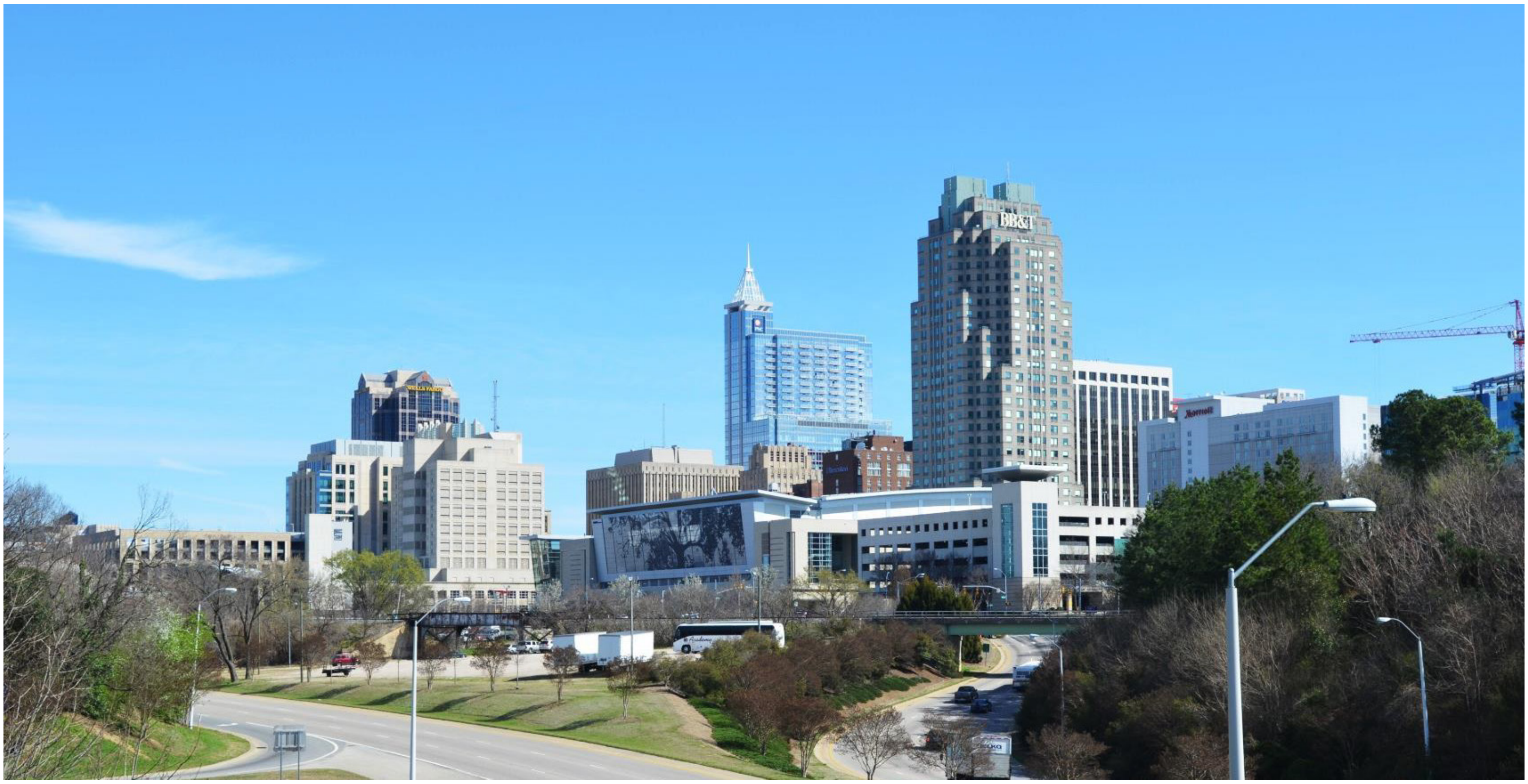

CITY OF RALEIGH

GREENHOUSE GAS INVENTORY REPORT

FISCAL YEAR 2014

JULY 1, 2013 - JUNE 30, 2014

Completed December 2016

CITY OF RALEIGH

GREENHOUSE GAS INVENTORY REPORT
FISCAL YEAR 2014

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Executive Summary

Gases that trap heat in the atmosphere are called greenhouse gases (GHGs). The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases. These gases enter the atmosphere from activities such as burning fossil fuels, the decay of organic waste in landfills and from various industrial processes. Each gas's effect on climate change depends on three main factors: how much of these gases are in the atmosphere; how long do they stay in the atmosphere; and, how strongly do they impact global temperatures.

The City of Raleigh recognizes the challenges that climate change presents and is committed to reducing greenhouse gas emissions. The Raleigh City Council established the Environmental Advisory Board in 2006 to help address the Council's commitment to environmental stewardship. The City Council also endorsed the U.S. Mayor's Climate Protection Agreement in 2007. The City of Raleigh has taken many actions to work towards achieving energy and greenhouse gas emission reductions including smart building systems to manage lighting; the heating, ventilation and air conditioning (HVAC); the sub-metering, and the electrical systems; introducing electric vehicle charging stations; streetlight replacement; renewable energy projects; and the recently completed Renewable Energy Overview. The City is also working to transform the fleet to cleaner or alternative fuels and/or electric vehicles and more fuel efficient vehicles.

Preparing a GHG emissions inventory provides the City with an understanding of where Raleigh's GHG emissions are coming from and serves as a starting point for developing strategies that can effectively reduce GHG emissions. The City has developed two sets of greenhouse gas emissions inventories:

1. The **Community Inventory** represents total emissions from activities occurring within the City limits, such as vehicle trips, home and business energy use, and solid waste generation.
2. The **Local Government Operations (LGO) Inventory** represents a subset of the community inventory, and illustrates the emissions generated as a direct result of actions taken by the City government.

The inventories presented within this report update the 2007 Community and LGO inventories for the 2014 fiscal year and discuss trends between the two inventory years.

Community Inventory

The Community Inventory estimates the total amount of emissions generated from activities within the City of Raleigh jurisdictional boundary. The inventory represents emissions from residential, commercial and institutional, industrial, and public activities and includes emissions from the following sectors:

- Stationary Energy (i.e., electricity and natural gas consumption on homes, offices, stores and other buildings within the community);
- Transportation (i.e., on-road vehicle trips that begin and/or end within the City's boundaries and off road transportation such as construction vehicles); and
- Waste (i.e., emissions associated with solid waste disposal and biological process emissions resulting from wastewater treatment[1]).

Community activities in the City of Raleigh generated approximately 5,489,000 MT CO_2e in 2014. In 2007 communitywide emissions were estimated to be approximately 4,877,000 MTCO_2e. In the comparable[2] 2014 calculation, communitywide activities generated approximately 4,998,000 MT CO_2e, representing a 2% increase from the 2007 baseline (approximately 120,000 MTCO_2e) despite an approximate 16% increase in population and steady increase in the number of jobs in the city over the same period.[3]

In 2014 stationary energy emissions were the largest contributor to the community inventory, accounting for 56% of total emissions, most significantly from electricity use in commercial/institutional facilities and residential buildings (representing 24% and 17% of total emissions, respectively). At the community level, only aggregated energy use was available from the utilities that serve the city. Transportation emissions contributed an additional 42%, with the waste sector responsible for the remaining less than 2% of community emissions which is typical for most cities.

Further analysis indicates that going forwards implementing strategies that result in increased vehicle efficiency, alternative fuel vehicle use, an/or alternative transportation options in urban areas such as continued development of walking and cycling paths, public transportation expansion, and expanded electric vehicle infrastructure would affect a significant part (nearly 40%) of total emissions. Raleigh's Union Station is an example of what is being done for improved transportation options. Similarly strategies designed to reduced electricity use such as energy audits for commercial/institutional facilities would address nearly one-quarter (24%) of total emissions.

Community emissions reduction opportunities can also be assessed based on the type of energy used. With over 40% of total emissions related to community electricity use, the electric utilities' portfolio of electricity sources supplying the grid is a huge influence on the City's emissions. If electricity on the grid can be generated from more renewable sources and less carbon-intense fossil fuels, then another significant primary emissions source can be mitigated.

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[1] While the City operates multiple wastewater/water treatment plants, in keeping with accepted standards for GHG emissions accounting, only those serving Raleigh are included in the community inventory. By contrast, all the plants operated by the City are included in the LGO inventory.

[2] Note that in 2014 communitywide emissions totaled 5,489,378 MT CO_2e; however, as some emission sources included in the 2014 inventory were not estimated in past inventories (namely fuel oil and LPG stationary sources, off-road transportation and waste disposal) those sources were removed from the comparison in order to provide trending consistency across the years.

[3] Population data for growth calculations sourced from: https://www.raleighnc.gov/government/content/PlanDev/Articles/LongRange/RaleighDemographics.html - 2015 data book; http://www.raleighnc.gov/environment/content/AdminServSustain/Articles/SustainabilityReport.html - Community-wide GHG Inventory Years 2007 and 2010, Exhibit 3

LGO Inventory

The LGO inventory is organized into the following four sectors:

- Municipal Buildings and Other Facilities (e.g. energy used by City Hall, streetlights and water and wastewater pumping and treatment facilities);
- Vehicles (e.g. Police and Fire Department vehicles and the Go-Raleigh bus fleet);
- Waste Disposal Facilities; and,
- Other Process and Fugitive Emissions.

City operations for Fiscal Year (FY) 2014 generated approximately 130,800 MT CO_2e, representing only 2% of the total Community emissions, which is within the typical range of 1-5% seen in other local government emission inventories. LGO emissions from City operations in 2007 were estimated to be approximately 151,500 MT CO_2e; therefore, 2014 emissions represent a 14% reduction from the 2007 baseline.

The Municipal Buildings and Other Facilities sector accounts for the majority (69%) of LGO emissions. The vehicle fleet and transit fleet each contribute 13% and 7% of total emissions, respectively. Emissions from the waste disposal sector represent 10% of total emissions and the remaining (less than 1%) emissions come from other Process and Fugitive Emissions.

Further departmental analysis indicates that the primary source of emissions from City operations is related to the provision of electricity for Public Utilities (36% of total emissions). Electricity consumption is also the largest source of emissions across all sectors and departments.

The City of Raleigh has numerous active renewable energy and energy efficient initiatives in addition to existing strategies that have yielded favorable results to reduce energy consumption and costs. Recently the City of Raleigh completed the replacement of approximately 30,000 conventional streetlights with high efficiency LEDs, which will reduce 8% of total LGO emissions.

However, the high contribution of electricity use by the Public Utilities department to the total LGO emissions is largely due to electricity consumption at the three wastewater treatment plants, two water treatment plants and over 150 remote facilities for distributing water and collecting wastewater throughout the City's service area. While efficiency measures can help reduce the amount of electricity used to move water and wastewater, an alternative approach would be to reduce the carbon intensity of the electricity used by Public Utilities. For example, the conversion of the Neuse River Resource Recovery Facility to an anaerobic system will use less energy and will generate methane. The City is evaluating capture of the off-gassed methane as an energy source.

Within vehicle energy use the Go-Raleigh and Police Department fleets contribute 7% and 4% of total LGO emissions, respectively. Since 2002 the City has been actively encouraging and accelerating the use of alternative fuel vehicles within the City's vehicle fleet. The Go-Raleigh transit fleet runs on Biodiesel B5, which although is less carbon intensive than conventional diesel/gasoline is still largely fossil fuel based (i.e., B5 is only 5% biodiesel) and results in savings of 430 MT CO_2e per year. The use of biofuel blends with a higher percentage of biodiesel for the transit fleet, similar to what is in use in select vehicles in the City vehicle fleet, would target 7% of total emissions. Typically biofuel blends of up to 20% biodiesel can be incorporated without the need for vehicle modifications.

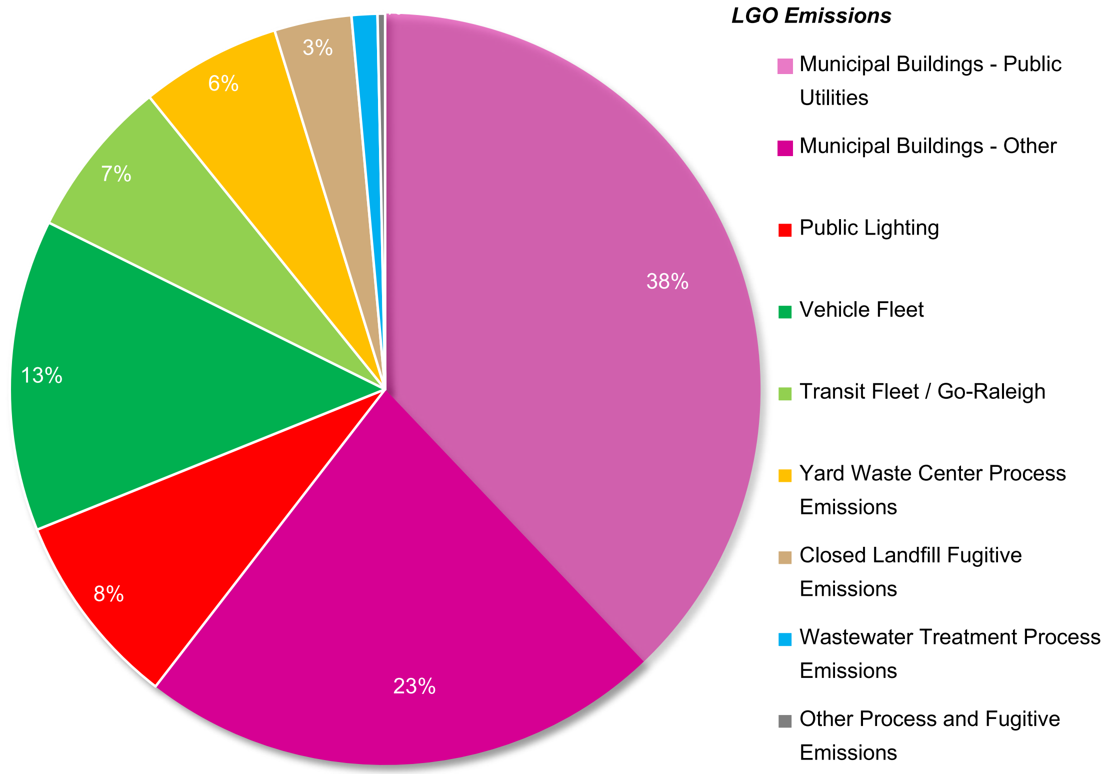
The City's Inventory in Perspective

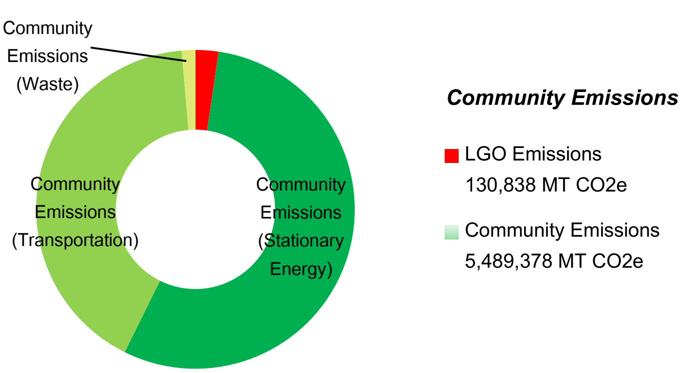
GHG inventory estimates can differ greatly between cities. Not only is each city unique in the types of services they provide (e.g., some may have significant transit operations or rely on other entities for water and wastewater), but also GHG inventories can often differ in the organization and operational boundaries, timeframe, data sources and calculation approach used.

However, there are still benefits to comparing the GHG emissions for the City of Raleigh to emission estimates for other cities and communities. A comparison of Raleigh's community and LGO GHG emissions per capita to those of other local, regional and national cities are provided below in order to provide some context. In addition, in April 2016 the EPA published its annual inventory of total US GHG emissions. This indicates like for like average US GHG emissions of ~13.1 MT CO_2e per capita nationally[4] which is comparable to Raleigh's community emissions per capita of ~12.5 MT CO_2e per capita.

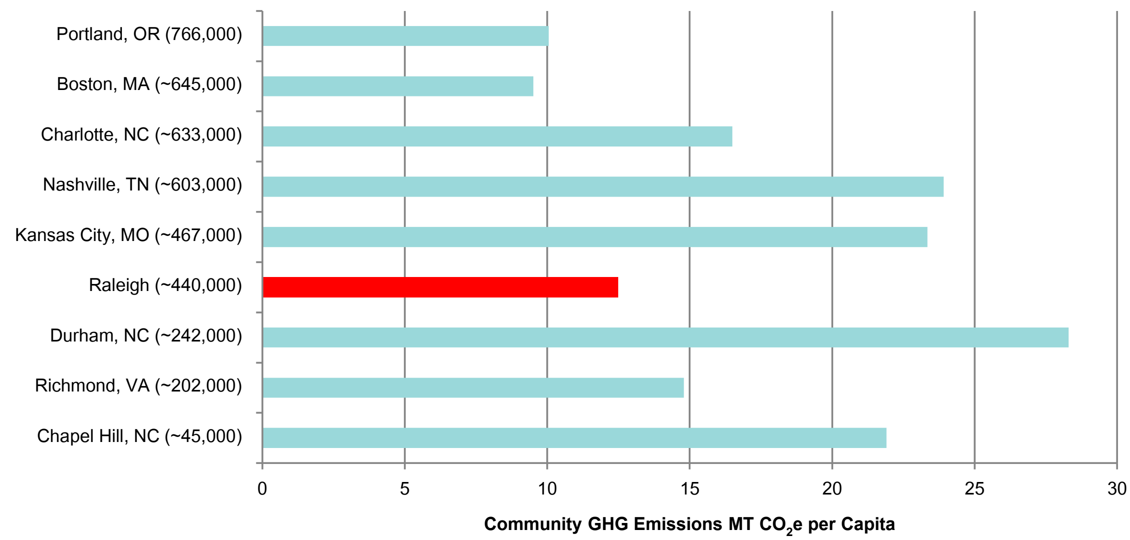
[4] Based on 2014 population estimates published by the US Census Bureau and 2014 US GHG emissions from residential, commercial, industrial, transportation and waste sectors as published in EPA's *"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014"*

2014 LGO and Community Greenhouse Gas Emissions Inventories

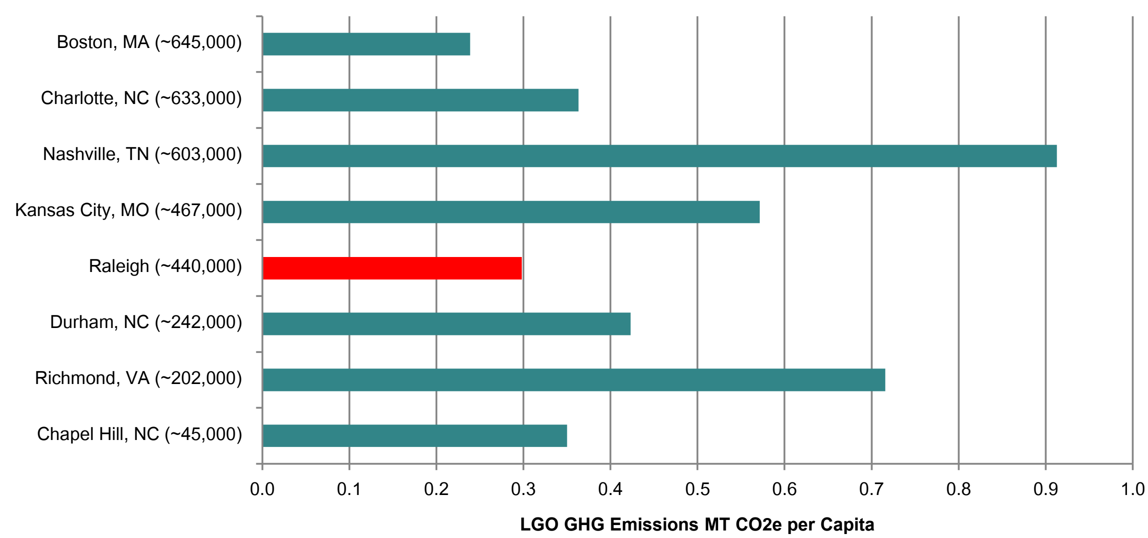




Comparison of Community Emission Inventories



Comparison of LGO Emission Inventories



Introduction

Gases that trap heat in the atmosphere are called greenhouse gases. The main greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and fluorinated gases.

- Carbon dioxide enters the atmosphere through burning fossil fuels (coal, natural gas and oil), solid waste, trees and wood products, and also as a result of certain chemical reactions (e.g., manufacture of cement). Carbon dioxide is removed from the atmosphere (or "sequestered") when it is absorbed by plants as part of the biological carbon cycle.
- Methane is emitted during the production and transport of energy sources such as coal, natural gas, and oil. Methane emissions also result from livestock and other agricultural practices and by the decay of organic waste in municipal solid waste landfills.
- Nitrous oxide is emitted during agricultural and industrial activities, as well as during combustion of fossil fuels and solid waste.
- Fluorinated gases are manmade, powerful greenhouse gases that are emitted from a variety of industrial processes.

Each gas's effect on climate change depends on three main factors: how much of these gases are in the atmosphere, how long do they stay in the atmosphere, and how strongly do they impact global temperatures.[5]

Given that more than half of the world's population lives in cities and cities consume approximately 78% of energy globally[6], cities can and should lead the way in the effort to protect the environment for future and present generations.

The City of Raleigh (the City) recognizes the challenges that climate change presents and is committed to reducing greenhouse gas emissions. The Raleigh City Council established the Environmental Advisory Board in 2006 to help address the Council's commitment to environmental stewardship. The City Council also endorsed the U.S. Mayor's Climate Protection Agreement in 2007.

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[5] https://www3.epa.gov/climatechange/ghgemissions/gases.html

[6] Source:https://www.cdp.net/Documents/cities/cities-infographic-2015.pdf

Many actions have been taken to work towards achieving energy and greenhouse gas emission reductions including:

- Building automation and control systems allow for setbacks after hours and time of use rates;
- Capturing and selling the methane from the closed Wilders Grove landfill for energy recovery between 1989 and 2013;
- Requiring LEED Silver standards for new municipal buildings over 10,000 square feet and prioritizing energy efficiency improvements to existing City buildings;
- Completing a project to replace approximately 30,000 conventional street lights with high efficiency LED lights;
- Completing energy audits on City facilities including fire stations, One Exchange Plaza, and numerous community centers;
- Introducing of electric vehicle charging stations, affordable transit and bicycle lanes impacting both City operations and local citizens;
- Combusting biofuels to help reduce the City's dependence on fossil fuels; and,
- Implementing a number of renewable energy initiatives including solar and geothermal projects.

Components of the Report

This report is presented in five sections, beginning with an introduction to the emissions inventory process and its purpose. The other sections present the results and analysis for each inventory, including a description of the specifics of the emissions sectors that were analyzed, trends over time, and identification of the major emissions sources that will in turn inform future emissions reduction actions and strategies. This is followed by a section which presents a comparison of the City of Raleigh's inventories against proximal and similar sized cities. The final section presents the conclusion and a summary of recommended actions.

THE EMISSIONS INVENTORY

The City has developed two sets of greenhouse gas emissions inventories for fiscal year 2014.

1. The **Community Inventory** represents total emissions from activities occurring within the city limits, such as vehicle trips, home and business energy use, and solid waste generation.
2. The **Local Government Operations (LGO) Inventory** represents a subset of the community inventory, and illustrates the emissions generated as a direct result of actions taken by the City government.

For example, the Community Inventory includes vehicle emissions from all journeys within the city limits, while the LGO Inventory includes emissions from the operation of the City's vehicle fleet only. These inventories, along with the analysis included in this report, will serve as the basis for developing a comprehensive emissions reduction strategy for the City of Raleigh.

Purpose of Emissions Inventories

A greenhouse gas (GHG) emissions inventory is an estimate of GHGs emitted to, or removed from, the atmosphere over a specific period (usually one year). Preparation of an emissions inventory provides the City with an understanding of where Raleigh's GHG emissions are coming from and serves as a starting point for developing strategies that can effectively reduce GHG emissions. The City has previously developed greenhouse gas (GHG) emissions inventories for the baseline year of fiscal year 2007, and in the case of the community inventory, also fiscal year 2010[7]. The inventories presented within this report update both the Community and LGO inventories for the 2014 fiscal year and discuss trends between the inventory years.

An emissions inventory can help with any or all of the following tasks:

- Identifying the greatest sources of GHG emissions within a particular geographic region, department, or activity;
- Understanding emission trends;
- Quantifying the benefits of activities that reduce emissions;
- Establishing a basis for developing an action plan;

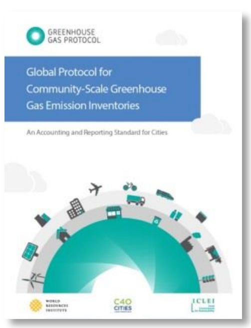
[7] Note: In 2012 the City developed a community wide inventory for 2007 and 2010

- Tracking progress in reducing emissions; and,
- Setting goals and targets for future reductions.

Overview of Greenhouse Gas Inventory Methodology

Emissions inventories provide a snapshot of the amount and source of greenhouse gas emissions in a given year. The base year inventory serves as a reference point against which future performance and progress can be monitored and can help to assess the effectiveness of City strategies and actions.

The 2014 Community Inventory adheres to guidance provided in the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC)[8]. The 2014 LGO Inventory followed additional guidance provided in the *Local Government Operations Protocol (LGOP), Version 1.1*[9]. Both the GPC and LGOP are highly respected protocols with established and well-vetted methodological guidelines. The 2007 emissions inventories followed the same protocols; however, there have been updates and revisions since 2007 that were implemented in the 2014 emission inventories.



The GPC provides guidance on how to standardize emissions inventories.

The following sections give an overview of the emissions estimation process and sectors analyzed in each inventory. Additional details on the emissions reporting protocols, inventory methodologies, and data sources are provided in a supporting Technical Appendix.

How Are Emissions Measured?

Emissions inventories are commonly expressed in metric tons (or tonnes[10]) of carbon dioxide equivalent per year (MT CO_2e/year). Carbon dioxide equivalent is the universal unit for comparing emissions of different GHGs to CO_2 based upon the varying global warming potentials (GWP) of each gas[11]. GWPs were developed by the Intergovernmental Panel on Climate Change (IPCC) and describe how much heat a GHG can trap in the atmosphere compared to carbon dioxide, which has a GWP of 1 (because it is the gas being used as the reference). The idea is to express the impact of each different GHG in terms of the amount of CO_2 that would create the same amount of warming so that an emissions inventory consisting of many different greenhouse gases can be expressed as a single number. For example as depicted in Figure , methane has a GWP of 25, which means that 1 metric ton of methane will trap 25 times more heat than 1 metric ton of carbon dioxide, making it a more potent greenhouse gas. Some gases used in industrial applications can have a GWP thousands of times larger than CO_2.

To maintain consistency within each inventory and between the baseline and subsequent emission inventories, all GHG emissions have been quantified in units of MT CO_2e/yr. To obtain CO_2 equivalent emissions, the mass of each GHG is multiplied by its

[8] http://www.ghgprotocol.org/city-accounting

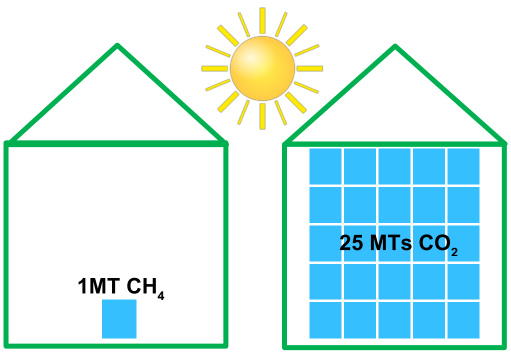
[9] https://www.theclimateregistry.org/tools-resources/reporting-protocols/local-goverment-operations-protocol/

[10] "tonne", also called a metric ton, is the standard international unit for measuring GHG emissions. It is different than a U.S. short ton (or "ton"). 1 U.S. short ton (ton) = 0.9072 metric tons (tones).

[11] All seven GHGs that contribute to climate change covered by the Kyoto Protocol were included: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride (SF_6) and nitrogen trifluoride (NF3). However, activities within the City of Raleigh emit only CO_2, CH_4, N_2O and HFCs. There were no emissions of PFCs or SF_6 identified in the emissions analysis as these emissions are generally associated with the transmission and distribution of electricity from generation facilities and/or the manufacture of semi-conductors. Fugitive emissions of HFCs are associated with refrigerant usage.

respective GWP[12] and then added together to give CO_2e.

Figure 1 A Ton of Methane Has the Same Heat Trapping Effect as 25 Tons of CO_2 (i.e., 25 MT CO_2e)



The 2014 emissions inventories were prepared using a combination of empirical (measured) and estimated (modeled) data, depending on their availability. Data were collected from many sources including City records and utility company reports. Activity data were then converted into greenhouse gas emissions estimates using relevant emissions factors. Emission factors relate the amounts of greenhouse gases emitted by an action to a set amount of activity under that action.

Emissions were calculated using the following equation:

Amount of Activity x Emissions Factor = GHG Emissions for the Action

Where examples of actions include lighting homes and buildings, commuting, or treating wastewater, and the amounts of activity electricity consumed (i.e., kilowatt hours/year), vehicle miles traveled, and gallons of wastewater generated.

What Is Included in the Inventory?

The first step in developing a GHG inventory is to define the inventory boundary, i.e. the geographic area, gases, and emission sources covered by a GHG inventory.

GHG emissions can be described as direct or indirect, depending upon where the emissions generation occurs. In GHG accounting there are three 'scopes' of GHG emissions:

SCOPE 1	What we combust (e.g. heating oil, transport fuel)
SCOPE 2	Purchased emissions from energy we consume (e.g. grid supplied electricity)
SCOPE 3	Other indirect emissions (e.g., waste disposal at third party landfills, electricity losses from energy transmission)

Scope 1 direct emissions are those where the source directly generates the emissions, such as combusting natural gas in a boiler for heating a building or an industrial process, or gasoline combustion by a bus. The source is owned and operated by the City (or within the city boundary for the Community Inventory) and the resulting emissions are a direct result of that consumption.

Scope 2 indirect emissions are those where the activity takes place within the city jurisdiction, but the actual emissions generation occurs outside of that boundary. By definition, Scope 2 is limited to purchased electricity and steam. For example, a Raleigh resident can consume electricity within their home, but that electricity was generated in an area outside of the city's jurisdiction (e.g., power plants throughout North Carolina).

Scope 3 other indirect GHG emissions is an optional reporting category that allows for quantification of all other indirect emissions. Scope 3 emissions are a

[12] GWPs were sourced from the IPCC's 4th Assessment Report

consequence of the activities of the city, but occur from sources not owned or controlled by the city (are outside the city boundary for the Community Inventory).

Inventory Boundary

The boundary for this inventory is the City of Raleigh's jurisdiction within Wake County. The city occupies a 144-square-mile area and is home to nearly 440,000 citizens, as well as university and college campuses, and state and county government complexes. Because the Raleigh-Durham International Airport is outside the City's jurisdiction, it is therefore not included in the inventory boundary.

Emission Sources

Both of the inventories are organized into categories, or sectors, that represent the commonly understood, major sources of emissions. These sectors are largely consistent between the Community and LGO Inventories, though naming conventions differ slightly, as guided by the relevant Protocols. The City of Raleigh's Community Inventory includes emissions from the following sectors:

- Stationary Energy (i.e., electricity and natural gas);
- Transportation; and,
- Waste.

The LGO Inventory includes slightly different sectors, to more clearly reflect the emissions sources relevant to the services provided by the City:

- Municipal Buildings and Other Facilities;
- Public Lighting;
- Vehicles;
- Waste Disposal; and,
- Other Process and Fugitive Emissions.

Scope Limitations

The inventories presented in the report cover the material and significant sources of emissions across the sectors outlined in the relevant Protocols. However, in defining the scope, the following emissions were excluded:

<u>Community Inventory</u>

- Collecting community-level refrigerant and fire suppression chemical usage would require a supplier data collection survey, which time did not permit for this inventory. Emissions from refrigerant and fire suppression chemical usage, however, are not expected to be a significant proportion of the overall GHG emissions.
- Community-wide stationary combustion of fuel oil was collected for 2013 from the North Carolina Department of Environment Quality – Division of Air Quality, which was the most recent record available.

<u>LGO Inventory</u>

- City employee commute emissions were not included as they are accounted for in the transportation sector emissions in the Community Inventory

Future emissions inventories may be enhanced by:

- Including emissions from electric vehicles in the LGO On-Road Vehicles Sector.
- Reporting on emissions avoided by the generation of electricity from City owned or leased solar installations.

Community Inventory

The Community Inventory estimates the total amount of emissions generated from activities within the City of Raleigh boundary. The inventory represents emissions from residential, commercial and institutional, industrial, and public activities. This section introduces the emissions sectors used to organize the community inventory. It then presents the 2014 year community inventory and describes sub-sector emissions, as necessary, to provide greater detail on how emissions are generated in the City of Raleigh. Emissions trends compared to the 2007 baseline are then presented. Finally, the primary sources of community emissions are described.

Emissions Sectors and Subsectors

The community inventory is organized into the following sectors to describe the primary sources of emissions in the community. A supporting Technical Memorandum provides additional details on these sectors, the emissions reporting protocol, and data sources used to guide preparation of this inventory.

Stationary Energy

The Stationary Energy sector includes emissions generated as a result of energy consumption in homes, offices, schools, stores, manufacturing facilities and other buildings within the community. Emissions result from the consumption of electricity from the local utility grid, as well as the direct combustion of natural gas and fuel oil. This sector also includes energy-related emissions attributed to the community's share of wastewater treatment and potable water conveyance.

The Stationary Energy sector is organized into three sub-sectors: residential buildings, commercial and institutional buildings and manufacturing and construction industries. All of Raleigh's drinking water is sourced from lakes and rivers inside the city's boundary and Raleigh's wastewater treatment conveyance also stays inside the City's boundary; therefore, the city consumes and pays for all the associated energy costs directly.

Transportation

The Transportation sector represents mobile emissions associated with two sub-sectors, on-road vehicle use on community roadways and off-road equipment emissions (e.g., forklifts, lawnmowers). The community's on-road transportation emissions come from vehicle trips that begin and/or end within the City's boundaries. Pass-through trips (for example, non-local drivers on the

Interstate) are not included within the emissions inventory because they do not occur as a result of community activity (e.g., jobs, retail or housing in Raleigh). The community's off-road transportation emissions account for mobile sources associated with construction, lawns/gardens, industrial manufacturing, commercial retail, and railroads.

Waste

The Waste sector includes emissions associated with solid waste disposal and biological process emissions resulting from wastewater treatment (separate from the energy-related wastewater treatment emissions included in the Stationary Energy sector). Solid waste collected in the community is sent to the South Wake county landfill. Although the North Wake and Wilder's Grove landfills are now closed, they continue to produce methane emissions due to historical waste deposits; therefore, emissions from these two closed landfills were also accounted for in this inventory. Waste collection and hauling activities also generate GHG exhaust emissions. However, hauling-related emissions from private haulers are assumed to be included within the transportation model and represented within the Transportation sector. While recycling of solid waste also produces greenhouse gas emissions, these emissions have not been included in the scope of this inventory due to the complexity involved in producing an emissions estimate and the likelihood they would not significantly impact the overall outcome of the inventory.

The City of Raleigh's process of treating wastewater generates nitrous oxide (N_2O) emissions. The majority of emissions related to wastewater treatment result from the use of electricity, however, electricity related emissions are considered in the Stationary Energy Sector. This section refers only to direct emissions from the treatment processes that were employed at the wastewater treatment plants.

The Waste sector includes four sub-sectors:

- Solid waste landfill disposal;
- Solid waste biological treatment;
- Solid waste incineration; and,
- Wastewater treatment and discharge.

How Do Landfills Create GHG Emissions?

After being placed in a landfill, organic waste (such as paper, food scraps, and yard trimmings) is initially decomposed by aerobic bacteria. After the oxygen has been depleted, the remaining waste is available for consumption by anaerobic bacteria, which break down organic matter into substances such as cellulose, amino acids, and sugars. These substances are further broken down through fermentation. These bacteria convert the fermentation products into gas including carbon dioxide (CO_2) and methane (CH_4).

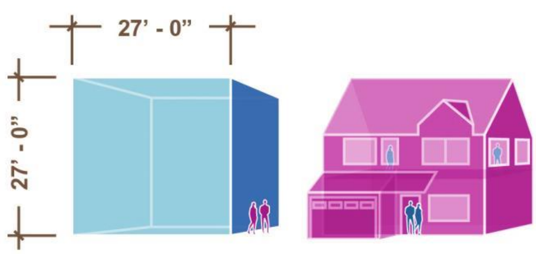
Fiscal Year 2014 Inventory

As shown in Figure 3 and Table 1 on the following pages, **Community activities in the City of Raleigh generated approximately 5,489,000 MT CO_2e in 2014.** Stationary Energy emissions were the largest contributor to the community inventory, accounting for 56% of total emissions. Transportation emissions contributed an additional 42%, with the waste sector responsible for the remaining <2% of community emissions.

However, understanding the scale of a community's emissions can be challenging. The EPA created a greenhouse gas equivalencies calculator to help convert annual emissions into more accessible concepts.

Figure 2 illustrates the scale of one metric ton of carbon dioxide as compared to a single-family house.

Figure 2 – How Large is One Metric Ton of CO_2?



One metric ton of carbon dioxide would fill a cube 27 feet tall! That's about the size of a two-story home, totaling more than 1,400 square feet.

In addition to understanding the scale of a single metric ton of carbon dioxide, the City of Raleigh's total community emissions inventory can also be compared to other more common metrics. For example, it would take more than 5,000,000 acres of U.S. forest one year to capture and store the total Raleigh 2014 community emissions.[13] **A forest over 50 times larger than the City of Raleigh (93,306 acres) would be required to sequester the total community emissions for one year.**

Alternatively, if the entire inventory were represented as home energy use, then it would take a community of nearly 580,000 homes to generate the same amount of emissions as the 2014 community inventory. For comparison, the city had approximately 192,504 households[14] in the 2014 inventory year. That is over 3 times the number of homes in the city[15].

The following pages provide greater detail on the distribution of emissions within each sector. Emissions are represented according to sectors, sub-sectors and fuel-type.

[13] U.S. Environmental Protection Agency, Greenhouse Gas Equivalencies Calculator. Available online: http://www2.epa.gov/energy/greenhouse-gas-equivalencies-calculator. Accessed August 2016.

[14] https://www.raleighnc.gov/government/content/PlanDev/Articles/LongRange/RaleighDemographics.html

[15] Please note that the Community Inventory includes more than household energy use.

Figure 3 – 2014 Community Greenhouse Gas Emissions Inventory

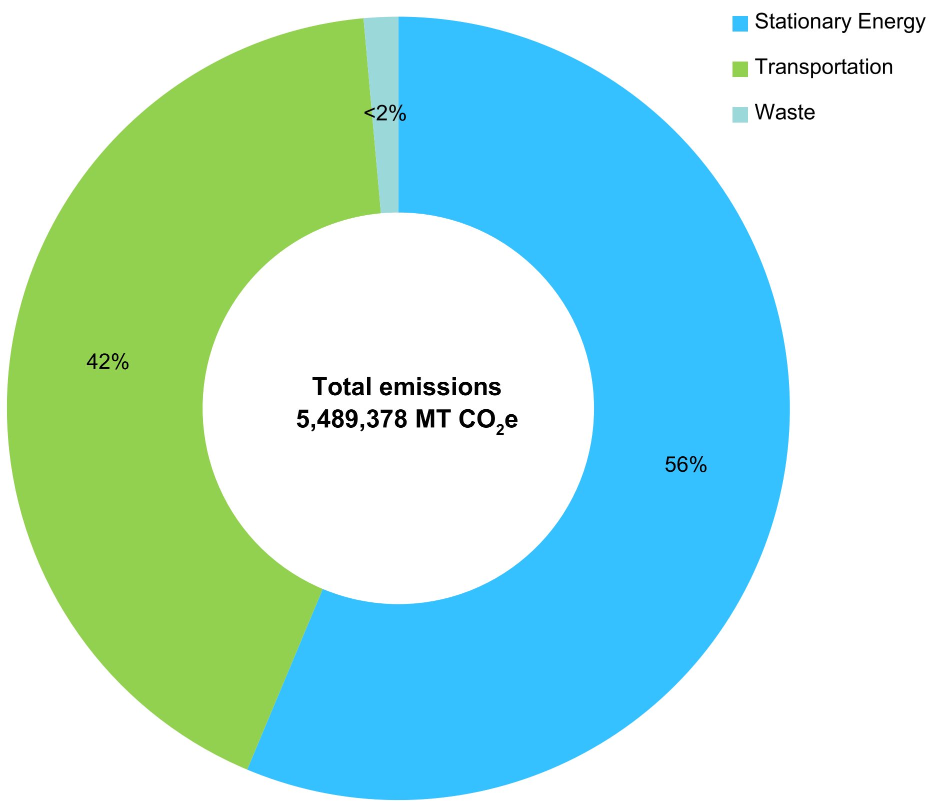


Table 1 – 2014 Community Greenhouse Gas Emissions Inventory by Sector and Sub-Sector

Sector	Emissions MT CO_2e/yr				% of Total
	Scope 1	Scope 2	Scope 3	Total	
Stationary Energy	**743,028**	**2,150,849**	**197,233**	**3,091,110**	**56%**
Residential buildings	*322,663*	*854,313*	*78,341*	*1,255,317*	*23%*
Commercial and institutional buildings and facilities	*277,961*	*1,191,269*	*109,239*	*1,578,469*	*29%*
Manufacturing industries and construction	*142,404*	*105,267*	*9,653*	*257,323*	*5%*
Transportation	**2,320,358**	**0**	**0**	**2,320,358**	**42%**
On-road transportation	*2,114,273*	*0*	*0*	*2,114,273*	*39%*
Off-road transportation	*206,085*	*0*	*0*	*206,085*	*4%*
Waste	**16,275**	**N/A**	**61,636**	**77,911**	**<2%**
Solid Waste Landfill Disposal	*4,350*	*N/A*	*61,636*	*65,986*	*1%*
Solid Waste Biological Treatment	*7,912*	*N/A*	*0*	*7,912*	*<1%*
Solid Waste Incineration	*2,682*	*N/A*	*0*	*2,682*	*<1%*
Wastewater Treatment and Discharge	*1,330*	*N/A*	*0*	*1,330*	*<1%*
TOTAL	**3,079,660**	**2,150,849**	**258,868**	**5,489,378**	***100%***

Key:

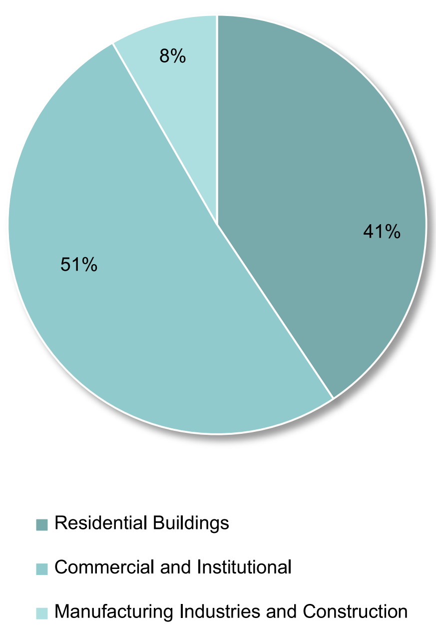
Scope1	GHG emissions generated directly from sources located within the City boundary e.g. combusting gas or fuel oil in a boiler, gasoline combustion by a bus or direct emissions from an industrial process.
Scope 2	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
Scope 3	All other GHG emissions that occur outside the City boundary as a result of activities taking place within the City boundary e.g. emissions from solid waste generated within the city boundary but treated biologically outside of the City boundary.
Stationary Energy	Stationary Energy Sector emissions generated as a result of energy consumption in homes, offices, schools, stores, manufacturing facilities and other buildings within the community, e.g., electricity consumption from the local utility grid, as well as the direct combustion of natural gas and fuel oil. Also includes energy-related emissions attributed to the community's share of wastewater treatment and potable water conveyance.

Transportation	Transportation sector emissions include: • Emissions from personally owned and commercial vehicles that operate on roadways such as cars, trucks, vans and sport-utility vehicles (SUVs) • Emissions from personally owned and commercial vehicles that operate off roadways such as construction, landscaping, and industrial equipment and rail
Waste	Waste sector emissions include: • Emissions from solid waste generated by businesses and residents within the city boundary and disposed / treated / incinerated within the city boundary, i.e., the City's closed Wilder Grove landfill, the City's Yard Waste Compost Center and a private sector clinical waste incinerator; • Scope 3 emissions from solid waste generated within the city boundary but disposed outside of the city boundary (South Wake and North Wake County landfills); and • Process emissions from treating wastewater generated by business and residents within the city boundary and treated within the city boundary (i.e., the City of Raleigh currently has three wastewater treatment plants within its operational control: Little Creek, Neuse River and Smith Creek; however, the Neuse River Facility is the only plant that serves the Raleigh population and therefore is the only plant included in the Community inventory). • Biological Treatment emissions are from green waste composting at the City's Yard Waste Compost Center

Stationary Energy

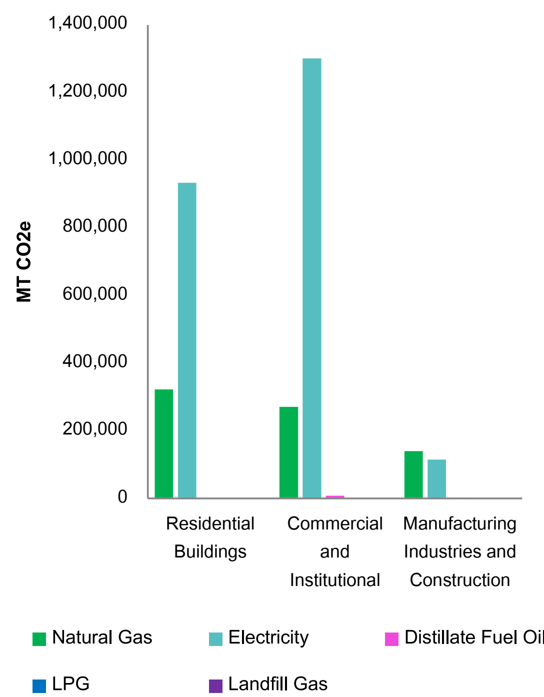
Stationary energy related emissions from buildings account for 56% of total community emissions. Commercial and institutional buildings generate just over half of the stationary energy sector emissions (51%), and residential buildings provide an additional 41%. Manufacturing and construction industries contribute the reaming 8% of sector emissions.

Figure 4 – 2014 Community Stationary Energy Emissions by Sector



The stationary energy sector can also be analyzed according to the type of energy used (Figure 5). Electricity use generated over three quarters of the sector's emissions (76%). Natural gas combustion contributed 24%; and heating fuel oil (i.e., distillate fuel oil) and liquefied petroleum gas (LPG) combustion and landfill gas provided less than 1%. **Electricity use by the commercial and institutional sub-sector contributed 42% of the stationary energy sector emissions.** This suggests that reduction strategies focused on increasing electrical energy efficiency across the city's commercial and institutional portfolio would have the biggest impact. Manufacturing and construction is the only sub sector where emissions from natural gas outweighed those from electricity.

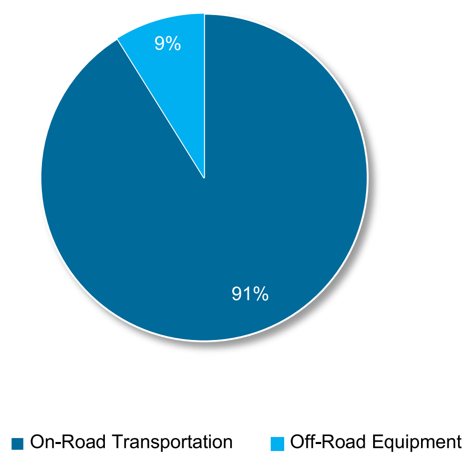
Figure 5 – 2014 Community Stationary Energy Emissions by Energy Type



Transportation

Transportation sector emissions account for 42% of total community emissions. As shown in Figure 6, the majority of transportation emissions come from on-road vehicles driving on roadways within the community (91%). Off-road equipment, such as lawnmowers, forklifts, construction equipment, and railway operations provide the remaining 9% of sector emissions.

Figure 6 – 2014 Community Transportation Emissions by Sub-Sector



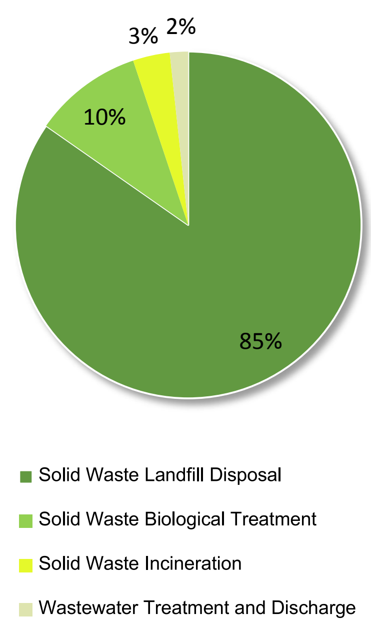
The majority of transportation emissions come from on-road vehicles driving on roadways within the community (91%).

The City's transportation emissions can also be viewed as rural transportation versus urban transportation. The distinction between the two is sourced from U.S. Census data that uses population density and land use data. On-road vehicles operating on urban roadways accounted for 91% of Transportation sector emissions, while rural on-road emissions accounted for less than 1%. This is as expected as most of the roadways within the City of Raleigh would be considered urban.

Waste

Accounting for only <2% of total community emissions, the Waste sector includes emissions from solid waste landfilling, biological treatment and incineration, and also the biological process emissions related to wastewater treatment. The majority of waste sector emissions are due to the landfilling of the City's solid waste in the South Wake County landfill. Emissions from the (now closed) North Wake and Wilders Grove landfills are also included in this sector.

Figure 7 – 2014 Community Waste Emissions by Sub-Sector



Emissions Trends

In 2014 Forbes ranked Raleigh the second-fastest growing city in the US. In 2012 the City of Raleigh developed a communitywide GHG emissions inventory for the base year 2007 and also 2010. As shown in Table 3 total communitywide **emissions** from activities occurring within both the city's geographical boundary and its service areas (e.g. water/sewer provision, trash collection, etc.) **in 2007 were estimated to be approximately 4,877,000 MTCO$_2$e. In the comparable 2014 calculation, communitywide activities generated approximately 4,998,000 MT CO$_2$e, representing a 2% increase from the 2007 baseline (approximately 120,000 MTCO$_2$e) despite an approximate 16% increase in population and steady increase in the number of jobs in the city over the same period.**[16]

Note that in 2014 communitywide emissions totaled 5,489,378 MT CO$_2$e; however, as some emission sources included in the 2014 inventory were not estimated in past inventories (namely fuel oil and LPG stationary sources, off-road transportation and waste disposal) those sources were removed from the 2014 data presented in Table 3 in order to provide trending consistency across the years.

Based on the data collected and emissions quantified for the Community Inventory the following trends were observed.

- In 2007 transportation sector emissions were the largest contributor to the total community emissions (47%) followed by purchased electricity (43%). However, between 2007 and 2014 transportation sector emissions reduced by 8% and emissions from purchased electricity increased by 3%. Therefore in 2014, purchased electricity represents 43% of the total community emissions followed by transportation (42%).

- Communitywide emissions from purchased electricity increased due to an increase in population, coupled with an improvement in data accuracy. In 2014 electricity consumption data was provided for key end user categories, rather than calculated on a per capita basis as per the previous inventories. Similarly emissions from stationary combustion saw a 51% increase between 2007 and 2014 due to a population increase coupled with a more complete inventory of sources.

- Despite an increase in population, comparable transportation sector emissions saw an 8% decrease between the baseline year and 2014. This is likely due to the combination of a more appropriate basis for estimating vehicle mileage specific to Raleigh, plus the application of a more current emissions estimation model which in turn reflects the average national improvement in vehicle fuel efficiency and emissions as older, higher emitting vehicles are replaced.

Results indicate a 2% increase from the 2007 baseline to 2014 (approximately 120,000 MTCO$_2$e), despite an approximate 16% increase in population and steady increase in the number of jobs in the city over the same period.

[16] Population data for growth calculations sourced from: https://www.raleighnc.gov/government/content/PlanDev/Articles/LongRange/RaleighDemographics.html - 2015 data book; http://www.raleighnc.gov/environment/content/AdminServSustain/Articles/SustainabilityReport.html - Community-wide GHG Inventory Years 2007 and 2010, Exhibit 3

Table 2 – Community Emissions Inventory Trends (all emission sources)

Sector	Emissions (MT CO_2e /year)		
	2007	2010	2014
Stationary Energy	**2,575,827**	**2,883,240**	**3,091,110**
Residential buildings	-	-	*1,255,317*
Commercial and institutional buildings and facilities	-	-	*1,578,469*
Manufacturing industries and construction	-	-	*257,323*
Transportation	**2,301,350**	**2,499,240**	**2,320,358**
On-road transportation	*2,301,350*	*2,499,240*	*2,114,273*
Off-road transportation	-	-	*206,085*
Waste	**-**	**-**	**77,911**
Solid Waste Landfill Disposal	-	-	*65,986*
Solid Waste Biological Treatment	-	-	*7,912*
Solid Waste Incineration	-	-	*2,682*
Wastewater Treatment and Discharge	-	-	*1,330*
TOTAL	**4,877,177**	**5,382,480**	**5,489,378**

Key:

Blank cells	Table only compares like for like emission sources between 2007, 2010, and 2014. Enhancements to the 2014 inventory allowed for more detailed data collection and analysis. Therefore, when a source type was not analyzed in a given year, emissions for that source and the percent change are denoted with a "-".
Stationary Energy	Stationary Energy sector emissions come from the combustion of fuel in residential, commercial/institutional buildings and facilities and manufacturing industries and construction, as well as power plants to generate grid-supplied energy.
Transportation	Transportation sector emissions include emissions from on-road operated sources such as cars, trucks, vans and sport-utility vehicles (SUVs); and off-road operated sources such as construction, landscaping, and industrial equipment and rail operated in the city's boundaries
Waste	Waste sector emissions include emissions from solid waste generated by businesses and residents within the City boundary and disposed / treated / incinerated within the City boundary (i.e., the City's closed Wilder Grove landfill, the City's Yard Waste Compost Center and a private sector clinical waste incinerator); emissions from solid waste generated within the City boundary but disposed outside of the city boundary (i.e., at South Wake and North Wake County landfills) (a Scope 3 source of emissions); and process emissions from treating wastewater generated by business and residents within the City boundary and treated within the city boundary (i.e., the City of Raleigh currently has three wastewater treatment plants within its operational control: Little Creek, Neuse River and Smith Creek; however, the Neuse River Facility is the only plant that serves the Raleigh population and therefore is the only plant included in the Community inventory).
Biological Treatment	Treatment emissions are from green waste composting at the City's Yard Waste Compost Center

Table 3 – Community Emissions Inventory Trends (like for like emission sources only)[17]

Sector	2007 (MT CO_2e)	%	2010 (MT CO_2e)	%	2014 (MT CO_2e)	%	% Change 2010 - 14	% Change 2007 - 14
Stationary Energy	**485,397**	**10%**	**670,910**	**13%**	**732,425**	**15%**	**9%**	**51%**
Residential	*207,090*	*4%*	*317,760*	*6%*	*322,663*	*6%*	*2%*	*56%*
Commercial	*248,400*	*5%*	*280,010*	*5%*	*270,306*	*5%*	*-3%*	*9%*
Industrial	*32,710*	*1%*	*77,810*	*1%*	*139,457*	*3%*	*79%*	*326%*
City of Raleigh Operations[18]	*-2,803*	-	*-4,670*	-	-	-	-	-
Purchased Electricity	**2,090,430**	**43%**	**2,212,330**	**41%**	**2,150,849**	**43%**	**-3%**	**3%**
Transportation	**2,301,350**	**47%**	**2,449,240**	**46%**	**2,114,273**	**42%**	**-14%**	**-8%**
TOTAL	**4,877,177**		**5,332,480**		**4,997,547**		**-6%**	**2%**

Key:

Blank cells	Table only compares like for like emission sources between 2007, 2010, and 2014. Enhancements to the 2014 inventory allowed for more detailed data collection and analysis. Therefore, when a source type was not analyzed in a given year, emissions for that source and the percent change are denoted with a "-".
Stationary Energy	Stationary Energy sector emissions come from the combustion of fuel in residential, commercial/institutional buildings and facilities and manufacturing industries and construction, as well as power plants to generate grid-supplied energy.
City of Raleigh Operations	Represents a subset of the community inventory and illustrates the emissions generated as a direct result of actions taken by the City government.
Transportation	Transportation sector emissions include emissions from on-road operated sources such as cars, trucks, vans and sport-utility vehicles (SUVs); and off-road operated sources such as construction, landscaping, and industrial equipment and rail operated in the City's boundaries

[17] Note: Stationary Combustion only includes natural gas for this particular comparison, as this is the only information available for 2007 and 2010. Mobile Combustion only includes On-Road Emissions,

[18] Emissions from City of Raleigh Operations were subtracted from Community totals in 2007 in order to avoid double counting.

Priority Emissions Sources

As shown throughout this section, community emissions are primarily a result of stationary energy consumption in buildings and on-road transportation in the community, which is typical for most cities. The flow charts below trace three primary emissions sources from the sector level to a specific fuel type or end use. This type of analysis establishes a framework for defining future emissions reduction strategies. The sub-sectors that are highlighted in red represent the areas to focus on for these strategies.

For example, strategies designed to reduced electricity use by commercial and institutional facilities would address nearly one-quarter (24%) of total emissions. This could include energy audits for both commercial/institutional and residential entities. Audits are often conducted by the utility provider, and could be encouraged by the City of Raleigh.

Similarly, strategies that result in increased vehicle efficiency, alternative fuel vehicle use, or alternative transportation options in urban areas such as continued development of walking and cycling paths, public transportation expansion, and expanded electric vehicle infrastructure would affect nearly 40% of total emissions.

Figure 8 – 2014 Community Transport Emissions Summary

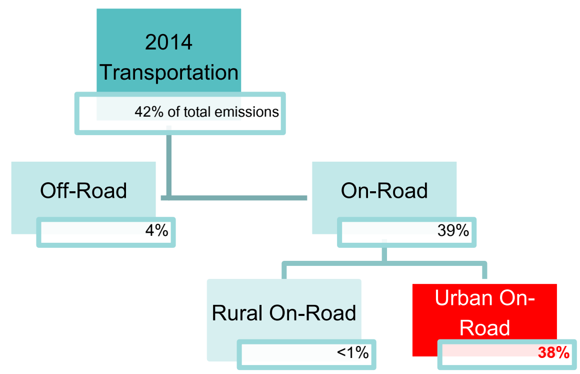
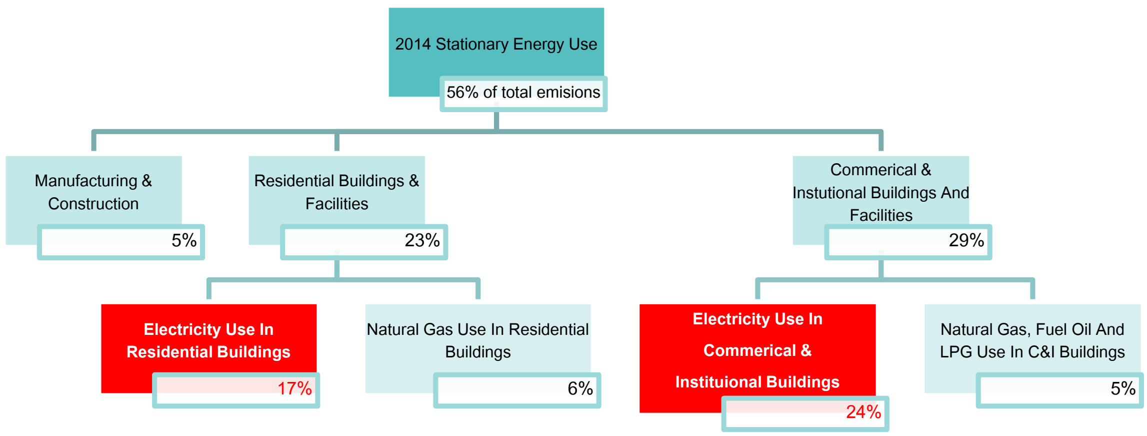


Figure 9 – 2014 Community Stationary Energy Emissions Summary



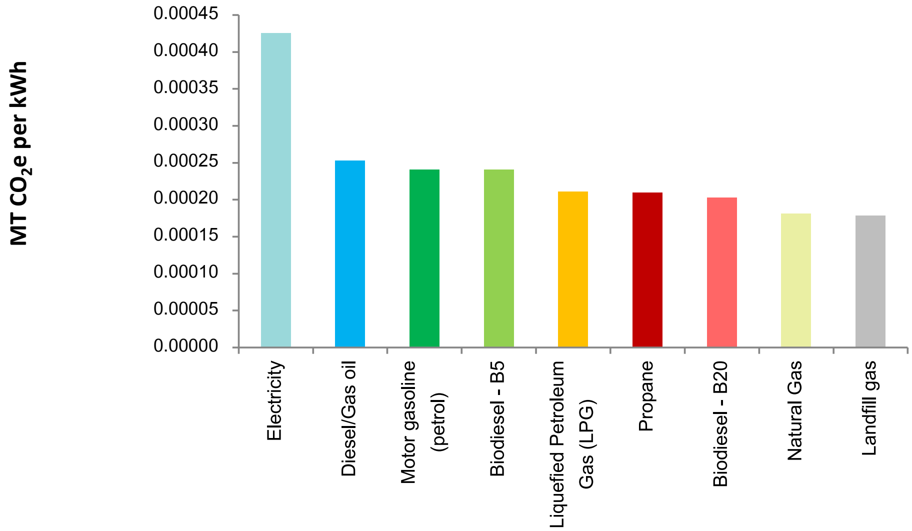
Community emissions reduction opportunities can also be assessed based on the type of energy used. With over 40% of total emissions related to community electricity use, the electric utilities' portfolio of electricity sources supplying the grid is a huge influence on the city's emissions. If electricity on the grid can be generated from more renewable sources and less carbon-intense fossil fuels, then another primary emissions source can be mitigated. As shown in Figure 10 electricity consumption generates the highest emissions per unit of energy (kWh) of any fuel source analyzed in the inventory. This is due to the mix of fuel sources used to generate electricity sold in the Virginia / Carolina region (approximately 41% nuclear, 35% coal, 20% natural gas, 3% renewable and <1% other fossil fuel[19]) as shown in Figure 11. Note that Figure 11 depicts fuel mix changes over time.

Over time, the proportion of fossil fuel energy types (e.g. gas, coal, oil) in the electricity portfolio is projected to decrease, while the share of renewable sources (e.g., hydro, wind, solar) to increase. The result will be lower community electricity-related emissions. For example, 35% of cites that disclosed their energy mix to CDP's cities program, indicated that already more than 75% of their electricity is from non-fossil fuel sources[20]. The City may identify local opportunities to accelerate this transition toward a lower-carbon electricity grid in order to realize greater emissions reductions in the local inventory.

[19] Source: eGRID 2005, 2009 and 2012 Sub-Region Generation Resource Mix – Summary Tables for the SERC Virginia/Carolina (SRVC) eGRID subregion (2005, 2009 and 2012 data were used in the 2007, 2010 and 2014 Community Inventories; 2012 is the most recent data available) - https://www.epa.gov/energy/egrid

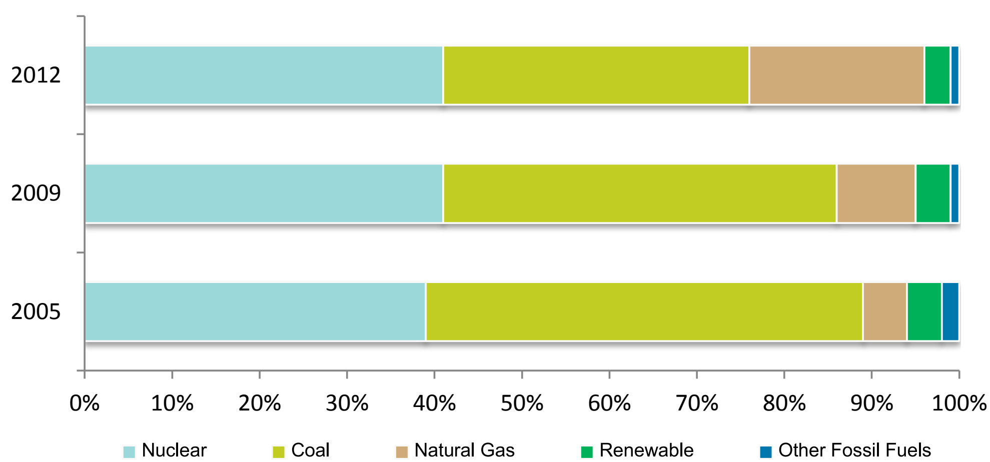
[20] Source:https://www.cdp.net/Documents/cities/cities-infographic-2015.pdf

Figure 10 – Emissions Intensity per Kilowatt Hour per Energy Type[21]



Source: AECOM 2015. Figure 10 depicts the MT CO2e per KWh (i.e., how much CO2e is released per KWh used) for each energy type (propane, natural gas, etc.). Electricity use emits the highest amount of CO2e per KWh, whereas natural gas and landfill gas produce the least.

Figure 11 – Mix of Fuel Sources Used to Generate Electricity Sold in the Virginia / Carolina Region[17]



Source: eGRID 2005, 2009 and 2012 Sub-Region Generation Resource Mix – Summary Tables for the SERC Virginia/Carolina (SRVC) eGRID subregion (2005, 2009 and 2012 data were used in the 2007, 2010 and 2014 Community Inventories; 2012 is the most recent data available) - https://www.epa.gov/energy/egrid.

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[21] Figure 10 depicts the MT CO_2e per KWh (i.e. how much CO_2e is released per KWh used) for each energy type (propane, natural gas, etc.). Electricity use emits the highest amount of CO_2e per KWh, whereas natural gas and landfill gas produce the least

Local Government Operations Inventory

The City of Raleigh provides a variety of services to community residents and businesses. The provision of these services results in energy consumption by buildings, lighting and other facilities, fuel consumed by vehicles and equipment, and the use of chemical refrigerants. The LGO inventory described here estimates the emissions related to the provision of these services.

This section first describes the LGO inventory emissions categories that are included in this analysis. The results of the 2014 inventory are then presented with additional detail provided for certain sub-sectors based on data availability. A comparison of emissions to the 2007 baseline is then presented along with a discussion on trends. Finally, the section concludes with a high-level analysis of the primary emissions sources in the LGO inventory in order to inform future efforts to reduce emissions.

Emissions Sectors

The LGO inventory is organized into the following four sectors: Municipal Buildings and Other Facilities, Vehicles, Waste Disposal, and Other Process and Fugitive Emissions.

Municipal Buildings and Other Facilities

The Municipal Buildings and Other Facilities sector represents the energy consumption from all City-operated buildings and facilities, e.g., City Hall, the Convention Center and water and wastewater pumping and treatment facilities. This sector includes emissions resulting from the consumption of electricity, natural gas, and fuel oil used in emergency backup generators. Data based on utility billing records and equipment maintenance records were used to attribute emissions according to the following department sub-sectors, including:

- Convention Center;
- Fire Department;
- Housing and Neighborhoods;
- Information Technology;
- Parks, Recreation & Cultural Resources;
- Police Department;
- Public Utilities;

- Public Works[22];
- Raleigh-Wake Emergency Communications Center;
- Shared Facilities;
- Solid Waste Services; and,
- Other City Departments.

This sector also includes electricity consumption from City-operated streetlights, traffic lights, and sports field lighting.

Vehicles

On-Road Vehicle Fleet

This sector includes emissions from fuel consumption in City-operated on-road vehicles (e.g. Police and Fire Department vehicles and Public Works vehicles). Emissions were analyzed according to vehicle fuel type, including gasoline, diesel, biodiesel, compressed natural gas (CNG) and liquefied petroleum gas (LPG). The City's fleet management system also allows the data to be analyzed according to City department.

Off-Road Vehicle Fleet and Equipment

The Off-Road Vehicles and Equipment sector includes the fuel consumption from specialized equipment operated by City departments, such as construction and landscape maintenance equipment. As with On-Road Vehicles emissions, this sector was analyzed based on fuel type, including, gasoline, diesel, biodiesel, and LPG.

Transit Fleet

The Transit Fleet sector includes the gasoline and biodiesel consumption of the Go-Raleigh bus fleet.

Waste Disposal

This Waste Disposal sector represents process and fugitive emissions from the City's solid and liquid waste disposal facilities, specifically:

- Wilders Grove Landfill (now closed);
- Yard Waste Compost Center; and,
- Neuse River, Smith Creek and Little Creek wastewater treatment plants.

Other Process and Fugitive Emissions

The Other Process and Fugitive Emissions sector represents emissions resulting from the use of refrigeration systems in the City's vehicle fleet and Go-Raleigh bus fleet and refrigerants and fire suppression equipment used in City owned buildings. This category was not included in the community inventory as it was not feasible to access this information at the community-wide scale.

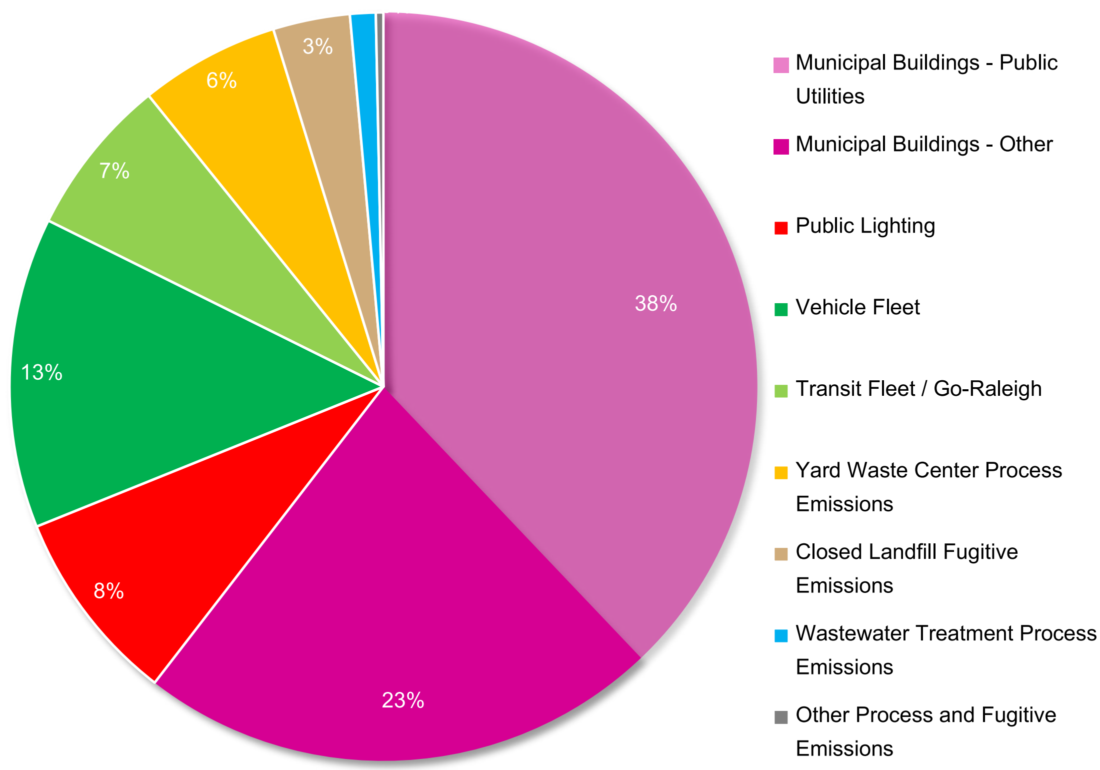
2014 Inventory

City operations for Fiscal Year (FY) 2014 generated approximately 130,800 MT CO_2e, representing only 2% of the total Community emissions, which is within the typical range of 1-5% seen in other local government emission inventories. As shown in Figure 12 on the following page, the Municipal Buildings and Other Facilities sector accounts for the majority (69%) of LGO emissions. The vehicle fleet and transit fleet each contribute 13% and 7% of total emissions respectively. Emissions from the waste disposal sector represent 10% of total emissions (6% from the Yard Waste Center, 3% from the Wilders Grove closed landfill and 1% from the wastewater treatment plants). The remaining (less than 1%) emissions come from other Process and Fugitive Emissions.

Based on this inventory, as shown in Table 4 the primary source of emissions from City operations is related to the provision of electricity for Public Utilities, e.g., wastewater treatment plants. This information can begin to inform the types of actions that would be most effective in reducing the LGO's emissions in the future.

[22] As of July 1, 2016, the former Public Works Department has been split into the new Engineering Services and the new Transportation Departments.

Figure 12 – 2014 Local Government Operations Greenhouse Gas Emissions Inventory



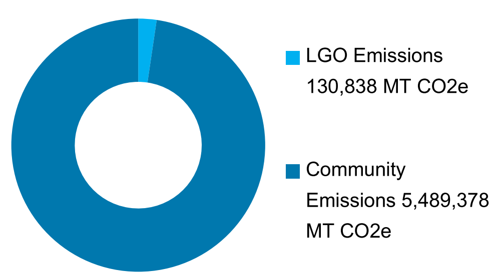


Table 4 – 2014 Local Government Operations Emissions Greenhouse Gas Emissions Inventory by Department

Department[23]	MUNICIPAL BUILDINGS and OTHER FACILITIES (STATIONARY)					VEHICLES (MOBILE)		WASTE DISPOSAL			OTHER PROCESS & FUGITIVE	MT CO_2e/yr	% of Total
	Scope 1			Scope 2	Scope 3	Scope 1		Scope 1			Scope 1		
	Natural Gas	Diesel / Gas Oil	Propane	Electricity	Electricity T&D Losses[24]	Vehicle Fleet	Transit Fleet	Landfill	Yard Waste Center	Wastewater Treatment	Refrigerants & Fire Suppressants		
Fire Department	435	-	-	1,102	101	1,571	-	-	-	-	-	3,209	2%
Police Department	225	21	-	1,017	93	5,740	-	-	-	-	-	7,097	5%
Public Works	330	12	-	13,662	1,253	1,745	-	-	-	-		17,001	13%
Streetlights	-	-	-	*9,548*	*876*	-	-	-	-	-	-	*10,424*	*8%*
Traffic Lights	-	-	-	*70*	*6*	-	-	-	-	-	-	*76*	*0%*
Go-Raleigh	-	-	-	-	-	-	8,993	-	-	-	425	9,418	7%
Public Utilities	238	1,741	-	43,613	3,999	3,206	-	-	-	1,450	-	54,247	41%
Solid Waste Services	-	16	-	283	26	3,230	-	4,350	7,912	-	-	15,817	12%
Parks, Recreation & Cultural Resources	1,930	11	-	7,147	655	1,586	-	-	-	-	<1	11,329	9%
Sports Field Lighting	-	-	-	*481*	*44*	-	-	-	-	-	-	*525*	*<1%*
Shared Facilities	19	62	-	3,229	296	-	-	-	-	-	-	3,607	3%
Convention Center	-	-	-	5,854	537	-	-	-	-	-	-	6,391	5%
Raleigh-Wake Emergency Communications Center	3	6	-	48	4	-	-	-	-	-	-	61	0%
Housing & Neighborhoods	-	-	-	27	3	-	-	-	-	-	-	30	0%
Information Technology	-	-	-	1	-	-	-	-	-	-	-	1	0%
Other City Departments	2,150	-	-	-	-	-	-	-	-	-	-	2,630	2%
TOTAL	***5,331***	***1,868***	***0***	***75,983***	***6,968***	***17,556***	***8,993***	***4,350***	***7,912***	***1,450***	***425***	***130,838***	***100%***

[23] As of July 1, 2016, the former Public Works Department has been split into the new Engineering Services and the new Transportation Departments

[24] Scope 3 emissions associated with electricity transmission and distribution losses are included in the LGO inventory because electricity use is a significant contributor to the total inventory

Key:

Scope1	GHG emissions generated directly from sources owned or operated by the City e.g. natural gas and fuel oil by all City-operated buildings and facilities, gasoline combustion by City's vehicle fleet or direct emissions from a landfill owned by the City
Scope 2	GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling by the City
Scope 3	All other GHG emissions that occur due to activities undertaken by the City but occur from sourced now owned or controlled by the City
Blank cells	When a source or scope is not applicable to a department this is denoted with a "-".
Transportation	Transportation sector emissions include emissions from on-road operated sources such as cars, trucks, vans and sport-utility vehicles (SUVs); and off-road operated sources such as construction, landscaping, and industrial equipment and rail operated in the City's boundaries
Waste Disposal	Waste Disposal emissions represents process and fugitive emissions from solid and liquid waste disposal facilities operated by the City, specifically the Wilders Grove Landfill (now closed); the Yard Waste Compost Center; and the Neuse River, Smith Creek and Little Creek wastewater treatment plants. By comparison, as directed in GHG accounting protocols, the Community inventory includes: • Emissions from solid waste generated by businesses and residents within the City boundary and disposed / treated / incinerated within the City boundary, i.e., the Wilders Grove landfill, the Yard Waste Compost Center and a private sector clinical waste incinerator; • Scope 3 emissions from solid waste generated within the City boundary but disposed outside of the City boundary (South Wake and North Wake County landfills); and • Process emissions from treating wastewater generated by business and residents within the City boundary and treated within the City boundary (The City of Raleigh currently has three wastewater treatment plants within its operational control: Little Creek, Neuse River and Smith Creek; however, the Neuse River Facility is the only plant that serves the Raleigh population and therefore is the only plant included in the Community inventory).

The following pages provide greater detail on the distribution of emissions within each sector. Emissions are represented according to departmental sub-sectors, fuel-type, or both.

Municipal Building and Other Facilities Emissions

The City of Raleigh's buildings, facilities, water and wastewater pumping and treatment plants, and lighting installations consume electricity that is mostly produced through the combustion of fossil fuels. Although these emissions are generated by power plants outside of the City's direct control, by creating demand for this electricity, the City is indirectly responsible for these emissions. Therefore, electricity consumed at City facilities is considered a Scope 2 emission source, and represents more than half of the City's emissions.

Municipal Buildings

Emissions from municipal buildings account for 61% of total LGO emissions and were further analyzed according to department sub-sectors to illustrate the primary contributors of emissions within the sector (Table 5). This sector includes hundreds of City operated buildings such as City Hall, the Department of Public Works offices and treatment plants, and the Convention Center.[25] The buildings occupied by the City's Public Utilities department comprise water and wastewater treatment facilities, pumping and lift stations, and generated the majority (63%) of municipal building-related emissions. The buildings occupied by the Parks, Recreation and Cultural Resources Department were the second highest contributor with 12% of sector emissions.

The buildings occupied by the City's Public Utilities Department comprise water and wastewater treatment facilities, and generated the majority (63%) of municipal building-related emissions.

[25] As of July 1, 2016, the former Public Works Department has been split into the new Engineering Services and the new Transportation Departments

Table 5 – 2014 LGO Municipal Buildings and Other Facilities Emissions by Department

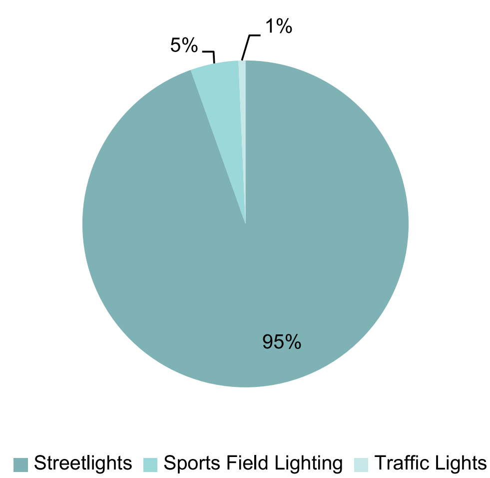
Sub Sector[26]	Emissions (MT CO2e)	%
Public Utilities[27]	49,590	63%
Parks, Recreation & Cultural Resources	9,218	12%
Convention Center	6,391	8%
Public Works[28]	4,757	6%
Shared Facilities	3,607	5%
Other City Departments	2,150	3%
Fire Department	1,638	2%
Police Department	1,357	2%
Solid Waste Services	325	<1%
Raleigh-Wake Emergency Communications Center	61	<1%
Housing & Neighborhoods	30	<1%
Information Technology	1	<1%
TOTAL	**79,125**	**100%**

Building emissions can also be evaluated based on the type of energy used (Figure 13 at the end of this section). Electricity use generated over 90% of all building-related emissions. Natural gas provides 7% and diesel provides approximately 2% of the municipal buildings sector emissions. The distribution of emissions by fuel type can inform the future reduction strategy development process. For example, strategies that aim to reduce the amount of natural gas used for heating will impact only 7% of municipal building related emissions. To achieve a meaningful reduction in emissions from this sector, strategies to reduce use of electricity and increase the use of renewable energy within the electricity portfolio are needed to address the primary emissions source in the Municipal Buildings sector.

Other Facilities (Public Lighting)

Public lighting accounts for 8% of the total LGO emissions and includes electricity consumption from City-operated streetlights, traffic lights, and sports field lighting. **City operated streetlights generate nearly 95% of emissions in the public lighting sector.** The conversion of approximately 30,000 conventional streetlights to high efficiency LEDs in 2015 was therefore a key initiative for reducing emissions from this sector; these reductions will be captured in the next update to the inventory. Sports field lighting contributes an additional 5% of sector total emissions and traffic lights account for the remaining emissions for this sector. All emissions from this sector are associated with electricity use.

Figure 13 – 2014 LGO Public Lighting Emissions by Sub-Sector



[26] The Northeast Remote Operations, Central Operations Facility, and Central Communications Center became operational after FY2014 and are therefore not included in this inventory update. It is recommended that future inventory updates present remote operations data separately. These facilities, while efficient, are large and as a result may merit unique tracking and analyses.

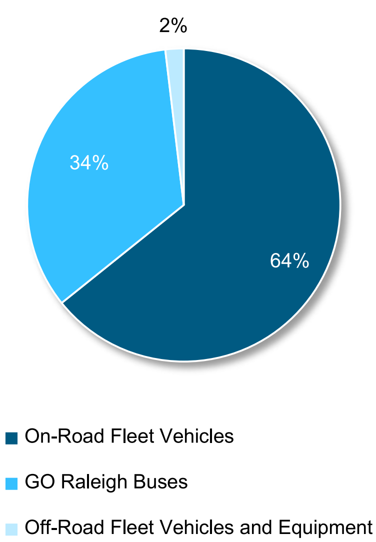
[27] Per GHG inventory reporting convention, electricity use at Public Utilities is included with buildings and other facilities

[28] As of July 1, 2016, the former Public Works Department has been split into the new Engineering Services and the new Transportation Departments

Vehicles

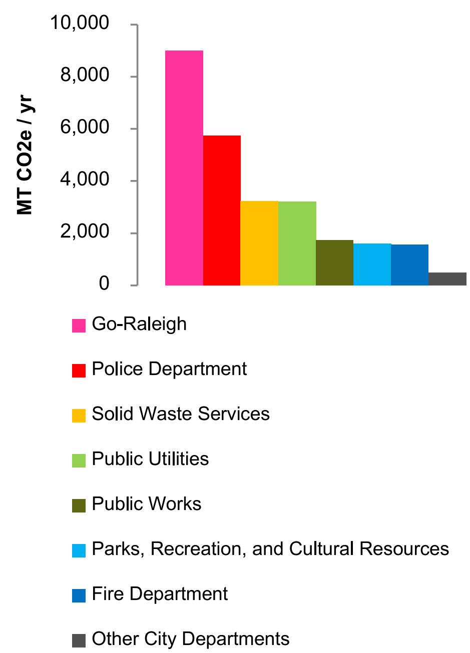
Vehicles contribute approximately 26,500 $MTCO_2e$ or 20% of the total LGO emissions. The City's on-road vehicle fleet operations in Fiscal Year 2014 consisted of over 650 passenger cars including police cruisers, over 900 light duty vehicles such as pickup trucks and sport utility vehicles, and over 450 heavy duty vehicles, and nearly 100 Go-Raleigh buses in the transit fleet. Collectively, the vehicle and transit fleets contribute 64% of vehicle sector total emissions. Off-road vehicles and equipment includes the fuel consumption from specialized equipment operated by City departments, such as construction and landscape maintenance equipment and generates only 2% of sector total emissions. Over one-third (34%) of the vehicle sector emissions are due to the gasoline and biodiesel consumption of the Go-Raleigh bus fleet.

Figure 14 – 2014 LGO Vehicles Emissions by Sub-Sector



The City's fleet management system allows the data to be analyzed according to City department. As shown in Figure 16 the Go-Raleigh bus fleet was the largest contributor providing 34% of sector emissions followed by the Police department with 22% of sector emissions. Solid Waste Services vehicles and Public Utilities vehicles each provide 12% of sector emissions, followed by Public Works; Parks, Recreation and Cultural Resources; and vehicles owned by the Fire Department. Other miscellaneous vehicles (i.e., insufficient data available to allocate vehicles to a specific department) contributed the remaining 2% of vehicle sector emissions.

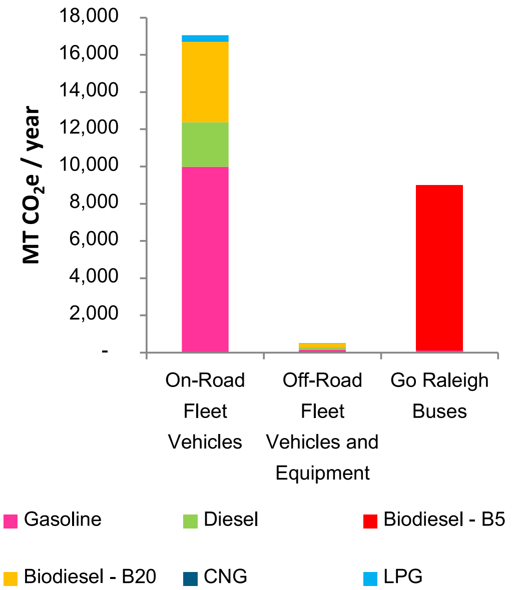
Figure 15 – 2014 LGO Vehicles Emissions by Department



When analyzed by fuel type, as shown in Figure 17 below, **gasoline vehicles and equipment generate nearly 40% of sector emissions**. Biodiesel (B5) consumption by the Go-Raleigh bus fleet contributes just over 30% of vehicle sector emissions and biodiesel (B20) fleet vehicles contribute just fewer than 20%.

Diesel vehicles provide 10% of vehicle emissions. CNG and LPG vehicles provide the remaining 1%.

Figure 16 – 2014 LGO Vehicles Emissions by Fuel Type



Did you know?

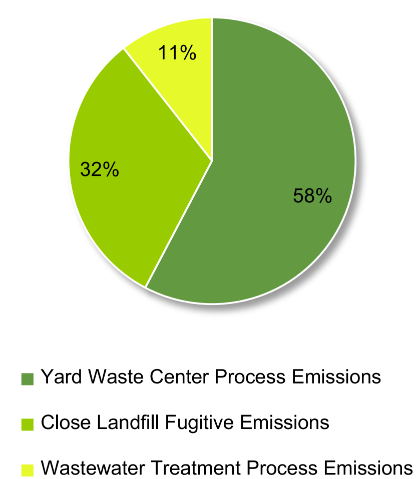
Biodiesel B20 is a blend of 20% biodiesel and 80% regular petroleum diesel and B5 is 5% biodiesel and 95% petroleum diesel. Biodiesel is a type of fuel made from crops or vegetable oil. In accordance with the LGO Protocol the CO_2 emissions from the combustion of biodiesel have been determined net '0'. This is because the carbon in biodiesel was recently in living organic matter so has already recently "taken out" of the atmosphere, thereby creating a net-neutral carbon-balancing cycle. The use of biofuel blends has reduced the City's total LGO emissions by 1,505MTCO_2e (approximately 1%). See Technical Appendix for further details.

Waste Disposal

GHGs including methane (CH_4) and nitrous oxide (N_2O) are emitted by landfills and composting facilities. In particular, CH_4 is generated by the anaerobic decomposition of waste in landfills, while both CH_4 and N_2O are emitted by composting facilities.

Emissions from City operated waste disposal facilities contribute 10% of total LGO emissions, comprising 7,900 MT CO_2e from the Yard Waste Center, 4,350 MT CO_2e from the Wilders Grove closed landfill and 1,450 MTCO_2e from the wastewater treatment plant processes.

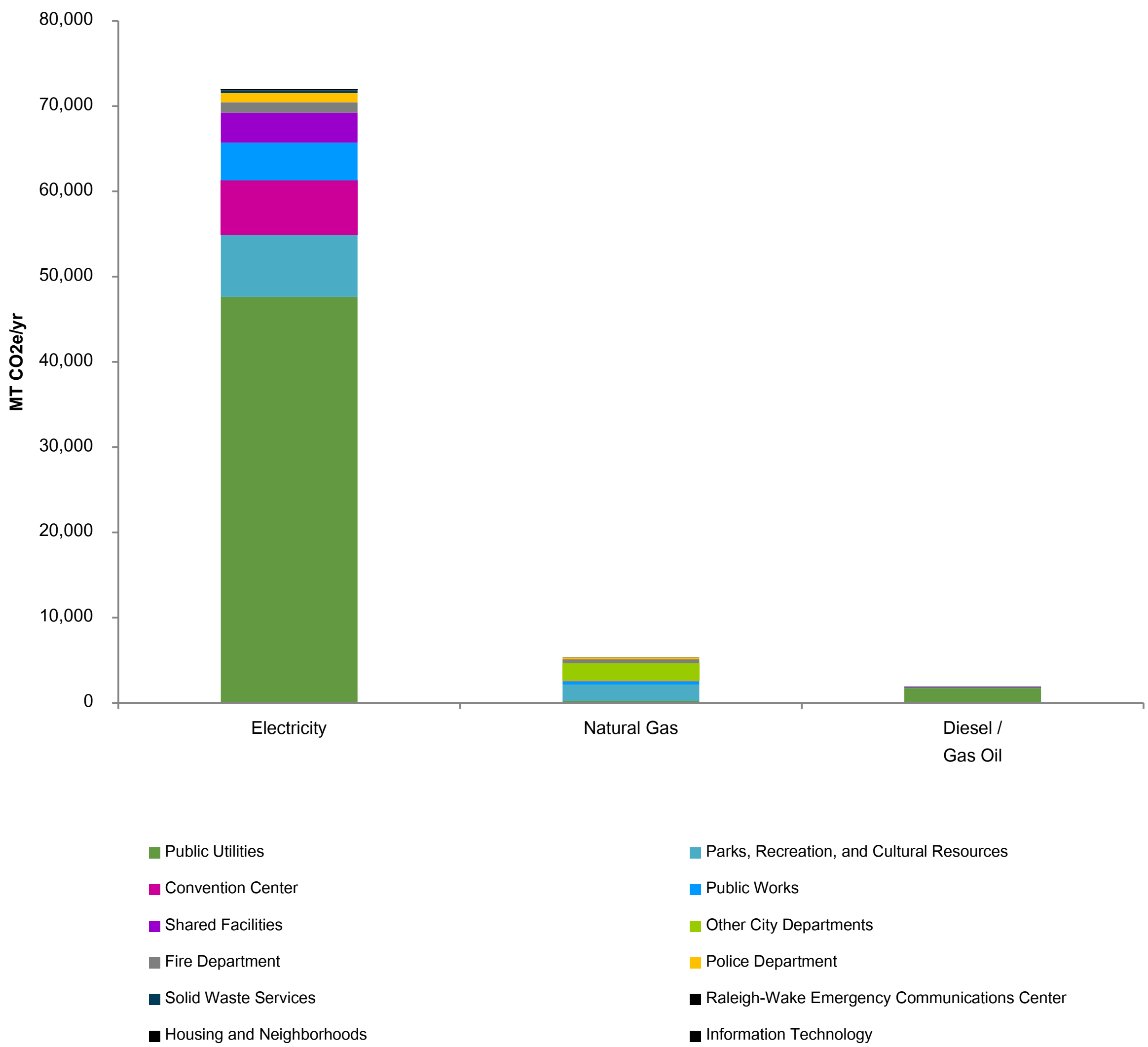
Figure 17 – 2014 LGO Waste Disposal Emissions



Other Process and Fugitive Emissions

Other process and fugitive emissions contribute less than 1% of total LGO emissions and represent emissions resulting from the use of refrigerants in the City's vehicle and Go-Raleigh bus fleet and refrigerants used in City-owned buildings.

Figure 18 – 2014 LGO Municipal Buildings Emissions by Energy Type and Department



Emission Trends

In 2010, the City of Raleigh developed a GHG emissions inventory for selected city operations for the base year 2007. As shown in Table 6 on the following page total LGO emissions from City operations in 2007 were estimated to be approximately 151,500 $MTCO_2e$, and in the 2014 calculation, City operations generated approximately 131,000 MT CO_2e, representing a 14% reduction from the 2007 baseline (approximately 20,000 $MTCO_2e$, equivalent to the emissions from 1,825 homes in one year[29]).

LGO operations in 2014 generated approximately 131,000 MT CO_2e, representing a 14% reduction from the 2007 baseline.

Based on the data collected and emissions quantified for the LGO inventory the following trends were observed. In 2007 emissions were estimated for each City department, with the largest three departments being Public Utilities (35%), Solid Waste Services (28%), and Public Works (11%). At a department level, emissions from Public Utilities remain the most significant contributor to the total 2014 LGO footprint (41%) largely due to electricity consumption at the water and waste water treatment plants and pumping stations.

Overall, emissions decreased from 2007 to 2014. Between 2007 and 2014, numerous capital upgrades including energy efficient lighting upgrades, building envelope improvements, and life cycle upgrades of HVAC systems with building automation and controls as well as roof replacements were enacted by the City. In addition, Parks, Recreation, and Cultural Resources facilities at or above 10,000 square feet were built to LEED standards. These upgrades, along with a preventative maintenance program, ensure the buildings are operating efficiently and likely contributed to the decrease in emissions observed for several sectors/departments.

This decrease is not uniform across all sectors/departments, however. The following departments saw a greater than 5% *increase* in emissions compared to 2007 mainly due to an increase in the scope of City operations and number of facilities; the scope of the Fire Department and the Parks, Recreation, and Cultural Resources Department in particular grew during this time period:

- Fire Department;
- Police Department;
- Public Works[30];
- Go-Raleigh (formerly capital area transit (CAT));
- Parks, Recreation, and Cultural Resources;
- Raleigh-Wake Emergency Communications Center;
- Housing and Neighborhoods; and,
- Other City Departments.

Whereas the following departments have seen a greater than 5% *decrease* in emissions compared to 2007:

- Solid Waste Services;
- Shared Facilities;
- Convention Center; and,
- Information Technology.

Emissions from the Public Utilities department remained fairly consistent at approximately 54,000 MT CO_2e per year.

[29] https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator

[30] As of July 1, 2016, the former Public Works Department has been split into the new Engineering Services and the new Transportation Departments

Emissions from the Solid Waste Services Department have seen the biggest decrease (26,400 MT CO_2e). This is mainly due to a substantial decrease in methane emissions from the closed Wilders Grove Landfill (from 33,000 MT CO_2e in 2007 to 4,350 MT CO_2e in FY 2014), which is to be expected for a closed landfill of its age, whose emission rates decay over time. Additional departmental reductions were due to upgrades to the Solid Waste Services building, a LEED Platinum facility.

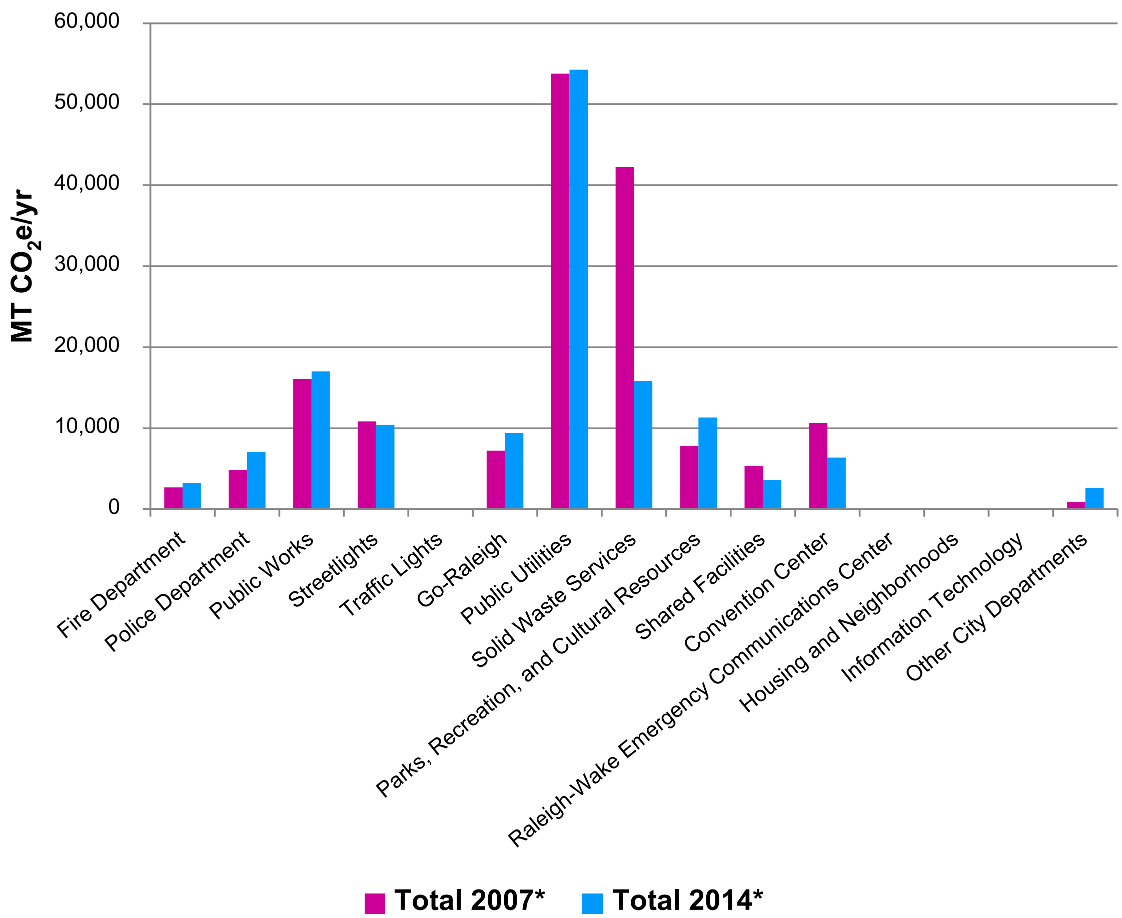
In both 2007 and 2014 the largest source of emissions was electricity use.

Table 6 – LGO Emissions Inventory Trends

Sector/Department	2007		2014		% Change 2007 - 2014
	MT CO_2e/yr	% of Total	MT CO_2e/yr	% of Total	2007-2014
Fire Department	2,675	2%	3,209	2%	20%
Police Department	4,820	3%	7,097	5%	47%
Public Works	16,075	11%	17,001	13%	6%
Streetlights	*10,823*	*7%*	*10,424*	*8%*	*-4%*
Traffic Lights	*0*	*0%*	*76*	*0%*	*N/A*
Go-Raleigh[31]	7,227	5%	9,418	7%	30%
Public Utilities	53,789	36%	54,247	41%	1%
Solid Waste Services	42,224	28%	15,817	12%	-63%
Parks, Recreation, and Cultural Resources	7,785	5%	11,329	9%	46%
Shared Facilities	5,339	4%	3,607	3%	-32%
Convention Center	10,661	7%	6,391	5%	-40%
Raleigh-Wake Emergency Communications Center	8	0%	61	0%	666%
Housing and Neighborhoods	7	0%	30	0%	329%
Information Technology	5	0%	1	0%	-85%
Other City Departments	879	1%	2,630	2%	199%
TOTAL	***151,494***	***100%***	***130,838***	***100%***	**-14%**

[31] Go-Raleigh replaced Capital Area Transit (CAT)

Figure 19 – Total LGO Emissions 2007 and 2014

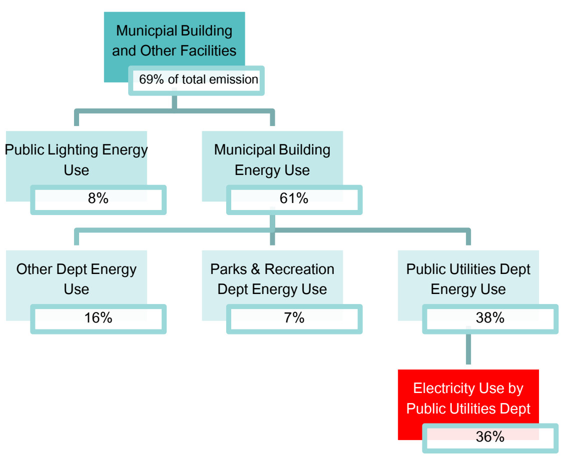


*Note: Biogenic emissions are excluded.

Priority Emissions Sources

As shown in Figure 23, electricity consumption is the largest source of LGO emissions across all sectors and departments, suggesting a broad opportunity for emissions reductions. The department and energy type data allow for further analysis, which begins to suggest the kind of near-term strategies or actions that would help the City reduce emissions. The flow charts below outline the path towards potential reduction strategies based on drilling down through the primary LGO emissions sources to the underlying energy type and department level data to identify the biggest sources of GHG emissions. As shown in Table 4, LGO emissions are primarily a result of electricity consumption by City municipal buildings and public lighting. However, based on the departmental sub-sector analysis, Public Utilities is the largest contributor within the Municipal Buildings and Facilities sector.

Figure 20 – 2014 LGO Municipal Building and Other Facilities Emissions Summary

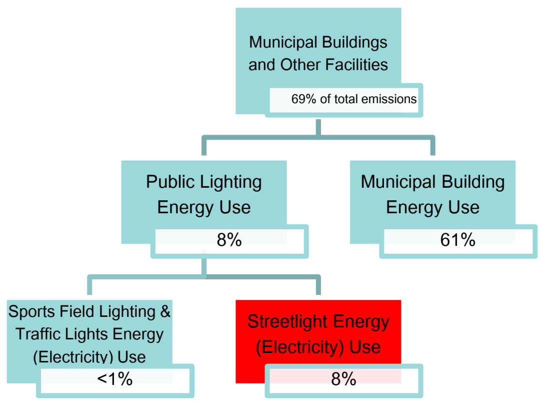


The high contribution of electricity use by the Public Utilities Department to the total LGO emissions is largely due to electricity consumption at the three wastewater treatment plants, two water treatment plants and over 150 remote facilities for distributing water and collecting wastewater throughout the City's service area.

While efficiency measures can help reduce the amount of electricity used to move water and wastewater, an alternative approach would be to reduce the carbon intensity of the electricity used by Public Utilities.

For example the EM Johnson Water Treatment Plant has a rooftop solar photovoltaic system (a system which uses one or more solar panels to convert sunlight into electricity). This 250kW solar array on top of the water treatment plant's clear well building produces an estimated 325,000 kWh of electricity per year. The Neuse River Wastewater Treatment Plant also features a 1.3MW ground-mounted solar photovoltaic system. The electricity generated at both of these plants is returned to the local electric utility. However, where financially feasible the solar photovoltaic program could be expanded so that not only is more renewable solar energy generated by the City but also that the renewable energy generated by the City is also used by the City, reducing the amount of (more carbon intensive) electricity required from the local grid. For example the Wilders Grove Solid Waste Services Center has a solar electricity system which produces approximately 103,500kWh of electricity per year. All energy generated is used on site, offsetting approximately 12% of the electrical power needed for the facility and thereby 40 $MTCO_2e$. In addition, the conversion of the Neuse River Resource Recovery Facility to an anaerobic system will use less energy and will generate methane. The City is evaluating capture of the off-gassed methane as an energy source.

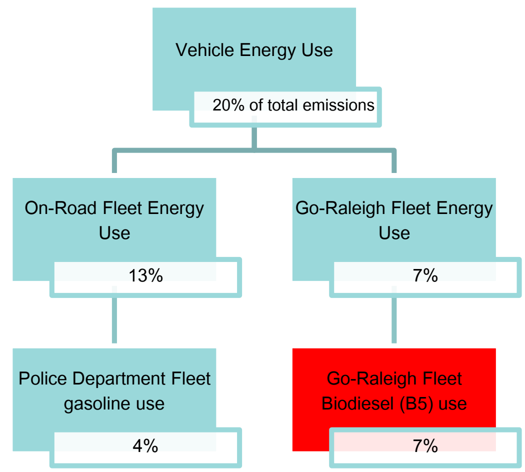
Figure 21 – 2014 LGO Public Lighting Emissions Summary



The conversion of approximately 30,000 conventional streetlights to high efficiency LEDs in 2015 targeted the third largest GHG emissions source in the sector, as shown in Figure 21, and thereby affected 8% of total LGO emissions. Emissions reductions associated with this initiative will be captured in the next update to the inventory.

At 20% of total emissions, the vehicles sector is the second largest emissions source in the inventory. Within vehicle energy use the Go-Raleigh and Police Department fleets contribute 7% and 4% of total LGO emissions respectively.

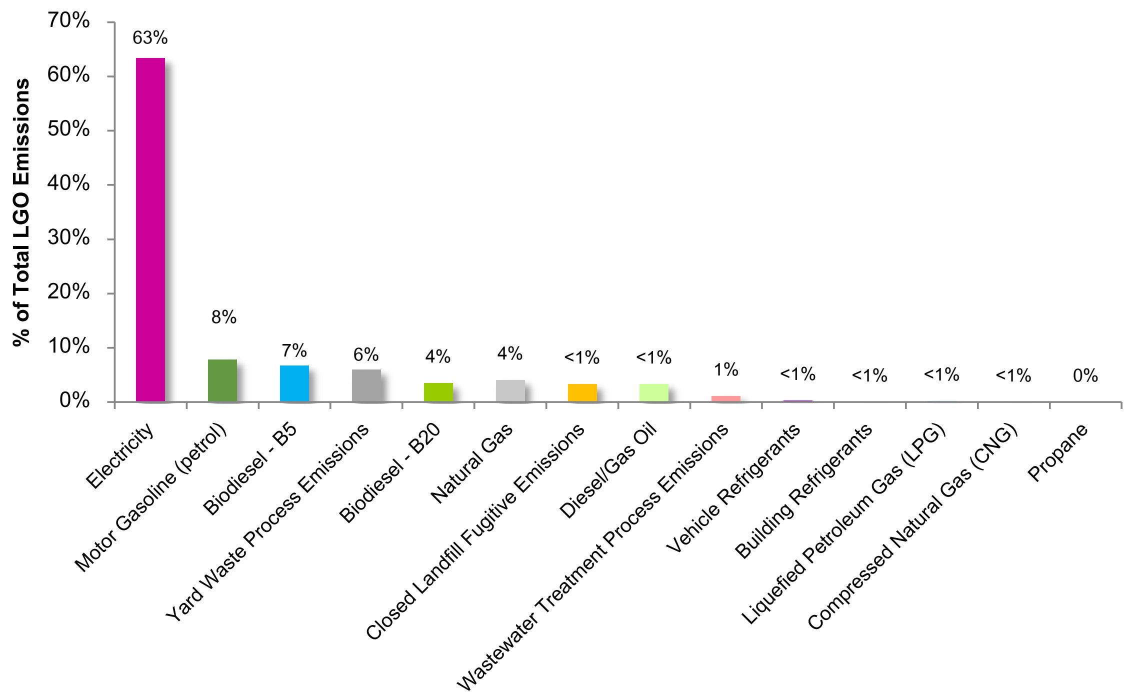
Figure 22 – 2014 LGO Vehicle Energy Use Emissions Summary



Since 2002 the City has been actively encouraging and accelerating the use of alternative fuel vehicles within the City's vehicle fleet. The Go-Raleigh transit fleet runs on Biodiesel B5, which although is less carbon intensive than conventional diesel/gasoline is still largely fossil fuel based (i.e. B5 is only 5% biodiesel) and results in savings of 430 MT CO_2e per year. The use of biofuel blends with a higher percentage of biodiesel for the transit fleet, similar to what is in use in select vehicles in the City vehicle fleet, would target 7% of total emissions. Typically biofuel blends of up to 20% biodiesel can be incorporated without the need for vehicle modifications. Compressed Natural Gas (CNG) is also used by Public Works and Parks, Recreation and Cultural Resources in on-road vehicles. In addition, the City is exploring the potential to collect and compress methane that will be produced at the Neuse River Resource Recovery Facility for vehicle use.

Currently twenty police cars are fitted for duel fuel (utilizing both gasoline and propane). As shown in Figure 10 propane is greater than 10% less carbon intensive compared to gasoline; therefore, expanding this program would target 4% of total LGO emissions.

Figure 23 – 2014 LGO Emissions by Source



THE CITY'S GHG EMISSIONS IN PERSPECTIVE

GHG inventory estimates can differ greatly between cities. Not only is each city unique in the types of services they provide (e.g. some may have significant transit operations or rely on other entities for water and wastewater), but also GHG inventories can often differ in the organization and operational boundaries, timeframe, and data sources and at times the calculations approach used.

However, there are still benefits to comparing the GHG emissions for the City of Raleigh to emission estimates for other cities and communities. Figures 24 and 25 compare Raleigh's community and LGO GHG emissions per capita to those of other local, regional and national cities in order to provide some context. To provide a clear comparison between cities only like-for-like emission categories are presented. Cities are listed in order of their population (smallest being Chapel Hill and the largest being Portland).

In addition, in April 2016 the EPA published its annual inventory of total US GHG emissions. This indicates like-for-like average US GHG emissions of approximately 13.1 MT CO_2e per capita nationally[32] which is comparable to Raleigh's community emissions per capita of approximately 12.5 MT CO_2e per capita.

Figure 24 – Comparison of Community Emissions

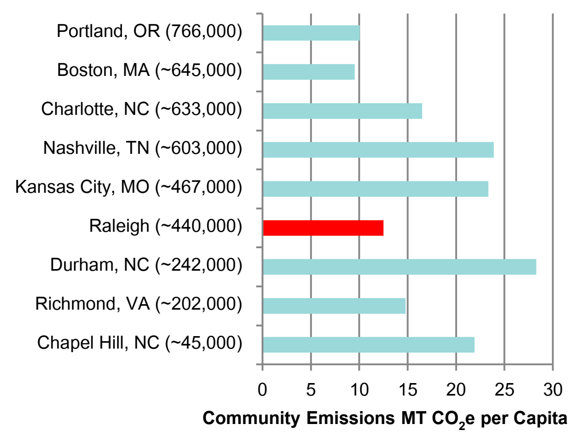
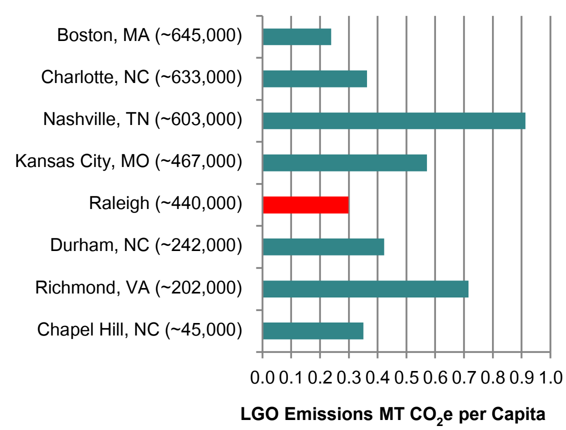


Figure 25 – Comparison of LGO Emissions



[32] Based on 2014 population estimates published by the US Census Bureau and 2014 US GHG emissions from residential, commercial, industrial, transportation and other sectors as published in EPA's *"Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990-2014"*

Conclusions and Recommendations

This 2014 inventory presents the profile of Raleigh's community wide GHG emissions and also those that are a direct result of actions taken by the City government. As with most cities the largest source of GHG emissions from both the community and LGO inventory are from consumption of electricity by buildings, followed by emissions from transportation.

- **Community activities in the City of Raleigh generated approximately 5,489,000 MT CO2e in 2014.** In 2014 stationary energy emissions were the largest contributor to the community inventory, accounting for 56% of total emissions, most significantly from electricity use in commercial/institutional facilities and residential buildings (representing 24% and 17% of total emissions, respectively). Transportation emissions contributed an additional 42%, with the waste sector responsible for the remaining less than 2% of community emissions which is typical for most cities.
- **City operations for 2014 generated approximately 130,800 MT CO2e, representing only 2% of the total Community emissions**. Emissions from stationary energy use by Municipal Buildings and Other Facilities (e.g. energy used by municipal buildings, streetlights and water and wastewater pumping and treatment facilities) accounts for the majority (69%) of City emissions, most significantly electricity use. The City's vehicle fleet and transit fleet each contribute 13% and 7% of total emissions, respectively. Emissions from the waste disposal sector represent 10% of total emissions and the remaining (less than 1%) emissions come from other Process and Fugitive Emissions

Suggested Actions

The City of Raleigh has taken many actions to work towards achieving energy and greenhouse gas emission reductions including smart building systems to manage lighting; the heating, ventilation and air conditioning (HVAC); the sub-metering, and the electrical systems; introducing electric vehicle charging stations; streetlight replacement; renewable energy projects; and the recently completed Renewable Energy Overview. The City is also working to transform the fleet to cleaner or alternative fuels and/or electric vehicles and more fuel efficient vehicles. Completion of the 2014 emission inventories not only gives an understanding of emissions trends since 2007 but also provide an up-to-date indication of the most significant sources of Raleigh's GHG emissions. Therefore, the City is well positioned to continue to develop a comprehensive GHG emission reduction strategy for Raleigh.

AECOM makes the following recommendations for the City going forward (see Table 7). Many of our recommendations also align with actions required by third party initiatives and standards aimed at enhancing the climate change mitigation and adaptation activities of cities such as CDP Cities[33], The Compact of Mayors (COM)[34] and STAR Communities[35].

[33] https://www.cdp.net/en-US/Programmes/Pages/CDP-Cities.aspx
[34] https://www.compactofmayors.org/
[35] https://reporting.starcommunities.org/communities/77-raleigh-north-carolina

Table 7 – Recommended Actions

Action	Comments	Community or LGO Inventory	Alignment with Public Initiative / Standard
1. Set and publically communicate targets for future reduction in GHG emissions relative to a baseline year	Developing emissions inventories, setting targets and tracking progress are at the core of any emission reduction strategy and provide a clear indication of the commitment to GHG emissions reduction. As an example the STAR Community Rating System criteria require cities to demonstrate progress towards achieving an 80% reduction in community wide GHG emissions by 2050.	Community LGO	CDP Cities COM Phase 3 STAR Communities CE-2
	The City could also consider setting a target regarding renewable electricity use and/or generation (e.g., 20% of total electricity consumption to be met by renewable electricity by 2020).	Community LGO	CDP Cites
2. Implement additional emission reduction initiatives / actions focused on the priority sources of GHG emissions (Stationary Energy)	**Stationary Energy** **a)** Initiatives focused on increasing electrical energy efficiency across the city's commercial/institutional portfolio would address nearly one-quarter (24%) of total community emissions. The city's residential properties represent a further 17% of total community emissions. These initiatives could include: i. Work with the local utilities to obtain granular community-level data to help support the identification of energy saving opportunities and public awareness and outreach campaigns ii. Energy audits for both commercial/institutional and residential entities. Audits are often conducted by the utility provider, but could be encouraged by the City of Raleigh. iii. Collaborate with the state of North Carolina to develop energy efficiency codes/standards to encourage new and renovated buildings to be more energy efficient iv. Encourage the continued construction of energy efficient certified buildings (e.g. the City's map of sustainable projects indicates that there are currently twenty LEED certified buildings located within the city, many of which are commercial/institutional properties)[36]	Community	CDP Cities COM Phase 4 STAR Communities CE-5

[36] http://maps.raleighnc.gov/sustainable/

Action	Comments	Community or LGO Inventory	Alignment with Public Initiative / Standard
2. Implement additional reduction initiatives / actions focused on the priority sources of GHG emissions (Stationary Energy [Continued])	**b)** With over 40% of total community emissions related to community electricity use, if the electricity on the local grid can be generated from more renewable sources and less carbon-intense fossil fuels, then a significant primary emissions source can be mitigated. Over time, the proportion of fossil fuel energy types (e.g. gas, coal, oil) in the electricity portfolio is projected to decrease, while the share of renewable sources (e.g., hydro, wind, solar) is projected to increase. However the City may identify local opportunities to accelerate the transition towards a lower carbon intensive electricity grid. For example: i. Create incentives to improve opportunities for on-site generation and use of renewable electricity within the community and at City facilities ii. Create programs and advocate for regulatory / policy changes that support the development of and investment in renewable energy and renewable energy distribution infrastructure iii. Establish partnerships and collaborate with critical energy providers, organizations attempting to bring new renewable energy technologies to market, the private sector and consumers to match renewable energy sources with community energy needs	Community LGO	CDP Cities COM Phase 4 STAR Communities CE-2 STAR Communities CE-3
	c) Electricity consumption by municipal buildings is also the largest source of emissions across all sectors and departments of the LGO inventory. Therefore, an efficiency program targeting electricity use across the hundreds of City operated buildings represents a significant opportunity for emissions reductions. These could include: i. Energy efficiency retrofits e.g. LEDs, lighting motion sensors ii. Implement a preventative maintenance program for key energy consuming buildings and equipment iii. Establish and adopt energy efficiency codes / guidance for City operated buildings iv. Conduct regular energy audits of City buildings	LGO	CDP Cities STAR Communities CE-2

Action	Comments	Community or LGO Inventory	Alignment with Public Initiative / Standard
2. Implement additional emission reduction initiatives / actions focused on the priority sources of GHG emissions (Stationary Energy [Continued], Transportation)	**d)** The primary source of emissions from City operations is related to the use of electricity specifically by the Public Utilities department (36% of LGO emissions) which is largely due to electricity consumption at the wastewater treatment plants, water treatment plants and over 150 remote facilities for distributing water and collecting wastewater throughout the City's service area. While efficiency measures can help reduce the amount of electricity used to move water and wastewater, a long term approach would be to reduce the carbon intensity of the electricity used by the public utilities department. This could be achieved either through the measures described above to influence grid supplied electricity and/or through increased on-site generation of renewable energy which can be used by the City, such as installation of solar panels at the closed Wilders Grove landfill.	LGO	CDP Cities
	Transportation **e)** Implementing initiatives aimed at reducing emissions from on-road vehicles operating on urban roadways would affect a significant part (nearly 40%) of total community emissions. Specific programs to help transition the local community towards the use of alternative modes of transport and low emission vehicles could include: i. More alternative transportation options in urban areas such as continued development of walking and cycling paths ii. Expansion of the public transportation system iii. Expanded electric vehicle infrastructure to encourage increased ownership of alternative fuel vehicles by residents. The city's map of sustainable projects indicates that there are currently twenty six electric vehicle charring stations within the city[37]. iv. Continued community outreach to raise awareness and education regarding non-motorized transport options and public transit options.	Community	CDP Cities COM Phase 4 STAR Communities CE-2 and CE-6
	f) The City's own vehicle and transit fleets contribute 20% of the total LGO emissions. Since 2002 the City has been actively encouraging and accelerating the use of alternative fuel vehicles which should be continued. For example the Go-Raleigh transit fleet runs on Biodiesel B5 and results in savings of 430 MT CO_2e per year. The use of biofuel blends with a higher percentage of biodiesel for the transit fleet, similar to what is	LGO	CDP Cities

[37] Source: http://maps.raleighnc.gov/sustainable/

Action	Comments	Community or LGO Inventory	Alignment with Public Initiative / Standard
2. Implement additional emission reduction initiatives / actions focused on the priority sources of GHG emissions (Transportation [Continued], Waste Disposal)	in use in select vehicles in the City vehicle fleet, would target 7% of total LGO emissions. Typically biofuel blends of up to 20% biodiesel can be incorporated without the need for vehicle modifications.		
	Waste Disposal The waste sector is responsible for less than 2% of Community emissions and for 12% of total LGO emissions. Recommended actions therefore focus on LGO operations and include: **g)** Implement plans to capture and generate energy from off-gases created by anaerobic system upgrades to the Neuse River Resource Recovery Facility, an important step towards mitigating an anticipated increase in methane generation. **h)** Reevaluate the business case for reuse of captured methane generated by the closed Wilders Grove landfill now that the gas is no longer used by a neighboring business as an energy source. While the gas generation rates continue to decrease with time as expected for a closed landfill, it may be appropriate to reuse the captured gas onsite for energy production.	LGO	CDP Cities COM Phase 4
3. Regularly and consistently track progress on emissions trends compared to the 2007 baseline	Tracking emissions over time is an important component of a GHG inventory because it provides information on historical emissions trends, and tracks the effects of policies and actions to reduce emissions. AECOM recommends that the frequency of inventory updates to be at least once every 1-3 years (LGO inventory) and once every 1-4 years (community inventory).	Community LGO	CDP Cities COM Phase 2
4. Review data collection and management systems	It is recommended that the City review existing facility energy data management and collection systems in order to 1) streamline the process for gathering and analyzing the energy data needed for GHG emissions calculations, and 2) provide real-time, highly granular data analyses across the City's facility portfolio. Such improvements would support identification and post-implementation tracking of emissions reduction and energy savings initiatives.	LGO	-

Action	Comments	Community or LGO Inventory	Alignment with Public Initiative / Standard
5. Update the Climate/Energy Action Plan	Given that the LGO GHG emissions inventory has been updated, AECOM recommends that the City also update the Climate/Energy Action Plan (CEAP) developed by the City in 2012[38] to include: a. Re-examining the GHG emissions projections b. Updating the list of priority actions and projects to achieve further emission reductions c. Providing a status update / progress report of emission reduction projects already undertaken	LGO	CDP Cities COM Phase 4

Note: Emissions resulting from the use of refrigerants in the City's vehicle and Go-Raleigh bus fleet and refrigerants used in City owned buildings represent <1% of total LGO emissions, therefore this are not considered a priority emission source.

[38] City of Raleigh (2012) *A Roadmap to Raleigh's Energy Future, City of Raleigh Climate / Energy Action Plan* http://www.raleighnc.gov/environment/content/AdminServSustain/Articles/SustainabilityReport.html

TECHNICAL APPENDIX

INTRODUCTION

The 2014 LGO and Community emissions inventories were prepared using standard methodologies which involve estimating emissions from an action based on ‘activity data’ and ‘emissions factors.’

Amount of Activity x Emissions Factor = GHG Emissions for the Action

Where examples of actions include lighting homes and buildings, commuting, or treating wastewater, and the amounts of activity are electricity consumed (i.e., kilowatt hours/year), vehicle miles traveled, and gallons of wastewater generated.

The following sections describe the methodology and data sources for the estimation of emissions from each sector. All calculations described below were accomplished via two separate Microsoft Excel workbooks (one for Community and one for Local Government Operations).

Community Inventory Calculation Methodology

Stationary Energy

Emissions from stationary fuel combustion by buildings and other facilities was calculated using annual consumption of each fuel and default emissions factors per fuel type.

1. **CO_2 Emissions from Stationary Combustion**

Annual emissions (metric tons CO_2) = Fuel consumption (MMBTU) × Emission factor (kg CO_2/MMBTU) × Conversion factor (kg to metric tons)

2. **CH_4 Emissions from Stationary Combustion**

Annual emissions (metric tons CH_4) = Fuel consumption (MMBTU) × Emission factor (g CH_4/MMBTU) × Conversion factor (g to metric tons)

3. **N_2O Emissions from Stationary Combustion**

Annual emissions (metric tons N_2O) = Fuel consumption (MMBTU) × Emission factor (g N_2O /MMBTU) × Conversion factor (g to metric tons)

4. **CO_2e Emissions from Stationary Combustion**

Annual emissions (metric tons CO_2e) = metric tons CO_2 + (metric tons CH_4 x GWP) + metric tons N_2O x (GWP)

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
Electricity consumption (kWh/ year)	Residential, Commercial & Institutional and Industrial electricity use provided by Duke/Progress Energy based on end use.	Table 1 eGRID2012 Sub-Region Emissions – Greenhouse Gases in the U.S. EPA eGRID2012 Summary Tables. The SERC Virginia/Carolina (SRVC) eGRID subregion emission factor was applied. https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf
Natural Gas (therms/year)	Residential, Commercial & Institutional and Industrial metered natural gas consumption data provided by PSNC accounts based on end use and those customers coded as inside the city limits.	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
Heating Oil (gallons/year) LPG (MJ/year)	Commercial and Institutional and Industrial Heating Fuel Oil and LPG Consumption sourced from the North Carolina Department of Environment – Division of	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub (N.B Diesel factor = Distillate Fuel Oil No. 2)

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
	Air Quality, 2013. Residential heating fuel oil was not included in the inventory due to difficulties in gathering data and the use of heating oil by City of Raleigh residents is very unlikely.	http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
Landfill Gas	Landfill gas used by Mallinckrodt - Raleigh Pharmaceutical Plant (industrial) sourced from the North Carolina Department of Environment – Division of Air Quality, 2013.	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

For the 2014 LGO inventory the amount of electricity transmission losses associated with building electricity consumption was modeled by multiplying the consumption of electricity (MWh/year) by a U.S. EPA eGRID transmission loss factor (9.17%) for the Eastern U.S. region sourced from Table 9 of eGRID2012 Sub-Region Emissions – Greenhouse Gases in the U.S. EPA eGRID2012 Summary Tables.

Transportation

Transportation on- and off-road vehicle emissions were calculated directly from the Motor Vehicle Emission Simulator 2014 (MOVES2014a) model.

On Road

MOVES2014a requires several input values, based on both local data and default data available in MOVES2014a. The assumptions relevant to the on-road MOVES2014a basic run specification inputs and county data manager inputs are listed in below. Wake County data for 2014 was provided by the North Carolina Department of Environmental Quality (NC DEQ), Division of Air Quality (DAQ), and is part of the data submitted to the EPA for the 2014 National Emissions Inventory (NEI). Community vehicle miles traveled (VMT) were extracted from the 2015 Triangle Regional Travel Demand Model data provided by the Capital Area Metropolitan Planning Organization (CAMPO). Calendar Year 2014 and 2015 data were the most readily available and served as proxies for Fiscal Year 2014 data.

<table>
<tr><th>MOVES2014a Basic Run Specification Input</th><th colspan="3">Assumptions</th></tr>
<tr><td rowspan="2">Scale</td><td>Domain/Scale</td><td colspan="2">County</td></tr>
<tr><td>Calculation Type</td><td colspan="2">Inventory</td></tr>
<tr><td rowspan="3">Time Spans</td><td>Year</td><td colspan="2">2014</td></tr>
<tr><td>Days</td><td colspan="2">Weekdays and Weekend Days</td></tr>
<tr><td>Hours</td><td colspan="2">All hours</td></tr>
<tr><td>Geographic Bounds</td><td colspan="3">North Carolina – Wake County</td></tr>
<tr><td rowspan="2">On Road Vehicle Equipment</td><td>Fuels</td><td>CNG, Diesel Fuel, Electricity, Ethanol, and Gasoline</td><td rowspan="2">All resulting Fuel/Type combinations</td></tr>
<tr><td>Source Use Types</td><td>All</td></tr>
<tr><td>Road Type</td><td colspan="3">Rural Restricted Access, Rural Unrestricted Access, Urban Restricted Access, and Urban Unrestricted Access</td></tr>
<tr><td>Pollutants and Processes</td><td>Total Gaseous Hydrocarbons
Methane (CH_4)
Nitrous Oxide (N_2O)
Total Energy Consumption
Atmospheric CO_2</td><td colspan="2">Running Exhaust
Crankcase Running Exhaust</td></tr>
<tr><td rowspan="4">General Output</td><td>Mass Units</td><td colspan="2">Grams</td></tr>
<tr><td>Energy Units</td><td colspan="2">Joules</td></tr>
<tr><td>Distance Units</td><td colspan="2">Miles</td></tr>
<tr><td>Activity</td><td colspan="2">Distance Traveled</td></tr>
<tr><td>Output Emissions Detail</td><td colspan="3">Output by fuel type, road type, and source use type (vehicle type)</td></tr>
</table>

MOVES 2014a County Data Manager Inputs	Data Source/Assumption
Fuel	Fuel formulation, fuel supply, and fuel usage fractions data obtained from DAQ Default alternative vehicle fuels and technology (AVFT) data in MOVES2014a
Meteorology Data	2014 Wake County data obtained from DAQ
I/M Programs	Data obtained from DAQ (same for all I/M programs in North Carolina)
Age Distribution	County-specific data obtained from DAQ
Speed Distribution	County-specific data obtained from DAQ
Road Type Distribution	Developed from the 2015 Triangle Regional Travel Demand Model provided by CAMPO
Source Type Population	County-specific data obtained from DAQ
Vehicle Type VMT	Developed from the 2015 Triangle Regional Travel Demand Model provided by CAMPO

MOVES2014a outputs a database table with the emissions total for each pollutant, vehicle type, fuel type, road type combination for each hour for a typical weekday and typical weekend day for each month. The hourly weekday emissions were multiplied by the number of weekdays for that month, and the hourly weekend day emissions were multiplied by the number of weekend days for that month. These emission values were then summed for each road type for the AM peak, PM peak, and off peak hours. The CO_2 equivalent values were calculated by summing the CO_2, CH_4, and N_2O emissions after being multiplied by their respective global warming potentials (GWP).

The distinction between urban and rural data is an output of the model and relies on U.S. Census data on population density and land use types in the area.

Off Road

The MOVES2014 model calculated off-road activity and emissions in Wake County. Emissions were provided for weekday and weekend days for each month of the year, which were then annualized. To isolate the City of Raleigh's Equipment Type annual emissions, the following demographic indicators we used.

Demographic Data	Equipment Type	Units	Percent of Indicator in City of Raleigh	Source
Building Permits	Construction	Permits	27%	Wake County Government Statistics, 2014
Households	Lawn & Garden	Households	47%	2014 American Community Survey 1-Year

Demographic Data	Equipment Type	Units	Percent of Indicator in City of Raleigh	Source
				Estimates (US Census). 2014 data is for July 1, 2014
Manufacturing Jobs	Industrial	Jobs	39%	2014 American Community Survey 1-Year Estimates (US Census).
Retail Jobs	Commercial	Jobs	49%	2014 American Community Survey 1-Year Estimates (US Census).
Railroad Miles	Railroad	Miles	26%	City of Raleigh Office of Transportation Planning

Waste

South Wake (Active) Landfill

Emissions from City generated waste disposed of in the South Wake landfill were calculated as per Equations 8.3 and 8.4 of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol) for each individual waste stream.

Methane commitment estimate for solid waste sent to landfill

Annual emissions (metric tons CH_4) = MSW_x x L_o x (1-f_{rec}) x (1-OX)

Term	Description	Value	Source
MSW_x	Mass of solid waste sent to landfill in inventory year MT (waste stream specific)	216,527	Waste deposition for open landfill provided by Wake County Environmental Services. Waste composition data sourced from Wake County Waste Characterization Study, 2011
f_{req}	Fraction of methane recovered at the landfill	70%	Estimate provided by Wake County
OX	Oxidation factor	10%	IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3, 3.15, 3.19 (2006)
GWP	Global Warming Potential to convert metric tons of methane into metric tons of CO_2 equivalent (CO_2e)	25	IPCC's Fourth Assessment Report

Methane generation potential (L_o) = MCF x DOC x DOC_f x F x 16/12			
Term	**Description**	**Value**	**Source**
MCF	Methane capture rate	1	Default value for managed landfill
DOC	Degradable organic carbon	16%	GPC, Equation 8.1, using South Wake Landfill's waste composition 2011
DOC_f	Fraction of DOC that is ultimately degraded; default per waste composition	Per waste type	IPCC IPCC Guidelines Volume 5 Table 2.4, 2006
F	Fraction by volume of CH_4 in LF gas fraction	50%	Default Value, GPC
16/12	Molecular weight ratio of Carbon to Methane	16/12	Standard conversion factor

North Wake (Closed) Landfill

Emissions were calculated from publically available federally reported emissions data from the North Wake County landfill's EPA e-GGRT FLIGHT report for 2014. As this landfill serves more than just the City of Raleigh, a population percentage of Raleigh citizens in Wake County was calculated via City of Raleigh data. This was applied to the total reported methane emitted in 2014 to get total methane attributed to Raleigh's waste in 2014. Calendar Year 2014 data served as a proxy for Fiscal Year 2015.

CO2e Emissions from North Wake County Landfill Annual emissions from North Wake County Landfill due to Raleigh waste (metric tons CO2e) = Annual methane emissions (metric tons CH4) x % of Raleigh population in Wake country x GWP		
Input	**Value**	**Source**
2014 Methane emissions from EPA's online Facility Level Information on Greenhouse Gases Tool (FLIGHT), Equation HH-6, (MT CH_4)	3,102	From EPA FLIGHT report from inventory year 2014 - https://ghgdata.epa.gov/ghgp/main.do
% of Raleigh population in Wake county, 2014	44%	From City of Raleigh data for Raleigh population percentage of Wake County
Global Warming Potential to convert metric tons of methane into metric tons of CO_2e	25	IPCC's Fourth Assessment Report

Wilders Grove (closed) Landfill

The LGO Protocol provides guidance on estimating the fugitive CH_4 emissions released from solid waste facilities, namely landfills that accept (or accepted) organic waste. In accordance with the LGO Protocol only CH_4 from landfills are estimated. Direct CO_2 emissions from landfills are considered biogenic and not included in LGO GHG Inventories.

According to the LGO Protocol's "Methodology Decision Tree for CH_4 Emissions from Landfills", the Wilders Grove fugitive landfill CH_4 emissions can be derived using the data on actual Landfill Gas (LFG) collected and the following equation (Equation 9.1 of the LGO Protocol).

CO2e Emissions from landfills with comprehensive LFG collection systems
Annual emissions (metric tons CO2e) = LFG collected x CH4% x {(1-DE) + [((1-CE) / CE) x (1 – OX)]} x unit conversion x (GWP)

Term	Description	Value	Source
LFG collected	Annual LFG collected by the collection system (million standard cubic feet/year)	346.3	Primary data from Wilders Grove landfill EPA GHG MRR reports
CH_4%	Fraction of CH_4 in landfill gas	39%	Primary data from Wilders Grove landfill EPA GHG MRR reports
DE	CH_4 destruction efficiency, based on the type of combustion/flare system.	98%	Wilders Grove Landfill Permit
CE	Collection efficiency	95%	Area weighted average collection efficiency based on landfill area and soil cover type from EPA GHG MRR reports
OX	Oxidation factor	10%	IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3, 3.15, 3.19 (2006)
Unit conversion	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of methane into metric tons of CO2 equivalent (CO2e)	25	IPCC's Fourth Assessment Report

Yard Waste Center Biological Treatment

Composting is an aerobic process and a large fraction of the degradable organic carbon in the waste material is converted into CO_2. CH_4 is formed in anaerobic sections of the compost, but it is oxidized to a large extent in the aerobic sections of the compost. Anaerobic sections are created in composting piles when there is excessive moisture or inadequate aeration (or mixing) of the compost pile. The estimated CH_4 released into the atmosphere ranges from less than 1% to a few % of the initial carbon content in the material. Composting can also produce emissions of N_2O. The range of the estimated emissions varies from <0.5% to 5% of the initial nitrogen content of the material.

Emissions from the composting of City waste at the City's Yard Waste Center were calculated using the following equation from the IPCC 2006 Guidelines, Chapter 4 (adaption of Equations 4.1 and 4.2[39])

CO2e Emissions from Yard Waste Center

Annual emissions (metric tons CO2e) = waste treated x unit conversion(kg/ton) x [(EF_{CH4} x GWP_{CH4}) + (EF_{N2O} x GWP_{N2O})] x unit conversion (MT/g)

Term	Description	Value	Source
Waste treated	Annual short tons of waste treated (wet basis)	50,851	Total material received by the Yard Waste Compost Center (Includes mulch and Grade A compost created and/or stored onsite during FY14. Woodchips are not included as they do not sit and decompose.)
Unit conversion $_{kg/ton}$	For converting short tons to kg (kg/ton)	907.18	Standard conversion factor
EF_{CH4}	CH_4 emission factor (wet weight basis) for composting (g CH4/kg waste treated)	4	IPCC 2006 Guidelines, Chapter 4, Table 4.1
GWP_{CH4}	Global Warming Potential to convert metric tons of methane into metric tons of CO_2 equivalent (CO_2e)	25	IPCC's Fourth Assessment Report
EF_{N2O}	N_2O emission factor (wet weight basis) for composting (g N_2O/kg waste treated)	0.24	IPCC 2006 Guidelines, Chapter 4, Table 4.1
GWP_{N2O}	Global Warming Potential to convert metric tons of nitrous oxide into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report
Unit conversion$_{MT/g}$	For converting grams to metric tons (metric tons/g)	1.00E-06	Standard conversion factor

Clinical Waste Incineration

Emissions from clinical waste incineration calculated as per Equation 8.6 of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC Protocol).

[39] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

Non-biogenic CO2 Emissions from the incineration of waste Annual emissions (metric tons CO_2) = m x (WF_i x dm_i x CF_i x FCF_i x OF_i) x (44/12)			
Term	**Description**	**Value**	**Source**
m	Mass of waste incinerated in tonnes	3,048	The North Carolina Department of Environment – Division of Air Quality, 2013.
Wf_i	Fraction of waste consisting of clinical waste	1	The North Carolina Department of Environment – Division of Air Quality, 2013.
dm_i	dry matter content in the type I matter	NA	Table 8.4 of the GPC: Default data for CO_2 emission factors for incineration and open burning (Only Clinical Waste values)
Cf_i	Fraction of carbon in the dry matter of type I matter	0.60	
FCF_i	Fraction of fossil carbon in the total carbon component of type I matter	0.40	
Of_i	Oxidation fraction or factor	1	
i	Matter type of the Solid Waste incinerated	Clinical	
44/12	molecular weight ratio of CO_2 to C	44/12	Standard conversion factor

Neuse River Wastewater Treatment Plants

The City of Raleigh currently has three wastewater treatment plants within its operational control: Little Creek, Neuse River and Smith Creek; however, the Neuse River Facility is the only plant that serves the Raleigh population and therefore is the only plant included in the Community inventory (the Neuse River, Smith Creek and Little Creek WWTPs are all included in the LGO inventory).

The plant employs advanced wastewater treatment technology, relying on nitrification/denitrification technology and the aerobic digestion of biosolids. The majority of emissions related to wastewater treatment result from the use of electricity; however, these emissions are considered to be Scope 2 and are included in Stationary emissions discussed above. This section refers only to direct fugitive emissions of N_2O emitted during the treatment process.

Process N_2O emissions from nitrification / denitrification treatment were calculated using the following equation (Equation 10.7 of the LGO Protocol). The LGO Protocol was applied to Community emissions estimation from wastewater treatment plants because it provides a consistent approach, it will be easier for City personnel to update in the future using data that are routinely collected, and any differences in emissions estimates between the two methodologies would not be material to the outcome of the inventory.

CO2e Emissions from Process N_2O Emissions from WWTP with Nitrification/Denitrification Annual emissions (metric tons CO2e) = ((Ptotal x Find-com) x EF nit/denit x unit conversion$_{g/MT}$) x GWP			
Term	**Description**	**Value**	**Source**
P_{total}	Total population served by the WWTP adjusted for industrial discharge, if applicable [person]	509,738	Estimated based on 2010 and 2013 population estimates for jurisdictions in Wake County; data provided by the Public Works Department. Populations were then associated with City's three treatment plants to determine total population served by each plant in 2010 and 2013. 2014 population estimates were extrapolated assuming linear growth from 2010 to 2013 values.
$F_{ind\text{-}com}$	Factor for industrial and commercial co-discharge waste into the sewer system	1.25	LGOP equation 10.7
EF nit/denit	Emission factor for a WWTP with nitrification/denitrification [g N_2O/person/year]	7.00	LGOP equation 10.7
Unit conversion$_{MT/g}$	For converting grams to metric tons (metric tons/g)	0.000001	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of N_2O into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report

Process N_2O emissions from the effluent discharged from each wastewater treatment plant into streams and rivers were calculated using the following equation (Equation 10.9 of the LGO Protocol).

CO2e Emissions from Process N2O Emissions from Effluent Discharge Annual emissions (metric tons CO2e) = (N Load x EF effluent x 365.25 x 10-3 x 44/28) x GWP			
Term	**Description**	**Value**	**Source**
N Load	measured average total nitrogen discharged [kg N/day]	Neuse River = 13,400 million gallons / year and 2.25 mg/L/year	Total effluent from facility (15,952 million gallons (US) / year was multiplied by the percentage of the population treated by this facility from the City of Raleigh (84%). This percentage was sourced from the City of Raleigh. City staff provided average total nitrogen content and effluent treatment volume per facility for the inventory year.

Term	Description	Value	Source
EF effluent	emission factor [kg N_2O-N/kg sewage-N produced]	0.005	LGOP equation 10.9
365.25	conversion factor [day/year]	365.25	Standard conversion factor
10^{-3}	conversion from kg to metric ton [metric ton/kg]	0.001	Standard conversion factor
44/28	molecular weight ratio of N_2O to N_2	1.57	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of N_2O into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report

LGO Inventory Calculation Methodology

Municipal Buildings and Other Facilities

Emissions from stationary fuel combustion by municipal buildings and other facilities were estimated using annual consumption of each fuel and default emissions factors per fuel type.

1. **CO_2 Emissions from Stationary Combustion**

Annual emissions (metric tons CO_2) = Fuel consumption (MMBTU) × Emission factor (kg CO_2/MMBTU) × Conversion factor (kg to metric tons)

2. **CH_4 Emissions from Stationary Combustion**

Annual emissions (metric tons CH_4) = Fuel consumption (MMBTU) × Emission factor (g CH_4/MMBTU) × Conversion factor (g to metric tons)

3. **N_2O Emissions from Stationary Combustion**

Annual emissions (metric tons N_2O) = Fuel consumption (MMBTU) × Emission factor (g N_2O /MMBTU) × Conversion factor (g to metric tons)

4. **CO_2e Emissions from Stationary Combustion**

Annual emissions (metric tons CO_2e) = metric tons CO_2 + (metric tons CH_4 x GWP) + metric tons N_2O x (GWP)

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
Electricity consumption (kWh/ year)	Total electricity use in City buildings/facilities and City-owned park and other public lighting not included within streetlights data provided by City of Raleigh and sourced from the Facilities Department and Duke/Progress Energy (VAN/EDI accounts). Account numbers allowed accounts to be linked to specific buildings and departments. Total electricity use in City-owned streetlights and traffic lights sourced from Transportation Department utility bills.	Table 1 eGRID2012 Sub-Region Emissions – Greenhouse Gases in the U.S. EPA eGRID2012 Summary Tables. The SERC Virginia/Carolina (SRVC) eGRID subregion emission factor was applied. https://www.epa.gov/sites/production/files/2015-10/documents/egrid2012_summarytables_0.pdf
Natural Gas (therms/year)	City building/facility metered natural gas consumption by department data provided by City of Raleigh from PSNC accounts. Natural gas used in backup generators sourced from maintenance records.	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
		factors-hub
Heating Oil (gallons/year)	Diesel and Propane fuel used in backup generators sourced from maintenance records	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub (N.B Diesel factor = Distillate Fuel Oil No. 2) http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub

For the 2014 LGO inventory the amount of electricity transmission losses associated with municipal building electricity consumption was modeled by multiplying the consumption of electricity (Mwh/year) by a U.S. EPA eGrid transmission loss factor (9.17%) for the Eastern U.S. region sourced from Table 9 of eGRID2012 Sub-Region Emissions – Greenhouse Gases in the U.S. EPA eGRID2012 Summary Tables.

Vehicles

Emissions from the City's fleet of vehicles and equipment were calculated using annual consumption of each fuel and default emissions factors per fuel type.

1. **CO_2 Emissions from Vehicles**

Annual emissions (metric tons CO_2) = Fuel consumption (gallons) × Emission factor (kg CO_2/gallon) × Conversion factor (kg to metric tons)

2. **CH_4 Emissions from Vehicles**

Annual emissions (metric tons CH_4) = Fuel consumption (gallon) × Emission factor (g CH_4/gallon) × Conversion factor (g to metric tons)

3. **N_2O Emissions from Vehicles**

Annual emissions (metric tons N_2O) = Fuel consumption (gallon) × Emission factor (g N_2O /gallon) × Conversion factor (g to metric tons)

4. **CO_2e Emissions from Vehicles**

Annual emissions (metric tons CO_2e) = metric tons CO_2 + (metric tons CH_4 x GWP) + metric tons N_2O x (GWP)

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
Gasoline (gallons/year)	Total vehicle gasoline use by department and vehicle type (including on-road / off road / Go-Raleigh bus feet) sourced from fleet management database. All Fire Department vehicle fuel consumption	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
	data were provided separately.	factors-hub
Diesel (gallons/year)	Total vehicle diesel use by department and vehicle type (including on-road / off road / Go-Raleigh bus feet) sourced from fleet management database. All Fire Department vehicle fuel consumption data were provided separately.	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub (factor for Distillate Fuel Oil No. 2 used) http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
Biodiesel (gallons/year)	Total vehicle biodiesel use by department and vehicle type (including on-road / off road / Go-Raleigh bus feet) sourced from fleet management database. All Fire Department vehicle fuel consumption data were provided separately.	Table 2 Mobile Combustion Emission Factors in the 2014 U.S. EPA Greenhouse Gas Emissions Factors Database B5 = 95% Distillate Fuel Oil No.2 and 5% Biodiesel B20 = 80% Distillate Fuel Oil No.2 and 20% Biodiesel CO_2 emissions from the biofuel portions of B5 and B20 are considered biogenic, and in accordance with the LGO Protocol, biogenic emissions are not included in the City's total emissions. CO_2 emissions from these fuels were therefore estimated yet omitted from the emissions total while the CH_4 and N_2O emissions from these fuels were included in the totals. Biogenic emissions are discussed in further detail below.
CNG (gallons/year)	Total vehicle CNG use by department and vehicle type (including on-road / off road / Go-Raleigh bus feet) sourced from fleet management database. All Fire Department vehicle fuel consumption data were provided separately.	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse Gas Emissions Factors Hub (factor for Natural Gas used) http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
LPG (gallons/year)	Total vehicle LPG use by department and vehicle type (including on-road / off road / Go-	Table 1 Stationary Combustion Emission Factors in the 2015 U.S. EPA Greenhouse

Fuel Type	Fuel Consumption Activity Data Source	Emission Factor Source
	Raleigh bus feet) sourced from fleet management database. All Fire Department vehicle fuel consumption data were provided separately.	Gas Emissions Factors Hub http://www.epa.gov/climateleadership/center-corporate-climate-leadership-ghg-emission-factors-hub
Electricity	The City has nine electric vehicles, but cannot currently track their electricity consumption	N/A

While the LGOP recommends that CH_4 and N_2O emissions from on road vehicles are calculated using annual miles travelled per vehicle type data rather than annual fuel consumption (as per the CO_2 emissions calculation) because CH_4 and N_2O emissions depend more on the emission control technologies employed in the vehicle along with distance traveled, for ease of future updates by City personnel, all emissions from vehicles were calculated using annual fuel consumption and related factors. This simplified approach for CH_4 and N_2O emissions does not affect the outcome of the inventory significantly as the bulk of vehicle GHG emissions are CO_2.

Waste Disposal

Landfill

The LGO Protocol provides guidance on estimating the fugitive CH_4 emissions released from solid waste facilities, namely landfills that accept (or accepted) organic waste. In accordance with the LGO Protocol only CH_4 from landfills are estimated. Direct CO_2 emissions from landfills are considered biogenic and not included in LGO GHG Inventories.

According to the LGO Protocol's "Methodology Decision Tree for CH_4 Emissions from Landfills", the Wilders Grove fugitive landfill CH_4 emissions can be derived using the data on actual Landfill Gas (LFG) collected and the following equation (Equation 9.1 of the LGO Protocol).

CO2e Emissions from landfills with comprehensive LFG collection systems
Annual emissions (metric tons CO2e) = LFG collected x CH4% x {(1-DE) + [((1-CE) / CE) x (1 – OX)]} x unit conversion x (GWP)

Term	Description	Value	Source
LFG collected	Annual LFG collected by the collection system (million standard cubic feet/year)	346.3	Primary data from Wilders Grove landfill EPA GHG MRR reports, with Calendar Year 2014 serving as a proxy for Fiscal Year 2014.
CH_4%	Fraction of CH_4 in landfill gas	0.39	Primary data from Wilders Grove landfill EPA GHG MRR reports
DE	CH_4 destruction efficiency, based on the type of	98%	Wilders Grove Landfill Permit

Term	Description	Value	Source
	combustion/flare system.		
CE	Collection efficiency	95%	Area weighted average collection efficiency based on landfill area and soil cover type from EPA GHG MRR reports
OX	Oxidation factor	10%	IPCC Guidelines for National Greenhouse Gas Inventories, Chapter 3, 3.15, 3.19 (2006)
Unit conversion	Applies when converting million standard cubic feet of methane into metric tons of methane (volume units to mass units)	19.125	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of methane into metric tons of CO2 equivalent (CO2e)	25	IPCC's Fourth Assessment Report

Yard Waste Center

Composting is an aerobic process and a large fraction of the degradable organic carbon in the waste material is converted into CO_2. CH_4 is formed in anaerobic sections of the compost, but it is oxidized to a large extent in the aerobic sections of the compost. Anaerobic sections are created in composting piles when there is excessive moisture or inadequate aeration (or mixing) of the compost pile. The estimated CH_4 released into the atmosphere ranges from less than 1% to a few % of the initial carbon content in the material. Composting can also produce emissions of N_2O. The range of the estimated emissions varies from <0.5% to 5% of the initial nitrogen content of the material.

The LGO Protocol does not include standardized methodologies to estimate fugitive emissions from composting; therefore, emissions from the composting of waste at the City's Yard Waste Center were calculated using the following equation from the IPCC 2006 Guidelines, Chapter 4 (adaption of Equations 4.1 and 4.2[40])

[40] http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_4_Ch4_Bio_Treat.pdf

CO2e Emissions from Yard Waste Center Annual emissions (metric tons CO2e) = waste treated x unit conversion(kg/ton) x [(EF_{CH4} x GWP_{CH4}) + (EF_{N2O} x GWP_{N2O})] x unit conversion (MT/g)			
Term	**Description**	**Value**	**Source**
Waste treated	Annual short tons of waste treated (wet basis)	50,851	Total material received by the Yard Waste Compost Center. (Includes mulch and Grade A compost created and/or stored onsite during FY14. Woodchips are not included as they do not sit and decompose.)
Unit conversion $_{kg/ton}$	For converting short tons to kg (kg/ton)	907.18	Standard conversion factor
EF_{CH4}	CH_4 emission factor (wet weight basis) for composting (g CH4/kg waste treated)	4	IPCC 2006 Guidelines, Chapter 4, Table 4.1
GWP_{CH4}	Global Warming Potential to convert metric tons of methane into metric tons of CO_2 equivalent (CO_2e)	25	IPCC's Fourth Assessment Report
EF_{N2O}	N_2O emission factor (wet weight basis) for composting (g N_2O/kg waste treated)	0.24	IPCC 2006 Guidelines, Chapter 4, Table 4.1
GWP_{N2O}	Global Warming Potential to convert metric tons of nitrous oxide into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report
Unit conversion$_{MT/g}$	For converting grams to metric tons (metric tons/g)	1.00E-06	Standard conversion factor

Wastewater Treatment Plants

The City of Raleigh currently has three wastewater treatment plants within operational control: Little Creek, Neuse River and Smith Creek. All three treatment plants in the City of Raleigh employ advanced wastewater treatment technology, relying on nitrification/denitrification technology and the aerobic digestion of biosolids. The majority of emissions related to wastewater treatment result from the use of electricity, however these emissions are considered to be Scope 2 and are included in Municipal Building emissions discussed above. This section refers only to direct fugitive emissions of N_2O emitted during the treatment processes.

Process N_2O emissions from nitrification / denitrification process were calculated using the following equation (Equation 10.7 of the LGO Protocol).

CO2e Emissions from Process N_2O Emissions from WWTP with Nitrification/Denitrification Annual emissions (metric tons CO2e) = ((Ptotal x Find-com) x EF nit/denit x unit conversion$_{g/MT}$) x GWP			
Term	**Description**	**Value**	**Source**
P_{total}	Total population served by the WWTP adjusted for industrial discharge, if applicable [person]	509,738 (Neuse River) 17,636 (Smith Creek) 4,644 (Little Creek)	Estimated based on 2010 and 2013 population estimates for jurisdictions in Wake County; data provided by Public Utilities. Populations were then associated with City's three treatment plants to determine total population served by each plant in 2010 and 2013. 2014 population estimates were extrapolated assuming linear growth from 2010 to 2013 values.
$F_{ind\text{-}com}$	Factor for industrial and commercial co-discharge waste into the sewer system	1.25	LGOP equation 10.7
EF nit/denit	Emission factor for a WWTP with nitrification/denitrification [g N_20/person/year]	7.00	LGOP equation 10.7
Unit conversion$_{MT/g}$	For converting grams to metric tons (metric tons/g)	0.000001	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of N_20 into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report

Process N_2O emissions from the effluent discharged from each wastewater treatment plant into streams and rivers were calculated using the following equation (Equation 10.9 of the LGO Protocol).

CO2e Emissions from Process N20 Emissions from Effluent Discharge Annual emissions (metric tons CO2e) = (N Load x EF effluent x 365.25 x 10-3 x 44/28) x GWP			
Term	**Description**	**Value**	**Source**
N Load	measured average total nitrogen discharged [kg N/day]	• Neuse River = 15,952 million gallons / year and 2 mg/L/year • Smith Creek= 584 million gallons / year and 3 mg/L/year • Little Creek= 284	City staff provided average total nitrogen content and effluent treatment volume per facility for the inventory year

Term	Description	Value	Source
		million gallons / year and 4 mg/L/year	
EF effluent	emission factor [kg N_20-N/kg sewage-N produced]	0.005	LGOP equation 10.9
365.25	conversion factor [day/year]	365.25	Standard conversion factor
10^{-3}	conversion from kg to metric ton [metric ton/kg]	0.001	Standard conversion factor
44/28	molecular weight ratio of N_20 to N_2	1.57	Standard conversion factor
GWP	Global Warming Potential to convert metric tons of N_20 into metric tons of CO_2 equivalent (CO_2e)	298	IPCC's Fourth Assessment Report

Process and Fugitive Emissions

Total amount (lbs) of refrigerants and fire suppression chemicals (HFCs and/or blends containing HFCs) used in City buildings/facilities by chemical type and piece of equipment was sourced from purchase records. Annual quantities of refrigerants used by the City's vehicle fleet were sourced from the fleet management database. CO_2e emissions were calculated by multiply the pounds of fugitive refrigerant by the refrigerant's global warming potential factor sourced from the IPCC's 4th Assessment Report.

CO2e Emissions from Refrigerants
Annual emissions (metric tons CO2e) = lbs refrigerant x GWP x lbs to metric tons conversion factor

Biogenic Emissions

Biogenic emissions are those that result from the combustion of biomass materials such as wood, crops, vegetable oils, or animal fats. In accordance with the GPC and LGO Protocols CO_2 emissions from the combustion of materials of biogenic origin (meaning that it was recently contained in living organic matter) have been calculated, but are reported separately and not included in the total emissions presented in the main report. The biogenic CO_2 emissions are kept separate because they have been determined to be net '0', since the fuel source itself absorbs an equivalent amount of CO_2 during the growth phase (through the process of photosynthesis) as the CO_2 that is released through combustion, which is different to the carbon in fossil fuels (such as coal and oil) which has been trapped in geologic formations for millions of years. In other words, the accessible carbon found in biomass that is converted to CO_2 through combustion has already been recently "taken out" of the atmosphere, thereby creating a net-neutral carbon-balancing cycle. However, the biogenic CO_2 are still required to be documented to ensure complete accounting of all the emissions created.

Note that the distinction of emissions from biomass combustion applies only to CO_2 and not to methane (CH_4) and nitrous oxide (N_2O), which are also released during biomass combustion. The CH_4 and N_2O emissions released during the combustion of biomass materials are included in the total reported emissions as these emissions are not absorbed during the growth of the biomass material and CH_4 or N_2O would not have been produced had the biomass naturally decomposed. It is only the combustion of the biomass that caused these emissions to be produced and they are therefore as presented in the sections above are treated the same as the CH_4 or N_2O from fossil fuel combustion.

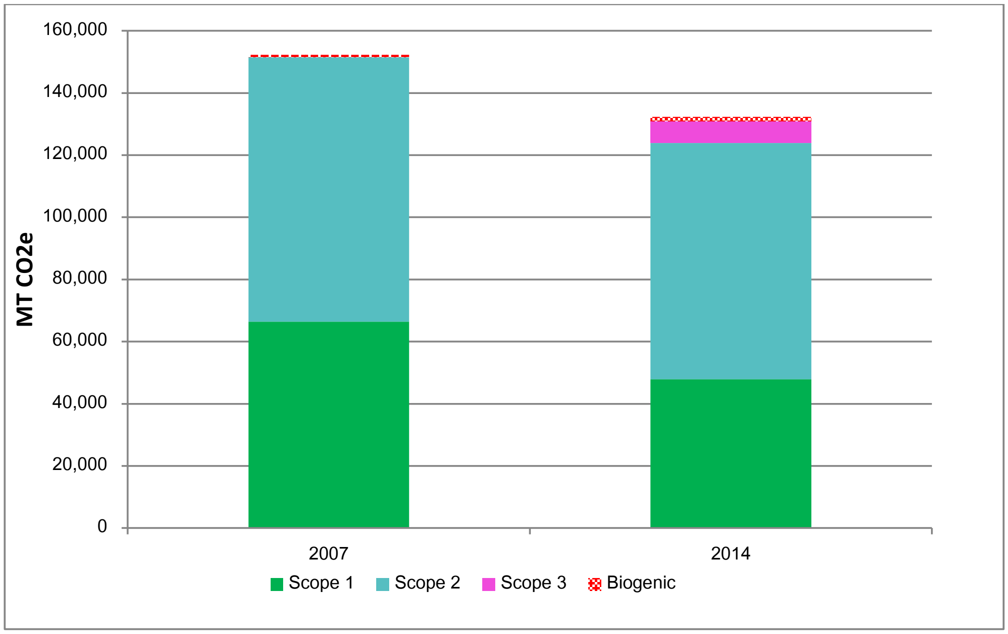
As shown in the table below, the biogenic CO_2 emissions for the City of Raleigh's operations total 1,505 MT CO_2e and are due to the combustion of biodiesel by the City's vehicle and transit fleets.

Local Government Inventory Trends (all emission sources)

	Municipal Buildings and Other Facilities	Vehicle Fleet	Transit Fleet	Landfill	Yard Waste Center	Wastewater Treatment	Refrigerants & Fire Suppressants	TOTAL MT CO_2e/yr
Non-Biogenic Emissions	**90,150**	**17,556**	**8,993**	**4,350**	**7,912**	**1,450**	**425**	**130,838**
Biogenic Emissions	*0*	*1,072*	*435*	*0*	*0*	*0*	*0*	*1,505*

The vehicle fleet uses B20 while the transit fleet uses B5. Biofuel B20 is a blend of 20% biodiesel and 80% fossil fuel oil and biofuel B5 is 5% biodiesel and 95% fossil fuel. Therefore, in accordance with the LGO Protocol, the biogenic CO_2 emissions presented above represent only the biofuel portions of B5 and B20 (the CH_4 and N_2O emissions from the biodiesel are included in the non-biogenic totals along with the emissions from the fossil fuel oil portion). Therefore switching to biofuel blends has reduced the City's total emissions by 1,505 $MTCO_2e$ (approximately 1%). As shown in the figure below, compared to the 2007 baseline biogenic CO_2 emissions have increased from 765 to 1,505 $MTCO_2e$, due to the increased use of biofuel, but total emissions have also decreased.

2014 LGO Emissions by Scope (including Biogenic CO_2)



The calculation of biogenic CO_2 emissions is important to provide a complete picture of the City's energy use. As discussed above, currently the biogenic CO_2 emissions from the combustion of biomass have been determined to be net '0'. However, the boundaries of this inventory do not include fuel life-cycle emissions for any fuels. The extraction, processing, and transportation of biofuels and fossil fuels result in GHG emissions that can affect their net life-cycle emissions. In some cases biofuels can be derived from sources that significant embodied energy or other environmental impacts. For example, biofuel derived from a crop that requires significant petrochemical inputs such as fertilizers and pesticides. The impacts can significantly vary depending on the type of fuel crop, the region, growing practices and processing methods. Therefore, if the biofuels used by the City have greater life-cycle emissions than the equivalent fossil fuels, then the net GHG savings may be smaller than calculated here. Life cycle assessment is beyond the Scope of the LGO Protocol but is important for the City to be mindful of the potential upstream emissions from the specific source of biofuels when making decisions regarding which fuels to use.