City of Richmond 2008 Greenhouse Gas Emissions Inventory

Prepared by ICLEI – Local Governments for Sustainability USA
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ICLEI – Local Governments for Sustainability USA - Lead Organization

ICLEI – Local Governments for Sustainability USA (ICLEI) is a membership association of more than 1,200 local governments worldwide—more than 600 in the United States—committed to advancing climate protection and sustainability. Through technical expertise, direct network engagement, and the innovation and evolution of tools, ICLEI strives to empower local governments to set and achieve their emissions reduction and sustainability goals.

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Executive Summary

The city of Richmond requested that ICLEI perform this inventory as Richmond recognizes that local governments play a leading role in both reducing greenhouse gas emissions and adapting to the potential impacts of climate change. Taking action to reduce emissions, through such measures as increasing energy efficiency in facilities and vehicle fleets, utilizing renewable energy sources, enacting sustainable purchasing policies, reducing waste, and supporting alternative modes of working and transportation for employees, can lead to benefits which include lower energy bills, improved air quality, and more efficient government operations.

This greenhouse gas emissions inventory is an important first step in Richmond's climate protection initiative and serves as a baseline for determining what types of actions the city will take to reduce its energy use and associated energy costs. As advised by ICLEI, it is essential to first quantify greenhouse gas (GHG) emissions to establish:

- A baseline emissions inventory, against which to measure future progress, and
- An understanding of the scale of emissions from various sources.

Presented here are estimates of greenhouse gas emissions in 2008 resulting from the city of Richmond's government operations and from the community-at-large. All government operations emissions estimates in this report refer to emissions generated from sources over which the city has *direct operational control* or a significant level of influence, regardless of physical location. This includes all government-operated facilities, streetlights, traffic signals and other stationary sources; process emissions from wastewater treatment; emissions from the city's on-road vehicle fleet and off-road equipment; municipal solid waste disposal; and emissions from employees commuting to work. This does not include the city of Richmond public schools, as the city administration does not have direct operational control over school operations. This inventory also estimates emissions from the community-at-large. Community-scale emissions are reported by six primary sectors: residential, commercial, industrial, transportation, waste, and wastewater treatment.

Like all emissions inventories, the inventory for the city of Richmond relied on the best available data and calculation methodologies. Emissions estimates presented in this report are subject to change as better data and calculation methodologies become available in the future. Nevertheless, the findings of this analysis provide a solid basis upon which Richmond can begin planning and taking action to reduce its greenhouse gas emissions.

This inventory is one of the first government operations inventories to use a new national standard developed in conjunction with ICLEI, the California Climate Action Registry, and The Climate Registry. This standard, called the Local Government Operations Protocol (LGOP), provides standard accounting principles, boundaries, quantification methods, and procedures for reporting greenhouse gas emissions from local government operations in the United States. The LGOP represents a strong step forward in standardizing how inventories are conducted and reported, providing a common national framework for all local governments to establish their emissions baseline. More information on the LGOP is provided in Appendix A of this report.

While the Richmond inventory was not able to follow all of the guidance provided in the LGOP, the city should be commended for striving towards this standard. In addition to providing inventory results, this report also denotes areas where the city wasn't able to meet the LGOP guidance and provides recommendations on how the city could meet this standard in the future.

There is currently no standard protocol for conducting a community scale greenhouse gas emissions inventory in the United States. However, the community emissions inventory conducted by ICLEI for the city of Richmond follows the standard outlined in the draft International Local Government Greenhouse Gas Emissions Analysis Protocol (IEAP). ICLEI has been developing this guidance since the inception of its Cities for Climate Protection Campaign in 1993, and has recently formalized version 1 of the IEAP as a means to set a common framework for all local governments worldwide to use when conducting a greenhouse gas emissions inventory. Due to its global audience, the IEAP provides only a general framework for conducting a community inventory. As such, methodologies and emissions factors from the LGOP and other United States or region-specific sources were used in the community inventory whenever applicable. See Appendix E of this report for more information on the Community Inventory Methodology.

Selecting a Baseline Inventory Year

Selecting a baseline year for an emissions inventory is an important first step in addressing climate and energy issues. A baseline inventory is important because it establishes an emissions level against which the city can set emissions reductions targets and measure future progress. Because a baseline inventory serves as a point of comparison for measuring the city's progress in future inventory years, a baseline inventory should be conducted in a "typical" year. For example, a baseline inventory should not be conducted for an extremely hot or cold year because these extremes in temperature could result in unusually high energy consumption. However, the availability of data is typically the determining factor when selecting a baseline year. Calendar year 2008 was selected as the city of Richmond's baseline year due the accessibility of complete datasets.

Government Operations Inventory Results

In 2008, Richmond's operational greenhouse gas emissions totaled 173,660 metric tons of CO_2e.[1-2] Of the total emissions accounted for in this inventory, emissions from buildings and facilities were the largest (24 percent or 41,894 metric tons of CO_2e as shown in Figure ES.1 and Table ES.1). Emissions from city employees commuting to work were the second largest source of government emissions (17 percent or 29,087 metric tons of CO_2e). The operation of the city's water treatment and delivery infrastructure, along with the operation of the city's vehicle fleet, contributed 26 percent of overall government emissions (13 percent each). Municipal solid waste collected by the city of Richmond from residential and non-residential customers in 2008 is expected to produce 21,210 metric tons of CO_2e as it decomposes (12 percent of overall government emissions). Operation of the wastewater treatment plant building, along with emissions from treating the wastewater, accounted for 11 percent of total government emissions (18,686 metric tons of CO_2e), while electricity consumption from streetlights and traffic signals contributed a combined 10 percent of emissions (17,751 metric tons of CO_2e). The emissions generated by electricity consumption at the East Richmond Road Convenience Center, the only solid waste facility operated by the city, accounted for less than one percent of overall emissions (2 metric tons of CO_2e).[3] The emissions associated with leaks and system operations from the city of Richmond natural gas utility are not included in this assessment.

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[1] This number represents a "roll-up" of emissions, and is not intended to represent a complete picture of emissions from Richmond's operations. This roll-up number should not be used for comparison with other local government roll-up numbers without a detailed analysis of the basis for this total.

[2] This number does not include 14 metric tons of CO_2e resulting from the biogenic component of biodiesel (B20) fuel consumed in the city's vehicle fleet and from employee commutes. The carbon dioxide emissions from the biodiesel component of a B20 fuel blend (a fuel that is 20 percent biogenic and 80 percent diesel) is considered informational because the emissions released during the combustion of the fuel would theoretically have been returned through the atmosphere if the biogenic material were allowed to decompose naturally.

[3] The figure for Solid Waste Facilities should include methane emissions from decomposing organic waste in the city's closed landfills. However, data were unavailable to calculate these emissions.

Figure ES.1: 2008 Richmond Government Operations Emissions by Sector

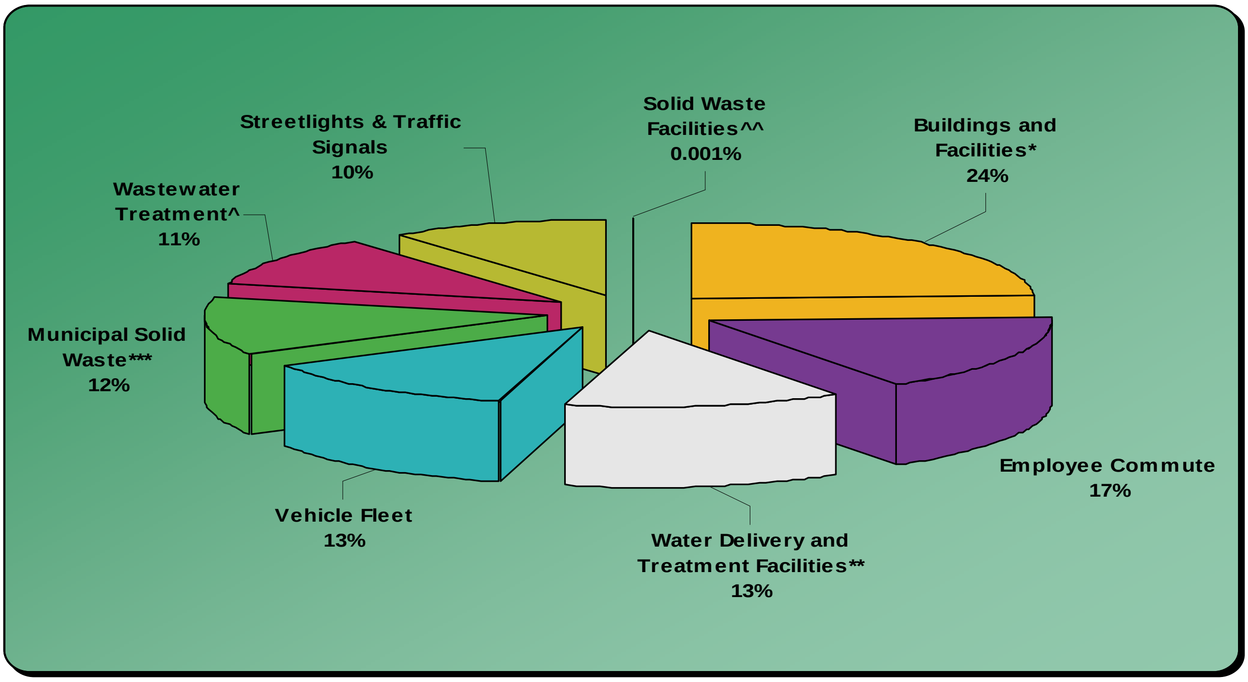

Table ES.1: 2008 Richmond Government Operations Emissions by Sector

Sector	Greenhouse Gas Emissions (metric tons CO_2e)
Buildings and Facilities*	41,894
Employee Commute	29,087
Water Delivery and Treatment Facilities**	22,593
Vehicle Fleet	22,437
Municipal Solid Waste***	21,210
Wastewater Treatment^	18,686
Streetlights & Traffic Signals	17,751
Solid Waste Facilities^^	2
Streetlight Electricity Loses (Distribution Lines)	no data
Leaked SF6 (Streetlight Electricity Distribution)	no data
Leaked Natural Gas (Distribution lines)	no data
Leaked Refrigerants and Fire Suppressants (Buildings and Facilities)	no data
TOTAL	**173,660**

NOTES FROM FIGURE ES.1 and TABLE ES.1

*The buildings and facilities sector does not include emissions from operating the wastewater or water treatment plants, or facilities at closed landfills owned by the city. Those emissions are included in the Wastewater Treatment, Water Delivery and Treatment Facilities, and Solid Waste Facilities categories.

**Emissions from energy used to operate the water treatment facility and water transport infrastructure. This figure does not include emissions associated with the treatment of water as LGOP does not include methods for calculating this source.

***This figure includes emissions associated with disposing of municipal solid waste – including all waste generated by residential and non-residential customers of the city of Richmond's waste collection service.

^Emissions from energy used to operate the wastewater treatment facility at 1400 Brander Street and emissions from wastewater treatment processes.

^^Only represents emissions resulting from operating the transfer facility at 3800 E Richmond Road. This figure does not include methane emissions from decomposing organic waste in the city's seven closed landfills; data were unavailable to calculate methane emissions from decaying organic waste in the city's closed landfills.

As shown in Table ES.2, the city of Richmond spent approximately $22,842,220[4] on energy costs for all city operations (electricity, natural gas, gasoline, diesel, and biodiesel [B20]). Of this total, the majority of energy expenses (31 percent or $7,048,894) were from the heating, cooling, and lighting of city buildings and facilities.[5] Gasoline, diesel, and biodiesel (B20) purchases for the city's vehicle fleet accounted for 30 percent of energy costs ($6,913,070), while 15 percent of total expenditures ($3,355,131) were associated with operating the water treatment facility and the transportation of water. Of remaining energy expenses, 13 percent were from electricity used to power the city's streetlights and traffic signals, and 11 percent was associated with the heating, cooling, and lighting of the wastewater treatment plant. Less than 1 percent of 2008 energy spending was from operating the city's solid waste facilities. These numbers demonstrate the potential for significantly reducing energy costs while also mitigating climate change impacts and helping to stimulate green job development and economic recovery.

Table ES.2: 2008 Richmond Government Operations Costs by Sector

Sector	Percent of Energy Costs	Cost ($)
Buildings and Other Facilities	31%	$7,048,894
Vehicle Fleet	30%	$6,913,070
Water Delivery and Treatment Facilities	15%	$3,355,131
Streetlights & Traffic Signals	13%	$2,912,159
Wastewater Treatment Facility	11%	$2,612,558
Solid Waste Facilities	0.002%	$408
TOTAL	**100%**	**$22,842,220**

Energy costs were also analyzed based on energy source. Of this total, the majority of energy expenses (60 percent or $13,581,163) were from electricity consumption (Table ES.3). Gasoline and diesel purchases for the city's vehicle fleet accounted for 30 percent of energy costs ($6,911,854), while 10 percent of total expenditures ($2,347,987) were from natural gas. Biodiesel (B20) purchases for the vehicle fleet contributed less than one percent of total energy costs ($1,216).

Table ES.3: 2008 Richmond Government Operations Energy Costs by Source

Sector	Percent of Total Energy Costs	Cost ($)
Electricity	60%	$13,581,163
Gasoline	15%	$3,500,842
Diesel	15%	$3,411,012
Natural Gas	10%	$2,347,987
Biodiesel (B20)	0.01%	$1,216
Fuel Oil	no data	no data
TOTAL	**100%**	**$22,842,220**

[4] Cost data were unavailable for vehicle refrigerant purchases or for fuel oil purchases.
[5] Data for buildings and facilities excludes the water treatment plant, water delivery facilities, the wastewater treatment plant, and a building at the East Richmond Road landfill. Cost data for these facilities are included in the Water Delivery and Treatment Facilities, Wastewater Treatment, and Solid Waste Facilities categories.

Community Inventory Results

In 2008, the Richmond community emitted approximately 2,987,651 metric tons of CO_2e. As shown in Figure ES.2 and Table ES.4, the commercial / industrial sector was the largest source of emissions in 2008 (44 percent of community emissions or 1,320,955 metric tons of CO_2e). Transportation produced 868,373 metric tons of CO_2e (29 percent) as a result of diesel and gasoline combustion in vehicles traveling on both local roads and state highways that pass through the jurisdictional boundaries of Richmond. Energy consumption in the residential sector was the next largest source of greenhouse gas emission, contributing 25 percent of community emissions or 748,191 metric tons of CO_2e. Estimated methane emissions that will result from the decomposition of waste generated by the Richmond community during 2008 accounted for 2 percent of emissions, while the treatment of wastewater contributed less than one percent of total emissions.

Figure ES.2: 2008 Richmond Community Emissions by Sector

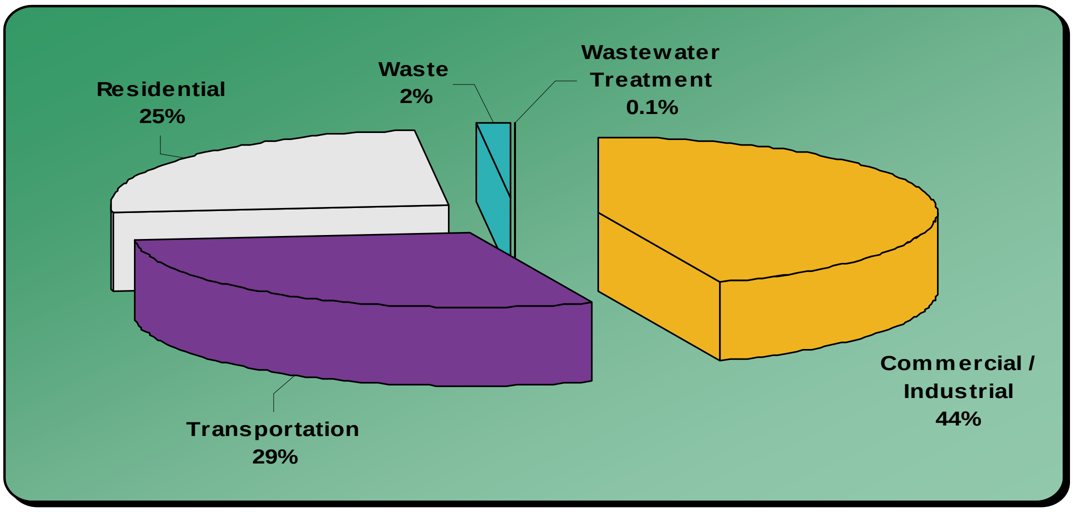

Table ES.4: 2008 Richmond Community Emissions by Sector

Sector	Greenhouse Gas Emissions (metric tons CO_2e)
Commercial / Industrial	1,320,955
Transportation	868,373
Residential	748,191
Waste*	47,773
Wastewater	2,359
TOTAL	**2,987,651**

*Includes emissions associated with disposing of municipal solid waste and waste collected by private haulers.

This report is the first step in Richmond's climate and sustainability efforts; it provides guidance to the city on major emissions sources within both governmental operations and the community as a whole. The next step for the city is to work with ICLEI and the relevant community stakeholders to identify an emissions reduction target and design a Climate Action or Sustainability Plan that identifies strategies the city can employ to reduce energy usage and associated greenhouse gas emissions.

Section One: Introduction

Introduction

While local governments cannot solve the problems of climate change by themselves, their policies can dramatically reduce greenhouse gas emissions from a range of sources and can prepare their communities for the potential impacts of climate change. The benefits of a climate protection initiative are shared by both the local government and the community and include reduced costs due to energy efficiencies, cleaner air and improved transportation choices.

Within the context of government operations, local governments have direct control over their emissions-generating activities. They can reduce energy consumption in buildings and facilities, reduce fuel consumption in fleet vehicles and equipment, reduce the amount of municipal solid waste that is sent to a landfill, and increase the amount of energy that is obtained through alternative energy sources. By quantifying the emissions coming from government operations, this report will assist policymakers and stakeholders in addressing Richmond’s institutional contribution to climate change.

Local jurisdictions in Virginia also have influence over activities in the community that generate greenhouse gas emissions, such as new construction, the operation of buildings, transportation, and solid waste disposal. That influence may be exercised directly through the jurisdiction’s authority over local land use planning and building standards, and indirectly through programs that encourage sustainable behavior among local residents and businesses. The community inventory provides a starting point for addressing how the city can impact emissions within its jurisdictional boundaries.

1.1 Climate Change Background and Potential Impacts

In the phenomenon known as the greenhouse effect, naturally-occurring atmospheric gases help regulate global climate by trapping solar radiation within the Earth's atmosphere. Evidence suggests that modern human activity is artificially intensifying the greenhouse effect, causing global average surface temperatures to rise. This intensification is caused by activities that release carbon dioxide and other greenhouse gases into the atmosphere—most notably the burning of fossil fuels for transportation, electricity, and heating.

Rising temperatures affect local and global climate patterns, and these changes are forecasted to manifest themselves in a number of ways that may impact the Richmond region. In 2008, the State of Virginia released *Inventory and Projection of Greenhouse Gas Emissions (2000 – 2025)* indicating that carbon dioxide emissions rose in Virginia by approximately 34 percent from 1990 to 2004, a rate nearly twice the national average. This increase is a result of growth in Virginia's economy and changes in development patterns that have produced sprawl and long commutes, which is evidenced by Virginia's 30 percent increase in gasoline-powered cars during this period.

Over the long term, climate change will affect Virginia's population, wildlife, and economy. The Virginia Institute for Marine Science estimates that in the mid-Atlantic, sea-level will rise between four and twelve inches by 2030, threatening coastal islands, low-lying areas, and the people and organisms that rely on those regions.[6] Air and sea temperatures are rising and are forecasted to continue increasing, which would cause more frequent tropical storms with increased damage to Virginia communities, as well as threats to public health and increased demand on emergency personnel. The Chesapeake Bay is particularly susceptible to damage caused by climate change, through changes in sea levels, salt water inundation, storm surges, and shifts in biological habitat. Additionally, changing rain and temperature patterns are likely to disrupt agriculture and forestry systems and could impact tourism and construction industries.

In September 2007, the state administration released a first-ever comprehensive energy plan for the Commonwealth. *The Virginia Energy Plan* was prepared pursuant to legislation that was enacted in 2006, and covers all aspects of energy production and consumption in Virginia, including: fuel demand and supply, infrastructure, impacts of energy use on the environment, and energy research and development capabilities. The Plan identifies four overall goals, one of which is to reduce greenhouse gas emissions by 30 percent by 2025, bringing emissions back to 2000 levels. This goal will be partially achieved through energy conservation and renewable energy actions identified in the Plan.

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[6] Excerpt taken from Report by Governors Commission on Climate Change: http://www.governor.virginia.gov/Initiatives/ExecutiveOrders/pdf/EO_59.pdf

While state-wide action is important for addressing climate change threats, so too are local and federal actions. Recognizing the importance of local action, many communities in the United States are taking responsibility at the local level. Since many of the major sources of greenhouse gas emissions are directly or indirectly controlled through local policies, local governments have a strong role to play in reducing greenhouse gas emissions within their boundaries. Through proactive measures around sustainable land use patterns, transportation demand management, energy efficiency, green building, waste diversion, and public education, local governments can dramatically reduce emissions in their communities. In addition, local governments are primarily responsible for the provision of emergency services and the mitigation of natural disaster impacts. As the effects of climate change become more common and severe, local government adaptation policies will be fundamental in preserving the welfare of residents, businesses, and the natural environment.

1.2 Purpose of Inventory

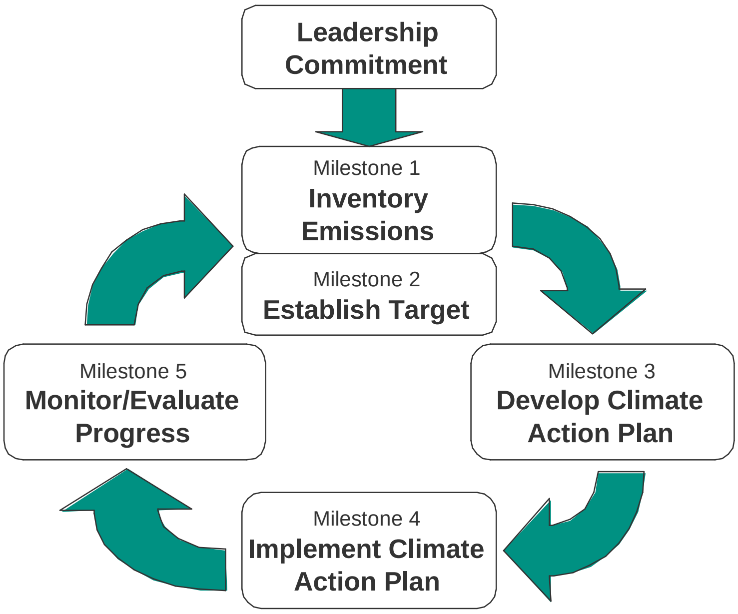
The objective of this greenhouse gas emissions inventory is to identify the sources and quantities of greenhouse gas emissions resulting in Richmond in 2008. This inventory is a necessary first step in addressing greenhouse gas emissions and serves two purposes:

- It creates an emissions baseline against which the city can set emissions reductions targets and measure future progress, and
- It allows the city to understand the scale of emissions from various sources.

While Richmond has already begun to reduce greenhouse gas emissions through its actions (See Section 1.4), this inventory represents the first step in a comprehensive approach to reducing the city's emissions. This approach, developed by ICLEI, is called the Five Milestones for Climate Mitigation. This Five-Milestone process includes:

Milestone One: Conduct a baseline emissions inventory and forecast
Milestone Two: Adopt an emissions reduction target for the forecast year
Milestone Three: Develop a local climate action plan
Milestone Four: Implement the climate action plan
Milestone Five: Monitor progress and report results

Figure 1.1: Five Milestones for Climate Mitigation



1.3 Climate Change Mitigation Activities in Virginia

In 2007, former Governor Timothy M. Kaine established the Governor's Commission on Climate Change. In December 2008 the Commission published its report, *A Climate Change Action Plan*, with a GHG reduction target of 30% by 2025 based on 2000 emissions. The Commission made the following recommendations for local governments to take actions in reducing GHG emissions:

- Lead by example on building energy efficiency, fleet efficiency and VMT reduction;
- Work with state agencies to establish a central, publicly-administered capital fund for energy efficiency investments in residential and small commercial markets;
- Coordinate and harmonize state and local transportation and land use plans;
- Zoning for TOD (transit-oriented-development);
- Provide incentives for redevelopment;
- Deploy agriculture best management practices and promote tree canopy preservation and no net loss of natural carbon sequestration; and
- Develop renewable energy projects such as landfill gas and waste-to-energy.

Based on the Commission's report, former Governor Timothy M. Kaine launched Renew Virginia in 2008, a year-long series of legislative and administrative actions that promoted renewable energy, created green jobs, and encouraged preservation of the environment. Moreover, in 2009, the Virginia General Assembly passed several bills including rewarding electric utilities for investing in energy efficiency, setting a goal of raising the state's renewable portfolio standard to 15 percent by 2025, and encouraging development of biofuels from non-food crops. For example:

- SB1212 on clean energy financing states that any locality may, by ordinance, authorize contracts to provide loans for the initial acquisition and installation of clean energy improvements with free and willing property owners of both existing properties and new construction; and

- HB1994 allows for the sale of electricity from renewable sources through a renewable energy portfolio standard program.

1.4 The City of Richmond and Climate Change Mitigation

The city of Richmond is the capital of the Commonwealth of Virginia. Like all Virginia municipalities incorporated as cities, it is an independent city and not part of any county. The population was 202,002 in 2008,[7] with an estimated population of 1,212,977 for the Richmond Metropolitan Area — making it the third largest metropolitan area in Virginia.

Founded in 1737, Richmond is a historic city filled with important landmarks, including the Virginia State Capitol, and areas of beautifully preserved period architecture. Richmond's employment base is diverse and extends from chemical, food and tobacco manufacturing to biotechnology, semiconductors and high-tech fibers. Richmond consistently ranks among "Best Places to Live and Work in America" in several national publications.

In addition to being one of the nation's most historical cities, Richmond is also striving to become a Tier One City.

Table 1.1: 2008 Richmond Profile

Size (sq. miles)	Population	Employees	Climate Zone	Heating Degree Days	Cooling Degree Days
60.07	202,002	4,762	Zone 4[8]	3,831[9]	1,291[10]

To support that goal, the city has implemented or is developing a number of policies and programs to be a more sustainable community and reduce greenhouse gas emissions. The following provides some examples of these programs and policies.

Programs

- A 2009 green certification award for participation in the Virginia Municipal League's Green Government Challenge. Some of the items Richmond earned points for included the James River Park Conservation Easement, installing push button lighting systems and tankless hot water systems in Parks & Recreation Facilities, and implementing an Environmental Management System which reduced the City's wastewater treatment facility's power consumption;

[7] U.S. Census Bureau
[8] DOE: Energy Information Administration (EIA)
[9] NOAA: National Climatic Data Center http://lwf.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html
[10] NOAA: National Climatic Data Center http://lwf.ncdc.noaa.gov/oa/documentlibrary/hcs/hcs.html

- Developing a green building program to support low impact development (LID) and other sustainable practices in the city of Richmond.
- Creating a new policy for use of city property for community gardens.
- Working with the Green Infrastructure Center, the Richmond Regional Planning District Commission (RRPDC) and E2 Inc. to assess the city's green infrastructure (tree canopy, rivers, parks, greenways, etc.) as well as inventory vacant and underutilized parcels to develop a Green Infrastructure Map for the city. This map of green opportunities will create a "greenprint" for the city's future development.
- Conversion of existing incandescent traffic signals to LED lights including pedestrian signal heads;
- Pilot project using solar powered street lights in Randolph West Subdivision;
- Greater Richmond Transit Company (GRTC) Rideshare program for city employees;
- A webpage to communicate with and engage citizens in sustainability efforts; and
- A Green Lunch Program to educate city employees on sustainability topics.

Policies & Commissions

- Resolution to apply LEED Silver standards to new and renovated city facilities;
- Green City Commission to advise the City on sustainability issues;
- Urban Forestry Commission to help improve the urban tree canopy;
- Membership in ICLEI – Local Governments for Sustainability, an international membership association of local governments working to reduce greenhouse gas emissions and achieve tangible improvements in sustainability;
- Membership in the U.S. Green Building Council
- Membership in the Urban Sustainability Directors Network (USDN), a group of over 70 sustainability directors from cities in the U.S. and Canada formed to accelerate achievement of municipal sustainability goals.

The remainder of this report provides information on where energy usage and costs are the highest in the city, thereby providing information on where potential saving opportunities exist. The city is encouraged to use this information to assist them in determining which measures to pursue to help them achieve their climate and sustainability goals.

Section Two: Methodology

Methodology

The inventories in this report follow two standards: one for government operations emissions and one for community emissions. As local governments all over the world continue to join the climate protection movement, the need for common conventions and a standardized approach to quantifying greenhouse gas (GHG) emissions is more pressing than ever.

The government operations component of the greenhouse gas emissions inventory follows, to the extent possible, the standard methodology outlined in the Local Government Operations Protocol (LGOP), which serves as the national standard for quantifying and reporting greenhouse emissions from local government operations.

The community emissions inventory follows the standard outlined in the draft International Local Government Greenhouse Gas Emissions Analysis Protocol (IEAP). ICLEI has been developing this guidance since the inception of its Cities for Climate Protection Campaign in 1993, and has recently formalized version 1 of the IEAP as a means to set a common framework for all local governments worldwide.

This chapter outlines the basic methodology utilized in the development of this inventory to provide clarity on how the inventory results were reported. Specifically, this section reviews:

- The greenhouse gases measured in this inventory.
- The general methods used to estimate emissions.
- How emissions estimates can be reported.
- How emissions estimates were reported in this inventory.

More detailed information about the methodology used in this inventory can be found in Appendices A, B, and E.

2.1 Greenhouse Gases

According to both the LGOP and the IEAP, local governments should assess emissions of all six internationally recognized greenhouse gases regulated under the Kyoto Protocol. These gases are outlined in Table 2.1, which includes the sources of these gases and their global warming potentials (GWP).[11] This report discusses the emissions results of the following four greenhouse gases released by the city of Richmond's government operations and by the Richmond community as a whole during 2008: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and hydrofluorocarbons (HFCs).

In addition to these four gases, leaked emissions of sulfur hexafluoride (SF_6), a gas used in electricity distribution systems, can also be a significant source of greenhouse gas emissions. This is because SF_6 has a global warming potential, or the ability of the gas to trap heat in comparison to carbon dioxide, of 23,900. The city operates a streetlight utility which controls the electricity distribution lines for Richmond's streetlights. Data were unavailable to calculate fugitive SF_6 from the city's streetlight distribution lines in 2008. However, the city should account for fugitive emissions of SF_6 in future inventories.

Emissions of perfluorocarbons (PFCs) were not included in this inventory due to a lack of data. However, Richmond's government operations do not include manufacturing, so it is unlikely that PFCs were emitted from the city's municipal operations. PFC emissions from manufacturing would ideally be included in a community inventory, but very limited data exist to quantify private sector PFC emissions. As a result of data limitations, community greenhouse gas emissions inventories do not typically include emissions from PFCs.

Table 2.1: Greenhouse Gases

Gas	Chemical Formula	Activity	Global Warming Potential (CO_2e)
Carbon Dioxide	CO_2	Combustion	1
Methane	CH_4	Combustion, Anaerobic Decomposition of Organic Waste (Landfills, Wastewater), Fuel Handling	21
Nitrous Oxide	N_2O	Combustion, Wastewater Treatment	310
Hydrofluorocarbons	Various	Leaked Refrigerants, Fire Suppressants	12–11,700
Perfluorocarbons	Various	Aluminum Production, Semiconductor Manufacturing, HVAC Equipment Manufacturing	6,500–9,200
Sulfur Hexafluoride	SF_6	Distribution of Power	23,900

[11] Global warming potential (GWP) is a measure of the amount of warming a greenhouse gas may cause, measured against the amount of warming caused by carbon dioxide.

2.2 Calculating Emissions

The majority of the emissions recorded in this inventory have been calculated using **calculation-based methodologies** to derive emissions using activity data and emission factors. To estimate emissions accordingly, the basic equation below is used:

Activity Data x Emission Factor = Emissions

Activity Data

Activity data refer to the relevant measurement of energy use or other greenhouse gas-generating processes such as fuel consumption by fuel type, metered annual electricity consumption, and annual vehicle miles traveled. Please see the appendices for a detailed listing of the activity data used in compiling this inventory.

Emission Factors

Emission factors are used to convert energy usage or other activity data into associated emissions quantities. They are usually expressed in terms of emissions per unit of activity data (e.g., lbs CO_2/kWh). Please see Appendices B and E for a listing of emissions factors and methodologies used in this report. Table 2.2 demonstrates an example of common emission calculations that use this formula.

Table 2.2: Basic Emissions Calculations

Activity Data	Emissions Factor	Emissions
Electricity Consumption (kilowatt hours)	CO_2 emitted/kWh	CO_2 emitted
Natural Gas Consumption (therms)	CO_2 emitted/therm	CO_2 emitted
Gasoline/Diesel Consumption (gallons)	CO_2 emitted /gallon	CO_2 emitted
Waste Generated by Government Operations (tons)	CH_4 emitted/ton of waste	CH_4 emitted

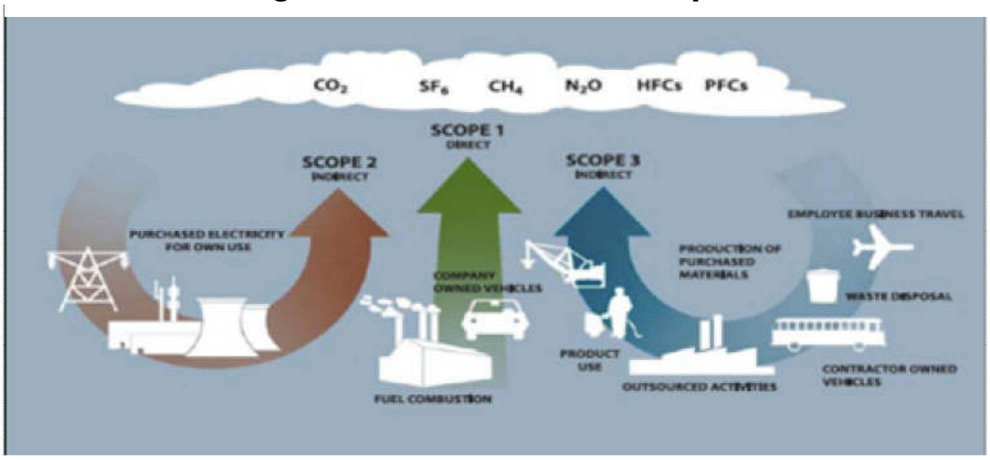
2.3 Reporting Emissions

This section defines the two reporting frameworks—scopes and sectors—and discusses how they are used in this inventory. It also discusses the concept of "rolling up" emissions into a single number. In addition, this section provides guidance on communicating the results of the inventory and using the inventory to formulate emissions reductions policies.

2.3.1 The Scopes Framework

For government operations and community inventories, emissions sources can be categorized by "scope" according to the entity's degree of control over the emissions source and the location of the source. Emissions sources are categorized as direct (Scope 1) or indirect (Scope 2 or Scope 3), in accordance with the World Resources Institute and the World Business Council for Sustainable Development's *Greenhouse Gas Protocol Corporate Standard.* Please see Figure 2.1 for a description of some common emission scopes reported in a greenhouse gas emissions inventory.

Figure 2.1: Emissions Scopes



Source: WRI/WBCSD GHG Protocol Corporate Accounting and Reporting Standard (Revised Edition), Chapter 4.

Community Scope Definitions

The scopes framework includes three categories for community emissions:

Scope 1: All direct emissions from sources located within the jurisdictional boundaries of the local government, including fuel combusted in the community and direct emissions from landfills in the community.

Scope 2: Indirect emissions associated with the consumption of energy that is generated outside the jurisdictional boundaries of the community.

Scope 3: All other indirect or embodied emissions not covered in Scope 2 that occur as a result of activity within the jurisdictional boundaries.

Scope 1 and Scope 2 sources are the most essential components of a community greenhouse gas analysis. This is because these sources are typically the most significant in scale, and are most easily impacted by local policy. The IEAP also includes, in its *Global Reporting Standard*, the reporting of Scope 3 emissions associated with the future decomposition of solid waste generated in the community in the base year.

Government Scope Definitions

Similar to the community framework, the government scopes are divided into three main categories:

Scope 1: Direct emissions from sources within a local government's operations that it owns and/or controls. This includes stationary combustion to produce electricity, steam, heat, and power equipment; mobile combustion of fuels; process emissions from physical or chemical processing; fugitive emissions that result from production, processing, transmission, storage and use of fuels; leaked refrigerants; and other sources.

Scope 2: Indirect emissions associated with the consumption of electricity or steam that is purchased from an outside utility.

Scope 3: All other emissions sources that hold policy relevance to the local government that can be measured and reported. This includes all indirect emissions not covered in Scope 2 that occur as a result of activities within the operations of the local government. Scope 3 emission sources include (but are not limited to) tailpipe emissions from employee commutes, employee business travel, and emissions resulting from the decomposition of municipal solid waste.

2.3.2 Double Counting and Rolling Up Scopes

Many local governments find it useful for public awareness and policymaking to use a single number (a "roll-up" number) to represent emissions in their reports, target setting, and action plans. A roll-up number allows local governments to determine the relative proportions of emissions from various sectors (e.g., 30 percent of rolled up emissions came from the vehicle fleet), which can help policymakers and staff identify priority actions for reducing emissions from their operations.

For these reasons, this report includes roll-up numbers as the basis of both the government operations and community emissions analyses in this inventory. This roll-up number is composed of direct emissions (Scope 1), all emissions from purchased electricity (Scope 2), and other indirect emissions (Scope 3).

The roll-up number for the government inventory includes emissions from the following sources:[12]

- Energy consumption (such as electricity, natural gas, and fuel oil) consumed in the city-owned buildings and facilities;

[12] Emissions resulting from buildings, facilities, vehicles, or processes operated by the Port of Richmond, Richmond Public Schools, Richmond Redevelopment Housing Authority, Richmond Metropolitan Authority, Greater Richmond Transportation Company, and the Richmond Ambulance Authority were excluded from the inventory as they did not fall within the operational control of Richmond's government operations. However, there were additional sources of emissions that were excluded from the inventory due to a lack of data; see section 3.4.9 for information on missing sources of emissions.

- Electricity consumed by Richmond's streetlights and traffic signals;
- Methane and nitrous oxide emissions from the treatment of wastewater;
- Fuel consumed and refrigerants leaked by the city's vehicles and mobile equipment;
- Fuel consumed by employees driving alone and carpooling to work; and
- Solid waste generated by government operations during 2008.

The roll-up number for the community inventory includes emissions from the following sources:

- Energy consumption from buildings, facilities, and other infrastructure (electricity, natural gas, fuel oil, and kerosene) in the residential, commercial, and industrial sectors;
- Fuel consumption from vehicles traveling on roads located inside the city of Richmond's jurisdictional boundaries;
- Methane emissions from solid waste generated by the Richmond community; and
- Methane and nitrous oxide emitted by wastewater treated at the city of Richmond wastewater treatment plant.

While this report uses standard roll-up numbers, these numbers should be used with caution, as they can be problematic for three reasons:

First, a roll-up number does not represent all emissions from Richmond's operations, only a summation of inventoried emissions using available estimation methods. Reporting a roll-up number can be misleading: citizens, staff, and policymakers may think of this number as the local government's **total** emissions. Therefore, when communicating a roll-up number it is important to represent it only as a sum of inventoried emissions, not as a comprehensive total. For more information on emissions sources that were not included in the city's inventory, please see Section 3.4.9.

Second, rolling up emissions may not simply involve adding emissions from all sectors, as emissions from different scopes can be double-counted when they are reported as one number. For example, if a local government operates a municipal utility that provides electricity to government facilities, these are emissions from both the power generation and facilities sectors. If these sectors are rolled up into a single number, these emissions are double counted, or reported twice. For these reasons, it is important to be cautious when creating a roll-up number to avoid double counting; the roll-up number used in this report was created specifically to avoid any possible double counting.

Third, it is very difficult to compare a roll-up number with other local governments, which is how the results are sometimes applied. Currently, there is no national or international standard for reporting emissions as a single roll-up number. In addition, local governments provide different services to their citizens, and the scale of the services (and thus the emissions) is highly dependent upon the size of the jurisdiction. Comparisons between local government roll-up numbers should not be made without significant analysis of the basis of the roll-up number and the services provided by the local governments being compared.

Lastly, the results from both the government operations and community inventories should not be rolled-up into one number, as government operations emissions are already accounted for in the community inventory.

2.3.3 Emissions Sectors

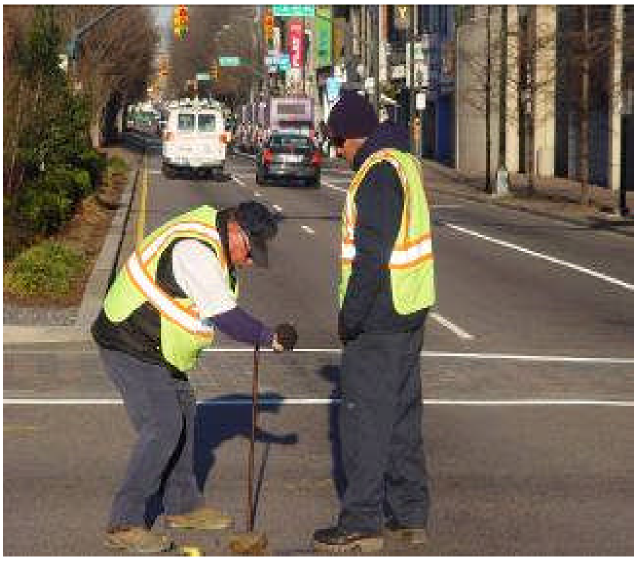
In addition to categorizing emissions by scope, ICLEI recommends that local governments examine their emissions in the context of the sector that is responsible for those emissions. Many local governments will find a sector-based analysis more directly relevant to policy making and project management, as it assists in formulating sector-specific reduction measures and climate action plan components. The government operations inventory uses LGOP sectors as a primary reporting framework, including the following sectors:

- Buildings and other facilities;
- Streetlights, traffic signals, and other public lighting;
- Water delivery facilities;
- Wastewater facilities;
- Vehicle fleet and mobile equipment;
- Solid waste facilities
- Municipal solid waste; and
- Emissions from employee commutes.

The community inventory reports emissions by the following sectors:

- **Residential.** This sector includes Scope 1 fuel consumption (natural gas, fuel oil, and kerosene combustion) and Scope 2 electricity consumption;
- **Commercial/Industrial**. This sector includes Scope 1 fuel consumption and Scope 2 electricity consumption;
- **Transportation.** This sector includes exclusively Scope 1 transportation fuel consumption;
- **Solid Waste.** This includes Scope 1 emissions from landfills located in the jurisdiction and Scope 3 emissions from future decomposition of solid waste generated in the community in the base year;
- **Wastewater.** This is a Scope 1 sector that is an estimate of the emissions created by the processing of wastewater that is generated in Richmond.

Section Three: Government Operations Inventory Results



Government Operations Inventory Results

This chapter provides a detailed description of Richmond's greenhouse gas emissions from government operations in 2008, rolling up and comparing emissions across sectors and sources as appropriate. This chapter also provides details on emissions from each sector, including a breakdown of emissions types and, where possible, an analysis of emissions by department. This information identifies more specific sources of emissions (such as particular buildings) that can help staff and policymakers in Richmond to best target emissions reduction activities in the future.

For a report of emissions by scope, and a detailed description of the methodology and emission factors used in calculating the emissions from the city's operations, please see Appendix B: LGOP Standard Report.

3.1 Summary by Sector

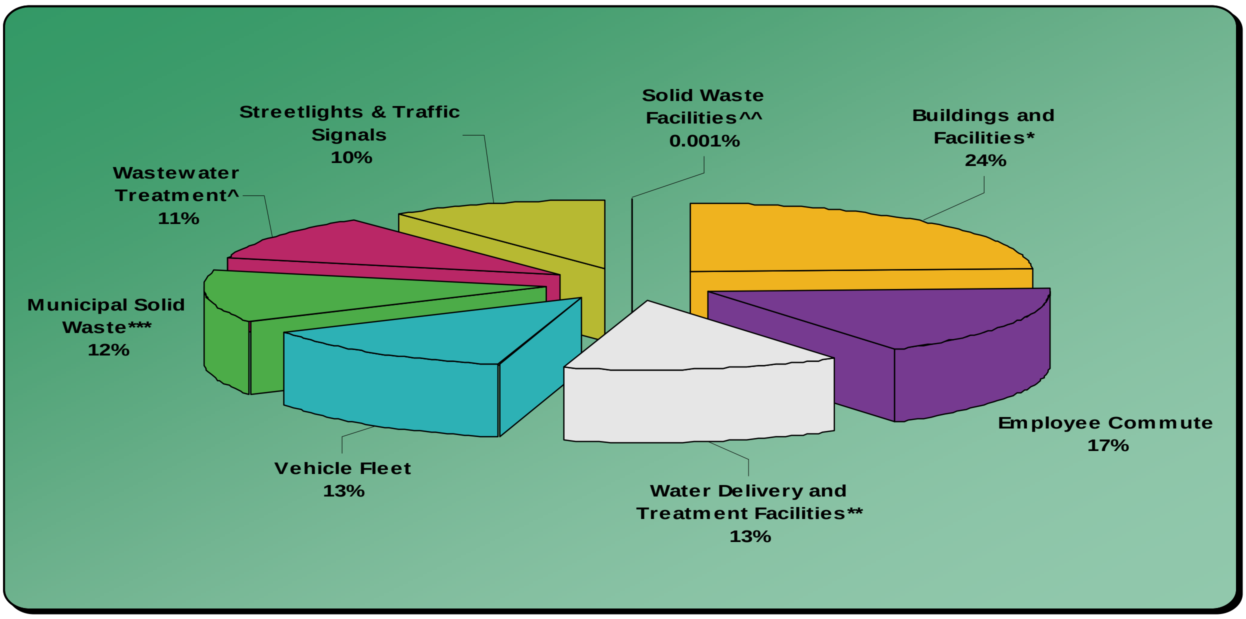
In 2008, Richmond's greenhouse gas emissions from government operations totaled 173,660 metric tons of CO_2e.[13/14] What follows is a breakdown of this total by sector. Reporting emissions by sector provides a useful way to understand the sources of Richmond's emissions. By better understanding the relative scale of emissions from each of the sectors, the city of Richmond can more effectively focus emissions reduction strategies to achieve the greatest emissions reductions, energy and resource reductions and cost savings opportunities.

[13] This number represents a roll-up of emissions, and is not intended to represent a complete picture of emissions from Richmond's operations. This roll-up number should not be used for comparison with other local government roll-up numbers without a detailed analysis of the basis for this total. See section 2.3.2 for more detail.

[14] This number does not include 14 metric tons of CO_2e resulting from the biogenic component of biodiesel (B20) fuel consumed by the city's vehicle fleet and by employee commuter vehicles. The carbon dioxide emissions from the biogenic component of a B20 fuel blend (a fuel that is 20 percent biogenic and 80 percent diesel) is considered informational because the emissions released during the combustion of the fuel would theoretically have returned to the atmosphere if the biogenic material were allowed to decompose naturally.

As visible in Figure 3.1 and Table 3.1, Richmond's buildings and facilities produced the majority of the city's 2008 emissions (24 percent or 41,894 metric tons of CO_2e). Emissions from employees driving alone and carpooling to work produced the second highest quantity of emissions, resulting in 29,087 metric tons of CO_2e (17 percent), while operation of the city's water treatment and delivery facilities was the third largest contributor (13 percent or 22,593 metric tons of CO_2e). The city's vehicle fleet contributed another 13 percent of emissions (22,437 metric tons of CO_2e). Municipal solid waste collected by the city of Richmond from residential and non-residential customers during 2008 is expected to produce 21,210 metric tons of CO_2e as it decomposes (12 percent of overall government emissions). Emissions from treating wastewater and operating the wastewater treatment facility accounted for 18,686 metric tons CO_2e (11 percent), while emissions from streetlights and traffic signals produced 17,751 metric tons CO_2e (10 percent). The emissions generated by electricity consumption at the East Richmond Road Convenience Center, the only solid waste facility operated by the city, accounted for less than one percent of overall emissions.[15]

Figure 3.1: 2008 Richmond Government Operations Emissions by Sector



*The buildings and facilities sector does not include emissions from operating the wastewater or water treatment plants, or facilities at closed landfills owned by the city. Those emissions are included in the Wastewater Treatment, Water Delivery and Treatment Facilities, and Solid Waste Facilities categories.
**Emissions from energy used to operate the water treatment facility and water transport infrastructure. This figure does not include emissions associated with the treatment of water as LGOP does not include methods for calculating this source.
***This figure includes emissions associated with disposing of municipal solid waste – including all waste generated by residential and non-residential city of Richmond customers.
^Emissions from energy used to operate the wastewater treatment facility at 1400 Brander Street and from wastewater treatment processes.
^^Only represents emissions resulting from operating the transfer facility at 3800 E Richmond Road. This figure does not include methane emissions from decomposing organic waste in the city's seven closed landfills; data were unavailable to calculate methane emissions from decaying organic waste in the city's closed landfills.

[15] The figure for Solid Waste Facilities should include methane emissions from decomposing organic waste in the city's closed landfills. However, data were unavailable to calculate these emissions.

Table 3.1: 2008 Richmond Government Operations Emissions by Sector

Sector	Greenhouse Gas Emissions (metric Tons CO_2e)
Buildings and Facilities*	41,894
Employee Commute	29,087
Water Delivery and Treatment Facilities**	22,593
Vehicle Fleet	22,437
Municipal Solid Waste***	21,210
Wastewater Treatment^	18,686
Streetlights & Traffic Signals	17,751
Solid Waste Facilities^^	2
Streetlight Electricity Loses (Distribution Lines)	no data
Leaked SF6 (Streetlight Electricity Distribution)	no data
Leaked Natural Gas (Distribution lines)	no data
Leaked Refrigerants and Fire Suppressants (Buildings and Facilities)	no data
TOTAL	**173,660**

*The buildings and facilities sector does not include emissions from operating the wastewater or water treatment plants, or facilities at closed landfills owned by the city. Those emissions are included in the Wastewater Treatment, Water Delivery and Treatment Facilities, and Solid Waste Facilities categories.
**Emissions from energy used to operate the water treatment facility and water transport infrastructure. This figure does not include emissions associated with the treatment of water as LGOP does not include methods for calculating this source.
***This figure includes emissions associated with disposing of municipal solid waste – including all waste generated by residential and non-residential city of Richmond customers.
^Emissions from energy used to operate the wastewater treatment facility at 1400 Brander Street and emissions from wastewater treatment processes.
^^Only represents emissions resulting from operating the transfer facility at 3800 E Richmond Road. This figure does not include methane emissions from decomposing organic waste in the city's seven closed landfills; data were unavailable to calculate methane emissions from decaying organic waste in the city's closed landfills.

3.2 Summary by Source

When considering how to reduce emissions, it is helpful to look not only at which sectors are generating emissions, but also at the specific raw resources and materials (such as gasoline, diesel, electricity, natural gas, and solid waste) whose use and generation directly result in the release of greenhouse gases. This analysis can help target resource management in a way that will successfully reduce greenhouse gas emissions. Table 3.2 and Figure 3.2 provide a summary of Richmond’s 2008 government operations greenhouse gas emissions by fuel type or material.

Table 3.2: 2008 Richmond Government Operations Emissions by Source

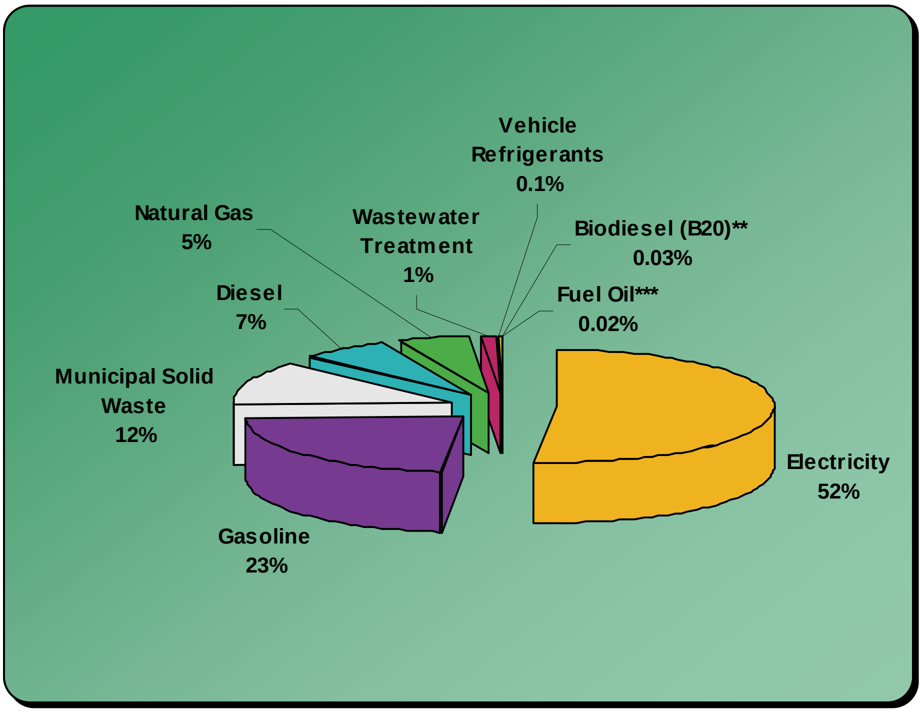
Source*	Greenhouse Gas Emissions (metric tons CO_2e)
Electricity	89,552
Gasoline	39,554
Municipal Solid Waste	21,210
Diesel	11,748
Natural Gas	8,976
Wastewater Treatment	2,359
Vehicle Refrigerants	164
Biodiesel (B20)**	59
Fuel Oil***	38
Building Refrigerants and Fire Suppressants	no data
Streetlight Electricity Loses, Leaked Natural Gas and SF_6 (Distribution Lines)	no data
TOTAL	**173,660**

*Gasoline, diesel, and biodiesel (B20) include emissions from both the city's vehicle fleet and from employees driving alone and carpooling to work.

**This number represents only the emissions from carbon dioxide produced by the 80 percent of the fuel composed of diesel. Fourteen metric tons of CO_2e were produced by the remaining 20 percent of the biogenic fuel; the carbon dioxide produced from the biodiesel portion of the fuel is considered informational only, as the carbon dioxide released during combustion would theoretically be offset by the carbon absorbed from the atmosphere by the biogenic material during its lifecycle. Methane and nitrous oxide emissions from biodiesel were not included in this inventory, as the vehicle miles traveled (VMT) data did not show any vehicles using biodiesel. Methane and nitrous oxide emissions are calculated based on VMT. However, methane and nitrous oxide emissions comprise only a small portion of overall emissions from vehicles.

***With the exception of the water treatment plant and water delivery infrastructure, data were unavailable for facilities that used fuel oil for heating or in back-up generators. It should be noted that City Hall used fuel oil in back-up generators during 2008 after the building's boiler broke, although no data were available to calculate emissions from this source. It is unlikely that other facilities were using significant amounts of fuel oil in 2008.

Figure 3.2: 2008 Richmond Government Operations Emissions by Source*



*Gasoline, diesel, and biodiesel (B20) include emissions from both the city's vehicle fleet and from employees driving alone and carpooling to work.
**This number represents only the emissions from carbon dioxide produced by the 80 percent of the fuel composed of diesel. Fourteen metric tons of CO_2e were produced by the remaining 20 percent of the biogenic fuel; the carbon dioxide produced from the biodiesel portion of the fuel is considered informational only, as the carbon dioxide released during combustion would theoretically be offset by the carbon absorbed from the atmosphere by the biogenic material during its lifecycle. Methane and nitrous oxide emissions from biodiesel were not included in this inventory, as the vehicle miles traveled (VMT) data did not show any vehicles using biodiesel. Methane and nitrous oxide emissions are calculated based on VMT. However, methane and nitrous oxide emissions comprise only a small portion of overall emissions from vehicles.
***With the exception of the water treatment plant and water delivery infrastructure, data were unavailable for facilities that used fuel oil for heating or in back-up generators. It should be noted that City Hall used fuel oil in back-up generators during 2008 after the building's boiler broke, although no data were available to calculate emissions from this source. It is unlikely that other facilities were using significant amounts of fuel oil in 2008.

3.3 Summary of Energy-Related Costs

In addition to tracking energy consumption and generating estimates on emissions per sector, ICLEI has calculated the basic energy costs of various government operations. In 2008, the city of Richmond spent approximately $22,842,220 on energy (electricity, natural gas, gasoline, diesel, fuel oil,[16] and biodiesel [B20]) for its operations. As shown in Table 3.3, the buildings and other facilities sector, which excludes the wastewater plant, water treatment plant and water delivery infrastructure, and solid waste facilities, accounted for nearly one-third of the energy costs ($7,048,894 or 31 percent) in 2008. Fuel purchased for the city's vehicle fleet was the next largest energy expenditure, costing the city $6,913,070. Electricity and natural gas purchases for operating the city's water

[16] Cost data were unavailable for 3,765 gallons of fuel oil used in back up generators at the water treatment plant and water transportation infrastructure.

delivery and water treatment infrastructure was the third largest expenditure, costing the city $3,355,131 (15 percent of 2008 energy costs). Electricity purchased to operate the city's streetlights cost $2,912,159 (13 percent), and energy consumption from operating the waste water treatment plant cost $2,612,558 (11 percent). Electricity consumption from a facility at the East Richmond Road Landfill cost the city $408.

Table 3.3: 2008 Richmond Government Operations Costs by Sector

Sector	Percent of Energy Costs	Cost
Buildings and Other Facilities	31%	$7,048,894
Vehicle Fleet	30%	$6,913,070
Water Delivery and Treatment Facilities	15%	$3,355,131
Streetlights & Traffic Signals	13%	$2,912,159
Wastewater Treatment Facility	11%	$2,612,558
Solid Waste Facilities	0.002%	$408
TOTAL	**100%**	**$22,842,220**

ICLEI also analyzed energy costs by source, as shown in Table 3.4. Electricity purchases from Dominion Virginia Power accounted for over half of energy expenditures in 2008 (60 percent or $13,581,163). Richmond's vehicle fleet and motorized equipment comprised 30 percent of total costs from fuel purchases of gasoline ($3,500,842 or 15 percent), diesel ($3,411,012 or 15 percent), and biodiesel (B20) ($1,216 or 0.01 percent). The city of Richmond operates a natural gas utility that serves the entire community of Richmond; natural gas consumed in the city's government operations was purchased from the city-run utility and accounted for 10 percent of energy costs ($2,347,987). In addition to reducing harmful greenhouse gases, any future reductions in energy use will have the potential to reduce energy costs, enabling Richmond to reallocate limited funds toward other municipal services or create a revolving energy loan fund to support future climate protection activities.

Table 3.4 2008 Richmond Government Operations Energy Costs by Source

Source	Percent of Total Energy Costs	Cost ($)
Electricity	60%	$13,581,163
Gasoline	15%	$3,500,842
Diesel	15%	$3,411,012
Natural Gas	10%	$2,347,987
Biodiesel (B20)	0.01%	$1,216
Fuel Oil	no data	no data
TOTAL	**100%**	**$22,842,220**

3.4 Detailed Sector Analyses

3.4.1 Buildings and Other Facilities

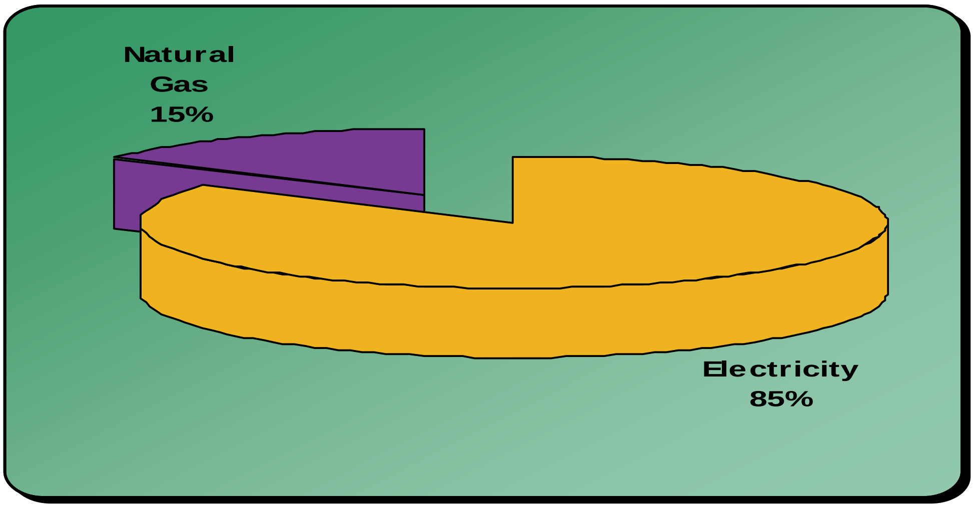
Through their use of energy for heating, cooling, lighting, and other purposes, buildings and other facilities operated by local governments constitute a significant amount of greenhouse gas emissions. Richmond operates buildings, facilities, and parks at nearly 300 service addresses. Examples of buildings and facilities operated by the city of Richmond include: City Hall, 20 different fire companies, 14 service address locations for police precincts, police headquarters and training facilities; nine libraries, and over 60 service address locations of parks and recreation facilities. This report does not address operation of city schools as they are operated independently by the School Board and Superintendent of Schools. Facility operations contribute to greenhouse gas emissions in two ways: 1) emissions from energy consumption; and 2) releases of refrigerants and fire suppressants from leaking equipment. The majority of greenhouse gas emissions are attributed to consumption of electricity and fuels such as natural gas. However, fire suppression, air conditioning, and refrigeration equipment in buildings can emit hydrofluorocarbons (HFCs) and other greenhouses through leakage or when fire suppression equipment is deployed.[17]

In 2008, the operation of Richmond's facilities[18] produced approximately 41,894 metric tons of CO_2e (24 percent of overall government emissions). Of the total facility emissions, the majority were from electricity consumption (85 percent). The remaining 15 percent of emissions came from natural gas consumption (Figure 3.3). Richmond spent approximately $7,048,894 on the energy sources (electricity and natural gas) that contributed to these emissions.

It is important to note that fuel oil was consumed in back-up generators at City Hall during 2008 after the building's boiler broke; however, data were unavailable to calculate the emissions from this source. Except for water treatment and transportation facilities, fuel oil data were unavailable in any of the city's facilities in 2008, although it is unlikely that facilities other than City Hall were using significant amounts of fuel oil. Also, data were unavailable to calculate emissions from leaked fire suppressants and refrigerants used in Richmond's buildings and facilities during 2008. Even though it is estimated that annual fuel oil consumption and refrigerant leaks are minimal, the city should begin tracking usage so that these sources can be included in a future inventory analysis.

[17] Data were unavailable to calculate emissions from refrigerants, fire suppressants, and fuel oil used in back up generators from the buildings and facilities in this inventory.
[18] Unless otherwise specified, the analysis of buildings and facilities in this section does not include emissions from operating the wastewater treatment plant, water treatment plant and water transportation infrastructure, or solid waste facilities owned by the city. Those sources are discussed in later sections of this report.

Figure 3.3: 2008 Emissions from Buildings and Facilities by Source*

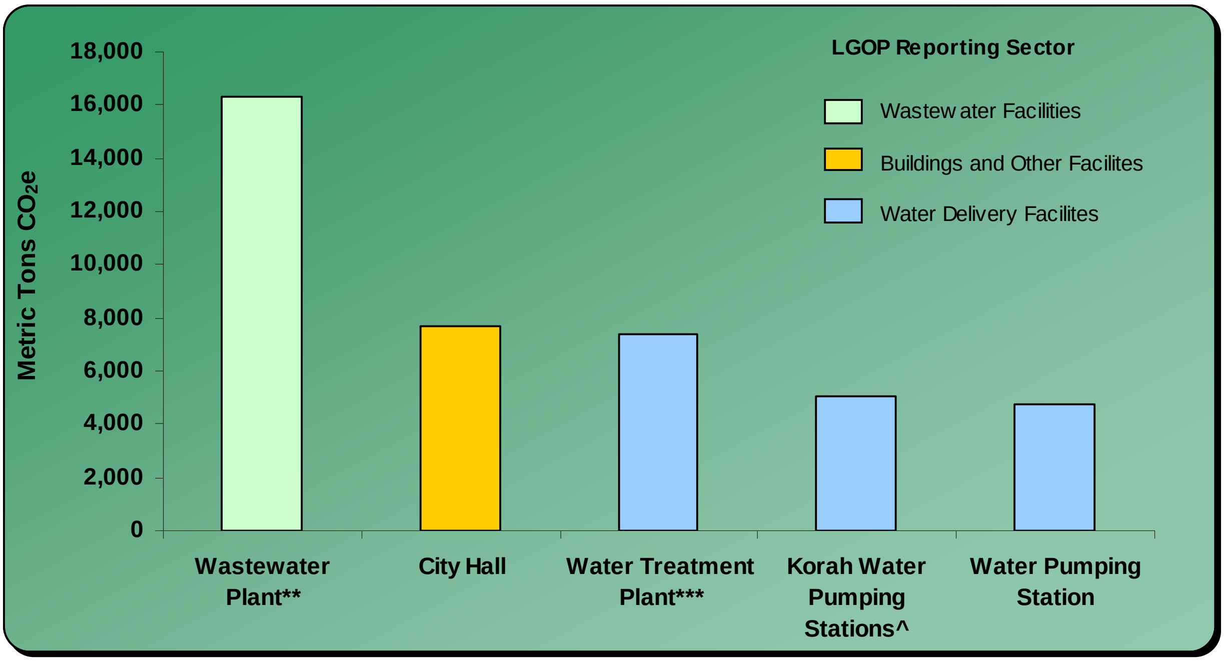


*The buildings and facilities analysis does not include emissions from the wastewater treatment plant, water treatment plant, or facilities at closed landfills owned by the city. Those emissions are included in the wastewater treatment, water delivery and treatment facilities, and solid waste facilities categories.

ICLEI also analyzed emissions by service address. Analyzing emissions at this level of detail can be useful when selecting buildings or facilities for specific energy reduction measures. Figure 3.4 and Table 3.5 compare greenhouse gas emissions for the five service addresses that produced the largest amount of greenhouse gas emissions from all LGOP reporting sectors.

The wastewater treatment plant, City Hall, and the water treatment plant were the three largest contributors of emissions from Richmond's facilities, generating a combined 31,385 metric tons of CO_2e or 18 percent of overall inventory emissions. Two of these facilities, the wastewater treatment plant and City Hall, were identified in Richmond's Energy Efficiency and Conservation Strategy as locations where Richmond could use funding to implement emissions reduction measures.

Figure 3.4: 2008 Five Highest Emissions Sources by Service Address from All Sectors*



* Emissions shown in this table are from electricity and natural gas consumption used to operate the identified facilities. Emissions from fuel oil used in back up generators were also included in water delivery and treatment facilities; fuel oil data were unavailable for facilities in other sectors. Data also were unavailable to calculate emissions from refrigerants and fire suppressants used in Richmond's buildings and facilities.

**The wastewater treatment plant consists of two service addresses: 1400 Brander St. and 1400 Brander St. TRL-B. Emissions shown in this table are the result of energy consumed to operate the treatment facility. This table does not include greenhouse gases released from the processes used to treat wastewater.

***The water treatment plant is assumed to consist of four service addresses: 3800 Douglasdale Rd., 3801 Douglasdale Rd., 3910 Douglasdale Rd., and 3920 Douglasdale Rd. It was assumed that all Douglasdale Rd. service addresses were part of the water treatment facility. This table does not include greenhouse gases released from the processes used to treat water as no methodologies are provided to quantify this source in LGOP.

^The Korah water pumping stations consist of three stations at the water treatment plant. Korah 1 and 2 service Richmond and Chesterfield. Korah 3 services Henrico.

Table 3.5: 2008 Five Highest Emissions by Service Address from All Sectors*

Building Description	Service Address	LGOP Sector	Greenhouse Gas Emissions (metric tons CO_2e)
Wastewater Treatment Plant**	1400 Brander St	Wastewater	16,327
City Hall	900 E Broad St	Buildings and Facilities	7,703
Water Treatment Plant***	Douglasdale Rd.	Water Delivery	7,355
Korah Water Pumping Stations^	Grayland Ave	Water Delivery	5,053
Water Pumping Station	2701 Trafford Rd	Water Delivery	4,757
TOTAL			**41,195**

* Emissions shown in this table are from electricity and natural gas consumption used to operate the identified facilities. Emissions from fuel oil used in back up generators were also included in water delivery and treatment facilities; fuel oil data were unavailable for facilities in other sectors. Data also were unavailable to calculate emissions from refrigerants and fire suppressants used in Richmond's buildings and facilities.

**The wastewater treatment plant consists of two service addresses: 1400 Brander St. and 1400 Brander St. TRL-B. Emissions shown in this table are the result of energy consumed to operate the treatment facility. This table does not include greenhouse gases released from the processes used to treat wastewater.

***The water treatment facility is assumed to consist of four service addresses: 3800 Douglasdale Rd., 3801 Douglasdale Rd., 3910 Douglasdale Rd., and 3920 Douglasdale Rd. It was assumed that all Douglasdale Rd. service addresses were part of the water treatment facility. This table does not include greenhouse gases released from the processes used to treat water as no methodologies are provided to quantify this source in LGOP.

^The Korah water pumping stations consists of three stations at the water treatment plant. Korah 1 and 2 service Richmond and Chesterfield. Korah 3 services Henrico.

3.4.2 Streetlights and Traffic Signals

Richmond operates a range of public lighting, such as the city's streetlights and traffic signals. The city of Richmond also operates a streetlight utility, which operates the electricity distribution lines for the city's streetlights. There are three sources of emissions from streetlights and traffic signals: 1) electricity consumed from running the streetlights; 2) emissions from electricity that is "lost" during distribution; and 3) the fugitive emissions of sulfur hexafluoride (SF_6). Leaked emissions of SF_6, a gas used in electricity distribution systems, can be a significant source of emissions. This is because SF_6 has a global warming potential, or the ability of the gas to trap heat in comparison to carbon dioxide, of 23,900.[19] Of these three sources of emissions from streetlights and traffic signals, data were only available to calculate electricity emissions from operating the lights.

In 2008, public lighting in Richmond consumed a total of 34,283,189 kilowatt hours (kWh) of electricity, producing approximately 17,751 metric tons of CO_2e. The city spent approximately $2,912,159 on the electricity used to power streetlights and traffic signals. Table 3.6 depicts the emissions per lighting type, estimated electricity consumption, and energy costs.

[19] Source: LGOP 2008 Version 1.0, Table E.1

Table 3.6: Energy Use and Emissions from Public Lighting

Source	Greenhouse Gas Emissions (metric tons CO_2e)	Percent Emissions of All Lighting	Electricity Use (kWh)	Cost ($)
Streetlights	16,126	91%	31,143,608	$2,655,995
Traffic Signals	1,626	9%	3,139,581	$256,164
TOTAL	**17,751**	**100%**	**34,283,189**	**$2,912,159**

3.4.3 Water Delivery and Treatment Facilities

This section addresses any equipment used for the distribution of water, as well as energy consumed from the operation of water treatment facilities. Typical systems included in this section are water pumps/lifts, irrigation controls, sprinkler systems, and treatment facilities. This section does quantify emissions that might be associated with the treatment of water, as no standard methodology currently exists to quantify these potential emissions.

Richmond operates a range of water transport equipment; energy use records show eight service addresses for water pumping stations and infrastructure, four service addresses for the Douglasdale Road water treatment facility, and four service addresses for irrigation equipment. In 2008, this equipment was responsible for transporting 346,563 hundred cubic feet (CCF) of water.

In 2008, the operation of Richmond's water transport equipment and treatment facility produced approximately 22,593 metric tons of CO_2e. Table 3.7 shows emissions per equipment type or facility. Richmond spent approximately $3,355,131 on the electricity required for water transport and operation of the treatment plant.

Table 3.7: Energy Use and Emissions from Water Transport and Treatment Facilities

Source	Greenhouse Gas Emissions (metric tons CO_2e)	Percent Water Transport and Treatment Emissions	Electricity Use (kWh)	Natural Gas Use (CCF)	Fuel Oil Use (gallons)	Total Cost ($)
Pumping Stations and Equipment	15,173	67%	29,299,380	0	265	$2,321,879
Water Treatment Facility (Douglasdale Rd.)	7,355	33%	13,780,866	33,515	3,500	$1,016,215
Irrigation / Sprinkler Systems	65	0.3%	14,522	10,404	0	$17,037
TOTAL	**22,593**	**100%**	**43,094,768**	**43,919**	**3,765**	**$3,355,131**

3.4.4 Wastewater Facilities and Treatment

Wastewater coming from homes and businesses is rich in organic matter and has a high concentration of nitrogen and carbon (along with other organic elements). As wastewater is collected, treated, and discharged, chemical processes in aerobic and anaerobic conditions lead to the creation and emission of two greenhouse gases: methane and nitrous oxide. Local governments that operate wastewater treatment facilities, including centralized wastewater treatment plants, septic systems, and collection lagoons, must account for the emission of these gases in their overall greenhouse gas emissions inventory. Local governments must also account for the energy use, such as electricity and natural gas, used to operate the treatment facilities.

Richmond operates a centralized wastewater treatment facility at 1400 Brander Street, along with a network of 100 septic systems. The centralized treatment plant has an anaerobic digester[20] to treat biosolids removed during the wastewater treatment process, and also uses both nitrification and denitrification as a form of tertiary treatment.

In 2008, wastewater treatment processes produced approximately 2,359 metric tons of CO_2e or 1 percent of all emissions from government operations (see Table 3.2). Electricity (14,801 metric tons of CO_2e) and natural gas (2,246 metric tons of CO_2e) consumption from operating the treatment facility resulted in 16,327 metric tons of CO_2e (9 percent of government emissions). Table 3.8 and Figure 3.7 break down wastewater emissions by source. Of total wastewater facility emissions, 76 percent came from electricity consumption, 12 percent came from natural gas consumption, and the remaining twelve percent of emissions were associated with the treatment of wastewater. Richmond spent approximately $2,612,558 in 2008 on the natural gas and electricity used to operate the treatment facility.

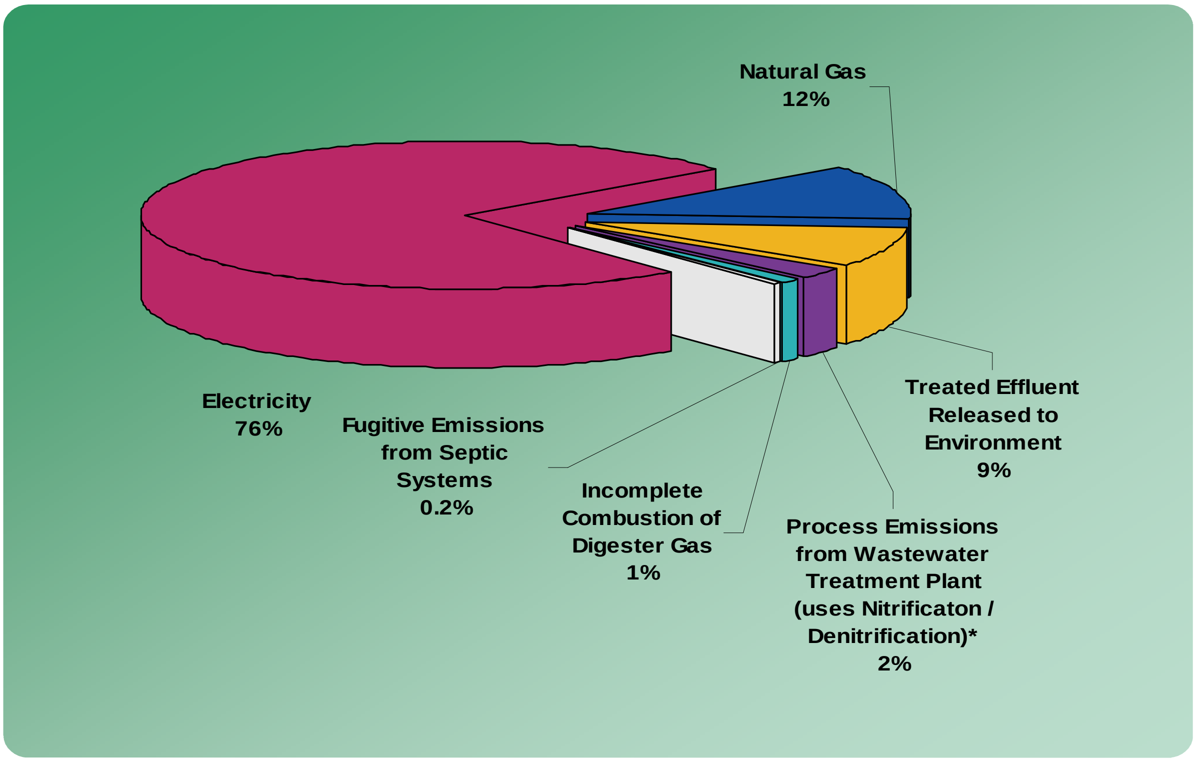
Table 3.8: Wastewater Treatment Emissions by Source

Source	Type of Greenhouse Gas	Greenhouse Gas Emissions (metric tons CO_2e)
Electricity	CO_2, CH_4, N_2O	14,081
Natural Gas	CO_2, CH_4, N_2O	2,246
Treated Effluent Released to Environment	N_2O	1,617
Process Emissions from Wastewater Treatment Plant (uses Nitrificaton/Denitrification)*	N_2O	467
Incomplete Combustion of Digester Gas	CH_4	244
Fugitive Emissions from Septic Systems	CH_4	31
TOTAL		**18,686**

*Does not include emissions from the nitrogen contributions of industry. The wastewater treatment plant does treat wastewater from industry, but does not test for the amount of nitrogen added to the system by industrial water.

[20] Anaerobic digester gas can either be flared or used as an energy source. If the anaerobic digester gas is used as an energy source, the emissions reductions would not be reflected in the wastewater treatment section of a greenhouse gas inventory. This is because successfully combusted digester gas produces carbon dioxide, which is considered biogenic by LGOP and is not included in the inventory. Anaerobic digester gas used to generate energy would be reflected in the inventory as reduced energy consumption elsewhere (such as reduced emissions from electricity). The emissions shown in Table 3.8 for the "incomplete combustion of digester gas" reflect gas that was not flared/combusted, remaining as methane. Methane is not considered biogenic by LGOP and must be reported in the greenhouse gas inventory.

Figure 3.5: 2008 Wastewater Treatment Emissions by Source



*Does not include emissions from the nitrogen contributions of industry. The wastewater treatment plant does treat wastewater from industry, but does not test for the amount of nitrogen added to the system by industrial water.

3.4.5 Vehicle Fleet and Mobile Equipment

The majority of local governments use vehicles and other mobile equipment as an integral part of their daily operations—from maintenance vehicles used for parks and recreation to police cruisers and fire trucks. These vehicles and equipment burn gasoline, diesel, and other fuels, which result in greenhouse gas emissions. In addition, vehicles with air conditioning or refrigeration equipment use chemicals which are potent greenhouse gases that can leak from vehicles and equipment. Because of the significance of vehicles and mobile equipment in maintaining most governmental operations, these sources traditionally compose a significant portion of a local government's greenhouse gas emissions profile.

In 2008, Richmond emitted approximately 22,273 metric tons of CO_2e as a result of the combustion of fuels to power the city's vehicle fleet and 164 metric tons of CO_2e were released from vehicles leaking refrigerants (Table 3.9). Consumption of diesel fuel accounted for 11,591 metric tons of CO_2e, 10,680 metric tons of CO_2e were from gasoline, and 3 metric tons of CO_2e were from biodiesel (B20).[21]

Table 3.9: Vehicle Fleet and Mobile Equipment Emissions by Department

Function	GHG Emissions (metric tons CO_2e)	Percent of All Mobile Emissions	Gasoline Consumption (gal)	Diesel Consumption (gal)	Biodiesel (B20) Consumption (gal)	Cost ($)
City of Richmond*^	22,273	99%	1,206,989	1,141,768	380	$6,913,070
Refrigerants	164	1%	-	-	-	no data
TOTAL	**22,438**	**100%**	**1,206,989**	**1,141,768**	**380**	**$6,913,070**

* Does not include 0.7 Metric Tons of CO_2 emitted from the biogenic component of the B20 biodiesel blend. Emissions from the biogenic portion of the B20 fuel consumption are considered informational and not included in the roll-up numbers in this inventory. This is because carbon dioxide emissions released from combusting biodiesel would theoretically be offset by the carbon stored in the biogenic material during its lifecycle. However, emissions from the diesel component of the B20 fuel are included in this total.
^ Nitrous oxide (N_2O) and methane emissions (CH_4) were not calculated for non-highway vehicles. For non-highway vehicles, the gallons of fuel consumed is required to calculate N_2O and CH_4 emissions, but fuel consumption data were only available in aggregate. However, N2O and CH4 emissions comprise only a small amount of overall vehicle emissions.

Of all mobile emissions calculated in 2008, emissions from powering the vehicle fleet and mobile equipment made up 99 percent of total mobile emissions, while emissions from leaked refrigerants made up only 1 percent of total mobile emissions (Table 3.9). Emissions from all mobile sources represented 13 percent (22,437 metric tons of CO_2e) of emissions from the city of Richmond's government operations in 2008. Richmond spent approximately $6,913,070 in 2008 on the fuels that contributed to these emissions.

3.4.6 Solid Waste Facilities

There are a variety of emissions associated with solid waste management services including the collection, processing, and storage of solid waste generated from residents and businesses. The most prominent source of emissions from solid waste facilities is fugitive methane released by the decomposition of organic waste over time in landfills. The scale of these emissions depends upon the size and type of the landfill and the presence of a landfill gas collection system.

[21] Does not include 0.7 Metric Tons of CO_2 emitted from the biodiesel component of the B20 biodiesel blend. Emissions from the biodiesel portion of the B20 fuel consumption is considered informational and not included in the roll-up numbers in this inventory. This is because carbon dioxide emissions released from combusting biodiesel would theoretically be offset by the carbon stored in the biogenic material during its lifecycle. However, emissions from the diesel component of the B20 fuel are included in this total.

The city of Richmond does not currently operate any open landfills, but does own seven closed landfills. The city is responsible for hauling residential and municipal waste; however, this waste is brought to the East Richmond Road Convenience Center, a transfer station, which sends waste to the Charles City County Landfill in Charles City, Virginia. None of Richmond's landfills currently have active landfill gas capture systems, although four of the city's landfills had active flaring equipment in the past.[22] Because decaying organic waste can continue to produce emissions for many years after a landfill is closed, it is important to account for closed landfills in an emissions inventory.

However, records are unavailable to estimate methane emissions from the city's closed landfills in 2008. Yet, electricity data were available to calculate emissions from the East Richmond Road Convenience Center, which produced 2 metric tons of CO_2e (less than 1 percent of overall government emissions) and cost the city $408 in energy costs in 2008.

3.4.7 Municipal Solid Waste

Many local government operations generate solid waste, much of which is eventually sent to a landfill. Typical sources of waste generated by a local government include paper and food waste from offices and facilities, construction waste from public works, and plant debris from park maintenance. Organic materials in municipal solid waste (including paper, food scraps, plant debris, textiles, and wood waste) generate methane as they decay in the anaerobic environment of a landfill. An estimated 75 percent of this methane is routinely captured via landfill gas collection systems;[23] the portion of the methane gas not captured by a collection system escapes into the atmosphere and contributes to the greenhouse effect. As such, estimating emissions from waste generated by government operations is an important component of a comprehensive emissions inventory.

Municipal solid waste is considered a Scope 3 emissions source and is optional to report under LGOP for two reasons:

- The emissions do not result at the point of waste generation (as with fuel combustion), but in a landfill located outside of Richmond's jurisdictional boundaries.
- The emissions are not generated in the same year that the waste is disposed, but over a lengthy decomposition period.

[22] Source: Brian Cecil; Staff Consultant; Joyce Engineering, Inc.

[23] This is a default methane collection rate per LGOP. This rate can vary from 0 to 99 percent based upon the presence and extent of a landfill gas collection system at the landfill(s) where the waste is disposed. Most commonly, captured methane gas is flared into the atmosphere, which converts the methane gas to CO_2 and effectively negates the human-caused global warming impact of the methane. Increasingly, landfill methane is being used to power gas-fired turbines as a carbon-neutral means of generating electricity.

Since inventorying these emissions is considered optional, LGOP does not provide guidance on recommended methods for quantifying these types of emissions. ICLEI has devised data collection and calculation methods based upon previous experience and national standards. See Appendix D for more information on quantifying emissions from municipal solid waste.

Data were unavailable to calculate emissions from waste generated exclusively by the city of Richmond's government operations in 2008. However, the city is responsible for hauling residential and municipal waste, and data were available to calculate emissions from the total waste collected by the city during 2008 (88,004[24] tons). Throughout its entire decomposition period, this waste is expected to generate 21,210 metric tons of CO_2e (see Table 3.1). Municipal solid waste emissions comprised 12 percent of government emissions in 2008 (see Figure 3.1).

3.4.8 Employee Commute

Fuel combustion from employees commuting to work is another important emissions source from Richmond's governmental operations. This area is also another opportunity for the city to explore more efficient methods of doing business. Similar to the city's vehicle fleet, personal employee vehicles use gasoline and other fuels which, when burned, generate greenhouse gas emissions. Emissions from employee commutes are considered Scope 3 and are optional to inventory under LGOP because the vehicles are owned and operated privately by the employees. However, LGOP encourages reporting these emissions because local governments can influence how their employees commute to work through incentives and commuting programs. For this reason, employee commute emissions were included in this report as an area where Richmond could achieve reductions in greenhouse gases.

To calculate emissions, Richmond administered a survey to all of its employees regarding their current commute patterns and preferences. ICLEI then extrapolated the results of the survey to represent emissions from all employees. Even though employees were asked about their current (2009) commuting patterns, these results are still relevant to the 2008 emissions inventory. Of the 678 employees who completed the survey, 83 percent said that they worked for the city in 2008. In addition, 92 percent of respondents who worked for the city in 2008 said their commuting patterns have not changed over the last few years. See Appendix C for a detailed description of the survey and methods used to calculate emissions associated with employee commutes.

[24] The tons of solid waste generated were only available on a fiscal year basis; the 88,004 tons of waste generated is the average of waste tonnages for fiscal years 2007-2008 and 2008-2009.

Based on 2009 commuting data, employees who commute to work in single occupancy vehicles and in carpools emit 29,087 metric tons of CO_2e[25] annually, comprising 17 percent of overall 2008 government emissions (see Figure 3.1). Employees commuting in single occupancy vehicles to and from their jobs at the city of Richmond emit an estimated 28,550 metric tons of CO_2e annually, while emissions from employees carpooling to work produce 544 metric tons of CO_2e annually. Table 3.10 shows estimated annual emissions and vehicle miles traveled for all Richmond employees who commute by driving alone and carpooling.

Table 3.10: Emissions from Employee Commutes

Transportation Mode	Greenhouse Gas Emissions (metric tons CO_2e)*	Estimated Vehicle Miles Traveled to Work	Percent of employees Commuting to Work 1+ days/wk
Drive Alone	28,550	30,338,552	84%
Carpool	544	1,074,227	9%
Total	**29,087**	**31,412,779**	**-**

* Does not include 13 metric tons of CO_2 emitted from the biodiesel component of the B20 biodiesel blend.

3.4.8.1 Employee Commute Indicators

In addition to estimating greenhouse gas emissions from employee single occupancy vehicle and carpooling commutes, ICLEI examined other policy-relevant information that was extracted from the employee commute survey. It is hoped that this information will assist city staff in developing the most effective policies to reduce emissions from employee commutes.

Commute Modes: In 2009, the majority (84 percent) of respondents said they commute to work in single occupancy vehicles one day or more per week. Nine percent of employees reported that they carpool to work at least once a week, while 28 percent of all respondents use some form of alternative transportation (bicycle, walking, telecommuting, or public transit) at least once a week. Public transit was the most used form of alternative transportation (23 percent of total respondents). Only 5 percent of survey respondents said that they walk, bike, or telecommute to work one day or more a week.

Commute Time and Costs: Table 3.11 shows the median time, cost, and distance of Richmond's employees' commutes. In addition to reducing the city's greenhouse gas emissions, commuting alternatives may reduce commuting costs, time spent in traffic, and increase overall employee satisfaction.

[25] This emissions total represents only the carbon dioxide emissions from employees driving alone and carpooling to work. It does not included methane or nitrous oxide emissions; however, methane and nitrous oxide are estimated to comprise only a small amount of overall vehicle emissions.

Table 3.11: Distance and Time to Work and Cost of Employee Commutes

	Median Time to Work (daily minutes)	Median Cost of Commute ($/week)	Median Distance To Work (daily miles)
Responding Employees	20	$21	12

3.4.9 Missing Data Sources

Data were not available to calculate emissions from all sources suggested by LGOP and ICLEI for this inventory. Table 3.12 summarizes the missing data and the emissions source and activity data needed to calculate emissions. Table 3.12 also indicates whether data or data collection systems currently exist within the city of Richmond to supply the missing activity data, and provides suggested departments to help gather missing data or devise a system for tracking the data.

Emissions from autonomous agencies, ports, and other organizations were excluded from this inventory because these entities did not fall under the city of Richmond's operational control.[26] For more information on what entities and emissions sources fall under Richmond's operational control, see Chapter 3 of the Local Government Operations Protocol (LGOP).

[26] Electricity and natural gas data for the Port of Richmond and Richmond Public Schools are available from Susan Mallory, Dominion Virginia Power (electricity) and from Brenda Pomfrey, Utility Financial Analyst, Department of Public Utilities (natural gas). Fuel oil, gasoline, diesel, and propane consumption for the Port of Richmond is available from David McNeel, Executive Director, Port of Richmond.

Table 3.12: 2008 Richmond Emissions Sources Missing from Inventory

Emissions Source	Activity Data Needed	Data Currently Available	Potential Future Data Source
Streetlight electricity losses during distribution	kWh of electricity lost	No	Department of Public Utilities
SF_6 leaked from electricity distribution	See LGOP Section 8.4.1	No	Department of Public Utilities
Natural gas leaked during distribution	Amount leaked CCF, therms, etc.	No	Department of Public Utilities
Refrigerants and fire suppressants leaked (buildings and facilities)	See LGOP Section 6.6	No	Department of General Services
Leased Facilities	Electricity, natural gas, fuel oil, and other energy sources	No	Department of Economic and Community Development
Wastewater treatment process N_2O emissions from industry	kg of total nitrogen/day discharged by industry into the plant	No	Department of Public Utilities
Fuel Oil Consumption[27]	Gallons of fuel oil used for heating or in back-up generators for all facilities except water treatment plant and water pumps	No	Department of General Services
Closed Landfills	Landfill gas collected -OR-historical waste deposition data	No	Department of Public Works
Non-Highway Vehicle Fleet N_2O and CH_4 Emissions	Gallons of each fuel type consumed by vehicle type	Yes	Department of General Services

[27] City Hall consumed fuel oil in back up generators in 2008 after a boiler broke. It is unknown whether fuel oil was used in any other locations.

Section Four: Community Inventory Results

Community Inventory Results

4.1 Community Inventory Summary

In 2008, activities and operations taking place within Richmond's jurisdictional boundaries resulted in approximately 2,987,651 metric tons of CO_2e emissions. This number includes all Scope 1 emissions from the on-site combustion of fuels in the residential and commercial / industrial sectors, the combustion of gasoline and diesel in vehicles traveling on local roads and state highways within Richmond, the treatment of wastewater at the city of Richmond wastewater treatment plant, and the consumption of electricity that is produced within the geographical boundaries of the city. Additionally, this number includes all Scope 2 emissions associated with electricity generated outside of Richmond but consumed within the community's boundaries and all Scope 3 emissions from waste generated by the Richmond community.[28]

4.1.1 Summary by Scope

As shown in Table 4.1, Scope 1 sources produced the largest amount of community greenhouse gas emissions in 2008, totaling 2,507,743 metric tons of CO_2e. Scope 2 emissions were the second largest amount: 432,135 and Scope 3 emissions constituted the smallest amount: 47,773 metric tons of CO_2e.

Table 4.1: Community Emissions Summary by Scope

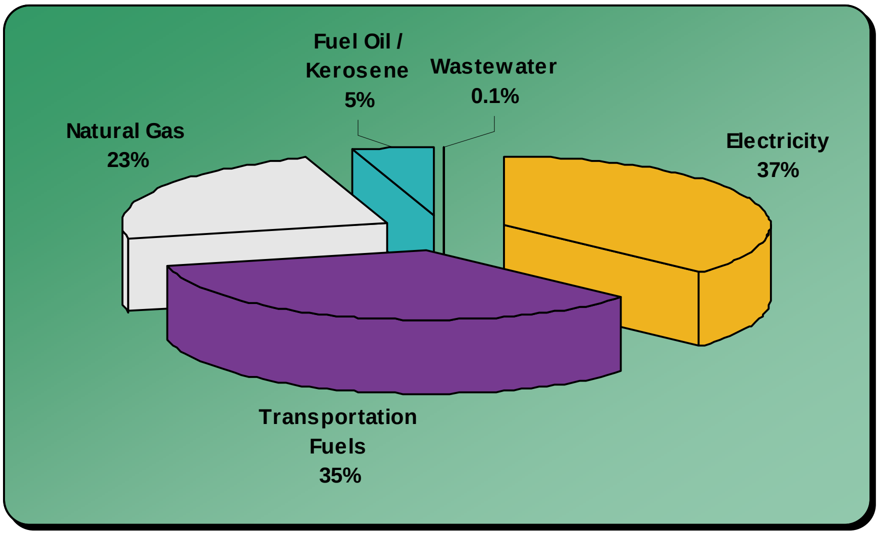
Activity	Metric tons of CO_2e
Scope 1	
Electricity	926,996
Transportation Fuels	868,372
Natural Gas	585,985
Fuel Oil/Kerosene	124,031
Wastewater	2,359
TOTAL	*2,507,743*
Scope 2	
Electricity	432,135
Scope 3	
Community-Generated Solid Waste	47,773
Total	**2,987,651**

[28] For a detailed description of scopes, please see Section 2: Methodology

Scope 1 Emissions

In 2008, Richmond's community produced 2,507,743 metric tons CO_2e of Scope 1 greenhouse gas emissions. As seen in Figure 4.1, over a third of Scope 1 emissions (37 percent) resulted from electricity that was provided by generation facilities located within the city of Richmond.[29] Gasoline and diesel consumed by vehicles traveling on roadways located within Richmond were the second largest source of Scope 1 emissions (35 percent). The third largest source of Scope 1 emissions was natural gas, constituting 23 percent of Scope 1 emissions. Fuel oil and kerosene usage accounted for 5 percent of Scope 1 emissions and wastewater treatment added less than 1 percent to community emissions.

Figure 4.1: Community Scope 1 Emissions



Scope 2 Emissions

In 2008, there were two power generation facilities located within the city of Richmond: Dominion Bellemeade Power Station or the Spruance Genco LLC power generation facility. The net power generated by these two power stations was 1,790,321 MWh,[30] or 68 percent of all electricity consumed within the city of Richmond. ICLEI assumed that all of the electricity generated at these two facilities was consumed within the Richmond community. However, the remaining 32 percent of electricity consumed within the city of Richmond was imported from generation facilities located outside the city's geographic boundary. This imported electricity is considered Scope 2 and resulted in 432,135 MT CO_2e in 2008.

[29] It was assumed that all electricity generated within the city of Richmond at the Dominion Bellemeade Power Station and the Spruance Genco LLC power generation facility was consumed within the city of Richmond.
[30] Source: Virginia Department of Environmental Quality

Scope 3 Emissions

In 2008, Richmond generated 47,773 metric tons of CO_2e in the form of Scope 3 emissions. All Scope 3 sources included in this report are an estimate of methane emissions that will result from the anaerobic decomposition of solid waste that was generated by the Richmond community during 2008 and was sent to the Charles City County Landfill in Charles City, VA.

Information Item – Electricity Generation

There were two power generation facilities located within the city of Richmond in 2008: Dominion Bellemeade Power Station and Spruance Genco LLC. ICLEI was able to obtain information on the raw fuels used to generate electricity at each of these facilities and was able to use this information to generate an estimate of emissions produced at each location (Figure 4.2 and Table 4.2). Ideally, these emissions should be defined as Scope 1 emissions because they are occurring within the geographical boundaries of the city. However, no information was available on what percentage of electricity from each facility was consumed in the residential or commercial/industrial sectors.

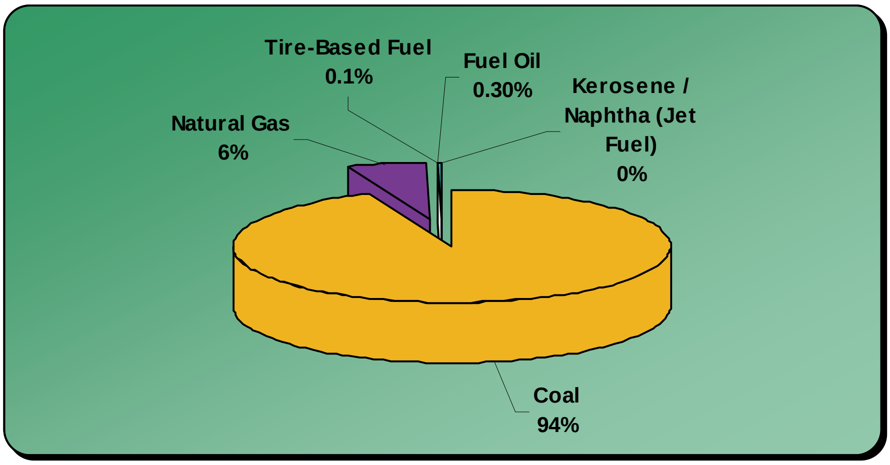
Because emissions could not be organized in a policy relevant manner, a decision was made to report emissions calculated from operating these two facilities, as determined by the Virginia Department of Environmental Quality dataset, as informational items. However, emissions from consumed electricity within the residential and commercial/industrial sectors of Richmond were still captured in the inventory (see Scope 1 Emissions and Scope 2 Emissions sections above) through the use of a regional electricity emissions factor and consumption data provided by Virginia Dominion Power. Since the Virginia Department of Environmental Quality was able to provide ICLEI with the net power generated by the Bellemeade and Spruance Genco LLC facilities (1,790,321 MWh), ICLEI was able to subtract this electricity usage figure from aggregate electricity usage figures provided by Dominion Virginia Power, thereby allowing ICLEI to assess what percentage of electricity was generated at the two facilities located within Richmond (Scope 1 emissions) and what percentage was imported (Scope 2).

The result is that the Richmond community inventory uses regional electricity emissions factors combined with actual electricity usage figures to estimate community-wide electricity emissions. It should be noted that the emissions from the Bellemeade and Spruance Genco LLC facilities are not, nor should they be included in the total emissions figure (2,987,651 metric tons of CO_2e emissions) for the city of Richmond's community inventory as their inclusion would lead to double counting.

Table 4.2: 2008 Energy Consumption and Carbon Dioxide Emissions from Richmond Power Generation Facilities

Facility	Natural Gas (million cubic feet)	Fuel Oil (gallons)	Coal (tons)	Tire-Based Fuel	Kerosene / Naphtha (Jet Fuel) (million Btu)	Carbon Dioxide Emissions ($MTCO_2$)*
Dominion - Bellemeade Power Station	2,090	601,741	-	-	-	120,439
Spruance Genco LLC	-	-	855,484	15,752	62	1,914,964
TOTALS	**2,090**	**601,741**	**855,484**	**15,752**	**62**	**2,035,403**

Figure 4.2: 2008 CO_2 Emissions from Richmond Power Generation Facilities by Source



4.1.2 Summary by Sector

By better understanding the relative scale of emissions from each primary sector, Richmond can more effectively focus on strategies to achieve the greatest emissions reductions. For this reason, an analysis of emissions by sector is included in this report. The five sectors included in this inventory are:

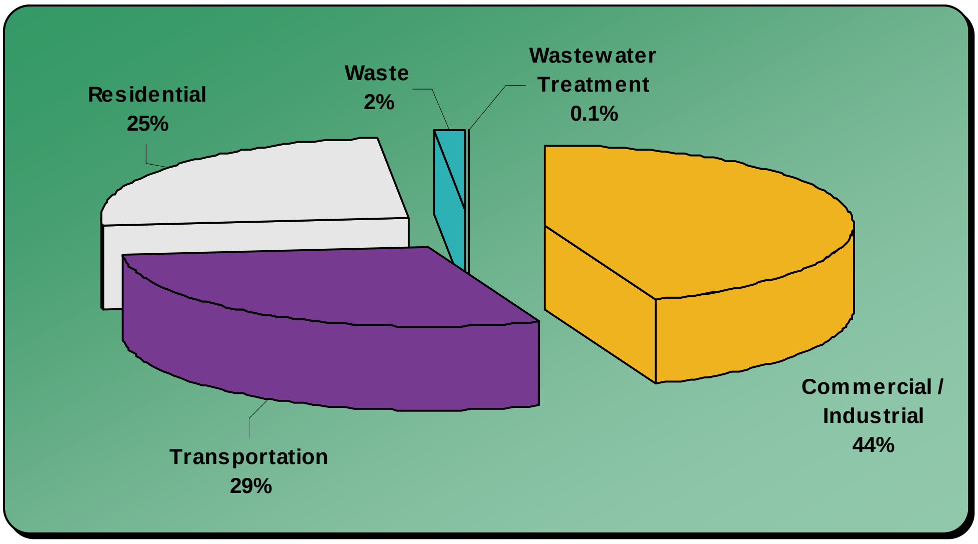
1. **Residential**
2. **Commercial / Industrial**
3. **Transportation**
4. **Solid Waste**
5. **Wastewater**

As shown in Table 4.3 and Figure 4.3, the energy consumption in the commercial / industrial sector was the largest emissions source (44 percent) in 2008 producing 1,320,995 metric tons of CO_2e. Emissions from the transportation sector produced the second highest quantity of greenhouse gas emissions, resulting in 29 percent of community emissions, or 868,373 metric tons of CO_2e. Emissions from the energy use in the residential sector generated 748,191 metric tons of CO_2e or 25 percent of community emissions. The remainder of emissions came from solid waste disposal (2 percent) and wastewater treatment (0.1 percent).

Table 4.3: Community Emissions Summary by Sector

Sector	Greenhouse Gas Emissions (metric tons CO2e)
Commercial / Industrial	1,320,995
Transportation	868,373
Residential	748,191
Waste	47,773
Wastewater	2,359
TOTAL	**2,987,651**

Figure 4.3: Community Emissions Summary by Sector



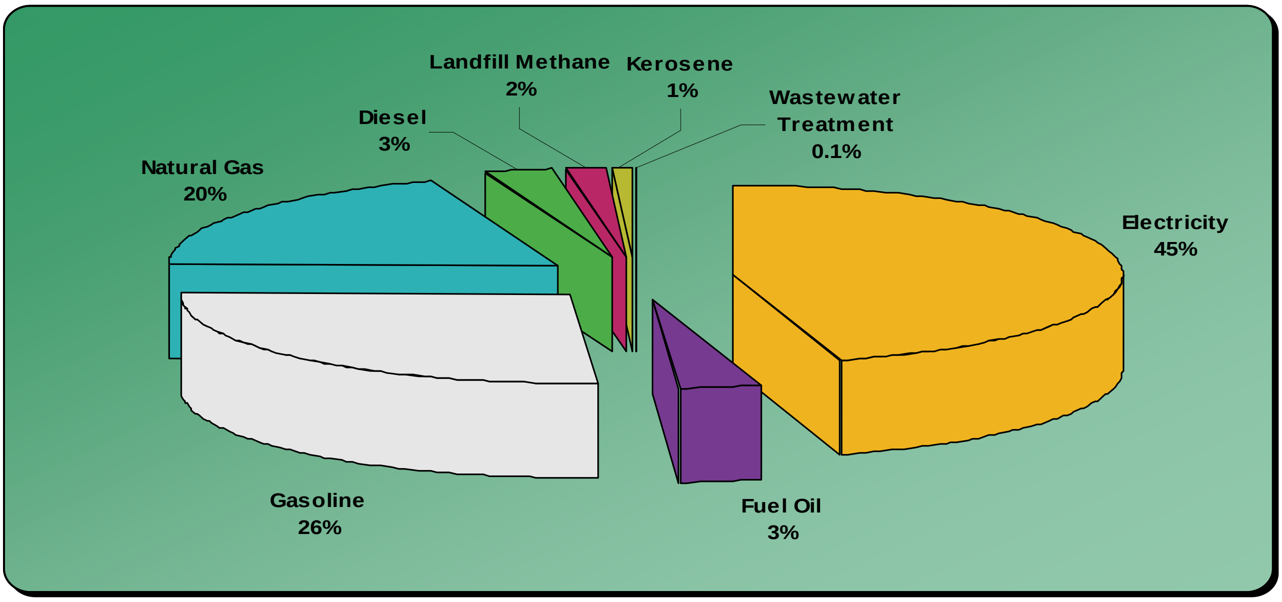
4.1.3 Summary by Source

When considering how to reduce emissions, it is also helpful to look at the specific raw resources and materials (gasoline, diesel, electricity, natural gas, and solid waste) whose use and generation directly result in the release of greenhouse gases. Table 4.4 and Figure 4.4 summarize Richmond's 2008 greenhouse gas emissions by fuel type or material, based upon the total community emissions.

Table 4.4: Community Emissions Summary by Source

Source	Greenhouse Gas Emissions (metric tons CO_2e)
Electricity	1,359,131
Fuel Oil	100,417
Gasoline	785,879
Natural Gas	585,985
Diesel	82,493
Landfill Methane	47,773
Kerosene	23,614
Wastewater Treatment	2,359
TOTAL	**2,987,651**

Figure 4.4: Community Emissions Summary by Source



4.2 Community Inventory by Sector

This section explores community activities and emissions by taking a detailed look at each primary sector. As listed above, the sectors included in the community emissions analysis are:

- Residential

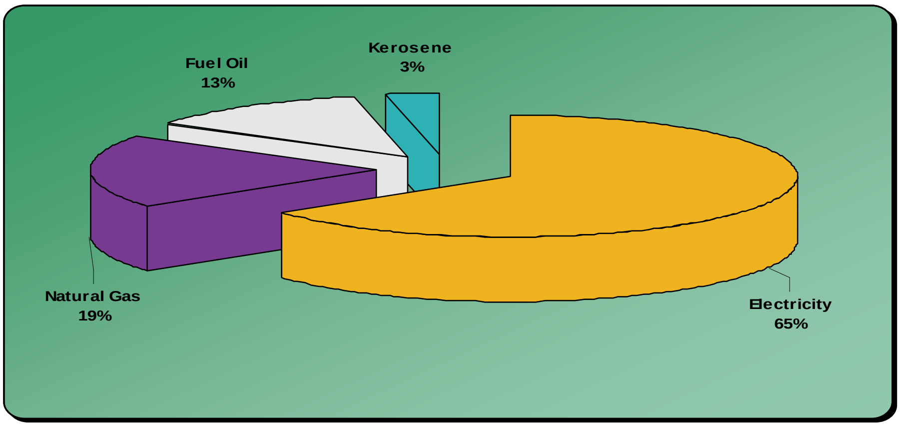
- Commercial / Industrial
- Transportation
- Waste Generation
- Wastewater Treatment

4.2.1 Residential Sector

Energy consumption associated with Richmond homes produced 748,191 metric tons of greenhouse gas emissions in 2008 (25 percent of total community emissions). All residential sector emissions are the result of electricity consumption and the on-site combustion of natural gas, fuel oil, and kerosene. Emissions from lawn equipment, wood-fired stoves, transportation and waste generation are **not** included in the total for the residential sector.

In 2008, Richmond's entire residential sector consumed 936,390,636 kWh of electricity, 2,652,573 thousand cubic feet of natural gas, 9,266,105 gallons of fuel oil, and 2,405,448 gallons of kerosene. As shown in Figure 4.5, 65 percent of total residential emissions were the result of electricity consumption, and 19 percent were the result of natural gas consumption. Fuel oil and kerosene usage made up 13 and 3 percent, respectively. Natural gas is typically used in residences as a fuel for home heating, water heating and cooking, and electricity is generally used for lighting, heating, and to power appliances. Both kerosene and fuel oil are used for home heating.

Figure 4.5: Residential Emissions by Source

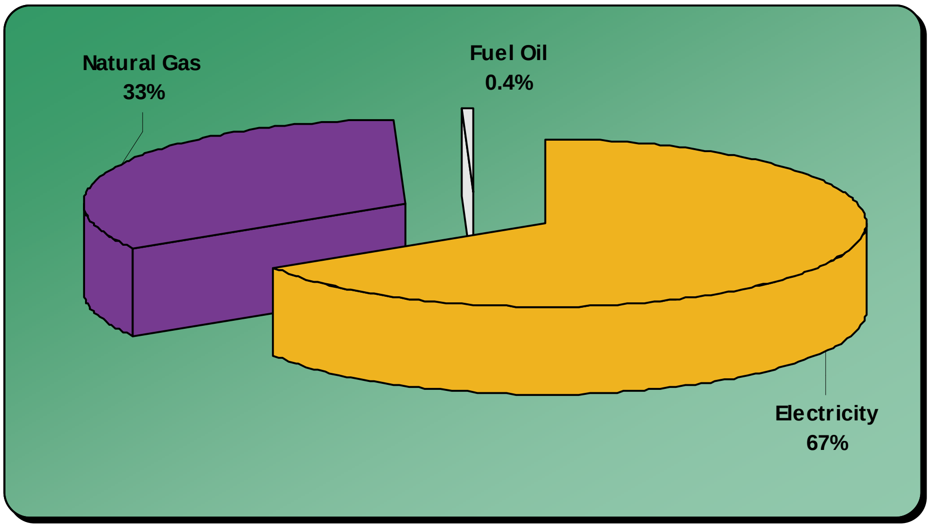


4.2.2 Commercial / Industrial Sector

The commercial / industrial sector includes emissions from the operations of businesses as well as public buildings and facilities. For example, the majority of buildings and facilities included in the government operations inventory are also included as a subset of the commercial / industrial sector. In 2008, buildings and facilities within the commercial / industrial sector produced 1,320,955 metric tons of greenhouse gas emissions (44 percent of total community emissions). All commercial / industrial sector emissions included in this inventory are the result of electricity consumption and the on-site combustion of natural gas and fuel oil. It is important to note that emissions from off-road equipment, transportation, waste generation, stationary combustion other than natural gas, and other industrial processes are **not** included in the total for this sector.

As shown in Figure 4.6, 67 percent of total commercial / industrial emissions were the result of electricity use, and 33 percent were the result of natural gas consumption. Less than one percent of emissions were due to fuel oil usage. Natural gas and fuel oil are typically used in the commercial / industrial sector to heat buildings, fire boilers, and generate electricity. Electricity is generally used for lighting, heating, and to power appliances and equipment.

Figure 4.6: Commercial / Industrial Emissions by Source



4.2.3 Transportation Sector

Transportation within Richmond's geographical boundary contributed 29 percent of community wide greenhouse gas emissions in 2008, or 868,373 metric tons of CO_2e. The transportation sector was the second largest source of community emissions.

As shown in Table 4.5, 65 percent of transportation sector emissions came from state routes, with the remaining 35 percent originating from interstate[31] roads. Of state route transportation activity, travel on primary[32] roads constituted 33 percent of emissions, and 32 percent came from travel on secondary[33] roads within the jurisdictional boundaries of Richmond. An estimated 91 percent of transportation emissions were due to gasoline consumption with the remaining 9 percent coming from diesel use.

Table 4.5: Transportation Emissions by Type

Source	Greenhouse Gas Emissions (metric tons CO_2e)	Share of Total Transportation Emissions
State Routes		
Primary	286,562	33%
Secondary	277,880	32%
State Routes Subtotal	***564,442***	***65%***
Interstate	303,931	35%
TOTAL	**868,373**	**100%**

31 "Interstate' includes routes in the Interstate System.
32 "Primary' includes routes designated as 'US', 'SR' (Virginia State Route) and Frontage Roads.
33 'Secondary' includes routes in the VDOT secondary system, (unnumbered) routes maintained by Arlington and Henrico Counties, and unnumbered routes maintained by cities and towns.

Please see Appendix E for more detail on methods and emissions factors used in calculating emissions from the transportation sector.

4.2.4 Solid Waste Sector

As noted in Figure 4.3, the solid waste sector constituted 2 percent of total emissions for the Richmond community in 2008. Emissions from the solid waste sector are an estimate of methane generation from the decomposition of municipal solid waste sent to landfills in the base year (2008). These emissions are considered Scope 3 because they are not generated in the base year, but will result from the decomposition of 2008 waste over the full 100+ year cycle of its decomposition. Please see Table 4.6 for a summary of emissions by source that were generated in 2008.

Table 4.6: Waste Emissions Sources

Source	Greenhouse Gas Emissions (metric tons CO_2e)	Percent of Total Waste Emissions
Paper Products	36,528	77%
Food Waste	7,073	15%
Plant Debris	3,084	6%
Wood / Textiles	1,088	2%
TOTAL	**47,773**	**100%**

There are also seven closed landfills located in Richmond that are operated by the city. Even though these landfills are closed, they still generate methane from waste decomposing already in the landfill. However, data were unavailable to calculate emissions from these sources.

4.2.5 Wastewater Sector

Wastewater coming from homes and businesses is rich in organic matter and has a high concentration of nitrogen and carbon (along with other organic elements). As wastewater is collected, treated, and discharged, chemical processes in aerobic and anaerobic conditions lead to the creation and emission of two greenhouse gases: methane and nitrous oxide. Results from the wastewater sector are an estimate of methane and nitrous oxide emissions generated in the process of wastewater treatment.

It was assumed that all wastewater treatment occurring inside Richmond's geographical boundary occurred at the wastewater treatment facilities operated by the city of Richmond, which encompass a centralized wastewater treatment facility and a series of 100 septic systems. The centralized treatment plant has an anaerobic digester to treat biosolids removed during the wastewater treatment process, and also uses both nitrification and denitrification as a form of tertiary treatment.

The wastewater sector contributed 2,359 metric tons of greenhouse gas emissions, constituting 0.1 percent of total emissions for the Richmond community in 2008. Table 4.7 breaks down wastewater treatment emissions by source. It should be noted that industrial contributions of nitrogen were not included in the process emissions calculations for Richmond's centralized wastewater treatment plant. This is because the wastewater treatment plant does not test for the amount of nitrogen added to the system by industrial water.

Table 4.7: Wastewater Treatment Emissions by Source

Source	Type of Greenhouse Gas	Greenhouse Gas Emissions (metric tons CO_2e)	Percent of Wastewater Emissions
Treated Effluent Released to Environment	N_2O	1,617	69%
Process Emissions from Wastewater Treatment Plant (uses Nitrificaton/Denitrification)*	N_2O	467	20%
Incomplete Combustion of Digester Gas	CH_4	244	10%
Fugitive Emissions from Septic Systems	CH_4	31	1%
TOTAL		**2,359**	**100%**

*Does not include emissions from the nitrogen contributions of industry. The wastewater treatment plant does treat wastewater from industry, but does not test for the amount of nitrogen added to the system by industrial water.

4.3 Community Emissions Forecast

To illustrate the potential emissions growth based on projected trends in energy use, driving habits, job growth, and population growth from the baseline year going forward, this report includes an emissions forecast for the year 2020. Under a business-as-usual scenario, Richmond's emissions will grow by approximately 6.24 percent by the year 2020, growing from 2,987,651 metric tons CO_2e in 2008 to 3,174,193 metric tons of CO_2e in 2020. Figure 4.7 and Table 4.8 show the results of the forecast. Various reports and projections were used to create the emissions forecast as discussed in the following sections.

Figure 4.7: Community Emissions Forecast for 2020

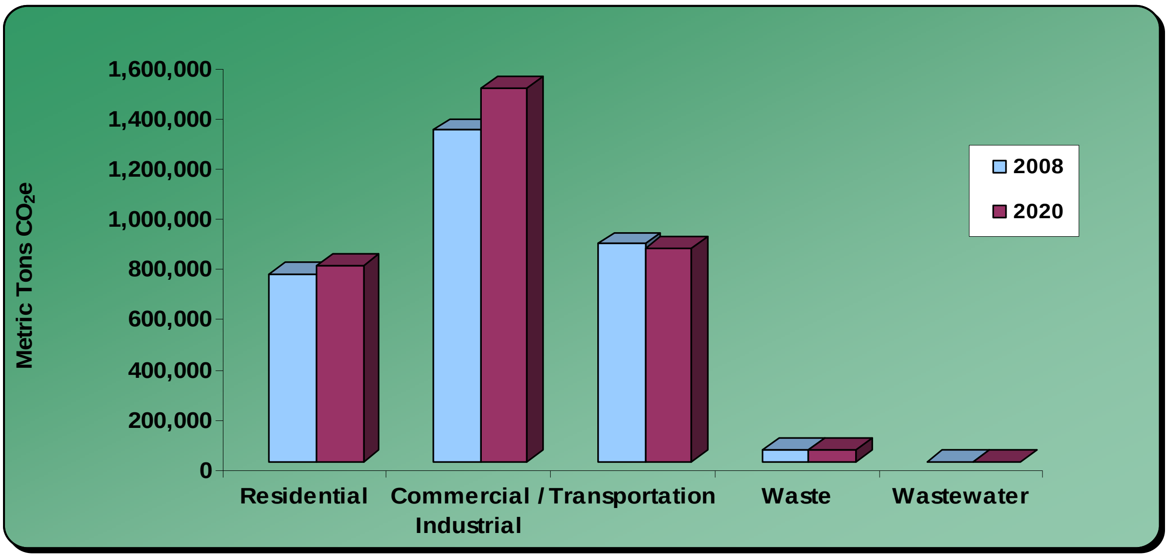


Table 4.8: Community Emissions Growth Forecast by Sector

Sector	2008 (metric tons CO_{2e})	2020 (metric tons CO_2e)	Annual Energy Growth Rate*	Percent Change from 2008 to 2020
Residential	748,191	784,072	varies by fuel type	4.58%
Commercial / Industrial	1,320,955	1,488,485	1%	12.68%
Transportation	868,372	852,102	-0.16%	-1.87%
Waste	47,773	47,203	-0.10%	-1.19%
Wastewater	2,359	2,331	-0.10%	-1.19%
ALL SECTORS	**2,987,651**	**3,174,193**	**--**	**6.24%**

*Residential – Energy Information Administration, *Supplemental Tables to Annual Energy Outlook 2010*. Regional Energy Consumption and Prices by Sector Table 5. 2009

*Commercial / Industrial - Energy Information Administration, Annual Energy Outlook 2009 with Projections to 2030. 2009

*Transportation - Energy Information Administration, Annual Energy Outlook 2009 with Projections to 2030. 2009 and CACP Forecast Builder tool default vehicle fuel efficiency growth rates

*Waste and Wastewater - Richmond Regional Planning District Commission, Population Projections for the PDC & the Richmond-Petersburg MSA (2003).

4.3.1 Residential Forecast

For the residential sector, the average annual increase in energy consumption was based on Energy Information Administration (EIA)[34] projected increases in fuel consumption for the South Atlantic residential sector. The EIA estimated that annual average residential electricity consumption would increase approximately 1 percent from 2008 through 2035. Over this same time period, the EIA predicted annual natural gas consumption would increase approximately 0.4 percent, and annual fuel oil consumption and kerosene consumption would both decrease (2.4 percent and 3 percent, respectively). As shown in Table 4.8, emissions from the residential sector increases over 4.58 percent from 2008 (748,191 metric tons CO_{2e}) to 2020 (784,072 metric tons CO_{2e}).

4.3.2 Commercial / Industrial Forecast

Using data from the Energy Information Administration, it is estimated that the average annual growth in energy use in the commercial/industrial sector between 2008 and 2020 will be 1 percent annually.[35] As shown in Table 4.8, under a business-as-usual scenario, the commercial/industrial sector will experience almost 13 percent growth in emissions between 2008 levels (1,320,955 metric tons CO_{2e}) and 2020 levels (1,488,485 metric tons CO_{2e}).

4.3.3 Transportation Forecast

Growth in transportation emissions over the forecast period are closely related to planned transportation infrastructure investments and the associated vehicle activity, as measured in vehicle miles traveled (VMT). Long-term transportation infrastructure is planned through the Virginia Department of Transportation. Energy use for transportation is estimated to grow by 0.5 percent per year from 2008 to 2030[36] with all of the growth resulting from increased fuel use for freight trucks and air transportation. However, efficiency improvements in light duty and passenger vehicles, which make up the largest segment of energy use in the transportation sector and rising energy prices are projected to offset increases in the number of vehicles sold and miles traveled.[37] The overall decline in emissions in the transportation sector between 2008 and 2020 is attributable to these factors. Under a business-as-usual scenario, the transportation sector will see a 1.87 percent decline in emissions between 2008 levels (868,373 metric tons of CO_{2e}) and 2020 levels (852,102 metric tons of CO_{2e}) as detailed in Table 4.8.

[34] Energy Information Administration, Supplemental Tables to the Annual Energy Outlook 2010.Regional Energy Consumption and Prices by Sector Table 5. 2009
[35] Energy Information Administration, *Annual Energy Outlook 2009 with Projections to 2030*. 2009
[36] Energy Information Administration, *Annual Energy Outlook 2009 with Projections to 2030*. 2009
[37] Default vehicle fuel efficiency growth rates in the CACP 2009 Forecast Builder tool

4.3.4 Solid Waste and Wastewater Forecast

Population is the primary determinate for growth in emissions pertaining to waste and wastewater generation. Therefore, the average annual population growth rate from 2008 to 2020 (-0.1 percent[38]) was used to estimate future emissions from waste disposal and wastewater treatment. As shown in Table 4.8, emissions from wastewater are estimated to go down 1.19 percent between 2008 (2,359 metric tons CO_{2e}) and 2020 (2,331 metric tons CO_{2e}) as a result of population decline. Emissions from solid waste are also projected to decrease between 2008 (47,773 metric tons CO_{2e}) and 2020 (47,203 metric tons CO_{2e}).

[38] Richmond Regional Planning District Commission, Population Projections for the PDC & the Richmond-Petersburg MSA (2003).

Section Five: Conclusion

Conclusion

By completing a greenhouse gas emissions inventory and undertaking activities such as participating in the Virginia Municipal League's Go Green Initiative and other sustainability programs, the city of Richmond is taking crucial steps toward reducing its impacts on the environment. Staff and policymakers have chosen to take a leadership role in addressing climate change. This leadership will allow the city to make important decisions to create and implement innovative approaches to reduce its emissions thereby reducing energy use and creating cost savings in order to promote its vision for a more sustainable future. This conclusion discusses how to utilize this inventory as a baseline for setting emissions targets and suggests steps for Richmond to move forward to reduce emissions from its internal operations.

5.1 Setting Emissions Reduction Targets

This inventory provides an emissions baseline that Richmond can use to inform Milestone Two of ICLEI's Five-Milestone process—setting emissions reduction targets for its municipal operations and for the community as a whole. The greenhouse gas emissions reduction target is a goal to reduce emissions in government operations and the community as a whole to a certain percentage below base year levels, by a chosen planning horizon year. An example target might be a 30 percent reduction in emissions below 2008 levels by 2020. A target provides an objective toward which to strive and against which to measure progress. It allows a local government to quantify its commitment to fighting climate change—demonstrating that the jurisdiction is serious about its commitment and systematic in its approach.

In selecting a target, it is important to strike a balance between scientific necessity, ambition, and what is realistically achievable. Richmond will want to give itself enough time to implement chosen emissions reduction measures—but note that the farther out the target year is, the more that the city should pledge to reduce. ICLEI recommends that regardless of Richmond's chosen long-term emissions reduction target (e.g., 15-year, 40-year), it should establish interim targets for every three to five-year period. Near-term targets facilitate additional support and accountability, and help to ensure continued momentum around Richmond's local climate protection efforts. To monitor the effectiveness of its programs, Richmond should plan to re-inventory its emissions on a regular basis. See Appendix F for more information on how to re-inventory the city of Richmond's emissions.

5.1.1 State of Virginia Target and Guidance

The Virginia Energy Plan, released in September 2007, set a goal for the Commonwealth to reduce greenhouse gas emissions from 2005 levels by 30 percent by 2025. The reduction in emissions will be partially achieved through energy conservation and renewable energy actions listed in the energy plan.

5.1.2 Proposed Emissions Reduction Target for Richmond

The city will create a comprehensive Sustainability Plan in 2011. This plan will address the three aspects of sustainability: Planet, People and Prosperity. ICLEI recommends that the city determine an emissions reduction target and develop strategies to meet that target under the Planet portion of the Sustainability Plan. Once the city establishes an emissions reduction target, it can begin working to reduce emissions in Richmond sooner, rather than later.

5.1.3 Department Targets

If possible, once the city determines its emissions reduction target ICLEI recommends that Richmond consider specific targets for each department that generates emissions within its operations. This allows city staff to do a more in-depth analysis of what is achievable in each sector in the near, mid- and long-term, and also encourages each department head to consider their department's impact on the climate and institute a climate-conscious culture in their operations.

ICLEI was unable to analyze emissions results by department for the city of Richmond. Even though energy consumption data were categorized by "department," these department labels were for billing purposes only and did not reflect the actual energy consumed within each department. To complete department-specific analyses, Richmond would need to identify the departments responsible for emissions occurring at the facility level.

5.2 Creating an Emissions Reduction Strategy

This inventory identifies the major sources of emissions from Richmond's operations and the community, thereby indicating where policymakers will need to target emissions reduction activities if they are to make significant progress toward adopted targets. For example, since buildings and facilities were a major source of emissions from Richmond's governmental operations, it is possible that the city could meet near-term targets simply by implementing a few major actions within this sector. In addition, medium-term targets could be met by focusing emissions reduction actions on the employee commute and vehicle fleet sectors.

Given the results of the inventory, ICLEI recommends that the city of Richmond focus on the following tasks in order to significantly reduce emissions from its government operations:

- Install energy efficient equipment in city buildings and facilities;
- Perform energy audits and complete energy efficiency and weatherization retrofits in existing city facilities and in residential and commercial buildings;
- Provide city employees with incentives to increase the use of alternative modes of working and transportation such as telecommuting, bicycling, public transportation, and vanpooling;
- Replace streetlights with more energy efficient LED or fluorescent induction models;
- Educate employees on fuel-efficient driving practices and convert the fleet to more fuel-efficient or alternative fuel vehicles; and
- Increase energy conservation behavior by educating and motivating employees; instituting facility energy reduction challenges or by giving away green employee awards.

In addition to the types of actions described above, which reduce emissions from government operations, ICLEI recommends developing policies and actions that will help to reduce emissions throughout the entire Richmond community. Examples include:

- Promote growth through redevelopment and infill that maintains or improves the quality of life for existing neighborhoods;
- Adopt local parking standards that encourage reduced single-occupancy vehicle travel;
- Using land use tools such as density bonuses, lower permitting fees, or expedited permitting;
- Establish water conservation guidelines and standards for existing development, new development and city facilities; and
- Provide public education programs on waste prevention, source reduction, recycling, yard waste, wood waste, and hazardous waste.

By implementing these types of strategies, Richmond should be able to reduce its impact upon the global climate while lowering its costs and operating more efficiently. In the process, the city should also be able to improve the quality of its services, stimulate local economic development, and inspire residents and businesses to redouble their own efforts to combat climate change.

Appendices

Appendix A: The Local Government Operations Protocol

This inventory follows the standard outlined in the Local Government Operations Protocol (LGOP) which serves as the national standard for quantifying and reporting greenhouse emissions from local government operations. This inventory is among the first to use LGOP, representing a strong step toward standardizing how inventories are conducted and reported. In order to meet the ICLEI Comprehensive Reporting Standard, as well as the California Climate Action Registry (CCAR) reporting standard, an inventory must include all emissions sources specified by LGOP. Of these sources, 95 percent must be quantified using the recommended methods in LGOP; no more than 5 percent of emissions may be calculated using alternative methods to stay within the significance threshold. Richmond was unable to quantify 100 percent of its 2008 emissions due to missing data sources.[39] Section 3.4.9 of this report discusses the emissions sources that were not included in this inventory due to a lack of data. Of the emissions sources included in the inventory, only 0.13 percent[40] were calculated using alternative methodologies.

A.1 Local Government Operations Protocol

A.1.1 Background

In 2008, ICLEI, the California Air Resources Board, and the California Climate Action Registry (CCAR) released the LGOP to serve as a U.S. supplement to the International Emissions Analysis Protocol. The purpose of LGOP is to provide the principles, approach, methodology, and procedures needed to develop a local government operations greenhouse gas emissions inventory. It leads participants through the process of accurately quantifying and reporting emissions, including providing calculation methodologies and reporting guidance. LGOP guidance is divided into three main parts: identifying emissions to be included in the inventory, quantifying emissions using best available estimation methods, and reporting emissions.

The overarching goal of LGOP is to allow local governments to develop emissions inventories using standards that are consistent, comparable, transparent, and recognized nationally, ultimately enabling the measurement of

[39] See Section 3.4.9 for more information on data sources missing from the inventory.
[40] The 0.13 percent represents leaked refrigerants from the city’s vehicle fleet.

emissions over time. LGOP adopted five overarching accounting and reporting principles toward this end: relevance, completeness, consistency, transparency and accuracy. Methodologies that did not adhere to these principles were either left out of LGOP or included as Scope 3 emissions. LGOP was created solely to standardize how emissions inventories are conducted and reported; as such it represents a currently accepted standard for inventorying emissions but does not contain any legislative or program-specific requirements. Program-specific requirements, such as ICLEI's Milestones, are addressed in LGOP but should not be confused with LGOP itself.

Also, while LGOP standardizes inventories from government operations, it does not seek to be a wholly accurate inventory of all emissions sources, as certain sources are currently excluded or are otherwise impossible to accurately estimate. This and all emissions inventories therefore represent a best estimate of emissions using best available data and calculation methodologies; it does not provide a complete picture of all emissions resulting from Richmond's operations, and emissions estimates are subject to change as better data and calculation methodologies become available in the future.

A.1.2 Organizational Boundaries

Setting an organizational boundary for greenhouse gas emissions accounting and reporting is an important first step in the inventory process. The organizational boundary for the inventory determines which aspects of operations are included in the emissions inventory, and which are not. Under LGOP, two control approaches are used for reporting emissions: operational control or financial control. A local government has operational control over an operation if it has full authority to introduce and implement its operating policies at the operation. A local government has financial control if the operation is fully consolidated in its financial accounts. If a local government has joint control over an operation, the contractual agreement will have to be examined to see who has authority over operating policies and implementation, and thus the responsibility to report emissions under operational control.[41] Local governments must choose which approach is the most applicable and apply this approach consistently throughout the inventory.

While both control approaches are acceptable, there may be some instances in which the choice may determine whether a source falls inside or outside of a local government's boundary. LGOP strongly encourages local governments to utilize operational control as the organizational boundary for a government operations emissions inventory. Operational control is believed to most accurately represent the emissions sources that local governments can most directly influence, and this boundary is consistent with other environmental and air quality reporting program requirements. For this reason, this inventory was conducted according to the operational control framework.

[41] Please see the Local Government Operations Protocol for more detail on defining your organizational boundary: http://www.icleiusa.org/programs/climate/ghg-protocol

A.1.3 Types of Emissions

The greenhouse gases inventoried in this report are described in Section 2.1. As outlined in the LGOP, emissions from each of the greenhouse gases can come in a number of forms:

Stationary or mobile combustion: Emissions resulting from on-site combustion of fuels (natural gas, diesel, gasoline, etc.) to generate heat, electricity, or to power vehicles and mobile equipment.

Purchased electricity: Emissions produced by the generation of power from utilities outside of the jurisdiction.

Fugitive emissions: Emissions that result from the unintentional release of greenhouse gases into the atmosphere (e.g., leaked refrigerants, methane from waste decomposition, etc.).

Process emissions: Emissions from physical or chemical processing of a material (e.g., wastewater treatment).

A.1.4 Quantifying Emissions

Emissions can be quantified two ways:

Measurement-based methodologies refer to the direct measurement of greenhouse gas emissions (from a monitoring system) emitted from a flue of a power plant, wastewater treatment plant, landfill, or industrial facility. This methodology is not generally available for most types of emissions and will only apply to a few local governments that have these monitoring systems.

The majority of the emissions recorded in the inventory can be and will be estimated using **calculation-based methodologies** to calculate their emissions using activity data and emission factors. To calculate emissions, the equation below is used:

Activity Data x Emission Factor = Emissions

Activity data refer to the relevant measurement of energy use or other greenhouse gas–generating processes such as fuel consumption by fuel type, metered annual energy consumption, and annual vehicle mileage by vehicle type. Emissions factors are calculated ratios relating emissions to a proxy measure of activity at an emissions source (e.g., CO_2 generated/kWh consumed). For a list of common emissions calculations see Table 2.2.

The guidelines in LGOP are meant to provide a common method for local governments to quantify and report greenhouse gas emissions by using comparable activity data and emissions factors. However, LGOP recognizes that local governments differ in how they collect data concerning their operations and that many are not able to meet the data needs of a given estimation method. Therefore, LGOP outlines both “recommended” and “alternative” methods to estimate emissions from a given source. In this system, recommended methods are the preferred method for estimating emissions, as they will result in the most accurate estimate for a given emission source. Alternative methods often require less intensive data collection, but are likely to be less accurate. This approach allows local governments to estimate emissions based on the data currently available to them. It also allows local governments that are unable to meet the recommended methods to begin developing internal systems to collect the data needed to meet these methods.

This inventory has used the recommended activity data and emissions factors wherever possible, using alternative methods where necessary. For details on the methodologies used for each sector, see Appendix B.

A.1.5 Reporting Emissions

A.1.5.1 Significance Thresholds

Within any local government's own operations there will be emission sources that fall within Scope 1 and Scope 2 that are minimal in magnitude and difficult to accurately measure. Within the context of local government operations, emissions from leaked refrigerants and backup generators may be common sources of these types of emissions. For these less significant emissions sources, LGOP specifies that up to 5 percent of total emissions can be reported using estimation methods not outlined in LGOP.[17]

In this report, the following emissions fell under the significance threshold and were reported using best available methods:

- Scope 1 emissions from vehicle refrigerants

A.1.5.2 Units Used in Reporting Emissions

LGOP requires reporting of individual gas emissions, and this reporting is included in Appendix B. In this narrative report, emissions from all gases released by an emissions source (e.g., stationary combustion of natural gas in facilities) are combined and reported in metric tons of carbon dioxide equivalent (CO_2e). This standard is based on the global warming potential (GWP) of each gas, which is a measure of the amount of warming a greenhouse gas may cause, measured against the amount of warming caused by carbon dioxide. For the GWPs of reported greenhouse gases, see Table 2.1.

A.1.5.3 Information Items

Information items are emissions sources that, for a variety of reasons, are not included as Scope 1, 2, or 3 emissions in the inventory. In order to provide a more complete picture of emissions from Richmond's operations, however, these emissions should be quantified and reported.

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[17] In the context of registering emissions with an independent registry, emissions that fall under the significance threshold are called *de minimis*. This term, however, is not used in LGOP and was not used in this inventory.

In this report, the following emissions are included as information items (emission quantities are reported in Appendix B):

- CO_2 emissions from biodiesl (B20) consumption by the city's vehicle fleet and employees commuting to work

A common emission that is categorized as an information item is carbon dioxide emitted in the combustion of biogenic fuels. Local governments will often burn fuels that are of biogenic origin (wood, landfill gas, organic solid waste, biofuels, etc.) to generate power. Common sources of biogenic emissions are the combustion of landfill gas from landfills or biogas from wastewater treatment plants, as well as the incineration of organic municipal solid waste at incinerators.

Carbon dioxide emissions from the combustion of biogenic fuels are not included in Scope 1 based on established international principles.[42] These principles indicate that biogenic fuels (e.g., ethanol, biodiesel), if left to decompose in the natural environment, would release CO_2 into the atmosphere, where it would then enter back into the natural carbon cycle. Therefore, when wood or another biogenic fuel is combusted, the resulting CO_2 emissions are akin to natural emissions and should therefore not be considered as human activity-generated emissions. The CH_4 and N_2O emissions, however, would not have occurred naturally and are therefore included as Scope 1 emissions.

A.2 Baseline Years

Part of the local government operations emissions inventory process requires selecting a "performance datum" with which to compare current emissions, or a base year. Local governments should examine the range of data they have over time and select a year that has the most accurate and complete data for all key emission sources. It is also preferable to establish a base year several years in the past to be able to account for the emissions benefits of recent actions. A local government's emissions inventory should comprise all greenhouse gas emissions occurring during a selected *calendar* year.

For the city of Richmond, 2008 was chosen as the baseline year, since this year is increasingly becoming the standard for such inventories; the 1990 baseline year is usually difficult for most local governments to meet and would not produce the most accurate inventory.

After setting a base year and conducting an emissions inventory for that year, local governments should make it a practice to complete a comprehensive emissions inventory on a regular basis to compare to the baseline year. ICLEI recommends conducting an emissions inventory at least every five years.

[42] Methane and nitrous oxide emissions from biogenic fuels are considered Scope 1 stationary combustion emissions and are included in the stationary combustion sections for the appropriate facilities.

Appendix B:
LGOP Standard Report

Local Government Operations Standard Inventory Report

1. Local Government Profile

Jurisdiction Name:	City of Richmond
Street Address:	900 East Broad St
City, State, ZIP, Country:	Richmond, VA 23219 USA
Website Address:	http://www.ci.richmond.va.us/
Size (sq. miles):	60
Population:	202,002
General Fund Budget:	630,000,000
Employees (Full Time Equivalent):	4,762
Climate Zone:	4
Annual Heating Degree Days:	3,831
Annual Cooling Degree Days:	1,291
Lead Inventory Contact Name:	Alicia Zatcoff
Title:	Sustainability Manager
Department:	Department of Public Utilities
Email:	alicia.zatcoff@richmondgov.com
Phone Number:	(804) 646 - 3055

Services Provided:

- ☑ Water treatment
- ☑ Water distribution
- ☑ Wastewater treatment
- ☑ Wastewater collection
- ☐ Electric utility
- ☑ Fire Protection
- ☑ Police
- ☐ Mass transit (buses)
- ☐ Mass transit (light rail)
- ☐ Mass transit (ferries)
- ☐ Schools (primary/secondary)
- ☐ Schools (colleges/universities
- ☑ Solid waste collection
- ☐ Solid waste disposal
- ☐ Hospitals
- ☐ Airport
- ☐ Seaport/shipping terminal
- ☐ Marina
- ☐ Stadiums/sports venues
- ☐ Convention center
- ☑ Street lighting and traffic signals
- ☑ Natural gas utility
- ☑ Other (Specify below)

Streetlight Utility

Local Government Description:

Founded in 1737, Richmond is a historic city filled with important landmarks, including the Virginia State Capitol, and areas of beautifully preserved period architecture. Richmond's employment base is diverse and extends from chemical, food and tobacco manufacturing to biotechnology, semiconductors and high-tech fibers. Richmond consistently ranks among "Best Places to Live and Work in America" in several national publications.

2. GHG Inventory Details

Reporting Year:	2008
Protocol Used:	Local Government Operations Protocol, Version 1.0 (September 2008)
Control Approach:	Operational Control

GHG Emissions Summary (All Units in Metric Tons Unless Stated Otherwise)

Note: CO_2e totals listed here are summed totals of the estimated emissions of each inventoried gas based upon their global warming potentials (Appendix E of LGOP)

BUILDINGS & OTHER FACILITIES

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs
Stationary Combustion	6,489.764	6,473.172	0.610	0.012	-	-
Fugitive Emissions	-	-	-	-	no data	no data
Total Direct Emissions from Buildings & Facilities	6,489.764	6,473.172	0.610	0.012	no data	no data

SCOPE 2	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	35,403.953	35,193.198	0.737	0.614

STREETLIGHTS AND TRAFFIC SIGNALS

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	SF_6
Fugitive SF_6 Emissionsfrom Electricity Distribution	no data	-	-	-	no data

SCOPE 2	CO_2e	CO_2	CH_4	N_2O	SF_6
Purchased Electricity	17,751.221	17,648.057	0.370	0.308	-
Electricity Lost During Transmission and Distribution	no data	no data	no data	no data	no data
Total Indirect Emissions from Streetlights and Traffic Signals	17,751.221	17,648.057	0.370	0.308	-

WATER DELIVERY FACILITIES

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs
Stationary Combustion	278.817	277.985	0.028	0.001	-	-
Fugitive Emissions	no data	-	-	-	no data	no data
Total Direct Emissions from Water Delivery Facilities	278.817	277.985	0.028	0.001	-	-

SCOPE 2	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	22,313.698	17,159.964	0.359	0.299

WASTEWATER FACILITIES

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs
Stationary Combustion	2,490.052	2,240.023	11.844	0.004	-	-
Fugitive Emissions	31.104	0.000	1.481	0.000	no data	no data
Process Emissions	2,083.795	0.000	0.000	6.722	-	-
Total Direct Emissions from Wastewater Facilities	4,604.951	2,240.023	13.325	6.726	no data	no data

SCOPE 2	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	14,081.050	13,999.216	0.293	0.244

SOLID WASTE FACILITIES

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
Fugitive Emissions	no data	-	-	-	no data	no data	no data

SCOPE 2	CO_2e	CO_2	CH_4	N_2O
Purchased Electricity	1.893	1.882	0.00004	0.00003

VEHICLE FLEET

SCOPE 1	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs
Mobile Combustion	22,273.658	22,225.611	0.154	0.145		
Fugitive Emissions	163.673	0.000	0.000	0.000	0.126	0.000
Total Direct Emissions from Vehicle Fleet	22,437.331	22,225.611	0.154	0.145	0.126	0.000

INDICATORS	
Number of Highway Vehicles	1,352
Vehicle Miles Traveled	10,375,129
Number of Pieces of Non-Highway Vehicles or Equipment	107

MUNICIPAL SOLID WASTE

SCOPE 3	CO_2e	CO_2	CH_4	N_2O
Landfill Methane	21,210	-	1,010	-

INDICATORS		
INDICATORS	Short tons of solid waste (residential and non-residential) collected by the City of Richmond	68,004

EMPLOYEE COMMUTE

SCOPE 3	CO_2e	CO_2	CH_4	N_2O
Stationary Combustion	29,086.939	29,086.939	not calculated	not calculated

INDICATORS		
INDICATORS	Number of Employees	4,762

INFORMATION ITEMS

	CO_2e
CO_2 Emissions from biogenic portion of biodiesel (B20)	13.804
Total Information Items	13.804

Total Emissions

	CO_2e	CO_2	CH_4	N_2O	HFCs	PFCs	SF_6
SCOPE 1	39,810.863	31,216.791	14.117	6.884	0.126		
SCOPE 2	89,551.815	84,007.317	1.780	1.465			
SCOPE 3	50,296.939	29,086.939	1,010.000				
INFORMATION ITEMS	13.804						

POSSIBLE SOURCES OF OPTIONAL SCOPE 3 EMISSIONS	POSSIBLE INFORMATION ITEMS
Employee Commute	Biogenic CO_2 from Combustion
Employee Business Travel	Carbon Offsets Purchased
Emissions From Contracted Services	Carbon Offsets Sold
Upstream Production of Materials and Fuels	Renewable Energy Credits (Green Power) Purchased
Upstream and Downstream Transportation of Materials and Fuels	Renewable Energy Credits Sold (GreenPower)
Waste Related Scope 3 Emissions	Ozone-depleting Refrigerants/Fire Suppressants not in LGOP
Other Scope 3	Other Information Items

Local Government Operations Standard Inventory Report

3. Activity Data Disclosure

Every emission source must be accompanied by a reference for the activity data. This worksheet is meant to assist in recording activity data and the methods used to gather those data for government operations. Activity data represent the magnitude of human activity resulting in emissions; data on energy use, fuel consumtion, vehicle miles traveled, and waste generation are all examples of activity data that are used to compute GHGs. Detailed disclosure should be made of the activity data used and at what quantities. This disclosure should also cite the source(s) of the data and the methodology used, including whether that methodology is a recommended method or an alternate method.

Deviations from the primary methodology should be explained in detail. All assumptions and estimations should be cited as such. Local governments may also use this space in the reporting format to discuss the rationale for the inclusion or exclusion of optional inventory components. It is good practice to include appropriate citations (such as website URL, report title, etc) and all contact information that is necessary to verify the source and accuracy of the activity data.

BUILDINGS & OTHER FACILITIES

SCOPE 1

Stationary Combustion

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Natural Gas	CO_2	Primary	Known fuel use	1,185,590	CCF	Brenda Pomfrey; Utility Financial Analyst; Department of Public Utilities; brenda.pomfrey@richmondgov.com
	CH_4	Primary	Known fuel use	1,185,590	CCF	
	N_2O	Primary	Known fuel use	1,185,590	CCF	

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Electricity	CO_2	Primary	Known Electricity Use	68,376,166	kWh	Susan Mallory; Dominion Virginia Power; susan.c.mallory@dom
	CH_4	Primary	Known Electricity Use	68,376,166	kWh	
	N_2O	Primary	Known Electricity Use	68,376,166	kWh	

STREETLIGHTS AND TRAFFIC SIGNALS

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Electricity	CO_2	Primary	Known Electricity Use	34,283,189	kWh	Susan Mallory; Dominion Virginia Power; susan.c.mallory@dom.com
	CH_4	Primary	Known Electricity Use	34,283,189	kWh	
	N_2O	Primary	Known Electricity Use	34,283,189	kWh	

WASTEWATER FACILITIES

SCOPE 1

Stationary Emissions

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Unit	Data Sources and Refere
Natural Gas	CO_2	Primary	Known Fuel Use	410,270	CCF	Brenda Pomfrey; Financial Analyst; Department of Public Utilities; brenda.pomfrey@richmondgov.com
	CH_4	Primary	Known Fuel Use	410,270	CCF	
	N_2O	Primary	Known Fuel Use	410,270	CCF	
Incomplete Combustion of Digester Gas	CH_4	Primary, LGOP Equation 10.1	Stationary Methane from Incomplete Combustion of Digester Gas (site-specific data). The raw datum was provided in cubic feet of methane instead of digester gas, so the fraction measured fraction of methane in the biogas was not needed for this equation.	170,000	cu ft/ day of methane	Eric Whitehurst; Superintendent - DPU Wastewater Division;Eric.Whitehurst@richmondgov.com

Fugitive Emissions

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Unit	Data Sources and Refere
Septic Systems	CH_4	Primary, LGOP Equation 10.5	Fugitive Methane Emissions from Septic Systems (site-specific BOD_5 load data)	14	kg/day	Eric Whitehurst; Superintendent - DPU Wastewater Division;Eric.Whitehurst@richmondgov.com

Process Emissions

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Unit	Data Sources and Refere
Centralized Wastewater Treatment Plant with nitrification/denitrification	N_2O	Primary, LGOP Equation 10.7	Process Nitrous Oxide Emissions from a Wastewater Treatment Pland with Nitrification/denitrification	215,274	# people served by the facility (data unavailable to calculate population equivalent from industrial contributions of nitrogen)	Eric Whitehurst; Superintendent - DPU Wastewater Division;Eric.Whitehurst@richmondgov.com
Nitrous Oxide Emissions from Effluent Discharge	N_2O	Primary, LGOP Equation 10.9	Nitrous Oxide Emissions from Effluent Discharge (site-specific N load data)	2,856	kg N/day	

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Electricity	CO_2	Primary	Known Electricity Use	27,194,936	kWh	Susan Mallory; Dominion Virginia Power; susan.c.mallory@dom.com
	CH_4	Primary	Known Electricity Use	27,194,936	kWh	
	N_2O	Primary	Known Electricity Use	27,194,936	kWh	

WATER DELIVERY FACILITIES

SCOPE 1

Stationary Emissions

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Unit	Data Sources and Refere
Natural Gas	CO_2	Primary	Known Fuel Use	43,919	CCF	Brenda Pomfrey; Utility Financial Analyst, Department of Public Utilities; brenda.pomfrey@richmondgov.com
	CH_4	Primary	Known Fuel Use	43,919	CCF	
	N_2O	Primary	Known Fuel Use	43,919	CCF	

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Unit	Data Sources and Refere
Fuel Oil	CO_2	Primary	Known Fuel Use	3,765	gallons	Robert Steidel, Deputy Director - WWTP and Water Utility; Department of Public Utilities; Robert.Steidel@richmondgov.com
	CH_4	Primary	Known Fuel Use	3,765	gallons	
	N_2O	Primary	Known Fuel Use	3,765	gallons	

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Electricity	CO_2	Primary	Known Electricity Use	43,094,768	kWh	Susan Mallory; Dominion Virginia Power; susan.c.mallory@dom.com.
	CH_4	Primary	Known Electricity Use	43,094,768	kWh	
	N_2O	Primary	Known Electricity Use	43,094,768	kWh	

SOLID WASTE FACILITIES

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Electricity	CO_2	Primary	Known Electricity Use	3,656	kWh	Susan Mallory; Dominion Virginia Power; susan.c.mallory@dom.com.
	CH_4	Primary	Known Electricity Use	3,656	kWh	
	N_2O	Primary	Known Electricity Use	3,656	kWh	

VEHICLE FLEET

SCOPE 1

Mobile Combustion

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Gasoline	CO_2	Primary	Known Fuel Use	1,206,989	gallons	Brian Howard; Fleet Manager - General Services; brian.howard@richmondgov.com. Fuel consumption was given in aggregate, so methane and nitrous oxide emissions were not calculated for non-highway vehicles.
	CH_4	Primary	Vehicle miles traveled by vehicle type, fuel type, and model year	8,805,109	Vehicle Miles Travled	
	N_2O	Primary	Vehicle miles traveled by vehicle type, fuel type, and model year	8,805,109	Vehicle Miles Traveled	

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and References
Diesel	CO_2	Primary	Vehicle miles traveled by vehicle type, fuel type, and model year	1,141,788	Gallon	Brian Howard; Fleet Manager - General Services; brian.howard@richmondgov.com. Fuel consumption was given in aggregate, so methane and nitorus oxide emissions were not calculated for non-highway vehicles.
	CH_4	Primary	Vehicle miles traveled by vehicle type, fuel type, and model year	1,570,020	Vehicle Miles Traveled	
	N_2O	Primary	Vehicle miles traveled by vehicle type, fuel type, and model year	349,053	Vehicle Miles Traveled	
Biodiesel (B20)	CO_2	Primary	Known Fuel Use	1,141,788	Gallon	Brian Howard; Fleet Manager - General Services; brian.howard@richmondgov.com. Vehicle miles traveled data were did not show any vehilces consuming biodiesel, so methane and nitrous oxide emissiosn were not calculated from this source.
	CH_4	no data	no data	no data	Vehicle Miles Traveled	
	N_2O	no data	no data	no data	Vehicle Miles Traveled	

Fugitive Emissions

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Refrigerants	R134-A	Alternate	The quantity of refrigerants purchased during calander year 2008 was assumed to replace refrigerants that had leaked. The quanity of R-134a purchased was provided in lbs and ounces, and was coverted to metric tons. The metric tons of 134a was multiplied by a global warming potential of 1300 (LGOP Table E.1) to convert into metric tons of carbon dioxide equivalent.	126	kg	Brian Howard; Fleet Manager - General Services; brian.howard@richmondgov.com.

EMPLOYEE COMMUTE

SCOPE 3

Mobile Combustion

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Refere
Gasoline	CO_2	See Appendix C of inventory report	Estimated fuel consumption	3,277,436	gallons	See Appendix C of inventory report
	CH_4	Not calculated				
	N_2O	Not calculated				
Diesel	CO_2	See Appendix C of inventory report	Estimated fuel consumption	15,426	gallons	See Appendix C of inventory report
	CH_4	Not calculated				
	N_2O	Not calculated				
Biodiesel (B20)	CO_2	See Appendix C of inventory report	Estimated fuel consumption	6,916	gallons	See Appendix C of inventory report
	CH_4	Not calculated				
	N_2O	Not calculated				

MUNICIPAL SOLID WASTE

SCOPE 3

Mobile Combustion

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Referenc
Landfill Methane	CH_4	See Appendix D of inventory report	EPA's WARM model, calculated all emissions that will result from the decomposition of waste landfilled in 2008	88,004	tons	Marvin Freeman; Facilties Maintenance Manager - Refuse; marvin.freeman@richmondgov.com

INFORMATION ITEMS

Mobile Combustion

Emissions Source Name	GHG	Methodology Type	Methodology Name and Description	Resource Quantity	Fuel Unit	Data Sources and Referenc
CO_2 Emissionss from biogenic portion of biodiesel (B20)	Biodiesel B20 blend	Primary	Known Fuel Consumption	7,296	gallons	B20 consumed by City Vehicle Fleet - Brian Howard, Fleet Manager - General Services; brian.howard@richmondgov.com. B20 consumed by employees commuting to work - See Appendix C of Inventory Report

POSSIBLE SOURCES OF OPTIONAL SCOPE 3 EMISSIONS

Employee Commute
Employee Business Travel
Emissions From Contracted Services
Upstream Production of Materials and Fuels
Upstream and Downstream Transportation of Materials and Fuels
Waste Related Scope 3 Emissions
Other Scope 3

POSSIBLE INFORMATION ITEMS

Biogenic CO_2 from Combustion
Carbon Offsets Purchased
Carbon Offsets Sold
Renewable Energy Credits (Green Power) Purchased
Renewable Energy Credits Sold (GreenPower)
Ozone-depleting Refrigerants/Fire Suppressants not in LGOP
Other Information Items

Local Government Operations Standard Inventory Report

4. Calculation Methodology Disclosure

In addition to activity data, every emission source must be accompanied by the emission factor used, a reference for each emission factor, and the calculation methodology used to quantify emissions. The use of default emission factors from this Protocol should be identified as an alternate emission factor.

Deviations from the default emission factors should be explained. All assumptions and estimations should be cited as such. Local governments may also use this space in the reporting format to discuss the rationale for selecting an alternate emission factor. Local governments must include the value of the alternate emission factor (emissions per unit) and identify the year (or range of years) for which the emission factors are specifically applicable. It is good practice to include appropriate citations (such as website URL, report title, etc) and all contact and information that is necessary to verify the source and accuracy of the emission factors so that consistent emission factors can be obtained in the future. All emissions were converted into units of CO2e using the global warming potentials (GWP) listed in LGOP Version 1.0 Table E.1.

BUILDINGS & OTHER FACILITIES

SCOPE 1

Stationary Combustion

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Natural Gas	CO_2	Default	53.06 kg/MMBtu	LGOP v1 Table G.1
	CH_4	Default	5 g/MMBtu	LGOP v1 Table G.3
	N_2O	Default	0.1 g/MMBtu	LGOP v1 Table G.3

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Electricity	CO_2	Default	1134.88 lbs /MWh	eGRID2007 Version 1.1 http://www.epa.gov/RDEE/energy-resources/egrid/index.html
	CH_4	Default	0.01979 lbs/ MWh	
	N_2O	Default	0.02377 lbs/MWh	

STREETLIGHTS AND TRAFFIC SIGNALS

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Electricity	CO_2	Default	1134.88 lbs /MWh	eGRID2007 Version 1.1 http://www.epa.gov/RDEE/energy-
	CH_4	Default	0.01979 lbs/ MWh	
	N_2O	Default	0.02377 lbs/MWh	

Wastewater Facilities

SCOPE 1

Stationary Emissions

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Natural Gas	CO_2	Default	53.06 kg/MMBtu	LGOP v1 Table G.1
	CH_4	Default	5 g/MMBtu	LGOP v1 Table G.3
	N_2O	Default	0.1 g/MMBtu	LGOP v1 Table G.3
Incomplete Combustion of Digester Gas	CH_4	Default	LGOP Equation 10.1	LGOP Equation 10.1

Fugitive Emissions

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Septic Systems	CH_4	Default	LGOP Equation 10.5	LGOP Equation 10.5

Process Emissions

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Centralized Wastewater Treatment Plant with nitrification/denitrification	N_2O	Default	LGOP Equation 10.7	LGOP Equation 10.7
Nitrous Oxide Emissions from Effluent Discharge	N_2O	Default	LGOP Equation 10.9	LGOP Equation 10.9

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Electricity	CO_2	Default	1134.88 lbs /MWh	eGRID2007 Version 1.1 http://www.epa.gov/RDEE/energy-
	CH_4	Default	0.01979 lbs/ MWh	
	N_2O	Default	0.02377 lbs/MWh	

WATER DELIVERY FACILITIES

SCOPE 1

Stationary Emissions

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Natural Gas	CO_2	Default	53.06 kg/MMBtu	LGOP v1 Table G.1
	CH_4	Default	5 g/MMBtu	LGOP v1 Table G.3
	N_2O	Default	0.1 g/MMBtu	LGOP v1 Table G.3
Fuel Oil	CO_2	Default	10.15 kg/gallon	LGOP v1 Table G.1
	CH_4	Default	11 g/MMBtu	LGOP v1 Table G.3
	N_2O	Default	0.6 g/MMBtu	LGOP v1 Table G.3

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Electricity	CO_2	Default	1134.88 lbs /MWh	eGRID2007 Version 1.1 http://www.epa.gov /RDEE/energy-
	CH_4	Default	0.01979 lbs/ MWh	
	N_2O	Default	0.02377 lbs/MWh	

SOLID WASTE FACILITIES

SCOPE 2

Purchased Electricity

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Electricity	CO_2	Default	1134.88 lbs /MWh	eGRID2007 Version 1.1 http://www.epa.gov /RDEE/energy-
	CH_4	Default	0.01979 lbs/ MWh	
	N_2O	Default	0.02377 lbs/MWh	

VEHICLE FLEET

SCOPE 1

Mobile Combustion

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Gasoline	CO_2	Default	8.81 kg/gallon	LGOP v1 Table G.9
	CH_4	Default	Varies by model year	LGOP v1 Table G.10
	N_2O	Default	Varies by model year	LGOP v1 Table G.10
Diesel	CO_2	Default	10.15 kg/gallon	LGOP v1 Table G.9
	CH_4	Default	Varies by model year	LGOP v1 Table G.10
	N_2O	Default	Varies by model year	LGOP v1 Table G.10
Biodiesel B20	CO_2	Default	10.15 kg/gallon (diesel portion)	LGOP v1 Table G.9
	CH_4	did not calculate	did not calculate	
	N_2O	did not calculate	did not calculate	

Fugitive Emissions

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Refrigerants	R - 134a	not applicable	GWP-1,300	LGOP v1 Table E.1

EMPLOYEE COMMUTE

SCOPE 3

Mobile Combustion

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Gasoline	CO_2	Default	8.81 kg/gallon	LGOP v1 Table G.9
	CH_4	did not calculate	did not calculate	
	N_2O	did not calculate	did not calculate	
Diesel	CO_2	Default	10.15 kg/gallon	LGOP v1 Table G.9
	CH_4	did not calculate	did not calculate	
	N_2O	did not calculate	did not calculate	
Biodiesel B20	CO_2	Default	10.15 kg/gallon (diesel portion)	LGOP v1 Table G.9
	CH_4	did not calculate	did not calculate	
	N_2O	did not calculate	did not calculate	

MUNICIPAL SOLID WASTE

SCOPE 3

Mobile Combustion

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
Landfill Methane Emissions	CH_4	not applicable, used EPA's WARM model to calculate methane	GWP - 21	LGOP v1 Table E.1

INFORMATION ITEMS				

Mobile Combustion

Emissions Source Name	GHG	Default/Alternate	Emission Factor	Emission Factor Sources and References
CO2 Emissionss from biogenic portion of biodiesel (B20)	CO_2	Default	9.45 kg/gallon (B100 portion)	LGOP v1 Table G.9

POSSIBLE SOURCES OF OPTIONAL SCOPE 3 EMISSIONS	POSSIBLE INFORMATION ITEMS
Employee Commute	Biogenic CO_2 from Combustion
Employee Business Travel	Carbon Offsets Purchased
Emissions From Contracted Services	Carbon Offsets Sold
Upstream Production of Materials and Fuels	Renewable Energy Credits (Green Power) Purchased
Upstream and Downstream Transportation of Materials and Fuels	Renewable Energy Credits Sold (GreenPower)
Waste Related Scope 3 Emissions	Ozone-depleting Refrigerants/Fire Suppressants not in LGOP
Other Scope 3	Other Information Items

Appendix C: Employee Commute

Emissions from employee commutes make up an important optional source of emissions from any local government's operations. The scale of emissions from employee commutes is often large in comparison with many other facets of local government operations, and local governments can affect how their employees get to and from work through a variety of incentives. For this reason, ICLEI recommends estimating emissions from employee commutes as part of a complete government operations greenhouse gas emissions inventory.

To assist in the data collection process, ICLEI provided Richmond with an online copy of an employee commute survey. The questions in the survey were aimed at finding two categories of information:

- **Activity data** to calculate emissions from employee commutes (vehicles miles traveled, vehicle type, vehicle model year) both current and in 2008.
- **Indicator data** to help the city of Richmond understand how much time and money employees spend as they commute, as well as how many employees use alternative modes of transportation to get to work.

ICLEI only quantified carbon dioxide emissions (not methane or nitrous oxide emissions) from employees who commuted to work in single occupancy vehicles or in carpools. However, ICLEI did provide quantitative indicator data from employee responses for all transportation modes. This section provides the emissions estimation methodology and a copy of the survey. Individual survey results are in the possession of city staff.

C.1 Methodology Summary

The methodology for estimating the carbon dioxide emissions of employees who commuted in single occupancy vehicles or by carpooling is similar to the mobile emissions methodology outlined in the mobile emissions section of Appendix B. The city of Richmond administered the employee commute survey to all current employees working for the city. Seven-hundred and forty-seven employees began the survey, with 678 answering enough questions to be included in the analysis (a response rate of 14 percent based on data showing 4,762 full time employees in 2009).

The survey was administered in 2009 and current data were used as a proxy for 2008 data. Both full time and part-time employee data were included in the analysis.

To calculate emissions, the survey collected the following information:

- The distance employees live from work
- The number of days employees drive alone to work (one-way) in an average week, their vehicle type, and the type of fuel consumed
- The number of days employees carpooled in an average week, how often they were the carpool driver in an average week, and the average number of people in the carpool

These weekly data were then converted into annual VMT estimates by the following equation:

(Distance employees live from work x 2) x ((number of days driven to work/wk x 52 wk/yr) – (number of sick, holiday, and vacation days))

The VMT for employees who carpooled as calculated above was divided by the number of people in the carpool. If the respondent did not indicate how many people are in the carpool, it was assumed that two people participate in the carpool. The average number of sick days and vacation days in 2008 and 2009 were provided by Shanone Sport, HR Consultant, Human Resources Department (Shanone.Sport@richmondgov.com). The human resources department does not track holidays, so it was assumed that each employee had 10 holidays each year.

Actual CO_2e emissions from respondents' vehicles were calculated by converting the vehicle miles traveled per week by responding employees into annual fuel consumption by fuel type (gasoline, diesel, and biodiesel (B20)) using fuel efficiencies. The fuel economies indicated by survey respondents for their vehicles were used to convert VMT into gallons of fuel consumed. If no fuel economy was provided by the respondent, then the average fuel economy for the employee's vehicle type as listed in CACP 2009 for the "alternative method" was used to calculate emissions. If the vehicle type was not indicated, then the vehicle was assumed to be a light truck. It was assumed that respondents who did not indicate what fuel type their vehicles used operate gasoline vehicles.

Carpooling survey respondents who were not the driver of their carpool were assigned fuel efficiencies that were the mean efficiency listed for light trucks and passenger vehicles in CACP 2009 for the "alternative method" in 2008. If a carpooling respondent shared driving responsibilities with another driver, then a weighted average of the CACP 2009 "alternative method" fuel economy for 2008 and the fuel economy provided in the survey for the respondent's vehicle was used to calculate fuel consumption based on annual VMT.

The factors used to calculate carbon dioxide emissions based on gasoline, diesel, and biodiesel (B20) are contained in Table G.9 of LGOP 2008 Version 1.0.

Once the carbon dioxide emissions from single occupancy vehicle and carpooling commutes had been calculated, ICLEI extrapolated estimated fuel consumption to represent all 4,762 of Richmond's full time employees in 2009. This was a simple extrapolation, multiplying the estimated fuel consumption number by the appropriate factor to represent all current employees. For example, if 33.3 percent of employees responded, fuel consumption numbers were tripled to estimate fuel consumption for all employees. Carbon dioxide emissions were re-calculated using this extrapolated number. This is not a statistical analysis and no uncertainty has been calculated as there is uncertainty not only at the extrapolation point but also in the calculation of actual emissions. Therefore, the resulting calculated emissions should be seen as directional and not as statistically valid.

C.2 Employee Commute Survey

1. Introduction

The purpose of this survey is to gather information on your commute to work. The information you provide will be used by the city of Richmond to calculate its greenhouse gas emissions. The survey should take no more than 15 minutes.

Unless otherwise indicated, all questions refer to a ONE-WAY commute TO WORK only. Please do not include any traveling you do during work hours (meetings, site visits, etc.). Any question with an asterisk (*) next to it requires an answer in order to proceed.

Please note that this survey is completely anonymous. We will not collect or report data on any individuals who respond to the survey.

Thank you for taking the time to complete this survey!

2. Workplace

Please provide the following information regarding your workplace. Click "Next" at the bottom when finished or click "Prev" to go back.

*1. What department do you work in?

3. Commuter Background Information

Please provide the following information regarding your background. Click "Next" at the bottom when finished or click "Prev" to go back.

1. What city/town do you live in?

*2. How many miles do you live from your place of work? (please enter a whole number)

3. How many minutes does your commute to work typically take? (please enter a whole number)

4. In a typical week, how much money do you spend on your ROUND TRIP commute (transit fees, gas, tolls, etc- please enter a number)? Enter "0" if you do not spend any money on your commute during a typical week.

4. Employment Information

Please provide the following information regarding your employment. Click "Next" at the bottom when finished or click "Prev" to go back.

1. Do you typically travel to work between 6-9 am Monday-Friday?

   Yes
   No

2. Does your position allow you to have flexible hours or to telecommute?

3. Are you a full time employee or part time employee?

   Full
   Part

*4. How many days per week do you work?

5. Drive Alone

Please provide the following information regarding your current daily commute. Click "Next" at the bottom when finished or click "Prev" to go back.

*1. In a typical week, do you drive to work alone at least once?

   Yes
   No

*2. How many DAYS a week do you drive alone to work? (please enter a number)

3. What type of vehicle do you usually drive?

   Passenger Car
   Light Truck/SUV/Pickup/Van
   Heavy Truck
   Motorcycle/Scooter

4. What model year is your vehicle? (please enter a four digit year)

5. What is the make and model of your vehicle? (Examples: "Toyota Prius," "Dodge Dakota").

6. What type of fuel does your vehicle use?

   Gas
   Diesel
   Biodiesel (B20)
   Biodiesel (B99 or B100)
   Electric
   Ethanol
   Other (please specify – if ethanol please indicate grade)

7. What is the average fuel economy of your vehicle (mpg)? It is okay to estimate or guess.

6. Carpool
Click "Next" at the bottom when finished or click "Prev" to go back.

*1. In a typical week, do you carpool to work at least once?
Yes
No

2. How many DAYS a week do you carpool? (please enter a number)

3. How many PEOPLE are in your carpool? (please enter a number)

4. How many DAYS a week are you the driver of the carpool? (please enter a number)

7. Public Transit

1. In a typical week, do you commute to work by public transit (such as GRTC Transit System buses) at least once?
Yes
No

*2. How many DAYS a week do you take public transit TO WORK? (please enter a number)

3. What type of public transit do you take TO WORK?

8. Bike/Walk

*1. In a typical week, do you bike or walk to work at least once?
Yes
No

2. How many DAYS a week do you bike to work? (please enter a number)

3. How many DAYS a week do you walk to work? (please enter a number)

9. Telecommute

1. If you telecommute: How many DAYS do you telecommute in a typical week? (please enter a number)

If you do not telecommute, leave this question blank.

10. Commute in 2006
Please provide the following information regarding your commute in 2006.

*1. Did you work for us in 2006?
Yes
No

*2. In 2006, did you typically commute by the same mode(s) as you do now? If not, please indicate how you used to commute to work.

Yes
No (please specify)

3. In 2006, did you reside at the same place that you do now? If no, please provide the distance your home was from work (in miles).

Yes
No

11. Commute in 2008

Please provide the following information about your commute in 2008.

1. Did you work for us in 2008?

Yes
No

2. In 2008, did you commute by the same mode that you do now? If not, please indicate how you used to commute to work.

Yes
No (please specify)

3. In 2008, did you reside at the same place that you do now? If no, please provide the distance your home was from work (in miles).

Yes
No (please specify)

12. Comments

1. If you have other concerns or issues related to your commute, or if something we should know about was not captured in any survey questions, please describe below.

13. Thank you

Thank you for responding to this survey!

Appendix D:

Municipal and Community - Generated Solid Waste Methodology

Emissions from the waste sector are an estimate of methane generation that will result from the anaerobic decomposition of all organic waste sent to the landfill in the base year. It is important to note that although these emissions are attributed to the inventory year in which the waste is generated, the emissions themselves will occur over the 100+ year timeframe that the waste will decompose. This frontloading of emissions is the approach taken by EPA's Waste Reduction Model (WARM). Attributing all future emissions to the year in which the waste was generated incorporates all emissions from actions taken during the inventory year into that year's greenhouse gas release. This facilitates comparisons of the impacts of actions taken between inventory years and between jurisdictions. It also simplifies the analysis of the impact of actions taken to reduce waste generation or divert it from landfills.

D.1 Emissions Calculation Methods

As some types of waste (e.g., paper, plant debris, food scraps, etc.) generate methane within the anaerobic environment of a landfill and others do not (e.g., metal, glass, etc.), it is important to characterize the various components of the waste stream. This information can be found in local, state, or regional waste composition studies. If localized waste composition data are unavailable, national default waste composition figures can be used instead.

Most landfills capture methane emissions either for energy generation or for flaring. The EPA estimates that 60 percent to 80 percent[22] of total methane emissions are recovered from landfills with gas collection systems, such as the Charles City County Landfill, where Richmond sends its waste. Following the recommendation of LGOP, ICLEI adopted a 75 percent methane recovery factor for use in this model.

Recycling and composting programs are reflected in the emissions calculations as reduced total tonnage of waste going to the landfills. The model, however, does not capture the associated emissions reductions in "upstream"

[22] AP 42, section 2.4 Municipal Solid Waste, 2.4-6, http://www.epa.gov/ttn/chief/ap42/index.html

energy use from recycling as part of the inventory.[23] This is in-line with the "end-user" or "tailpipe" approach taken throughout the development of this inventory. It is important to note that recycling and composting programs can have a significant impact on greenhouse gas emissions when a full lifecycle approach is taken. Manufacturing products with recycled materials avoids emissions from the energy that would have been used during extraction, transporting, and processing of virgin material.

Emissions calculations for both municipal and community-generated solid waste assumed a waste composition of 38 percent paper products, 13 percent food waste, 10 percent plant debris, 4 percent wood or textiles, and 35 percent composed of other wastes. These percentages represent national estimates of municipal waste composition contained in the Clean-Air and Climate Protection Software.

The quantity of waste generated by the city of Richmond's government operations was provided by Marvin Freeman, Facilities Maintenance Manager – Refuse in the city's Department of Public Utilities. Appendix E discusses the methodology for estimating waste generated by the Richmond community.

D.1.1 Methane Commitment Method

CO_2e emissions from waste disposal can be calculated using the methane commitment method outlined in the EPA WARM model. This model has the following general formula:

$$CO_2e = W_t * (1-R)A$$

Where:

W_t is the quantity of waste type "t"

R is the methane recovery factor,

A is the CO_2e emissions of methane per metric ton of waste at the disposal site (the methane factor)

While the WARM model often calculates upstream emissions, as well as carbon sequestration in the landfill, these dimensions of the model should be omitted for this type of study for two reasons:

- This inventory functions on an end-use analysis, rather than a life-cycle analysis, which would calculate upstream emissions
- This inventory solely identifies emissions sources, and no potential sequestration "sinks"

[23] "Upstream" emissions include emissions that may not occur in your jurisdiction resulting from manufacturing or harvesting virgin materials and transportation of them.

Appendix E: Community Inventory Methodology

This appendix expands on the description of methodology provided in Section 2, describing in more detail the data sources and processes used to calculate emissions in the community inventory.

E.1 Overview of Inventory Contents and Approach

The community inventory describes emissions of the major greenhouse gases from the residential, commercial / industrial, transportation, solid waste, and wastewater sectors. As explained in Section 2, emissions are calculated by multiplying activity data—such as kilowatt hours or gallons of gasoline consumed—by emissions factors, which provide the quantity of emissions per unit of activity. Activity data is typically available from electric and gas utilities, planning and transportation agencies and air quality regulatory agencies. Emissions factors are drawn from a variety of sources, including the Virginia Department of Transportation (VDOT), utility providers, and the Local Governments Operations Protocol.

In this inventory, all GHG emissions are converted into carbon dioxide equivalent units, or CO_2e, per guidance in the Local Government Operations Protocol (LGOP). The LGOP provides standard factors to convert various greenhouse gases into carbon dioxide equivalent units; these factors are known as Global Warming Potential factors, representing the ratio of the heat-trapping ability of each greenhouse gas relative to that of carbon dioxide.

The community inventory methodology is based on guidance from ICLEI's draft International Local Government GHG Emissions Analysis Protocol (IEAP).

E.1.1 Emissions Sources Included and Excluded

In general, local jurisdictions should seek to measure all emissions of the six Kyoto Protocol greenhouse gases[43] occurring within the jurisdictional boundaries. In practice, this level of detail may not be feasible for the local jurisdiction. The table below (E.1) describes sources included in this community inventory, followed by sources that were excluded:

[43] CO_2, CH_4, N_2O, SF_6, perfluorocarbons (PFCs) and hydrofluorocarbons (HFCs)

Table E.1: Sources of Emissions for Richmond's Community Inventory

Sector	Emissions Source	Sector	Emissions Source
Residential	Bundled Electricity	**Transportation**	On-Road Transportation
	Direct Access Electricity		Travel on Primary Roads
	Bundled Natural Gas		Travel on Secondary Roads
	Direct Access Natural Gas		Travel on Interstate Highways
	Fuel Oil Consumption	**Wastewater**	Community-generated Wastewater
Commercial / Industrial	Bundled Electricity	**Solid Waste**	Community-generated Solid Waste
	Direct Access Electricity		Landfill Waste-in-Place
	Bundled Natural Gas		
	Direct Access Natural Gas		
	Fuel Oil Consumption		

Local governments will often choose to exclude emissions sources that meet the following criteria:

- ***Below the significance threshold***. In the ICLEI reporting standard, emissions sources can be excluded from the analysis (e.g. are "de minimis") if, when combined, the excluded emissions total less than 5% of the total of the emissions from the Community or Government Inventory.[44]
- ***Insufficient data or accepted standard methodology.*** The science is still evolving in many sectors, and accurate records or standards for measuring emissions are not always available. Examples include non-combustion industrial emissions sources or emissions from composting activities.
- ***Emissions largely located outside the jurisdiction's boundaries***. These types of emissions could include such sources as aviation departing from local airports or regional transit emissions.

In this inventory, the following emissions were excluded for the reasons listed above:

- SF_6, perfluorocarbons (PFCs) and hydrofluorocarbon (HFCs) emissions;
- Emissions of minor off-road sources (those not included in the table above);
- Stationary emissions from propane and diesel fuels; and
- Non-combustion industrial emissions sources.

E.2 Emissions Forecast

This inventory includes a "business-as-usual" forecast to 2020, estimating emissions that will occur if no new emissions reduction policies are implemented. The forecast is based on household, population, job projections and information from Energy Information Administration's (EIA) A*nnual Energy Outlook 2009*. As a business-as-usual projection, the forecast does not take into account legislation or regulation currently under development, and relies on demographic data as the basis for estimating growth in each sector. The forecasting approach for each sector was based on projected energy increases.

[44] Note: an inventory should include at least 95% of the emissions released by the government and community as a whole. Therefore, if a large number of small emissions sources occur within the jurisdiction, they cannot all be ignored.

E.3 The Built Environment: Residential, Commercial, and Industrial Sectors

Information on electricity sold to Dominion Virginia Power customers as bundled service (both energy generation and distribution) was provided by Susan Mallory at Dominion Virginia Power. Natural gas information was provided by Brenda Pomfrey, city of Richmond Department of Public Utilities, which records the distribution through its grid. Natural gas and electricity emissions were calculated in ICLEI's CACP 2009 software using EPA eGrid emissions factors. All criteria air pollutants were calculated in CACP 2009 with emissions factors from the North American Electric Reliability Corporation (NERC).

E.4 Transportation

Transportation emissions were derived from daily vehicle miles traveled (DVMT) in 2008 on primary, secondary, and interstate roads and road segments located within the city of Richmond. DVMT were obtained from the Virginia Department of Transportation organized by road and vehicle type.[45] It was assumed that all motorcycles, passenger cars, and two-axle, four tire single unit vehicles were fueled by gasoline. It was assumed that all remaining vehicle types consumed diesel fuel. CACP 2009 was used to calculate greenhouse gas emissions from transportation based the DVMT counts.

E.5 Solid Waste

Emissions from solid waste were captured via future emissions from decomposition of waste generated in the local jurisdiction in the base year ("community-generated solid waste").

E.5.1 Community-Generated Solid Waste

Community-generated solid waste emissions were calculated in CACP 2009 using waste disposal data obtained from the EPA's Waste Reduction Model (WARM). WARM calculates and totals GHG emissions of baseline and alternative waste management practices—source reduction, recycling, combustion, composting, and landfilling. The model calculates emissions in both metric tons of carbon equivalent (metric tons of C) and metric tons of carbon dioxide equivalent (metric tons of CO_2e) across a wide range of material types commonly found in municipal solid waste (MSW). See Appendix D for more information on how emissions were calculated using the WARM model.

The tons of solid waste generated by the Richmond community, one of the inputs required by the WARM model, was calculated by calculating 50 percent of the waste received by the Charles City County Landfill according to the 2008 Virginia Department of Environmental Quality annual solid waste report. The Waste Management transfer

[45]2008 DVMT data were from report "1220 – DVMT by Physical Jurisdiction by Federal Vehicle Class All Roads." http://www.virginiadot.org/info/2008_traffic_data_daily_vehicle_miles_traveled.as

station which received all of Richmond's waste in 2008 sent all non-recovered materials to the Charles City County Landfill. According to the Charles City County Landfill, approximately 50 percent of the waste received was from the city of Richmond.

E.6 Wastewater

Data used to calculate emissions from wastewater treatment were provided by Eric Whitehurst, Department of Public Utilities, with the city of Richmond. ICLEI Wastewater emissions were calculated in metric tons using the following equations from LGOP:

Stationary CH4 from Incomplete Combustion of Digester Gas:
Annual CH4 emissions (metric tons) = Digester Gas x FCH4 x ρ(CH4) x (1-DE) x 0.0283 x 365.25 x 10-6

Fugitive CH4 from Septic Systems (default BOD5 load):
Annual CH4 emissions (metric tons) = P x BOD5 load x Bo x MCFseptic x 365.25 x 10-3

Process N2O Emissions from WWTP with Nitrification/Denitrification:
Annual N2O emissions (metric tons) = Ptotal x EF nit/denit x 10-6

Process N2O Emissions from Effluent Discharge:
Annual N2O emissions (metric tons) = N Load x EF effluent x 365.25 x 10-3

Emissions were converted from metric tons to metric tons of CO_2e using CACP 2009.

Appendix F: Conducting a Monitoring Inventory

The purpose of this appendix is to assist city staff in conducting a monitoring inventory to measure progress against the baseline established in this inventory report. Conducting such an inventory represents milestone five of the Five-Milestone for Climate Mitigation Process, and allows a local government to assess how well it is progressing toward achieving its emissions reduction targets. This section focuses on conducting a monitoring inventory for government operations, but the same approach should be applied when conducting a community inventory.

To facilitate a monitoring inventory, ICLEI has documented all of the raw data, data sources, and calculation methods used in this inventory. Future inventories should seek to replicate or improve upon the data and methods used in this inventory. Wherever possible, however, ICLEI strongly recommends institutionalizing internal data collection in order to be able to meet the recommended methods outlined in LGOP.

F.1 ICLEI Tools for Local Governments

ICLEI has created a number of tools for Richmond to use to assist in future monitoring inventories. These tools are designed to work in conjunction with LGOP, which is, and will remain, the primary reference document for conducting an emissions inventory. These tools include:

- A “master data sheet” that contains most or all of the raw data (including emails), data sources, emissions calculations, data templates, notes on inclusions and exclusions, and reporting tools (charts and graphs and the excel version of LGOP reporting tool).
- A copy of all electronic raw data, such as finance records or Excel spreadsheets.
- LGOP reporting tool (included in the master data sheet and in Appendix B) that has all activity data, emissions factors, and methods used to calculate emissions for this inventory.
- Sector-specific instructions that discuss the types of emissions, emissions calculations methods, and data required to calculate emissions from each sector, as well as instructions for using the data collection tools and calculators in the master data sheet.
- The appendices in this report, which include detailed methodologies for calculating emissions from Scope 3 employee commute and municipal solid waste, as well as a full version of the employee commute survey.

It is also important to note that all ICLEI members receive on-demand technical assistance from their ICLEI liaison, which local staff should feel free to contact at any point during their re-inventory process.

F.2 Relationship to Other Climate Protection Initiative Inventories

Local governments in Virginia may benefit by cooperating during the re-inventorying process. For example, by coordinating inventories, they may be able to hire a team of interns to collectively perform the inventories – saving money in the process. In addition, local staff may be able to learn from each other during the process or conduct group training sessions if necessary.

F.3 Improving Emissions Estimates

One of the benefits of a local government operations inventory is that local government staff can identify areas in their current data collection systems where data collection can be improved. For example, a local government may not directly track fuel consumption by each vehicle and instead will rely upon estimates based upon VMT or purchased fuel to calculate emissions. This affects both the accuracy of the emissions estimate and may have other implications for government operations as a whole.

During the inventory process, ICLEI and local government staff identified the following gaps in data that, if resolved, would allow Richmond to meet the recommended methods outlined in LGOP for calculating Scope 1 and 2 emissions as well as Scope 3 emissions suggested by ICLEI for future government operations inventories. If followed, this would mean that the city of Richmond would have a LGOP compliant inventory.

- Refrigerants recharged into HVAC and refrigeration equipment
- Fire suppressants recharged into fire suppression equipment (CO_2 fire extinguishers on all fire trucks)
- Electricity lost during distribution for the streetlight utility lines owned by the city
- Sulfur hexafluoride (SF_6) leaked from the streetlight utility distribution lines owned by the city
- Tracking of fuel use and mileage for business travel including car stipends, out of town travel and mileage reimbursements
- Natural Gas leaked during distribution
- Energy consumed by facilities leased by the city
- Nitrogen discharged by industry into the city's wastewater treatment plant
- Fuel oil consumed by city facilities or in generators.
- Information on methane emissions associated with closed landfills owned by the city of Richmond

ICLEI encourages staff to review the areas of missing data and establish data collection systems for this data as part of normal operations. In this way, when staff are ready to re-inventory for a future year, they will have the proper data to make a more accurate emissions estimate. Section 3.4.9 of this report provides more information on the above missing data sources, including contact information for individuals who may be able to provide this data. ICLEI also has data collection forms, trainings, and other resources to assist members with conducting an emissions inventory. As an ICLEI member, Richmond may want to utilize these resources, such as the stationary source, mobile source, and wastewater treatment data collection forms during its next inventory.

F.4 Conducting the Inventory

ICLEI recommends the following approach for local governments that wish to conduct a monitoring inventory:

Step 1: Identify a Climate Steward

This steward will be responsible for the jurisdiction's climate actions as a whole and could serve as an ICLEI liaison in all future climate work. In the context of a monitoring inventory, the steward will be responsible for initiating discussions on a new inventory.

Step 2: Determine which Sectors to Inventory

There are many ways to determine which sectors apply to a local government's operations, but the easiest is to review the LGOP Standard Report, which is located both in Appendix B and in the master data sheet. This document clearly delineates which sectors will need to be inventoried within a local government's operations and which LGOP sectors do not apply to a jurisdiction.

Step 3: Gather Support: Identify Data Gathering Team

Coordination and acceptance among all participating departments is an important factor in coordinating a successful inventory. To that end, the inventory coordinator should work with the Chief Administrative Officer to identify all staff who will need to be part of the inventory. To facilitate this process, ICLEI has documented all people associated with the inventory in the master data sheet—these names are located in the final completed data form for each sector. Once this team has been identified, the inventory coordinator should hold a kickoff meeting with the CAO, all necessary staff, and relevant department heads to clearly communicate the priority of the inventory in relationship to competing demands. At this meeting, the roles of each person, including the inventory coordinator, should be established.

Step 4: Review Types of Emissions and Available Methodologies for Applicable Sectors

Staff should then review LGOP and the instructions documents provided through this inventory to better understand the types of emissions for each sector (for example, within Mobile Emissions, CO_2 emissions and CH_4/N_2O emissions represent two different data requirements and emissions calculations methodologies). Each emissions type may have more than one possible estimation methodology, and it is important that the inventory coordinator understands all possible methodologies and be able to communicate this to all parties assisting in the data gathering.

Step 5: Review Methodologies Used for the 2008 Inventory to Determine Data to Collect

In order to duplicate or improve upon the methods used in this inventory, local staff should again review the methods used for this inventory—these methods are located in Appendix B—and within the master data sheet. These methods reflect the data limitations for each local government (as many local governments could not obtain data necessary to meet the recommended methods in LGOP). Wherever possible, these methods should be duplicated or, if it is possible, replaced with the recommended methods outlined in LGOP. Using these methodologies, staff will determine what data needs to be collected and communicate this effectively to the data gathering team.

Step 6: Begin Data Collection

With the exception of electricity and natural gas for stationary sources, all data collection will be internal. To obtain stationary source energy consumption data, staff will need to contact the city's ICLEI representative to determine who the contact is for data (other utilities will need to be contacted directly).

Step 7: Use the Data Forms as a Resource During Data Gathering

A number of questions will come up during the data gathering process that may be difficult to answer. ICLEI has attempted to capture all of the questions that arose during the 2008 inventory and how they were addressed through the master data sheet. Within the master data sheet, staff should review the raw data, working data, and completed data forms to review how raw data was converted to final data, and also to review any notes taken by ICLEI staff during the 2008 inventory process.

For example, reviewing the stationary sources data within the master data sheet will allow local staff to review how individual accounts were separated into each category and which accounts may have been excluded from the inventory.

Step 8: Use Emissions Software to Calculate Emissions

ICLEI has provided the staff lead on the 2008 inventory with a backup of the software used to calculate many of the emissions included in this report. Staff should use this (or more current ICLEI software) to calculate emissions by inputting the activity data into the software. ICLEI staff and ICLEI trainings are available to assist local government staff in calculating emissions.

Step 9: Report Emissions

The master data sheet also contains the LGOP Standard Reporting Template, which is the template adopted as the official reporting template for government operations emissions inventories. This tool, as well as the charts and graphs tool provided by ICLEI can be used to report emissions from government operations. Also, local government staff should utilize this narrative report as a guide for a future narrative report if they so choose.

Step 10: Standardize and Compare to Base Year

Conducting a monitoring inventory is meant to serve as a measuring point against the baseline year represented in this report. In order to make a more accurate comparison, it is necessary to standardize emissions from stationary sources based upon heating and cooling degree days (staff can use a ratio of heating /cooling degree days to standardize across years).

In addition, it is important, when comparing emissions across years, to clearly understand where emissions levels may have changed due to a change in methodology or due to excluding an emissions source. For example, if the default method was used to estimate refrigerant leakage in 2008 (this method highly overestimates these emissions), and the recommended method was available in a monitoring year, this would appear as a dramatic reduction in these emissions even though actual leaked refrigerants may be similar to the base year. Changes such as these should not be seen as progress toward or away from an emissions reduction target, but emissions estimates should be adjusted to create as much of an apples-to-apples comparison as possible. If such an adjustment is not possible, staff should clearly note the change in methodology between years when comparing emissions.