CF_i \times FCF_i \times OF_i) \times (44/12)$ CO_2 $Emissions$ = Total CO_2 emissions from incineration of MSW in metric tonnes m = Mass of waste incinerated WF_i = Fraction of waste of consisting of type *I* matter dm_i = Dry matter content in the type *I* matter CF_i = Fraction of carbon in the dry matter of type *I*

matter

FCF_i = Fraction of fossil carbon in the total carbon component of type *I* matter

OF_i = Oxidation fraction or factor

I = Matter type of the MSW incinerated such as paper/cardboard, textile, food waste, etc.

NOTE: $\sum_i WF_i = 1$

Source : 2006 IPCC Guidelines for National Greenhouse Gas Inventories

The oxidation factor was 1, based on the IPCC 2006 emission factors. Other factions in the equation are set out in the waste disposal (landfill) section of the methodology.

For CH_4 emissions

CH_4 (tonnes) = Tonnes Incinerated x CH_4 Emissions Factor * 0.001

IPCC, 2006 emission factor for batch stoker type incineration used. For CH_4 this is 60.

For N_2O emissions

N_2O (tonnes) = Tonnes Incinerated x N_20 Emissions Factor * 0.001

IPCC, 2006 emission factor for batch type incineration used. For N_20 is 56.

Scope 2	None
Scope 3	None

III.1 Wastewater Treatment and Discharge

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Descriptions of wastewater treatment volumes and processes were provided by Johannesburg Water. The methodology for capturing emissions from electricity use in wastewater treatment is captured in I.2 Scope 2 All treatment processes are described in the Model. However they are principally phoredox processes. In terms of the GPC these processes are categorized as central

	treatment plant with nitrification/denitrification. And are summarized below

Plant	Process	Litres Managed in 2007
1. Driefontein Wastewater Treatment Works	5 stage Phoredox	9,701,000,000
2. Ennerdale Wastewater Treatment Works	3 stage phoredox	1,954,000,000
3. Bushkoppie Wastewater Treatment Works	3 stage phoredox	72,043,000,000
4. Goudkoppies Wastewater Treatment Works	5 stage Phoredox	46,253,000,000
5. Olifantsvlei Wastewater Treatment Works	combination, including 4 stage Joburg	69,925,000,000
6. Northern Wastewater Treatment Works	combination inc 5 stage Phordeox and 4 stage Joburg	131,145,000,000

Centralized wastewater treatment plant with nitrification/denitrification process N_2O emissions

The equation for emissions from wastewater treatment with nitrification and denitrification is set out below.

Emissions from the wastewater treatment process with plants with nitrification/denitrification

$$N_2O\ Emissions = \left(P_{total} \times F_{ind-com} \times EF_{nit/denit} \times 10^{-6}\right)$$

N_2O Emissions	=	Total N_2O emissions in metric tonnes
P_{total}	=	Total population that is served by the centralized WWTP adjusted for industrial discharge
$F_{ind-com}$	=	Factor for industrial and commercial co-discharge waste into the sewer
$EF_{nit/denit}$	=	Emissions factor for a WWTP with nitrification/denitrification (g N_2O /person/year)

Source : ICLEI-USA *Local Government Operations Protocol*, Chapter 10 (2010).

ICLEI emissions factors were used for both the industrial and commercial discharge to sewer and the emissions factors for WWTP with nitrification/denitrification as set out below.

$F_{ind-com}$ = 1.25

$EF_{w/o-nit/denit}$ = 7

Scope 2	All emissions from electricity use in wastewater treatment are included in I.2 (scope 2)

Scope 3	N/a

IV. Industrial Processes and Product Use

(Chapter 7 in Methodology Guide)

IV.1 Industrial Processes

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Not calculated. Insufficient data.
Scope 2	Not calculated. Insufficient data.
Scope 3	N/a

IV.2 Product Use

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Not calculated. Insufficient data.
Scope 2	Not calculated. Insufficient data.
Scope 3	N/a

V. Agriculture, Forestry, and Land Use

(Chapter 8 in Methodology Guide)

Methodology Description

Description of accounting methodologies (overall concept, equations, etc.), if the methodologies used are different from the GPC Methodology Guide, please describe the differences	
Scope 1	Not calculated. Insufficient data.
Scope 2	Not calculated. Insufficient data.
Scope 3	N/a

Appendix x Johannesburg Water Wastewater treatment plants

The treatment activities at Johannesburg's six wastewater treatment sites are described below:

1. **Driefontein Wastewater Treatment Works:** Collects and treats sewage from the northern areas of Roodepoort and Mogale City. The works consist of screening, degritting, flow balancing, primary sedimentation, acid fermentation of raw sludge, a five stage Phoredox activated sludge process, final clarification, chlorination, waste sludge thickening and dewatering. The final effluent produced is discharged to the Crocodile River.

2. **Ennerdale Wastewater Treatment Works: C**ollects and treats sewage from Orange Farm, Poortjie and parts of Ennerdale. The works consists of screening, degritting, flow balancing, and activated sludge reactor incorporating the 3 stage Phoredox process, final clarification and chlorination.

3. **Bushkoppie Wastewater Treatment Works: C**ollects and treats sewage from the southern suburbs of Johannesburg, Soweto East and from industries to the south of Johannesburg. It consists of screening, degritting, primary sedimentation, thickeners for waste activated sludge, bioreactors incorporating the 3 stage Phoredox process configuration, final clarification, maturation ponds, and a recently constructed digestion, dewatering and solar drying of sludge.

4. **Goudkoppies Wastewater Treatment Works: C**ollects and treats sewage from the City Centre and the south-eastern areas of Johannesburg. The works consist of screening, degritting, primary sedimentation, raw sludge thickening and acid fermentation, flow balancing, activated sludge incorporating the 5 stage Phoredox process, final clarification, chlorination, waste sludge thickening, digestion, dewatering and solar drying of sludge.

5. **Olifantsvlei Wastewater Treatment Works: C**ollects and treats sewage from 3 outfalls serving Soweto, the southern and south-eastern areas of Johannesburg and Lenasia via the Van Wyksrust pump station. Wastewater is treated by two activated sludge bioreactors and final clarification. Each bioreactor was designed to treat 30 Ml/day. In addition a further unit consists of screening, degritting, primary sedimentation, acid fermentation, flow balancing, four stage bioreactors incorporating the 4 stage Johannesburg process and final clarification. Effluents are combined and flow through a series of five maturation ponds before being discharged into Klip River.

Sludge treatment consists of a sludge dewatering facility (belt presses) with belt underflow liquor treatment. All primary sludge is thickened in acid fermenters and anaerobically digested before being dewatered. Filtrates from the dewatering unit are lime treated to reduce phosphates.

6. **Northern Wastewater Treatment Works: C**ollects and treats mainly domestic sewage from Alexandra, Sandton, Randburg, the northern areas of Johannesburg, Bedfordview and portions of Edenvale and Germiston. There are five units. Unit 1 is a biofilter plant consisting of lime addition, primary sedimentation, primary biological filtration, primary humus removal and secondary biological filtration. The Unit treats stormwater and sewage overflows and the effluent produced provides irrigation water for the Northern Farm. Unit 2 decommissioned except for 6 of the digesters, 4 of which have been completely refurbished. The biofilters were demolished in 2007 to allow for construction of a new 50 Ml/d activated sludge treatment plant. Unit 3 was initially designed as a five stage Phoredox process but converted to a four-stage Johannesburg process in 1993. It consists of screening, degritting, primary sedimentation, acid fermentation of raw sludge, flow balancing, bioreactors, final clarification and chlorination. Unit 4 is a four stage Johannesburg process for biological nutrient removal. It consists of screening, degritting, primary sedimentation, acid fermentation of raw sludge, flow balancing, final clarification, chlorination, sludge thickening, dewatering, solar drying and composting. Unit 5 is a new 50Ml/d extension was completed in October 2009. It consists of primary sedimentation, acid fermentation of raw sludge, flow balancing, a four stage Johannesburg process bioreactor, chlorination and waste sludge thickening. Many of the operations on the works are automated via PLC and SCADA systems. Waste activated sludge is gravity thickened, anaerobic digested, dewatered on filter belt presses and the dewatered sludge produced is solar dried and composted. The design treatment capacity of the plant is 435 Ml/d and incorporates a 100 dry ton per day drying/composting area. The final effluent produced by the works is discharged to the Jukskei River. Northern Works supplies about 30 Ml/d of final effluent as cooling water to the Kelvin power station. The pump station and pipeline are owned by the City of Johannesburg. A biogas to electrical energy installation was commissioned in 2012. The installation provides 760 kW of electrical energy to Unit 5 of the Works.

[i] http://www.joburg.org.za/gds2040/pdfs/joburg2040_gds.pdf
[ii] Provincial and Region Economic Outlook 2010, Guateng
[iii] http://c40-production-images.s3.amazonaws.com/fact_sheets/images/5_Fact_20Sheet_20Why_20Cities_203.1.12.original.pdf?1390370461
[iv] City Power Annual Report 2006-07, identifies 149,000 street lights provided

[v] http://www.egoligas.co.za/about-us.html
[vi] SAPIA Fuel Sales by region 2007

[vii] http://www.johannesburgwater.co.za/AboutUs/corporate_profile.aspx
[viii] http://www.joburg-archive.co.za/2009/pdfs/economic_development/city_power.pdf