City of Detroit Greenhouse Gas Inventory:

An Analysis of Citywide and Municipal Emissions for 2011 and 2012

Preliminary Report

April 2014

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

Faculty Advisors:
Professor Gregory Keoleian
Professor Rosina Bierbaum
Robb De Kleine

An opus submitted in partial fulfillment of the requirements for the degree of Master of Science in Natural Resources and Environment at the University of Michigan

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Preface

This report, at the time of submission and release to the University of Michigan School of Natural Resources and Environment in April 2014, presents preliminary analyses, findings, and narrative that will continue to be internally verified and presented to our project client, the Detroiters Working for Environmental Justice, as well as the Detroit Climate Action Collaborative and the City of Detroit, for their review and feedback. After this review process, a final report will be publically released by the University of Michigan's Center for Sustainable Systems.

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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 Interdisciplinary Award for Sustainability, and the Erb Institute for Global Sustainable Enterprise at the University of Michigan.

Graphics Credits

The activity category icons, Figure 7, and Figure 8 were developed by Mason Phillips. All other graphics and the report design were developed by the project team, led by Jill Carlson.

Abstract

This study develops the first comprehensive greenhouse gas (GHG) inventory that quantifies both citywide and municipal GHG emissions for the City of Detroit. The inventory provides a baseline from which to set GHG emissions reduction targets and from which to measure the effects of climate actions or new policy. This work complements efforts of the Detroit Climate Action Collaborative (DCAC) to develop local strategies that address climate change, informing the ongoing development of a formal Detroit Climate Action Plan.

The Detroit GHG inventory accounts for emissions generated from energy use from buildings and facilities and transportation, industrial processes, solid waste, and wastewater treatment. Emissions sequestered by land use (specifically by Detroit's trees) are estimated but not included in the total emissions calculations. In addition, emissions associated with activities under the operational control of the municipal government are analyzed in the Municipal Government Inventory section of the report.

Using activity data collected from calendar years 2011 and 2012, the inventory accounts for citywide totals of 10.5 million metric tons (million t) of carbon dioxide equivalents (CO_2e) emitted in 2011 and 10.6 million t CO_2e emitted in 2012. The largest emitting activity citywide is energy use from buildings and facilities (both electricity and natural gas), which accounts for more than 60% of total citywide emissions in both analysis years. The Municipal Government Inventory finds city operations emitted approximately 1.1 million t CO_2e in both 2011 and 2012. As a percentage of citywide, municipal emissions make up approximately 10.5% of the citywide total in 2011 and approximately 10.6% in 2012.

This project recommends that the City of Detroit regularly conduct inventories, and the final section of the report outlines suggestions for how to improve this analysis to further aid in decision-making.

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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, under a higher emissions scenario, summers in the Midwest may be more like the current summers in Oklahoma or northern Texas.[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 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 an example of one such action that aims to provide information that better enables 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 emissions of carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_20) from the following: buildings and facilities energy use; public transportation; municipal vehicle fleets; passenger car, truck, and on-road freight; 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 in this analysis but reported separately (i.e., not included in total citywide emissions).

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

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[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)

Key Findings

Results from 2011 and 2012 show that citywide emissions were nearly equal, with 10.5 million metric tons (million t) of carbon dioxide equivalents (CO_2e) emitted in 2011 and 10.6 million t CO_2e emitted in 2012 (as illustrated in Figure 1). Because these values (and their proportional composition) were nearly identical across the two analysis years, most of the analyses in the report present only 2012 emissions for simplicity. However, complete 2011 results and figures are included as appendices to the report.

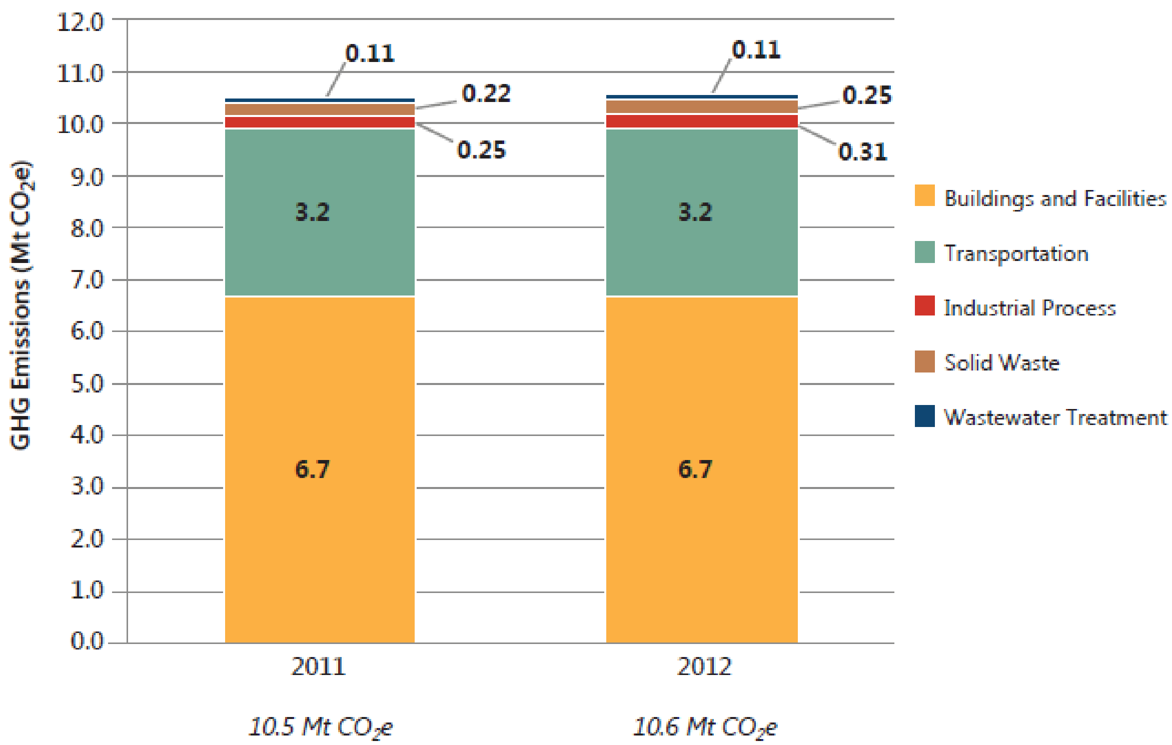

Figure 1: Detroit Citywide GHG Emissions by Activity (million t CO2e)

In 2012, 63% of Detroit's citywide emissions (6.7 million t CO_2e) were a result of electricity and natural gas use in Detroit's buildings and facilities (Figure 1). Electricity use in the city contributed 46% to 2012 citywide emissions, due in part to DTE Energy's fuel mix, which consists of more than 75% coal.[4]

Detroit's per capita emissions (15.1 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 2.

[4] DTE Energy. (2014)

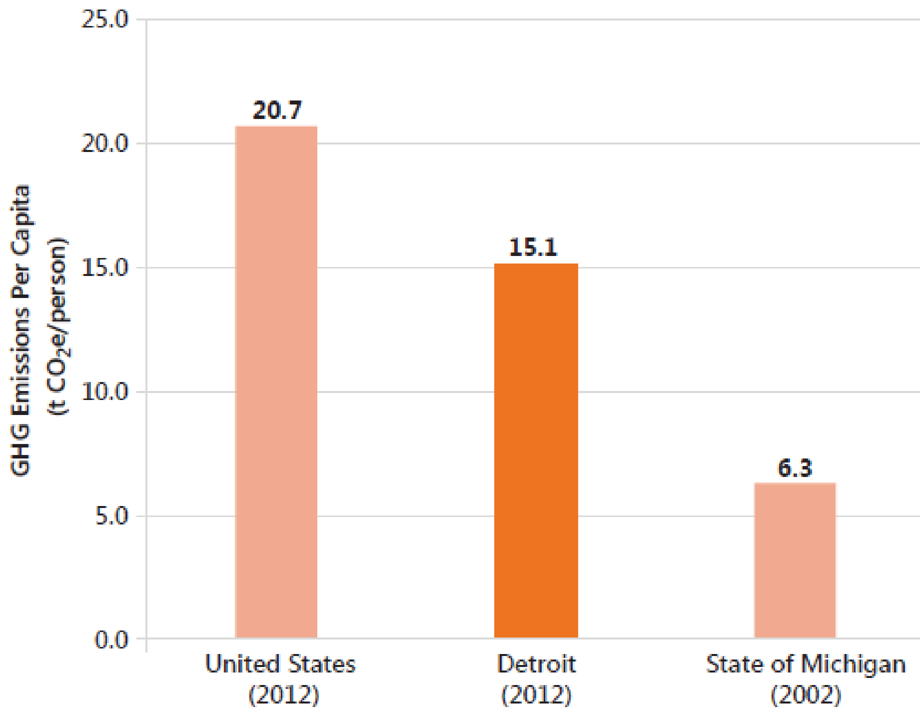

Figure 2: U.S., Detroit, and State of Michigan per Capita Emissions Comparison (t CO2e)

Detroit's per capita emissions are lower than the national average, as expected because national inventory accounting standards tend to be more comprehensive in the activities and emission sources included than local GHG inventories. The per capita emissions in Detroit are also higher than those reported by the State of Michigan, likely because Detroit, as a more urbanized area, has relatively higher and more concentrated amounts of commercial and industry activity, as well as greater energy demand than many other areas of the state have.

In a comparison of fourteen select North American cities, Detroit's total 2012 citywide emissions fell below the sample's average, as illustrated in Figure 3. It is important to keep in mind that the cities selected for this comparison have conducted inventories for a range of years, using 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.

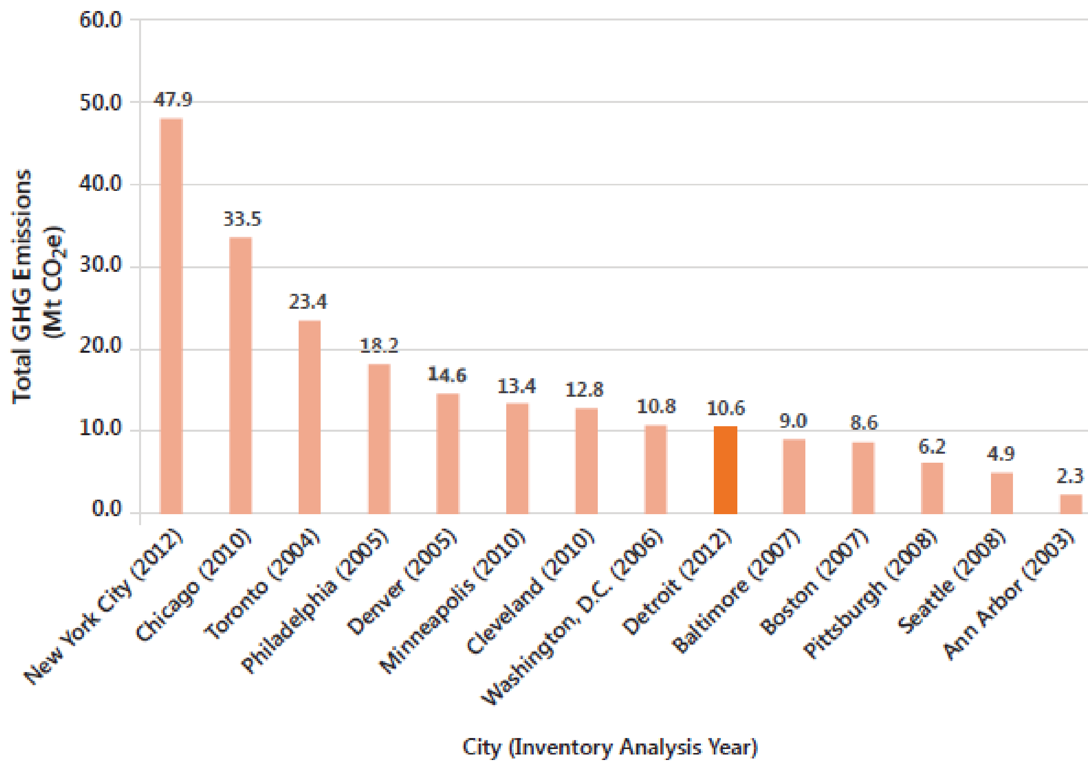

Figure 3: Comparison of Citywide Emissions from Select North American Cities (million t CO_2e)

Other Citywide Key Findings

- Approximately 40% of emissions from stationary sources, such as buildings and facilities, occurred in four of Detroit's thirty Zip Codes (these high-emitting Zip Codes are 48217, 48209, 48226, 48211);
- 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, including public transportation vehicles, contributed only 2% of citywide transportation emissions.

Municipal Inventory Key Findings

- City of Detroit's municipal government operations accounted for 11% (1.1 million t CO_2e) of 2012 emissions, as shown in Figure 4.

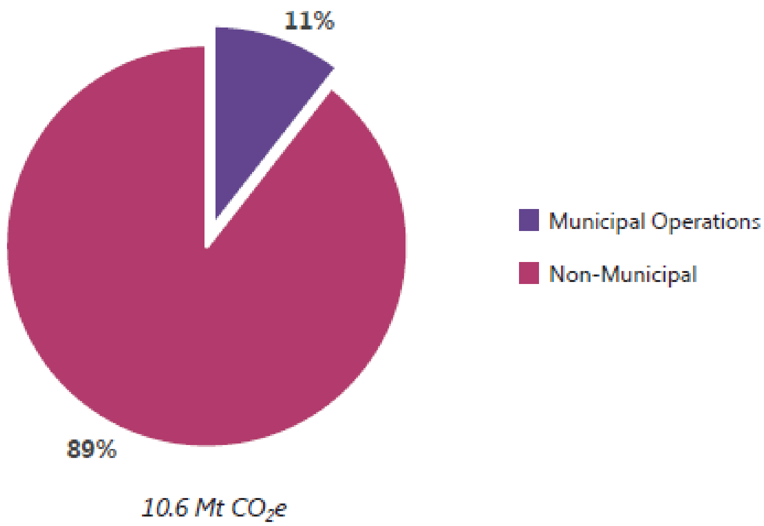

Figure 4: Detroit Municipal Operations GHG Emissions as a Percentage of Citywide, 2012

- In 2012, four City of Detroit departments (Detroit Public Lighting Department, Detroit Water and Sewerage Department, Detroit Department of Public Works, and Greater Detroit Resource Recovery Authority) were responsible for 92% of City of Detroit's municipal emissions.

Conclusions and Next Steps

Detroit is at the early stage of developing a strategy to address climate change and incorporate climate change mitigation and adaption into long-term planning decisions. Adaptation and mitigation choices in the near-term will affect the risks that climate change imposes locally throughout the coming century. This report of the City of Detroit GHG inventory identifies key activities and sectors at both citywide and municipal operations scales, which 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 and supports the development of both implementation strategies, as well as a system to conduct future inventories and benchmark progress over time. Improving the inventory process, conducting regular inventories, and incorporating these inventory results into decision-making are critical for evaluating progress toward emissions reductions targets and for identifying cost-savings opportunities.

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 fifty organizations in and around the city. In the coming months, the team will continue to engage with the Detroit community and DCAC, internally verify GHG inventory results presented in this preliminary report, and begin to share results more broadly through publically available materials, presentations, and stakeholder meetings. In addition, an "inventory procedure manual" will be developed to assist in the development of future Detroit GHG inventories. These immediate next steps will lead to more durable outcomes and strengthen the impact of this work moving forward.

2012 CITY OF DETROIT CITYWIDE GHG INVENTORY: BY THE NUMBERS

10.6 million tons CO2e: 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

1.12 million tons CO2e: 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 Mississippi and Arkansas.[5]

The City of Detroit is home to just over 700,000 residents,[6] has a growing number of corporate headquarters and small businesses, and has a vibrant community of citizens 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 other 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) aims to increase Detroit's climate change preparedness and find cost-effective ways to reduce Detroit's GHG emissions.[7]

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[5] U.S. EPA (2013a). For additional 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).

[6] Estimated 2012 population, U.S. Census (2014)

[7] 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)[8] partnered with DWEJ and DCAC to develop the first comprehensive inventory of Detroit's GHG emissions, the results of which are included in this preliminary 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.[9] GHG 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.[10] 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.[11]

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."[12] More than 170 local governments have joined the "Cities for Climate Protection Campaign" through ICLEI Local Governments for Sustainability (ICLEI),[13] conducting GHG inventories or undertaking climate action planning efforts.[14] 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

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[8] 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.
[9] U.S. EPA (2013b)
[10] Lutsey and Sperling (2008)
[11] Bull et al. (2002), Edison et al. (2007), and MDEQ (2009)
[12] Hoornweg et al. (2011)
[13] 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.
[14] Wheeler (2008), pp. 481

below 1990 baseline levels, in accordance with Kyoto Protocol[15] targets.[16] 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.

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, or 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).[17]

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 earth's atmosphere, which in turn warms the earth's surface and regulates global temperatures.[18] This phenomenon is illustrated in Figure 5.

[15] 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).
[16] U.S. Mayors (2013)
[17] IPCC (2013)
[18] CSS (2013a)

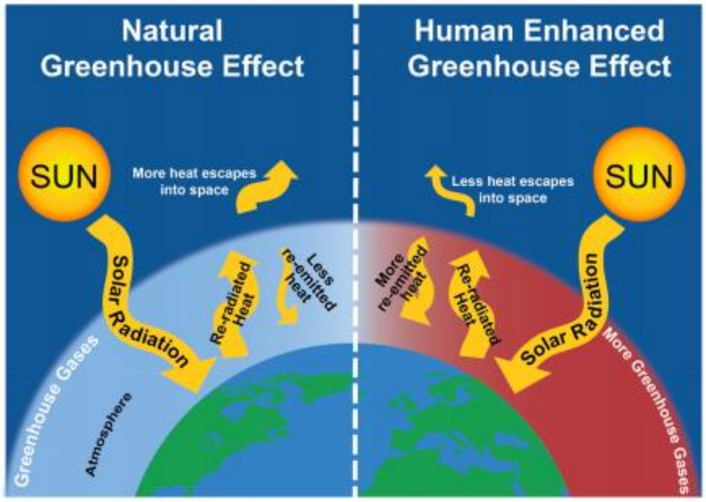

Figure 5: Illustration of the Greenhouse Effect[19]

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 then 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 concentration of GHGs in the atmosphere recently 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.[20] 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.[21]

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.[22]

Never before in human history has the earth's system undergone such a rapid change in atmospheric concentrations of GHGs.[23] The resulting changes in climate, at both global and local scales, are straining the capacity of ecosystems and human societies to adapt.

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[19] CSS (2013a)

[20] National Research Council (NRC) (2012), p. 7; U.S. National Academy of Sciences (NAS) (2014), p. 10

[21] NAS (2014), pp. 3

[22] IPCC (2013)

[23] 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).

Climate Vulnerability in Detroit

The City of Detroit and the greater Southeastern Michigan region are already experiencing climate change, and the science points to the impacts of climate change increasing over time.[24] 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.[25]

The Natural Resources Defense Council (NRDC) predicts that the average excessive heat event[26] days per summer (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 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.[27] 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 which have poor cooling capacity further exacerbates climate change vulnerability in the built, urbanized environment of Detroit.[28]

As part of the DCAC planning process, Detroit-specific climate and vulnerability analyses have been undertaken. The Great Lakes Integrated Sciences and Assessments Center (GLISA) has published reports on the climate impacts that the city will likely face using down-sized climate models, which outline expected increases in precipitation and extreme heat events.[29] 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 has begun to experience and will continue to face as a result of climate change.[30]

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.

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[24] Walsh and Wuebbles (2013)
[25] U.S. EPA (2013a)
[26] 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.
[27] NRDC (2012)
[28] Larsen et al. (2011)
[29] GLISA (2013)
[30] Gregg et al. (2013)

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.

GHG Emissions Mitigation, Efficiency Improvements, and Cost Savings

While the threat of climate change is formidable, there are many actions that Detroit and its residents can take to simultaneously limit the growth of GHG emissions and 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, 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 emissions and to account for the quantity of 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.

There are many examples of energy efficiency-related programs already underway in collaboration with the City of Detroit that are already having an impact on emissions reductions and 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[31] and set the stage for the city's involvement with the Carbon Disclosure Project (CDP), 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.

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.[32]

Finally, at the broader community 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

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[31] Based on 3% inflation of annual energy and operations savings. These projected savings are estimated to heat and power about 1,680 homes per year for 10 years (City of Detroit 2012).

[32] 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.

for residents to make energy efficient improvements" to their homes.[33] This three-year program ended in June 2013 with energy-saving upgrades in 500 Southeastern Michigan homes resulting in an average saving of $580 per year per home and a reduction of 5000 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 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.

This accounting of GHGs 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, as shown in Figure 6.

Different activities emit different types of GHGs, which each have a different impact on climate change. 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 carbon dioxide, which has a GWP value of 1.

$$\boldsymbol{activity\ data \times emission\ factor \left(\frac{t\ GHG\ emitted}{unit\ activity}\right) \times GWP\ = emissions\ (tCO_2e)}$$

Figure 6: 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 pervasive GHG, and GHG emissions for a period of time are typically reported in the standard unit of metric tons of CO_2 equivalent (t CO_2e).

[33] Southeastern Michigan Regional Energy Office (2013)

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).

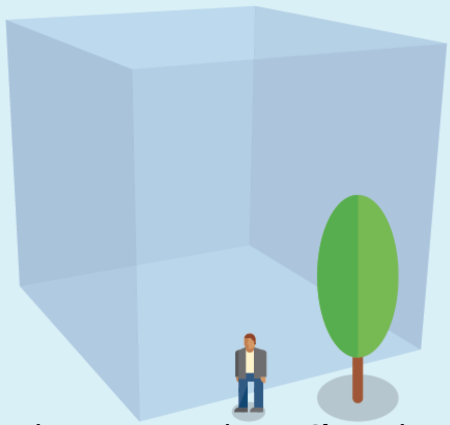

Figure 7: A Metric Ton Shown in Proportion to a Person and a Tree

The cube illustrated here in Figure 7shows 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 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). Approximately, one could drive approximately 2660 miles on 113 gal. of gas (U.S. EPA 2014a). The driving distance from Ann Arbor to Detroit is approximately 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 quantify 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 activity data.

Standard protocols recommend that local GHG inventories account for emissions of these 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 occurring in-boundary.[34] The alternative to production-based inventories is a consumption-based approach, which accounts for

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

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 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.[35] 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 industry standard and recommended by 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.

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)

By convention, GHG inventories report in-boundary sources and activities associated with both direct emissions (Scope 1) and indirect (Scope 2 and Scope 3) emissions from the organization or community. See Figure 8 for a visual representation of emission scopes for the Detroit GHG inventory.

[35] *Ibid.*

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 is found in subsequent sections of this report.

City of Detroit GHG Inventory

Inventory Objectives

The Detroit GHG inventory aims to serve the following benchmarking objectives:

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;
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.

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 8: What Is Included in the Detroit GHG Inventory?

Overview of Detroit Inventory Analyses

This report contains the results of two distinct analyses:

1) A **citywide** inventory of GHG emissions associated with or driven by activities[36] within in the geographic, jurisdictional boundary of the City of Detroit;
2) A **municipal** inventory of GHG emissions associated with municipal government operations of the City of Detroit. The municipal inventory is a subset of the larger, citywide total, as illustrated in Figure 9.

Figure 9: 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 years were not available because of difficulty in retrieving certain records due to data archiving systems during the project's period of data collection.

The broad categories of emissions activities accounted for in the Detroit citywide inventory are outlined in Figure 10. This conceptual map also illustrates the complexity associated with delineating an 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

[36] 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 residential waste produced in the city but disposed of at landfills outside the city. Additional discussion of this complexity follows and is illustrated in Figure 10.

citywide emissions are driven by activities occurring outside 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.

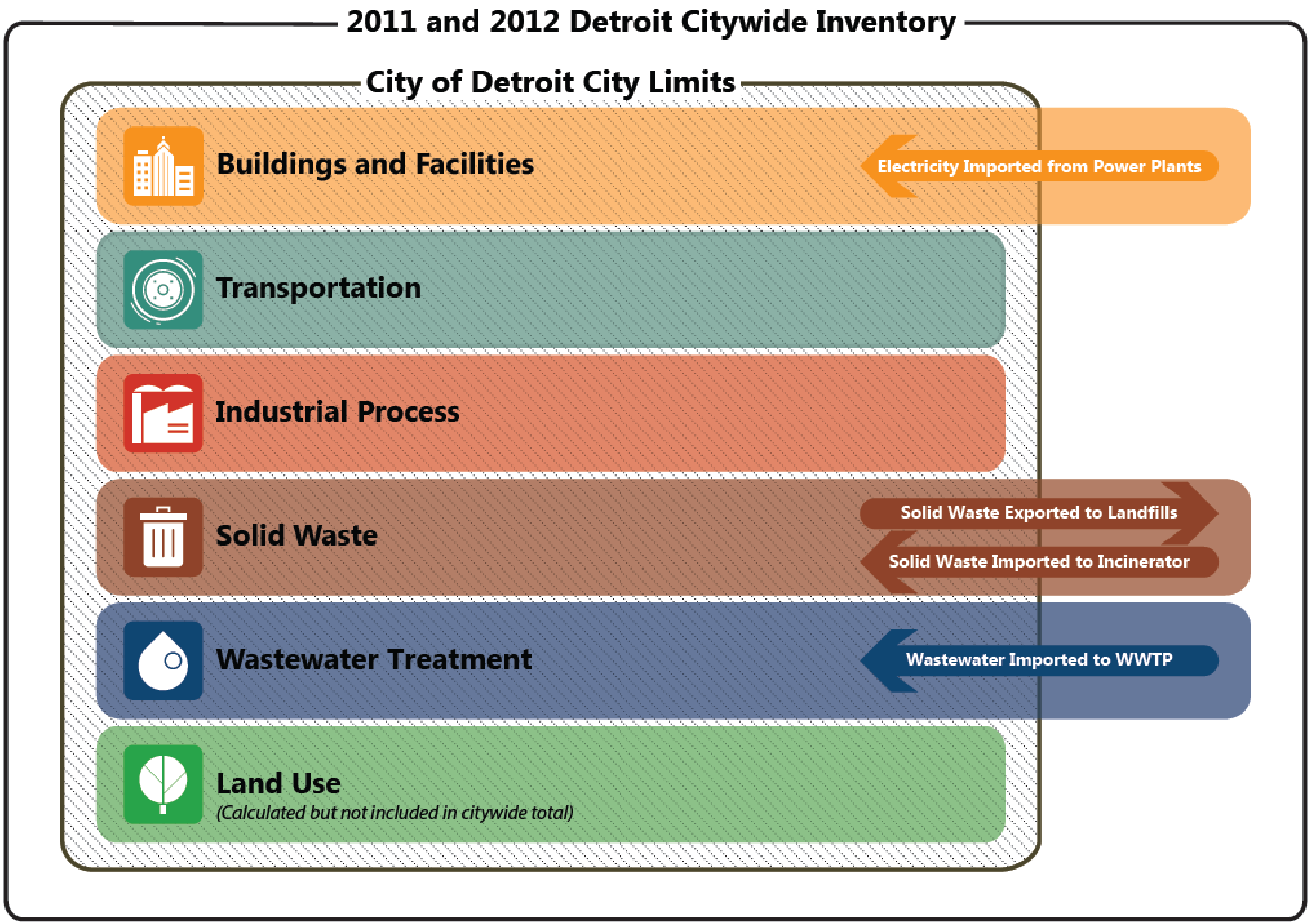

Figure 10: Detroit GHG Inventory System Boundary

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[37]

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; No sources of biogenic CO_2 are included in this inventory

[37] 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 are not included in this inventory.

The GWP values used for these gases are those recommended by ICLEI Protocol (2012); they are summarized in Table 2.

Table 2: Global Warming Potentials of Detroit Inventory GHGs[38]

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,[39] 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[40]). Also, high GWPs 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.[41]

In short, the inventory methods, which determined what is or is not included and which were used 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.

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[38] 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).

[39] 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.

[40] 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.

[41] 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 conducted throughout 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:

Buildings and Facilities
Residential, Commercial, Industrial, and Municipal Energy Use

Transportation
Community and Municipal Transportation

Industrial Process
Non-energy Use Processes such as Hydrogen Production and Petroleum Refining

Solid Waste
Municipally-operated Residential Solid Waste Disposal, Waste Incineration

Wastewater Treatment
Municipally-operated Non-energy Use, Wastewater Treatment Processes

Land Use
Tree Cover Canopy CO_2 Sequestration

Emissions sequestered from land use are not included 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.[42]

The emissions from boats, airplanes, marine and railroad freight and inter-city passenger trains, as well as agriculture and fertilizer applications within the city are 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 vs. mobile 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 increased from 10.5 million tons CO_2e in 2011 to 10.6 million tons CO_2e in 2012 (Figure 11), an increase of 0.64%. 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 Appendix F.

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 31% to the total.

[42] 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.

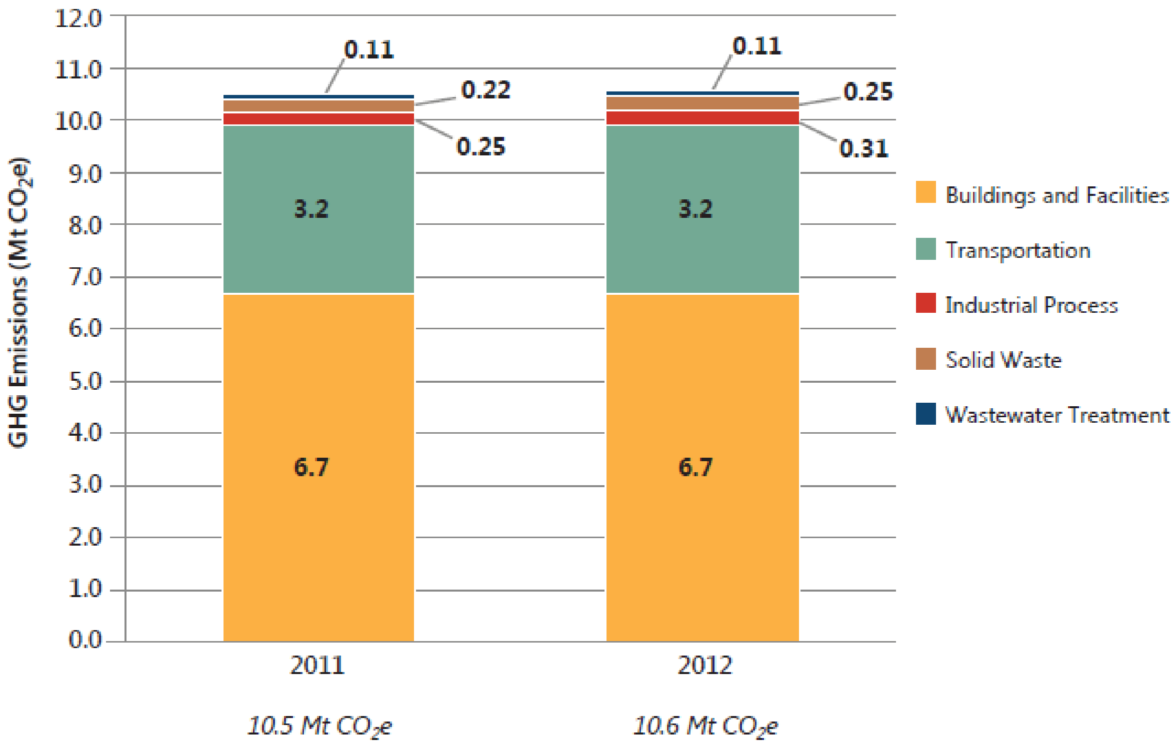

Figure 11: Detroit Citywide GHG Emissions by Activity (million t CO_2e)

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*	**10.5**	**100%**	**10.6**	**100%**

*Note that % of Total may not add to 100% 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.

The consumption of energy, whether in the form of electricity or fuel, drives the 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 6% to Detroit's 2012 citywide emissions.

As shown in Figure 12, electricity is the predominant carrier[43] of GHG emissions in both 2011 and 2012, contributing 43% and 46% of citywide emissions respectively. 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.[44]

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

[44] Steam used for heating and cooling of buildings is generated at the energy to waste 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.

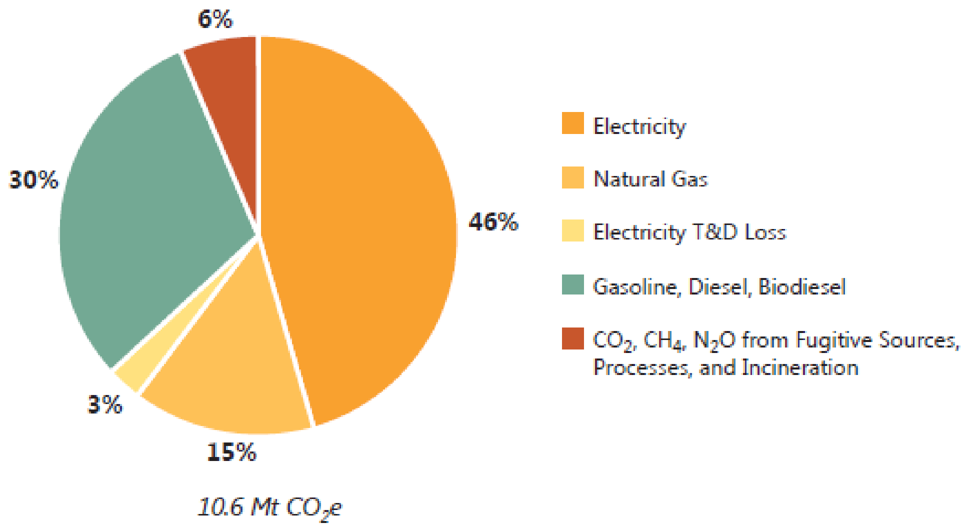

Figure 12: Detroit Citywide GHG Emissions by Carrier, 2012

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 13, DTE Energy's fuel mix in 2012 predominantly consists of coal (76%). Other electricity is generated from nuclear power, natural gas, hydroelectric plants, and renewable energy sources.

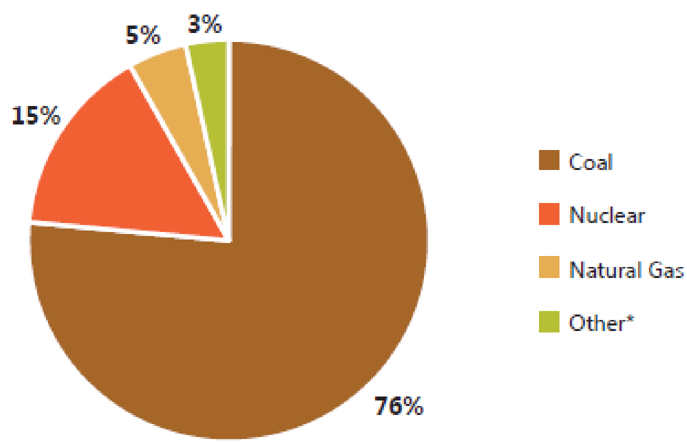

Figure 13: DTE Energy Electricity Generation Fuel Mix, 2012

**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.[45]

Table 4: CO_2 Produced from Fossil Fuel Generated Electricity[46]

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

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

[46] 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).

source emissions by Zip Code, allowing for spatial analysis of how these emissions vary across the city as a whole. As shown in Figure 14, approximately 70% of total citywide emissions are stationary (i.e., they occur at a fixed, immobile location such as a home, industrial plant, or office space). These stationary emissions are generated from energy use from buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment.

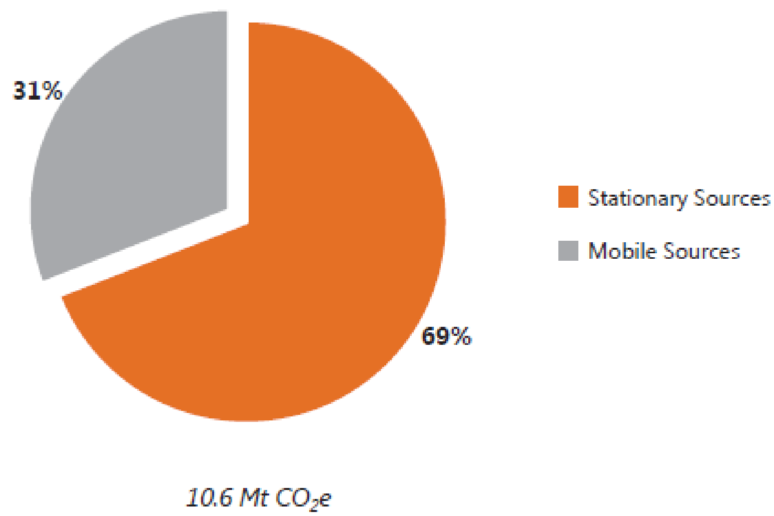

Figure 14: Detroit Citywide Stationary GHG Emissions vs. Mobile GHG Emissions, 2012

Of the 70% of citywide emissions from stationary sources (Figure 14), approximately 40% of these emissions occurred in only four Zip Codes (48217, 48209, 48226, and 48211) of the 30 Zip Codes of Detroit, as shown by the map in Figure 15. In other words, stationary sources of emissions in four Zip Codes account for 28% of Detroit's 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 emissions hot spots from mobile sources within the city.

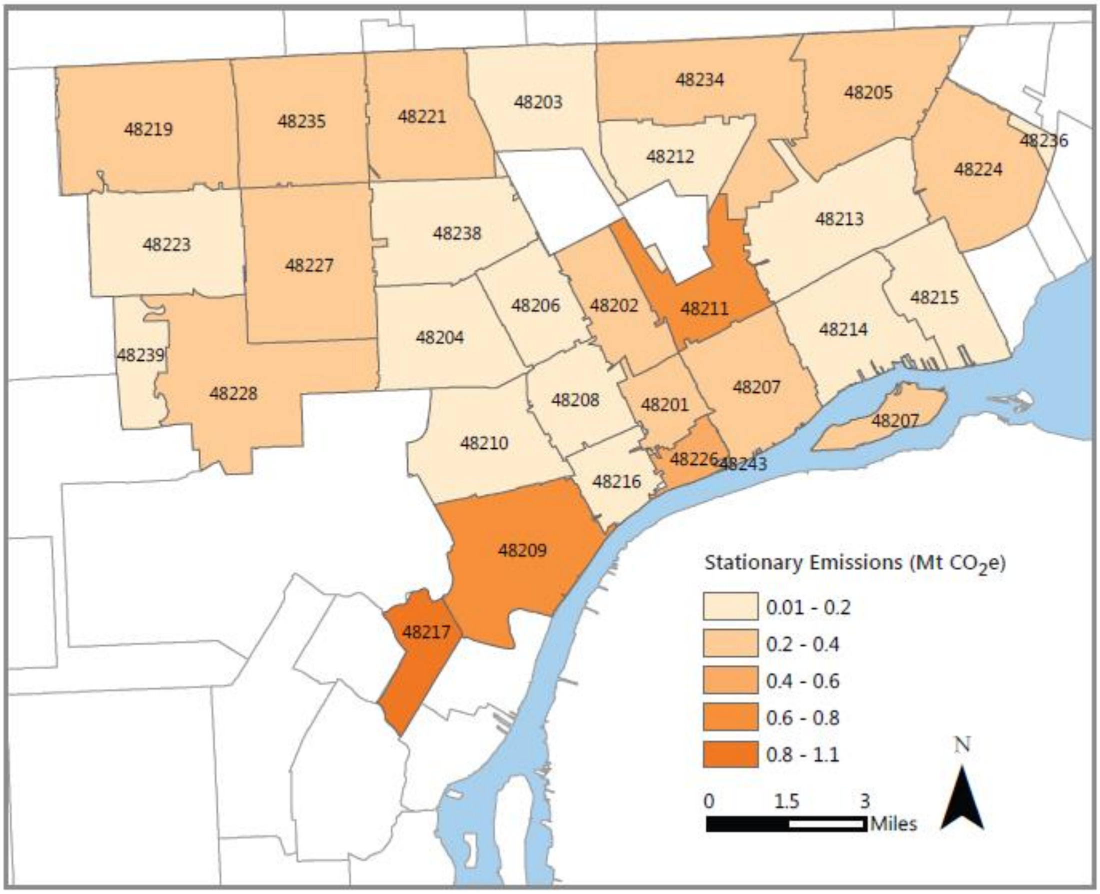

Figure 15: Detroit Citywide Stationary GHG Emissions by Zip Code, 2012

Stationary sources include energy use in buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment.

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 2012) can be found in Appendix G (Figure 33).

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, industrial, and institutional 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. DTE Energy, the utility that serves Detroit, 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[47] 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 Standard Industry Classification (SIC) codes[48] or other identifiers (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 16, 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 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.

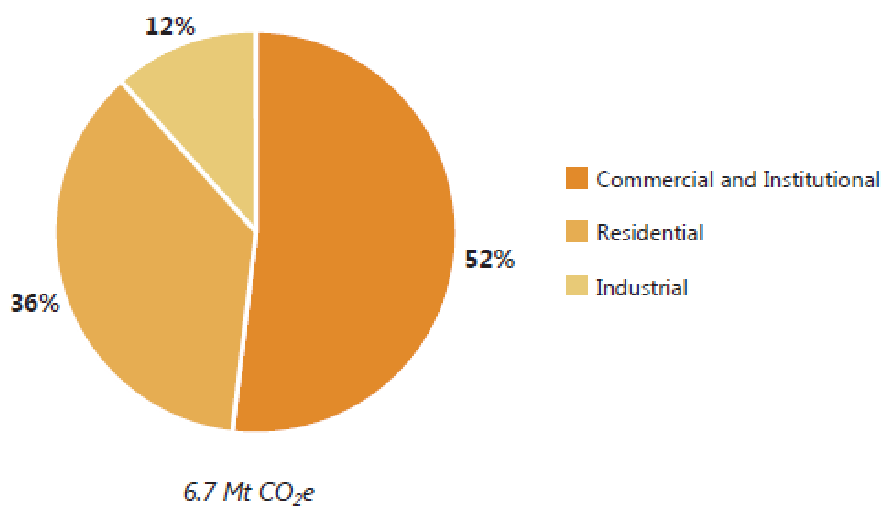

Figure 16: Detroit Citywide Buildings and Facilities GHG Emissions by End-Use Sector, 2012

[47] 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.

[48] 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.

GHG Inventory in Action: Chicago

Chicago Green Business Challenge

The City of Chicago is reaching its climate action plan goals through the 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 its climate action goals and are recognized annually at an awards ceremony with the mayor.[viii]

viii. ICLEI (2014b)

Transportation

Methods

GHG emissions from transportation are associated with the operation of passenger cars, passenger and freight trucks, public transportation (i.e., from city buses, the Detroit Transit Corporation's People Mover,[49] Suburban Mobility Authority for Regional Transportation or SMART Bus), and the city-operated municipal vehicle fleet.

Emissions from the combustion of gasoline and diesel fuel 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.[50] Emission rates were calculated via 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.

Emissions from 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

[49] Emissions from the People Mover are derived from the amount of electricity used to operate it.
[50] 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.

calculated using municipal government fuel use or purchase data.[51] 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 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 to allocate emissions associated with bus trips that occur within the Detroit city limits.

Results

As shown in Figure 17, 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) as well as the municipal vehicle fleet that provide various city services.

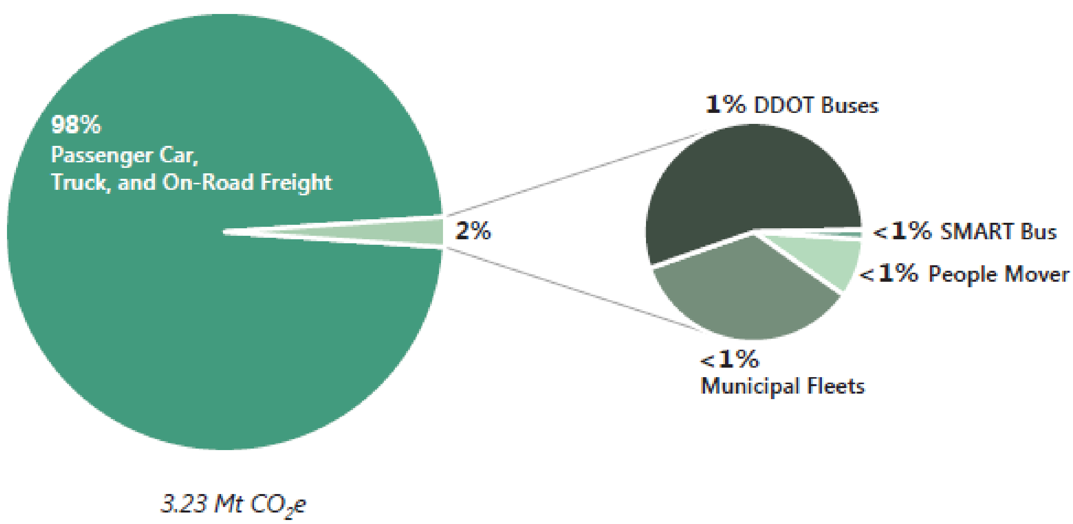

Figure 17: Detroit Citywide Transportation GHG Emissions by Source, 2012

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

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—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. 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[52] 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 residential solid waste that was generated in Detroit, and incineration emissions from all solid waste processed by the energy from waste facility (incinerator) in Detroit.

In the inventory analysis years of 2011 and 2012, landfilled residential waste was collected by the Detroit Department of Public Works and transported to landfills in Canton, Michigan and New Boston, Michigan. 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), which is a tool that estimates current and future emissions associated with each unit of disposed solid waste. Emissions associated with the transport of this landfilled waste by the City of Detroit Department of Public Works are

[52] These Industrial Process emission absolute values as well as 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.

assumed to be captured in the preceding citywide transportation analysis which should avoid double counting those transportation-related emissions in the citywide totals.

Detroit's residential solid waste is only one component of the city's total solid waste stream. Due to data availability, this inventory does not include the landfill disposal of commercial or construction and demolition waste. Therefore, this inventory shows a portion of Detroit's total solid waste emissions from landfill disposal and, as a result, underestimates the contribution of solid waste activities in the citywide analysis.

Solid waste incineration emissions that occur within the Detroit city limits result from the incineration of solid waste generated in Detroit, as well as from solid waste imported to the city from the greater Southeastern Michigan region and elsewhere. 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 energy from waste 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 more than 0.25 million t CO_2e, or close to 2% of total 2012 citywide emissions (Figure 18).

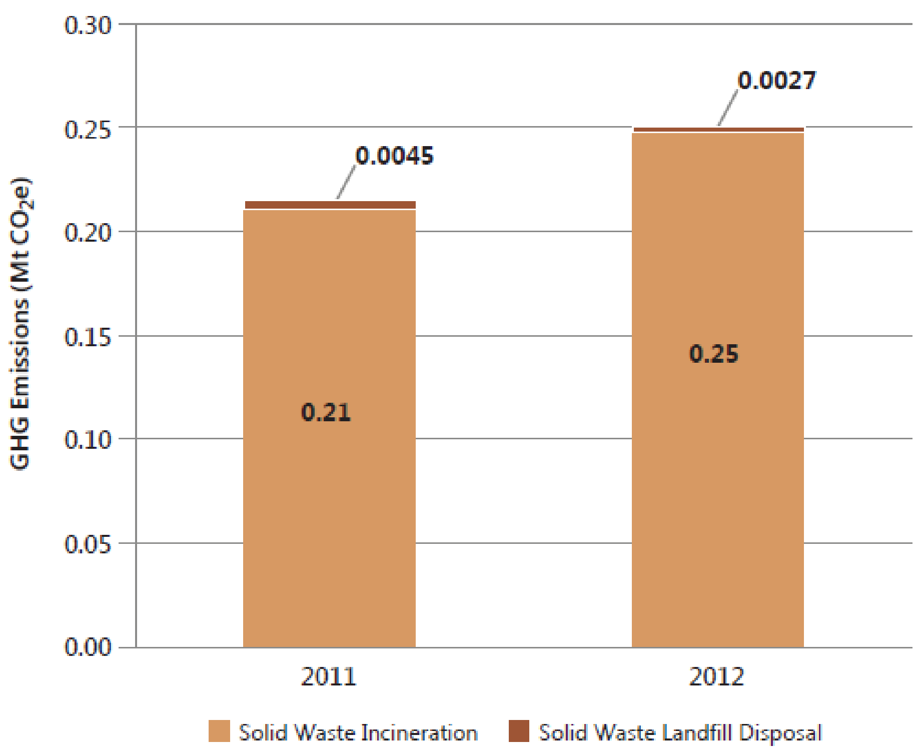

Figure 18: Detroit Citywide GHG Emissions from Solid Waste Incineration and Landfill Disposal

Total solid waste GHG emissions from both incineration and residential landfill disposal is shown in Figure 18. 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 19, the amount of residential solid waste generated in 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 residential solid waste between 2011 and 2012, are unclear. 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.

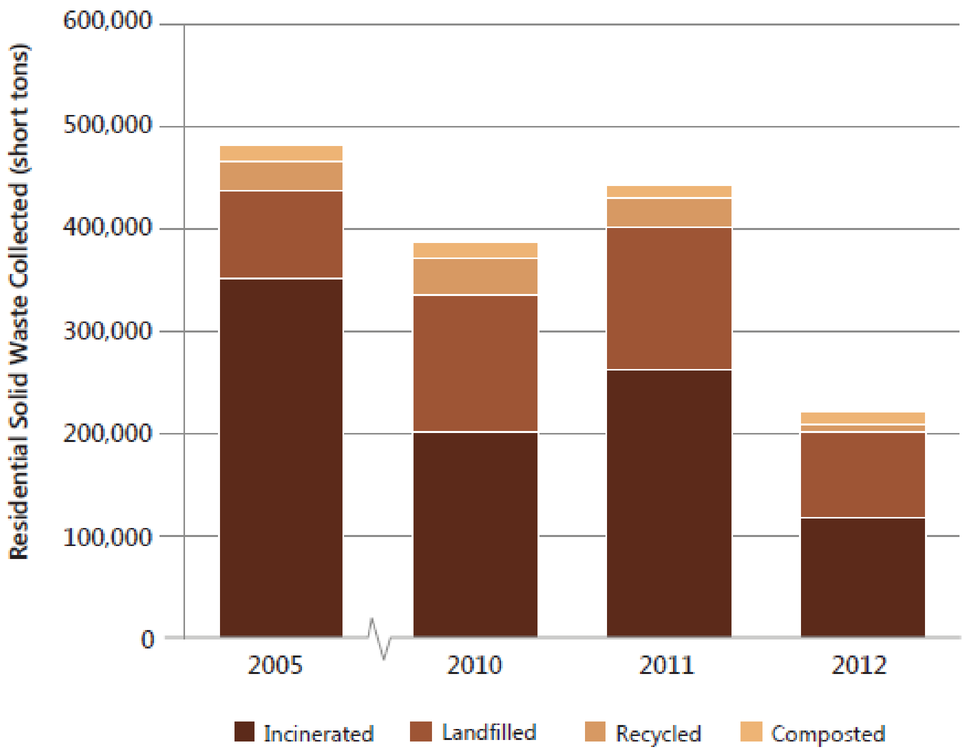

Figure 19: Residential Solid Waste Collected by the City of Detroit Department of Public Works by Weight (short tons)

The cause of decline in solid waste collection between 2011 and 2012 is not readily apparent in the aggregated data report by the City of Detroit to Wayne County. At the time of analysis, the project team was unable to investigate this trend further. The raw solid waste collection data that correspond to this chart are presented in Table 18, in Appendix F.

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 M: "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 incineration emission results 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 at fourteen 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.[53]

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.

Based on the ICLEI Community Protocol, wastewater treatment emissions were modeled using a combination of plant-specific data (i.e., the weight wet of the biosolids incinerated) and a

[53] Fugitive emissions associated with septic systems, 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, and those emissions from biogenic sources of CO_2 in the wastewater treatment process were not included in the citywide inventory.

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,[54] 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.

Results

In 2012, the non-energy related process, fugitive, and incineration emissions from wastewater treatment accounted for about 0.11 million t CO_2e, or 1% 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 20). Based on emission calculations and wastewater treatment assumptions[55] (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[56]—a percentage decrease in the amount of biosolids incinerated of 37.7%, over the seven-year time frame.

[54] 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.
[55] These calculations and assumptions are outlined in greater detail in Appendix E of this report.
[56] DWSD (2014)

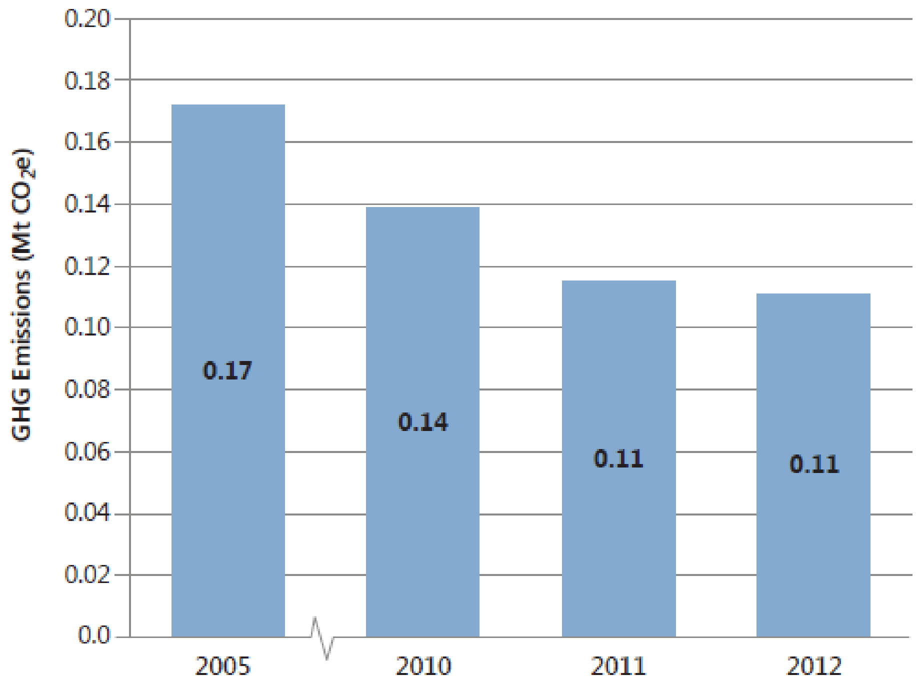

Figure 20: Detroit Citywide Wastewater Treatment GHG Emissions from Fugitive Sources, Processes, and Incineration

As ICLEI protocol and other resources discuss, the modeling of emissions from the wastewater treatment is a complex exercise given differences in size and variations in processes among local WWTPs.[57] For future Detroit GHG inventories, these results for DWSD should continue to be refined based on specific DWSD operations and improvements in wastewater treatment 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 sector's effect 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

[57] ICLEI (2012), Water Environment Federation (2009)

vacant and abandoned parcels.[58] 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 the 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 as well as reducing the energy necessary to cool buildings.[59] 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.[60,61]

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 of and non-permanence of carbon stocks can be a major challenge of using vegetation as a strategy to mitigate GHG emissions.

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

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[58] DFC (2013)

[59] 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).

[60] ICLEI (2006)

[61] McHale et al. (2007)

sequestered by tree canopy[62] in the City of Detroit in 2010, which was the most recent year spatial data suited to this analysis was available. The U.S. Forest Service i-Tree Canopy online model[63] 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[64] 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[65] 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.

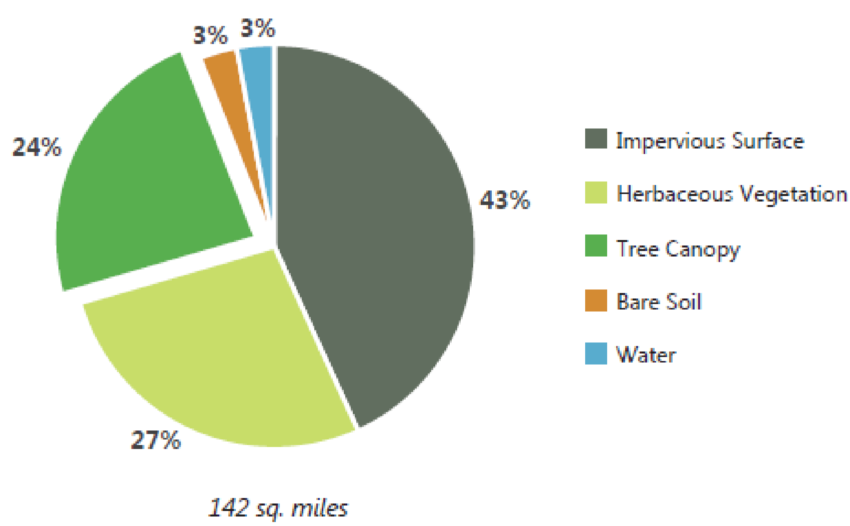

Figure 21: Detroit Citywide Land Cover, 2010

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 21, Detroit is estimated to have roughly 24% tree canopy cover,[66] which is estimated to

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[62] The land use analysis does not currently account for emissions from other land cover classes or the impact of land use change over time.
[63] i-Tree Canopy is a program developed by the U.S. Forest Service to user-identified land cover classes.
[64] Nowak (2013)
[65] 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.
[66] 95% Confidence Interval: 20.9 -26.1%.

sequester 70,400 t CO_2 (0.07 million t CO_2e) annually. This is equivalent to taking approximately 15,000 cars off of the road for one year.[67]

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.[ix]

ix. MillionTreesNYC (2014)

DETROIT MUNICIPAL GOVERNMENT INVENTORY SUMMARY

Methods

Overview

The municipal government inventory analysis accounts for emissions generated from operations managed directly or 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 Detroit 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,[68] the Detroit Transit Corporation (Detroit People Mover), the Greater Detroit Resource Recovery Authority (GDRRA), and Detroit Renewable Power. 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 may be relatively

[67] U.S. EPA (2014a)

[68] 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.

financially independent from the City of Detroit (i.e., they may be enterprise departments with 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. That said, the analyses presented here for 2011 and 2012, however, report emissions results using the structure of the City of Detroit municipal government and departments as it existed during those years.

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.

Municipal Transportation, Solid Waste, and Wastewater Treatment

Methodologies outlined in the Detroit Citywide Inventory methods for the activities of Municipal Transportation, Solid Waste, and Wastewater Treatment are the same in this municipal inventory analysis, 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.

Results

Emissions from Detroit's municipal government operations accounted for 11% of total citywide emissions (1.12 million t CO_2e) in 2012, as shown in Figure 22. 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 (1.12 million t CO2e). A summary and results from the 2011 municipal government operations inventory are presented in Appendices J and K.

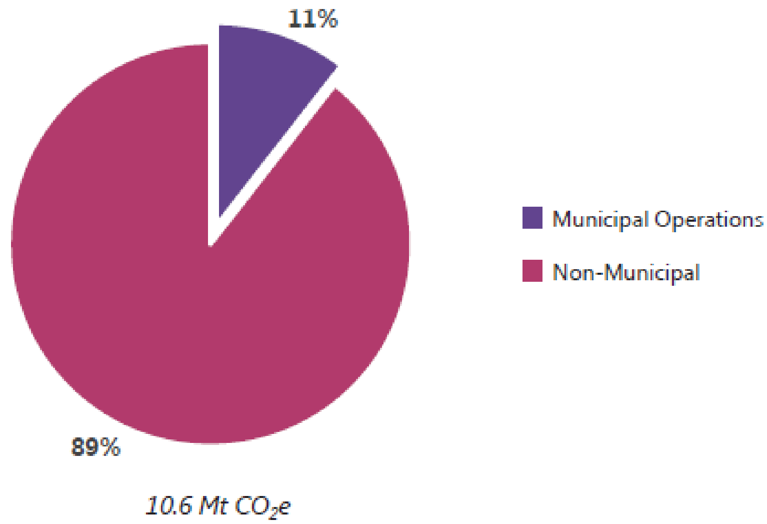

Figure 22: Detroit Municipal Operations GHG Emissions as a Percentage of Citywide, 2012

As shown in Figure 23, municipal buildings and facilities were the largest source of emissions contributing almost 61% 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 23% of emissions. Wastewater treatment emissions contributed approximately 10% to the total municipal inventory.

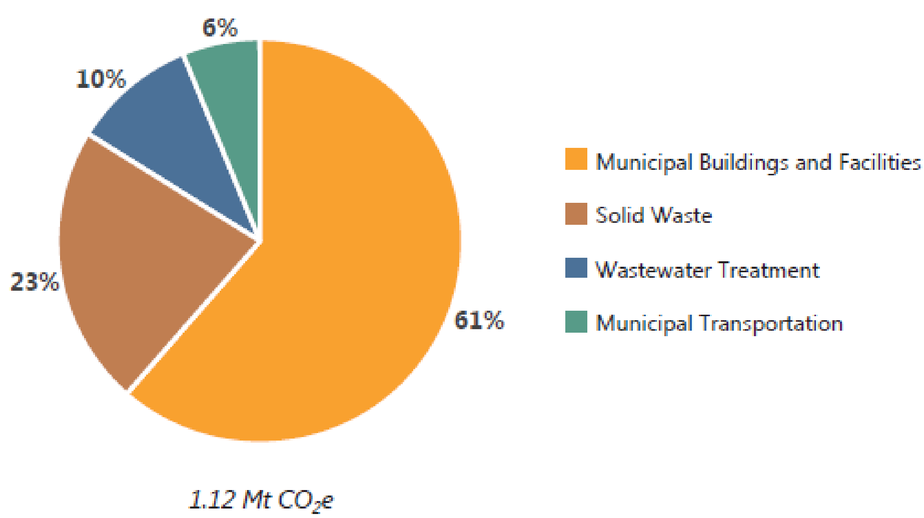

Figure 23: Detroit Municipal Operations GHG Emissions by Activity, 2012

Detroit's infrastructure including GDRRA's solid waste incinerator and DWSD's wastewater treatment plant (WWTP) support people and activities both inside and outside of Detroit. The energy from waste 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.[69] It is important to note that the wastewater treatment emissions presented in Figure 23, include the non-energy related fugitive, process, and incineration[70] 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 waste incinerator 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.

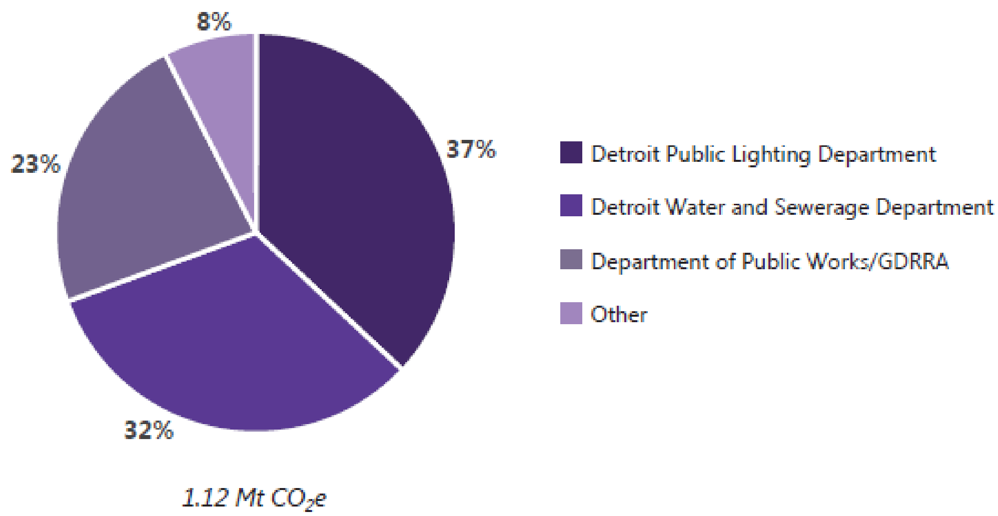

Figure 24: Detroit Municipal Operations GHG Emissions by Department, 2012

The Detroit Public Lighting Department (PLD), DWSD, Detroit Department of Public Works, and the Greater Detroit Resource Recovery Authority (GDRRA) respectively manage the city's streetlights and traffic signals, its water supply and wastewater treatment services, residential solid waste disposal, as well as other essential public utilities and works. As illustrated in Figure 24, these four departments manage operations that contribute approximately 92% of total municipal GHG emissions. The remaining eight percent of municipal operations emissions are

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[69] 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.

[70] The Detroit WWTP currently uses fourteen hearth incinerators to incinerate a portion of dewatered biosolids.

attributable to the remaining City of Detroit Departments, a complete list of which is included in Appendix H.

Although these four municipal departments manage operations and services that contribute approximately 92% 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.

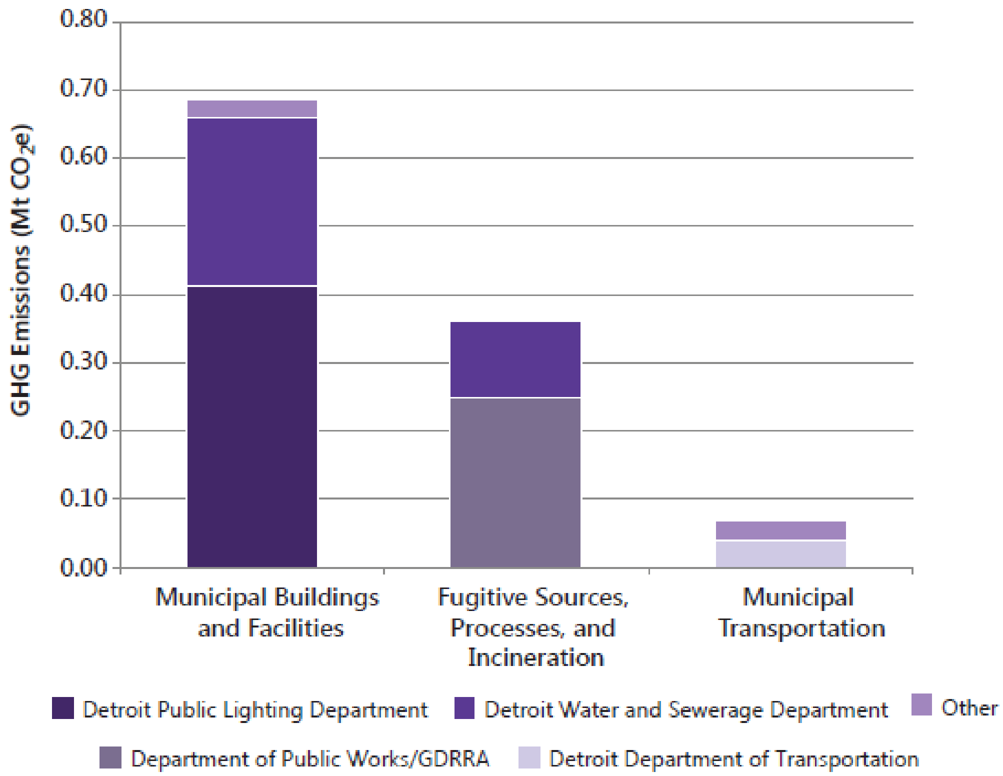

Figure 25: Detroit Municipal Operations GHG Emissions by Activity and Department, 2012

As shown in Figure 25, 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 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 buildings and facilities emissions, which accounts for energy used in both drinking water service and wastewater treatment.[71] 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.[72]

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 25, as well.

During the inventory 2011 and 2012 study years, the City of Detroit government restructured city service management 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 inventories. For example, in 2013 an independent Public Lighting Authority (PLA)[73] 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.[74]

As shown in Figure 26, 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 due to other city services such as public safety or public transportation *could* increase due to other restructuring that aim 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.

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[71] 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.
[72] WEF (2009)
[73] 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).
[74] 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).

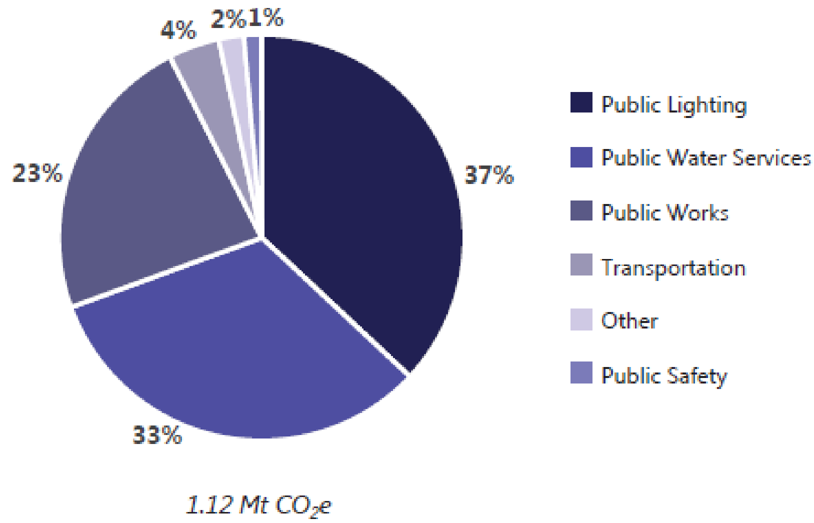

Figure 26: Detroit Municipal Operations GHG Emissions by Service, 2012

The GHG emissions of the municipal inventory subset of the greater citywide inventory should not be examined in isolation; rather it should be examined against the backdrop of 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

During the course of its 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 citywide and per capita emissions. This analysis provides an illustration of where the City of Detroit stands in relation 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[75] and that of the State of Michigan[76] 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 27, the City of Detroit's per capita emissions of 15.1 t CO_2e/person, fall below the latest 2012 national average of 20.7 t CO2e/person, but above that of the State of Michigan per capita emissions 6.3 t CO_2e/person reported in 2002.

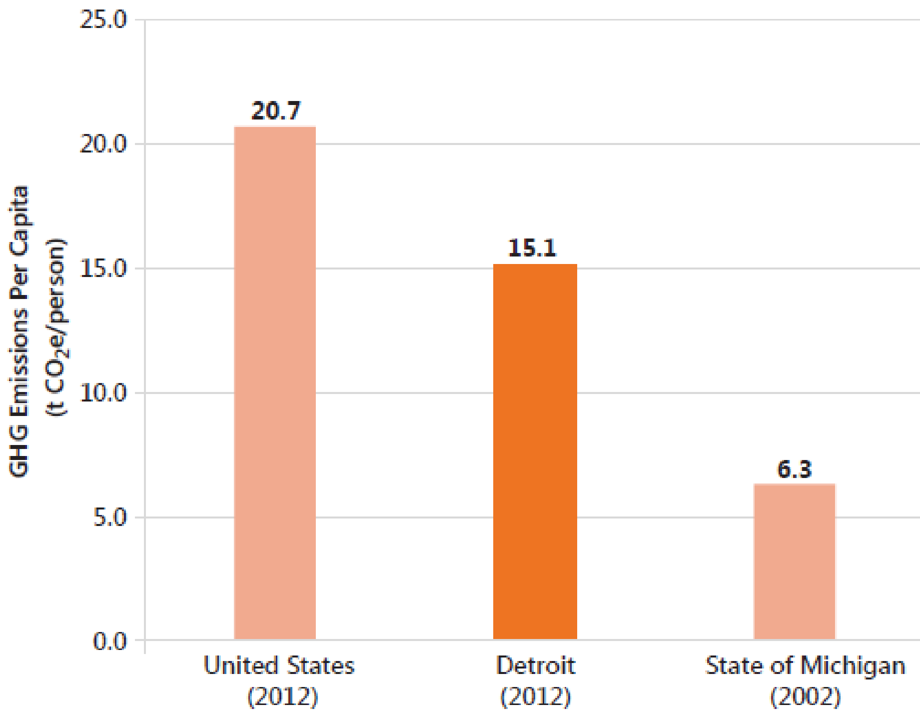

Figure 27: U.S., Detroit, and State of Michigan per Capita Emissions (t CO_2e /person)

[75] U.S. EPA (2014b)
[76] Epstein et al. (2002)

In 2012, Detroit's per capita emissions are lower than the national average. This is as expected because national inventory accounting is more comprehensive than that of local GHG inventories—for example, national accounting includes modeling of high GWP gases (e.g., refrigerant leakage) and lower activity levels involving carbon intensive activities such as agriculture.

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 6.3 t CO_2e/person, much lower than the per capita emissions in Detroit from the latest analysis year of 2012. The per capita emissions in Detroit are higher than those reported by the State of Michigan, likely because Detroit has relatively higher and more concentrated amounts of commercial and industry activity than do other areas of the state. In general, more urbanized areas—with larger populations and therefore greater demand for energy, more built infrastructure, and more commercial and industrial activity—often have higher overall and per capita emissions than rural areas.[77] As a result, it follows that Detroit, as the largest city in Michigan, would see larger per capita emissions than the state average.

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.[78] This analysis includes total citywide inventory emissions, estimated population, land area, and, if conducted, results from the cities' municipal 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 28, 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.

[77] UN Habitat (2011)
[78] For each city in the sample, the most recent inventory analysis year available was used.

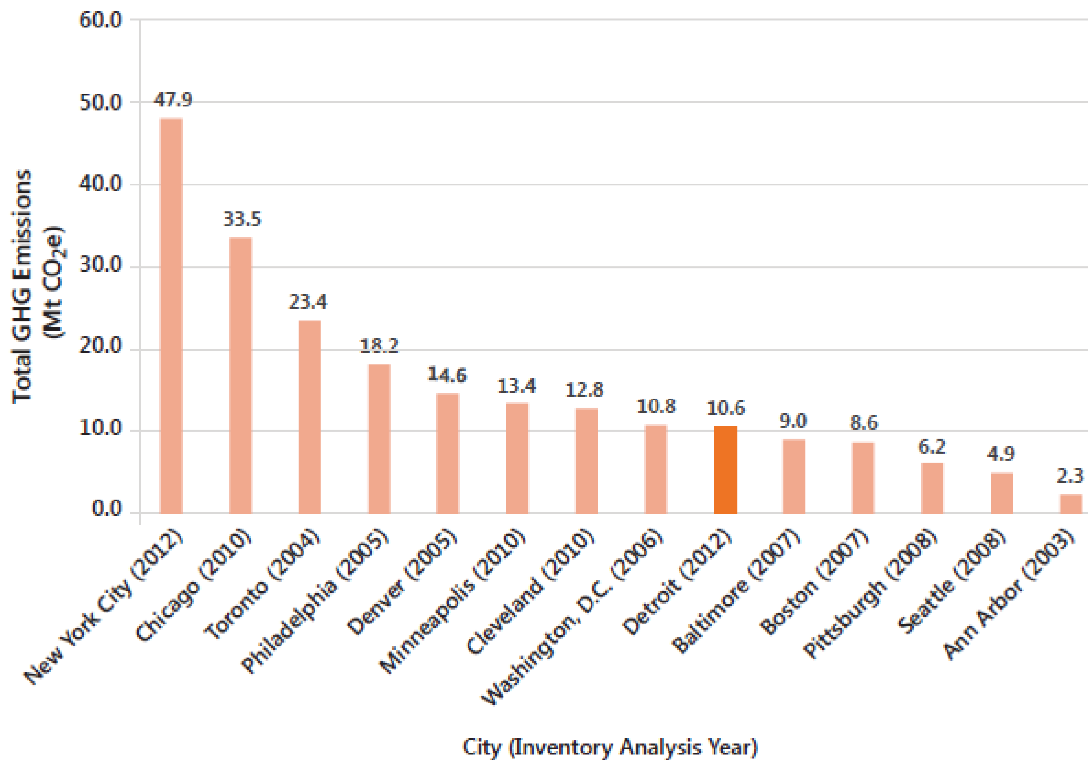

Figure 28: Comparison of Citywide Emissions from Select North American Cities (million t CO_2e)

The City of Detroit's 2012 citywide emissions (10.6 million t CO2e) fall below the mean (average) of 15.4 million t CO_2e of emissions found in this sample. Of these cities, Detroit is the sixth lowest total emitter. It falls in the lower 50th percentile—below the median of 11.8 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 of this sample, has the lowest citywide emissions total (2.3 million t CO_2e).

As shown in Figure 29, 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.

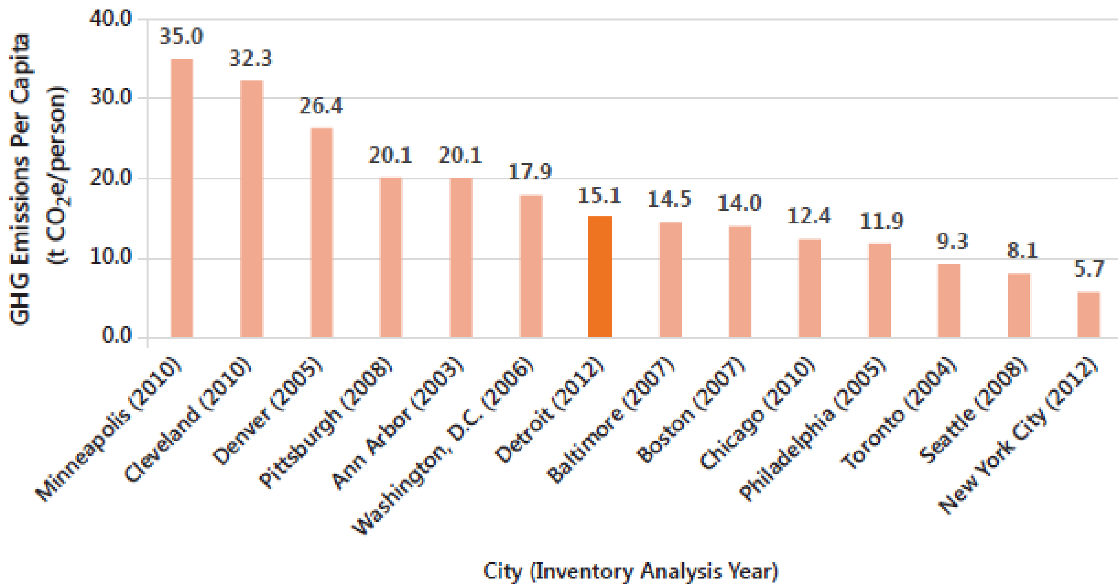

Figure 29: Comparison of Citywide per Capita Emissions across Select North American Cities (t CO_2e/person)

On a per capita basis, Detroit's 2012 emissions (15.1 t CO_2e/person) still fall below average in the dataset. Average per capita emissions of the cities in this sample are 17.4 t CO_2e/person. As illustrated by Figure 29, Detroit's per capita emissions rank eighth lowest, and in this analysis Detroit now falls in the upper 50^{th} percentile of emitters—falling above the median of 14.8 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 28) to the lowest per capita emitter (far right position in Figure 29). Alternatively, Minneapolis, Minnesota, which previously fell in the middle of total citywide emissions, now falls on the far left of the per capita emissions graph, with the highest per capita emissions in the sample (35 t CO_2e/person)—likely due to relatively high winter energy use for its population size, compared to the other cities. 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.[79] 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.

[79] Dodman (2009)

CONCLUSIONS AND NEXT STEPS

The GHG citywide and municipal inventory analyses for 2011 and 2012 presented in this preliminary 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 10.5 million t CO_2e and 10.6 million t CO_2e emitted in 2011 and 2012, respectively. 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 46% to 2012 citywide emissions, due in part to DTE Energy's fuel mix, which consists of more than 75% coal.[80]

Other Citywide Key Findings

- Approximately 40% 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, 48226, 48211);
- 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% (1.1 million t CO_2e) of citywide emissions in both 2011 and 2012. In 2012, four City of Detroit departments (Detroit Public Lighting Department, Detroit Water and Sewerage Department, Detroit Department of Public Works, and Greater Detroit Resource Recovery Authority) were responsible for 92% of City of Detroit's municipal emissions.

Additional analyses that complement these key citywide and municipal inventory findings were also pursued. Emissions sequestered from Detroit's urban tree canopy Detroit's citywide emissions 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 15.1 t CO_2e/person in 2012. Comparatively speaking, Detroit's per capita emissions were lower than the U.S. average, higher than the State of Michigan, and fell in the middle of a select sample of North American cities whose citywide inventories were analyzed.

[80] 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.

After more than a year of work conducting the GHG inventory of Detroit and connecting with more than 50 organizations to collect data and contextual information, the project team outlines the following recommendations to both refine and strengthen the Detroit GHG inventory process, data collection, and analysis.

Institutionalization of the GHG Inventory Process

- **Internally verify Detroit GHG inventory analyses and results.** The first step in the institutionalization of the Detroit GHG inventory is to internally verify the results presented in this preliminary report with the Center for Sustainable Systems, DCAC, and the City of Detroit, so that final results can be published and used as a baseline for future inventories.
- **Institutionalize the GHG inventory process and conduct inventories at regular time intervals**. The inventories for 2011 and 2012 show a snapshot of where Detroit is with regard to its GHG emissions contribution, and it will inform the development of a climate action plan. However, conducting subsequent inventories is critical to showing Detroit's trajectory, progress, and journey 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, based on baseline inventory analyses, are produced in collaboration between DCAC and the City of Detroit, conducting future inventories would enable the measurement of progress toward those goals over time.
- **Develop a transparent, easy-to-follow "Inventory Procedure Manual" to facilitate the development of future Detroit GHG inventories.** This manual should include resources, methods, and sources tailored to the City of Detroit inventory. It would include explicit and detailed documentation to help improve and institutionalize this process for future inventories.[81]

[81] The UM SNRE team will author an "Inventory Procedure Manual" for other analysts to help in future efforts to replicate and conduct Detroit GHG inventories.

- **Collaborate across sectors, organizations, and departments to facilitate GHG inventory data collection and climate planning initiatives.** Collaboration—not only at the municipal, but also at the city and regional scale—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.
- **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 avoid mitigation policies that reduce resilience or, alternatively, adaptation initiatives that increase GHG emissions.
- **Continue City of Detroit participation with the Carbon Disclosure Project (CDP).**[82] 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 plans to work with the City of Detroit to compare our results with the city's records, as well as help establish the framework and structure that will allow the city to continue to report its emissions through the CDP in future years.
- **Obtain ICLEI membership, and complete third-party verification of the inventory analyses, and/or peer-review of this report (City of Detroit GHG Inventory: An Analysis of Citywide and Municipal Emissions from 2011 and 2012).**

GHG Inventory in Action: Toronto

Exceeding Emissions Reduction Targets

The **City of Toronto has successfully reduced its GHG emissions to below 1990 levels, reducing 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 its reliance on air conditioning from fossil-fuel based energy.[x]

x. City of Toronto (2014)

[82] For more information about the Carbon Disclosure Project, visit their website here.

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.[83]
- **Establish robust spatial analysis of Detroit's GHG emissions.** Such analyses could provide useful insights for 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 undertaking similar efforts.[84]
- **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 staff of inventory data contacts and agencies to improve understanding of data availability, quality, and archiving processes

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[83] The UM SNRE project team plans to develop data visualization and communication tools to inform a communication initiative and stakeholder meetings, as well as to use these tools to pursue additional graphical and spatial visuals of the baseline GHG inventory data that may be useful for decision-making.

[84] 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).

- **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 will be imperative for 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 N), disaggregation of results by Zip Code, further characterizing commercial, institutional, and industrial building and facilities emissions by disaggregating by Standard Industry Classification (SIC) Code (which were provided by DTE Energy in 2011 and 2012), as well as a more robust land use analysis that calculates emission sources and sinks from other types of land cover.
- **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. The inventory team anticipates conducting and incorporating some of this analysis for the 2011 and 2012 citywide results in the final report released in the coming months.

- **Future Detroit GHG inventories will qualify 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.

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 N. 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, including 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, in addition to the demand for public transportation—both within the City of Detroit, as well as across the city's borders.
- **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 energy from waste 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 and those currently being undertaken by the City of Detroit, Detroit Future City, and the Detroit Blight Authority.[85]
- **For Detroit GHG inventories for 2014 and beyond, revise data collection and analysis processes for solid waste activities commensurate with structural changes to the City government that effect waste collection and processing.** In early 2014, the City of Detroit privatized its residential waste collection process, managed previously by the City's Department of Public Works.[86] As a result, inventory analyses for 2014 or later will need to revise how residential solid waste data is gathered and organized. Depending on the language of these new contracts, future inventories may need to reevaluate whether or not to continue including residential waste management under the operational control of the City of Detroit (and therefore including these emissions in future municipal inventory analyses).

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 anaerobic 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 unfortunately not in the form needed for the more precise calculations

[85] Gallagher et al. (2014)
[86] Guillen (2014)

currently outlined and recommended by ICLEI. A revised method would 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. Verification of the 2010 land cover analysis undertaken here would ensure that Detroit has a sound baseline from which to measure land cover change in the future. Furthermore, a more thorough examination of the possible GHG impact from agricultural practices and restoration and conservation projects could further integrate land uses with climate mitigation and adaptation efforts in the City.

Municipal Inventory Recommendations

- **Refine methodology to gain a better understanding of energy usage in municipal buildings and facilities operated by the City of Detroit.** Further attempts could be made to resolve differences between existing City of Detroit energy use datasets and those provided by DTE Energy. Additional data from the Detroit Public Lighting Department (PLD) may allow for greater disaggregation of the public utility's energy use and distribution, than that currently provided within the DTE Energy dataset.

- **Calculate and include GHG emissions from employee commute in subsequent municipal GHG inventories of Detroit.** While not always required, 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

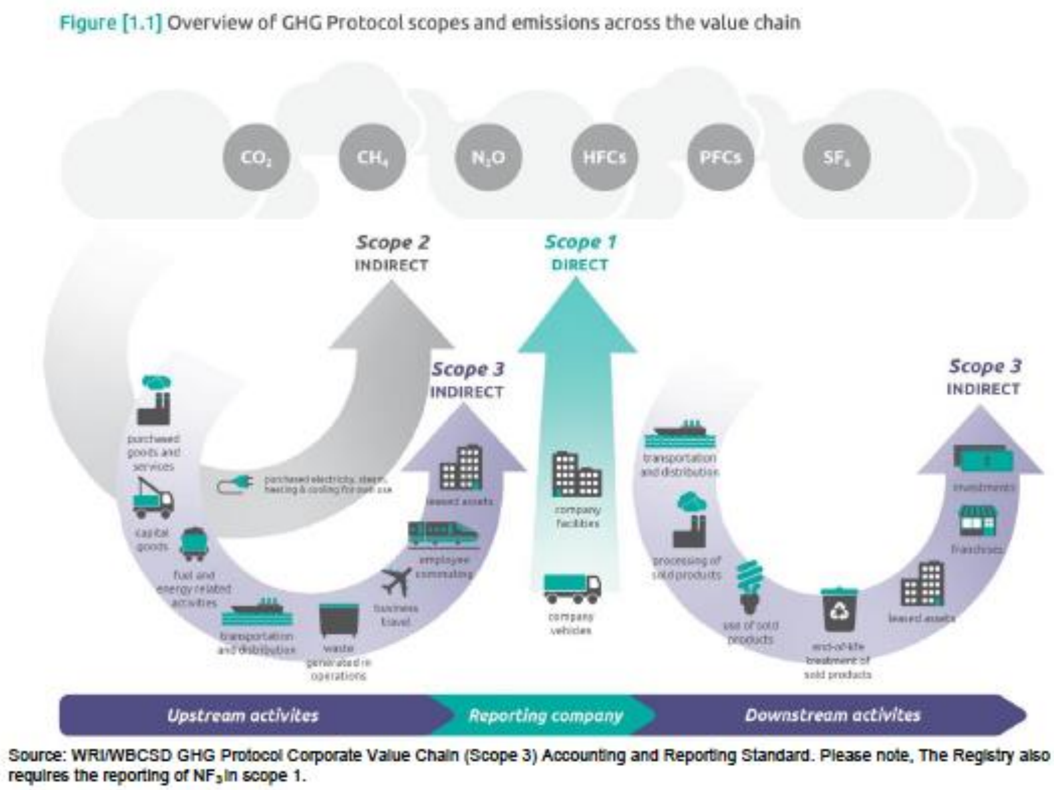

Figure 30: GHG Inventory Scopes, Activities, and Sources
Image Source: Climate Registry (2013)

This image is a frequently cited depiction of GHG inventory accounting scope categories, with examples of common activities associated with each. 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 tend to be much more complex at the city scale as compared to 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.

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

Buildings and facilities activity category includes CO_2, CH_4, and N_2O emissions [87] associated with heating, cooling, and powering residential, commercial and institutional (including municipally-operated buildings), as well as 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.[88]

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[89] sub-region emission factors (listed in Appendix C, Table 7).

DTE Energy provided the project with average monthly usage data for all of their City of Detroit customer accounts on an annual basis for 2011 and 2012 (scrubbed of any confidential and 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[90] to

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[87] 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.

[88] Richter (2012), Sugar et al. (2011)

[89] 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.

[90] Electricity and natural gas emission factors vary based on year and type of carrier.

find emissions in CO_2e. Emissions due to T&D line losses for electricity were calculated by multiplying an annual transmission line loss emission factor[91] 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:

$$\boldsymbol{Composite\ Electricity\ EF} = (\%\ \boldsymbol{Purchased\ Electricity} \times \boldsymbol{eGRID\ EF}) + (\%\ \boldsymbol{DTE\ Energy\ Fuel\ Mix} \times \boldsymbol{DTE\ Energy\ EF})$$

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

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

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 the difference between one and the eGRID Line Loss Factor as follows:

$$\boldsymbol{T\&D\ EF} = \frac{(\boldsymbol{eGRID\ Line\ Loss\ Factor\ \times Composite\ EF})}{(\boldsymbol{1 - eGRID\ Line\ Loss\ Factor})}$$

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 dataset 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.

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 serve as the best available approximation for VMT within Detroit. Although SEMCOG also provided in-boundary VMT data, following suggestions from ICLEI protocol [92] and transportation literature,[93] 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

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

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

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,[94] 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 subequently);
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.[95]

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 because of lack of data. Due to the transportation

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

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

planning processes at SEMCOG, VMT data are only available every five years; data is available for 2010, but not for 2011 and 2012.[96]

SMART Bus calculates that 9% of total SMART Bus VMT occurred within the city boundary of Detroit. 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.

Municipal Government Transportation

Municipal Government transportation consists of vehicles used for public transportation (City of Detroit's Detroit Transit Corporation People Mover 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.[97]

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 (GSD, DWSD), we multiplied total diesel usage and total unleaded gasoline usage by the corresponding emissions factors to obtain total CO_2 emissions associated with the fuel use, as illustrated in Table 10.

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[96] 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) is approximately 22% of the total land area of Wayne County (614 sq. miles).]

[97] ICLEI (2012)

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)[98] 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.

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 to verify fuel usage data reported to NTD, which may have only included buses, and not repair or maintenance vehicles operated by DDOT.

At the time of inventory development, sufficient 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 make it difficult to analyze these emissions in finer detail or determine the underlying drivers of the 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

[98] 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).

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[99] that are reported to the U.S. EPA Greenhouse Gas Reporting Program (GHGRP). Annual industrial process emissions that fall under U.S. EPA's requirements for emissions disclosure[100] reported total GHG emissions data from 2010 onward to GHGRP. We downloaded the 2010, 2011, and 2012 datasets from U.S. EPA Facility Level Information on Greenhouse Gases Tool (FLIGHT) database,[101] using "Detroit" and "Michigan" as spreadsheet filters in the "City" and "State" columns respectively to the isolate emitters relevant to this report. We selected industrial process emissions for petroleum refining and hydrogen production activities. 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.

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;[102]

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[6] 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 production or use.

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

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

[102] 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

4. Any facilities that are not required to report to U.S. EPA GHGRP have small emissions and would therefore have a minimal effect on citywide inventory totals.

Solid Waste

Methods

Solid waste emissions are associated with residential waste landfill disposal and solid waste incineration. Detroit exported residential 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 waste management practices.[103]

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

City of Detroit Residential 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 energy from waste incinerator, owned and operated by Detroit Renewable Power through a contract with the Department of Public Works and GDRRA, which processes residential and commercial 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]").

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 activities, e.g. residential, commercial, etc. We did not investigate the decline in waste collection from 2011 to 2012, as shown in Table 11; this trend may or may not indicate poor data quality.

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within the City of Detroit. Therefore, the State of Michigan GHG inventory provides more certainty to the comprehensiveness of the industrial process analysis here.

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

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 here.

We followed ICLEI's 2012 Community Protocol Water and Wastewater Appendix[104] 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.

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.

Table 12: Detroit Water and Sewerage Department 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)

N_2O 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,[105] 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.

[104] ICLEI (2012) Appendix F: Wastewater and Water Emission Activities and Sources

[105] City of Detroit (2013)

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.

Land Use

Methods

The land use emissions analysis attempts to measure the emissions effects of land cover on GHG removals. The primary GHG that is impacted by land cover change is CO_2, which is part of the respiratory cycle of vegetation and is stored as stocks in biomass.

Our methodology estimates annual uptake of CO_2 from tree canopy cover within Detroit's city boundaries for 2010. Accurate estimates of GHG emissions and removals 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 GHG emissions and removals, particularly due to the fact that Detroit has such a large land area the city has been undergoing significant land-use changes in recent years, and there is significant stakeholder interest in land use practices and projects designed to leverage the urban landscape to improve quality of life.[106]

Our methodology estimates GHG emissions and removals based on land-use categories clipped to the City of Detroit boundary. Using a tool called i-Tree Canopy from the U.S. Forest Service, we analyzed 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[107] 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. Future analysis will benchmark this classification output from i-Tree Canopy with a land-cover layer

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[106] ICLEI (2006)

[107] 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%).

professionally produced for SEMCOG for the year 2010 (this is based on remotely sensed ortho-imagery from the National Agriculture Imagery Program or NAIP[108]).

Using this land cover classification, we applied a Michigan-specific CO_2 sequestration factor found in the literature for the tree canopy cover. Future analysis could also examine the carbon sequestration of herbaceous cover as well as bare soil.

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, and natural life cycles of living organisms. Further, rates of emission and removal by vegetation also differs by plant species. An analysis based on an annual time scale and the division of landscapes into categories (tree, herbaceous and bare ground cover), 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.

Ortho-images and GoogleEarth imagery are snapshots 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 three 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 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 not all of the above assumptions hold; yet given the current information and circumstances, these assumptions and methods are what are currently practical. The analysis is ultimately meant to provide an approximation of land use emissions and removals, serving as a starting point for future work to refine and sharpen this analysis.

[108] NAIP data was used for the 2010 Ann Arbor tree canopy cover analysis (City of Ann Arbor 2014).(

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	10.5	1.10	14.9	76,087
Detroit	MI	2012	701,475	2012	138	10.6	1.10	15.1	76,812

*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	5,679,858	54.1%	5,453,826	51.6%
Scope 2	4,531,194	43.2%	4,809,082	45.5%
Scope 3	285,182	2.7%	300,451	2.8%
Citywide Inventory Total	**10,496,233**	**100.0%**	**10,563,359**	**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	1,003
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	-	-	-	6,305
	Process Emissions from Wastewater Treatment		-	-	-	3,720
	Sludge Incineration		-	-	-	100,671
2012 Citywide Inventory Total						**10,563,359**

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	1,090
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	-	-	-	6,305
	Process Emissions from Wastewater Treatment		-	-	-	3,720
	Sludge Incineration		-	-	-	104,898
2011 Citywide Inventory Total						**10,496,233**

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

City of Detroit Zip Code*	2011		2012	
	Emissions (t CO2e)	% of Total	Emissions (t CO2e)	% of Total
48217	966,723	13.3%	1,033,458	14.1%
48209	705,342	9.7%	707,075	9.6%
48211	623,174	8.6%	697,322	9.5%
48226	515,293	7.1%	538,751	7.3%
48202	301,202	4.2%	304,791	4.2%
48201	279,832	3.9%	298,859	4.1%
48235	284,160	3.9%	278,118	3.8%
48228	279,937	3.9%	277,658	3.8%
48219	270,210	3.7%	267,038	3.6%
48207	260,967	3.6%	260,380	3.6%
48221	253,939	3.5%	241,241	3.3%
48205	243,846	3.4%	239,462	3.3%
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	2.8%
48238	193,390	2.7%	181,761	2.5%
48210	183,807	2.5%	180,009	2.5%
48214	183,334	2.5%	173,630	2.4%
48223	157,632	2.2%	158,695	2.2%
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	**7,247,270**	**100%**	**7,330,870**	**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 emissions 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 Residential Solid Waste Collection (Short Tons)

City of Detroit Residential 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		6,305
		Process Emissions from Treatment without Nitrification or Denitrification		3,720
2005 Total Wastewater Treatment Emissions				**171,703**
2010	Wastewater Treatment	Sludge Incineration	CO_2, CH_4, N_2O from Fugitive Sources, Processes, and Incineration	128,567
		Fugitive Emissions from Effluent Discharge		6,305
		Process Emissions from Treatment without Nitrification or Denitrification		3,720
2010 Total Wastewater Treatment Emissions				**138,592**

Appendix G: Citywide Inventory Results and Charts, 2011

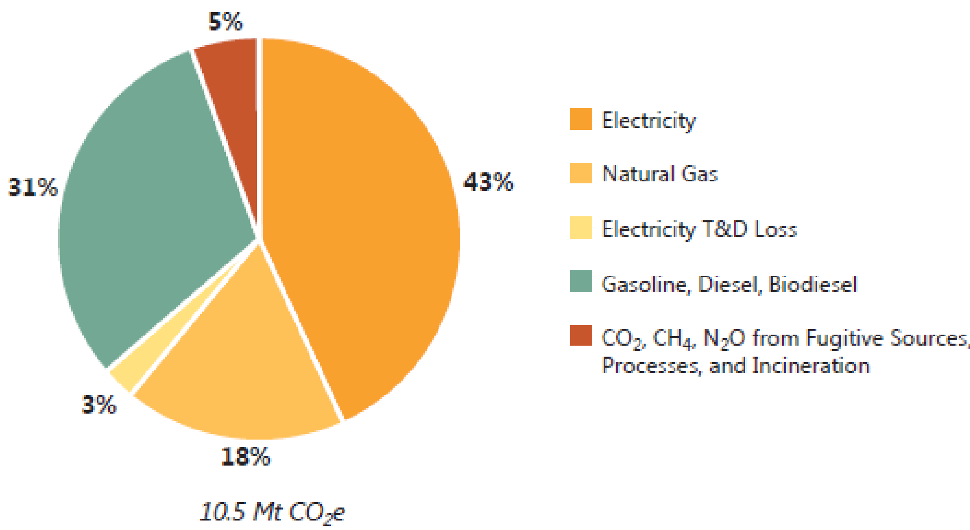
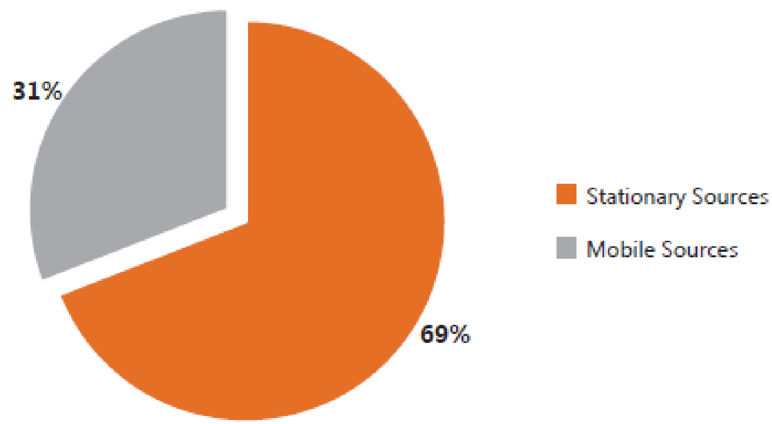


Figure 31: Detroit Citywide GHG Emissions by Carrier, 2011



10.5 Mt CO_2e

Figure 32: Detroit Citywide Stationary vs. Mobile GHG Emissions, 2011

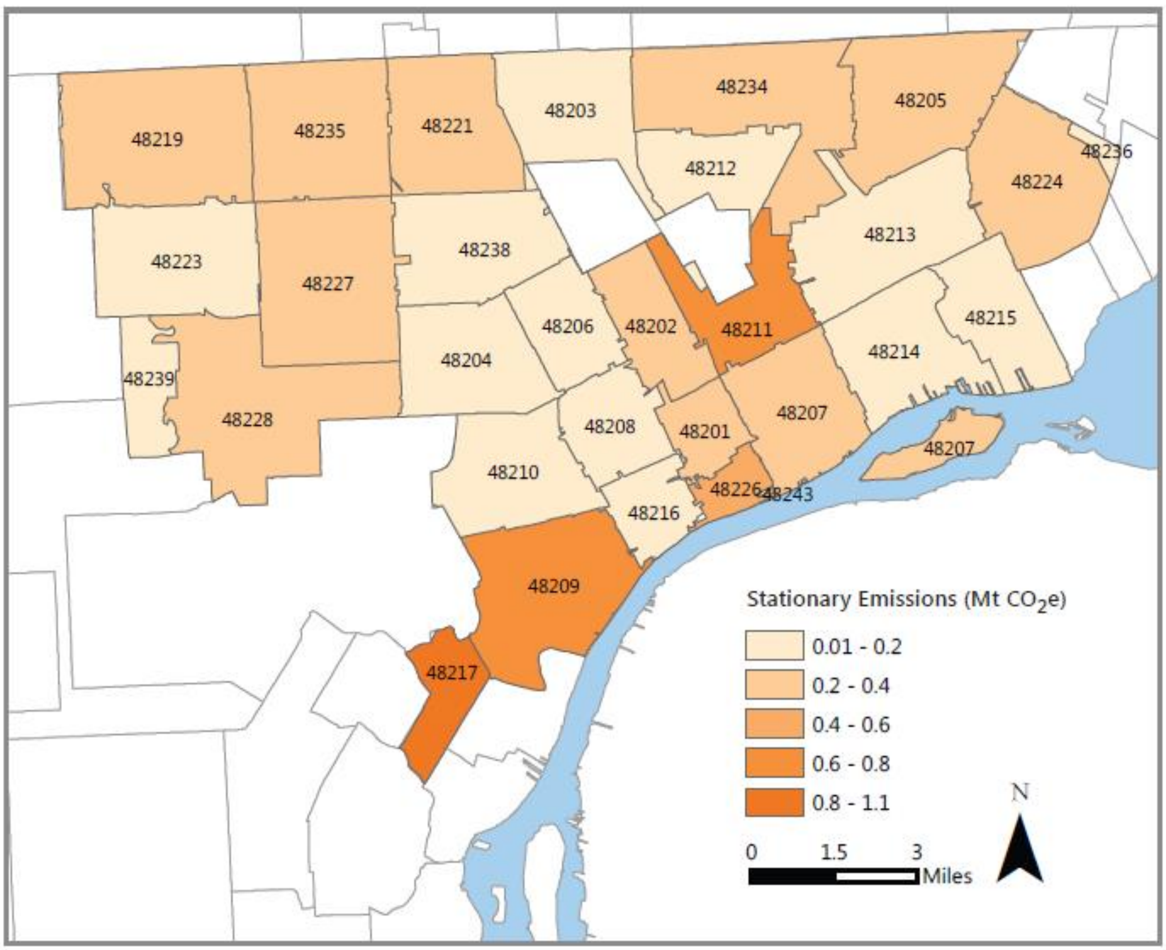


Figure 33: Detroit Citywide Stationary GHG Emissions by Zip Code, 2011
Stationary sources include energy use in buildings and facilities, industrial processes, solid waste incineration, and wastewater treatment.

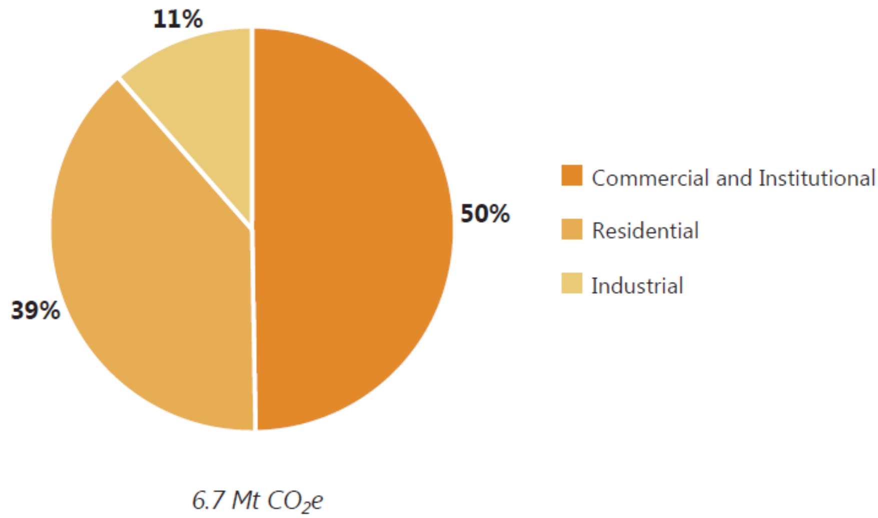


Figure 34: Detroit Citywide Buildings and Facilities GHG Emissions by End-Use Sector, 2011

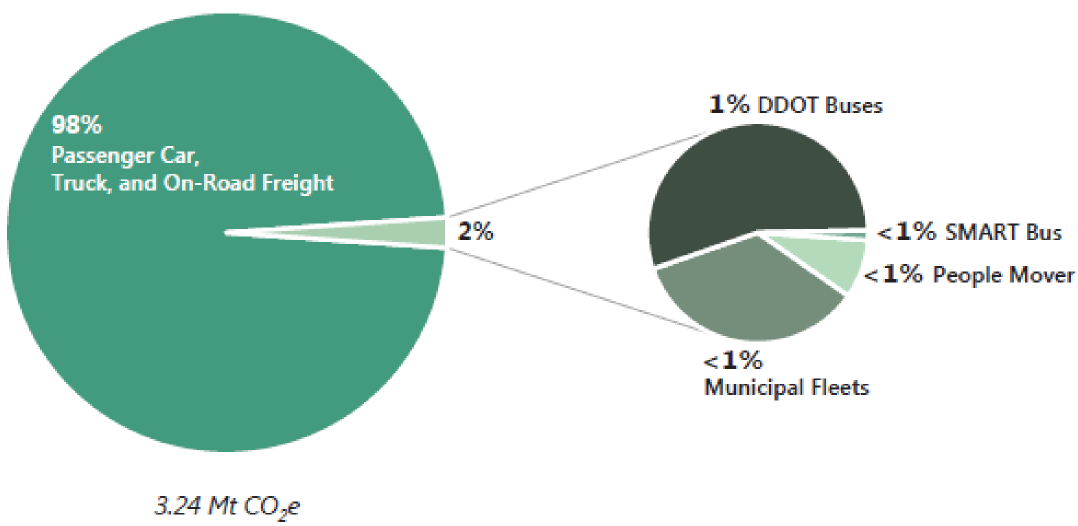


Figure 35: Detroit Citywide Transportation GHG Emissions by Source, 2011

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[109] 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.

Annual total 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 municipal data set was identical to Citywide Inventory 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 of 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.

[109] 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	36.22%	411,750	36.92%
	Detroit Water and Sewerage Department	41 and 42	274,163	24.86%	248,069	22.25%
	All Other Municipal Buildings and Facilities*	-	27,532	2.50%	25,171	2.26%
Municipal Transportation	Detroit Department of Transportation	20	39,185	3.55%	38,542	3.46%
	All Other Municipal Transportation**	-	32,565	2.95%	30,564	2.74%
Solid Waste Fugitive Sources and Incineration	Detroit Public Works and GDRRA	19	215,051	19.50%	250,335	22.45%
Wastewater Treatment Fugitive Sources, Processes, and Incineration	Detroit Water and Sewerage Department	42	114,924	10.42%	110,697	9.93%
Municipal Inventory Total			**1,102,863**	**100%**	**1,115,128**	**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 Public Lighting Department	38	400,269	36.29%	412,526	36.99%
Detroit Water and Sewerage Department	41 and 42	393,441	35.67%	361,713	32.44%
Department of Public Works	19	223,110	20.23%	257,454	23.09%
Department of Transportation	20	39,185	3.55%	38,542	3.46%
City of Detroit, unclassified*	-	6,732	0.61%	13,781	1.24%
Police	37	13,201	1.20%	11,485	1.03%
People Mover	People Mover	4,199	0.38%	6,047	0.54%
Fire	24	6,966	0.63%	4,236	0.38%
Recreation Department	39	5,460	0.50%	2,405	0.22%
General Services Department	47	2,310	0.21%	1,969	0.18%
Detroit Workforce Development Department	21	2,182	0.20%	1,921	0.17%
Municipal Parking	34	611	0.06%	703	0.06%
Election Commission	71	523	0.05%	530	0.05%
Information Technology Services	31	268	0.02%	314	0.03%
Detroit Public Library	72	1,135	0.10%	285	0.03%
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	0.02%
Historical	26	173	0.02%	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		**1,102,863**	**100%**	**1,115,128**	**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 the 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		2012	
		Emissions (t CO_2e)	% of Total	Emissions (t CO_2e)	% 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 the City of Detroit assigned to departmental budget code 35.

Appendix K: Municipal Government Inventory Results and Charts, 2011

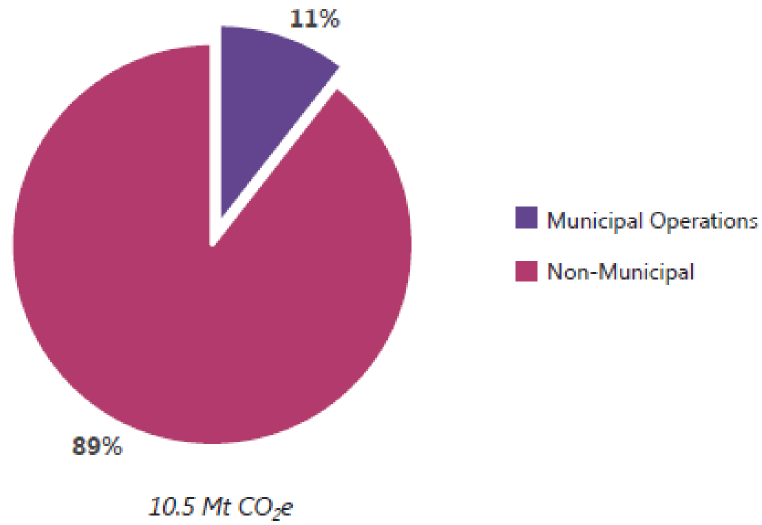


Figure 36: Detroit Municipal Operations Emissions as a Percentage of Citywide, 2011

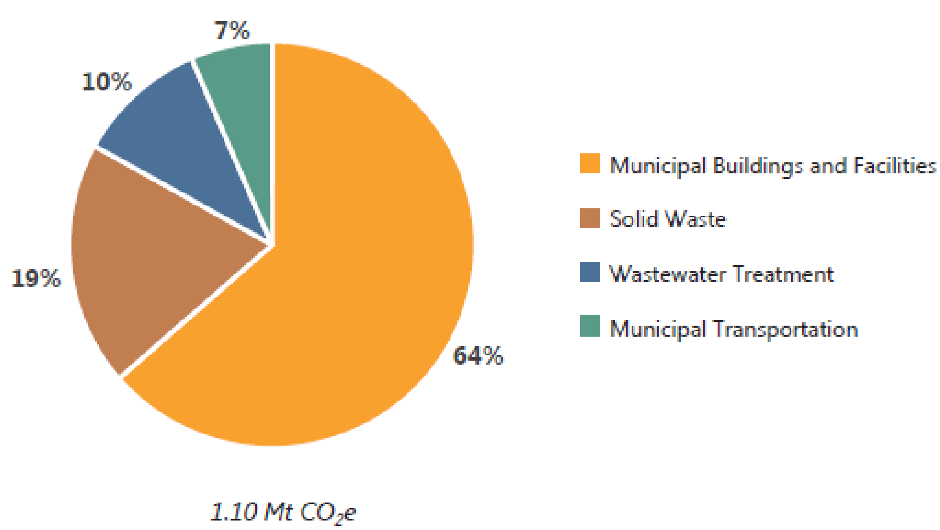


Figure 37: Detroit Municipal Operations GHG Emissions by Activity, 2011

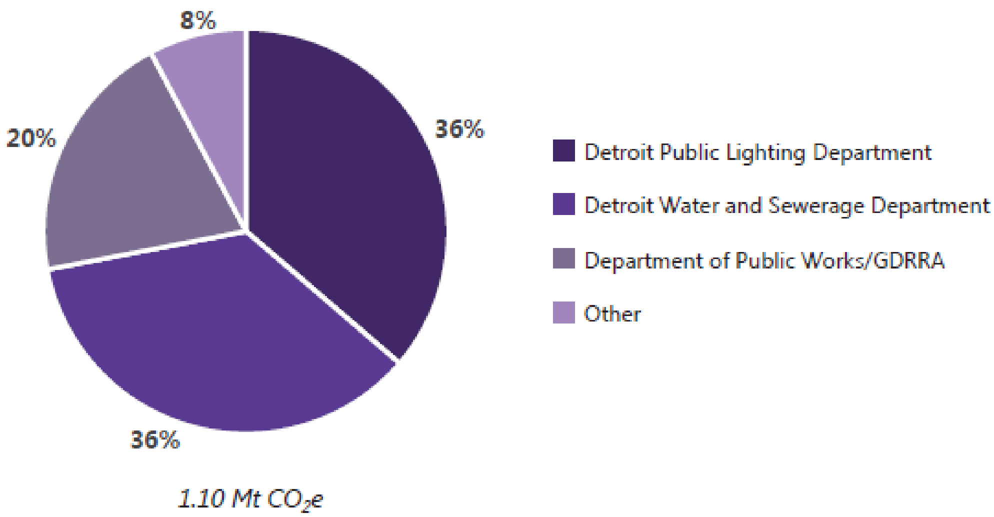


Figure 38: Detroit Municipal Operations GHG Emissions by Department, 2011

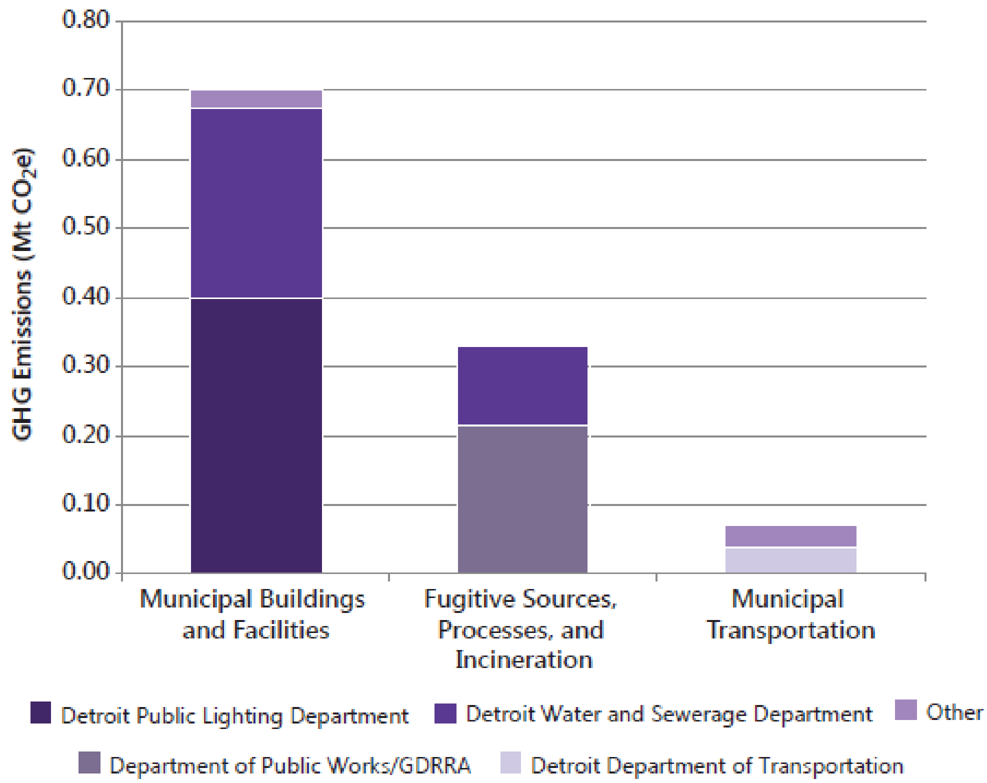


Figure 39: Detroit Municipal Operations GHG Emissions by Activity and Department, 2011

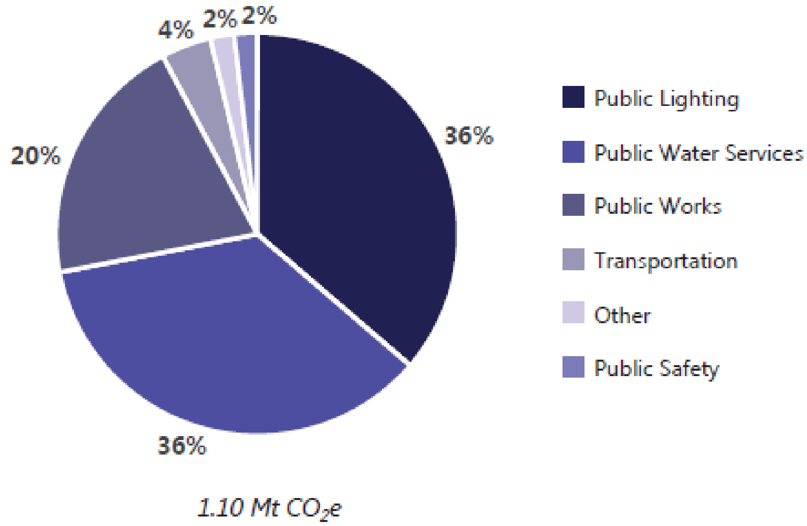


Figure 40: Detroit Municipal Operations GHG Emissions by Service, 2011

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	-	26.4	95,425	5
Detroit	MI	2012	701,475	2012	138†	10.6	1.10	15.1	76,812	6
Minneapolis	MN	2010	382,578	2010	55	13.4	-	35.0	244,080	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	9.3	96,168	11
Washington	D.C.	2006	601,723	2010	61	10.8	-	17.9	176,427	2
City Comparison Sample Mean (n = 14)						15.4		17.4	131,072	
City Comparison Sample Median (n = 14)						11.8		14.8	122,925	

*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
Detroit	MI	2012	701,475	2012	138	10.6	1.10	15.1	76,811.6	6
State of Michigan	MI	2002	9,938,444	2000	56,539	62.6	-	6.3	1,107.0	13

*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: Avoided Emissions from Residential Recycling and Composting in Detroit

According to U.S. EPA, recycling and composting can reduce a city's total solid waste emissions by diverting waste, which would otherwise have been landfilled (where it would decompose and produce emissions over time).[110] The avoided emissions from the amount of material recycled and composted reported by the City of Detroit Department of Public Works in 2005, 2010, 2011, and 2012, are estimated (in comparison to emissions from solid waste landfill and incineration) in Table 27. 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 27, but net emissions from municipal solid waste were not calculated across analysis years or presented in conjunction with citywide results.

Table 27: City of Detroit Residential Solid Waste Emissions and Avoided Emissions from Recycling and Compost

Activity	Emissions (t CO_2e)			
	2005	2010	2011	2012
Landfill and Incineration	2,754	166,366	215,051	250,335
Avoided from Recycling and Compost	(91,336)	(114,347)	(90,651)	(27,372)

These results suggest that Detroit could see reduced emissions from solid waste by increasing residential 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."[111] The avoided emissions from the

[110] U.S. EPA (2012b)
[111] ICLEI (2013)

recycling and compost collected by the City of Detroit were each calculated using data provided by Wayne County[112] and emission factors adapted from U.S. EPA WARM (described subsequently). Once converted into common units, avoided emission results from both recycling and composting could be added together, presented as total avoided emissions from recycling and composting in Table 27.

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,[113] 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 28 shows the recycling emissions factors used for each type of recycled material and inputted into U.S. EPA WARM.

Table 28: Detroit Residential 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

[112] Wayne County (2013)
[113] U.S. EPA (2012b)

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.

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.[114] We estimated the emissions reductions benefits of Detroit's Durable Goods material type with the U.S. EPA's Durable Goods Calculator,[115] which, although no longer being updated by U.S. EPA, likely provides the best emissions estimate.[116]

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.[117] 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 estimate an amount composted in 2012.

[114] Personal communication with U.S. EPA Office of Resource Conservation & Recovery (Jan. 14, 2014).
[115] U.S. EPA (2005)
[116] Personal communication with U.S. EPA Office of Resource Conservation & Recovery, (Jan. 14, 2014).
[117] U.S. EPA (2014d)

Appendix N: 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. 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" is "a measure that gauges the amount of heating or cooling needed for a building using 65 degrees [F] as a baseline." 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 (NOAA National Weather Service 2014).

Table 29 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 29: 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.

Abbreviations

Agencies and Organizations

CDP – Carbon Disclosure Project
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
CDD – Cooling Degree Day
CO_2e – carbon dioxide equivalent
CY – calendar year
EF – emission factor
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
mmBtu – 1 million British Thermal Units
Million t CO_2e – megatonne (or million metric tons (tonnes)) of carbon dioxide equivalents

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 as well as 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., lbs 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.

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 vs. life cycle emissions: 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.

Life cycle emissions estimate a product, process, or service's emissions across its life stages (i.e. from its origin to its disposal).

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

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