Report No. CSS14-21
September 15, 2014

City of Detroit Greenhouse Gas Inventory:

An Analysis of Citywide and Municipal Emissions for 2011 and 2012

Final Report

Jill Carlson, Jenny Cooper, Marie Donahue,
Max Neale, and Anis Ragland

CENTER FOR
SUSTAINABLE SYSTEMS
UNIVERSITY OF MICHIGAN

CITY OF DETROIT GREENHOUSE GAS INVENTORY

An Analysis of Citywide and Municipal Emissions for 2011 and 2012

Final Report
September 2014

A collaboration of the University of Michigan School of Natural Resources and Environment, University of Michigan Center for Sustainable Systems, Detroiters Working for Environmental Justice, and the Detroit Climate Action Collaborative

City of Detroit Greenhouse Gas Inventory:
An Analysis of Citywide and Municipal Emissions for 2011 and 2012

Final Report

Written by: Jill Carlson, Jenny Cooper, Marie Donahue, Max Neale, and Anis Ragland
University of Michigan

This document is available online: http://css.snre.umich.edu

Report submitted in fulfillment of the opus requirement for the Master of Science degree at the University of Michigan School of Natural Resources and Environment.

Project Advisors

Rosina Bierbaum
Professor of Natural Resources & Environment Policy
School of Natural Resources & Environment
School of Public Health
University of Michigan

Gregory A. Keoleian
Director, Center for Sustainable Systems
Peter M. Wege Professor of Sustainable Systems
School of Natural Resources & Environment
Professor, Civil and Environmental Engineering
University of Michigan

Robb De Kleine
Research Specialist, Center for Sustainable Systems
School of Natural Resources & Environment, University of Michigan

Suggested Report Citation

Carlson, Jill, Jenny Cooper, Marie Donahue, Max Neale, and Anis Ragland. (September 2014) *City of Detroit Greenhouse Gas Inventory: An Analysis of Citywide and Municipal Emissions for 2011 and 2012. Final Report*. University of Michigan Center for Sustainable Systems, School of Natural Resources and Environment, Report No. CSS14-21. Ann Arbor, Michigan.

Contact Information

For questions or comments concerning the City of Detroit Greenhouse Gas Inventory, please contact Robb De Kleine (Center for Sustainable Systems) at detroitghg [at] umich.edu.

For questions concerning the Detroit Climate Action Collaborative, please contact Kimberly Hill Knott (Detroiters Working for Environmental Justice) at kimberly [at] dwej.org.

Preface

A preliminary version of this report was submitted to the University of Michigan School of Natural Resources and Environment in April 2014. The preliminary report was internally reviewed and verified by the University of Michigan Center for Sustainable Systems in May 2014. Subsequently, the report was presented to project client Detroiters Working for Environmental Justice and various stakeholders involved in the Detroit Climate Action Collaborative for their review and feedback. This final report is a culmination of this extensive verification and vetting process.

Some results presented herein have been adjusted from those presented in the preliminary analysis, as methods were refined, errors were corrected, and new information was incorporated.

This analysis is not intended to account for every emissions source attributable to the City of Detroit and its municipal government operations, rather it attempts to provide as accurate, credible, and policy-relevant a baseline emissions inventory for 2011 and 2012, as possible.

Acknowledgements

We wish to thank the many people and organizations, who were integral to the completion and success of this project: our visionary client, Detroiters Working for Environmental Justice and Kimberly Hill-Knott (Senior Policy Analyst and Program Director for the Detroit Climate Action Collaborative), for their dedication to this project and for leading the charge to address climate change and environmental justice in Detroit; the Detroit Climate Action Collaborative whose work to create a Detroit Climate Action Plan gives meaning and relevance to our work on the greenhouse gas inventory; our faculty advisors Dr. Gregory Keoleian and Dr. Rosina Bierbaum, for their unwavering support and guidance; the invaluable technical and project management assistance of Robb De Kleine, verification assistance from Stephanie Smith, and administrative assistance of Helaine Hunscher at the Center for Sustainable Systems; guidance from Missy Stults; and DTE Energy, the City of Detroit, and numerous others for their collaboration in our research and data collection efforts.

The project received generous financial support from the University of Michigan Center for Sustainable Systems, the DTE Energy Foundation, the University of Michigan School of Natural Resources and Environment Master's Project Funding, the University of Michigan Dow Distinguished Award for Interdisciplinary Sustainability, and the Erb Institute for Global Sustainable Enterprise at the University of Michigan.

Graphics Credits

The cover and back report pages, activity category icons, Figure 3, and Figure 4 were developed by Mason Phillips. All other graphics and the report design were developed by the project team, led by Jill Carlson.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

FOREWORD

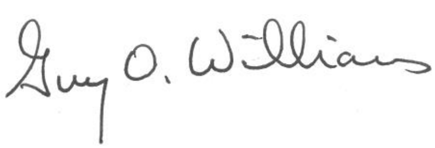
A Message from Detroiters Working for Environmental Justice

Climate change is an issue that is quickly gaining momentum throughout the country, particularly in urban areas. This global phenomenon has, and will continue to, affect Detroit and its residents, putting the city's vulnerable communities at even greater risk. Given this reality, Detroiters Working for Environmental Justice has convened key stakeholders in the city's government, nonprofit, academic, health, and business sectors to form the Detroit Climate Action Collaborative (DCAC), a group that seeks to develop a formal Climate Action Plan that will identify the strategic actions the city and its residents can take to reduce greenhouse gas emissions and to ready Detroiters for coping with the impacts of climate change.

I am proud to present this report—a comprehensive inventory of the city's greenhouse gas emissions, which is the first of its kind for Detroit. It is a significant milestone for DCAC and a key step toward our city's efforts to find opportunities to mitigate climate change, to increase energy efficiency, and to increase our resilience to the impacts of climate change. This inventory provides the city with a baseline from which to track emission reductions and energy use—both citywide and within the City of Detroit municipal government.

Working together with residents of Detroit and partners in the public, private, and nonprofit sectors to reduce emissions and adapt to climate impacts will improve the long-term health of Detroit's environment, economy, and community. We have researched best practices from across the U.S. and are striving to move Detroit to the forefront of such efforts in the country.

This report and the work of the Detroit Climate Action Collaborative more broadly are an integral part of shaping Detroit's future. Many bright opportunities lie ahead. Let us take action now to create a stronger, healthier, more vibrant, and more resilient Detroit.



Guy O. Williams, President & CEO
Detroiters Working for Environmental Justice

EXECUTIVE SUMMARY

Introduction

Climate change is one of the greatest challenges of our time. Since the 1970s, the Great Lakes region has been warming at a rate of 0.4°F per decade and average winter temperatures are rising at a rate of 0.9°F per decade.[1] By the end of the century, when scientists consider 'business as usual' scenarios with consistent growth in greenhouse gas emissions, summers in the Midwest may be more like the current summers in Arkansas or Mississippi.[2] The latest science from the Intergovernmental Panel on Climate Change (IPCC), the U.S. Environmental Protection Agency (U.S. EPA), the U.S. Global Change Research Program, and a host of other research institutions, shows that climate change will increase the frequency and intensity of extreme weather events such as heat waves, droughts, and floods in the Midwest, as well as degrade air and water quality.[3] These impacts threaten ecosystems, economic activities, public health, and infrastructure.

Responding to climate-related risks and joining global efforts to mitigate climate change involve adjusting current policies and decision-making at a variety of scales. The Detroit Climate Action Collaborative (DCAC), a multi-stakeholder group convened by Detroiters Working for Environmental Justice (DWEJ), is leading efforts in the City of Detroit to initiate policy reform and drive actions to reduce greenhouse gases, to increase the city's climate change preparedness, and to seize opportunities for cost-savings that come from energy efficiency improvements. The Detroit greenhouse gas (GHG) inventory is a resource that facilitates climate-smart decision-making that leads to a healthy, vibrant Detroit.

This GHG inventory quantifies Detroit's citywide emissions from calendar years 2011 and 2012. The inventory accounts for the anthropogenic GHG emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)[4] and follows methods determined by U.S. EPA guidance and ICLEI Community and Municipal Protocols to model emissions from available activity data. These data were collected from a variety of sources, including DTE Energy, Southeast Michigan Council of Governments (SEMCOG), U.S. EPA, Federal Transit Administration's National Transit Database, and various departments within the City of Detroit municipal government.

The inventory is organized into the following activity categories: energy use from buildings and facilities, passenger cars, trucks, and on-road freight, public transportation, and municipal vehicle fleets; industrial processes; solid waste landfill disposal and incineration; and wastewater treatment. Carbon dioxide sequestered or removed from the atmosphere by land use, specifically by Detroit's trees, is estimated but reported separately (i.e., these emissions are not included in

[1] UCS (2009)
[2] U.S. Global Change Research Program (2009)
[3] IPCC (2013), U.S. EPA. (2013a), U.S. Global Change Research Program (2013)
[4] The anthropogenic GHGs hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), and sulfur hexafluoride (SF_6) were not included in this analysis based on current protocol and data availability.

citywide totals), as directed by current inventory protocols. A summary of the activity categories used by this inventory is outlined in Figure ES-1.

Figure ES-1: Summary of Detroit Emission Sources and Activities

Detroit's total citywide emission calculations include emissions from the city's municipal government operations, which are also reported and analyzed in a distinct municipal government inventory section of the report.

In general, GHG emissions are modeled using the parameters of annual activity data (such as electricity use) and emission factors (the per unit GHG intensity of the corresponding activity). For both the citywide and municipal inventory analyses, a variety of activity-specific models, data, and emission factors were used—all of which (along with corresponding complexities and limitations for each activity) are explained in detail in the methods presented in the inventory report and appendices.

WHAT IS INCLUDED IN THE DETROIT GREENHOUSE GAS INVENTORY?

Nearly all of our daily activities cause greenhouse gas (GHG) emissions. The Detroit GHG Inventory is an accounting of the GHG emissions from activities in Detroit. It is a tool to guide policy and management decisions to address climate change.

SCOPE 1

All activities within the City boundary that directly emit GHGs

Forms of transportation like **1** cars, **2** trucks, **3** buses, and **4** the People Mover contribute to GHG emissions. **5** Industrial processes like refining oil also produce GHGs, as does **6** treating the water that goes down our sinks and toilets, and **7a** using natural gas to heat our homes.

SCOPE 2

GHG emissions that result from the production of purchased electricity that is generated outside of Detroit (indirect emissions)

Buildings and facilities, including **7b** homes, **8** commercial buildings, and **9** municipal government buildings purchase electricity for power and cooling. Electricity is also purchased to **10** pump water through pipes to our faucets. The production of this electricity, at **11** power plants outside of Detroit, emits GHGs.

SCOPE 3

Other indirect emissions

Some electricity is lost when transmitted through **12** power lines; the production of this electricity emits GHGs. **13** Trees and other plants sequester GHGs through growth and emit GHGs when cut down. **14** Landfills outside Detroit that contain garbage from the city also emit GHGs.

EXCLUDED SOURCES

15 Boats, **16** airplanes, and **17** freight trains all emit GHGs but are excluded from the Detroit GHG inventory, as are emissions from the production of **18** food and **19** goods (like cell phones and refrigerators) that are consumed in the city but produced elsewhere.

Figure ES-2: What Is Included in the Detroit GHG Inventory?

Key Findings

Results from 2011 and 2012 show that citywide emissions were nearly equal, with approximately 10.6 million metric tons (million t) of carbon dioxide equivalents (CO_2e) emitted in both 2011 and 2012,[5] as illustrated in Figure ES-3.

Because emissions values (and their proportional composition) were nearly identical across the two analysis years, most of the analyses in the report present 2012 emissions for simplicity. However, complete 2011 results and figures are included as appendices to the report.

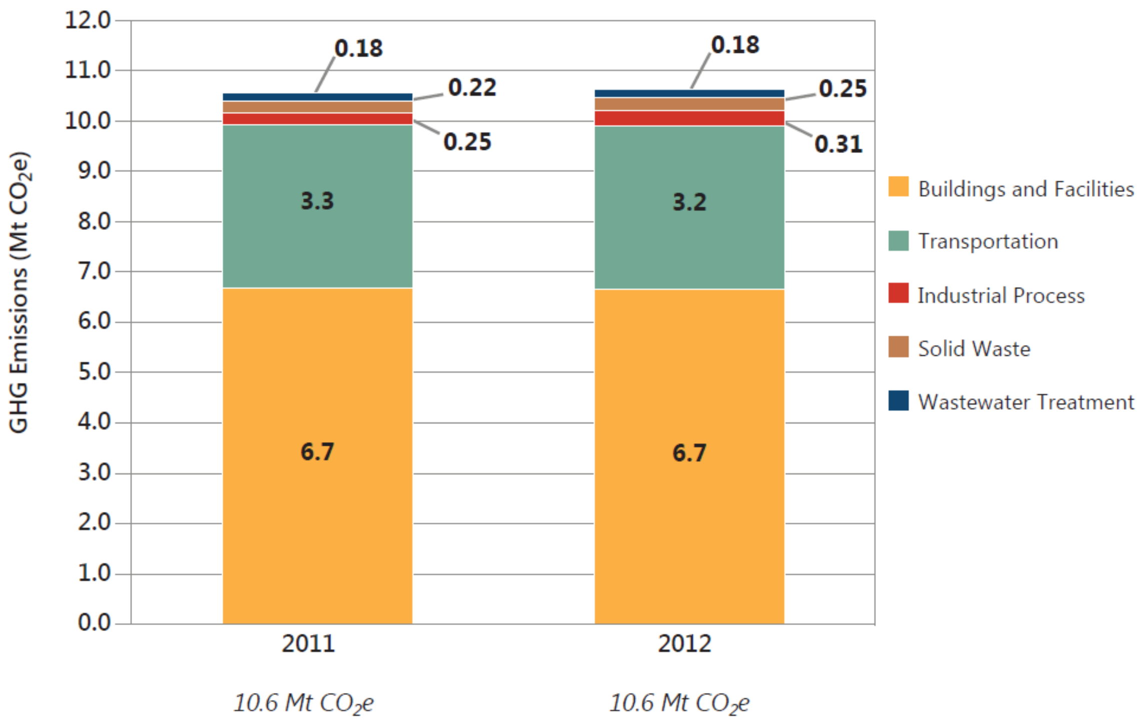


Figure ES-3: Detroit Citywide GHG Emissions by Activity (million t CO2e)

In 2012, 63% of Detroit's citywide emissions (6.7 million t CO_2e) were a result of electricity and natural gas used in buildings and facilities within the city limits (Figure ES-3); these buildings and facilities include residential, commercial and institutional, and industrial customers of DTE Energy, the city's primary utility company. Electricity use in the city contributed 45% to 2012 citywide emissions, due in part to DTE Energy's fuel mix, which consists of more than 75% coal.[6]

---

[5] While this approximately 1% increase (about 0.07 million t CO_2e) in total citywide GHG emissions was found between 2011 and 2012, it is important to keep in mind that this difference (or its directionality) may not be significant in reality, given the precision and comprehensiveness of data, methods, and models used.

[6] DTE Energy (2014)

Detroit's citywide emissions per person or per capita emissions (15.2 t CO_2e/person) were approximately 27% less than the United States average per capita emissions (20.7 t CO_2e/person) in 2012, as illustrated in Figure ES-4.

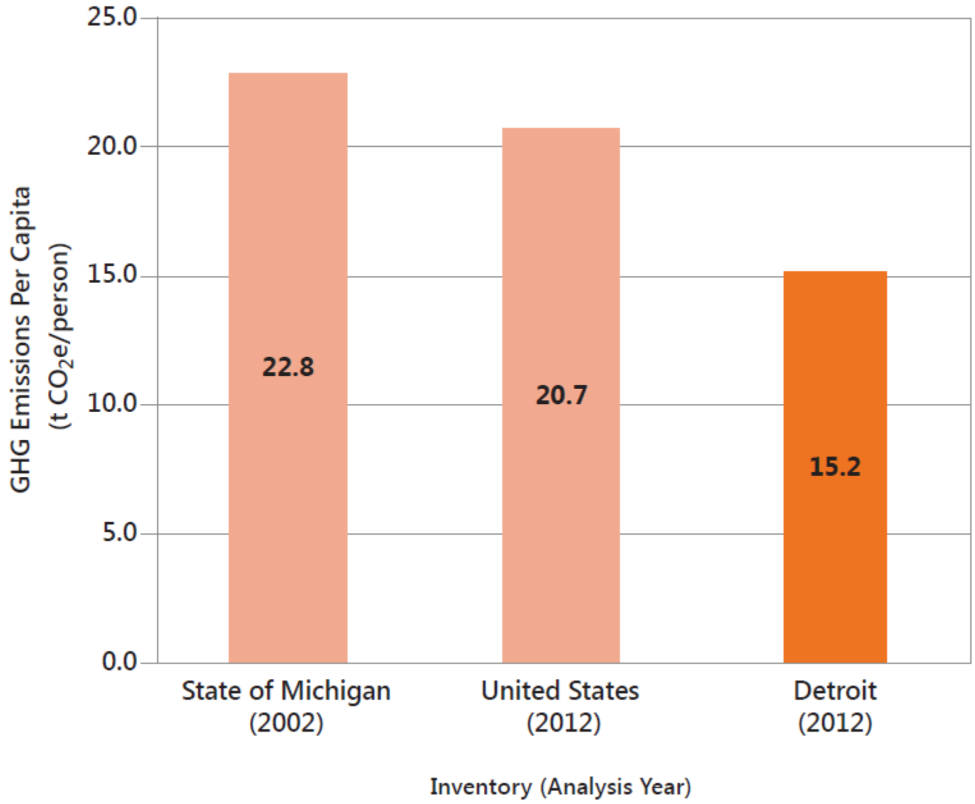


Figure ES-4: U.S., Detroit, and State of Michigan per Capita Emissions Comparison (t CO2e)

Detroit's per capita emissions are lower than both the national and State of Michigan[7] averages in this comparison. The difference can be attributed in part to the fact that inventory accounting standards and available data for national and state-level inventories tend to be more comprehensive (in the GHGs, activities, and emission sources included) than those of local GHG inventories. While the 2012 per capita emissions in Detroit are lower than those reported by the State of Michigan in 2002, Detroit, as a more urbanized area, may still have relatively higher and more concentrated amounts of commercial and industrial activity, as well as greater energy demand, than many other areas of the state. Accordingly, when comparing and differentiating these local, regional, and national inventories it is important to carefully examine the potential differences in methods and drivers of emissions at different scales of analysis.

In a comparison of fourteen select North American cities, Detroit's total 2012 citywide emissions (10.6 million t CO_2e) fell below the sample's average (14.8 million t CO_2e), as illustrated in Figure

[7] A GHG inventory completed for the State of Michigan by the University of Michigan Center for Sustainable Systems presents statewide emissions from 2002 (Bull et al. 2005). Michigan has not updated its inventory since this time. It is important to keep in mind the difference in the inventory analysis years and that the state's emissions per person may have changed since the analysis cited here was performed.

ES-5, which summarizes the total citywide emissions of the sampled cities. While the cities selected for this comparison have some similarities, it is important to keep in mind that their inventories, populations, and infrastructure are all quite different from one another. They have, for example, conducted inventories for a range of different years and have used different geographic boundaries, assumptions, protocol resources, and methods than the City of Detroit analysis. As a result, this comparative analysis is only meant to provide a high-level view of the range of emissions contributed by different cities and Detroit's relative position in this sample.

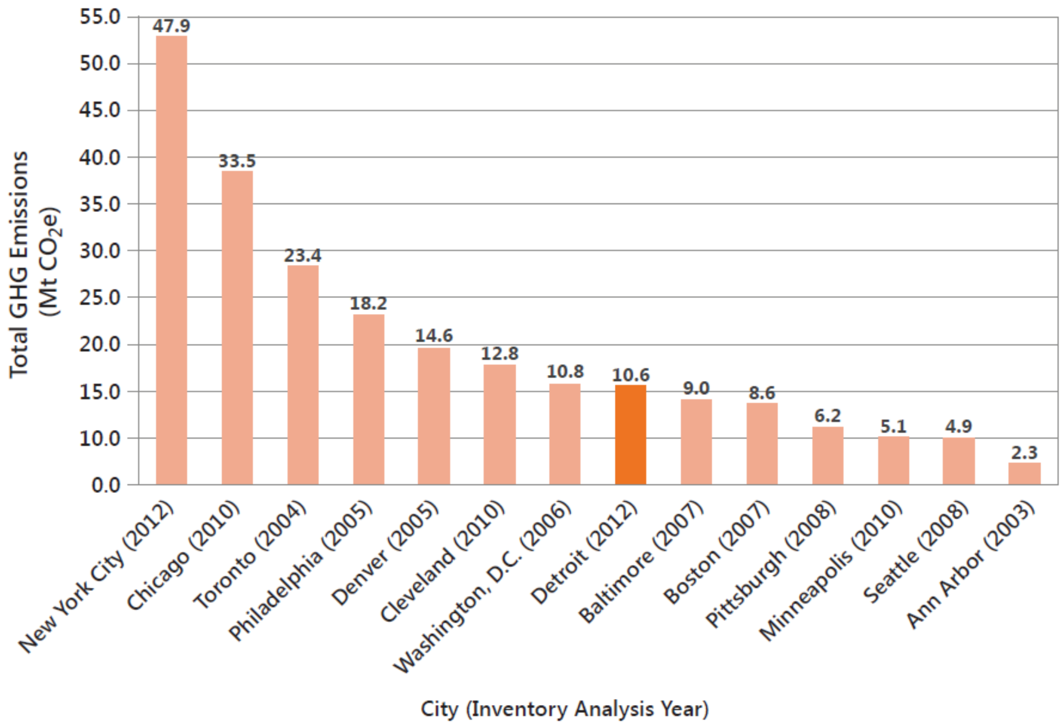


Figure ES-5: Comparison of Citywide Emissions from Select North American Cities (million t CO_2e)

Other Citywide Key Findings

- Approximately 41% of emissions from stationary sources, such as buildings and facilities, are concentrated in four of Detroit's thirty Zip Codes (these high-emitting Zip Codes are 48217, 48209, 48211, and 48226);
- The Commercial and Institutional end-use sector—which includes retail goods and services, non-profit agencies, and academic institutions—accounted for more than 50% of the buildings and facilities total emissions in 2012;
- Passenger car, truck, and on-road freight contributed 98% of total citywide transportation emissions. The municipal government vehicle fleet and public transportation vehicles contributed only 2% of citywide transportation emissions;

- Two industrial process facilities, the Air Products and Chemicals Inc. hydrogen facility and the Marathon Petroleum Co. petroleum refinery, are responsible for 3% of total citywide emissions; and
- Carbon sequestration from tree canopy cover—estimated to be slightly more than 0.07 million t CO_2e annually—is relatively small compared to the citywide emissions total (i.e., less than 1% of that total). Nonetheless, this supplemental land use analysis is of great interest to Detroit stakeholders, who are particularly interested in land use mitigation strategies, given the city's size, the amount of vacant land, and the potential for co-benefits to climate adaptation and public health goals from urban forests.

Municipal Inventory Key Findings

- City of Detroit's municipal government operations accounted for 11% (1.18 million t CO_2e) of 2012 emissions, as shown in Figure ES-6.

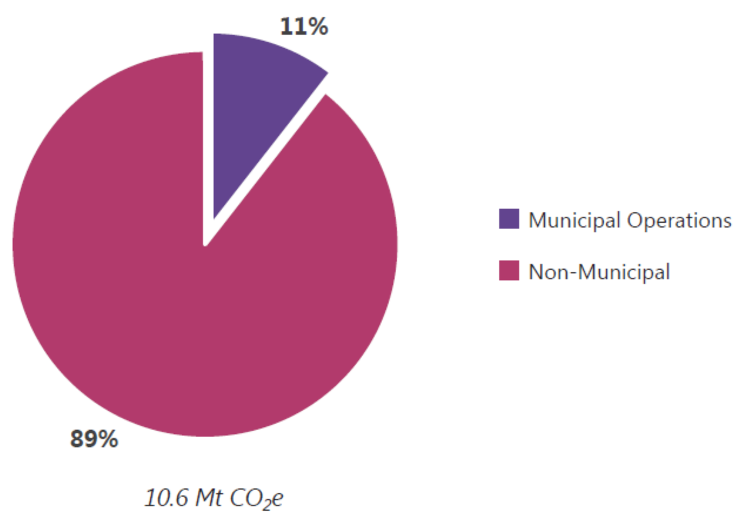


Figure ES-6: Detroit Municipal Operations GHG Emissions as a Percentage of Citywide, 2012

- In 2012, four City of Detroit departments (Detroit Water and Sewerage Department, Detroit Public Lighting Department, Detroit Department of Public Works, and Greater Detroit Resource Recovery Authority) were responsible for 93% of City of Detroit's municipal emissions.

Conclusions and Next Steps

A coalition of community, government, private sector, and academic leaders are in the early stages of developing a strategy to address climate change and incorporate climate change mitigation and adaptation into long-term planning decisions in the City of Detroit. Adaptation and mitigation choices in the near-term will affect the risks that climate change imposes locally throughout the

coming century. This report, in analyzing the GHG emissions of the City of Detroit, identifies key activities and sectors at both citywide and municipal operations scales that contribute the largest relative amounts of GHG emissions. Drawing from the results, activities can then be targeted for improvement and mitigation.

The City of Detroit GHG inventory supports ongoing work in Detroit that seeks to establish emissions reduction and energy efficiency targets. It also encourages the development of both implementation strategies and a system to conduct future inventories in order to benchmark progress over time.

Improving the inventory process, conducting regular inventories, and incorporating these inventory results into decision-making will be critical for evaluating progress toward emissions reductions targets and for identifying cost-savings opportunities in the future.

As a result, in order to continue to build momentum around this work and to improve future inventory processes, the project team recommends that DCAC and the City of Detroit prioritize the following:

- Conduct citywide and municipal GHG inventories at regular time intervals to monitor and to evaluate progress toward emissions reductions goals and impacts from policy changes;
- Collaborate across organizations and departments to facilitate efficient, accurate, and timely data collection for tracking activities and emissions;
- Consider measurable climate mitigation, efficiency improvements, and climate adaptation actions synergistically.

To produce the first inventory of Detroit's GHG emissions, the project team spent more than a year gathering and analyzing data and consulting with more than 50 organizations in and around the city. Once a preliminary inventory report was completed in April 2014, the project team continued to engage with the Detroit community and DCAC in order to strengthen the impact of this work, by verifying GHG inventory results presented in this preliminary report with additional support from the University of Michigan Center for Sustainable Systems, undertaking a report review and vetting process, and hosting a presentation and discussion of inventory results with data contacts and DCAC stakeholders.

Next steps in the DCAC process include beginning to share inventory results more broadly through publically available materials, presentations, and stakeholder meetings. In addition, materials developed by this project will assist in the development of future Detroit GHG inventories, the continued reporting by the City of Detroit to the Carbon Disclosure Project, and ultimately the development of a comprehensive Detroit Climate Action Plan.

2012 CITY OF DETROIT CITYWIDE GHG INVENTORY: BY THE NUMBERS

10.6 million	t CO_2e: total citywide emissions
5.74 million	megawatt hours of electricity used citywide
288 million	Ccfs of natural gas used citywide
5.80 billion	vehicle miles traveled in Detroit
1.18 million	t CO_2e: total municipal government emissions
1.32 million	gallons of gasoline combusted in municipal government vehicles
5.04 million	gallons of diesel combusted in municipal government vehicles
197,000	gallons of biodiesel combusted in public buses
50	organizations in and around the City of Detroit consulted during inventory project

INTRODUCTION

As climate change accelerates, cities in the United States and around the world have embraced the importance of developing more formalized local and regional climate action plans to address challenges compounded by climate change, challenges similar to those Detroit currently faces. Climate action plans help cities mitigate greenhouse gas (GHG) emissions, adapt to the effects of climate change, and incorporate climate change considerations into long-term policy and planning.

In Detroit and Southeastern Michigan, the impacts of climate change have begun to strain the capacity of the electricity grid, increase health-related ailments caused by poor air quality and heat waves, change agricultural practices and yields, and make transportation within the Great Lakes more difficult as water levels change. Climate projections suggest that changes will accelerate; the U.S. Environmental Protection Agency (U.S. EPA) estimates that within a few generations, summers in the Midwest will be similar to the current summers in Arkansas or Mississippi.[8]

The City of Detroit is home to just over 700,000 residents,[9] has a growing number of corporate headquarters and small businesses, and has a vibrant community of residents working hard to improve the long-term sustainability of the city. At the same time, the city is also in the midst of confronting myriad social, economic, and environmental challenges. Climate change exacerbates many of these challenges. However, comprehensive, collaborative climate mitigation and adaptation actions can alleviate many of these social, economic, and environmental issues, providing co-benefits that simultaneously reduce costs, reduce climate vulnerability, and improve quality of life for Detroit residents.

In the face of local challenges related to climate change and long-term city planning, Detroiters Working for Environmental Justice (DWEJ), a non-profit environmental justice organization, initiated collaboration with the City of Detroit, various Detroit stakeholders, the University of Michigan Center for Sustainable Systems, and several departments at the University of Michigan to develop a climate action plan for the city. This multi-stakeholder climate planning effort called the Detroit Climate Action Collaborative (DCAC), which includes various private and public stakeholders, aims to increase Detroit's climate change preparedness and find cost-effective ways to reduce Detroit's GHG emissions.[10]

---

[8] U.S. EPA (2013a). For additional information on climate impacts and vulnerabilities in Detroit, see the University of Michigan report Foundations for Community Climate Action: Defining Climate Change Vulnerability in Detroit (Gregg et al. 2012).
[9] Estimated 2012 population, U.S. Census (2014)
[10] See a full description of DCAC participants and process on the DWEJ website (http://www.dwej.org/do/dcac/).

In March 2013, a group of graduate students from the University of Michigan School of Natural Resources and Environment (SNRE)[11] partnered with DWEJ and DCAC to develop the first comprehensive inventory of Detroit's GHG emissions, the results of which are included in this final inventory report.

Broadly defined by the U.S. EPA, a GHG inventory is "an accounting of greenhouse gases emitted to or removed from the atmosphere over a period of time" and provides an indicator of local contribution to climate change.[12] Greenhouse gas inventories help set a baseline from which to create emissions reduction targets and to measure impacts of mitigation and adaptation strategies. While GHG inventory methodologies vary, these inventories can be bounded either geographically (e.g., at the local or citywide, regional, or national levels) or at the institutional level (e.g., municipal, corporate, or university inventories).

GHG inventories have become an important planning tool for local governments in the face of climate change, especially where states and cities—at least in the U.S.—have taken on a larger leadership role in an absence of robust national policy.[13] An inventory for the State of Michigan, for example, was released in 2002, followed subsequently by the report entitled 'Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World" in 2007, and the Michigan Climate Action Council's Climate Action Plan.[14]

Furthermore, cities have often taken the lead in local climate planning efforts "because of their proximity to the public and their focus on providing day-to-day services," which, as a result, can make cities "more pragmatic than senior levels of government."[15] More than 170 local governments have joined the "Cities for Climate Protection Campaign" through ICLEI Local Governments for Sustainability (ICLEI),[16] conducting GHG inventories or undertaking climate action planning efforts.[17] Thousands of communities, including the City of Detroit, have signed on to the U.S. Conference of Mayors Climate Protection Agreement to reduce emissions at or below 1990 baseline levels, in accordance with Kyoto Protocol[18] targets.[19] These local climate actions have occurred due to a variety of reasons including the opportunity for cost-savings from reduced energy use and for greater resilience in the face of more severe weather.

---

[11] The project team includes SNRE Master's students Jill Carlson, Jenny Cooper, Marie Donahue, Max Neale, and Anis Ragland. This team conducted the Detroit inventory as their Master's Project, which fulfills the school's M.S. degree requirement that students complete a significant capstone project.

[12] U.S. EPA (2013b)

[13] Lutsey and Sperling (2008)

[14] Bull et al. (2002), Edison et al. (2007), and MDEQ (2009)

[15] Hoornweg et al. (2011)

[16] Originally founded in 1990 as the "International Council for Local Environmental Initiatives", ICLEI-Local Governments for Sustainability is an international membership association of localities working toward sustainability goals. In particular, ICLEI-Local Governments for Sustainability provides numerous local GHG accounting tools and resources.

[17] Wheeler (2008), pp. 481

[18] The Kyoto Protocol is "an international agreement linked to the United Nations Framework Convention on Climate Change, which commits its Parties by setting internationally binding emission reduction targets" (UNFCCC 2013).

[19] Former City of Detroit Mayor Kenneth Cockrel, Jr., signed the Climate Protection Agreement in January 2009 (U.S. Mayors 2013).

Rationale for a GHG Inventory and Climate Action

Climate Change Science

Global climate change is one of the greatest challenges of our time. Our daily lives are intimately linked to the natural and atmospheric systems that support us, and climate change significantly alters those systems. The earth's atmosphere contains greenhouse gases (GHGs). While some GHG emissions come from natural processes (e.g., decomposition of previously living organisms, natural fires, volcanic eruptions), many GHG emissions are a direct result of human activity (e.g., energy used to heat our homes, the burning of fossil fuels for transportation, land use change). As outlined by the Intergovernmental Panel on Climate Change (IPCC), GHGs commonly associated with human activities include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), and the fluorinated gases sulfur hexafluoride, perfluorocarbons, and hydrofluorocarbons (SF_6, PFCs, HFCs, respectively).[20]

The concentrations of GHGs in the atmosphere regulate the earth's climate. This is due to the "greenhouse effect"—a process by which incoming solar radiation (energy from the sun) is absorbed by the earth's surface and reradiated as infrared energy (often experienced as heat). Some of this infrared energy is then trapped by GHGs in the earth's atmosphere, which in turn warms the earth's surface and regulates global temperatures.[21] This phenomenon is illustrated in Figure 1.

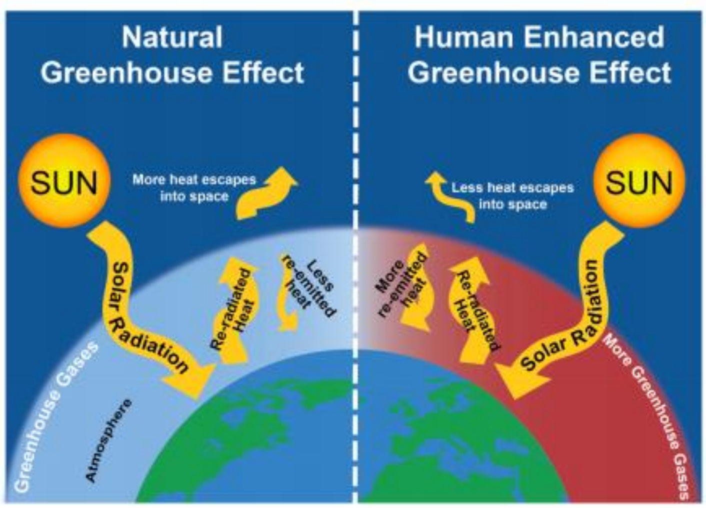


Figure 1: Illustration of the Greenhouse Effect[22]

As emissions-intensive human activities increase the concentration of GHGs in the atmosphere, the enhanced greenhouse effect causes an increase in trapped infrared energy (heat energy), which in turn further warms the temperature of the air, land, and water, causing climate change.

Greenhouse gas emissions from human activities have drastically changed the composition of earth's atmosphere over the past 150 years. The atmospheric concentration of GHGs recently

[20] IPCC (2013)
[21] CSS (2013a)
[22] CSS (2013a)

surpassed 400 parts per million (ppm), rising from 285 ppm in the pre-Industrial Revolution period, with greater than 40% more CO_2 in the atmosphere than there was in the 1800s.[23] Such dramatic increases in GHG concentrations are directly correlated with a rise in global average temperature, which has increased 0.8°C (1.4°F) since the start of the 20th century.[24]

While such temperature changes may seem small, they are by no means trivial. The natural systems that sustain us are highly sensitive to small perturbations in temperature. For example, sustained changes in average air temperature affect the frequency and intensity of storms and droughts, water levels in lakes, heat waves, and wind patterns, all of which in turn impact human societies and ecosystems.[25]

Never before in human history has the earth's system undergone such a rapid change in atmospheric concentrations of GHGs.[26] The resulting changes in climate, at both global and local scales, are straining the capacity of ecosystems and human societies to adapt.

Climate Vulnerability in Detroit

The City of Detroit and the greater Southeastern Michigan region are already experiencing climate change, and current science suggests that impacts of climate change will increase over time.[27] According to the U.S. EPA, the frequency and intensity of heat waves and precipitation events will increase as a result of rising air, water, and land temperatures.[28]

The Natural Resources Defense Council (NRDC) predicts that the average excessive heat event[29] days per summer in Detroit (based on data from 1975-1995) will increase from nine to 15 days by mid-century, and 36 days by the end of the century, due to climate change assuming a business-as-usual GHG emissions scenario, where emissions continue to increase. Further, they predict that the city's average mortality per summer from excessive heat event days (based on data from 1975-2004) will increase from 52 to 185 deaths by mid-century, and more than 450 by the end of the century. By these measures, Detroit is considered the second-most climate change impacted city of the 40 largest cities in the United States.[30] These impacts have a disproportionate effect on sensitive or vulnerable populations that include those over 65 years of age, children, and those living in poverty. Infrastructure, such as buildings or facilities that are prone to flooding or that

---

[23] National Research Council (NRC) (2012), p. 7; U.S. National Academy of Sciences (NAS) (2014), p. 10
[24] NAS (2014), pp. 3
[25] IPCC (2013)
[26] Testing air bubbles trapped in ice cores from Antarctica, scientists have shown variations in CO_2 concentrations that are currently higher than any time in the past 800,000 years (NRC 2012, p. 7).
[27] Walsh and Wuebbles (2013)
[28] U.S. EPA (2013a)
[29] Excessive heat event days, according to NRDC's definition, occur "when a location's temperature, dew point temperature cloud cover, wind speed and surface atmospheric pressure throughout the day combine to cause or contribute to heat-related deaths" (NRDC 2012). The temperature threshold to calculate excessive heat event days for a specific location often varies from one region to another.
[30] NRDC (2012)

have poor cooling capacity, further exacerbates climate vulnerability[31] in the built, urbanized environment of Detroit.[32]

As part of its planning process, DCAC has established partnerships to analyze the unique climate and vulnerability context in which Detroit is situated. The Great Lakes Integrated Sciences and Assessments Center (GLISA) published a report on the climate impacts that the city will likely face using down-sized climate models, which outlines expected increases in precipitation and extreme heat events.[33] Additionally, DCAC worked with the University of Michigan Taubman College of Architecture & Urban Planning to conduct assessments of the impacts and vulnerabilities that the city and its residents have begun to experience and will continue to face as a result of climate change.[34]

Both GLISA and the Taubman College studies have found that heat exposure and increased precipitation events are critical climate impacts to address in Detroit. In addition, they outline that strategic changes in land use (e.g., planting trees or reducing impervious surfaces in flood-prone areas) and increases in the accessibility of cooling centers are examples of actions that can help reduce climate vulnerability.

Given the climate change projections in the near- and long-term, and the climate vulnerabilities that Detroit faces, this GHG inventory seeks to assist the city and its residents in incorporating climate change planning into long-term decision-making, which can increase climate resilience and reduce GHG emissions in the future.

Mitigation of GHG Emissions, Efficiency Improvements, and Cost Savings

While the threat of climate change is formidable, there are many actions that Detroit and its residents can simultaneously take to limit the growth of GHG emissions and to improve energy or operational efficiency of city systems. These actions can build on existing programs in Detroit that already work to improve quality of life and reduce energy use through energy efficiency efforts, ultimately resulting in cost savings and a strengthened economy.

A GHG inventory is the first step to assess the sources of GHG emissions and to account for the quantity of these emissions, and in turn can be used to inform policy and management decisions to reduce emissions and identify opportunities for efficiency gains. As highlighted by the "GHG Inventory in Action" examples featured throughout this report, cities across North America have undertaken specific climate actions that have resulted in win-wins for both climate mitigation and energy efficiency.

---

[31] Climate vulnerability is defined as the extent to which a system (e.g., a nation, region, community, or household) is exposed to, sensitive to, and/or unable to cope with the harmful effects of climate change, such as climate variability and extremes in temperatures and precipitation patterns.

[32] Larsen et al. (2011)

[33] The full report of "The Potential Impacts of Climate Change on Detroit, Michigan" is available online, as is a one-page executive summary (GLISA 2013).

[34] Gregg et al. (2013)

There are many examples of energy efficiency-related programs already underway in collaboration with the City of Detroit, which have likely reduced emissions and are projected to result in cost savings. For instance, a partnership between the City of Detroit General Services Department (GSD), NextEnergy, and Clean Energy Coalition to improve city-owned building efficiency was completed with 10-year projected energy and operations savings of more than $36 million[35] and set the stage for the city's involvement with the Carbon Disclosure Project (CDP).[36] The City of Detroit began formally reporting to the CDP in 2013 (in which emissions data from 2011 were reported).

Another example is the creation of the Detroit Future City (DFC) Strategic Framework, a long-term strategy for decision-making, and its recommendations for the city to install more energy efficient lighting, transportation, and water infrastructure as part of the 'City Systems Element' of the DFC implementation plan.[37]

Finally, at the regional level, the Southeast Michigan Regional Energy Office collaborated with the U.S. Department of Energy-funded BetterBuildings for Michigan program to offer low-cost energy audits in the Detroit metropolitan region that have "helped people learn more about their homes" in addition to rebates and financing to make it "easy for residents to make energy efficient improvements."[38] This three-year program ended in June 2013 with energy-saving upgrades in 500 Southeastern Michigan homes, which has resulted in an average saving of $580 per year per home and a reduction of 5,000 t CO_2. Additionally, over 1,000 Detroit homes received air-sealing programs resulting in between 20% and 30% reductions in their energy bills.

GHG Inventory Framework

What is a GHG Inventory?

A GHG inventory typically accounts for GHG emissions (generated and sequestered) from human activities within a specified geographic or organizational boundary on an annual basis and is used for planning and policy purposes. Typical activities that generate emissions in cities include but are not limited to energy use in buildings (e.g., electricity or natural gas), transportation, industrial processes, and waste disposal and treatment.

This accounting of GHG emissions is conducted using activity data, such as kilowatt hours (kWh) of electricity or gallons of gasoline, instead of direct emissions monitoring. The activity data are multiplied by an emission factor (or the GHG intensity of the activity) to estimate GHG emissions,

---

[35] Based on 3% inflation of annual energy and operations savings. These estimated savings are enough to heat and power about 1,680 homes per year for 10 years (City of Detroit 2012).
[36] The Carbon Disclosure Project is a global system for both companies and cities to measure, disclose, manage, and share vital environmental information, including climate indicators like annual GHG emissions or energy use. More information on the Cities Program is available via the Carbon Disclosure Project Cities Program Portal.
[37] Released in January 2013, the Detroit Future City (DFC) Strategic Framework outlines strategies for long-term planning using the framework of Economic Growth, Land & Buildings Resources, City Systems, Land Use, and Neighborhoods (DFC 2013). To learn more about the Detroit Future City strategic plan and ongoing implementation efforts, visit their website at: http://detroitfuturecity.com.
[38] Southeastern Michigan Regional Energy Office (2013)

as shown in the equation illustrated in Figure 2.

Different activities emit various types of GHGs, each of which have a distinct contribution to the greenhouse effect and relative impact on the global climate. Some GHGs are more potent or may stay in the atmosphere for a longer period of time than others. This "potency"—both in time and impact—is expressed as a GHG's Global Warming Potential (GWP) and is referenced to CO_2, which has a GWP value of 1.

$$\underset{\textit{(activity units)}}{\text{Activity Data}} \; * \; \underset{\left(\frac{\textit{t GHG emitted}}{\textit{unit activity}}\right)}{\text{Emission Factor}} \; * \; \text{GWP} \; = \; \underset{\textit{(t CO}_2\textit{e)}}{\text{Emissions}}$$

Figure 2: Equation of Standard GHG Emissions Calculation in CO_2e

Emission factors vary based on activity and type of energy used, and they enable the calculation of particular GHG emissions. CO_2 is the most highly concentrated anthropogenic GHG. As a result, GHG emissions occurring over a period of time are typically reported in the standard unit of metric tons of CO_2 equivalent.

What Is A Metric Ton of CO_2?

A metric ton (or tonne) is a metric system unit of mass. It is abbreviated as a lowercase "t" in the International System of Units or 'SI' system. One metric ton is equivalent to 1,000 kilograms (kg) or about 2,205 pounds (lb).

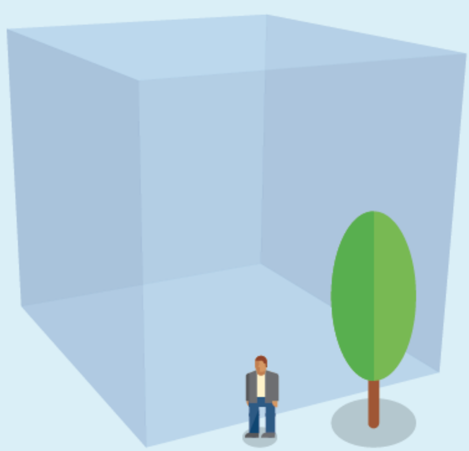


Figure 3: A Metric Ton of CO_2 Shown in Proportion to a Person and a Tree

The cube illustrated here in Figure 3 shows the approximate size of one metric ton of CO_2 found in the atmosphere. One million metric tons is indicated by the SI symbol "Mt;" however, in this report we use the delineation "million t" to express the quantity of GHG emissions in CO_2e.

If you drove from Detroit to Ann Arbor 60 times, you would emit a single metric ton of CO_2. That may not seem like much, but in that single metric ton of CO_2 emitted, there are approximately 13.7 x 10^{27} or 13.7 billion billion billion molecules of CO_2![i]

i. Utilizing the U.S. EPA Greenhouse Gas Equivalencies Calculator (U.S. EPA 2014a), we calculated that 1 t CO_2 is emitted from burning 113 gallons (gal.) of gasoline in a passenger vehicle. According to U.S. EPA fuel economy trends (U.S. EPA 2013b), the 2012 average fuel economy of passenger cars was 23.6 miles per gallon (mpg). One could drive approximately 2660 miles on 113 gal. of gas (U.S. EPA 2014a). The driving distance from Ann Arbor to Detroit is about 43 miles; therefore, driving from Detroit to Ann Arbor 60 times – or commuting back and forth for one month - would emit approximately 1 t CO_2. Molecular calculation: there are 1,000,000 g in 1 t CO_2. There are 44 g of CO_2 in 1 mol of CO_2 and there are 6.022 x 10^{23} molecules of CO_2 in one mol. Therefore, there are approximately 13.7 x 10^{27} molecules of CO_2 in that box. Or 13.7 billion billion billion CO_2 molecules.

Local GHG Inventory Protocols

Various resources exist to standardize the approaches used to quantify GHG emissions from a community or organization and to produce a GHG inventory. These protocols include both proprietary and nonproprietary resources and software programs that help communities and institutions model, estimate, and account for their GHG emissions in a standardized way. Protocol resources specify recommended primary activity data to collect—what is within "scope" or boundary of the inventory—and standard emission factors used in calculating GHG emissions from that activity data.

Available Local GHG Inventory Protocol Resources

In general, inventory protocols outline accounting standards to estimate GHG emissions from various sources and activities. Specifically, "local" GHG protocols are designed to help communities conduct citywide or municipal inventories. Other common protocols aid businesses or institutions, such as universities, develop inventories.

The following protocol resources were referenced during this project:

- ICLEI Community Protocol[ii]
- ICLEI Local Government Operations Protocol[iii]
- U.S. EPA State and Local Climate and Energy Program GHG Inventory Guidance and Resources, including the release of a draft version of the Local Government Greenhouse Gas Inventory Tool (forthcoming) and other modeling resources[iv]
- The Climate Registry[v]
- World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD)[vi]

ii. ICLEI (2012)
iii. ICLEI et al. (2010)
iv. U.S. EPA (2013c and 2013d)
v. Climate Registry (2013)
vi. WRI and WBCSD (2012)

Standard protocols recommend that local GHG inventories account when possible for emissions from the following six GHGs: carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulfur hexafluoride (SF_6), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs).

In accordance with standard protocol, local GHG inventories are generally production-based, accounting for emissions produced from activities that occur in-boundary.[39] An alternative to production-based inventories is a consumption-based approach, which accounts for emissions associated with the creation and transportation of goods and services that are consumed in a given location, even if those emissions occur outside of the boundary. Recent research indicates

[39] Peters and Hertwich (2008), Peters (2008), Dodman (2009)

that, in particular for metropolitan areas, consumption-based inventories could more accurately characterize GHG emissions driven by community demand, as these inventories treat the locality as a demand center, with goods shipped in and wastes shipped out.[40] Additionally, an inventory could include the full life cycle emissions of goods and services consumed—but the Detroit GHG Inventory does not. While these consumption-based and life cycle inventory approaches are becoming more common, production-based inventories continue to be the recommended standard of most protocols at this time. For this reason and because production-based inventories provide local institutions, residents, and government officials with data essential to accounting for activities for which these communities have ownership and control, this analysis uses a production-based approach.

By convention, GHG inventories report in-boundary sources and activities associated with both direct (Scope 1) and indirect (Scope 2 and Scope 3) emissions from the organization or community—defined in the callout box below.

Defining Inventory Scope

The term “scope” refers to a general organizing framework developed in protocols to categorize emissions from a company or institution as direct or indirect, upstream or downstream, and out-of-boundary for standardized accounting purposes. It remains common for these organizational categories to be used in local GHG inventories to orient the audience to what is or is not included in a given analysis. The common scopes are defined as:

Scope 1: Direct GHG emissions (except for direct CO_2 emissions from biogenic sources).

Scope 2: Indirect GHG emission associated with consumption of purchased or acquired electricity, steam, heating, or cooling.

Scope 3: All other indirect emissions not covered in Scope 2, such as life-cycle emissions resulting from the extraction and production of purchased materials and fuels, transport-related activities in vehicles not owned or controlled by the reporting entity (e.g., employee commuting and business travel), outsourced activities, etc.).

A visual commonly used to illustrate the concept of ‘scope’ can be found in Appendix A. Additional detail on what is or is not included in the boundary of the Detroit GHG Inventory analyses follows in subsequent sections of this report.

A visual representation of emission scopes and what is or is not included in the Detroit GHG inventory is illustrated in the subsequent infographic (Figure 4), on the following page.

[40] *Ibid.*

WHAT IS INCLUDED IN THE DETROIT GREENHOUSE GAS INVENTORY?

Nearly all of our daily activities cause greenhouse gas (GHG) emissions. The Detroit GHG Inventory is an accounting of the GHG emissions from activities in Detroit. It is a tool to guide policy and management decisions to address climate change.

SCOPE 1

All activities within the City boundary that directly emit GHGs

Forms of transportation like **1** cars, **2** trucks, **3** buses, and **4** the People Mover contribute to GHG emissions. **5** Industrial processes like refining oil also produce GHGs, as does **6** treating the water that goes down our sinks and toilets, and **7a** using natural gas to heat our homes.

SCOPE 2

GHG emissions that result from the production of purchased electricity that is generated outside of Detroit (indirect emissions)

Buildings and facilities, including **7b** homes, **8** commercial buildings, and **9** municipal government buildings purchase electricity for power and cooling. Electricity is also purchased to **10** pump water through pipes to our faucets. The production of this electricity, at **11** power plants outside of Detroit, emits GHGs.

SCOPE 3

Other indirect emissions

Some electricity is lost when transmitted through **12** power lines; the production of this electricity emits GHGs. **13** Trees and other plants sequester GHGs through growth and emit GHGs when cut down. **14** Landfills outside Detroit that contain garbage from the city also emit GHGs.

EXCLUDED SOURCES

15 Boats, **16** airplanes, and **17** freight trains all emit GHGs but are excluded from the Detroit GHG inventory, as are emissions from the production of **18** food and **19** goods (like cell phones and refrigerators) that are consumed in the city but produced elsewhere.

Figure 4: What Is Included in the Detroit GHG Inventory?

City of Detroit GHG Inventory

City of Detroit Inventory Objectives

The Detroit GHG inventory aims to:

1) Provide a baseline from which to create efficiency and emission reduction targets at both citywide and municipal government levels by identifying Detroit's major activities and sources of emissions; and
2) Provide a baseline from which to measure the effects of climate action.

In addition to these objectives, the inventory seeks to be descriptive, transparent, and accessible to a range of stakeholders and audiences in the City of Detroit and beyond.

Overview of Detroit Inventory Analyses

This report contains the results of two distinct analyses, as illustrated in Figure 5:

1) A **citywide** inventory of GHG emissions associated with or driven by activities within the geographic, jurisdictional boundary of the City of Detroit;[41] and
2) A **municipal** inventory of GHG emissions associated with City of Detroit municipal government operations (this analysis is a subset of the larger, citywide total).

Figure 5: Detroit Municipal Inventory as Subset of Citywide Inventory

Both of these analyses were conducted for the calendar years of 2011 and 2012. While some additional data for 2005 and 2010 were collected, complete citywide inventory data for these or earlier years were not available because of difficulty in retrieving certain records due to data collection and archiving systems.

[41] In general, the citywide inventory accounts for emissions associated with human activities within the Detroit city limits. However, certain emission sources that are standard to include and accounted for in the citywide analysis do occur outside the city limits but are driven by activities or demand from within the city. For example, emissions from electricity used in Detroit but generated at power plants outside the city are included, as are emissions from municipal solid waste produced in the city but disposed of at landfills outside the city. Additional discussion of this complexity follows and is illustrated in Figure 6.

The broad categories of emissions activities accounted for in the Detroit citywide inventory are outlined in Figure 6. This conceptual map also illustrates the complexity associated with delineating a GHG inventory system boundary. The figure shows that while emissions are primarily associated with sources within Detroit's geographic boundary (i.e., its city limits), a portion of citywide emissions are driven by activities occurring outside of the city. These sources are included in the inventory analysis where appropriate, based on protocol, existing infrastructure, and jurisdictional control. More information about exact emissions sources included in this inventory can be found in the methods outlined in the subsequent Detroit Citywide Inventory section and report appendices.

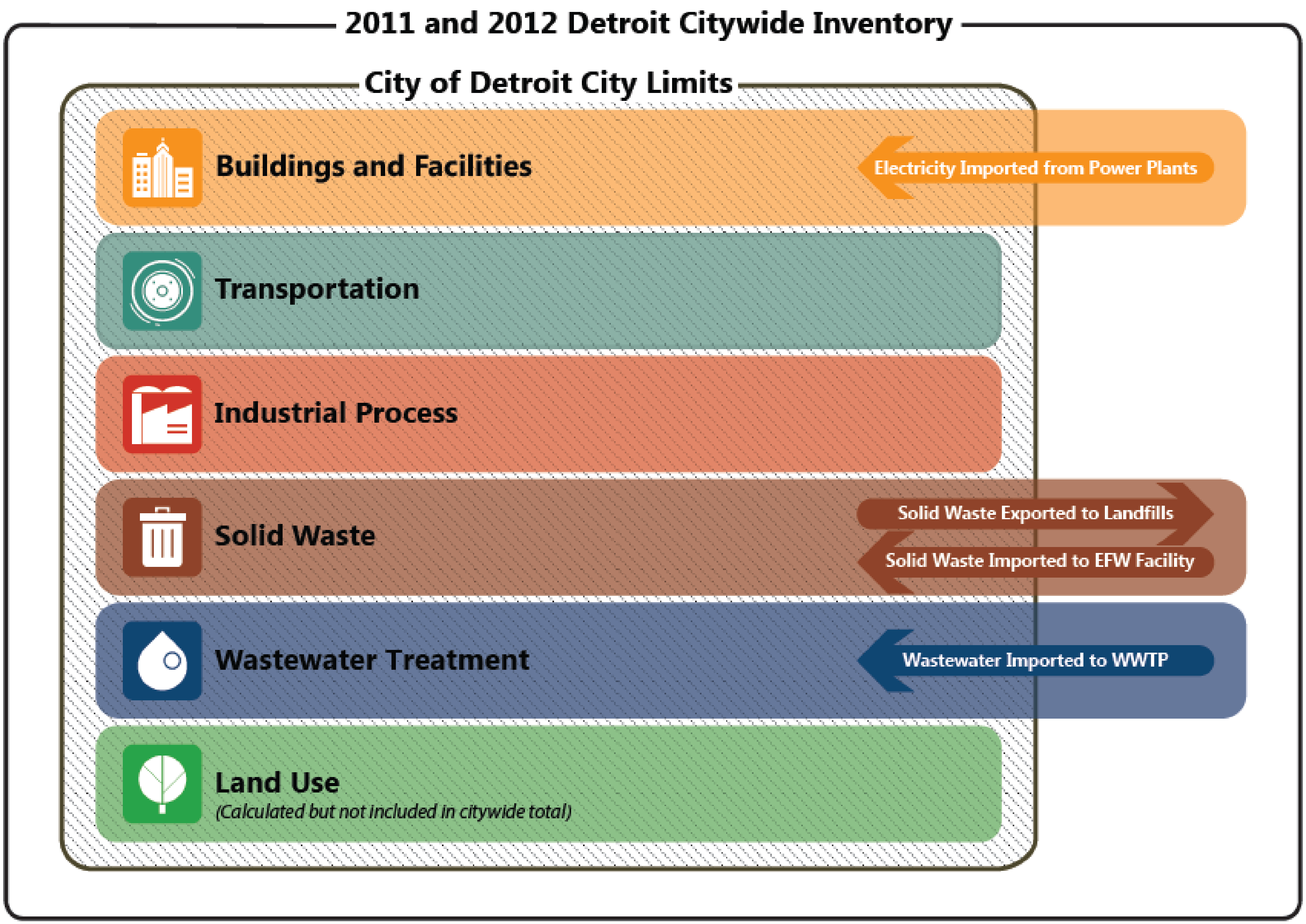


Figure 6: Detroit GHG Inventory System Boundary

The Detroit inventory analyses account for primary activities and sources that produce CO_2, CH_4, and N_2O within the boundary of the city. The specific GHGs accounted for in the Detroit inventory analyses and the associated activities and sources are illustrated in Table 1.

Table 1: GHGs Included in the Detroit Inventory[42]

Included in Total Citywide Emissions		**Greenhouse Gas**		
Activity	**Source**	**CO_2**	**CH_4**	**N_2O**
Buildings and Facilities	DTE Energy Electricity Fuel Mix	✓	○	○
	Purchased Electricity from the Grid	✓	✓	✓
	Natural Gas	✓	-	-
Transportation	Community Passenger Car, Truck, and On-Road Freight	✓	✓	✓
	Municipal Fleet	✓	○	○
	People Mover	✓	✓	✓
	SMART Bus	✓*	○	○
Industrial Process	Hydrogen Production	✓	-	-
	Petroleum Refining	✓	✓	✓
Solid Waste	Incineration	✓*	✓	✓
	Landfill	*	✓	
Wastewater Treatment	Sludge Incineration	*	✓	✓
	Fugitive Emissions from Effluent Discharge	-	-	✓
	Process Emissions from Wastewater Treatment	-	-	✓

Not Included in Total Citywide Emissions		**CO_2**	**CH_4**	**N_2O**
Land Use	Tree Canopy (Carbon Sequestration)	✓	-	-

Table Key	
✓	Occurring, accounted for in inventory analyses
-	Not occurring
○	Occurring, not accounted for due to data unavailability or likelihood of small impact
*	Indicates source of biogenic CO_2;[43] No sources of biogenic CO_2 are included in this inventory, except for minimal biogenic emissions from combustion of biodiesel in the SMART Bus.

[42] Natural gas systems produce CH_4, but the combustion of natural gas does not produce CH_4. It is important to note that CH_4 from leakage of natural gas systems is not included in this inventory.
[43] Biogenic CO_2 emissions are carbon dioxide emissions resulting from the combustion, decomposition, or processing of organic materials (other than fossil fuels, peat, and mineral sources of carbon) through combustion, digestion, fermentation, or decomposition processes. Specifically in the context of local GHG inventory accounting protocols, biogenic CO_2 is not included in the emissions total, as those emissions would occur naturally when the organic material breaks down over time. As such, only the gases that occur directly from anthropogenic sources are included. As illustrated in Table 1, solid waste incineration includes both biogenic (not included) and anthropogenic (included) CO_2 emissions. The combustion of biodiesel in the SMART Bus is also a source of biogenic and anthropogenic CO_2 emissions, which at the time of this analysis were not able to be reported separately.

The GWP values of these gases used in this report are those recommended by ICLEI Protocol (2012); they are summarized in Table 2. While CO_2 is the primary GHG emitted from human activities, each additional unit of the less prevalent gases CH_4 and N_2O has a higher impact on the greenhouse effect and therefore a higher corresponding GWP.

Table 2: Global Warming Potentials of Detroit Inventory GHGs[44]

Greenhouse Gas	GWP
Carbon Dioxide (CO_2)	1
Methane (CH_4)	21
Nitrous Oxide (N_2O)	310

Source: IPCC Second Assessment Report (1995)

While emissions of high GWP gases (SF_6, HFCs, and PFCs) occur in the City of Detroit,[45] emissions of these gases were not characterized during data collection due to data unavailability and time cost to pursue—in addition, precedent set by protocols and local GHG inventories from other North American cities have not commonly accounted for these emissions. High GWP gases are predominantly emitted from leaks, service, or disposal of refrigerants (as used most familiarly in car air conditioners), aerosol propellants, solvents, and fire retardants (where they were used as a substitute for ozone-depleting substances under the Montreal Protocol[46]). Also, high GWP gases are emitted from certain industrial processes and equipment used to transmit and distribute electricity. If any facility in the City of Detroit were to emit a critical amount of high GWP gases, it would have been reported under the U.S. EPA Greenhouse Gas Reporting Program (GHGRP). No facility in the City of Detroit reported high GWP gas emissions during the inventory years studied.[47]

In short, the inventory methods, which determined what is or is not included in our analyses, have been informed by data availability, protocol documentation, and modeling tools from ICLEI, U.S. EPA, as well as peer-reviewed literature and sector-specific resources.

[44] GWP values used are 100-year IPCC values, recommended by ICLEI (2012) for consistency across local GHG inventory accounting. Although these values are somewhat outdated and do not reflect the most recent science (i.e., IPCC GWP calculations have been updated in recent assessments to reflect more refined changes to the relative contribution of each GHG), the Second Assessment Report values are most commonly used by GHG inventories at this time (ICLEI 2012).

[45] To estimate the potential contribution of high GWP gases to the City of Detroit's GHG emissions, we examined the high GWP gas contribution to the State of Michigan's 2002 GHG Inventory (Bull et al. (2005)). The State of Michigan inventory determined approximately 1.8% of state's GHG emissions came from high GWP sources, specifically substitution of ozone-depleting substances, electrical transmission and distribution, and magnesium processing.

[46] The Montreal Protocol is an international treaty designed to protect the ozone layer by phasing out the production of numerous substances that are responsible for ozone depletion.

[47] For more information on the U.S. EPA GHGRP, visit the database's "Who Reports?" page, which includes valuable information on the reporting criteria for industries, based on activity and emissions threshold. (U.S. EPA 2013e and U.S. EPA 2013f).

Detroit Citywide Inventory

Overview

Methods

During the project planning and data collection phases of the project, over 50 different organizations provided primary data or consultation and additional guidance on the project, which ensured the analysis would be as comprehensive as possible. For a detailed list of data sources and stakeholder outreach consulted over the course of the project, see Appendix B.

When local data was not available or its quality suspect, every attempt was made to model or approximate emissions for those activities—instances where such assumptions were made or models used are indicated in the methods sections of the inventory.

The citywide GHG inventory of Detroit accounts for 2011 and 2012 emissions from the following activities:

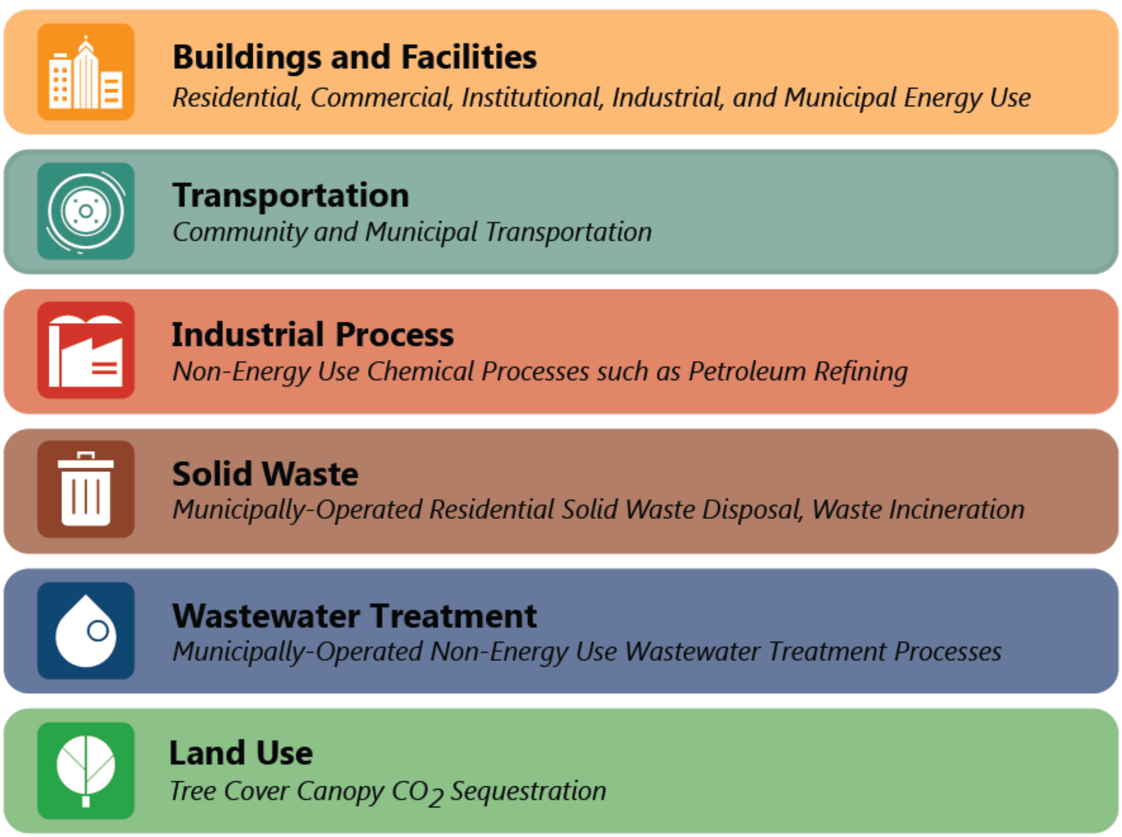


Figure 7: Summary of Detroit Emission Sources and Activities

Emissions sequestered from land use are not included in the calculation of total citywide emissions. Rather, they are reported separately because land use activities have not been incorporated into local community protocols to date.[48]

The emissions from boats, airplanes, marine and railroad freight, and inter-city passenger trains, as well as agriculture and fertilizer applications within the city, were not accounted for in the citywide inventory.

In the following sections, an analysis of total citywide emissions is presented, followed by methods and discussion for each category of activity. The total citywide emissions are analyzed by general activity, energy carrier, stationary versus other sources, and then disaggregated further by specific emission sources, end-use sectors, or City of Detroit departments, categories determined to be useful for future decision-making.

Results

Total annual citywide GHG emissions were found to increase by approximately 0.07 million t CO_2e between the two analysis years, as shown in Figure 8.[49] Given that citywide emissions—both in quantity and the proportional contribution from sources—remained relatively consistent between these years, much of the analysis in this report focuses on 2012 emissions. For charts and complete results for the 2011 analysis, please refer to Appendices F and G.

The largest source of citywide GHG emissions in 2012 was energy use in buildings and facilities (electricity and natural gas) contributing 6.7 million t CO_2e, followed by activities associated with transportation (3.2 million t CO_2e). In relative terms, buildings and facilities' energy use accounted for 63% of total 2012 citywide emissions, while the transportation sector contributed approximately 30% to the total.

---

[48] There are efforts underway to establish more standardized land use calculation methodologies to incorporate this activity more robustly within citywide analyses and to use in future local GHG inventories.

[49] While this approximately 1% increase (about 0.07 million t CO_2e) in total citywide GHG emissions was found between 2011 and 2012, it is important to keep in mind that this difference (or its directionality) may not be significant in reality, given the precision and comprehensiveness of data, methods, and models used.

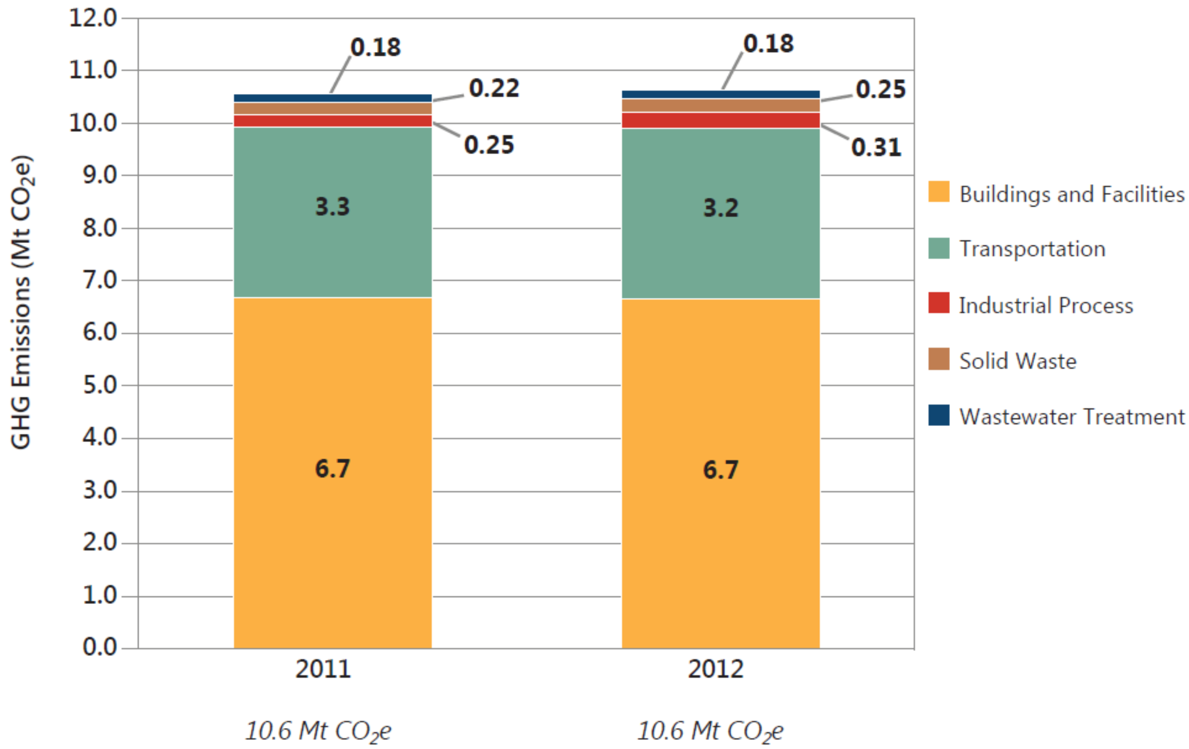


Figure 8: Detroit Citywide GHG Emissions by Activity (million t CO_2e)

The consumption of energy, whether in the form of electricity or fuel, drives total emissions for buildings and facilities as well as transportation. Therefore, the energy efficiency of the building stock or vehicle fleet greatly influences the emissions from these sources.

Emissions from industrial processes, solid waste landfills and incineration, and fugitive, process, and incineration emissions from wastewater treatment combined contribute approximately 7% to Detroit's 2012 citywide emissions.

Citywide GHG Emissions by Scope 1, 2, and 3

In Table 3, the citywide inventory direct and indirect emissions results are summarized in terms of GHG inventory protocol "Scope."

Table 3: Summary of Citywide Emissions Reported by Scope

	2011		2012	
	Emissions (million t CO_2e)	**% of Total**	**Emissions (million t CO_2e)**	**% of Total**
Scope 1	5.7	54%	5.5	52%
Scope 2	4.5	43%	4.8	46%
Scope 3	0.3	3%	0.3	3%
Citywide Inventory Total*	**10.6**	**100%**	**10.6**	**100%**

*Note that totals may not add up precisely due to rounding.

Recall, Scope 1 refers to any direct, in-boundary emissions—and here accounts for more than 50% of citywide emissions in both 2011 and 2012. On the other hand, Scope 2 and Scope 3 are indirect emissions. The largest driver of indirect Scope 2 emissions, which make up 46% of emissions in the 2012 inventory, is electricity demand from generation facilities outside the City of Detroit. For an illustration of examples of Detroit citywide emission sources by scope, please refer to Figure 4, earlier in the report.

As shown in Figure 9, electricity is the predominant carrier[50] of GHG emissions in 2012, contributing 45% of citywide emissions. The combustion of gasoline, diesel, and biodiesel for on-road passenger cars, trucks, freight, public transportation, and the City's municipal fleet are responsible for approximately 30% of citywide emissions each year.[51]

[50] The term 'carrier' refers to the end source of energy and/or emissions, such as electricity or unleaded gasoline.

[51] Steam used for heating and cooling of buildings is generated at the energy to waste (EFW) facility located within the city boundary from burning solid waste. Therefore, emissions associated with steam generation are accounted for in the solid waste activity, and not in buildings and facilities to avoid double counting.

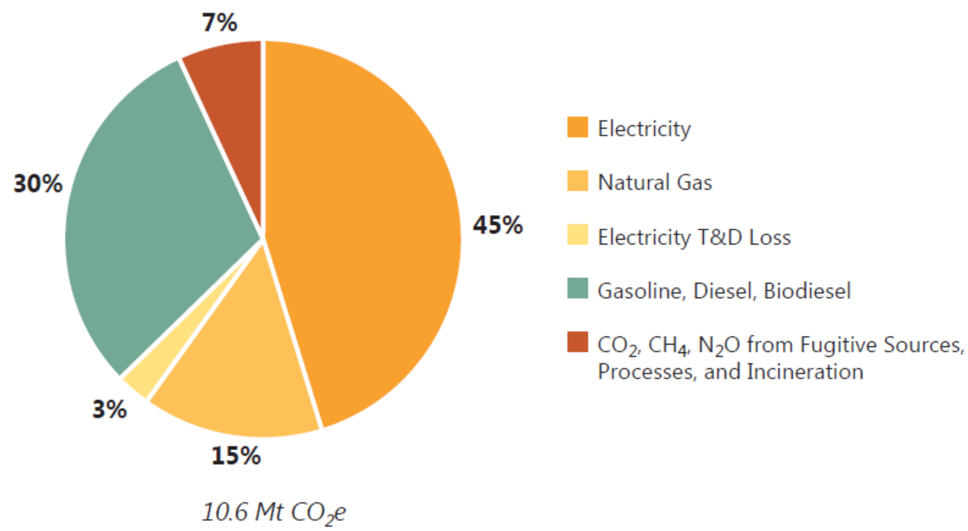


Figure 9: Detroit Citywide GHG Emissions by Carrier, 2012

DTE Energy is the primary utility in Southeastern Michigan and the Detroit metropolitan region and provides electricity and natural gas to City of Detroit households and businesses. In 2012, DTE Energy power plants (all of which currently operate outside of the City of Detroit) generated on-site approximately 79% of the electricity they provided to customers. The other 21% was purchased from other utilities through the electricity grid. As shown in Figure 10, DTE Energy's fuel mix in 2012 predominantly consisted of coal (76%). Other electricity was generated from nuclear power, natural gas, hydroelectric plants, and renewable energy sources.

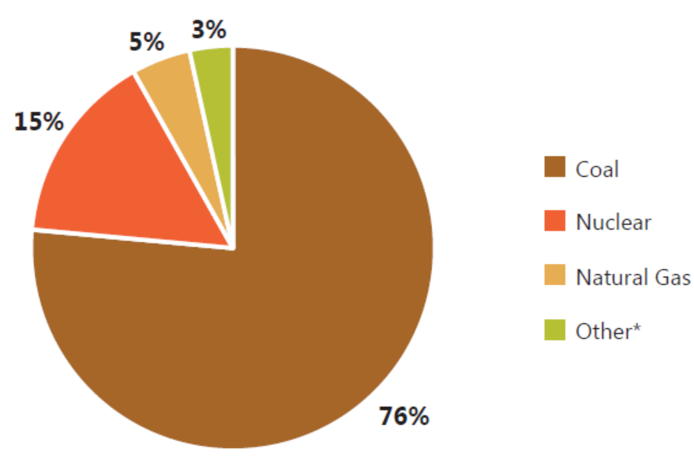


Figure 10: DTE Energy Electricity Generation Fuel Mix, 2012

**Category 'other' includes renewable energy sources (Wind, solar, hydroelectric, biomass, biofuel, wood, solid waste incineration) and Oil; percentages do not total 100% due to rounding.*

The CO_2 emissions of electricity generation vary greatly depending on the fuel mix used to produce the electricity; in particular, emissions depend on what is burned at a conventional power

plant and what other generation sources are integrated into the grid (nuclear power, renewable energy solar panels or wind turbines, hydroelectric power, etc.). As shown in Table 4, coal produces more CO_2 per Btu compared to natural gas. In other words, to produce the same amount of electricity, a plant powered by coal would emit approximately 70% more CO_2 per kWh than one powered by natural gas.[52]

Table 4: CO_2 Produced from Fossil Fuel Generated Electricity[53]

Fuel Type		Lbs of CO_2 per Million Btu	Heat Rate (Btu per kWh)	Lbs CO_2 per kWh
Coal	Bituminous	205.30	10,107	2.08
	Sub-bituminous	212.70	10,107	2.16
	Lignite	215.40	10,107	2.18
Natural Gas		117.08	10,416	1.22
Distillate Oil (No. 2)		161.39	10,416	1.68
Residual Oil (No. 6)		173.91	10,416	1.81

Source: EIA (2014a)

GHG Inventory in Action: Pittsburgh

Ramping Up Solar Power

Having recently completed a climate action plan, Pittsburgh **hired a Sustainability Coordinator to help in its implementation**. The expansion of solar power to meet 0.5% of all electricity needs in the short-term is one strategy included in the climate action plan. Pittsburgh is on track to meeting this goal with the assistance of a **U.S. Department of Energy (DOE) solar initiatives grant ($200,000).** Through this funding, Pittsburgh will work toward a replicable solar program that can be implemented elsewhere across the country.[vii]

vii. ICLEI (2014a)

Like other large cities, Detroit has unique infrastructure, a diverse building stock, and a range of industries, which correspond to large variations in the energy use and associated GHG emissions of city neighborhoods. As such, data has been collected to disaggregate stationary source emissions by Zip Code, allowing for spatial analysis of how these emissions vary across the city as a whole. As shown in Figure 11, approximately 70% of total citywide emissions are stationary (i.e., they are attributed to a fixed, immobile location such as a home, industrial plant, or office space)

[52] This relative CO_2 emissions difference compares carbon intensities per kWh of bituminous coal and natural gas found in Table 4.

[53] In the 1970s, DTE Energy primarily burned bituminous coal from the eastern U.S for electricity generation. More recently, the company has used a mix of eastern bituminous and western low-sulfur sub-bituminous coal (primarily to reduce SO_2 emissions) for electricity generation. Bituminous coal is the type of coal found predominantly in the Appalachian Mountains and other parts of the Midwestern United States (DTE Energy 2014).

and have a Zip Code identifier associated with its data set.[54] These stationary emissions are generated from energy use from buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment and do not include mobile sources of emissions or those occurring outside of the city limits (e.g. solid waste landfill disposal).

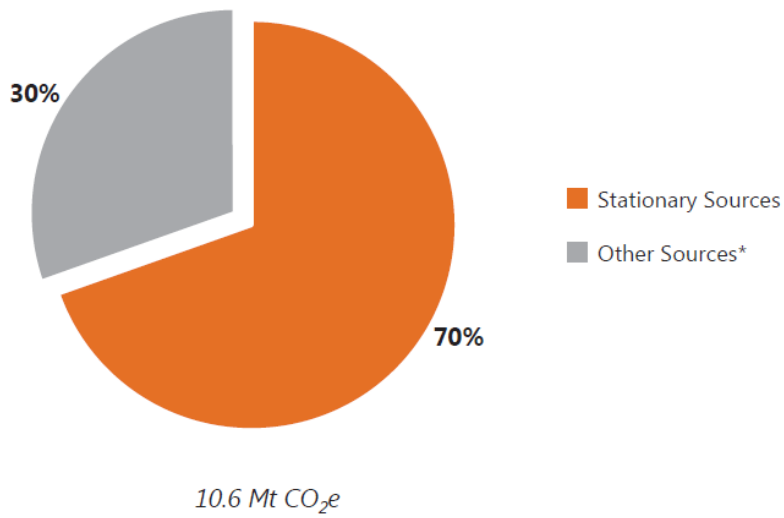


Figure 11: Detroit Citywide Stationary GHG Emissions vs. Other GHG Emissions Sources, 2012

**Category 'Other Sources' includes emissions from mobile sources, such as passenger cars, municipal fleet vehicles, and public buses, as well as solid waste landfill disposal, which occurs outside the jurisdictional boundary of Detroit.*

The stationary GHG emissions data and corresponding Zip Code identifiers made the subsequent spatial analysis possible. The following map (Figure 12) provides a greater understanding about where stationary GHG emissions sources were most concentrated within the city. To further understand the underlying drivers of top GHG-emitting Zip Codes, GHG emissions by Zip Code were disaggregated by end-use sector, as illustrated by Figure 13.

Of the 70% of citywide emissions from stationary sources (shown previously in Figure 11), approximately 41% of these emissions occurred in only four Zip Codes (48217, 48209, 48211, and 48226) of the 30 Zip Codes of Detroit, as shown by the map in Figure 12. In other words, stationary sources of emissions in four Zip Codes account for 29% of Detroit's total citywide emissions. As the map shows, these four Zip Codes are primarily concentrated in the Southwest, Midtown, and Downtown areas of Detroit. Future analyses could include GHG emissions hot spots from mobile sources within the city.

The higher annual stationary GHG emissions attributed to the top four Zip Codes are primarily derived from the Industrial end-use sector and Commercial and Institutional end-use sector. The

[54] While some Zip Codes extend beyond the City of Detroit jurisdictional boundary and include other neighboring municipalities (e.g. Hamtramck or Highland Park, MI), the emissions reported include those associated with stationary sources exclusively within the City of Detroit and not emissions from neighboring communities.

large industrial emission sources, shown in Figure 13, that include electricity and natural gas use, petroleum refining at the Marathon Petroleum Co. refinery, and hydrogen production are concentrated in Zip Code 48217. The three other top Zip Codes' emissions are primarily driven by Commercial and Institutional activities, which include wastewater treatment at the DWSD wastewater treatment plant (Zip Code 48209), electricity and natural gas use from municipal departments, solid waste incineration (Zip Code 48211), and electricity and natural gas use from non-profits, academic institutions, health care facilities, and any other commercial or institutional entities. Emissions in the northwestern, western, and northeastern Zip Codes in Detroit are primarily driven by Residential end-use sector electricity and natural gas that is used for heating, cooling, and powering homes and apartment buildings.

In addition to the figures below, a detailed table of stationary emissions by Zip Code for 2011 and 2012 can be found in Appendix F, and the map of 2011 stationary emissions results (showing similar spatial distribution of stationary emissions compared to those in 2012) can be found in Appendix G.

GHG Inventory in Action: Toronto

Exceeding Emissions Reduction Targets

The **City of Toronto has successfully reduced its GHG emissions to below 1990 levels, decreasing its emissions in 2012 by 15 percent.** To reach this goal, Toronto implemented aggressive building codes such as the "Green Roof Bylaw," where any new commercial, institutional and residential development with total floor area larger than 2,000 sq. meters had to install green roofs. The City of Toronto also helped partially fund the installation of a Deep Lake Water Cooling system, which uses heat transfer technology and water from Lake Ontario to cool buildings in the city, reducing peak demand for electricity on hot days and the city's reliance on air conditioning from fossil-fuel based energy.[viii]

viii. City of Toronto (2014)

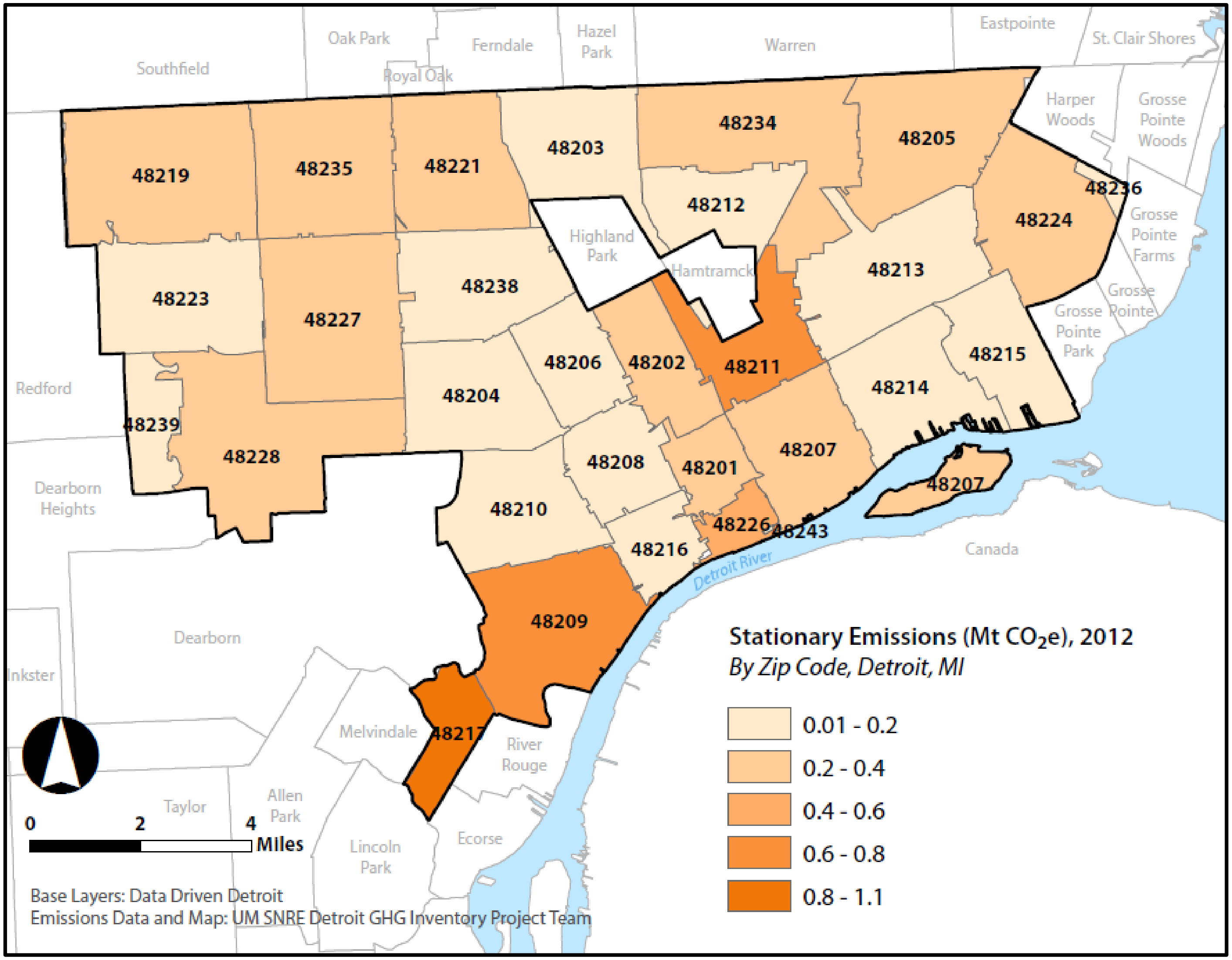


Figure 12: Detroit Citywide Stationary GHG Emissions by Zip Code, 2012

Stationary sources include energy use in buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment. Emissions from transportation and solid waste landfill disposal are not included in this map.

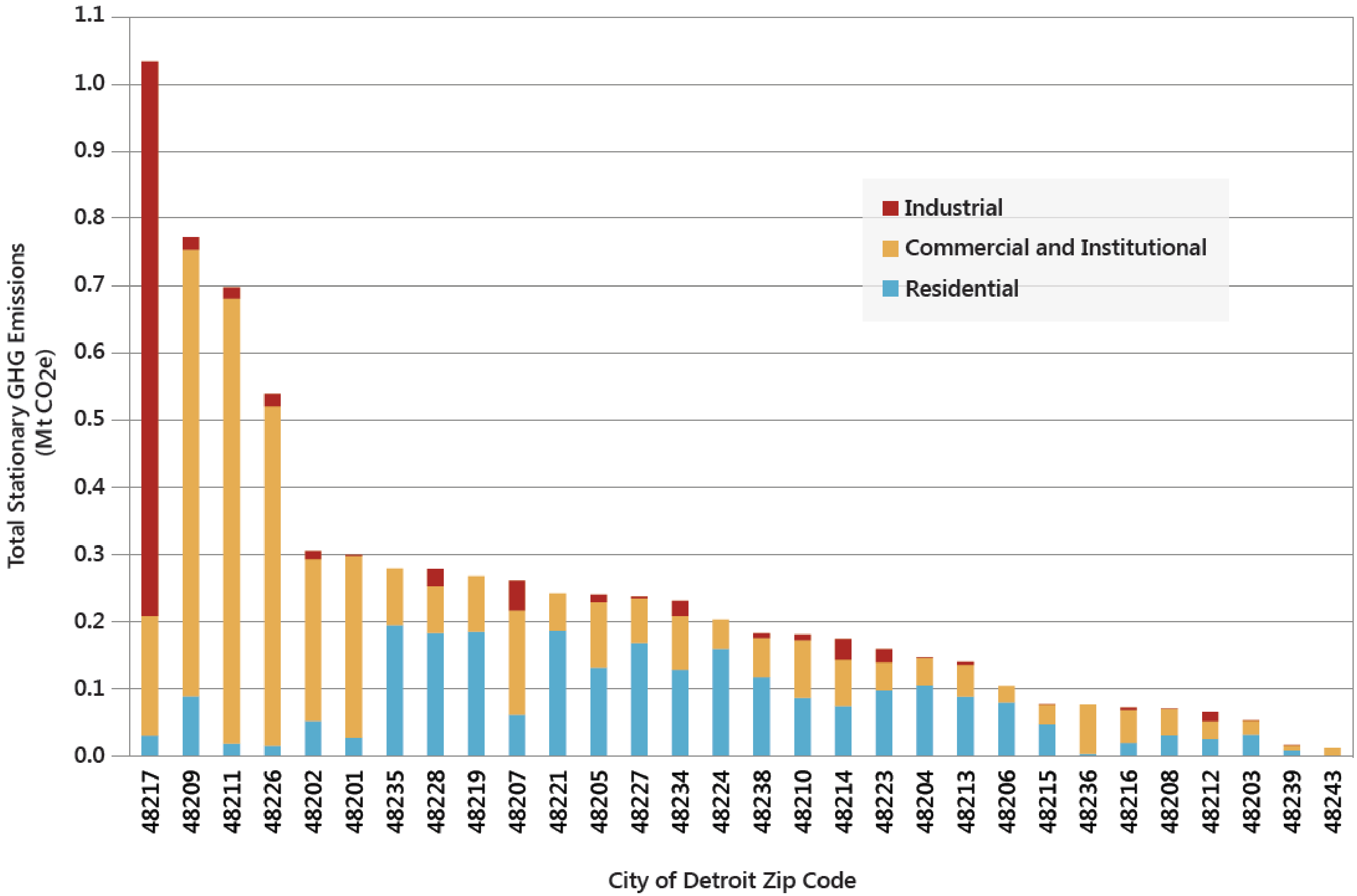


Figure 13: Detroit Citywide Stationary GHG Emissions by Zip Code and End-Use Sector, 2012

Buildings and Facilities

Methods

The citywide buildings and facilities activity includes GHG emissions associated with electricity generation and on-site stationary combustion of natural gas for heating, cooling, and powering Detroit's residential, commercial and institutional, and industrial buildings. Emissions in the buildings and facilities activity are also associated with the generation of electricity that is lost due to transmission and distribution (T&D) through the grid; as these losses vary geographically, a regional-specific line loss emission factor was used in this analysis. For the GHG emission calculations from building and facility energy use, DTE Energy, the utility company that serves Detroit,[55] provided electricity and natural gas consumption data as well as generation and grid emissions factors for 2011 and 2012, which were multiplied together to yield emissions.

Buildings and facilities emissions data can be classified into three end-use sectors[56] of (1) commercial and institutional, (2) residential, and (3) industrial. The commercial and institutional end-use sector includes non-profits, government agencies, and businesses primarily involved in the sale of goods or services (such as restaurants, hotels, retail stores). The residential end-use sector is comprised of private dwellings such as apartment buildings and houses. And lastly, the industrial end-use sector includes buildings and facilities owned and operated by industries engaged in activities such as manufacturing, mineral extraction, agriculture, and forestry. Customer classification was determined by either Standard Industry Classification (SIC) codes[57] or other identifiers (e.g., for the residential end-use sector) that were included in DTE Energy activity data—for a detailed explanation of the end-use sector definitions used here, refer to Table 8, in Appendix D.

Results

As shown in Figure 14, commercial and institutional customers were the largest end-use sector of GHG emissions in buildings and facilities, accounting for more than 50% of these emissions in

---

[55] While the Detroit Public Lighting Department (PLD) was once the City of Detroit's primary public electricity utility and managed its own electricity generation, the department has been restructured in recent years. In the inventory analysis years of 2011 and 2012, PLD has been solely an electricity distributor—purchasing electricity from DTE Energy and distributing this electricity to its customers. For the purposes of this analysis, all electricity supplied to City of Detroit customers is accounted for in data provided by DTE Energy (whether directly as DTE customers or indirectly through the Detroit Public Lighting Department's electricity purchases from DTE). This detail of the buildings and facilities accounting methodology was supported by conversations with DTE Energy about the transition of electricity customers from PLD to DTE Energy during the inventory analysis years.

[56] An end-use sector refers to commonly defined activity sectors that are the final or end-users of a good or service (in this case, the service provided is energy); these end-use sectors may include residential, commercial, and industrial customers.

[57] Standard Industry Classification (SIC) codes are a standardized system (currently being replaced by the North American Industry Classification System or NAICS) for use in classifying business establishments for the collection, tabulation, presentation, and analysis of statistical data—these industry identifiers were provided in energy use data provided by DTE Energy and were used to group end-use sectors in this analysis.

2012 (3.5 million t CO_2e). Residential customers contributed approximately 36% (2.4 million t CO_2e) of total buildings and facilities emissions in 2012.

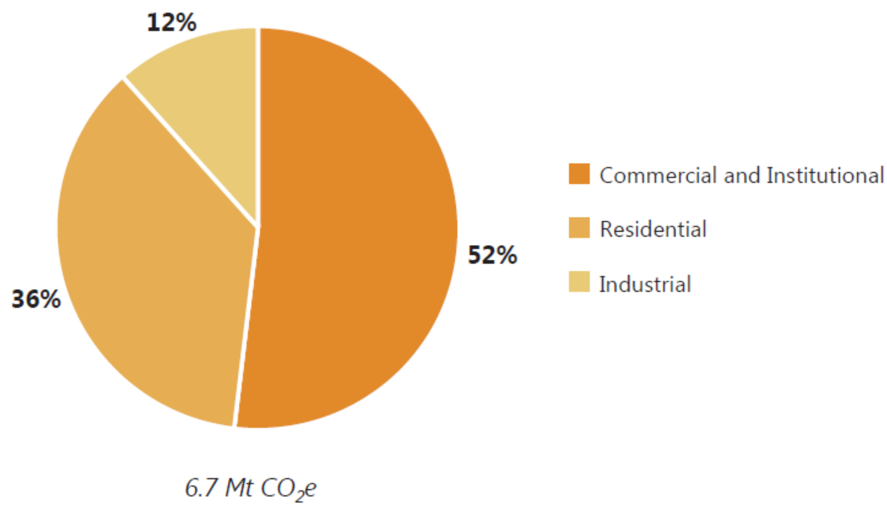


Figure 14: Detroit Citywide Buildings and Facilities GHG Emissions by End-Use Sector, 2012

The analysis of DTE Energy energy use data estimated that about 5.74 million megawatt hours (MWh) of electricity and 288 million ccf of natural gas were used citywide in 2012. This energy use is equivalent to approximately 51.7 billion megajoules (MJ). From this, the GHG intensity *per unit of total energy* used in buildings and facilities can be determined by dividing building and facilities emissions (approximately 6.67 million t CO_2e) by the total energy use in MJ, where the building and facilities' GHG intensity for 2012 could be expressed as 0.000129 t CO_2e per MJ.

A similar calculation can be made to compare the change in GHG emission intensity *per unit of electricity* used between 2011 and 2012, given that DTE Energy's fuel mix and the corresponding electricity emission factor changed between these years. In 2011, buildings and facilities electricity use was responsible for about 4.5 million t CO_2e from more than 21.0 billion MJ or 5.85 million MWh of electricity. In 2012, buildings and facilities electricity use emitted 4.8 million t CO_2e from 20.7 billion MJ or 5.74 million MWh of electricity. As a result, the GHG intensity of electricity use in buildings and facilities increased slightly (about 8.4%) from 0.000215 t CO2e per MJ in 2011 to 0.000233 t CO2e per MJ in 2012—revealing that building and facilities electricity use became more GHG-intensive in 2012 due primarily to changes in the electricity generation fuel mix and corresponding emission factor.

These calculations and comparisons of GHG emission intensity per unit of energy are useful indicators that provide a baseline for understanding how changes in fuel mix or energy use may affect the relative GHG emission intensity reported.

GHG Inventory in Action: Chicago

Chicago Green Business Challenge

The City of Chicago is reaching its climate action plan goals through innovative programming with local private businesses. In 2011, Chicago **saved more than $17 million in energy costs** by reducing energy use and **diverted more than 40% of waste from landfills** through the **Chicago Green Office Challenge**. The challenge included more than 150 participants from commercial property to tenant company managers. These business leaders assist the City of Chicago in reaching some of its climate action goals and are recognized annually at an awards ceremony with the mayor.[ix]

ix. ICLEI (2014b)

Transportation

Methods

GHG emissions from transportation are associated with community-wide sources including the operation of passenger cars, passenger and freight trucks, and the Suburban Mobility Authority for Regional Transportation or SMART Bus routes within the city. Emissions from transportation also include those from public transportation (i.e., from city buses, the Detroit Transit Corporation's People Mover[58]) and the city-operated municipal vehicle fleet.

Emissions from the combustion of gasoline and diesel fuel[59] used in passenger cars, passenger trucks, and on-road freight trucks were calculated based on trips starting and/or ending in the City of Detroit. Southeast Michigan Council of Governments (SEMCOG) data for average weekday vehicles miles traveled (VMT) for trips that start and/or end in the City of Detroit for 2010 was allocated to the City by the ICLEI Origin-Destination model. Average weekday VMT was prorated to a full 7-day week travel via U.S. EPA MOVES. This VMT data was estimated from SEMCOG's regional travel demand model.[60] Emission rates were calculated using U.S. EPA MOVES, a publicly available vehicle emissions modeling simulator and then applied to the VMT data to yield total GHG emissions. VMT data from 2010 were used as direct proxy for both 2011 and 2012 due to variability in projections of VMT trends from 2010 onward in the Southeastern Michigan region.

---

58 Emissions from the People Mover are derived from the amount of electricity used to operate it.

59 In U.S. EPA MOVES simulations, although Compressed Natural Gas (CNG) was selected as a potential vehicle fuel, no vehicles were paired with it, indicating that it is a negligible source of GHG emissions in the City of Detroit. Vehicles and trucks in the City of Detroit may use CNG, but those emissions are not estimated in this report. Similarly, the emissions from vehicles that use electricity were not quantified in this report. Future inventories could attempt to quantify the impacts from these alternative fuels.

60 For more information on private transportation, trends in modeled VMT in the City of Detroit, and how they compare to Wayne County, see the detailed Transportation Methods in Appendix E.

Emissions from city-operated vehicles used for public transportation, specifically, the People Mover and city buses managed by the Detroit Department of Transportation (DDOT), in addition to the city's municipal vehicle fleet (i.e., city-operated vehicles used for maintenance and operations) were calculated using municipal government fuel use or purchase data.[61] Gasoline and diesel fuel purchase data for city government departments (provided by the City of Detroit) were multiplied by U.S. EPA fuel-specific emission factors to yield total emissions. Fuel usage data for DDOT and electricity usage data for the People Mover were extracted from the publicly available Federal Transit Administration's National Transit Database for 2011 and 2012 and multiplied by relevant emissions factors (see Table 7 in Appendix C).

In addition, emissions associated with routes occurring within the city limits from SMART Bus, or the metropolitan commuter bus system, were calculated and added to citywide emissions totals. Fiscal year VMT and biodiesel fuel usage data for SMART Bus were combined with biodiesel emission factors[62] to allocate emissions associated with bus trips that occur within the Detroit city limits.

Results

Recall, transportation emissions in 2012 were 3.23 million t CO_2e, approximately 30% of citywide emissions. As shown in Figure 15, 2012 citywide transportation GHG emissions were dominated by private passenger car, truck, and on-road freight travel, which make up approximately 98% of total transportation emissions. The remaining 2% of GHG emissions from transportation consist of emissions from public transportation (People Mover, DDOT city buses, and SMART Bus) and the municipal vehicle fleet that provides various city services.

---

[61] Emissions associated with Coleman E. Young Municipal Airport, an airport with no commercial passenger flights, are not included in this inventory.

[62] In this inventory analysis, all tailpipe emissions for the SMART Bus—including those associated with biogenic sources—are accounted for and reported. In future GHG inventory analyses, biogenic CO_2 emissions from biodiesel combustion could be reported separately from fossil fuel based CO_2 emissions. Currently, local GHG inventory analyses do not reduce biofuel emissions reported due to *reduced life cycle emissions*, via carbon sequestration from the growing of the crop. As such, this analysis of biodiesel emissions from the SMART Bus is not a life cycle accounting of emissions.

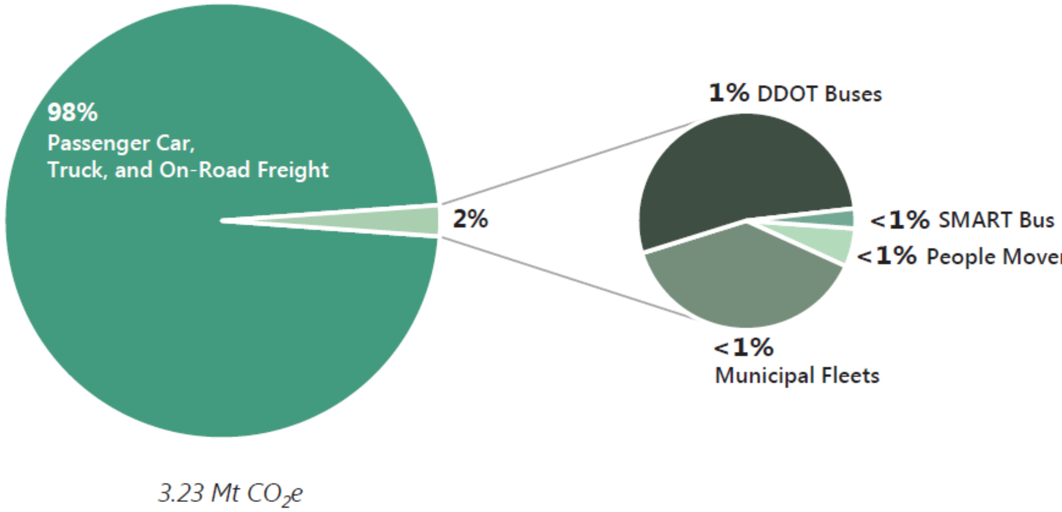


Figure 15: Detroit Citywide Transportation GHG Emissions by Source, 2012

For a breakdown of passenger car and freight truck emissions by an alternative transportation methodology, see Appendix N.

Industrial Process

Methods

Industrial process GHG emissions are produced from industrial methods that involve chemical transformations, other than combustion, of materials, such as hydrogen production and petroleum refining—the two industrial processes that occur within the City of Detroit. Hydrogen production releases CO_2 from the steam reforming process. Petroleum refining emits CO_2, CH_4, and N_2O from the catalytic reforming and delayed coking processes. They are distinct from industrial emissions associated with on-site energy production (e.g., combustion of natural gas) or use (e.g. electricity)—which in this inventory are captured in the Building and Facilities section. This inventory uses U.S. EPA GHGRP data from 2011 and 2012 to account for industrial process emissions in Detroit. The U.S. EPA GHGRP reporting entities may use Continuous Emissions Monitoring Systems (CEMS) or mass balance calculations to determine annual emissions from their operations. Municipal emissions generated from chemical reactions used at the wastewater treatment plant are included in the Wastewater Treatment activity section of the report.

Results

Emissions from industrial processes accounted for 3% (0.31 million t CO_2e) of total citywide emissions in 2012[63] and remained relatively steady from 2011 to 2012. These emissions came from two facilities in Detroit owned and operated by parent companies Air Products and Chemicals Inc. and Marathon Petroleum Co., which carry out hydrogen production and petroleum refining, respectively.

Solid Waste

Methods

When solid waste is processed—either by incineration, landfill disposal, recycling, or composting—it produces GHG emissions. Citywide emissions from solid waste are determined by the amount of waste generated, population served, and the waste management method used. This inventory accounts for fugitive emissions from landfilled municipal solid waste collected by the Detroit Department of Public Works and disposed of outside the city limits (the majority of this waste is from municipal waste streams generated within the city) and solid waste incineration emissions from all municipal solid waste processed by the energy from waste (EFW) facility,[64,65] located in Detroit.

In the inventory analysis years of 2011 and 2012, landfilled municipal solid waste was collected by the Detroit Department of Public Works and transported to landfills (Sauk Trail Hills and Carleton Farms landfills) located outside of the City of Detroit in Canton and New Boston, Michigan.[66] Emissions from the amount of solid waste sent to these landfills were calculated using data reported by the Detroit Department of Public Works to Wayne County and the U.S. EPA's Waste Reduction Model (WARM) recommended by U.S. EPA's local GHG inventory protocol guidance.[67]

---

[63] The absolute values of these Industrial Process emissions as well as the proportion of total Detroit citywide emissions are in line with the State of Michigan GHG inventory analysis. Bull et al. (2005) determined industrial processes contributed approximately 4.9% of total state GHG emissions in 2002.

[64] The Detroit EFW facility is more commonly known as the 'incinerator.' An incinerator combusts wastes primarily to reduce volume of material landfilled; whereas an EFW facility combusts wastes to generate energy, such as electricity and steam that can be used to power and heat buildings. Because energy is recovered from waste materials, the U.S. EPA currently classifies municipal solid waste managed via an EFW facility as a renewable energy power source.

[65] The steam and electricity generated at the EFW facility are sources of energy for the City of Detroit; however, the emissions associated with that generation (those from solid waste incineration) are accounted for here in the Solid Waste section, rather than in Buildings and Facilities, to avoid double counting.

[66] While, at one point of time, the City of Detroit may have had landfills within its city boundaries, there are none that are currently operating or accepting municipal solid waste in Detroit—that is, all landfilled municipal solid waste is exported to sites outside of the city. Solid waste decomposes over large periods of time during which waste emits CH_4. As such, the IPCC recommends a 'First Order Decay' method to account for emissions from this historic solid waste disposal (Pipatti and Svardal 2006). However, limited data was available on any retired landfills within Detroit. As a result, this method was not included in the analysis at this time, but it could be explored in the future.

[67] Some conflicting guidance exists on the 'best-available' methods and models for estimated emissions from municipal solid waste. As a result, the inventory presents results that use the U.S. EPA-recommended model. An alternative method for these calculations, supported by ICLEI, was compared to the chosen approach and is summarized in Appendix O.

U.S. EPA WARM is a tool that estimates current and future emissions associated with each unit of disposed solid waste. Transportation emissions associated with the collection of municipal solid waste by the City of Detroit Department of Public Works are assumed to be captured in the preceding citywide transportation analysis. This assumption avoids double counting transportation-related emissions from municipal solid waste in the citywide totals.

Detroit's municipal solid waste is only one component of the city's total solid waste stream. This inventory does not include the landfill disposal of privately managed construction and demolition, commercial, and industrial waste because data were not available publicly for these waste streams in 2011 and 2012. Therefore, this inventory shows a portion of Detroit's total solid waste emissions from landfill disposal and, as a result, would likely underestimate the contribution of all solid waste generated within the City of Detroit in its citywide analysis.

Solid waste incineration emissions that occur within the Detroit city limits result from the incineration of solid waste generated in Detroit, and from solid waste imported to the city from the greater Southeastern Michigan region and elsewhere. The majority of the municipal solid waste combusted at the Detroit EFW does not come from the City of Detroit.[68] While solid waste from the City of Detroit Department of Public Works was the facility's largest single source, it made up well less than 50% of the total waste received in the inventory analysis years.[69] Due to limited data availability, a breakdown of the specific sources and relative amounts of incinerated solid waste from these different communities was not available. These emissions, in aggregate, were reported to the U.S. EPA GHGRP by the EFW facility, operated by Detroit Renewable Power under contract with the City of Detroit and the Greater Detroit Resource Recovery Authority (GDRRA).

Results

Solid waste fugitive and incineration emissions accounted for approximately 0.25 million t CO_2e in 2012 (Figure 16), or more than 2% of total citywide emissions in that year.

[68] Email correspondence with representative from Detroit Renewable Power, May 2014.
[69] *Ibid.*

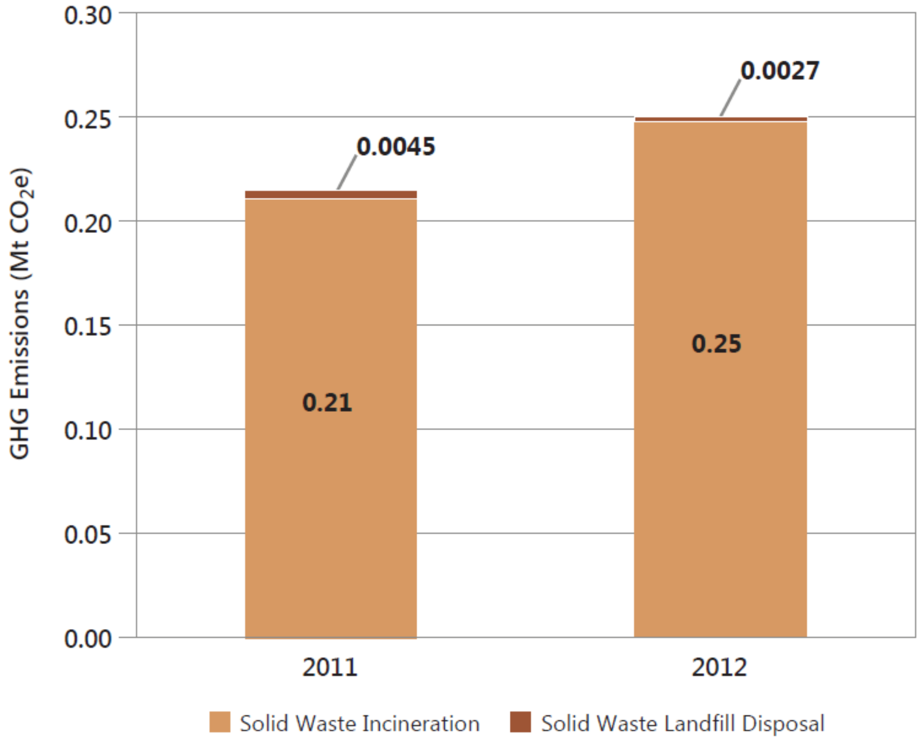


Figure 16: Detroit Citywide GHG Emissions from Solid Waste Incineration and Landfill Disposal

Total solid waste GHG emissions from both incineration and municipal solid waste landfill disposal are shown in Figure 16. Aggregate emissions from solid waste incineration—which includes an unknown but likely substantial amount of solid waste generated by commercial activities in Detroit or waste imported from outside the Detroit city limits—increased 18% from 2011 to 2012.

As is shown in Figure 17, the activity data showing the amount of municipal solid waste reported by the City of Detroit that was landfilled and incinerated declined 55% from 2011 to 2012. The causes of the dramatic decline in the reported amount of collected municipal solid waste between 2011 and 2012 were not evident or traced in the municipal solid waste reporting documents received.[70] More comprehensive and transparent monitoring of solid waste management will be critical to disaggregate the drivers of solid waste emissions in future Detroit GHG inventories and to assess the potential for emissions reductions related to this activity.

[70] This drop could include any combination of the following possible reasons: the city's population and economic activity continued to decline during the period of analysis, that reporting methods could have changed or data incorrectly submitted, or municipal solid waste collection services could have changed during this period (i.e., privately-operated commercial waste haulers do not have the same reporting standards as municipally-operated solid waste collection). These hypotheses, concerning the decrease in municipal solid waste activity data reported, illustrate that more transparent data gathering and reporting processes for this activity would allow for greater confidence in the municipal solid waste emissions accounted for in this inventory—and could be explored further. The raw solid waste collection data that correspond to Figure 17 are presented in Appendix F.

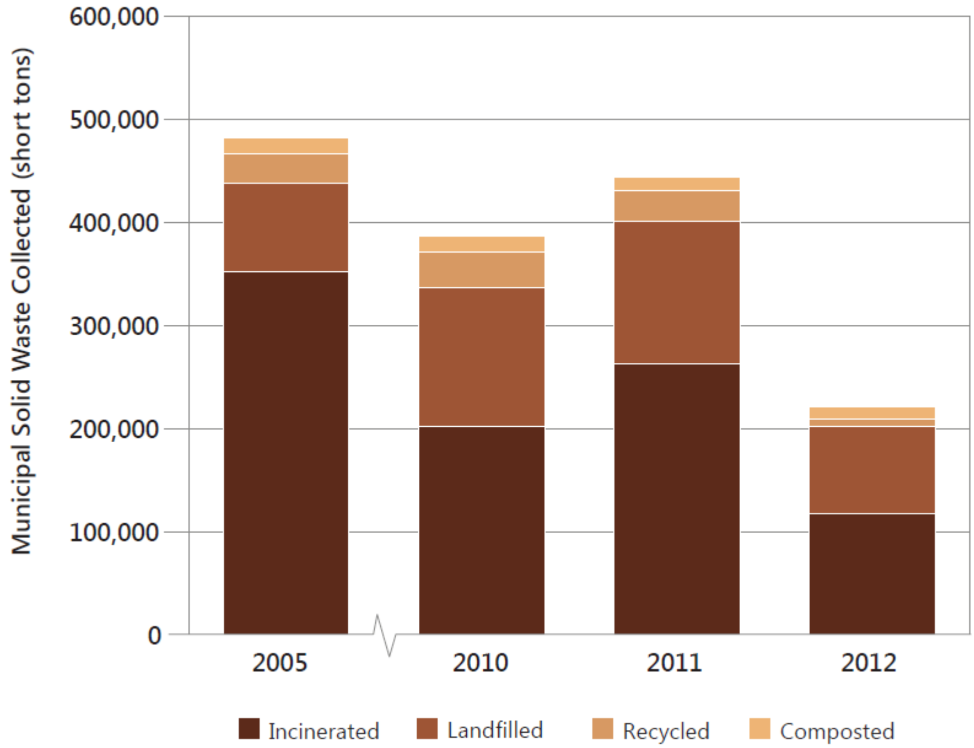


Figure 17: Municipal Solid Waste by Weight (short tons) Reported by City of Detroit Department of Public Works

Based on solid waste protocols, reducing solid waste generation and increasing recycling and compost could avoid or reduce total solid waste emissions. While not included in the citywide inventory totals, an analysis of avoided emissions from the City of Detroit's residential recycling and compost programs using U.S. EPA WARM can be found in Appendix P: "Avoided Emissions from Residential Recycling and Composting in Detroit."

In addition, disaggregating emissions from commercial solid waste as well as construction and demolition waste would increase the accuracy of future inventories. The emissions results from the EFW facility suggest that the incineration of solid waste generated outside of Detroit plays an important role in total in-boundary solid waste emissions. Future inventories should investigate this further.

Wastewater Treatment

Methods

The Detroit Water and Sewerage Department (DWSD) wastewater treatment plant (WWTP) is located in Detroit and is one of the largest WWTPs in the country. It treats wastewater from both the City of Detroit and DWSD's Southeastern Michigan suburban customers. The treatment process that occurs at DWSD's WWTP is aerobic without nitrification or

denitrification and includes the incineration of biosolids or sludge using multiple hearth incinerators.

The wastewater treatment activity includes non-energy related emissions (chemical processes, fugitive sources, and incineration) associated with the wastewater treatment process. These include process emissions (N_2O) from DWSD's chemical wastewater treatment process, emissions (N_2O and CH_4) associated with the incineration of biosolids in the treatment plant's incinerators, as well as fugitive emissions (N_2O) from treated effluent released into the Rouge River and Detroit River.[71]

It is important to note that any energy used by DWSD is not included in the wastewater treatment activity results in order to avoid double counting. This is because the inventory captures emissions associated with DWSD's energy use (both electricity and natural gas) from both its water supply service and the wastewater treatment process in the Buildings and Facilities section of the citywide inventory results.

Using ICLEI Community Protocol, wastewater treatment emissions were modeled using a combination of plant-specific data (i.e., the wet weight of the biosolids incinerated) and a service area population estimate to approximate emissions for process and fugitive emissions (recommended when plant-specific nutrient data is not available or in the correct form).

The service area population estimate used for all inventory analysis years is three million customers,[72] with DWSD providing wastewater treatment services to a significant industrial customer base, as well. Unfortunately at the time of this analysis, a more precise service area population estimate was not available—making it difficult to capture precise changes in emissions across time.

ICLEI Protocol cautions that modeling wastewater treatment emissions is plant-specific and highly complex, depending on the processes utilized during treatment.[73] As such, generalized models like those used in this analysis, while practical for standardized, local GHG inventory accounting, are based on national inventory accounting methods and, therefore, are highly uncertain at the local facility level.

---

[71] Fugitive emissions associated with septic systems are assumed to be negligible, as almost if not all Detroit buildings and facilities are connected to the city's public wastewater utility, according to conversations with DWSD. Those emissions from biogenic sources of CO_2 in the wastewater treatment process were not included in the citywide inventory.

[72] Calculations are based on this generalized, annual population-served estimate (DWSD wastewater and sewer service area includes Wayne, Macomb, and Oakland counties) (City of Detroit 2013). For simplicity and because more detailed population estimates were unavailable, these estimates assume service area population remains constant over all inventory years.

[73] ICLEI (2012)

Results

In 2012, the non-energy related process, fugitive, and incineration emissions from wastewater treatment accounted for about 0.18 million t CO_2e, or approximately 2% of total 2012 citywide emissions.

Unlike the majority of activity categories in the citywide analysis, wastewater treatment activity data were available and provided by DWSD for 2005 and 2010 through 2012. An analysis of emissions over time shows a decline in emissions in recent years (Figure 18). Based on emission calculations and wastewater treatment assumptions[74] (including that population served by DWSD wastewater treatment service remained constant during this period), the reduction of 0.06 million t CO_2e in total wastewater treatment emissions between 2005 and 2012 has been primarily driven by a reduction in the amount of biosolids incinerated. DWSD provided this raw data in terms of wet weight of biosolids incinerated, which reduced from approximately 580,000 metric wet tons in 2005 to approximately 360,000 metric wet tons in 2012[75]—a percentage decrease in the amount of biosolids incinerated of 37.7%, over the seven-year time frame.

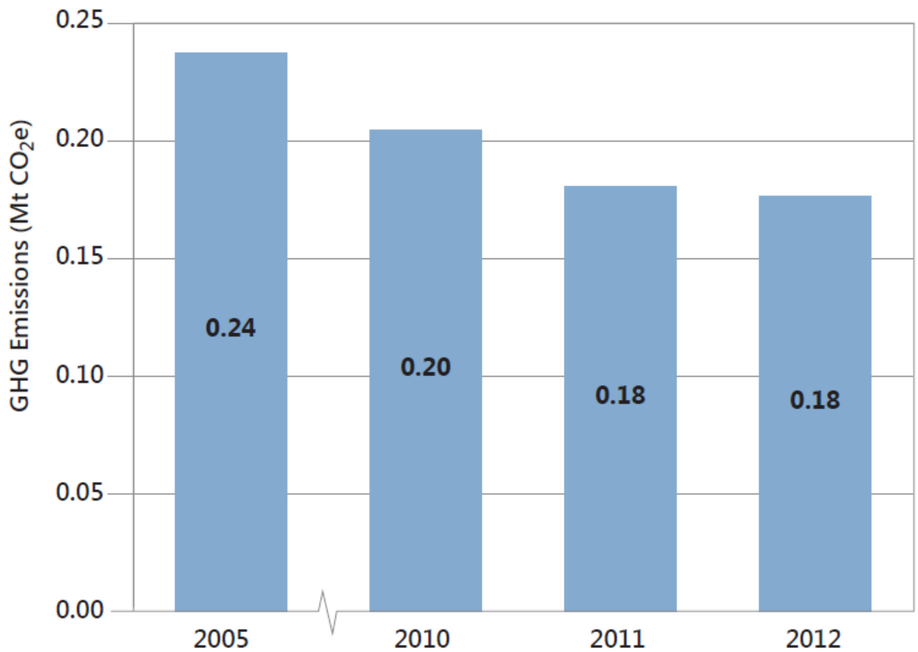


Figure 18: Detroit Citywide Wastewater Treatment GHG Emissions from Fugitive Sources, Processes, and Incineration

As ICLEI protocol and other resources discuss, the modeling of emissions from wastewater treatment is a complex exercise given differences in size and variations in processes among local WWTPs.[76] For future Detroit GHG inventories, these results for DWSD should continue to be

[74] These calculations and assumptions are outlined in greater detail in Appendix E of this report.
[75] DWSD (2014)
[76] ICLEI (2012), Water Environment Federation (2009)

refined based on specific DWSD operations and improvements in wastewater treatment emission modeling methods.

Land Use

Methods

Given the technical difficulty of estimating emissions from land use, emissions associated with this activity are not included in the overall calculation of Detroit's citywide GHG emissions. However, land use emissions estimates are included here as a reference point for future work on estimating this activity's impact on Detroit's citywide GHG emissions.

Of its 142 total square miles of land area (including water features), Detroit has an estimated 20 square miles of *vacant land* (roughly the size of Manhattan) made up of nearly 150,000 vacant and abandoned parcels.[77] This challenge also presents an opportunity to consider new possibilities for productive urban land use in Detroit. Innovative uses including urban agriculture, blue and green infrastructure (e.g., stormwater catchment, carbon forests) and parks and recreation spaces are being piloted or proposed to turn unproductive vacant land into productive spaces.

Using this vacant land to increase vegetation in Detroit can have positive impacts both for climate mitigation and adaptation, in addition to improving quality of life. As a mitigation strategy, planting trees can be a cost-effective way of offsetting carbon emissions, both by sequestering carbon in plant tissue and reducing the energy necessary to cool buildings.[78] Plants take in CO_2 as part of their respiratory process to build plant biomass. Thus, forests and other vegetation that remove carbon from the atmosphere are often referred to as "carbon sinks." Although plants are carbon sinks in net terms, it is difficult to estimate their effect on atmospheric carbon for a number of reasons: carbon is also released into the atmosphere during normal plant respiration and carbon exchange is influenced by time of day, season, plant species and stage of growth.[79,80]

Once vegetation is destroyed, the carbon that was stored in its biomass is eventually released into the atmosphere. Vegetation can be destroyed by fire, disease, deforestation or other clearing activities (e.g., mowing, pruning), extreme weather, or age. Thus, the reversibility and non-permanence of carbon stocks can be major challenges of using vegetation as a strategy to mitigate GHG emissions.

---

[77] DFC (2013)
[78] The benefits of urban trees can vary considerably by community and tree species. However, researchers of a five city urban forestry study determined that, on a per-tree basis, the cities accrued benefits ranging from about $1.50–$3.00 for every dollar invested (U.S. EPA 2013g).
[79] ICLEI (2006)
[80] McHale et al. (2007)

In addition to its potential to mitigate GHG emissions, increased vegetation has numerous adaptation benefits including cooling urban environments (known as reducing the urban heat island effect associated with large amounts of impervious surfaces), improved flood and stormwater runoff management, and improved air quality.

While not directly analyzed here, the carbon impact of landscape management across different scales should also be considered, since management can greatly impact land use emissions. The application of chemical fertilizers and mulch as well as the use of electric- or gas-powered tools, such as mowers, pruners, or cultivators, contribute to land use GHG emissions.

Given the opportunities for carbon sequestration from trees and the potential use of vacant land for additional carbon sequestering activities, this project assessed current land cover in Detroit to estimate carbon uptake from the current stock of trees. This analysis estimates CO_2 sequestered by tree canopy[81] in the City of Detroit in 2010, which was the most recent year that spatial data suited to this analysis was available. The U.S. Forest Service i-Tree Canopy online model[82] was utilized to statistically determine the percentage tree cover in the City of Detroit boundary. These data were then coupled with a Michigan-specific emission factor from the U.S. Forest Service[83] of annual CO_2 sequestered by tree canopy to estimate the carbon sequestration of Detroit's land cover.

Results

For this report, an analysis of land cover found that Detroit has approximately 23.5% tree canopy[84] cover—this value was derived using spatial data from 2010, though this analysis assumes that there has been no significant change in land cover since 2010. This land cover result is consistent with a 2008 finding of 22.5% by American Forests (down from 31% in 2005). Similarly, Nowak et al. found a 23.2% tree canopy cover in 2005 and 22.5% in 2009. Since the 1950s, when Dutch Elm Disease reached Detroit, and more recently in 2002, when the Emerald Ash Borer arrived in the city, a significant loss of trees has occurred.

---

[81] The land use analysis does not currently account for emissions from other land cover classes or the impact of land use change over time.

[82] i-Tree Canopy is a program developed by the U.S. Forest Service to identify and quantify land cover classes for user-specified extents of land, whether a neighborhood, city, state, or region. Within i-Tree Canopy, the user identifies the land cover classes. In this way, the user controls the specific land cover traits to distinguish. For example, in this inventory analysis of land cover, five cover classes were selected: herbaceous vegetation (shrubs and grasses), tree canopy (trees), water (water features such as rivers and creeks), bare soil (non-vegetated soil), and impervious surface (sidewalks, streets, rooftops, driveways). While sampling land cover within i-Tree Canopy, it is important to remain consistent in cover class identification. Therefore to reduce error in identification, one individual should complete entire assessment.

[83] Nowak (2013)

[84] Tree canopy is a term used to describe the portion of trees that are aboveground and form a shaded area that is larger than their tree trunk.

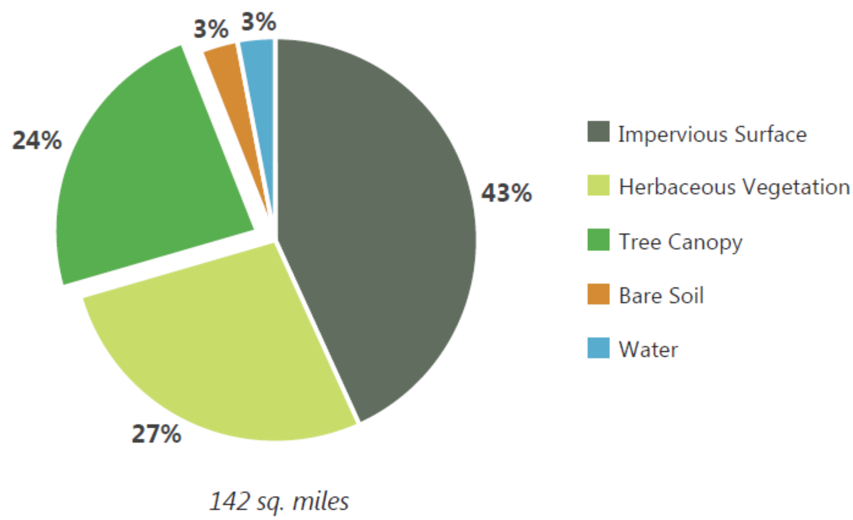


Figure 19: Detroit Citywide Land Cover, 2010

Using the i-Tree Canopy program in tandem with Google aerial photography (sampled in 2010) of the City of Detroit the percentage tree canopy cover was calculated. As shown in Figure 19, Detroit is estimated to have roughly 24% tree canopy cover,[85] which is estimated to sequester 70,400 t CO_2 (0.07 million t CO_2e) annually. This is equivalent to taking approximately 15,000 cars off the road for one year.[86]

GHG Inventory in Action: New York City

MillionTreesNYC Initiative

Since 2007, New York City has **planted over 750,000 new trees** through MillionTreesNYC, a public-private partnership. This program aims to plant and care for more than one million new trees across the city over the next decade. Why is the city government pursuing such an ambitious goal? **Urban forests create more livable communities** and can assist NYC in reaching climate mitigation goals. Trees sequester CO_2 in their leaves. Urban forest **reduces the urban heat island effect**, thereby **reducing the energy used to cool buildings and providing shade.** PlaNYC estimates that the City's trees store about 1.35 million tons of carbon, which they value at over $24 million.[x]

x. MillionTreesNYC (2014)

[85] 95% Confidence Interval: 20.9 -26.1%.
[86] U.S. EPA (2014a)

DETROIT MUNICIPAL GOVERNMENT INVENTORY SUMMARY

Methods

Overview

The municipal government inventory analysis accounts for emissions generated from operations managed directly or those contracted by the City of Detroit and is a subset of the citywide inventory results. The municipal inventory includes energy use in city-owned and operated buildings and facilities, energy used in city vehicle fleet operations and city-managed public transportation, as well as city-operated solid waste and wastewater treatment services.

The Detroit municipal inventory analysis includes emissions from certain quasi-public agencies and institutions of the City of Detroit. These include, but are not limited to, the Detroit Water and Sewerage Department,[87] the Detroit Transit Corporation (Detroit People Mover), and the Greater Detroit Resource Recovery Authority (GDRRA). The decision to include these entities in the municipal inventory is based on their close operational and contractual relationship with the City of Detroit for the provision of essential city services (e.g., transportation, waste, and water), even though these organizations, also known as enterprise departments, may have budgets separate from the City of Detroit General Fund.

Because the City of Detroit is currently restructuring many of its operations, following the appointment of an Emergency Financial Manager (Kevyn Orr) in spring 2013 and the city's municipal bankruptcy filing in summer 2013, future City of Detroit municipal inventories may need to reevaluate how emissions from city services or these quasi-public agencies are reported. The analyses presented for 2011 and 2012, however, report emissions results using the structure of the City of Detroit municipal government and departments as they existed during those years. More detailed municipal inventory methods are discussed in Appendix I.

Municipal Buildings and Facilities

Municipal buildings and facilities include emissions associated with heating, cooling, and powering municipal buildings and facilities with electricity and natural gas distributed by DTE Energy. Emissions are generated through the combustion of fossil fuels for electricity generation and on-site combustion of natural gas. Emissions are also associated with electricity losses due to transmission and distribution (T&D) through the grid. Electricity and natural gas consumption data by city department for 2011 and 2012 were combined with emission factors to yield total GHG emissions.

[87] DWSD is accountable to a Board of Water Commissioners with representation from both the City of Detroit and the larger Southeastern Michigan DWSD service area.

Municipal Transportation, Solid Waste, and Wastewater Treatment

Methodologies for the activities of Municipal Transportation, Solid Waste, and Wastewater Treatment are the same in this municipal inventory analysis as those outlined in the preceding citywide inventory methods sections, so they will not be repeated here.

At this time, the municipal transportation analysis does not separately model emissions associated with City of Detroit employee commute (as some local municipal inventories do), however these emissions would be captured in the aggregate citywide VMT and transportation emissions. An analysis of employee commute could be investigated in the future.

Results

Emissions from Detroit's municipal government operations accounted for 11% of total citywide emissions (1.18 million t CO_2e) in 2012, as shown in Figure 20. While this is a small portion of the total citywide emissions, the municipal government can serve as an example to the Detroit community as well as larger metropolitan region by pursuing climate mitigation and adaptation strategies informed by the municipal inventory findings.

The 2011 and 2012 municipal government emissions are very similar (particularly when presenting results in million t CO_2e). Thus, all analyses in this section are for calendar year 2012, and they explore and disaggregate this total (1.18 million t CO2e). A summary and results from the 2011 municipal government operations inventory are presented in Appendices J and K.

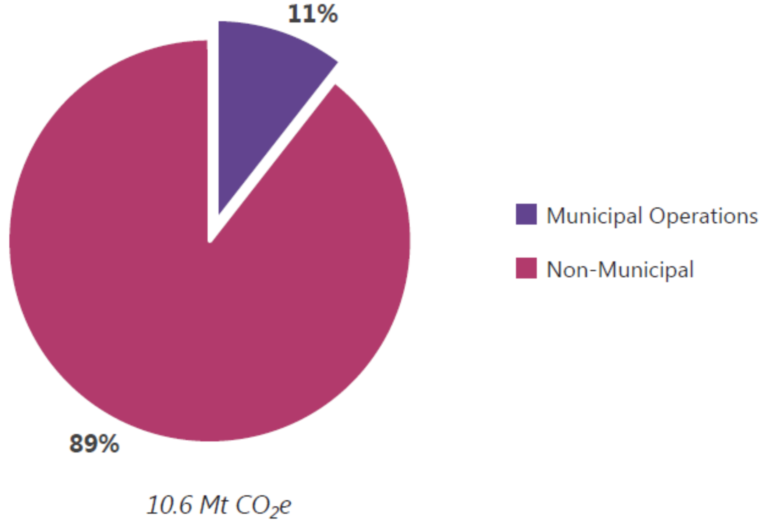


Figure 20: Detroit Municipal Operations GHG Emissions as a Percentage of Citywide, 2012

As shown in Figure 21, municipal buildings and facilities were the largest source of emissions contributing approximately 58% of emissions in 2012 (0.68 million t CO2e). Solid waste, which includes solid waste incineration and landfill disposal, was the second largest municipal source, contributing approximately 21% of emissions. Wastewater treatment emissions contributed approximately 15% to the total municipal inventory.

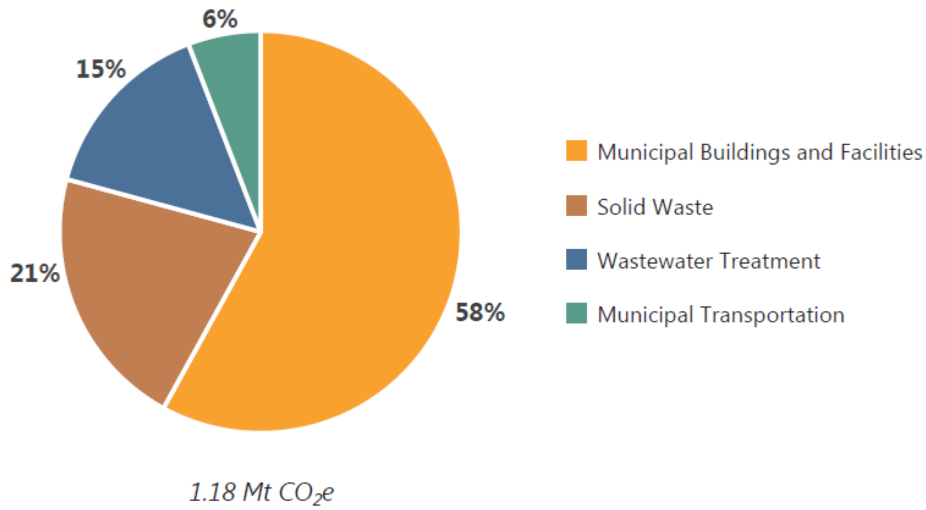


Figure 21: Detroit Municipal Operations GHG Emissions by Activity, 2012

Detroit's infrastructure, including GDRRA's energy from waste (EFW) facility and DWSD's wastewater treatment plant (WWTP), supports people and activities both inside and outside of Detroit. The EFW facility incinerates solid waste from other municipalities in the region as well as residential and commercial waste from the City of Detroit (unfortunately no disaggregated information about the solid waste or communities served was available from GDRRA at this time). The Detroit WWTP treats the wastewater for approximately three million people across a three-county Southeastern Michigan service area.[88] It is important to note that the wastewater treatment emissions presented in Figure 21 include only non-energy related fugitive, process, and incineration[89] emissions occurring at the plant (i.e., electricity and natural gas used by the WWTP are captured in the municipal buildings and facilities total).

While these facilities provide services to people located outside of Detroit, the emissions from both the EFW facility and DWSD's WWTP are direct emissions, occurring within the geographic boundary of the City of Detroit at municipally-operated or -contracted facilities. As a result, for the purposes of this municipal inventory analysis, these activities are therefore attributed to the Detroit city government and municipal operations.

The Detroit Water and Sewerage Department, the Detroit Public Lighting Department (PLD), Detroit Department of Public Works, and the Greater Detroit Resource Recovery Authority

[88] Calculations based on this generalized annual population served estimate (DWSD wastewater and sewer service area includes Wayne, Macomb, and Oakland counties) (City of Detroit 2013). For simplicity and because more detailed population estimates were unavailable, these estimates assume service area population remains constant over all inventory years.

[89] The Detroit WWTP operated fourteen hearth incinerators to incinerate a portion of dewatered biosolids in 2011 and 2012. One incinerator has since been decommissioned, so the Detroit WWTP currently operates thirteen hearth incinerators.

(GDRRA) respectively manage the city's water supply and wastewater treatment services, streetlights and traffic signals, , and municipal solid waste disposal, as well as other essential public utilities and works. As illustrated in Figure 22, these four departments manage operations that contribute approximately 93% of total municipal GHG emissions. The remaining seven percent of municipal operations emissions are attributable to the remaining City of Detroit Departments, a complete list of which is included in Appendix H.

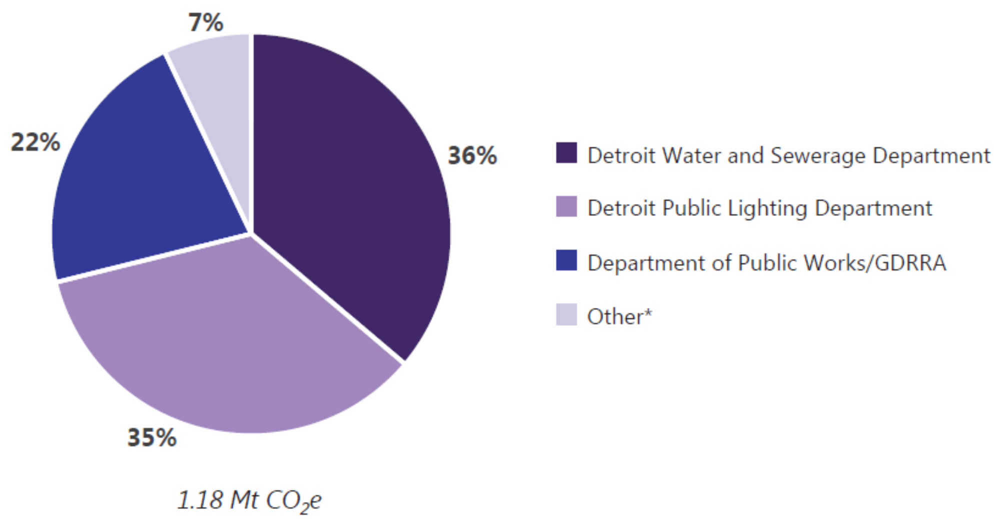


Figure 22: Detroit Municipal Operations GHG Emissions by Department, 2012

**Category 'Other' includes all other City of Detroit municipal departments. A complete list of Detroit municipal departments and their annual emissions are included in Appendix H.*

Although these four municipal departments manage operations and services that contribute approximately 93% to the municipal inventory total, the strategies that the City of Detroit could pursue to reduce costs and enhance city services would be vastly different for each agency. Energy efficiency improvements and cost reductions could involve many different areas of municipal government operations from targeting the wastewater treatment processes managed by DWSD to incentivizing energy efficiency projects in the administrative offices across City of Detroit Departments. Emissions reduction targets, energy efficiency initiatives, and cost-savings projects would therefore be more effectively directed at either specific activities or within the four largest emitting departments.[90]

As shown in Figure 23, DWSD is the second largest contributor to fugitive, process, and incineration emissions, which are a result of fugitive (N_2O) emissions from treated effluent released into River Rouge or the Detroit River, process emissions (N_2O) from the chemical wastewater treatment process, and emissions (N_2O and CH_4) associated with the incineration of biosolids in the treatment plant's incinerators. DWSD also is the second largest contributor to municipal

[90] For municipal operations emissions disaggregated by a comprehensive list of city departments, please see Appendix J.

buildings and facilities emissions, which accounts for energy used in both drinking water and wastewater treatment services.[91] It is common for municipal wastewater treatment facilities to be large users of electricity and to make up, as a result, a relatively large portion of municipal government inventories, given the energy-intensive processes associated with both water management services.[92]

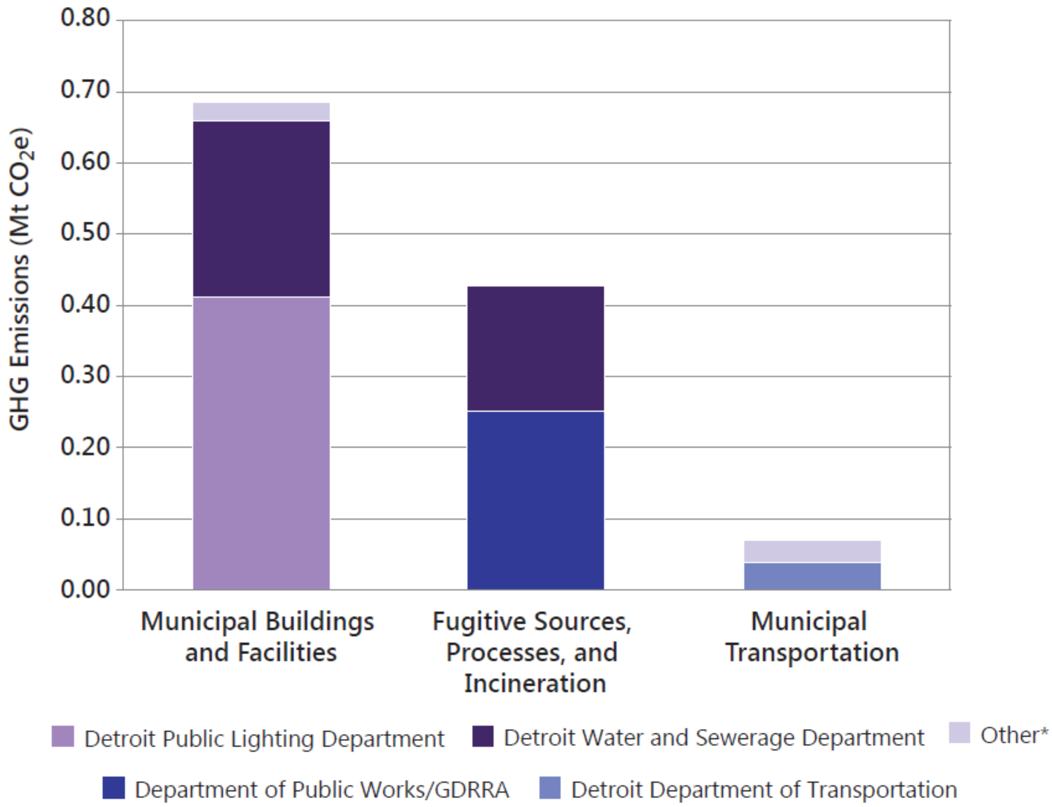


Figure 23: Detroit Municipal Operations GHG Emissions by Activity and Department, 2012

**Category 'Other' includes all other City of Detroit municipal departments. A complete list of Detroit municipal departments and their annual emissions are included in Appendix H.*

Although overall the Detroit Department of Transportation (DDOT) bus system is not a large contributor to the municipal inventory, it is the largest source of municipal transportation emissions, as illustrated in Figure 23.

As shown in Figure 24, most of the municipal inventory emissions when organized by service (or departmental purpose) originate from essential public services such as water supply, wastewater treatment, and solid waste. In future inventories, municipal emissions from other city services such

[91] Unfortunately, given the data provided by DTE Energy, the energy used by DWSD drinking water and wastewater treatment services could not be disaggregated in this analysis. Additional energy use data from monthly billing records was provided to the project by DWSD, which may be used to further verify and disaggregate the buildings and facilities energy use results presented here in future inventories.

[92] WEF (2009)

as public safety or public transportation *could* increase due to municipal restructuring that aims to increase quality of life and accessibility for Detroiters. For an explanation of which departments are included in each service category, please see Appendix H.

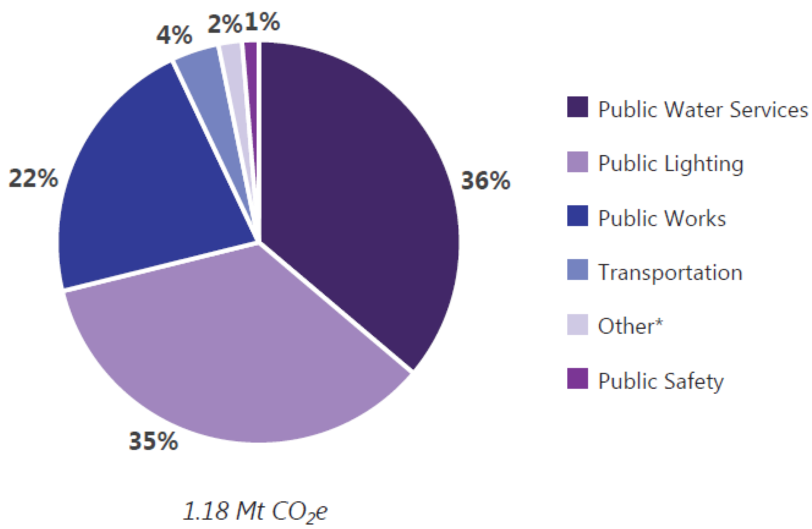


Figure 24: Detroit Municipal Operations GHG Emissions by Service, 2012

**Category 'Other' includes other municipal activities such as administrative services, culture and arts programming, the election commission, and health and human services.*

During the inventory 2011 and 2012 study years, the City of Detroit government restructured the management of city services as well as other institutional structures. For future municipal inventory benchmarking exercises, GHG emissions could be compared and normalized for the city services delivered.

During the inventory data collection and analysis process, the team noted numerous forthcoming restructuring that would greatly change the scope of the municipal inventory in future reporting. For example, in 2013 an independent Public Lighting Authority (PLA)[93] was created to manage the city's traffic and streetlight systems, and the Detroit Public Lighting Department's service and customers began to be transferred to accounts with DTE Energy. Furthermore, in early 2014, the Detroit City Council approved a privatization plan for municipal solid waste collection services, which will no longer be under the management of the Detroit Department of Public Works.[94]

[93] The Public Lighting Authority of Detroit (PLA) is an *independent authority* that was created in February 2013 to modernize the City's streetlights system that was in need of repair. Approximately half of the City's streetlights are not working due to myriad of reasons, including but not limited to low infrastructure investment over the past 20 years, vandalism, and obsolete technology (PLA 2014).

[94] Beginning May 2014, two companies Rizzo Environmental Services and Advanced Disposal Services will handle municipal waste collection, including residential solid waste and curbside recycling (Guillen 2014).

The GHG emissions of the municipal inventory should not be examined in isolation; rather they should be examined against the backdrop of the total citywide inventory, a government in transition, an evolving long-term plan for the city, and its interaction with the greater metropolitan region.

COMPARATIVE ANALYSIS OF DETROIT CITYWIDE GHG INVENTORY RESULTS

Over the course of both research and analysis, this project drew from a wealth of existing examples and case studies of GHG inventories at the national, state, and local scales. These examples and the data extracted from them allow for the following meta-analysis of both total inventory emissions (both citywide and municipal) and per person or per capita emissions.

The following analyses provide illustrations of where the City of Detroit stands relative to the U.S., the State of Michigan, and a peer group of North American cities engaged in climate action planning.

Comparison to U.S. and State of Michigan

An analysis of emissions reported in the U.S. National Inventory[95] and that of the State of Michigan[96] can be helpful to see where the City of Detroit falls relative to per capita emissions on a national or state level. As illustrated in Figure 25, the City of Detroit's per capita emissions of 15.2 t CO_2e/person, fall below the State of Michigan per capita emissions 22.8 t CO_2e/person reported in 2002 and the latest 2012 national average of 20.7 t CO2e/person reported by U.S. EPA.

Detroit's per capita emissions reported in 2012 are lower than both the national and state averages. This is as expected because national and regional GHG inventory accounting methods tend to be more comprehensive than those of local GHG inventories. For example, national and state accounting includes modeling of high GWP gases (e.g., refrigerant leakage) and more comprehensively accounts for other sources of emissions, such as agriculture, forestry, and other land use management practices.

---

[95] U.S. EPA (2014b)

[96] A GHG inventory completed for the State of Michigan by the University of Michigan Center for Sustainable Systems presents statewide emissions from 2002 (Bull et al. 2005). Michigan has not updated its inventory since this time. It is important to keep in mind the difference in the inventory analysis years and that the state's emissions per person may have changed since the analysis cited here was performed.

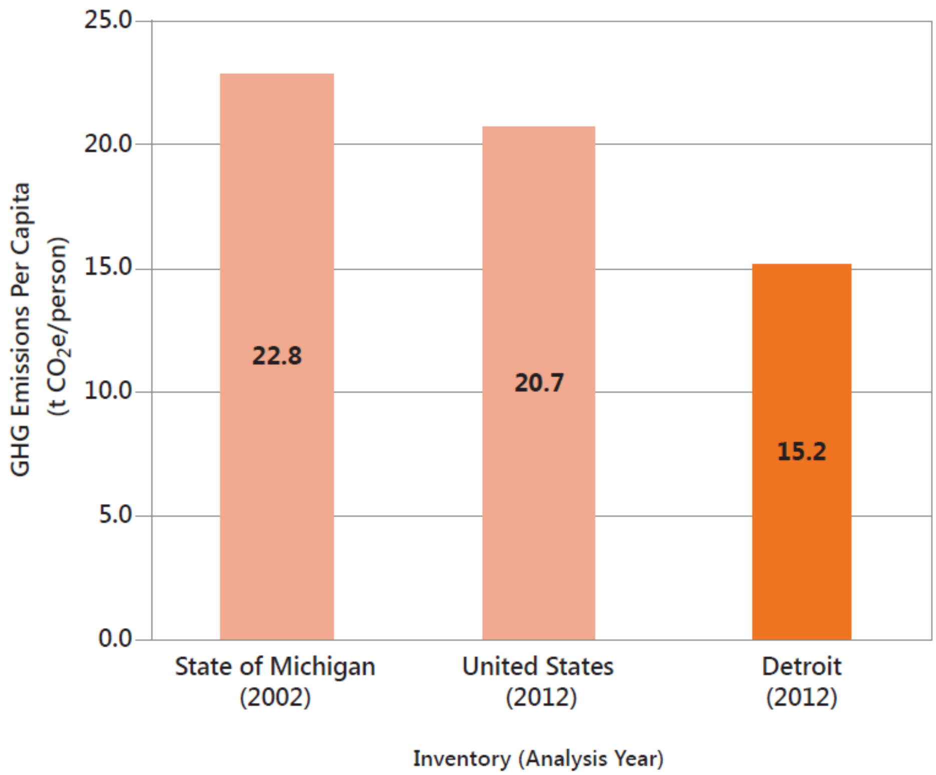


Figure 25: State of Michigan, U.S., and Detroit per Capita Emissions (t CO_2e /person)

While the State of Michigan has not conducted an emissions inventory since 2002, the per capita emissions calculated from the totals reported in that analysis reveal the average Michigan resident during that analysis year would contribute approximately 22.8 t CO2e/person, which is higher than the per capita emissions in Detroit (reported for 2012).

While Detroit has relatively higher and more concentrated amounts of commercial and industrial activity than many other areas of the state and remains the state's largest city in both population and land area, the relatively low per capita emissions value reported for Detroit in 2012 (as compared to the value reported for the State of Michigan in 2002) is likely due, at least in part, to the methods and inventory analysis years used in both reports.

Comparison to Select North American Cities

The following comparative analysis of Detroit's emissions relative to select other North American cities draws from existing literature and represents a collection of data reported in local inventory reports and other resources. This analysis helps both to characterize and to benchmark our results. Data was collected from a sample of fourteen cities across the U.S. and Canada, which had conducted inventories between 2003 and 2012.[97] This analysis includes total citywide inventory emissions, estimated population, land area, and, if conducted, results from the cities' municipal

[97] For each city in the sample, the most recent inventory analysis year available was used.

operations inventories. A summary table of the data collected for this section is available in Appendix L.

A comparison of total citywide emissions across these cities is presented in Figure 26, with the City of Detroit's emissions highlighted. This analysis only begins to illustrate where Detroit falls in comparison to other cities, since the drivers behind the difference and variation in total emissions presented here are difficult to tease out at this level of aggregation. Instead, this analysis provides a helpful starting point to analyze citywide emissions, orienting practitioners to how Detroit's GHG emissions compares relative to other North American cities.

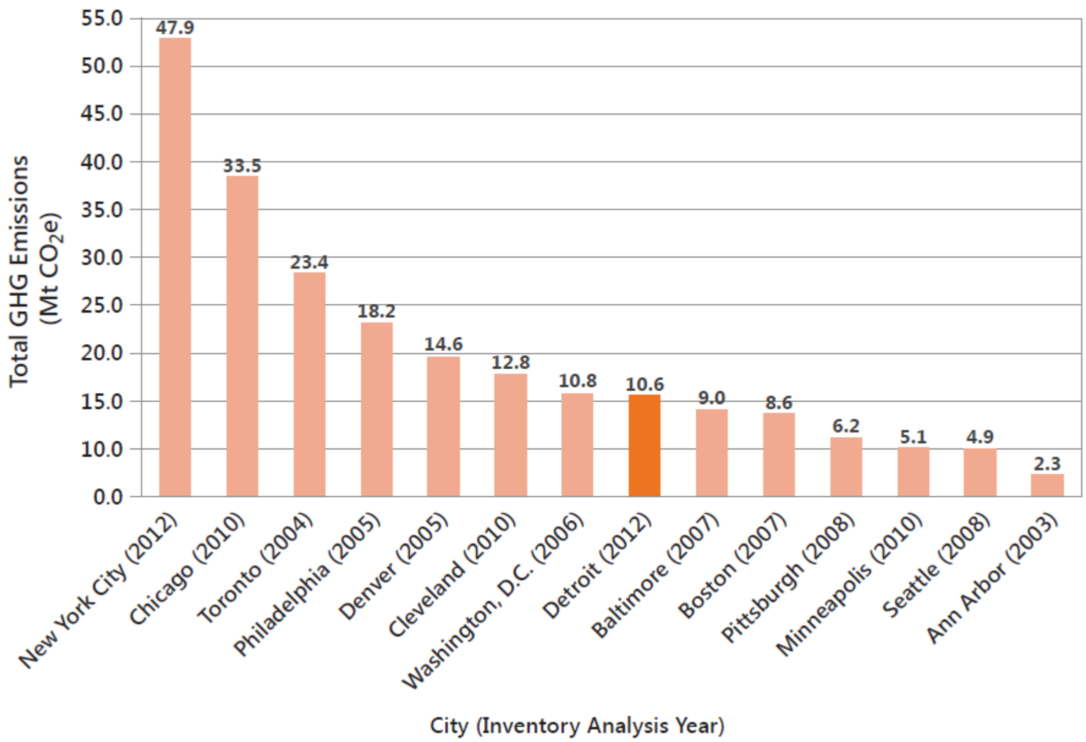


Figure 26: Comparison of Citywide Emissions from Select North American Cities (million t CO_2e)

The City of Detroit's 2012 citywide emissions (10.6 million t CO2e) fall below the mean (average) of 14.8 million t CO_2e of emissions found in this sample. Of these cities, Detroit is the seventh lowest total emitter. It falls within the lower 50th percentile—just below the sample median of 10.7 million t CO_2e. New York City has the highest citywide emissions total (47.9 million t CO_2e) but also has the largest population and largest land area of the cities in this sample. On the other end of the spectrum, Ann Arbor, Michigan, the smallest city in this sample, both in relative population and land area, has the lowest citywide emissions total (2.3 million t CO_2e).

As shown in Figure 27, a much different picture emerges when a per capita filter is applied to the citywide emissions of the same fourteen cities. Per capita emissions for each city were calculated by dividing total citywide emissions by that city's corresponding population estimate. Population

data were drawn primarily from the U.S. Census and corresponded as closely as possible to the inventory analysis year.

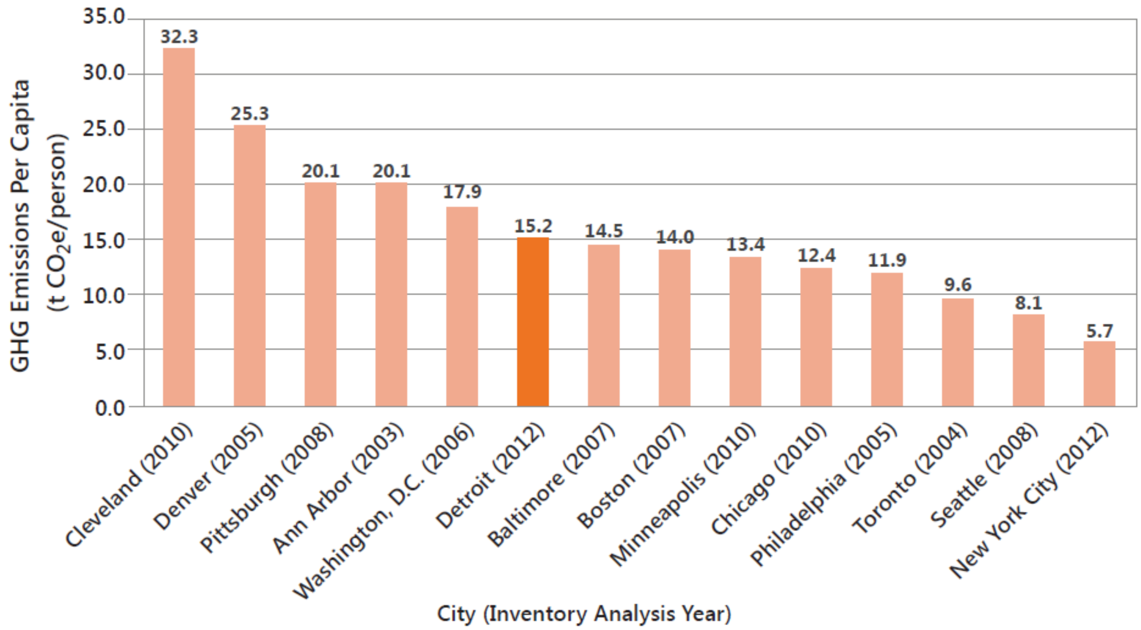


Figure 27: Comparison of Citywide per Capita Emissions across Select North American Cities (t CO_2e/person)

On a per capita basis, Detroit's 2012 emissions (15.2 t CO_2e/person) still fall below average in the data set. Average per capita emissions of the cities in this sample are 15.8 t CO_2e/person. As illustrated by Figure 27, Detroit's per capita emissions rank ninth lowest and fall in the upper 50th percentile of emitters, above the median of 14.3 t CO_2e/person.

When comparing total citywide emissions with those cities' per capita emissions, the relative position of a city can change drastically. While Detroit maintains its relative position in relatively the middle of the sample in both charts, New York City—which, as mentioned, has the largest population of the sample and the highest population density—moves from the largest total emitter (far left position in Figure 26) to the lowest per capita emitter (far right position in Figure 27). Alternatively, Pittsburgh, Pennsylvania, which previously fell below the average of total citywide emissions, now falls relatively higher on the per capita emissions graph, with the third highest per capita emissions of 20.1 t CO_2e/person. This trend could be driven by the age of its urban infrastructure, population decline, or the emissions-intensity of centralized public services, which may serve a larger regional base. This discussion illustrates that it is important to evaluate comparative metrics with an understanding of what factors may be driving a city's total emissions or how those emissions may be disaggregated.

While cross-city comparisons can be useful to understand relative contributions of emissions of a city or its residents, analyses comparing the results of local GHG inventories across cities are often

more complicated than they initially appear.[98] The total citywide and per capita emissions from a city depend on a number of important variables that include but are not limited to the level of industrial and commercial activity, efficiency of the city's infrastructure, its population (or number of households) and population density, any anomalies that may have occurred in the year of its inventory analysis, protocol and methodologies used (including what is or is not included), or its land area. As a result, continued disaggregation and refinement of these comparisons are needed.

In addition to comparing total citywide and citywide per capita emissions, eight of the inventories in this sample have conducted municipal inventories. Illustrated in Figure 28, those cities' municipal emissions range from 0.05 million t CO_2e (in Ann Arbor) to 3.12 million t CO_2e (in New York City).

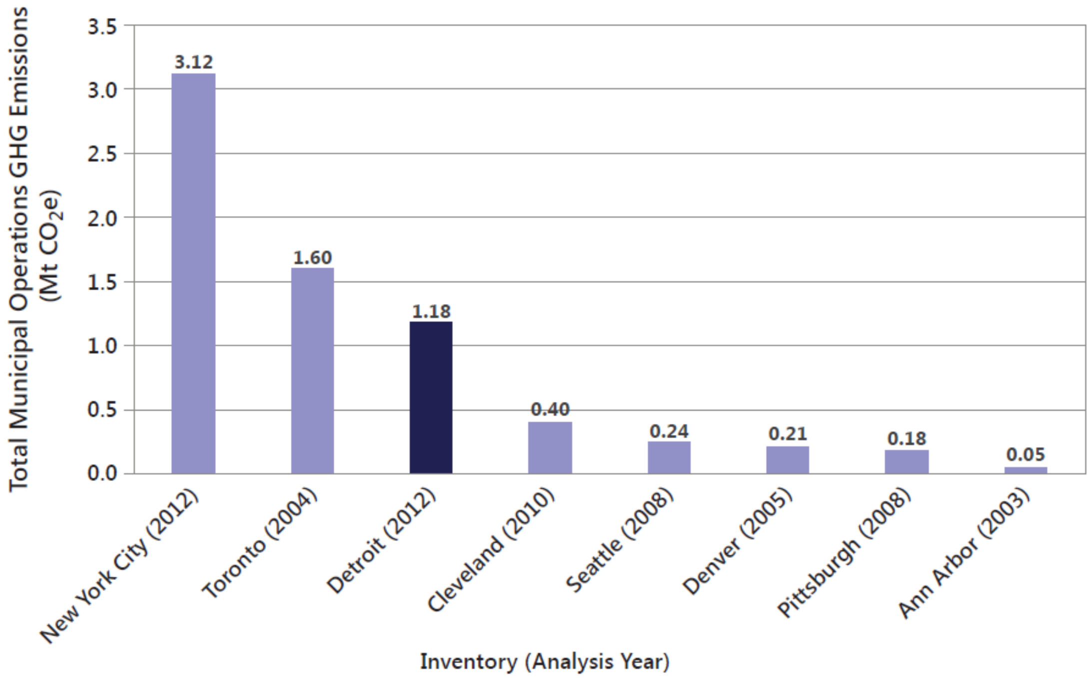


Figure 28: Comparison of Municipal Operations Emissions from Select North American Cities (million t CO_2e)

Emissions from City of Detroit municipal operations fall in the upper 50th percentile, with 1.18 million t CO_2e accounted for in 2012. One factor influencing the relative magnitude of Detroit's municipal operations emissions stems from the fact that the Detroit Water and Sewerage Department (the largest single departmental source of emissions in the Detroit municipal inventory) provides water and wastewater treatment services to the greater metropolitan region, while having highly-centralized operations within the city limits of Detroit. The wide range of municipal operation emissions is not surprising given differences in infrastructure, organization of city government, and public services provided by each municipality.

[98] Dodman (2009)

CONCLUSIONS AND NEXT STEPS

The GHG citywide and municipal inventory analyses for 2011 and 2012 presented in this report are the first to comprehensively account for GHG emissions in the City of Detroit. Key findings of this analysis, presented below, include an accounting of total citywide emissions, the contribution of municipal operations to emissions totals, and the relative contributions of major activities and sources of emissions in the city.

In 2011 and 2012, citywide emissions were nearly equal, with 10.6 million t CO_2e emitted in 2011 and 2012. In 2012, 63% of Detroit's citywide emissions (6.7 million t CO_2e) were a result of electricity and natural gas use in Detroit's buildings and facilities—the largest contributing activity in both years. Electricity use in the city contributed 45% to 2012 citywide emissions, due in part to DTE Energy's fuel mix, which consists of more than 75% coal.[99]

Other Citywide Key Findings

- Approximately 41% of emissions from stationary sources, such as buildings and facilities, occurred in four of Detroit's thirty Zip Codes (these Zip Codes are 48217, 48209, 48211, 48226);
- The Commercial and Institutional end-use sector—which includes retail goods and services, non-profit agencies, and academic institutions—accounted for more than 50% of the buildings and facilities total emissions in 2012; and
- Passenger car, truck, and on-road freight contributed 98% of total citywide transportation emissions. The municipal government vehicle fleet, including public transportation vehicles, contributed only 2% of citywide transportation emissions.

The City of Detroit's municipal government operations accounted for approximately 11% of citywide emissions in both 2011 and 2012 (1.17 and 1.18 million t CO_2e, respectively). In 2012, four City of Detroit departments (Detroit Water and Sewerage Department, Detroit Public Lighting Department, Detroit Department of Public Works, and Greater Detroit Resource Recovery Authority) were responsible for 93% of City of Detroit's municipal emissions.

Additional analyses that complement these key citywide and municipal inventory findings were also outlined. Emissions sequestered from Detroit's urban tree canopy were estimated to be approximately 0.07 million t CO_2e annually. Furthermore, Detroit's citywide emissions on a per capita basis were found to be 15.2 t CO_2e/person in 2012. Comparatively speaking, Detroit's per capita emissions were lower than both the U.S. and State of Michigan averages, and fell in the middle of a select sample of North American cities whose citywide inventories were analyzed.

[99] DTE Energy (2014)

Ultimately, this inventory analysis can be a tool to guide near and long-term policy and planning in Detroit and provides a snapshot Detroit's GHG emission contribution, illustrating which activities can be identified for efficiency improvements.

The data collection and analysis procedure developed by this inventory attempts to be comprehensive and account for Detroit's major GHG emitting activities. However, given that this project is the first-ever endeavor to quantify Detroit's GHG emissions, there are numerous ways to strengthen the process and ensure that the City of Detroit's climate action planning efforts continue to move forward.[100]

After more than a year of work conducting Detroit's GHG inventory and connecting with more than 50 organizations to collect data, gather contextual information, and share the results of this analysis, the project team has accomplished a number of steps and outlined additional recommendations to both DCAC and the City of Detroit to refine and strengthen the Detroit GHG inventory process, data collection, and analysis.

Institutionalization of the GHG Inventory Process

Steps Already Taken toward Institutionalization

- **Internally verified Detroit GHG inventory analyses and results.** One of the first steps in the institutionalization of the Detroit GHG inventory was to internally verify the results presented in the preliminary report, published in April 2014, with CSS, DCAC, and the City of Detroit. The analysis and results were internally verified, adding credibility to future analyses that aim to replicate this work. Other third-party verification services and resources, from organizations like ICLEI or The Climate Registry, exist but were cost-prohibitive. Future inventory analyses could explore the use of such services.
- **Conducted an external, peer-review and feedback process of the preliminary report (City of Detroit GHG Inventory: An Analysis of Citywide and Municipal Emissions from 2011 and 2012).** The preliminary report, published in April 2014, was reviewed by a team of more than 10 volunteer reviewers that are engaged in sustainability and climate efforts in and around Detroit. Their feedback has been incorporated to ensure that the final report is engaging, accessible to diverse audiences, and meaningful to the climate action planning efforts underway.
- **Developed a data- and people-side infrastructure that will facilitate future GHG inventory reporting.** The Detroit GHG inventory team and CSS is working with the City of Detroit municipal government and DCAC to facilitate the transition of data collection, storage, analysis, and reporting. A comprehensive suite of data and analysis files, work and data processing plans, slide decks, project notes and summaries, and accompanying report materials has been created to organize current project findings and facilitate project

[100] For discussion of assumptions and limitations of each activity, please see Appendices E and I.

management of future inventories. The team refined the GHG inventory analysis file system and data processing spreadsheets so that other potential inventory analysts can easily and credibly replicate the methods used.

- **Conducted stakeholder meetings, organized a half-day workshop, and met with the City of Detroit's Mayor's Office to share project objectives and results.** The Detroit GHG inventory team organized and participated in several meetings with stakeholders, GHG inventory data sources, and decision-makers from both the City of Detroit and greater Great Lakes region to share the final inventory results and to help facilitate future work.

Future Steps toward Institutionalization

- **Institutionalize the GHG inventory process and conduct inventories at regular time intervals**. The inventories for 2011 and 2012 show a snapshot of where Detroit was with regard to its GHG emissions contribution in recent years and will inform the development of a climate action plan. However, conducting subsequent inventories, ideally on an annual basis, would show Detroit's progress moving forward. Without subsequent GHG inventories it will be difficult to measure success of policies to reduce emissions or improve energy efficiency. Provided that emissions reduction targets are referenced to this baseline inventory analysis, future inventories would enable the measurement of progress toward those goals over time.
    - **Future inventory work could involve any or all of a spectrum of actions, from tracking emissions data internally to reporting analysis publicly.** This could include reporting annual emissions to the CDP, producing a public annual report, or internally documenting municipal emissions (with potentially different reporting mechanisms for citywide and municipal inventory analyses).
- **Match future GHG inventory analyses with municipal structures and government-wide priorities.** Future inventories should account for the unique governmental structure of the City of Detroit (particularly given any changes to its structure that may occur in the future), so that data collection, analysis, and reporting efforts aligns and can be integrated with departmental goals of efficiency, cost savings, and continued improvement of city services.
- **Build capacity for future GHG inventory work, climate action planning, and energy efficiency projects through dedicated staff and financial resources.** The establishment or hiring of a 'Sustainability Director,' dedicated grant-writer, or student fellows in partnership with the City of Detroit could greatly benefit climate action planning in the city by centralizing future GHG inventory data collection, analysis, and communication efforts, securing continued funding for climate work in Detroit, or supporting the efforts already underway in collaboration with DCAC and other partners.

- **Collaborate across sectors, organizations, and City of Detroit departments to facilitate GHG inventory data collection and climate planning initiatives.** Collaboration—not only at the municipal scale, but also at the city and regional scales—is critical to solving complex problems. Its importance increases with problem complexity and scarcity of human and financial resources, an issue that is of particular relevance to Detroit.
- **Continue City of Detroit participation in the CDP.** Ongoing efforts in Detroit to reduce emissions associated with municipal buildings and facilities and to report emissions to the CDP, which began in 2013, show a continuing commitment of the city to improve department-level energy and operational efficiencies. Building on these efforts, the inventory team worked with the City of Detroit to compare our results with the city's facility records and plans to help establish the framework and structure that will allow the city to continue to report its emissions to the CDP in future years.

Communication of Detroit GHG Inventory Results

- **Engage stakeholders and communicate GHG inventory results through publicly available materials, presentations of key findings, and meetings.** Ultimately, the long term value and impact of a GHG inventory depends on decision-makers' ability to understand its results and on the resources available to plan and implement climate-related measures. Thus, it is crucial that GHG inventory results are shared not only in this published report, but also through additional publicly available materials, presentations, and meetings with various stakeholder groups and decision-makers. Inventory results must be consistently presented in a manner digestible for both technical and non-technical audiences.[101]
- **Continue to explore the spatial analysis of Detroit's GHG emissions.** The spatial analyses of GHG emissions by Zip Code presented in this first comprehensive report was a good first step and generated significant interest from Detroit stakeholders. Further analyses could provide useful insights to stakeholders (including but not limited to city planners, policy-makers, and civil society) and could enable the City of Detroit to be a leader for other cities who plan to incorporate these innovative analyses.[102]

[101] The project team developed data visualization and communication tools to accompany the report and communicate results in an accessible and engaging manner at stakeholder meetings and to the public more broadly.
[102] Some precedent for spatial analysis of GHG emissions exists, though at the time of this report, few have been fully incorporated into citywide or local GHG inventory analyses. For reference, existing spatial analyses have included analysis of Toronto's residential carbon footprint, U.S. emissions associated with fertilizer application, and certain emissions at a regional level in research from the Delaware Valley Regional Planning Commission (VandeWeghe and Kennedy 2007, Pearson et al. 2010, DVRPC 2010).

- **In future Detroit GHG inventories, connect emissions reductions and efficiency improvements to opportunities for and estimations of cost-savings.** This would enable the City of Detroit and DCAC to better demonstrate the net benefits of climate action to both the climate system and city finances.

GHG Inventory Data Collection

- **Continue to strengthen relationships with key stakeholders in the public and private sectors to streamline data collection efforts.** Those conducting future inventories should work closely with inventory data contacts and staff of relevant departments or agencies to improve understanding of data availability, quality, and archiving processes.
- **Account for potential structural changes within City of Detroit municipal government.** As a result of the recent municipal bankruptcy and associated restructuring of city services within the City of Detroit government and through privatization and new municipal contracts, it is imperative that future municipal inventories to account for changes to the city's organizational structure moving forward (since the operational control of these services may no longer be under the direct jurisdictional control of the City of Detroit). In recent years, many large cities in the U.S. have privatized city services or established quasi-public agencies that manage these contracts and service agreements. Such agreements add complexity to decisions made by municipal inventories of what information or activities to include or not and may also lead to new data collection or transparency challenges.

GHG Inventory Data Analysis

- **Further disaggregate GHG inventory results to facilitate more targeted mitigation and climate policies.** Such disaggregation could include, but is not limited to: an analysis of seasonal sensitivity of GHG emissions to Heating and Cooling Degree days (preliminary data for this analysis was gathered and included in Appendix M), further disaggregation of results by Zip Code, characterizing buildings and facilities emissions by Standard Industry Classification (SIC) Code (which were provided by DTE Energy in 2011 and 2012), and a more robust land use analysis that calculates emission sources and sinks from other land cover classes (e.g., herbaceous vegetation and bare soil).
- **Future Detroit GHG inventories should revise calculations of 2011 and 2012 analyses, if new data or methodologies become available.** It is common for emissions calculations in baseline local GHG inventories to be revised or edited as new methods and information become available, in order to ensure standard comparisons across inventory analysis years.

- **Future Detroit GHG inventories should normalize emissions results on a 'functional unit' basis.** It is important to view the GHG Inventory in the context of the goods and services provided via the emissions-generating activities reported. In addition to observing absolute changes in emissions over time, it is equally important to analyze the *efficiency* by which goods and services are delivered. Therefore, future inventories would benefit from presenting normalized results from a given emissions source—such as wastewater treatment—to the service provided to the Detroit community—such as gallons of wastewater treated.
- **Future Detroit GHG inventories should explicitly quantify the impacts from services provided to the greater metropolitan community.** As demonstrated by key findings throughout this inventory**,** the City of Detroit provides numerous services to the larger metropolitan region. For example, DWSD treats wastewater from and supplies water services to three counties in Southeastern Michigan. Future GHG inventories would benefit from describing the relative contributions of communities outside of Detroit, thereby providing greater nuance to the specific leverage points that Detroiters may have to tackle climate change.
- **Consider climate mitigation, efficiency improvements, and climate adaptation measures synergistically, not in isolation.** For some activities such as land use, synergies exist between climate mitigation and adaptation. It is important not only to find overlap between such activities, but also to identify and minimize the impact of mitigation policies that reduce resilience or, alternatively, adaptation initiatives that increase GHG emissions. For example, cooling centers reduce exposure to extreme heat events and therefore serve as a climate adaptation strategy. While cooling centers use energy, if this energy were supplied through renewable technologies, there would be a potential to reduce emissions as compared to our current carbon intensive energy system.

Activity-Specific Recommendations

Buildings and Facilities

- **Normalize energy use based on weather.** Future inventories could normalize energy use in buildings and facilities activity calculations based on Heating Degree Days and Cooling Degree Days, as described in Appendix M. This would provide a more robust, seasonal analysis of energy use in Detroit's buildings and facilities.

Transportation

- **Track additional transportation indicators in order to avoid using complicated modeling approaches.** The City of Detroit could avoid complicated 'black box' modeling approaches and emissions calculations (e.g., the use of U.S. EPA MOVES modeling software in combination with estimations from regional travel demand models relied upon in the 2011 and 2012 analyses) by tracking additional transportation indicators to use for

benchmarking purposes. For example, these additional metrics could include changes in regional VMT and traffic flows into and out of Detroit, changes in aggregate fuel economy of vehicles *registered* in the City of Detroit, the number of alternative fueling stations in the City of Detroit, or the demand for public transportation—both within the City of Detroit and across the city's borders. These additional metrics could more meaningfully inform decision-making and measure progress toward more sustainable transportation systems.

- **Encourage further collaboration among key stakeholders working to reduce emissions from transportation.** Organizations like the Detroit Future City, SEMCOG, Southwest Detroit Environmental Vision, U.S. EPA OTAQ, and City of Detroit fleet and transportation managers should collaborate with DCAC to reduce community transportation emissions and to create a more robust, collaborative transportation future for Detroit.

Industrial Process

- **Perform additional analysis to understand process and fugitive emissions from smaller industrial sources (those not required to report to U.S. EPA).** The industrial process inventory methodology used in the Detroit GHG inventory for 2011 and 2012 accounts only for large sources of industrial process emissions—which during 2011 and 2012 included emissions associated with petroleum refining and hydrogen production within the city limits. Additional analyses or modeling could be performed to understand process and fugitive emissions from smaller industrial sources (those not required to report to U.S. EPA GHGRP). These methods may show sources of GHGs not accounted for in the current inventory analysis, such as SF_6, HFCs, or PFCs.

Solid Waste

- **Disaggregate and incorporate landfill emissions associated with solid waste disposal from other end-use sectors (e.g. commercial and industrial solid waste).** For example, it is unclear to what extent the current analyses account for solid waste generated from construction or demolition activities at the city's EFW facility, or what amount of the solid waste generated by these activities are landfilled. The waste materials generated from these activities would be important to disaggregate and include in future inventories in order to understand more specifically their GHG emissions impact and the impact, for example, of blight removal efforts proposed in the city's Plan of Adjustment blueprint[103] and those currently being undertaken by the City of Detroit, Detroit Future City, and the Detroit Building Authority and Detroit Land Bank Authority.[104]

- **Revise data collection and analysis processes for solid waste activities commensurate with structural changes to the City government that affect waste collection and processing.** In early 2014, the City of Detroit privatized its municipal solid waste collection

---

[103] Gallagher et al. (2014)

[104] This project was formerly co-managed by the Detroit Blight Authority (DBA).

process, managed previously by the City's Department of Public Works.[105] As a result, inventory analyses for 2014 or later will need to revise how these data are collected and analyze. Depending on the language of these new contracts, future inventories may need to reevaluate whether or not to continue including municipal solid waste management under the operational control of the City of Detroit (and therefore including these emissions in future municipal inventory analyses).

- **Scope potential GHG emission impacts from current and projected construction and demolition activities in the City of Detroit.** Preliminary steps should be taken to assess the potential impacts from construction and demolition projects in the City of Detroit, especially in light of continued, or potentially increasing, vacant housing demolition.[106] Depending on the magnitude of assessed impacts, steps could be taken to institutionalize data reporting for participating private companies so that emissions could be quantified and the sustainability of such processes optimized.

Wastewater Treatment

- **Revise wastewater treatment data analysis to better account for the actual population in DWSD's wastewater service area.** In this inventory, the methods used for several calculations relied on estimated population served parameter to calculate emissions from DWSD's aerobic treatment process and the fugitive emissions associated with wastewater effluent discharged into the Rouge River and Detroit River. ICLEI Community Protocol recommends these population-based methods only in the absence of plant-specific nutrient-load data. While DWSD tracks and provided the inventory with the nutrient-loading information it collects for regulatory purposes, these data were not in the form needed for the more precise calculations currently outlined and recommended by ICLEI. A revised, population-based method could utilize GIS software, DWSD service area maps, and U.S. Census information to estimate more accurately the population within DWSD's wastewater service area.

Land Use

- **Refine methodology for land cover calculations in Detroit.** Through conversations with stakeholders involved in the DCAC process, it is clear that land use and land cover change is an extremely important issue to climate planning in Detroit as well as relevant to other sustainability goals within the City. Furthermore, a more thorough examination of the possible GHG impacts from agricultural practices and restoration and conservation projects could further integrate land uses with climate mitigation and adaptation efforts in the City.

---

[105] Guillen (2014)
[106] Gallagher et al. (2014)

Municipal Inventory Recommendations

- **Refine methodology to gain a better understanding of energy usage in municipal buildings and facilities operated by the City of Detroit.** Additional data for 2011 and 2012 from the Detroit Public Lighting Department (PLD) about their electricity customers may allow for greater disaggregation of the public utility's electricity distribution in this inventory, than the level of detail currently provided within the DTE Energy dataset. As former customers of PLD shift their electricity purchases to DTE Energy, this additional data analysis will no longer be necessary.
- **Calculate and include GHG emissions from employee commute in subsequent municipal GHG inventories of Detroit.** While not required for protocol-compliant inventories, the activity category of "employee commute" is often recommended to include in a municipal inventory by local government inventory protocols, allowing municipalities to estimate the impact of their employees' transportation demand and to create targeted commute and carpool programs. Generally, this activity is measured by conducting a survey of municipal employee commutes, including estimated VMT and fuel use.

APPENDICES

Appendix A: Overview of GHG Inventory Scopes, Activities, and Sources

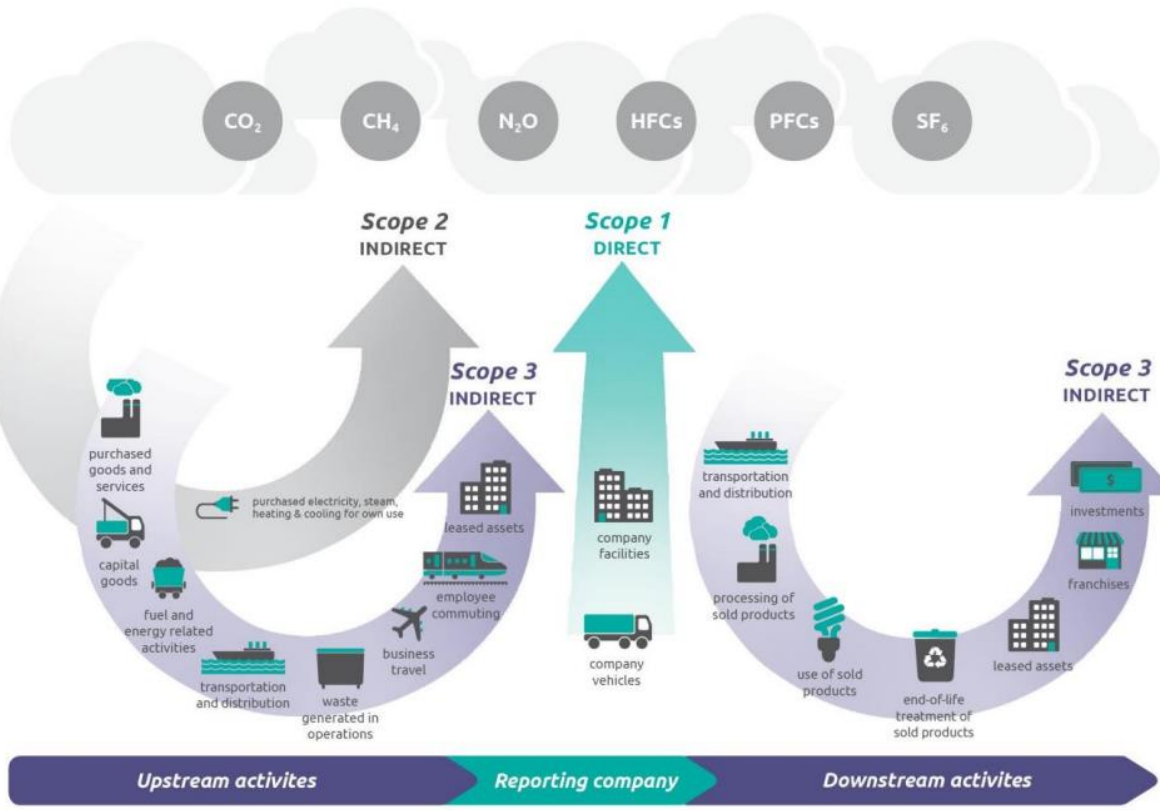


Figure 29: GHG Inventory Scopes, Activities, and Sources
Image Source: Climate Registry (2013)

This image is a frequently cited depiction of GHG inventory accounting scope categories, which classify direct and indirect emissions based on ownership and operational control of the reporting entity. The diagram shows common examples of each scope category. Originally developed by the WRI and WBCSD Protocol, the organizing framework of 'Scope 1, 2, and 3' is more commonly applied to corporate GHG inventories than local or community-wide inventories. This is because the geographic boundaries and jurisdictional control issues at the city scale tend to be much more complex than at an organizational or corporate scale. This difficulty often makes the line between direct and indirect emissions less clear in local inventory analyses, like the Detroit GHG Inventory. These boundary and scope complexities have been highlighted throughout the report and are important for any users of the inventory to keep in mind as they analyze the results.

Among other rationale, classifying emissions based on scope allows reporting entities to compare across years or to one another more readily and avoid double counting emissions. For example,

the indirect emissions of one corporate entity, such as those from electricity use, are the direct emissions of another corporate entity, that is, the electricity provider's emissions from power generation.

Appendix B: Inventory Data Sources and Stakeholder Outreach

Table 5: Citywide Inventory Data Summary and Sources

Activity	Data Provided	Data Year(s)	Source
Buildings and Facilities	Average monthly electricity and natural gas consumption	2011, 2012	DTE Energy
Transportation	VMT for passenger vehicles, trucks, and on-road freight (trips starting and/or ending within City of Detroit)	2010	SEMCOG (Planning and Policy Development)
	VMT and fuel use for City of Detroit SMART Bus routes (fiscal year data)	2011, 2012	SMART Bus
	People Mover electricity consumption	2011, 2012	National Transit Database
	DDOT fuel consumption by fuel type	2011, 2012	National Transit Database
	Fuel purchases by fuel type and department	2011, 2012	City of Detroit (GSD)
	Fuel purchases by fuel type	2011, 2012	City of Detroit (DWSD)
Industrial Process	Total annual emissions for hydrogen production and petroleum refining	2011, 2012	U.S. EPA GHGRP FLIGHT Database
Solid Waste	Tonnage of waste landfilled, incinerated, recycled, and composted	2005, 2010, 2011, 2012	Wayne County (City of Detroit Solid Waste Stream Reports)
	Total annual emissions for waste incineration	2011, 2012	U.S. EPA GHGRP FLIGHT Database
Wastewater Treatment	Mass of wet weight sludge (biosolids) incinerated	2005, 2010, 2011, 2012	City of Detroit (DWSD)
Land Use	GoogleEarth Imagery	2010	U.S. Forest Service i-Tree Canopy Software
Additional Municipal Inventory Activities and Data Source			
Buildings and Facilities	Total annual electricity and natural gas consumption by City of Detroit accounts	2011, 2012	DTE Energy

Table 6: Stakeholder Organizations Consulted during Inventory Project

Organization Name		
City of Ann Arbor, Systems Planning	Detroit Transit Corporation People Mover	Sierra Club, Michigan Chapter
City of Detroit, Buildings, Safety, Engineering, & Environmental	Detroit Water and Sewerage Department, City of Detroit	SMART Bus
City of Detroit, Coleman A. Young Municipal Airport	Detroiters Working for Environmental Justice	Southeast Michigan Council of Governments (SEMCOG)
City of Detroit, Department of Public Health	DTE Energy	Southwest Detroit Environmental Vision
City of Detroit, Department of Public Works	DTE Energy Foundation	U.S. EPA Office of Atmospheric Programs, State and Local Climate and Energy Program
City of Detroit, Detroit Department of Transportation	East Michigan Environmental Action Coalition	U.S. EPA Office of Resource Conservation and Recovery
City of Detroit, General Services Department	Ford Motor Company	U.S. EPA Office of Transportation and Air Quality, Transportation and Climate Division
City of Detroit, Parks and Recreation Department	Great Lakes Integrated Sciences and Assessments (GLISA)	U.S. EPA Region 5 Office
City of Detroit, Public Lighting Department	Greater Detroit Resource Recovery Authority	U.S. Green Building Council Detroit Regional Chamber
City of Detroit, Purchasing Department	Green Dearborn, City of Dearborn	University of Michigan Center for Sustainable Systems
City of Grand Rapids, Mayor Heartwell's Office	Institute for Population Health	University of Michigan Energy Institute
City of Missoula, Montana	Mayor Duggan's Office, City of Detroit	University of Michigan Erb Institute
Chrysler Group	McNeely Building Group	University of Michigan Graham Sustainability Institute
Clean Energy Coalition	Michigan Department of Environmental Quality	University of Michigan MCubed
ClimateRide	Michigan Environmental Council	University of Michigan School of Natural Resources and Environment
Columbia University	Michigan Suburbs Alliance	University of Michigan School of Public Health
Data Driven Detroit	National Wildlife Federation	University of Michigan Taubman School of Architecture and Urban Planning
Detroit Climate Action Collaborative Steering Committee	New York City Office of Long-Term Planning and Sustainability	WARM Training Center (now EcoWorks)
Detroit Climate Action Collaborative Working Groups	NextEnergy	Wayne County Department of Public Services
Detroit Future City, Detroit Economic Growth Corporation	Oakland Community College	Wayne County Land Resource Management Office
Detroit Housing Commission	Parjana Distribution and Parjana Green	Wayne State University Office of Sustainability
Detroit Regional Chamber	Photo Science Geospatial Solutions, Inc.	
Detroit Renewable Power	PureEco Environmental Solutions	

Appendix C: Citywide Inventory Emission Factors

Table 7: Emission Factors Summary

Carrier	Type	Analysis Year	Emission Factor	Unit	Data Source or Calculation Note
Electricity	Purchased Electricity - eGRID RFCM Sub-region	2009	1668.76	lb CO_2e/MWh	eGRID, U.S. EPA (2012a)
Electricity	DTE Energy Electricity Generation	2011	1715	lb CO_2e/MWh	DTE Energy
Electricity	DTE Energy Electricity Generation	2012	1895	lb CO_2e/MWh	DTE Energy
Electricity	Composite Electricity	2011	0.000775	t CO_2e/kWh	Calculated using DTE Energy, eGRID
Electricity	Composite Electricity	2012	0.000838	t CO_2e/kWh	Calculated using DTE Energy, eGRID
Electricity T&D Loss	Electricity T&D Loss	2011	0.0000479	t CO_2e/kWh	Calculated from DTE Energy, eGRID
Electricity T&D Loss	Electricity T&D Loss	2012	0.0000518	t CO_2e/kWh	Calculated from DTE Energy, eGRID
Natural Gas	DTE Energy Default U.S. EPA Higher Heating Value (HHV) Natural Gas	-	0.005424	t CO_2e/ccf	DTE Energy
Unleaded Gasoline	Unleaded Gasoline	-	8.78	kg CO_2/gal	U.S. EPA (2011), ICLEI
Diesel	Diesel	-	10.21	kg CO_2/gal	U.S. EPA (2011), ICLEI
Biodiesel (B100)	Biodiesel (B100)	-	9.45	kg CO_2/gal	U.S. EPA (2011), ICLEI

Appendix D: Citywide Building and Facilities End-Use Sector Categories

Table 8: End-Use Sector Categories for Building and Facilities Analysis

End-Use Sector Reported in Detroit Inventory	Definition and Explanation	2-Digit SIC Code* Range, if applicable	Examples of Standard Activities of SIC Code Categories
Industrial	Energy-consuming sector that consists of all facilities and equipment used for producing, processing, or assembling goods. The Industrial group used in this analysis was determined using 2-digit SIC Codes provided by DTE Energy.	01 to 39**	manufacturing, agriculture, forestry, and fishing, mining (including oil and gas extraction), and construction
Commercial and Institutional	Energy-consuming sector group that consists of both commercial (i.e., private service-providing facilities and retail businesses) and institutional (i.e., public or not-for-profit groups and organizations, such as nonprofits, hospitals, or municipal government) entities. The Commercial and Institutional group used in this analysis was determined using a combination of customer identifiers (including but not limited to small corporate customers, limited liability corporations, sole proprietorships, governmental customers, nonprofit customers) and 2-digit SIC Codes provided by DTE Energy.	40 to 99	wholesale and retail trade, transportation and warehouse services, information, finance and insurance, real estate, scientific and technical services, educational services, health care, arts and entertainment, hospitality and food service, public administration, among others
Residential	Energy-consuming sector that consists of living quarters for private households. The Residential group used in this analysis was determined by the 'Residential' customer identifier provided by DTE Energy in their dataset (which includes both single- and multi-family residential buildings).	n/a	n/a

*For a formal definition of the term "SIC Code," refer to the Glossary at the end of the report.

**Industrial end-use sector SIC Code delineation supported by EIA definition of industrial activities (EIA 2014b)

Appendix E: Citywide Inventory Detailed Methods

Buildings and Facilities

Methods

The buildings and facilities activity category includes CO_2, CH_4, and N_2O emissions [107] associated with heating, cooling, and powering residential, commercial and institutional (including municipally-operated buildings), and industrial buildings and facilities using electricity and natural gas distributed by DTE Energy. GHGs are emitted during the combustion of fossil fuels for electricity generation and on-site stationary combustion of natural gas for building heating and power. Emissions are also associated with electricity losses due to transmission and distribution (T&D) through the grid. Academic literature and standard GHG protocols encourage the calculation of emissions due to T&D loss—even though they are generally categorized as 'Scope 3' emissions—because these losses can be a significant source of annual emissions.[108]

To calculate total annual emissions from these sources, DTE Energy electricity and natural gas consumption data (in kWh and ccf, respectively) were multiplied by DTE Energy generation and U.S. EPA eGRID RFCM[109] sub-region emission factors (listed in Appendix C, Table 7).

DTE Energy provided the project with average monthly usage data (in kWh or ccf per month) for their customer accounts located in the City of Detroit on an annual basis for 2011 and 2012 (scrubbed of any confidential customer identification information). Because not all consumption values spanned a full calendar year, to and from meter read dates were used to determine the number of months a given account was metered. Consequently, a simple rule ("11-month rule") was applied to approximate total annual consumption for each customer: those whose usage spanned more than 11 months (some meter periods were more than one calendar year) were prorated to 12 months, whereas those spanning less than or equal to 11 months were not prorated. Prorating assumed that metered consumption data covering more than 11 months of a year sufficiently represented annual consumption patterns that vary with seasonality and customer habits. Prorating accounts according to this rule smoothed meter-reading inconsistencies in the datasets provided.

The average monthly usage values were multiplied by the adjusted number of months metered to find total annual energy consumption. Once calculated, total annual electricity and natural gas consumption values were then multiplied by their respective emission factors[110] to find emissions

[107] Buildings and facilities emissions includes CO_2 from the DTE Energy generated electricity, CO_2 from on-site stationary combustion of natural gas, and CO_2, CH_4, and N_2O emissions from grid-purchased electricity.
[108] Richter (2012), Sugar et al. (2011)
[109] To see the area that EPA eGRID Subregion RFCM covers, view map on the U.S. EPA eGRID FAQ webpage: http://www.epa.gov/cleanenergy/energy-resources/egrid/faq.html.
[110] Electricity and natural gas emission factors vary based on year and type of carrier.

in CO_2e. Emissions due to T&D line losses for electricity were calculated by multiplying an annual transmission line loss emission factor[111] from the U.S. EPA by annual total electricity consumption. Notable energy-related EF methodology is explained subsequently, and Table 9 summarizes the factors used.

Table 9: Electricity and Natural Gas Emission Factors

Carrier	Type	Analysis Year	Emission Factor	Unit	Data Source or Calculation Note
Electricity	Purchased Electricity - eGRID RFCM Sub-region	2009	1668.76	lb CO_2e/MWh	eGRID, U.S. EPA (2012a)
Electricity	DTE Energy Electricity Generation	2011	1715	lb CO_2e/MWh	DTE Energy
Electricity	DTE Energy Electricity Generation	2012	1895	lb CO_2e/MWh	DTE Energy
Electricity	Composite Electricity	2011	0.000775	t CO_2e/kWh	Calculated using DTE Energy, eGRID
Electricity	Composite Electricity	2012	0.000838	t CO_2e/kWh	Calculated using DTE Energy, eGRID
Electricity T&D Loss	Electricity T&D Loss	2011	0.0000479	t CO_2e/kWh	Calculated from DTE Energy, eGRID
Electricity T&D Loss	Electricity T&D Loss	2012	0.0000518	t CO_2e/kWh	Calculated from DTE Energy, eGRID
Natural Gas	DTE Energy Default U.S. EPA Higher Heating Value (HHV) Natural Gas	-	0.005424	t CO_2e/ccf	DTE Energy

For electricity emission factors, DTE Energy operates electricity generation plants to generate a portion of the electricity it distributes, but it also purchases electricity from the grid that relies on other generation sources. Therefore, we calculated an annual 'composite' electricity emission factor for the City of Detroit by combining: 1) a generalized grid electricity emission factor from U.S. EPA's eGRID sub-region RFCM, with 2) DTE Energy generation emission factor for their power plant fuel mixes. This 'composite' EF was calculated, as follows:

Composite Electricity EF = (% Purchased Electricity * eGRID EF) + (% DTE Energy Fuel Mix * DTE Energy EF)

To calculate emissions associated with the combustion of natural gas, DTE Energy provided natural gas emission factors or high heating values (HHV) for the gas they distribute to customers in the

[111] U.S. EPA Grid Line Loss factor from eGRID sub-region RFCM (Diem and Quiroz 2012)

City of Detroit. A HHV of 1028 Btu/scf was used to calculate the emissions from natural gas combustion.

To calculate the T&D emission factor, a Grid Line Loss emission factor for eGRID sub-region RFCM was multiplied by the emission rate for electricity dataset here (or the *Composite Electricity EF)* and divided by the difference between one and the eGRID Line Loss Factor as follows:

$$\text{T\&D EF} = \frac{(\text{eGRID Line Loss Factor} * \text{Composite Electricity EF})}{(1 - \text{eGRID Line Loss Factor})}$$

Assumptions and Limitations

Using the assumed 11-month rule, this analysis prorated the provided data to account for a single calendar year's total consumption as accurately as possible. That said, there continues to be some uncertainty with these data ranging from 0 - 11 months, which were not prorated to the full year. These data were metered for a smaller portion of time and may not fully reflect changes in energy consumption from seasonality. These short metering periods could occur in the data set for a number of real reasons: the customer or business may have moved and closed the account, or a customer only used that service over a short period of time (e.g., natural gas during the winter).

Furthermore, a third-party contractor archives DTE energy consumption data older than two years—making those data no longer available for research purposes such as this inventory. For this reason, DTE Energy consumption data from the years 2005 and 2010, while pursued initially, were deemed to be incomplete and unable to be used in these analyses.

Methane from leakage of natural gas systems is not included in this inventory.

While the Detroit Public Lighting Department (PLD) was once the City of Detroit's primary public electricity utility and managed its own electricity generation, the department has been restructured in recent years. In the inventory analysis years of 2011 and 2012, PLD has been solely an electricity distributor—purchasing electricity from DTE Energy and distributing this electricity to its customers. For the purposes of this analysis, all electricity supplied to City of Detroit customers is accounted for in data provided by DTE Energy (whether directly as DTE customers or indirectly through the Detroit Public Lighting Department's electricity purchases from DTE). This detail of the buildings and facilities accounting methodology was supported by conversations with DTE Energy about the transition of electricity customers from PLD to DTE Energy during the inventory analysis years.

Transportation

Citywide transportation includes both community transportation and municipal government transportation emissions—the distinct methods for these specific activities follow.

Community Transportation Methods

Non-municipal transportation, also called community transportation, includes CO_2, CH_4, and N_2O emissions due to the combustion of gasoline and diesel fuels from passenger cars, passenger trucks, and on-road freight travel whose trips start and/or end in the City of Detroit. To model these community transportation emissions, Southeast Michigan Council of Governments (SEMCOG) provided average weekday vehicles miles traveled (VMT) data for trips that start and/or end in the City of Detroit 2010. These Detroit-specific VMT data are estimated via the Southeastern Michigan regional travel demand model. Although the Detroit-specific VMT has less statistical certainty than the VMT projections for the entire region, the estimate serves as the best available approximation for VMT within Detroit. Although SEMCOG also provided in-boundary VMT data, following suggestions from ICLEI protocol[112] and transportation literature,[113] we utilized VMT data for trips that start and/or end in the City of Detroit to calculate emissions. The ICLEI Origin-Destination Model used in this analysis assumes that local governments have more control over vehicle travel that starts and/or ends in their community than it would over "in-boundary travel" necessarily.

We calculated an emission factor per VMT from U.S. EPA MOVES software,[114] utilizing the following specifications:

1. Selection of national domain with county geographical selection (Wayne County) as suggested via conversations in June 2013 with officials at the U.S. EPA Office of Transportation and Air Quality (OTAQ);
2. Selection of diesel, gasoline, and compressed natural gas as fuels;
3. Selection of combination long-haul truck, combination short-haul truck, light commercial truck, motor home, motorcycle, passenger car, passenger truck, refuse truck, single unit long-haul truck, single unit short-haul truck for vehicles. Excluded intercity bus, school bus, and transit bus to avoid double counting (since these modes are assumed to be captured in separate analyses outlined subsequently);
4. Due to conversations in December 2013 with transportation planners at SEMCOG regarding estimated VMT changes from year to year, we used 2010 numbers as a proxy for 2011 and 2012; we did not apply a percentage increase.[115]

---

[112] ICLEI (2012) Appendix D: Transportation and Other Mobile Emission Activities and Sources

[113] Davies, et al. (2007): 41-46.

[114] U.S. EPA MOVES is free, open-source software available online at this link (U.S. EPA 2014c).

[115] Via personal communications with SEMCOG, conflicting trends exist of how VMT is changing in SE Michigan and therefore difficulty in altering Wayne County trends to approximate City of Detroit VMT. Various sources (MDOT,

Furthermore, we examined the ratio of weekday to total week travel (1/1.8) to allocate emissions for Detroit. CO_2, CH_4, and N_2O emission factors for gasoline and diesel combustion are contained within the U.S. EPA MOVES software.

Community transportation also includes SMART Bus service within the boundary of Detroit. SMART Bus provided VMT and fuel use data in fiscal year increments. The analysis in this inventory assumes that 2011 calendar year emissions and VMT are equivalent to the provided Fiscal Year 2011-2012 fuel usage and VMT (similarly, 2012 calendar year assumed equivalent to FY2012-2013). SMART Bus uses B5 biodiesel from November through April, and B20 biodiesel from May through October. To determine a fuel mix emission factor, we assume that 50% of the fuel used each year is a B5 blend, and 50% is a B20 blend (See Table 10 for transportation emissions factors).

Assumptions and Limitations

Average emissions per VMT for Wayne County are assumed to be equal to average emissions per VMT for the City of Detroit. There are limitations associated with accounting for cross-boundary travel. There are local variations in vehicle type, age, fuel efficiency, and fuel type used that would improve the accuracy of this community transportation analysis. We excluded modeling community electric vehicles due to lack of data. Due to the transportation planning processes at SEMCOG, VMT data are only available every five years; data is available for 2010, but not for 2011 and 2012.

At this time, we are unable to determine the directionality of uncertainty for this analysis. However, this community transportation analysis was evaluated against other, cruder estimation methods and statistics. For example, the Michigan Department of Transportation reports more than 17 billion annual vehicle miles traveled in Wayne County in 2010 (MDOT 2010). Therefore, this emissions analysis estimates City of Detroit VMT (2011) as approximately 35% of total Wayne County VMT, in 2010. In this comparison, it is important to keep in mind that the City of Detroit land area (138 sq. miles, not including water features) is approximately 22% of the total land area of Wayne County (614 sq. miles).

SMART Bus calculated that 9% of total SMART Bus VMT occurred within the city boundary of Detroit in 2011 and 2012. Thus, to calculate emissions, we assumed that 9% of total SMART Bus VMT equaled 9% of total fuel (biodiesel) used for SMART Bus. There is uncertainty in this assumption, as well as in the assumption that the percent of SMART Bus VMT driven in Detroit remained constant from 2011 and 2012. However, data to provide further clarity was unavailable at the time of this inventory. The total tailpipe emissions (both biogenic and anthropogenic CO_2) from the combustion of biodiesel in the SMART Bus are accounted for in this inventory analysis. As advised by current local GHG inventory protocol, this inventory does not account for reduced life cycle emissions for biofuels due to carbon sequestration from the growing of the crop used in the fuel production process.

internal SEMCOG trend analysis) show diverse trends in future VMT ranging from stagnation, growth, and decrease over time.

Municipal Government Transportation

Municipal Government transportation consists of vehicles used for public transportation (City of Detroit People Mover managed by Detroit Transit Corporation and city buses managed by DDOT) and the city's municipal vehicle fleet (city-operated vehicles used for maintenance, operations, etc.). These calculations, based on direct fuel consumption of municipally-operated vehicles, are recommended by ICLEI Protocol.[116]

The City of Detroit General Services Department (GSD) manages the vehicle fleets of most city government departments, with the exception of DDOT and the Detroit Water and Sewerage Department (DWSD). Emissions from maintenance vehicles at the City of Detroit's Coleman A. Young International/Municipal Airport (formerly Detroit City Airport) are included in the fleet managed by GSD, but other transportation emissions associated with the municipal airport (i.e., emissions from air travel) are not included in this inventory.

With fuel purchase data from forty-four municipal departments and sub-departments (from GSD and DWSD fleet managers), we multiplied total diesel usage and total unleaded gasoline usage by the corresponding emissions factors to obtain total CO_2 emissions associated with fuel use, as illustrated in Table 10.

Table 10: Transportation Fuels Emission Factors

Carrier	Type	Emission Factor	Unit	Data Source or Calculation Note
Unleaded Gasoline	Unleaded Gasoline	8.78	kg CO_2/gal	U.S. EPA (2011), ICLEI
Diesel	Diesel	10.21	kg CO_2/gal	U.S. EPA (2011), ICLEI
Biodiesel (B100)	Biodiesel (B100)	9.45	kg CO_2/gal	U.S. EPA (2011), ICLEI

To calculate emissions from Detroit Department of Transportation (DDOT), we used energy consumption data from the National Transit Database (NTD)[117] for 2011 and 2012, and multiplied fuel usage by the relevant emissions factors.

We calculated People Mover emissions by extracting People Mover electricity data (kWh) from NTD energy consumption data. We multiplied this usage by the eGRID - DTE composite electricity EF (used in the electricity emissions calculations for buildings and facilities) for the relevant years. People Mover emissions associated with T&D loss were calculated using relevant composite T&D coefficients.

[116] ICLEI (2012)

[117] The Federal Transit Administration collects information and statistics for the National Transit Database in an annual survey of the largest transit agencies in the U.S. The information collected includes but is not limited to data on ridership, energy and fuel use, and route information (Federal Transit Administration 2013).

Assumptions and Limitations

In the 2011 calculation, fuel purchase data from GSD were not available for March 13, 2011 because the system that tracks purchases was inoperative; however, for the purpose of this analysis, this event was assumed to not compromise the overall quality of the fuel purchase data set provided by GSD.

We were not able to reach a relevant contact at DDOT or People Mover to verify or disaggregate fuel usage data reported to NTD, which may have only included buses, and not repair or maintenance vehicles operated by DDOT. For the People Mover, we were unable to determine if its electricity usage was captured already in the DTE Energy citywide Buildings and Facilities data set or a customer of the Detroit Public Lighting Department (and therefore may be double counted in the citywide and municipal analyses).

At the time of inventory development, information regarding the composition—year, make, and model of vehicles—of the municipal fleet was not available from GSD or DWSD. Similarly, a complete data set for VMT by municipal fleet was not available. The lack of these data makes it difficult to determine underlying fleet efficiency or other drivers of vehicle fleet emissions.

We were not able to obtain sufficient data for airport operations at the Coleman A. Young International Municipal Airport, a small airport within the city limits that is also operated as a department of the City of Detroit government. Reliable data on the average number of flights per day or fuel and energy use for general operations at the airport were not available at the time of this inventory. Access to such data would be useful in improving the comprehensiveness of future GHG inventories and the accounting in both the buildings and facilities and transportation activity categories.

For the public transit agencies and municipal airport, ridership information would also be useful to evaluate emissions per passenger mile traveled. This should be considered by city departments when using this report to assess their operations.

Industrial Process

Methods

Industrial process emissions include all non-municipal GHG emissions associated with in-boundary industrial processes[118] that are reported to the U.S. EPA Greenhouse Gas Reporting Program (GHGRP). The facilities, whose annual GHG emissions fall under the U.S. EPA's requirements for emissions disclosure,[119] reported total GHG emissions data from 2010 onward. We downloaded 2010, 2011, and 2012 data sets from U.S. EPA Facility Level Information on Greenhouse Gases Tool (FLIGHT) database,[120] using "Detroit" and

---

[118] Industrial process GHG emissions are produced as by-products from chemical reactions and other industrial methods. They are distinct from industrial emissions associated with on-site energy use.

[119] U.S. EPA (2013e)

[120] U.S. EPA (2013f)

"Michigan" as spreadsheet filters in the "City" and "State" columns respectively to isolate emitters relevant to this report.

We selected industrial process emissions for petroleum refining and hydrogen production activities, ensuring that emissions due to stationary combustion and/or electricity generation were not included. U.S. EPA GHGRP reporting entities calculate emissions using mass balance calculations and continuous emissions monitoring and then report these data points to the U.S. EPA. The yearly facility level information becomes available the fall after the year of data collected.

Assumptions and Limitations

There are numerous assumptions that underpin the comprehensiveness of the industrial process accounting in this report. We assume:

1. All facilities that should report to U.S. GHGRP do;
2. All facilities that report stationary combustion from natural gas are customers of DTE Energy and/or have natural gas distributed by DTE Energy, and therefore would be included in the DTE Energy dataset and not double counted here;
3. Due to reporting criteria, if the largest sources of industrial process emissions (e.g., cement production, lime production, adipic acid production) occurred in the City of Detroit, they would report to the U.S. EPA GHGRP. If they did not report, we assume they do not occur in boundary. This assumption is supported by analysis undertaken in the State of Michigan GHG inventory;[121]
4. Any facilities that are not required to report to U.S. EPA GHGRP have a relatively small emissions impact and would therefore have a minimal effect on citywide inventory total emissions.

[121] The State of Michigan GHG Inventory estimated that 4.9% of total state-wide GHG emissions were emitted from industrial processes. Most of the industrial processes documented in the state inventory occur at a handful of large, specialized facility sites within the state, a majority of which are not found within the City of Detroit. Therefore, the State of Michigan GHG inventory provides more certainty to the comprehensiveness of the industrial process analysis here.

Solid Waste

Methods

Solid waste emissions are associated with municipal waste landfill disposal and solid waste incineration. Detroit exported municipal solid waste to two landfills during the inventory period of 2011 and 2012. Landfill emissions were calculated using the data in Table 11 and U.S. EPA's WARM model, an online tool designed for estimating the emissions reductions from various alternative waste management practices.[122]

Table 11: Municipal Solid Waste Reported by City of Detroit Department of Public Works (short tons)

City of Detroit Municipal Solid Waste Type	2005	2010	2011	2012
Landfilled	85,331	133,632	138,312	85,234
Incinerated	353,089	203,212	263,365	117,840
Recycled	28,250	35,607	29,643	7,368
Composted	15,675	15,118	12,875	10,853
Total Waste Generated (short tons)	**482,345**	**387,568**	**444,195**	**221,295**

Source: Wayne County. (2013) City of Detroit Solid Waste Stream Reports.

Detroit has one EFW facility, owned and operated by Detroit Renewable Power through a contract with the City of Detroit Department of Public Works and GDRRA, which processes municipal solid waste from the City of Detroit, other communities in Southeastern Michigan, and elsewhere. Aggregate incineration emissions are reported by Detroit Renewable Power to the U.S. EPA GHGRP.

Assumptions and Limitations

The U.S. EPA WARM model includes user-inputs of solid waste tonnage and transportation distance to landfills. We estimated the transportation distance, an input required by U.S. EPA WARM, using Google Maps (search term: "Detroit, MI to [landfill address]"). Standard local GHG inventory protocol refers to this transportation distance as 'solid waste transportation' and is the transport of solid waste from the municipality to the landfill. Standard protocol recommends calculating the GHG emissions associated with this transportation. Conversely, GHG emissions from 'solid waste collection' – or the curb-side collection of solid waste from homes and businesses – are not recommended to be included in the analysis, as they are already captured in the municipal fleet transportation section of the report and would subsequently be double counted.

The accuracy of our analysis was limited by data availability and, potentially, data quality. Data were not available for the source and amount of incinerated waste and, therefore, we were not able to calculate what proportion of incineration emissions resulted from specific end-use sectors (e.g. residential, commercial, etc.). We were unable to determine the reasons behind the decline

[122] Documentation, including emissions factors, for U.S. EPA WARM can be found at http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html.

in municipal solid waste reported from 2011 to 2012, as shown in Table 11; this trend may or may not indicate poor data quality.

While, at one point of time, the City of Detroit may have had landfills within its city boundaries, there are none that are currently operating or accepting municipal solid waste in Detroit—that is, all landfilled municipal solid waste is exported to sites outside of the city. Solid waste decomposes over large periods of time during which waste emits CH_4. As such, the IPCC recommends a 'First Order Decay' method to account for emissions from this historic solid waste disposal.[123] However, limited data was available on any retired landfills within Detroit. As a result, this method was not included in the analysis at this time, but it could be explored in the future.
The steam and electricity generated at the EFW facility are sources of energy for the City of Detroit; however, the emissions associated with that generation (those from solid waste incineration) are accounted for here in the Solid Waste section, rather than in Buildings and Facilities, to avoid double counting.

Wastewater Treatment

Methods

Wastewater Treatment includes non-energy incineration (from biosolids or sludge), process, fugitive emissions (CH_4 and N_2O) associated with DWSD's treatment of wastewater from the department's service area. This treatment occurs at DWSD's single wastewater treatment plant (WWTP) located within the city limits of Detroit. Electricity and natural gas used by DWSD for the provisioning of both water supply and wastewater treatment services (e.g., energy use associated with pumping and treatment) are captured within the buildings and facilities activity and therefore not reported within this section.

We followed ICLEI's 2012 Community Protocol Water and Wastewater Appendix[124] to calculate wastewater process and fugitive emissions from DWSD operations. The DWSD WWTP process is aerobic without nitrification or denitrification and relies on incineration of sludge occurring at fourteen hearth incinerators. One of these incinerators was decommissioned on November 1, 2013.

Stationary CH_4 and N_2O emissions from the combustion of sludge during the treatment process were calculated using ICLEI Community Protocol (2012) Equations WW.4 and WW.5, based on plant-specific biosolids data from the DWSD WWTP for the years 2005 and 2010 through 2012, illustrated in Table 12.

[123] Pipatti and Svardal (2006)
[124] ICLEI (2012) Appendix F: Wastewater and Water Emission Activities and Sources

Table 12: DWSD Summary of Biosolids Incinerated at Wastewater Treatment Plant

	Year Reported			
	2005	2010	2011	2012
Wet Weight Biosolids Incinerated (metric wet tons)	579,068	460,477	375,705	360,566
Percentage Change from 2005	0.00%	-20.48%	-35.12%	-37.73%

Source: DWSD (2014)

Nitrous oxide emissions from the treatment process (without nitrification and denitrification) and fugitive N_2O emissions from effluent released to the Rouge River and Detroit River were calculated using ICLEI Community Protocol (2012) Equations WW.8 and WW.12 (alt). We used DWSD's WWTP approximate sewer service area population of three million,[125] for all inventory years. Calculations based on this generalized annual population served estimate (DWSD wastewater and sewer service area includes Wayne, Macomb, and Oakland counties). For simplicity and because more detailed population estimates were unavailable, these estimates assume service area population remains constant over all inventory years. We used the 2012 ICLEI Community Protocol's emission factors and other parameters provided for process and fugitive emissions calculations.

Assumptions and Limitations

Fugitive emissions associated with septic systems were not included in this inventory. A more precise estimate of DWSD service area population and Detroit population would increase the precision of wastewater treatment estimates. While an estimated population-based method was used here, facility-level nutrient data could be applied to alternative methodologies recommended by the ICLEI Protocol and therefore pursued in future inventories, if appropriate information becomes available.

Given the data provided by DTE Energy, the energy used by DWSD drinking water and wastewater treatment services could not be disaggregated in this analysis.

Land Use

Methods

The land use analysis estimates the CO_2 uptake by tree canopy within the City of Detroit for 2010. Carbon dioxide is part of the respiratory cycle of vegetation and is stored as stocks of carbon in plant biomass.

Accurate estimates of GHGs emitted and sequestered from land use change are methodologically complex and expensive and are therefore not considered standard for local GHG inventories. Nonetheless, our team chose to pursue at an estimate of the effect of tree cover canopy on CO_2 uptake. This was primarily due to the reality that Detroit has such a large land area, that the city has undergone significant land use change in recent years, and that there is significant stakeholder

[125] City of Detroit (2013)

interest in land use practices and projects designed to leverage the urban landscape in ways that would improve quality of life.[126]

Our methodology estimates CO_2 uptake based on land cover categories clipped to the City of Detroit boundary. Using a tool called i-Tree Canopy from the U.S. Forest Service, we analyzed 2010 GoogleEarth aerial photography, clipped to the City of Detroit boundary using an ArcGIS Shapefile.

The nonproprietary online i-Tree Canopy program uses a user-selected statistical sampling method to classify the land area into classes that are determined by the user. We chose five classes: tree cover, herbaceous vegetation, impervious surface, water surfaces, and bare soil[127] for the analysis. These classifications were then used to determine the proportions of the total land area that fell into each land cover category. To reduce error per guidance of i-Tree Canopy software instructions, 1000 sample points were classified into land cover types.

Using this land cover classification, we applied a Michigan-specific CO_2 sequestration factor[128] found in the literature for the tree canopy cover. Future analysis could examine the carbon sequestration of herbaceous cover and bare soil, in addition to the tree canopy analysis, if reliable methods and sequestration factors are recommended by future local GHG inventory protocols.

Assumptions and Limitations

There are many factors of land use that influence GHG emissions and removals. Change is always occurring in the natural world, whether stimulated by weather and climatic conditions, human or non-human disturbance, or natural life cycles of living organisms. Further, rates of CO_2 uptake by vegetation also differ by plant species. An analysis based on an annual time scale and the division of landscapes into categories (tree, herbaceous vegetation, water features, impervious surface, and bare soil), as we have done in this inventory, makes many assumptions. These assumptions were made out of both practical necessity (for lack of scientific and financial resources) and due to a knowledge gap related to appropriate land use inventory methods at the local scale.

GoogleEarth imagery presents a snapshot in time, and therefore our methodology assumes that the land cover analysis is constant for the entire year. Our methodology also relies on the accuracy of the land cover classification, which is dependent upon the accuracy of the statistical sampling method in i-Tree Canopy and the ability of the analyst to correctly and consistently classify each sampling point (vis-à-vis what land cover exists in actuality at that point on the ground). The division of land cover into five categories to which emissions and removal factors are applied assumes that all vegetation classified under each category are the same or are almost similar for

[126] ICLEI (2006)

[127] This is similar to the classification used by American Forests, which calculated carbon storage from trees in Detroit in 2005. A green data layer was created from a 1-meter Ikonos multi-spectral satellite imagery taken in 2005. The image was classified into five land cover categories: tree canopy comprises 27,863 acres (31%); urban land (defined by impervious surfaces) 41,843 acres (47%); open space (defined by grass and scattered trees) 17,860 (20%); bare soil 1,335 (2%); and water 314 acres (less than 1%).

[128] Nowak (2013)

the purposes of GHG emissions and removal rates. The emissions and removal factors themselves are also assumed to be accurate and to take into account all significant factors that influence changes in emissions and removal rates throughout the year, in this particular geographic area, for the type of vegetation and for the stages of succession of vegetation.

Clearly there are many assumptions in this type of analysis, yet given the current information and circumstances, these methods are currently practical. The analysis is ultimately meant to provide an approximation of the carbons sequestration potential of the City of Detroit's urban forest, serving as a starting point for future work.

The land use analysis does not currently account for emissions from other land cover classes or the impact of land use change over time.

Appendix F: Citywide Inventory Emissions Summary, 2011 and 2012

Table 13: City of Detroit Comparison for 2011 and 2012

City	State	Inventory Analysis Year	Approx. Population*	Population Year	Land Area** (sq. mi)	Citywide Inventory (Mt CO_2e)	Municipal Inventory (Mt CO_2e)	Citywide per capita** (t CO_2e/person)	Citywide per square mile (t CO_2e/sq. mi)
Detroit	MI	2011	706,640	2011	138	10.56	1.17	14.9	76,542
Detroit	MI	2012	701,475	2012	138	10.63	1.18	15.2	77,027

*Population (estimated or from U.S. Census) corresponds as closely to inventory analysis year as possible.

**City of Detroit Land Area used here does not include water features (if water features are included the City of Detroit's area is 142 sq. mi).

Table 14: Citywide Emissions Summary Reported by Scope

	2011		2012	
Citywide Inventory	**Emissions (t CO_2e)**	**% of Total**	**Emissions (t CO_2e)**	**% of Total**
Scope 1	5,746,358	54.4%	5,520,240	51.9%
Scope 2	4,531,194	42.9%	4,809,082	45.2%
Scope 3	285,182	2.7%	300,451	2.8%
Citywide Inventory Total	**10,562,733**	**100.0%**	**10,629,772**	**100.0%**

Table 15: Citywide Inventory Results Summary, 2012

Activity	Customer Type/Source	Carrier	Carrier Use	Carrier Units	Energy Use (MJ)	Emissions (t CO_2e)
Buildings and Facilities	Commercial and Institutional	Natural Gas	75,842,926	ccf	8,191,035,965	411,372
		Electricity	3,420,993,683	kWh	12,315,577,260	2,866,800
		Electricity T&D Loss	-	-	-	177,207
	Industrial	Natural Gas	89,732	ccf	9,691,076	487
		Electricity	870,090,638	kWh	3,132,326,298	729,138
		Electricity T&D Loss	-	-	-	45,071
	Residential	Electricity	1,441,262,143	kWh	5,188,543,714	1,207,778
		Natural Gas	211,804,074	ccf	22,874,839,955	1,148,825
		Electricity T&D Loss	-	-	-	74,657
Transportation	Detroit Department of Transportation Buses	Diesel	3,774,905	gal	513,387,080	38,542
	Municipal Fleet	Gasoline	1,321,746		161,253,001	11,605
		Diesel	1,264,659	gal	171,993,685	12,912
	Passenger Car, Truck, and On-Road Freight	Gasoline, Diesel	-	-	-	3,159,719
	People Mover	Electricity	6,795,920	kWh	24,465,312	5,695
		Electricity T&D Loss	-	-	-	352
	SMART Bus	Biodiesel (B20/B5)	197,123	gal	26,414,451	1,994
Industrial Process	Hydrogen Production	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	73,655
	Petroleum Refining		-	-	-	237,509
Solid Waste	Solid Waste Incineration	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	247,674
	Solid Waste Landfill Disposal		-	-	-	2,661
Wastewater Treatment	Fugitive Emissions from Effluent Discharge	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	71,728
	Process Emissions from Wastewater Treatment		-	-	-	3,720
	Sludge Incineration		-	-	-	100,671
2012 Citywide Inventory Total						**10,629,772**

Table 16: Citywide Inventory Results Summary, 2011

Activity	Customer Type/Source	Carrier	Carrier Use	Carrier Units	Energy Use (MJ)	Emissions (t CO2e)
Buildings and Facilities	Commercial and Institutional	Natural Gas	89,887,779	ccf	9,707,880,175	487,551
		Electricity	3,443,561,974	kWh	12,396,823,107	2,668,141
		Electricity T&D Loss	-	-	-	164,947
	Industrial	Natural Gas	436,736	ccf	47,167,519	2,369
		Electricity	928,988,644	kWh	3,344,359,117	719,744
		Electricity T&D Loss	-	-	-	44,499
	Residential	Electricity	1,470,611,898	kWh	5,294,202,831	1,139,724
		Natural Gas	254,290,954	ccf	27,463,423,060	1,379,274
		Electricity T&D Loss	-	-	-	70,442
Transportation	Detroit Department of Transportation Buses	Diesel	3,837,867	gal	521,949,912	39,185
	Municipal Fleet	Gasoline	1,531,075	gal	186,791,178	13,443
		Diesel	1,461,597	gal	198,777,216	14,923
	Passenger Car, Truck, and On-Road Freight	Gasoline, Diesel	-	-	-	3,171,660
	People Mover	Electricity	5,104,531	kWh	18,376,312	3,955
		Electricity T&D Loss	-	-	-	244
	SMART Bus	Biodiesel (B20/B5)	214,330	gal	28,720,166	2,168
Industrial Process	Petroleum Refining	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	245,069
Solid Waste	Solid Waste Incineration	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	210,587
	Solid Waste Landfill Disposal		-	-	-	4,464
Wastewater Treatment	Fugitive Emissions from Effluent Discharge	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	-	-	-	71,728
	Process Emissions from Wastewater Treatment		-	-	-	3,720
	Sludge Incineration		-	-	-	104,898
2011 Citywide Inventory Total						**10,562,733**

Table 17: Citywide Stationary Source Emissions by Zip Code, ranked by 2012 emissions

City of Detroit Zip Code*	2011 Emissions (t CO2e)	2011 % of Total	2012 Emissions (t CO2e)	2012 % of Total
48217	966,723	13.2%	1,033,458	14.0%
48209	770,764	10.5%	772,497	10.4%
48211	623,174	8.5%	697,322	9.4%
48226	515,293	7.0%	538,751	7.3%
48202	301,202	4.1%	304,791	4.1%
48201	279,832	3.8%	298,859	4.0%
48235	284,160	3.9%	278,118	3.8%
48228	279,937	3.8%	277,658	3.8%
48219	270,210	3.7%	267,038	3.6%
48207	260,967	3.6%	260,380	3.5%
48221	253,939	3.5%	241,241	3.3%
48205	243,846	3.3%	239,462	3.2%
48227	252,498	3.5%	236,528	3.2%
48234	253,641	3.5%	229,983	3.1%
48224	211,447	2.9%	202,266	2.7%
48238	193,390	2.6%	181,761	2.5%
48210	183,807	2.5%	180,009	2.4%
48214	183,334	2.5%	173,630	2.3%
48223	157,632	2.2%	158,695	2.1%
48204	155,637	2.1%	146,107	2.0%
48213	147,274	2.0%	139,424	1.9%
48206	113,637	1.6%	103,055	1.4%
48215	81,974	1.1%	75,956	1.0%
48236	37,621	0.5%	75,840	1.0%
48216	71,244	1.0%	71,328	1.0%
48208	72,077	1.0%	69,160	0.9%
48212	68,139	0.9%	64,829	0.9%
48203	55,268	0.8%	52,173	0.7%
48239	12,919	0.2%	14,806	0.2%
48243	11,105	0.2%	11,171	0.2%
Stationary Emissions Total	**7,312,692**	**100%**	**7,396,293**	**100%**

*While some Zip Codes in this list extend beyond the City of Detroit jurisdictional boundary and include other neighboring municipalities (e.g. Hamtramck or Highland Park, MI), the emissions reported in this table only include those associated with stationary sources exclusively within the City of Detroit (energy use by buildings and facilities, industrial process emissions, waste incineration, and wastewater treatment) and not emissions from neighboring communities.

Table 18: City of Detroit Municipal Solid Waste Reported (Short Tons)

City of Detroit Municipal Solid Waste Type	2005	2010	2011	2012
Landfilled	85,331	133,632	138,312	85,234
Incinerated	353,089	203,212	263,365	117,840
Recycled	28,250	35,607	29,643	7,368
Composted	15,675	15,118	12,875	10,853
Total Waste Generated (short tons)	**482,345**	**387,568**	**444,195**	**221,295**

Source: Wayne County. (2013) City of Detroit Solid Waste Stream Reports.

Table 19: Wastewater Treatment Emissions Results, 2005 and 2010

Year	Activity	Customer Type/Source	Carrier	Emissions (t CO_2e)
2005	Wastewater Treatment	Sludge Incineration	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	161,678
		Fugitive Emissions from Effluent Discharge		71,728
		Process Emissions from Treatment without Nitrification or Denitrification		3,720
2005 Total Wastewater Treatment Emissions				**237,126**
2010	Wastewater Treatment	Sludge Incineration	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	128,567
		Fugitive Emissions from Effluent Discharge		71,728
		Process Emissions from Treatment without Nitrification or Denitrification		3,720
2010 Total Wastewater Treatment Emissions				**204,014**

Appendix G: Citywide Inventory Results and Charts, 2011

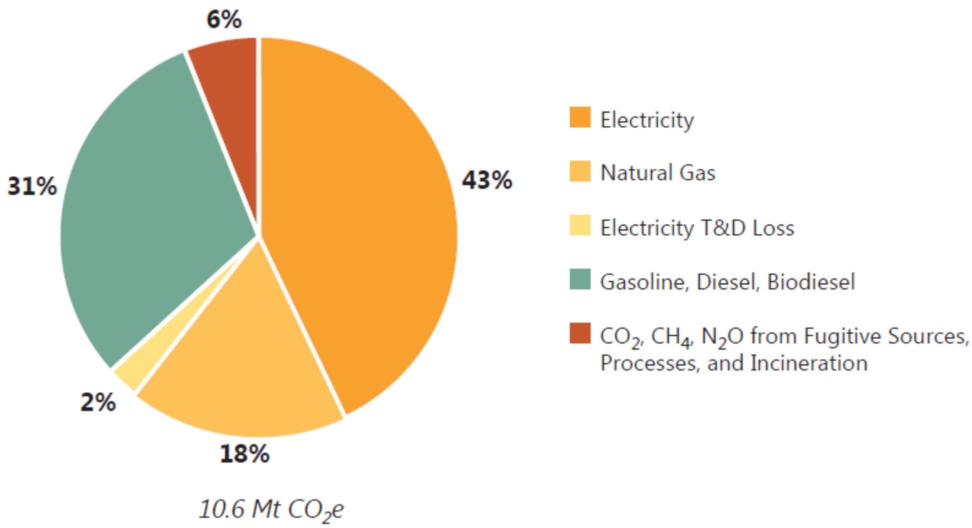


Figure 30: Detroit Citywide GHG Emissions by Carrier, 2011

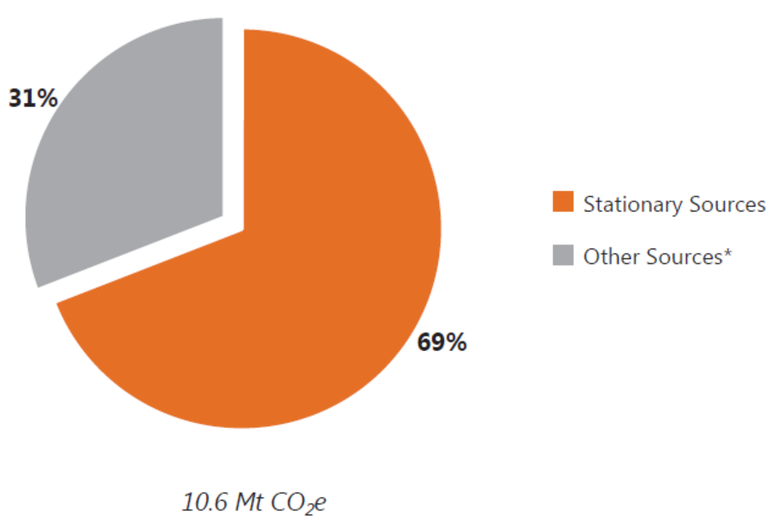


Figure 31: Detroit Citywide Stationary vs. Other GHG Emissions Sources, 2011

**Category 'Other Sources' includes emissions from mobile sources, such as passenger cars, municipal fleet vehicles, and public buses, as well as solid waste landfill disposal, which occurs outside the jurisdictional boundary of Detroit.*

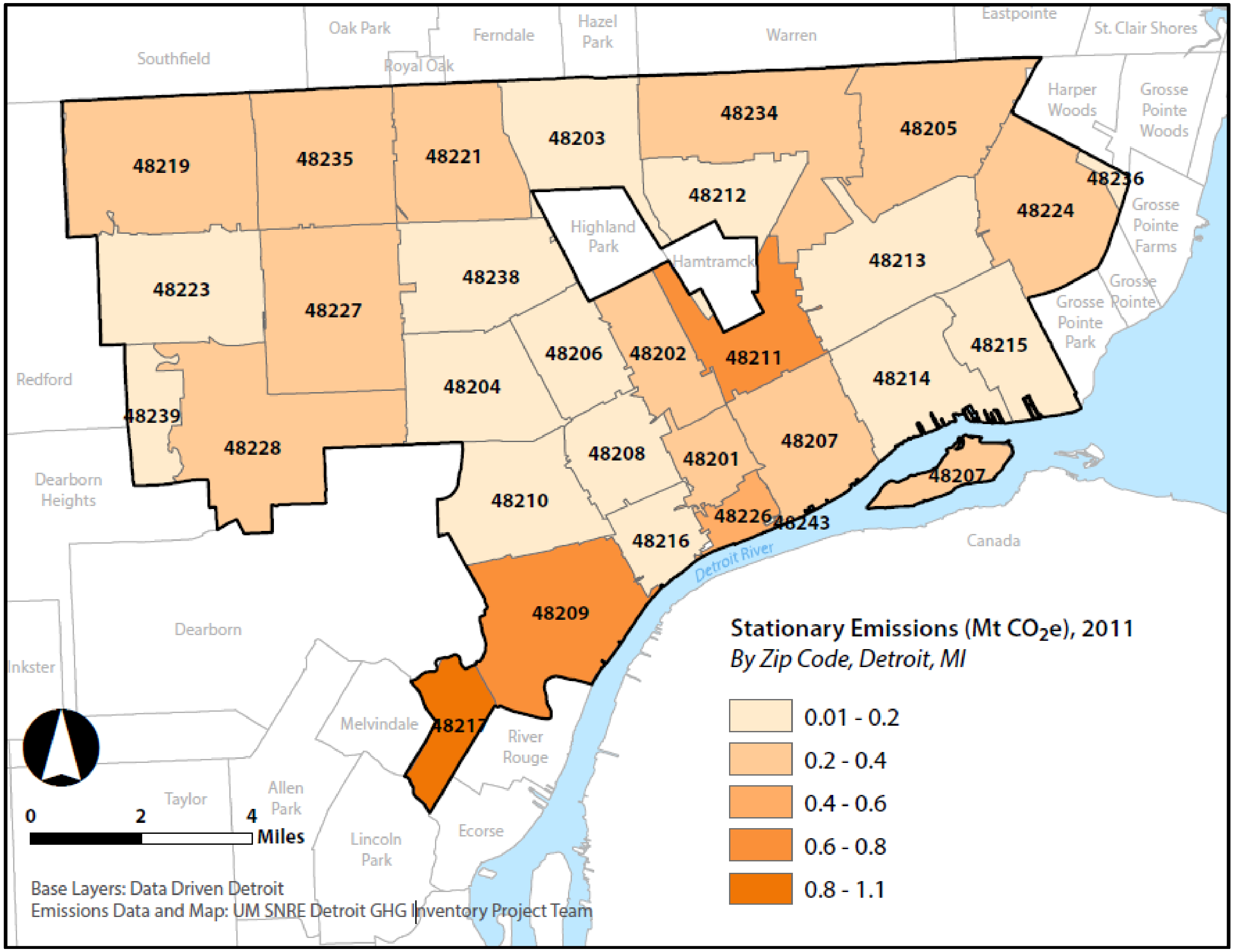


Figure 32: Detroit Citywide Stationary GHG Emissions by Zip Code, 2011

Stationary sources include energy use in buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment. Emissions from transportation and solid waste landfill disposal are not included in this map

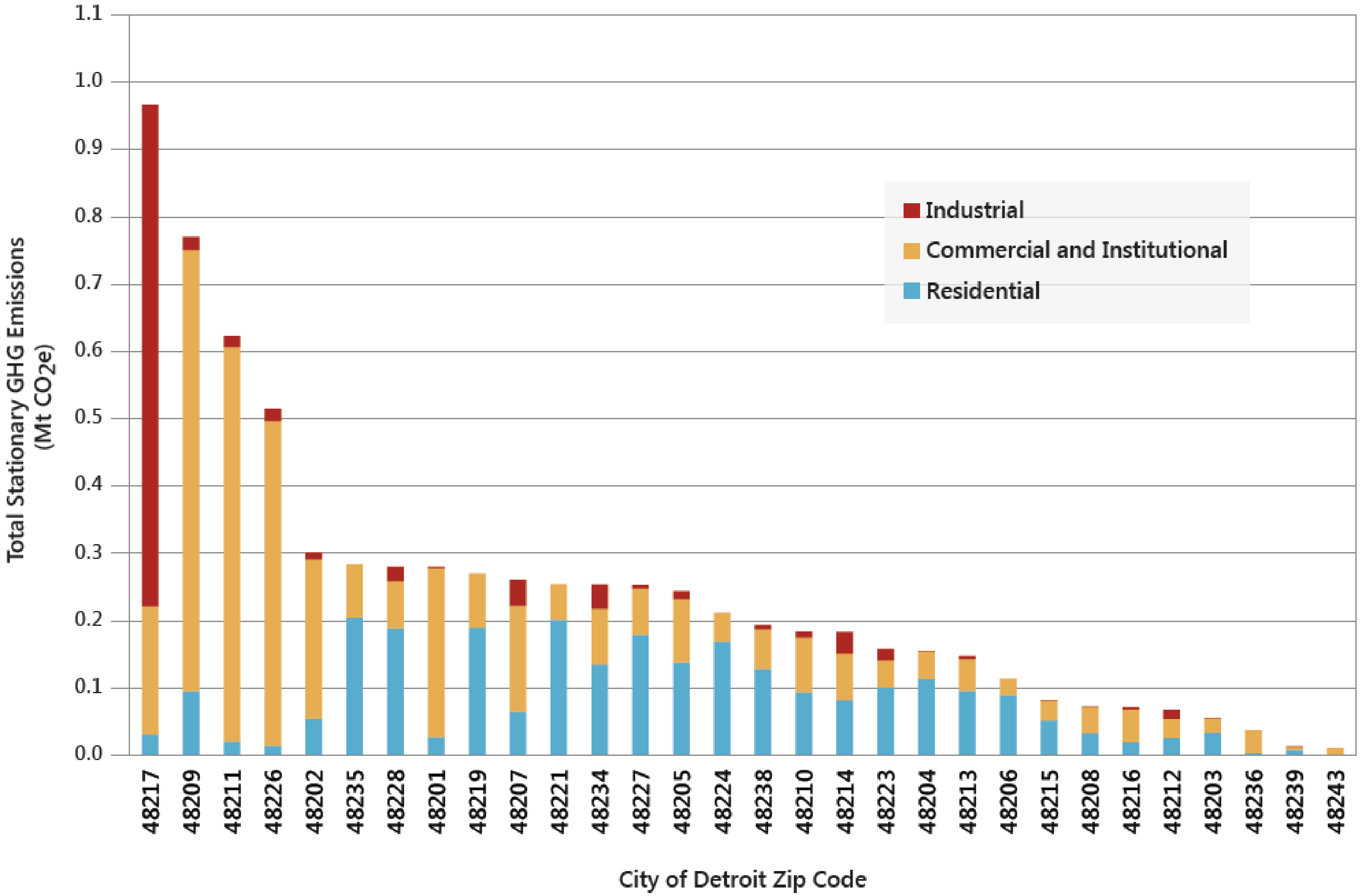


Figure 33: Detroit Citywide Stationary GHG Emissions by Zip Code and End-Use Sector, 2011

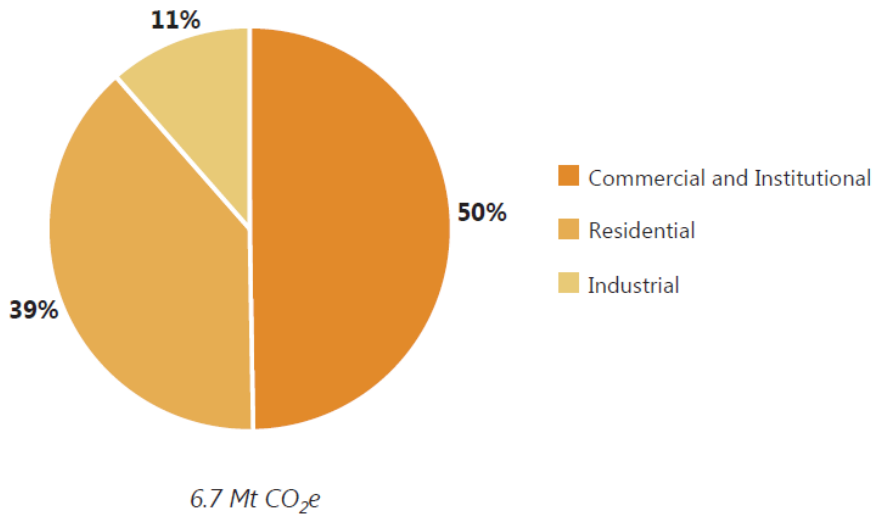


Figure 34: Detroit Citywide Buildings and Facilities GHG Emissions by End-Use Sector, 2011

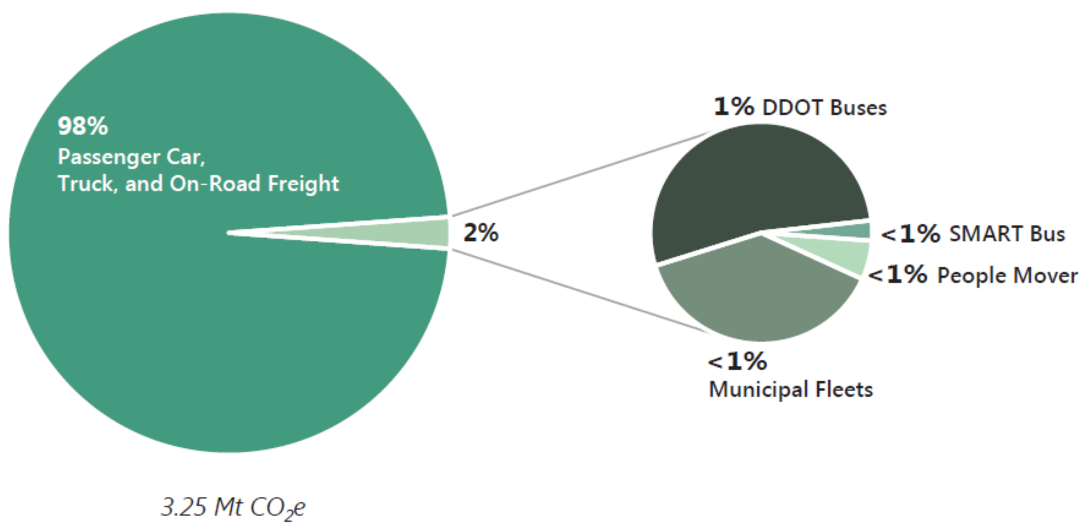


Figure 35: Detroit Citywide Transportation GHG Emissions by Source, 2011

Appendix H: City of Detroit Municipal Departments and Service Categories

Table 20: City of Detroit Municipal Departments and Budget Code Key

City of Detroit Department Name	Departmental Budget Code
Airport	10
Communications Department	15
Consumer Affairs	16
Department of Public Works	19
Detroit Department of Transportation	20
Detroit Workforce Development Department	21
Department of Environmental Affairs	22
Finance	23
Fire	24
Health Department	25
Historical	26
Department of Human Services	30
Information Technology Services	31
Law	32
Mayor's Office	33
Municipal Parking	34
Non-departmental items	35
Planning and Development Department	36
Police	37
Detroit Public Lighting Department	38
Recreation Department	39
Detroit Water and Sewerage Department	41 (Water Supply Service)
	42 (Wastewater Service)
Department of Administrative Hearings	45
Detroit Office of Homeland Security	46
General Services Department	47
Zoning Appeals Board	51
City Council	52
36th District Court	60
City Clerk	70
Election Commission	71
Detroit Public Library	72
City of Detroit, unclassified	-
People Mover	People Mover

Table 21: Service Organizational Categories for Municipal Operations Analysis

Service Provided	Departmental Budget Code	City of Detroit Department Name
Public Lighting	38	Public Lighting Department
Public Water Services	41 & 42	Detroit Water and Sewerage Department
Public Works	19	Detroit Public Works
	22	Department of Environmental Affairs
	51	Zoning Appeals Board
Transportation	20	Detroit Department of Transportation
	People Mover	People Mover
	10	Airport
	34	Municipal Parking
Other	70	City Clerk
	47	General Services Division
	31	IT Services
	23	Finance
	52	City Council
	36	Planning and Development Department
	15	Communications Department
	45	Department of Administrative Hearings
	72	Detroit Public Library
	26	Historical
	39	Recreation Department
	21	Detroit Workforce Development
	30	Department of Human Services
	25	Health Department
	46	Detroit Office of Homeland Security
	16	Consumer Affairs
	Other	City of Detroit, unclassified
	71	Election Commission
	35	Non-departmental items
	32	Law
	60	36th District Court
Public Safety	24	Fire
	37	Police

Appendix I: Municipal Government Inventory Detailed Methods

Municipal Buildings and Facilities

Municipal buildings and facilities includes CO_2, CH_4, and N_2O emissions[129] associated with heating, cooling, and powering municipal buildings and facilities with electricity and natural gas that are distributed by DTE Energy, the primary energy utility in Detroit and Southeastern Michigan. Emissions are generated through the combustion of fossil fuels for electricity generation and on-site combustion of natural gas. Emissions are also associated with electricity losses due to transmission and distribution through the grid.

Total annual CO_2e emissions were calculated by multiplying DTE Energy electricity and natural gas consumption data provided for City of Detroit municipal department accounts by DTE Energy-specific generation and U.S. EPA eGRID RFCM sub-region emission factors (listed in Appendix C, Table 7)—similar to the analysis performed for the Citywide Buildings and Facilities section. For reference, a table of all City of Detroit Departments that are analyzed in the municipal inventory is presented in Appendix H, Table 20.

Data processing for the municipal buildings and facilities data set was similar to citywide buildings and facilities data set methods presented earlier. Please refer to the Citywide Inventory Buildings and Facilities methods for more detailed information on our methods.

Municipal Transportation

These methods are described earlier in the Citywide Inventory Methods. Please refer to Citywide Municipal Transportation methodology for more detailed information on our methods. Emissions calculated here are attributed to DDOT, People Mover, and the municipal fleets managed by GSD and DWSD.

Solid Waste

These methods are described earlier in the Citywide Inventory Methods. Please refer to Citywide Solid Waste methodology for more detailed information on our methods. Emissions calculated here are attributed to the City of Detroit Department of Public Works and GDRRA.

Wastewater Treatment

These methods are described earlier in the Citywide Inventory Methods. Please refer to Citywide Wastewater Treatment methods for more detailed information on our methods. Emissions calculated here are attributed to DWSD in the Municipal Inventory.

---

[129] Buildings and facilities emissions includes CO_2 from the DTE Energy generated electricity, CO_2 from on-site stationary combustion of natural gas, and CO_2, CH_4, and N_2O emissions from grid-purchased electricity.

Appendix J: Municipal Operations Emissions Summary, 2011 and 2012

Table 22: City of Detroit Total Municipal Operations Emissions by Activity and Top Departments

Activity	City of Detroit Department Name	Departmental Budget Code	2011 Emissions ($t\ CO_2e$)	2011 % of Total	2012 Emissions ($t\ CO_2e$)	2012 % of Total
Municipal Buildings and Facilities	Detroit Public Lighting Department	38	399,444	34.19%	411,750	34.88%
	Detroit Water and Sewerage Department	41 and 42	274,163	23.47%	248,069	21.01%
	All Other Municipal Buildings and Facilities*	-	27,532	2.36%	25,171	2.13%
Municipal Transportation	Detroit Department of Transportation	20	39,185	3.35%	38,542	3.26%
	All Other Municipal Transportation**	-	32,565	2.79%	30,564	2.59%
Solid Waste Fugitive Sources and Incineration	Detroit Public Works and GDRRA	19	215,051	18.41%	250,335	21.20%
Wastewater Treatment Fugitive Sources, Processes, and Incineration	Detroit Water and Sewerage Department	42	180,346	15.44%	176,119	14.92%
Municipal Inventory Total			**1,168,285**	**100%**	**1,180,551**	**100%**

*All Other Municipal Buildings and Facilities includes emissions from remaining City of Detroit departments for which data were available.

**All Other Municipal Transportation includes transportation emissions from remaining City of Detroit departments (including, for example, DWSD fleet operations).

Table 23: Municipal Operations Emissions by Department, ranked by 2012

City of Detroit Department Name	Departmental Budget Code	2011		2012	
		Emissions (t CO_2e)	% of Total	Emissions (t CO_2e)	% of Total
Detroit Water and Sewerage Department	41 and 42	458,863	39.28%	427,135	36.18%
Detroit Public Lighting Department	38	400,269	34.26%	412,526	34.94%
Department of Public Works	19	223,110	19.10%	257,454	21.81%
Department of Transportation	20	39,185	3.35%	38,542	3.26%
City of Detroit, unclassified*	-	6,732	0.58%	13,781	1.17%
Police	37	13,201	1.13%	11,485	0.97%
People Mover	People Mover	4,199	0.36%	6,047	0.51%
Fire	24	6,966	0.60%	4,236	0.36%
Recreation Department	39	5,460	0.47%	2,405	0.20%
General Services Department	47	2,310	0.20%	1,969	0.17%
Detroit Workforce Development Department	21	2,182	0.19%	1,921	0.16%
Municipal Parking	34	611	0.05%	703	0.06%
Election Commission	71	523	0.04%	530	0.04%
Information Technology Services	31	268	0.02%	314	0.03%
Detroit Public Library	72	1,135	0.10%	285	0.02%
Department of Human Services	30	594	0.05%	270	0.02%
Finance	23	351	0.03%	243	0.02%
Department of Environmental Affairs	22	186	0.02%	169	0.01%
Historical	26	173	0.01%	166	0.01%
Health Department	25	674	0.06%	101	0.01%
Non-departmental items*	35	344	0.03%	81	0.01%
City Council	52	53	0.00%	42	0.00%
Airport	10	442	0.04%	36	0.00%
Mayor's Office	33	38	0.00%	30	0.00%
Planning and Development Department	36	338	0.03%	24	0.00%
Detroit Office of Homeland Security	46	23	0.00%	18	0.00%
City Clerk	70	12	0.00%	11	0.00%
Communications Department	15	9	0.00%	11	0.00%
Law	32	9	0.00%	8	0.00%
36th District Court	60	4	0.00%	4	0.00%
Zoning Appeals Board	51	6	0.00%	3	0.00%
Consumer Affairs	16	-	0.00%	1	0.00%
Department of Administrative Hearings	45	17	0.00%	-	0.00%
Municipal Inventory Total		**1,168,285**	**100%**	**1,180,551**	**100%**

*'City of Detroit, unclassified' category is one developed by this project and corresponds to municipal activity data that was not assigned a specific department in raw City of Detroit energy data from DTE Energy.
'Non-departmental items' is a specific accounting grouping used by City of Detroit and assigned to departmental budget code 35.

Table 24: Municipal Operations Transportation GHG Emissions by Department, Ranked by 2012

City of Detroit Department Name	Departmental Budget Code	2011 Emissions (t CO_2e)	2011 % of Total	2012 Emissions (t CO_2e)	2012 % of Total
Department of Transportation	20	39,185	54.61%	38,542	55.77%
Police	37	8,955	12.48%	7,906	11.44%
Department of Public Works	19	7,582	10.57%	6,958	10.07%
People Mover	People Mover	4,199	5.85%	6,047	8.75%
Fire	24	4,256	5.93%	3,844	5.56%
Detroit Water and Sewerage Department	41 and 42	4,354	6.07%	2,946	4.26%
General Services Department	47	1,587	2.21%	1,289	1.87%
Detroit Public Lighting Department	38	824	1.15%	776	1.12%
Municipal Parking	34	288	0.40%	316	0.46%
Department of Environmental Affairs	22	158	0.22%	169	0.24%
Recreation Department	39	59	0.08%	60	0.09%
Health Department	25	75	0.10%	50	0.07%
City Council	52	53	0.07%	42	0.06%
Election Commission	71	39	0.05%	41	0.06%
Non-departmental items*	35	18	0.03%	21	0.03%
Planning and Development Department	36	21	0.03%	21	0.03%
Detroit Office of Homeland Security	46	23	0.03%	18	0.03%
City Clerk	70	12	0.02%	11	0.02%
Communications Department	15	9	0.01%	11	0.02%
Detroit Workforce Development Department	21	16	0.02%	9	0.01%
Law	32	9	0.01%	8	0.01%
Mayor's Office	33	3	0.00%	5	0.01%
36th District Court	60	4	0.01%	4	0.01%
Airport	10	4	0.01%	4	0.01%
Zoning Appeals Board	51	6	0.01%	3	0.00%
Information Technology Services	31	4	0.01%	2	0.00%
Consumer Affairs	16	-	0.00%	1	0.00%
Finance	23	1	0.00%	0	0.00%
Department of Human Services	30	5	0.01%	0	0.00%
Municipal Transportation Total		**71,750**	**100%**	**69,106**	**100%**

*'Non-departmental items' is a specific accounting grouping used by City of Detroit assigned to departmental budget code 35.

Appendix K: Municipal Government Inventory Results and Charts, 2011

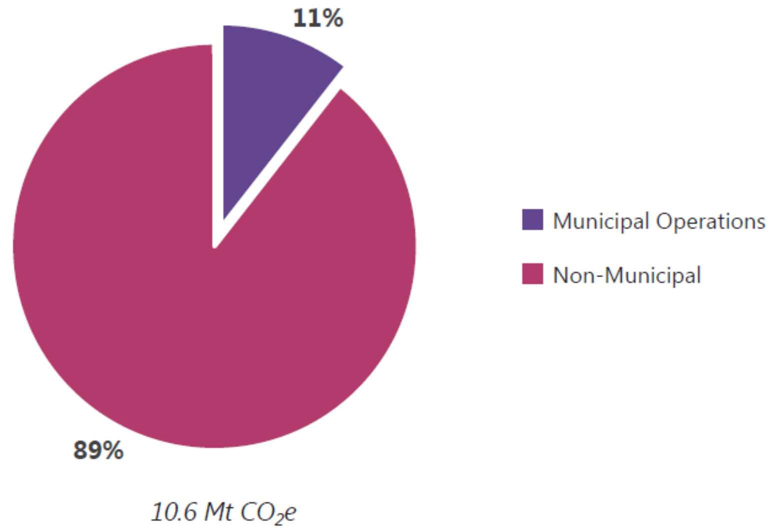


Figure 36: Detroit Municipal Operations Emissions as a Percentage of Citywide, 2011

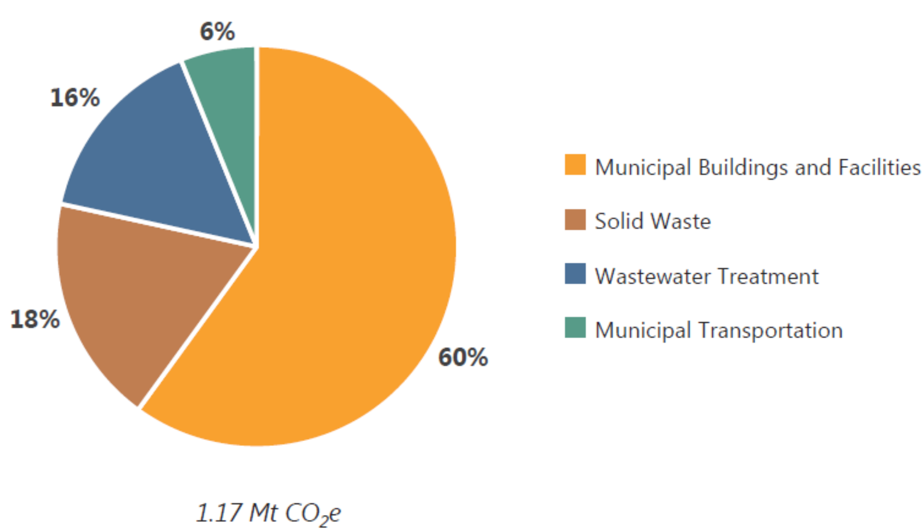


Figure 37: Detroit Municipal Operations GHG Emissions by Activity, 2011

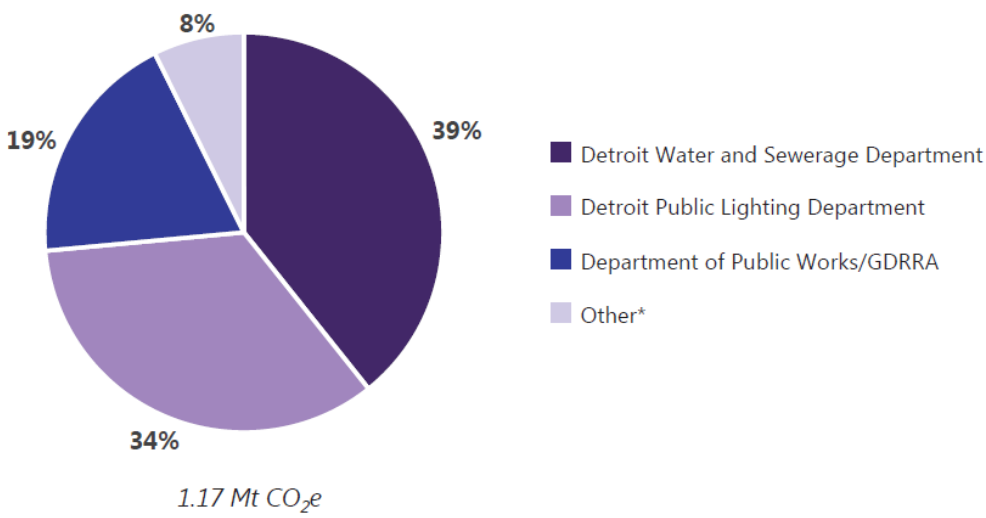


Figure 38: Detroit Municipal Operations GHG Emissions by Department, 2011

**Category 'Other' includes all other City of Detroit municipal departments. A complete list of Detroit municipal departments and their annual emissions are included in Appendix H.*

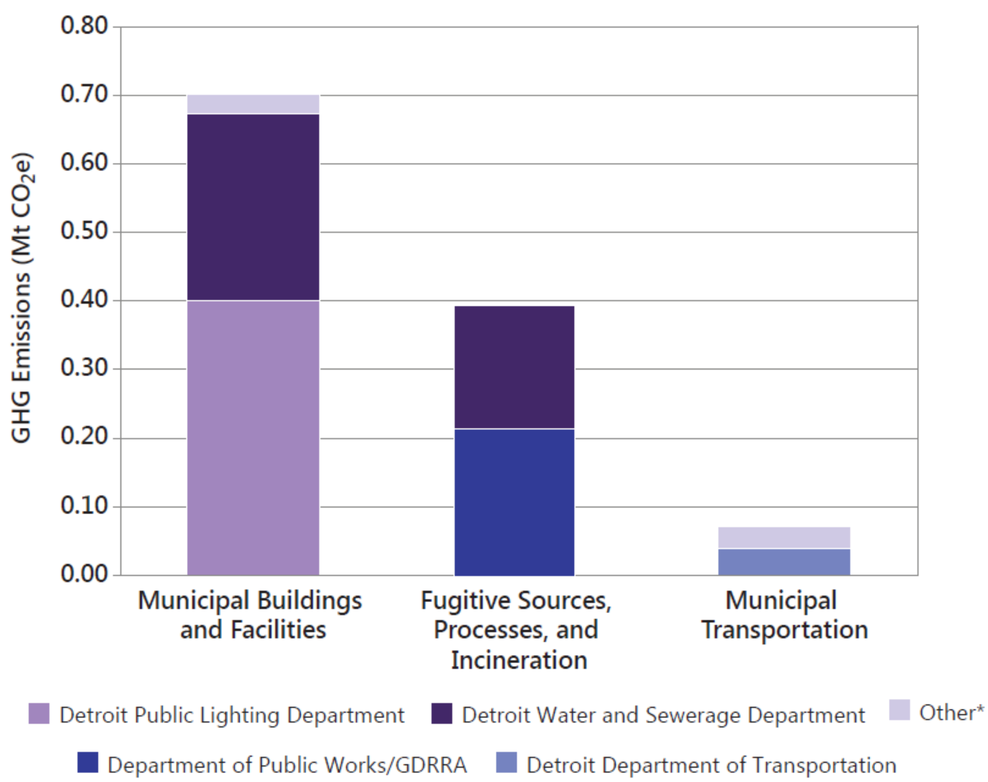


Figure 39: Detroit Municipal Operations GHG Emissions by Activity and Department, 2011

**Category 'Other' includes all other City of Detroit municipal departments. A complete list of Detroit municipal departments and their annual emissions are included in Appendix H.*

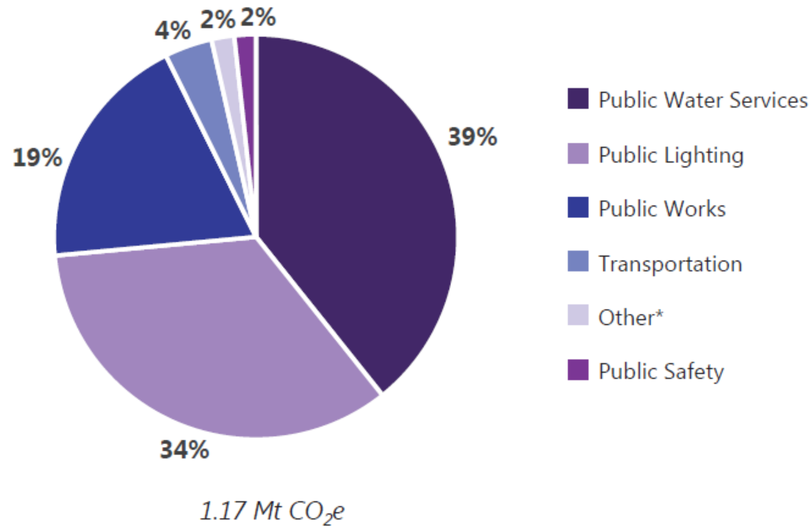


Figure 40: Detroit Municipal Operations GHG Emissions by Service, 2011

**Category 'Other' includes other municipal activities such as administrative services, culture and arts programming, the election commission, and health and human services.*

Appendix L: Comparative Analyses Summary Tables

Table 25: Select North American Cities Emissions Comparison

City	State or Province	Inventory Analysis Year	Approx. Pop.*	Pop. Year	Land Area (sq. mi)	Citywide Inventory** (Mt CO_2e)	Municipal Inventory (Mt CO_2e)	Citywide per capita*** (t CO_2e/person)	Citywide per square mile (t CO_2e/sq. mi)	Ref.
Ann Arbor	MI	2003	114,024	2000	28	2.3	0.05	20.1	82,458	1
Baltimore	MD	2007	620,961	2010	81	9.0	-	14.5	111,435	2
Boston	MA	2007	617,594	2010	48	8.6	-	14.0	178,643	2
Chicago	IL	2010	2,695,598	2010	227	33.5	-	12.4	147,512	2
Cleveland	OH	2010	396,815	2010	78	12.8	0.40	32.3	164,948	3, 4
Denver	CO	2005	553,594	2000	153	14.6	-	25.3	95,425	5
Detroit	MI	2012	701,475	2012	138†	10.6	1.10	15.2	77,027	6
Minneapolis	MN	2010	382,578	2010	55	5.1	-	13.4	92,896	7
New York City	NY	2012	8,336,697	2012	303	47.9	3.12	5.7	157,929	8
Philadelphia	PA	2005	1,526,006	2010	135	18.2	-	11.9	134,415	2
Pittsburgh	PA	2008	305,704	2010	56	6.2	0.18	20.1	109,996	9
Seattle	WA	2008	608,660	2010	84	4.9	0.24	8.1	58,762	2, 10
Toronto	ON, Canada	2004	2,503,281	2006	243	23.4	1.60	9.6	96,168	11
Washington	D.C.	2006	601,723	2010	61	10.8	-	17.9	176,427	2
City Comparison Sample Mean (n = 14)						14.8		15.8	120,289	
City Comparison Sample Median (n = 14)						10.7		14.3	110,716	

*Population (estimated or from U.S. Census) corresponds as closely to inventory analysis year as possible.

**Some results estimates were reported in short tons. For this analysis, all data were standardized in SI units.

***Per capita results calculated using Citywide Total and Population Estimate, except in cases where citywide results were unavailable (in those cases select per capita results were drawn from analysis in Chicago (2012) inventory report.

†City of Detroit Land Area used here does not include water features (if water features are included the City of Detroit's area is 142 sq. mi).

Table 26: National and State of Michigan Comparison

National and State Comparison		Inventory Analysis Year	Approx. Pop.*	Pop. Year	Land Area (sq. mi)	Total Emissions (Mt CO_2e)	Municipal Inventory (Mt CO_2e)	Emissions per capita** (t CO_2e/person)	Emissions per square mile (t CO_2e/sq. mi)	Ref.
National Inventory	U.S.	2012	313,873,685	2012	3,531,905	6501.5	-	20.7	1,840.8	12
State of Michigan	MI	2002	9,938,444	2000	56,539	229.5	-	22.8	4,059	13
Detroit	MI	2012	701,475	2012	138	10.6	1.18	15.2	77,027	6

*Population (estimated or from U.S. Census) corresponds as closely to inventory analysis year as possible.

**Per capita results calculated using Inventory Total and Population Estimate

Comparative Analysis References

	Sources for Population and Land Area Data: CensusViewer, Statistics Canada, U.S. Census Bureau (2000, 2014), U.S. EPA (2014b)
1	City of Ann Arbor Greenhouse Gas Emissions Reduction Plan (Epstein et al. 2003)
2	Chicago 2010 Regional Greenhouse Gas Emissions Inventory. (ICF International 2012)
3	Sustainable Cleveland Municipal Action Plan (City of Cleveland 2013a)
4	Cleveland Climate Action Plan: Building Thriving and Healthy Neighborhoods (City of Cleveland 2013b)
5	Gas Inventory for the City and County of Denver (Ramaswami et al. 2007)
6	City of Detroit Greenhouse Gas Inventory: An Analysis of Citywide and Municipal Emissions for 2011 and 2012. (2014)
7	City of Minneapolis Greenhouse Gas Inventories: A Geographic Inventory (2006-2010) and Household Consumption-based Inventory (2010) (City of Minneapolis 2012)
8	PlaNYC Inventory of New York City Greenhouse Gas Emissions, December 2013 (City of New York 2013)
9	2008 Pittsburgh Greenhouse Gas Emissions Inventory: A 5-Year Benchmark (Green Building Alliance 2010)
10	City of Seattle Municipal Greenhouse Gas Emissions Inventory: 2010 (City of Seattle 2011)
11	Greenhouse Gases and Air Pollutants in the City of Toronto: Toward a Harmonized Strategy for Reducing Emissions (ICF International 2007)
12	DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2012 (U.S. EPA 2014b)
13	Michigan Greenhouse Gas Inventory 1990 and 2002 (Bull et al. 2005)

Appendix M: Southeastern Michigan Analysis of Heating and Cooling Degree Days

Weather patterns and seasonality impact energy use in buildings and facilities and would accordingly impact the GHG emissions associated with that energy use, holding fuel mix constant. Analyses of energy use in relation to "degree days" would enhance understanding about how a particular year's weather affected the energy use in buildings in that year.

The U.S. National Oceanic and Atmospheric Administration (NOAA) defines a "degree day" as "a measure that gauges the amount of heating or cooling needed for a building using 65 degrees [F] as a baseline."[130] Degree days fall into two categories: Heating Degree Days (HDD) and Cooling Degree Days (CDD). HDD are calculated based on the amount of heating needed to bring building temperatures up to 65°F during cold days, and CDD are calculated based on the amount of cooling needed to bring building temperatures down to 65°F during hot days.[131]

Table 27 shows the total annual HDD and CDD for Southeastern Michigan for the years 2011 and 2012. It compares these years to five and ten year averages for Southeastern Michigan.

Table 27: Southeastern Michigan Analysis of Heating and Cooling Degree Days

	Year	Total Annual Days	% Difference from 5-Year Avg.	% Difference from 10-Year Avg.
Heating Degree Days	2011	6551	20%	< 1%
	2012	5578	2%	-15%
	5-Year Avg. (prior to 2012)	5477	-	-16%
	10-Year Avg. (prior to 2012)	6545	19%	-
Cooling Degree Days	2011	753	39%	17%
	2012	832	53%	30%
	5-Year Avg. (prior to 2012)	542	-	-15%
	10-Year Avg. (prior to 2012)	641	18%	-

Source: NOAA (2014)

The Detroit GHG Inventory presented in this report does not analyze its building and facilities activity data based on Degree Days at this time. However, in future Detroit GHG inventories it may prove useful to calculate GHG emissions in relations to Degree Days to gain a better understanding about how variations in annual weather or seasonal patterns may impact GHG emissions from energy use in buildings and facilities.

130 NOAA (2014)
131 *Ibid*.

NOAA advises that the most common use of degree days is for comparing energy use from two (or more) separate periods of time.[132] A facility manager or homeowner would divide the electricity consumption (in kWh) or the natural gas consumption (in ccf or therms) by the number of degree days. Although this calculation can assist facility managers and homeowners in understanding the impact of a certain retrofit or energy efficiency project, there are drivers other than weather and seasonality that affect powering buildings. For example, certain building energy uses are not primarily driven by weather, such as appliance use and lighting. To estimate this 'base' energy use of the building, one could examine energy use during temperate months, such as October and May, when little energy is used to heat and cool a building, respectively.

[132] NOAA (2010)

Appendix N: Alternative Community Transportation Emissions Methods

Quantifying community transportation emissions for GHG inventories in a policy-relevant manner is inherently difficult. Stationary emission sources such as buildings and facilities energy use can be quantified more easily with more clearly defined boundaries, more concrete and easily identifiable data sources (most often, the electric utility), and potentially existing reporting mechanisms of energy use or GHG emissions (such as larger GHG emitting facilities that report to the U.S. EPA GHGRP). Mobile sources of GHG emissions, such as organization-specific vehicle fleets, may also regularly quantify fuel purchases for billing or reporting purposes. Such fleets could include the City of Detroit's People Mover light rail, the vehicle fleets managed by DDOT, General Services Department, or DWSD, or the vehicle fleet of a business located in Detroit.

The emissions associated with the light-duty cars that residents drive to work or the heavy-duty freight trucks that commercial entities manage to deliver cargo across the U.S. are more difficult to quantify in a policy-relevant manner. These mobile sources are not cleanly contained within city boundaries. There is no local documentation or record-keeping of fuel purchases from these private vehicles.[133] Even if such data was recorded or quantified, the location of fuel purchases does not necessarily correspond to the point location of emissions for those vehicles, nor does it mean that the locale of emissions *has control or influence* over those emissions. These are a small sampling of the challenges of quantifying GHG emissions from community transportation sources.

Although there are challenges, many resources are available to estimate the magnitude of emissions that come from daily traffic in a community. For example, many metropolitan planning organizations are required by federal regulation to estimate community travel demand in order to comply with air quality standards. This first comprehensive GHG inventory for the City of Detroit benefited from the expertise of Southeastern Michigan's metropolitan planning organization SEMCOG—an entity that must complete the aforementioned air quality analysis and community travel demand modeling.

As mentioned in the transportation methods sections of this report, the community transportation analysis aims to be a comprehensive and accurate estimate of all GHG emissions from the entire fleet of vehicles on the road (sedans, motorcycles, SUVs, light-duty trucks, heavy-duty trucks, etc.). By coupling Vehicle Miles Traveled data from SEMCOG with emission factors from U.S. EPA MOVES, this analysis is able to capture the CH_4 and N_2O emissions in addition to the standard CO_2 emissions accounting. In this light, this analysis very closely answers the question, 'What is the magnitude of transportation emissions in the City of Detroit?' The analysis, however, fails to discern any on-the-ground trends that may be unique to the City of Detroit. As a result, a number of questions remain unanswered. What types of vehicles are Detroiters buying? Are Detroiters'

[133] Such statistics exist at the state-level for gallons of fuel purchased.

accessibility needs being met in addition to their mobility needs? Detroit is a large land-based freight hub; how much of the transportation GHG emissions in Detroit are from freight?

These 'on-the-ground' details can be illustrated by the following example of a potential emissions reduction strategy. The municipal government sets up a revolving fund to purchase more fuel efficient service vehicles. Five years after a city department implements this strategy and replaces its older vehicles with more fuel efficient ones, there is an analysis of the total gallons used by that department. The department finds the total number of gallons has decreased, but is that savings attributable to the more fuel efficient vehicles or other reasons? Fuel purchases—and therefore corresponding GHG emissions—may have decreased because of a change in the department's service area or the services it provides, a decreased budget, or changes in the department's record-keeping. This hypothetical example illustrates that municipal fleet average age, makes, models, fuel purchases, average fuel economy, and city services provided should be monitored and evaluated against future emissions scenarios—and that the drivers of vehicle fleet emissions may depend on this diverse range of factors.

This example further illustrates the need to evaluate other information and indicators, in addition to estimating annual GHG emissions attributed to transportation systems in the City of Detroit. For this reason, the analysis recommends monitoring additional transportation indicators in the future.

This monitoring could potentially answer some of the following questions that provide more nuance and detail about transportation systems and these systems' current and potential future impacts on GHG emissions in the City of Detroit:

- How can Detroit be an efficient land-based freight hub?
- How can accessibility be enhanced for residents, workers, and visitors?
- How easy (and useful) is it to bike in Detroit?
- How easy (and useful) is it to walk?
- How easy (and useful) is it to use public transportation?
- How many electricity fueling stations are there? (And relatedly, how carbon intensive is the electricity fuel mix for Southeastern Michigan?)
- How many hybrid vehicles are purchased in Detroit? How many vehicles above a certain specified fuel economy are purchased in Detroit?
- Do the zoning and parking regulations in Detroit facilitate Transit Oriented Development (TOD)?

All of this information can help inform future GHG inventory transportation analyses.

Additional transportation emission calculations were completed in response to feedback from the preliminary report review and verification processes. This further analysis was completed to

discern the contribution of passenger cars and freight trucks to total transportation emissions in the City of Detroit.

In the analysis, the same VMT data from SEMCOG was used; however it was not combined into 'total' City of Detroit VMT as in the inventory's transportation analysis. Rather, passenger car VMT and freight truck VMT were kept separate; the Origin-Destination model was then used to model the City of Detroit allocation for passenger car and freight truck VMT, similar to the inventory analysis. Then, a 2011 average fuel economy for light-duty vehicles[134] was multiplied by the annual passenger car VMT and a 2011 average fuel economy for Class 7-8 heavy trucks[135] was multiplied by freight truck annual VMT. Finally, fuel emission factors for unleaded gasoline and diesel (found in Table 10 of this report) were multiplied by the total light-duty gasoline usage and total heavy-duty diesel usage respectively.

In this alternate analysis, it was assumed that all light-duty vehicles used unleaded gasoline and all freight trucks used diesel fuel. As shown in Table 28, passenger cars dominate the annual VMT (contributing approximately 87%). However, due to the lower average fuel economy of heavy-duty trucks, each class of vehicles contributed almost equally to GHG emissions (passenger cars contributed 58% and freight trucks contributed 42%).

Table 28: Comparison of Different Transportation Methods, 2012

	Estimated Annual VMT (miles)	Estimated GHG Emissions (t CO_2e)
Light-Duty Passenger Cars	5,050,000,000	1,880,000
Heavy-Duty trucks (Class 7-8)	754,000,000	1,330,000
Alternate Method Total	**5,800,000,000**	**3,210,000**
Community Passenger Car, Truck, and On-Road Freight (2012 Baseline Inventory Total)	*5,800,000,000*	*3,160,000*

The presentation of an alternative method highlights the numerous accounting methods possible on the community scale and demonstrates the complexity of transportation emissions accounting. Future analysis can be informed by the two methods presented in this inventory analysis and would potentially benefit from bringing together more professionals involved in transportation systems in Southeastern Michigan, so that GHG emissions accounting provides meaningful information for benchmarking policy and programming efforts.

[134] Fuel economy (miles per gallon) for 2011 taken from Table 4.1 in U.S. DOT 2013. Additional resources concerning average fuel economy can be found on the Federal Highway Administration's website, http://www.fhwa.dot.gov.
[135] Fuel economy (miles per gallon) for 2011 taken from Table 5.2 in U.S. DOT 2013

Appendix O: Alternative Solid Waste Landfill Disposal Emissions Methods

Solid waste management in a community or municipality is a complex system involving a range of actors, multiple waste streams, and various disposal methods, locations, and emissions-generating processes.[136,137] Poor data collection or lack of transparency can make understanding this system and its emissions even more challenging. In addition, multiple methods (from ICLEI and U.S. EPA) for modeling these emissions are available—making it difficult for the end user to know which to follow. Furthermore, both ICLEI and U.S. EPA caution that their guidance for modeling solid waste emissions at the individual facility level are not precise, since solid waste facilities and GHG emissions vary by community (depending on the specific facilities or processes involved since emissions are generated from landfills over time). [138,139] The U.S. EPA stresses that "significant uncertainties exist" for the parameters used in standardized GHG inventory calculations.[140]

As discussed previously, the Solid Waste section presents estimates of emissions from the disposal of solid waste within the City of Detroit boundary (i.e., from the city's EFW facility) and municipal solid waste generated by the community (i.e., the portion of municipal solid waste that the city's Department of Public Works reports to Wayne County) and disposed at landfills outside of the city limits in 2011 and 2012. To model the emissions from the disposal of solid waste at landfills, this analysis referenced tools and guidance from U.S. EPA, and emissions were estimated using the U.S. EPA WARM tool. Other prominent local greenhouse gas inventories have relied on the U.S. EPA WARM tool, including those published by New York City's PlaNYC, so using this method better enables certain local inventory-to-inventory comparisons.

While not used in the baseline Detroit inventory, ICLEI Protocol recommends an alternative approach to calculating emissions from landfill disposal. This appendix presents a discussion of solid waste emissions using the alternative ICLEI method, as compared to the inventory results that rely on the U.S. EPA WARM model, and discusses the assumptions, differences, and uncertainties of each method, as well.

The calculation of emissions from landfill disposal using the ICLEI protocol-based method relies on similar data inputs to those used in the U.S. EPA WARM method:

- Mass or tonnage of municipal solid waste disposed (assumed to be reported in wet short tons by the City of Detroit Department of Public Works to Wayne County); and

136 Daniels (2003)
137 U.S. EPA (2002)
138 U.S. EPA (2014d)
139 ICLEI (2012) "Appendix E: Solid Waste Emission Activities and Sources"
140 U.S. EPA (2014d)

- Type of landfills (i.e., whether a landfill gas collection and control system was in place for the inventory year—both the Sauk Trail Hills and Carleton Farms landfills that process City of Detroit municipal solid waste use landfill gas recovery to produce energy).

As suggested by ICLEI Protocol when specific municipal solid waste composition is unavailable, a parameter for the default 'Mixed' municipal solid waste type is used (0.060 t CH_4/wet short ton of municipal solid waste).

Like U.S. EPA WARM, the ICLEI method estimates the current and future GHG emissions from municipal solid waste deposited in a given inventory year (i.e., it estimates the GHG emissions from each ton of municipal solid waste disposed of during the inventory year and the future emissions associated with that waste over time).

Based on the parameters outlined by the Protocol, one can then calculate[141] community-generated waste emissions (i.e., the present and future fugitive CH_4 emissions from the solid waste deposited in the landfill during the inventory analysis year), process emissions (i.e., those emissions, in CO_2e, associated with powering equipment needed to manage the waste and landfill; equipment assumed to use diesel fuel), and transportation emissions associated with solid waste landfill disposal (i.e., diesel fuel emissions occurring outside the City of Detroit in CO_2e, but that are attributable to the city's solid waste management system; based on the distance between the City of Detroit and the two landfill locations), as summarized in Table 29.

Table 29: Municipal Solid Waste Emissions using Alternative ICLEI Protocol Method

Type of Emissions Reported	**Emissions (t CO_2e)**	
	2011	2012
Community-generated waste	39,211	24,164
Process	2,268	1,398
Transportation	558	434
Alternative Method Grand Total	**42,037**	**25,996**
*Collection**	*2,766*	*1,705*
Grand Total + Collection*	***44,803***	***27,701***

*Emissions associated with collection are optional under ICLEI protocol

In the table above and similar to the trend found using the baseline inventory method of U.S. EPA WARM, there is a drop in emissions between the two years due to a substantial decrease in the tonnage of municipal solid waste reported by the City of Detroit Department of Public Works to Wayne County in 2012, as compared to 2011. At the time of inventory reporting for these years, a reason for this drop was unable to be determined.

[141] These calculations use ICLEI's SW. 4, 5 and 6 equations, respectively.

While ICLEI Protocol also outlines a method for calculating emissions associated with municipal solid waste collection, it is important to note that these emissions are optional to report and would likely be double counted based on assumptions of the community transportation model used in the Detroit inventory.

These results, even when not taking collection emissions into account, are significantly higher than those values reported earlier using U.S. EPA WARM (which were 4,464 t CO_2e in 2011 and 2,661 t CO_2e in 2012) and would lead to a higher share of total citywide GHG emissions from solid waste activities than those presented earlier in the report.

The significant difference in results from each method seemingly stems from different modeling approaches. U.S. EPA WARM accounts for the long-term carbon sequestration associated with organic matter present in municipal solid waste. It also accounts for the avoided utility emissions from fossil fuels that can be achieved through landfill gas capture and combustion. In so doing, it credits the avoided utility emissions associated with future methane emissions from the solid waste for a given inventory year and reduces the total solid waste GHG emissions reported, whereas "ICLEI's GHG Emissions Analysis Protocol and the California Air Resources Board Local Government Operations Protocol do not." [142] While the ICLEI method does account for landfill gas capture in calculating fugitive methane emissions, it does not account for avoided utility emissions that could be achieved through landfill capture, nor does it account for any carbon sequestration in solid waste. As a result, lower emissions reported in the Detroit Baseline Inventory using U.S. EPA WARM as compared to ICLEI Protocol are to be expected.

While ICLEI argues this method "allows for more straightforward local decision making with regard to policies that can influence the generation and fate of solid waste from a community,"[143] using generalized parameters with little data specific to the City of Detroit, the landfills it uses, or the type of municipal solid waste it produces likely results in a high degree of uncertainty.

While the U.S. EPA WARM model has similar drawbacks, it is a tool used by solid waste managers to understand the benefits of changes to management practices—specifically those from reduced municipal solid waste streams. And while it is available both online and in an Excel-based tool, it is however a 'black box' in terms of the parameters and calculations used to calculate emissions from solid waste, landfill processing, and transportation over time. Although the model does have extensive supporting documentation and the project team did rely on user support from U.S. EPA staff—it can be difficult for a layperson to use and understand what is driving the model results.

Ultimately, the guidance the Detroit inventory project team received from U.S. EPA and the precedent set by other high-profile inventories influenced our decision to rely on the U.S. EPA WARM tool in estimating the GHG emissions from solid waste presented in this baseline inventory analysis. Even so, this discussion illustrates available methodologies to estimate GHG emissions from solid waste activities may have similar inputs, but may lead to different results. The decision

[142] Materials Management Approaches for State and Local Climate Protection (2014) and U.S. EPA (2013h)
[143] ICLEI (2012) "Appendix E: Solid Waste Emission Activities and Sources"

to choose one set of guidance or the other is subjective, which the authors of this report fully acknowledge. It is important that future Detroit GHG inventories continue to investigate and evaluate each available solid waste method more thoroughly based on available data, any changes to the processes involved in solid waste management, and the ease of use of the method itself.

Appendix P: Avoided Emissions from Residential Recycling and Composting in Detroit

According to U.S. EPA, recycling and composting can reduce a city's total municipal solid waste emissions by diverting waste, which would otherwise have been landfilled (where it would decompose and produce emissions over time).[144] The avoided emissions from the amount of material recycled and composted reported by the City of Detroit Department of Public Works in 2011 and 2012, are estimated (in comparison to emissions from solid waste landfill and incineration) in Table 30. These avoided emissions are, like those from solid waste reported in the Detroit citywide inventory, attributed to the year in which the waste was generated even though the calculations account for the benefits of avoided emissions that occur over multiple years, as the recycled or composted waste would have otherwise been disposed of at a landfill and would have produced emissions as it decomposed over time.

Similar to this inventory's land use analysis, avoided emissions from recycling and composting are not currently included in Detroit's total citywide emissions because local GHG protocols do not recommend it at this time. As a result, total solid waste emissions and the avoided emissions from recycling and composting are illustrated in Table 30, but net emissions from municipal solid waste were not calculated across analysis years or presented in conjunction with citywide results.

Table 30: City of Detroit Municipal Solid Waste Emissions and Avoided Emissions from Recycling and Compost

Activity	Emissions (t CO_2e)	
	2011	2012
Landfill and Incineration	215,051	250,335
Avoided from Recycling and Compost	(89,293)	(23,650)

These results suggest that Detroit could see reduced emissions from solid waste by increasing municipal recycling and composting, and by encouraging recycling and composting elsewhere, such as in commercial buildings.

A discussion of methods (including emission factors) used to calculate these results follows.

Recycling and Composting Methods

Recycling and composting emissions were modeled using the ICLEI Recycling and Compost Emissions Protocol, Version 1.0, which outlines how to estimate "emissions reduction of community-scale recycling and composting efforts."[145] The avoided emissions from the recycling and compost collected by the City of Detroit were each calculated using data provided by Wayne County[146] and emission factors adapted from U.S. EPA WARM. Once converted into common

[144] U.S. EPA (2012b)
[145] ICLEI (2013)
[146] Wayne County (2013)

units, avoided emission results from both recycling and composting could be added together, presented as total avoided emissions from recycling and composting in Table 30.

The recycling material type categories reported by City of Detroit Department of Public Works to Wayne County did not match those categories outlined by ICLEI Protocol. Using guidance from U.S. EPA,[147] recycling emission factors were chosen based on the best match between the City of Detroit material type categories reported and those outlined by ICLEI.

Table 31 shows the recycling emissions factors used for each type of recycled material and inputted into U.S. EPA WARM.

Table 31: Detroit Municipal Solid Waste and Recycling Emission Factors.

Material Recycled	ICLEI Material Proxy	Emissions Factors ($t\ CO_2e$/short ton of material)		
		Recycled inputs (not virgin)	Landfill, gas & energy recovery	Combustion Facility
Commingled Rigids & Fibers	Mixed Recyclables	-2.8	-0.28	0.42
Commingled Rigids (Cans/Glass/Plastic)	Avg. Glass, Mixed Plastics, Steel Cans, Aluminum Cans	-1.74	-0.04	-0.08
Mixed or Other Fibers	Mixed Recyclables	-2.8	-0.28	0.42
Corrugated Cardboard	Corrugated Containers	-3.11	-0.36	0.48
Newsprint	Newspaper	-2.78	-0.15	0.55
Magazines & Catalogs	Magazines/Third-Class Mail	-3.07	-0.17	0.35
Office Paper	Office Paper	-2.85	-0.58	0.47
Phone Books	Phone Books	-2.65	-0.15	0.55
Mixed Glass	Glass	-0.28	-0.04	-0.05
Clear Glass	Glass	-0.28	-0.04	-0.05
Commingled Aluminum/Steel/Tin	Average of Steel and Aluminum Cans	5.35	-0.04	0.77
Ferrous & Non-Ferrous	Mixed Metals	-3.97	-0.04	1.06
Mixed Plastics (SPI Code 1-7)	Mixed Plastics	-0.98	-0.04	-1.25
Waste Tires	Tires	-0.39	-0.04	-0.51
Other	Mixed Recyclables	-2.8	-0.28	0.42
Household Batteries*, Major Appliances**				

*Not Estimated, **Estimated with U.S. EPA Durable Goods Calculator

In two cases, where there was no single best material proxy for Detroit's material type, so a combination of material types were used as a proxy that, in our opinion, best fit the data: (1) for Commingled Aluminum/Steel/Tin, an average of ICLEI's Aluminum and Steel Cans emissions factors was used; (2) for Commingled Rigids (Cans/Glass/Plastic), an average of ICLEI's Glass, Mixed Plastics, Steel Cans, and Aluminum Cans emissions factors was used.

147 U.S. EPA (2012b)

ICLEI emissions factors were not used to estimate two waste types: Household Batteries and Durable Goods. The Household Batteries material type was excluded from our estimate because they are not included in the U.S. EPA WARM model or the ICLEI protocol; the hazardous waste components of batteries make them difficult to model.[148] We estimated the emissions reductions benefits of Detroit's Durable Goods material type with the U.S. EPA's Durable Goods Calculator,[149] which, although no longer being updated by U.S. EPA, likely provides the best emissions estimate.[150]

Lacking composition data for durable goods, an assumption was made to equally distribute the total mass per year among fourteen of fifteen waste categories. We excluded tires because they are accounted for elsewhere in the data and assumed that there would not be tires in both the Waste Tires and Major Appliances material categories.

For the composting calculations, available data for Detroit's residential municipal solid waste did not include compost composition information. Therefore, as recommended by ICLEI Recycling and Composting Emissions Protocol, we use the national average composition for 2005, 2010, and 2011, from U.S. EPA's annual Waste Characterization Reports. The State of Michigan does not track municipal solid waste composition and does not produce a "Waste Characterization Report," so a national scale was the best available proxy.[151] At this time, U.S. EPA is currently in the process of updating its methodology for the national Municipal Solid Waste Characterization Report and had not yet published a report for 2012. Consequently, to estimate the composition for 2012, the mean of the national averages for 2005, 2010, and 2011, was used as a proxy to conservatively estimate an amount composted in 2012.

---

[148] Personal communication with U.S. EPA Office of Resource Conservation & Recovery (Jan. 14, 2014).
[149] U.S. EPA (2005)
[150] Personal communication with U.S. EPA Office of Resource Conservation & Recovery, (Jan. 14, 2014).
[151] U.S. EPA (2014e)

Abbreviations

Agencies and Organizations

CDP – Carbon Disclosure Project
DBA – Detroit Blight Authority
DCAC – Detroit Climate Action Collaborative
DDOT – City of Detroit Department of Transportation
DTC – Detroit Transportation Corporation
DWEJ – Detroiters Working for Environmental Justice
DWSD – Detroit Water and Sewerage Department
EIA – U.S. Energy Information Administration
GDRRA – Greater Detroit Resource Recovery Authority
GLISA - Great Lakes Integrated Sciences and Assessments Center
GSD – City of Detroit General Services Department
ICLEI – ICLEI Local Governments for Sustainability
IPCC – Intergovernmental Panel on Climate Change
NOAA – U.S. National Oceanic and Atmospheric Administration
NRDC – Natural Resources Defense Council
PLA – Public Lighting Authority
PLD – Public Lighting Department
SEMCOG – Southeast Michigan Council of Governments
UM - University of Michigan
UNFCCC – United Nations Framework Convention on Climate Change
SNRE – School of Natural Resources and Environment
U.N. – United Nations
U.S. – United States
U.S. EPA – United States Environmental Protection Agency
WBCSD - World Business Council for Sustainable Development
WRI – World Resources Institute

Acronyms

Ccf - 100 cubic feet of natural gas
CEMS – Continuous Emissions Monitoring System(s)
CDD – Cooling Degree Day
CO_2e – carbon dioxide equivalent
CNG – Compressed Natural Gas
CY – calendar year
EF – emission factor
EFW – energy from waste
FY – fiscal year
eGRID – Emissions and Generation Resource Integrated Database
GHG – greenhouse gas
GWP – Global Warming Potential

HDD – Heating Degree Day
HHV – High Heating Value
kWh – kilowatt hour
Million t CO_2e – megatonne (or million metric tons (tonnes)) of carbon dioxide equivalents
MJ – megajoule
mmBtu – 1 million British Thermal Units
MWh – megawatt hour
ppm – parts per million
SIC – Standard Industry Classification
t – metric ton (tonne), SI unit
t CO_2e – metric ton (tonne) of carbon dioxide equivalents
T&D – Transmission and Distribution
UNFCCC – United Nations Framework Convention on Climate Change
U.S. EPA FLIGHT – U.S. EPA Facility Level Information on Greenhouse Gases Tool
U.S. EPA GHGRP – U.S. EPA Greenhouse Gas Reporting Program
U.S. EPA MOVES – U.S. EPA Motor Vehicle Emissions Simulator
U.S. EPA OTAQ – U.S. EPA Office of Transportation and Air Quality
U.S. EPA WARM – U.S. EPA Waste Reduction Model
VMT – vehicle miles traveled
WWTP – Wastewater Treatment Plant

Glossary of Terms

Glossary of Terms adapted from resources from U.S. EPA, IPCC, EIA, UNFCCC, and others. A complete list of these resources is available at the end of this section.

Activity: organizing category used specifically in this report that refers to aggregate, citywide emissions sources, which include buildings and facilities, transportation, industrial process, solid waste, wastewater treatment, and land use. In other inventories, these activity categories may be referred to as 'sectors' but this project refrains from using the general term 'sector' to distinguish from and avoid confusion with the concept of 'end-use sector' used in our analysis and defined below.

Biogenic CO_2 emissions: carbon dioxide emissions resulting from the combustion, decomposition, or processing of organic materials (other than fossil fuels, peat, and mineral sources of carbon) through combustion, digestion, fermentation, or decomposition processes. Most commonly, stationary energy-related and industrial processes are sources of biogenic CO_2.

Currently in local GHG inventories, biogenic CO_2 emissions are not included in analyses. For example, the aerobic decomposition of organic matter in forests releases carbon dioxide into the atmosphere. Organic matter decomposes *anaerobically* in landfills, producing methane gas in addition to carbon dioxide. The carbon dioxide produced is biogenic and therefore not included in the GHG accounting. Methane is produced through this solid waste management technique and is included.

Carbon sequestration: process of carbon absorption. Carbon sequestration can occur naturally in the biosphere, where trees and other plants absorb carbon dioxide, release the oxygen, and store the carbon as plant tissue; or via direct geoengineering measures, such as the injection of carbon dioxide deep underground to be stored permanently.

Carrier: a substance in which energy can be stored and transported and ultimately from which energy be harnessed by an end-use application. Energy carriers include electricity and heat as well as solid, liquid and gaseous fuels. An energy carrier is thus a transmitter of energy.

Climate adaptation: preparation and adjustment of our built environment and natural ecosystems in response to a new or changing environment, to diminish potential harm or take advantage of possible beneficial opportunities.

Climate mitigation: actions implemented to decrease the human impact on the earth's climate system that can include both reducing greenhouse gas emissions and increasing both natural and human-constructed carbon sequestration sinks.

Climate vulnerability: the extent to which a system (e.g., a nation, region, community, or household) is exposed to, sensitive to, and/or unable to cope with the harmful effects of

climate change, such as climate variability and extremes in temperatures and precipitation patterns.

Co-benefit: other benefits of climate mitigation and adaptation actions and policies that are equally relevant and important such as sustainable development, environmental justice, public health benefits, and cost-savings. Although they are not the primary motivation, they add to the rationale for climate action.

Cooling degree day (CDD): a way to relate each day’s temperature to the demand for energy to cool buildings. A single day’s CDD is calculated by adding the day’s high and low temperatures and dividing by two. If result is more than 65, subtract 65 from number to find the number of cooling degree days.

Direct emissions: emissions of greenhouse gases from sources within the boundary or control of an organization or facility's processes or actions (often referred to as Scope 1 emissions). Examples of direct emissions include the combustion or burning of fossil fuels to power, heat, and cool buildings and emissions from industrial processes.

Double counting: an accounting error when the same emissions are counted twice instead of once, thereby overstating the total amount of emissions (e.g., accounting for emissions due to steam generation as well as the emissions from the solid waste incineration that produces steam at the energy from waste (EFW) facility).

Emission factor (also: emission coefficient): a unique value used to calculate emissions via activity data, expressed in terms of rate of emissions per unit of activity (e.g., metric tons of CO_2 per kWh of electricity generated).

End-use sector: the residential, commercial, industrial, and institutional sectors of the economy. Sometimes transportation is included as an end-use economic sector, however, in this report, that convention is not followed and transportation is instead referred to as an ‘activity’ category.

Energy efficiency: providing the same service with less energy input.

Excessive heat event: an instance when a location’s recorded temperature, dew point temperature cloud cover, wind speed and surface atmospheric pressure throughout the day combine to cause or contribute to heat-related deaths; the temperature thresholds of which are regionally dependent.

Fugitive emissions: unintended greenhouse gas emissions from the processing, transmission, and/or transportation of fossil fuels (e.g., high GWP gas emissions from refrigerator leaks or methane leaks from natural gas systems).

Global warming potential (GWP): a measure of the total infrared radiation (energy) that a gas absorbs over a specified period of time (usually 100 years), as compared to carbon dioxide; for use in normalizing impacts of different greenhouse gases.

Greenhouse gas: any gas that absorbs infrared radiation (commonly thought of as heat) in the atmosphere. Greenhouse gases include carbon dioxide, methane, nitrous oxide, ozone, chlorofluorocarbons, hydrofluorocarbons, perfluorocarbons, and sulfur hexafluoride.

Greenhouse gas (GHG) inventory: an accounting of greenhouse gas emissions for a specific period of time. Similar to any technical accounting exercise, a boundary of time, space, and degree of ownership and control must be specified (e.g., a citywide GHG inventory is an accounting of emissions based on city jurisdictional or geographic boundary; a municipal GHG inventory is an accounting of emissions from municipal operations and activities).

Heating degree day (HDD): a way to relate each day's temperature to the demand for energy to heat buildings. A single day's HDD is calculated by adding the day's high and low temperatures and dividing by two. If result is less than 65, subtract number from 65 to find the number of heating degree days.

Indirect emissions: emissions that are a consequence of the activities of an organization but occur from sources owned or controlled by another organization (also referred to as Scope 2 and Scope 3 emissions). A city's scope 2 indirect emissions include for example the consumption of purchased electricity, heat or steam and emissions from company owned vehicles. Scope 3 indirect emissions include transport related activities in vehicles not owner or controlled by the organization, out sourced activities, air travel and waste disposal.

Life cycle emissions: Life cycle emissions estimate a product, process, or service's emissions across its life stages (i.e. from its origin to its disposal). Life cycle emissions accounting can be used in concert with production- or consumption-based inventories.

Parts per million (ppm): is a dimensionless ratio used to convey the concentration of a substance diluted in another. Therefore, 400 ppm CO_2 refers to the ratio of CO_2 (molecules) in the atmosphere to all other molecules found in the atmosphere. It denotes that for every 1,000,000 non-CO_2 molecules in the atmosphere, there are 400 molecules of CO_2. One part per million = 1/1,000,000.

Process emissions: emissions from industrial methods that involve chemical transformations of materials other than combustion (e.g., CO_2 emissions from cement production).

Production- vs. consumption-based inventories: Geographic or production-based inventory is an emissions inventory that accounts for those emissions physically originating within the geographic boundaries of the community (national inventories are typically geographic).

Consumption-based inventory is an emissions inventory that covers the total global GHG emissions occurring from economic consumption within a set region (e.g., a country). Consumption-based inventories attempt to estimate all emissions—both inside and outside the community—that arise as a consequence of the demand for goods and services (or, the consumption activities) within that community.

Protocol: an accepted or established code of procedure for counting greenhouse gas emissions.

Scope: organization system for greenhouse gas emissions based on type of emission (direct, indirect) as well as level of control and/or ownership over emissions' sources of the reporting entity.

Scope 1 emissions: direct emissions from sources owned or controlled by reporting entity (e.g. combustion of gasoline to fuel a vehicle owned by the reporting entity).

Scope 2 emissions: indirect emissions from the generation of purchased energy (e.g., purchased electricity).

Scope 3 emissions: indirect emissions not accounted in Scope 2 emissions, involving upstream or downstream sources of emissions from the reporting entity, such as transport-related activities not owned or controlled by the reporting entity and electricity T&D losses.

Standard Industry Classification (SIC) system: The SIC system was developed as a standard for use by Federal agencies to classify business establishments for the collection, organization, and analysis of statistical data describing the U.S. economy. The SIC system relates number codes to establishment activity, which is determined by a proportion of production costs and/or capital investment. SIC codes are a multi-digit hierarchical classification system, in which more digits related to an establishment, provide a narrower, more detailed description of that business and its activities.

The SIC system was replaced by the North American Industry Classification System (NAICS) in 1997. However, organizations and local and state agencies may continue to use the SIC system for their own statistical analysis purposes and/or record-keeping.

Tree canopy: Tree canopy is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above.

Resource List

U.S. EPA

Glossary of Climate Change Terms

Developing a Greenhouse Gas Inventory (State and Local Climate and Energy Program)

Accounting Framework for Biogenic CO2 Emissions from Stationary Sources (Office of Atmospheric Programs)

Double Counting in Municipal Greenhouse Gas Emissions Inventories

Intergovernmental Panel on Climate Change

Climate Change 2007: Working Group III: Mitigation of Climate Change

EIA

U.S. EIA Online Glossary

National Oceanic and Atmospheric Administration

Frequently Asked Questions on Heating and Cooling Degree Days

California Air Resources Board

Glossary of Terms Used in Greenhouse Gas Inventories

UNFCCC

Glossary

GHG Protocol

Frequently Asked Questions

Additional Resources

Watershed Forestry Resource Guide

U.S. Census NAICS and SIC Code Frequently Asked Questions

350.org The Science Page

Reducing Carbon Emissions: A Guide for Architects, Glossary of Terms

Florida Solar Energy Center Glossary

West Coast Climate & Materials Management Forum Glossary

References

Bull, P., C. McMillan, and A. Yamamoto. (2005) "Michigan Greenhouse Gas Inventory 1990 and 2002." Center for Sustainable Systems, Report No. CSS05-07, University of Michigan, Ann Arbor, Michigan, April 8, 2005. 128 pp., tables, figures, 11 appendices.

CensusViewer. (2012) “Free Map and Data Version.” Various Cities U.S. Census 2000 and 2010. Accessed 15 March 2014. <http://censusviewer.com>.

Center for Sustainable Systems (CSS), University of Michigan. (2013a) “Climate Change: Science and Impacts Factsheet.” Pub. No. CSS05-19. Accessed Aug. 2013. <http://css.snre.umich.edu/css_doc/CSS05-19.pdf> .

City of Ann Arbor. (2014) “Urban Tree Canopy Analysis.” Accessed March 2014. <http://www.a2gov.org/government/publicservices/fieldoperations/forestry/Pages/UrbanTreeCanopyAnalysis.aspx>.

City of Cleveland. (2013a) "Sustainable Cleveland Municipal Action Plan." Sustainable Cleveland 2019 and Cleveland Office of Sustainability.

City of Cleveland. (2013b) "Cleveland Climate Action Plan: Building Thriving and Healthy Neighborhoods." Sustainable Cleveland 2019 and Cleveland Office of Sustainability.

City of Detroit. (2012) “Energy Efficiency Success Stories from Detroit’s City Buildings.” City of Detroit General Service Department. Presenter: B. Dick. Michigan Green Communities Network. Accessed Feb. 2014. <http://www.mml.org/pdf/resources/greencommunities/2012-MGC_SE_Detroit.pdf>.

City of Detroit. (2013) Financial and Operating Plan. Office of Emergency Manager, Kevyn D. Orr. 12 May 2013. pp. 11. Accessed Jan. 2014 <http://www.detroitmi.gov/Portals/0/docs/EM/Reports/City%20of%20Detroit%20-%20Final%20Financial%20&%20Operational%20Plan%20_45%20Day%20Pl.pdf>.

City of Minneapolis. (2012) City of Minneapolis Greenhouse Gas Inventories: A Geographic Inventory (2006-2010) and Household Consumption-based Inventory (2010). Written by: H. Lahd, B. Slotterback, G. Prest, A. Imboden.

City of New York PlaNYC. (2013) Inventory of New York City Greenhouse Gas Emissions, December 2013. Written by: J. Dickinson, J. Khan, and M. Amar. Mayor’s Office of Long-Term Planning and Sustainability. New York City, 2013.

City of Seattle. (2011) "City of Seattle Municipal Greenhouse Gas Emissions Inventory: 2010." Office of Sustainability & Environment. Prepared by: H. Papendick. Feb. 2011.

City of Toronto. (2014) “Living in Toronto: Environment & Energy Portal.” Accessed March 2014 <http://www1.toronto.ca/wps/portal/contentonly?vgnextoid=fd95ba2ae8b1e310VgnVCM10000071d60f89RCRD>.

Climate Registry, The. (2013) General Reporting Protocol. Version 2.0. March 2013. Accessed June 2013. <http://www.theclimateregistry.org/downloads/2013/03/TCR_GRP_Version_2.0.pdf>.

Daniels, Tom and Katherine Daniels. 2003. “Chapter Six: Planning for Solid Waste and Recycling.” In *The Environmental Planning Handbook for Sustainable Communities and Regions.* Pp. 151-164. Chicago, IL: Planners Press.

Davies, J., M. Grant, J. Venezia, and J. Aamidor. “Greenhouse Gas Emissions of the U.S. Transportation Sector: Trends, Uncertainties, and Methodological Improvements,” *Transportation Research Record* 2017 (2007): 41-46.

Delaware Valley Regional Planning Commission (DVRPC). “Regional Greenhouse Gas Emissions Inventory.” December 2010.

Detroit Future City (DFC). (2013) “Detroit Future City Strategic Framework.” Accessed Nov. 2013. <http://detroitfuturecity.com>.

Detroit Water and Sewerage Department (DWSD). (2014). ”Wet weight of biosolids incinerated at DWSD Wastewater Treatment Plant.” Data provided via direct email correspondence with project team. 10 Jan. 2014.

Diem, A. and C. Quiroz. (2012) “How to use eGRID for Carbon Footprinting Electricity Purchases in Greenhouse Gas Emission Inventories.” U.S. EPA. July 2012. Accessed Jan. 2014. <http://www.epa.gov/ttnchie1/conference/ei20/session3/adiem.pdf>.

Dodman, D. (2009) “Blaming cities for climate change? An analysis of urban greenhouse gas emissions inventories.” *Environment and Urbanization*. 21 (2009): 185. DOI: 10.1177/0956247809103016.

DTE Energy. (2014) “Generation and Emissions.” Accessed Dec. 2013. <http://goo.gl/2V6NdS>.

Edison M., K. Elliott, B. Fischlowitz-Roberts, R. Permut, S. Popp, and A. Winkelman (2007) Michigan at a Climate Crossroads: Strategies for Guiding the State in a Carbon-Constrained World. Faculty Advisor: G. Keoleian. Center for Sustainable Systems, Report No. CSS07-02

Energy Information Administration (EIA). (2014a) “How much carbon dioxide (CO_2) is produced per kilowatt hour when generating electricity with fossil fuels?” *Frequently Asked Questions*. Accessed 16 Jan. 2014 <http://www.eia.gov/tools/faqs/faq.cfm?id=74&t=11>.

EIA. (2014b) "Petroleum & Other Liquids: Definitions, Sources and Explanatory Notes." Accessed 16 April 2014. <http://www.eia.gov/dnav/pet/tbldefs/pet_pri_prop_tbldef2.asp>.

Epstein, S., J. Malcoun II, J. Oorbeck and M. Yamada. (2003) City of Ann Arbor Greenhouse Gas Emissions Reduction Plan. Center for Sustainable Systems, Report No. CSS03-02, University of Michigan, Ann Arbor, Michigan, May, 2003. 226 pp., tables, figures, 21 appendices.

Federal Transit Administration. (2013) “What is the NTD Program.” National Transit Database. Accessed July 2013. <http://www.ntdprogram.gov/ntdprogram/ntd.htm>.

Gallagher, J., P. Montemurri, and J. Reindl. (2014) “Monumental effort to tear down blight would improve neighborhoods and Detroit's image.” *Detroit Free Press*. Feb. 23, 2014. Accessed 28 March 2014. <http://www.freep.com/article/20140223/NEWS01/302230057/Blight-Orr-Detroit>.

Green Building Alliance. (2010) "2008 Pittsburgh Greenhouse Gas Emissions Inventory: A 5-Year Benchmark." City of Pittsburgh, Pittsburgh Climate Initiative.

Guillen, J. (2014) “Detroit privatizes trash collection, adds biweekly bulk pickup, recycling.” *Detroit Free Press*. Feb. 18, 2014. Accessed 28 March 2014. <http://www.freep.com/article/20140218/NEWS01/302180127/Detroit-City-Council-privatize-trash-service-bankruptcy>.

Hoornweg, D., L. Sugar, & C. Trejos Gómez (2011) “Cities and greenhouse gas emissions: moving forward.” *Environment & Urbanization*. 23(1), 207–227. DOI: 10.1177/0956247810392270.

ICF International. (2007) "Greenhouse Gases and Air Pollutants in the City of Toronto: Toward a Harmonized Strategy for Reducing Emissions." Toronto Atmospheric Fund and Toronto Environment Office. June 2007.

ICF International. (2012) Chicago 2010 Regional Greenhouse Gas Emissions Inventory. (ICF 112831.0.001.) . San Francisco, CA. Prepared for Global Philanthropy Partnership with the City of Chicago and the Chicago Metropolitan Agency for Planning, Chicago, IL. May 2012.

ICLEI Local Governments for Sustainability (ICLEI). (2006) “Talking Trees: An Urban Forestry Toolkit for Local Governments.” Nov. 2006. Accessed April 2014. <http://www.milliontreesnyc.org/downloads/pdf/talking_trees_urban_forestry_toolkit.pdf>

ICLEI et al. (2010) Local Government Operations Protocol for the Quantification and Reporting of GHG Emissions Inventories. Version 1.1 May 2010. Developed in partnership and adopted by: California Air Resources Board, California Climate Action Registry, ICLEI - Local Governments for Sustainability, and The Climate Registry. Accessed June 2013. <http://www.theclimateregistry.org/downloads/2010/05/2010-05-06-LGO-1.1.pdf>.

ICLEI. (2012) U.S. Community Protocol for Accounting and Reporting of GHG Emissions. Version 1.0. October 2012. ICLEI–Local Governments for Sustainability USA. Accessed June 2013. <http://www.icleiusa.org/tools/ghg-protocol/community-protocol>.

ICLEI. (2013) “Recycling and Composting Emissions Protocol: For Estimating Greenhouse Gas Emissions and Emissions Reductions Associated with Community Level Recycling and Composting.” July 2013. Accessed 15 Jan. 2013. <http://www.icleiusa.org/action-center/tools/recycling-and-composting-emissions-protocol-version-1>

ICLEI. (2014a) “Promoting solar in the steel city: lessons learned from the Pittsburgh solar Initiative.” Accessed Feb. 2014. <http://www.icleiusa.org/action-center/action-center/learn-from-others/ICLEI_CaseStudy_PittsburghSolar3.pdf>.

ICLEI. (2014b) “Chicago Green Office Challenge Success.” Accessed Feb. 2014. <http://www.icleiusa.org/climate_and_energy/green-business-challenge/success-stories/chicago-green-office-challenge-success>.

Intergovernmental Panel on Climate Change (IPCC). (2013) *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Summary for Policymakers. Stocker, T. D. Qin, G. Plattner, M. Tignor, S.

Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex, and P. Midgley (eds.). Cambridge University Press, Cambridge, United Kingdom and New York, NY USA, 1535 pp. Accessed March 2014. <http://www.climatechange2013.org/images/report/WG1AR5_SPM_FINAL.pdf>.

Great Lakes Integrated Sciences and Assessments (GLISA).(2013) "The Potential Impacts Of Climate Change on Detroit, Michigan" 13 Sept. 2013. Accessed Nov. 2013 <http://glisaclimate.org/media/DCAC_Climate_Impacts.pdf>.

Gregg, K., P. McGrath, S. Nowaczyk, A. Perry, K. Spangler, T. Traub, and B. VanGessel. (2012) Foundations for Community Climate Action: Defining Climate Change Vulnerability in Detroit. University of Michigan, Taubman School of Architecture and Urban Planning. Dec. 2012. Accessed Aug. 2013. <http://graham.umich.edu/media/files/ClimateChateActionDetroit.pdf>.

Larsen, L., N. Rajkovich, C. Leighton, K. McCoy, K. Calhoun, E. Mallen, K. Bush, J Enriquez, C. Pyke, S. McMahon, and A. Kwok. (2011) *Green Building and Climate Resilience: Understanding Impacts and Preparing for Changing Conditions*. University of Michigan; U.S. Green Building Council.

Lutsey, N. & D. Sperling. (2008) "America's bottom-up climate change mitigation policy." *Energy Policy*. 36, 673-685.

Materials Management Approaches for State and Local Climate Protection. (2014) "EPA's WAste Reduction Model (WARM)." Accessed 15 Aug. 2014. <http://captoolkit.wikispaces.com/WARM>.

McHale, M., E. McPherson, I. Burke. (2007) "The potential of urban tree plantings to be cost effective in carbon credit markets." *Urban Forestry & Urban Greening*. Elsevier GmbH. doi:10.1016/j.ufug.2007.01.001. Accessed April 2014. <http://www.fs.fed.us/ecosystemservices/pdf/urban-tree-planting.pdf>.

Michigan Department of Environmental Quality (MDEQ). (2009) Michigan Climate Action Council: Climate Action Plan. Accessed March 2014. <http://www.michigan.gov/documents/deq/deq-miclimateactionplan-part1_276563_7.pdf>.

Michigan Department of Transportation (MDOT). (2010) "Annual Vehicle Miles Traveled in the State of Michigan." Accessed 15 Oct. 2013. <http://www.michigan.gov/documents/mdot/MDOT_TOTALS_LENAVMTBYNFC_372812_7.PDF>.

MillionTreesNYC. (2014) "About: MillionTreesNYC." Accessed Feb. 2014. <http://www.milliontreesnyc.org/html/about/about.shtml>.

National Research Council of the National Academies of Sciences (NRC). (2012) "Climate Change: Evidence, Impacts, and Choices." Accessed March 2014. <http://nas-sites.org/americasclimatechoices/files/2012/06/19014_cvtx_R1.pdf>.

National Climate Assessment and Development Advisory Committee. (2014) Draft: National Climate Assessment. Accessed March 2014. <http://ncadac.globalchange.gov/>.

National Oceanic and Atmospheric Administration (NOAA) (2014). NOAA Satellite and Information Service Data Retrieval: Heating and Cooling Degree Days for Southeastern Michigan. National Climatic Data Center. Accessed March 2014. <http://www7.ncdc.noaa.gov/CDO/CDODivisionalSelect.jsp>.

NOAA (2010). NOAA National Weather Service Weather Forecast Office: Heating and Cooling Degree Days. National Climatic Data Center. Accessed July 2014. <http://www.srh.noaa.gov/key/?n=climate_heat_cool>.

Natural Resources Defense Council (NRDC). (2012) "Killer Summer Heat: Projected Death Toll from Rising Temperatures in America Due to Climate Change." Written by: P. Altman. May 2012. Accessed August 2013. <http://www.nrdc.org/globalwarming/killer-heat/files/killer-summer-heat-report.pdf>.

Nowak, D. (2013) "Carbon Storage and Sequestration by trees in urban and community areas of the United States" *Environmental Pollution* 178: 229-236.

Pearson, T., Grimland, S., and S. Brown. (2010) "A spatial analysis of greenhouse gas emissions from agricultural fertilizer usage in the US." Winrock International. April 2010.

Peters, G. and E Hertwich. (2008) "Post-Kyoto greenhouse gas inventories: production versus consumption." *Climate Change*. 86 (2008). Issue 1-2, pp. 51-66.

Peters, G. (2008) "Methodological and Ideological Options: from production-based to consumption-based national emission inventories." *Ecological Economics*. 65 (2008), pp. 13-23.

Pipatti, R. and P. Svardal. (2006) "Chapter 3: Solid Waste Disposal." IPCC Guidelines for National Greenhouse Gas Inventories: Volume 5. Accessed July 2014. <http://www.ipcc-nggip.iges.or.jp/public/2006gl/pdf/5_Volume5/V5_3_Ch3_SWDS.pdf>.

Ramaswami, A., B. Janson, T. Hillman, J. Wendrowski, M. Reiner, and M. Posner. (2007) Greenhouse Gas Inventory for the City and County of Denver. Urban Sustainable Infrastructure Engineering Project, Department of Civil Engineering, University of Colorado Denver. May 2007.

Richter, J. (2012) Counting in Cities: City-Scale Greenhouse Gas Inventory Standards and Indirect Emissions. ARSCP, Lund University, Sweden.

Southeast Michigan Regional Energy Office. (2013) "BetterBuildings for Michigan." Accessed March 2014. <http://regionalenergyoffice.org/home-business-programs/partners/>.

Statistics Canada. (2012) Toronto, Ontario (Code 3520) and Ontario (Code 35) (table). Census Profile. 2011 Census. Statistics Canada Catalogue no. 98-316-XWE. Ottawa. Released October 24, 2012. Accessed 18 March 2014. <http://www12.statcan.gc.ca/census-recensement/2011/dp-pd/prof/index.cfm?Lang=E>.

Sugar, L, D. Hoornweg, and C. Kennedy. (2011) Greenhouse Gas Emissions from Cities Comparison of International Inventory Frameworks. Draft Working Paper by UNEP, UN-Habitat and World Bank under the Joint Work Program for Cities and Climate Change. Accessed Jan. 2014. <http://siteresources.worldbank.org/INTUWM/Resources/340232-1303927718626/GHG_ReportingDraftAnnex_1.pdf>.

UN Habitat. (2011) "Hot Cities: Battle-ground for Climate Change." Global Report on Human Settlements 2011: Cities and Climate Change.

UNFCCC. (2013) Kyoto Protocol. *United Nations Framework Convention on Climate Change*. Accessed Dec. 2013. <http://unfccc.int/kyoto_protocol/items/2830.php>.

Union of Concerned Scientists (UCS). (2009) Climate change in the Midwest: Projections of Future Temperature and Precipitation. Written by: K. Hayhoe, J. VanDorn, V. Naik, and D. Wuebbles. Accessed 31 Mar. 2014 <http://www.ucsusa.org/assets/documents/global_warming/midwest-climate-impacts.pdf>.

U.S. Census Bureau (U.S. Census). (2000) "County and City Data Book: 2000, Table C-1." Accessed March 2014. <http://www.census.gov/statab/ccdb/cit1010r.txt>.

U.S. Census. (2014) "2010 Census - State and County Quickfacts." Data derived from Population Estimates, American Community Survey, Census of Population and Housing, County Business Patterns, Economic Census, Survey of Business Owners, Building Permits, Census of Governments." Accessed Feb. 2014. <http://quickfacts.census.gov/qfd/states/30/3050200.html>.

U. S. Department of Transportation (U.S. DOT) (2013). "Federal Highway Administration, Highway Statistics 2011." Washington, DC, 2013. Accessed July 2014. <http://www.fhwa.dot.gov/policyinformation/statistics/2011/index.cfm>.

U.S. EPA (2002). Solid Waste Management: A Local Challenge with Global Impacts. Solid Waste and Emergency Response. EPA530-F-02-026d (5306W). Accessed 15 July 2014. <http://www.epa.gov/epawaste/nonhaz/municipal/pubs/ghg/f02026.pdf>.

U.S. EPA (2005). Durable Goods Calculator Excel-based Tool. Accessed 15 Jan. 2014. <http://www.epa.gov/climatechange/wycd/waste/calculators/DGC_home.html>.

U.S. EPA. (2011) "Emission Factors for Greenhouse Gas Inventories." Created Nov. 2011. Accessed Sept. 2013. <http://www.epa.gov/climateleadership/documents/emission-factors.pdf>.

U.S. EPA. (2012a) "eGRID2012 Version 1.0: Year 2009 Summary Tables." Created April 2012. Accessed Sept. 2013. <http://www.epa.gov/cleanenergy/documents/egridzips/eGRID2012V1_0_year09_SummaryTables.pdf>.

U.S. EPA (2012b) "Using WARM Emission Factors for Materials and Pathways Not in WARM." Accessed 15 Jan. 2014. <http://epa.gov/epawaste/conserve/tools/warm/pdfs/Using_WARM_EFs_Materials_Pathways_111612.pdf>.

U.S. EPA. (2013a) "Midwest Climate Impacts & Adaptation." Accessed Feb. 2014 <http://www.epa.gov/climatechange/impacts-adaptation/midwest.html#ref1>.

U.S. EPA. (2013b) "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 – 2013." Office of Transportation and Air Quality. Accessed July 2013. <http://epa.gov/otaq/fetrends.htm>.

U.S. EPA. (2013c) Developing a Greenhouse Gas Inventory. *U.S. EPA State and Local Climate and Energy Program*. Accessed Dec. 2013 <http://www.epa.gov/statelocalclimate/local/activities/ghg-inventory.html>.

U.S. EPA. (2013d) Local Greenhouse Gas Inventory Tool (LGGIT) for Government Operations User's Guide (Beta-version of Community Protocol and Software and Local Government Operations Protocol and Software). ICF International. March 2013. Accessed July 2013.

U.S. EPA. (2013e) EPA FLIGHT Online. Accessed July 2013. <http://ghgdata.epa.gov/ghgp/main.do>.

U.S. EPA. (2013f) "EPA FLIGHT: 'Who Reports?'" Accessed June 2013. <http://www.ccdsupport.com/confluence/pages/viewpage.action?pageId=93290546>.

U.S. EPA. (2013g) "Heat Island Effect: Trees and Vegetation." 29 Aug. 2013. Accessed 15 April 2014. <http://www.epa.gov/heatisland/mitigation/trees.htm>.

U.S. EPA. (2013h) "WARM Frequently Asked Questions: What components make up the emissions factors associated with each process?" 19 April 2013. Accessed 15 Aug. 2014. <http://epa.gov/epawaste/conserve/tools/warm/WARM_faq.html#j>.

U.S. EPA. (2014a). EPA Greenhouse Gas Equivalencies Calculator. Accessed Feb. 2014. <http://www.epa.gov/cleanenergy/energy-resources/calculator.html>.

U.S. EPA. (2014b) DRAFT Inventory of U.S. Greenhouse Gas Emissions and Sinks: 1990 – 2012. February 21, 2014. Accessed March 2014. <http://www.epa.gov/climatechange/Downloads/ghgemissions/US-GHG-Inventory-2014-Main-Text.pdf>.

U.S. EPA. (2014c) "MOVES (Motor Vehicle Emission Simulator)." Accessed July 2013. <http://www.epa.gov/otaq/models/moves/>.

U.S. EPA (2014d) "Solid Waste Management and Greenhouse Gases." Waste and Resource Conservation. <http://epa.gov/epawaste/conserve/tools/warm/SWMGHGreport.html>.

U.S. EPA. (2014de) "List of Municipal Solid Waste Characterization Studies" Accessed 15 Jan. 2014. <http://www.epa.gov/epawaste/conserve/tools/recmeas/msw_st_rpt.htm>.

U.S. Global Change Research Program (2009). "Regional Climate Impacts: Midwest." Accessed March 2014. <http://downloads.globalchange.gov/usimpacts/pdfs/midwest.pdf>.

U.S. Global Change Research Program (2013). "Draft: Chapter 18: Midwest." Draft National Climate Assessment Report. Accessed March 2014. <http://ncadac.globalchange.gov/download/NCAJan11-2013-publicreviewdraft-chap18-midwest.pdf>.

U.S. Mayors. (2013) U.S. Conference of Mayors Climate Protection Agreement. Accessed Dec. 2013. <http://usmayors.org/climateprotection/agreement.htm>.

U.S. National Academy of Sciences and Royal Society. (2014) “Climate Change Evidence & Causes.” Accessed March 2014. <http://dels.nas.edu/resources/static-assets/exec-office-other/climate-change-full.pdf>.

VandeWeghe, J. and C. Kennedy. (2007) “A Spatial Analysis of Residential Greenhouse Gas Emissions in the Toronto Census Metropolitan Area.” Journal of Industrial Ecology, Vol. 11 No.2. MIT Press. 2007. Pp 133-144.

Water Environment Federation. (2009) “Protocols for Estimating Greenhouse Gas Emissions from Municipal Wastewater Sources.” Technical Practice Update. Accessed Nov. 2013. <http://www.wef.org>.

Wayne County. (2013) City of Detroit Solid Waste Stream Reports. Collected by team through FOIA Request Process, Fall 2013.

World Resources Institute (WRI) and the World Business Council for Sustainable Development (WBCSD). (2012) “Greenhouse Gas Protocol.” Accessed Aug. 2014 <http://www.ghgprotocol.org>.

Wheeler, S. (2008) “State and Municipal Climate Change Plans: The First Generation.” *Journal of the American Planning Association.* 74(4): 481-496. DOI 10.1080/01944360802377973.

School of Natural Resources and Environment
University of Michigan
440 Church Street
Ann Arbor, MI 48109-1041
www.snre.umich.edu

Detroiters Working for Environmental Justice
4750 Woodward Avenue,Suite 415
Detroit, MI 48201-1300
www.dwej.org

Center for Sustainable Systems
School of Natural Resources and Environment
University of Michigan
3012 Dana Building
440 Church Street
Ann Arbor, MI 48109-1041
css.snre.umich.edu

Detroit Climate Action Collaborative
a project of Detroiters Working
for Environmental Justice

cover photo by Andrew Langdal

CENTER FOR SUSTAINABLE SYSTEMS
UNIVERSITY OF MICHIGAN

School of Natural Resources & Environment, 440 Church Street, 3012 Dana Building, Ann Arbor, MI 48109-1041
734-764-1412 | css.snre.umich.edu