



CITY OF CHICAGO GREENHOUSE GAS INVENTORY REPORT

CALENDAR YEAR 2017

January 1 – December 31, 2017

Final Report

December 2019



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Acronyms and Abbreviations

AFOLU	Agriculture, Forestry, and Other Land Use
CCAP	Chicago Climate Action Plan
CH ₄	methane
City	City of Chicago
CMAP	Chicago Metropolitan Agency for Planning
CO ₂	carbon dioxide
CO ₂ e	carbon dioxide equivalent
DSS	Department of Streets and Sanitation
GCoM	Global Covenant of Mayors for Climate and Energy
GDP	gross domestic product
GHG	greenhouse gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emissions Inventories
GWP	global warming potential
HFCs	hydrofluorocarbons
IPCC	Intergovernmental Panel on Climate Change
IPPU	Industrial Process and Product Use
k	thousand
kWh	kilowatt hour
LPG	liquefied petroleum gas
MOVES	U.S. EPA Motor Vehicle Emission Simulator
MT CO ₂ e	metric tonnes of carbon dioxide equivalent
N ₂ O	nitrous oxide
NF ₃	nitrogen trifluoride
NTD	National Transit Database
PFCs	perfluorocarbons
SF ₆	sulphur hexafluoride
SUVs	sports utility vehicles
tonnes	metric tons
U.S. EPA	United States Environmental Protection Agency
VMT	vehicle miles traveled
WRP	Water Reclamation Plant

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EXECUTIVE SUMMARY

Summary of Results

The City of Chicago 2017 Community-scale Greenhouse Gas (GHG) Emissions Inventory results show that community activities within the city boundary generated approximately 31,035,000 metric tonnes of carbon dioxide equivalent (MT CO₂e) in 2017.

This number reflects a 15 percent reduction in total emissions since the Chicago 2005 base year inventory, an improvement in emissions intensity from approximately 13.0 MT CO₂e/capita¹ to 11.4 MT CO₂e/capita, and stronger improvements in economic efficiency, experiencing a change from approximately 7.8 MT CO₂e per \$100,000 (MT CO₂e/\$100k) of gross domestic product (GDP)² to 4.7 MT CO₂e/\$100k of GDP based on values for the Chicago metropolitan region. These results demonstrate net total emissions reductions in Chicago during a period where economic output has continued to grow. The rate of emissions reduction per year has also accelerated during each inventory period. The City is now 59% of the way to reaching its Paris Agreement 2025 target.

The following section provides context on the City's GHG inventory and target setting efforts, monitoring commitments, and previous emissions analysis work. The remainder of this Executive Summary presents the 2017 inventory results and updated emissions trends analysis to document how the City's emissions have changed since the 2005 base year and to demonstrate that the City is on track to achieve its 2025 target.

Background

The City of Chicago is a recognized leader in climate action planning. The City has assessed the economic, social and environmental risks of climate change and has begun implementing actions that will help minimize the effects on its community. The City has also begun taking aggressive action to reduce community GHG emissions and contribute to global climate protection efforts. In 2008, the City released the Chicago Climate Action Plan (CCAP),³ which outlined the City's ambitious goals and actions to reduce community GHG emissions to 80 percent below 1990 levels by the year 2050 and established an interim goal of reducing emissions to 25% below 1990 levels by the year 2020. In June 2017, the City continued this leadership and committed to the goal of reducing citywide greenhouse gas emissions to levels equivalent to or greater than 26-28% reduction from 2005 levels by 2025, which is the original commitment made by the Obama Administration as part of the United States' commitment to the Paris Climate Agreement.⁴

¹ City of Chicago population source: Census Bureau, United States Chamber of Commerce

² Regional GDP source: Bureau of Economic Analysis, United States Chamber of Commerce (values in 2017 dollars)

³ For more information, visit <https://www.chicago.gov/city/en/progs/env/climateaction.html>

⁴ "Mayor Emanuel Signs Executive Order Committing Chicago to Guidelines of Paris Agreement." Press Release, Mayor Rahm Emanuel. June 7, 2017.
<https://www.cityofchicago.org/city/en/depts/mayor/press_room/press_releases/2017/may/ParisAgreementExecOrder.html>

Chicago also recently committed to the goals of powering all public buildings with 100% renewable energy by 2025,⁵ and achieving 100% clean energy citywide by 2035.

To monitor progress toward these goals, the City has developed preliminary estimated GHG emissions for the years 1990 and 2000, as well as more complete GHG emissions inventories for the years 2005, 2010, 2015, and 2017.

The City of Chicago is a member of C40 Cities and joined the Global Covenant of Mayors for Climate and Energy (GCoM) in August 2015. The GCoM is the world's largest cooperative effort among mayors to reduce GHG emissions, track progress, and prepare for the impacts of climate change. As a signatory of the GCoM in 2015, the City of Chicago pledged to conduct a GHG emission inventory in compliance with the Global Protocol for Community-Scale GHG Emissions Inventories (GPC) in 2016.⁶

Chicago joined other global cities in completing one of the first GPC-compliant GHG inventories in the world when developing its 2015 inventory. The GPC provides the first global standard protocol under which cities can complete community-scale inventories. Where previous community-scale inventories have been difficult to compare because of wide differences in methodologies, both across geography and time, often resulting in “apples-to-oranges” comparisons, the GPC provides a foundation upon which cities can conduct “apples-to-apples” comparisons of their own year-over-year GHG emissions going forward, as well as evaluate performance compared to other cities around the world.

The inventory detailed in this report for calendar year 2017 is also GPC-compliant. These GPC-compliant 2015 and 2017 Chicago Community GHG Emissions Inventories meet the GCoM requirement and provide the City with data to continue to monitor its progress toward achieving its future GHG emissions reduction goals. The City also updated its 2005 and 2010 community inventories to be compliant with GPC guidelines. These updates allow direct, accurate comparisons of emissions between inventory years, and increase the City's ability to define effective emission reduction actions. As part of this previous effort, the City also attempted to revise its 1990 inventory to be GPC compliant, but the lack of available 1990 data prevented using the same methods that were used in the 2005, 2010, 2015, and 2017 inventories. Additionally, the methods used in the original 1990 inventory were determined to be insufficient for making accurate comparisons to the 2015 and 2017 inventories and the updated 2005 and 2010 inventories.⁷

Given these inventory improvements and its commitment to the Paris Climate Agreement goals, the City revised its emission target base year from 1990 to 2005, while maintaining an ambitious emissions reduction target that aligns with the Paris Agreement. This decision was made to allow increased accuracy in evaluating the community's emissions performance and its contribution to global climate protection efforts.

⁵ “Mayor Emanuel Announces City Buildings to be Powered by 100 Percent Renewable Energy by 2025.” Press Release, Mayor Rahm Emanuel. April 9, 2017.
<https://www.cityofchicago.org/city/en/depts/mayor/press_room/press_releases/2017/april/RenewableEnergy2025.html>

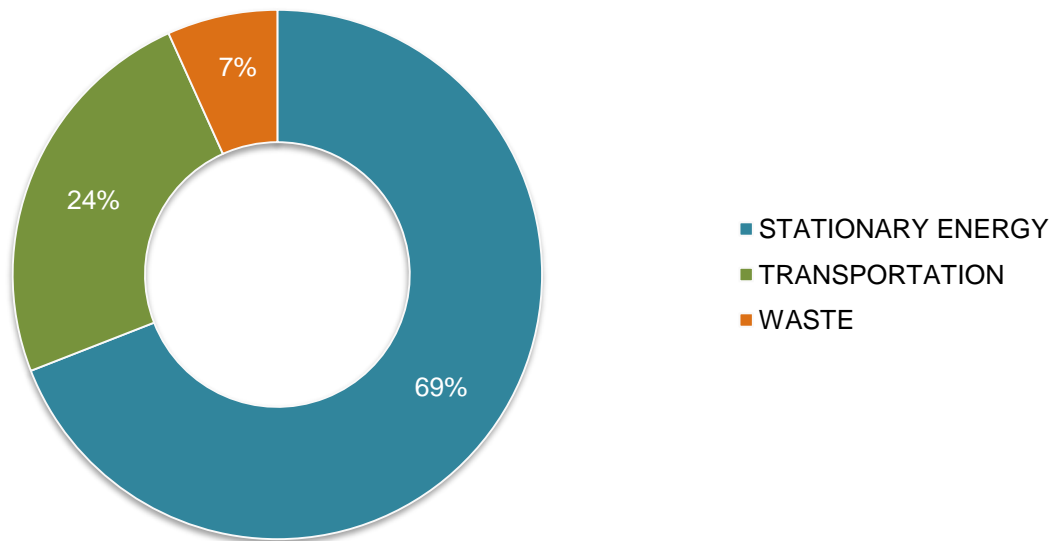
⁶ For more information about the GPC, visit the [Greenhouse Gas Protocol for Cities website](#).

⁷ See Section 1.1 of the 2015 GHG Inventory Report regarding the challenges in making the 1990 inventory comparable to newer inventories. The 2015 GHG Inventory Report is found online at: www.CityofChicago.org/Emissions

2017 Community GHG Emissions Inventory Results

In 2017, stationary energy emissions were the largest contributor to the community inventory, accounting for 69% (21,437,137 MT CO₂e) of total emissions. Transportation emissions contributed an additional 24% (7,504,969 MT CO₂e), with the waste sector responsible for the remaining 7% (2,093,279 MT CO₂e) of community emissions (see Figure 1). Four emissions sub-sectors were responsible for over 84% of Chicago's total 2017 GHG emissions, including residential buildings (27%), commercial and institutional buildings and facilities (25%), manufacturing industries and construction (17%), and on-road transportation (15%).

Figure 1 – 2017 GHG Emissions by Sector



Over half (51%) of Chicago's emissions are generated by fuel combustion within the city boundaries (Scope 1 emissions), followed by emissions from electricity consumption (Scope 2), which contributed approximately 42% of emissions. Remaining emissions (Scope 3) resulting from treatment and disposal of solid waste and wastewater generated within the city contributed the remaining 7% of 2017 emissions.

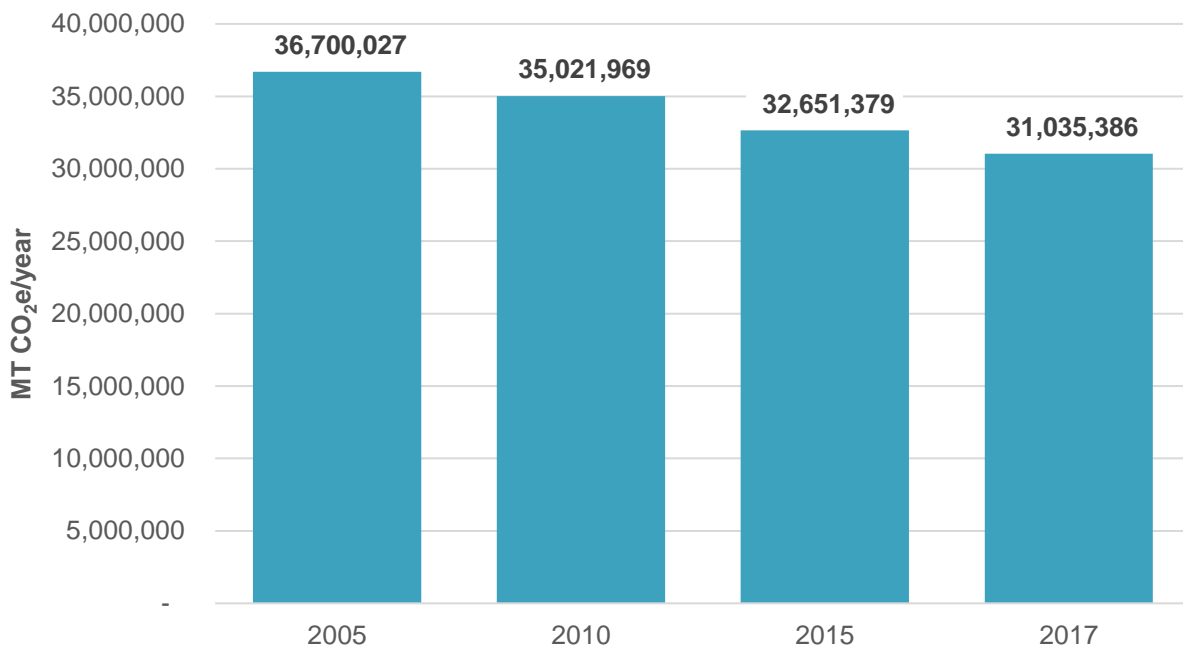
Over three-quarters of Scope 1 emissions were generated within three sub-sectors: residential buildings (31%), on-road transportation (30%), and commercial and institutional buildings and facilities (16%). Most electricity-related emissions are generated in the Stationary Energy sector, specifically from commercial and institutional buildings and facilities (39%), manufacturing industries and construction (32%), and residential buildings (27%).

Chicago's GHG Emission Trends

Preparing frequent and consistent inventory updates allows a city to evaluate progress toward its emission reduction targets. To ensure comparability among its inventories, the City updated the

previously prepared 2005 and 2010 inventories to follow the same methodology as used in the 2015 and 2017 inventories. These revisions allow the City to more directly compare community emissions in the four inventory years. Figure 2 shows the emissions trends from the 2005 to 2017 inventories, and a comparison to the City’s 2025 GHG target is shown in Figure 3. Key trends from the four inventories are shown in Tables 1 and 2 (on the next pages), including per capita emissions changes, economic emissions intensity changes, and significant emissions reductions by sub-sector.

Figure 2 – Community GHG Emissions 2005 to 2017



The City’s 2025 GHG target is to achieve emissions that are 26-28% below 2005 levels. Figure 3 plots the 26% target trajectory as a dotted line with the emissions inventory updates overlaid as a solid line. As shown, the City’s emissions are currently on track to achieve the 2025 target.

Figure 3 – 2025 GHG Target Trajectory and Progress

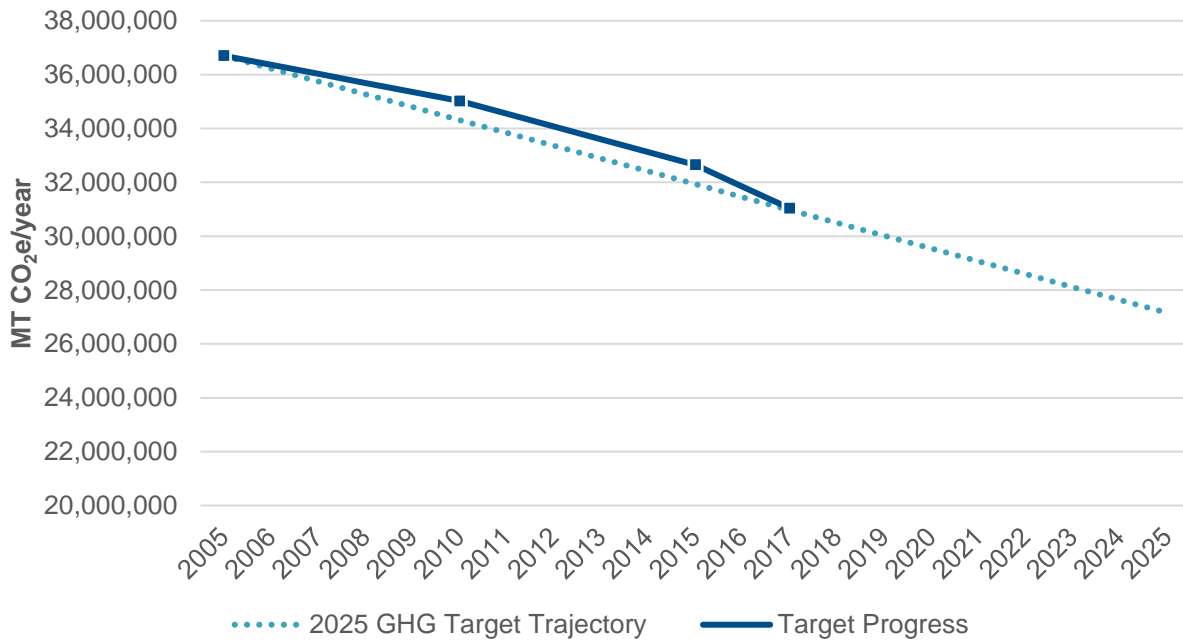


Table 1 – Community GHG Emissions Key Trends in 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	36,700,027	35,021,969	32,651,379	31,035,386
Emissions Change from 2005 (MT CO ₂ e/year)	-	-1,678,059	-4,048,648	-5,664,641
% Change from 2005	-	-4.6%	-11.0%	-15.4%
Emissions Intensity (MT CO ₂ e/capita)	12.91	12.99	12.00	11.40
Economic Emissions Intensity (MT CO ₂ e/\$100k of GDP)	7.81	6.81	5.20	4.7

Table 2 – Sub-Sectors and Activity Types with the Largest (>100,000 MT CO₂e/year) Emission Reduction 2005-2017

Rank	GPC Sector #	Sub-Sector and Activity Type	Reduction in Emissions 2005 to 2017 (MT CO ₂ e/year)
1	I.2.2 & I.3.2	Commercial and Manufacturing - Electricity	2,723,752
2	I.2.1 & I.3.1	Commercial and Manufacturing - Natural Gas	2,357,399
3	I.1.2	Residential - Electricity	1,312,748
4	II.1.1	On-Road Transportation - Gasoline and Diesel	435,017
5	II.4.1	Aviation - Jet Kerosene	167,298
6	III.4.1 & III.4.2	Wastewater Treatment and Discharge	104,630

Other key trends from the four inventories include:

1. The community achieved a modest improvement in emissions intensity from approximately 13 MT CO₂e/capita in 2005 to 11 MT CO₂e/capita in 2017.
2. During the same period, the community achieved stronger improvements in economic efficiency, experiencing a change from approximately 7.8 MT CO₂e/\$100k of gross domestic product (GDP) to 4.7 MT CO₂e/\$100k of GDP.
3. Between 2005 and 2017, considerable reductions (5.1 million MT CO₂e/year) occurred in electricity and natural gas emissions in the commercial (I.2) and manufacturing (I.3) sectors.⁸
4. Between 2005 and 2017, residential electricity emissions decreased by approximately 1.3 million MT CO₂e/year.
5. Electricity emissions per kilowatt hour (MT CO₂e/kWh) decreased by 2.2% from 2005 to 2010, by 10.0% between 2005 and 2015, and by 19.5% between 2005 and 2017.

The only large (i.e., >100,000 MT CO₂e/yr) increases in emissions occurred in residential natural gas consumption and solid waste disposal in landfills, with 22% and 51% increases from 2005 to 2017, respectively. Residential natural gas emissions increased by approximately 890,000 MT CO₂e between 2005 and 2017, and solid waste landfill emissions increased by approximately 678,000 MT CO₂e during the same period. Additional information about emission trends and the specific changes that occurred within each sector and sub-sector are described in the 'Emission Trends' section of this report.

⁸ Due to aggregation of commercial and industrial natural gas and electricity utility data in 2005, it is unknown what portion of the reduction is attributable to the commercial (I.2) or manufacturing (I.3) sectors.

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1 INTRODUCTION

The City of Chicago is recognized as a global leader in assessing, evaluating, and implementing actions to address the economic, social, and environmental risks and impacts of climate change. Cities contribute significantly to the generation of greenhouse gas (GHG) emissions, and the concentration of human activity in cities represents great opportunity for coordinated efforts to reduce GHG emissions while improving the quality of life for their citizens.

The City of Chicago has proactively pursued an aggressive GHG reduction agenda to positively influence the global impacts of climate change. In 2008, the City unveiled the Chicago Climate Action Plan (CCAP) which outlined the City's ambitious goals and actions to reduce Chicago's GHG emissions 80% below 1990 levels by the year 2050, with an interim goal for the year 2020 of 25% below 1990 levels. In June 2017, the City committed to the goal of reducing citywide greenhouse gas emissions to levels equivalent to or greater than 26-28% reduction from 2005 levels by the year 2025, which is the original commitment made by the Obama Administration as part of the United States' commitment to the Paris Accord.⁹ The City identified five categories for action to achieve these GHG reduction targets, including buildings, clean and renewable energy sources, transportation, waste and industrial pollution, and adaptation. Chicago also recently committed to the goals of powering all public buildings with 100% renewable energy by 2025¹⁰, and achieving 100% clean energy citywide by 2035.

The City has used GHG inventory updates to set its GHG reduction goals and monitor progress toward those goals over time. This City's original 1990 inventory provides historical context. Recent emissions analyses included preparing 2005, 2010, 2015, and 2017 inventories that follow the same methodology to support direct emissions analysis and target progress tracking. The City of Chicago is also a member of C40 Cities and joined the Global Covenant of Mayors for Climate and Energy (GCoM) in August 2015. The GCoM is the world's largest cooperative effort among mayors to reduce GHG emissions, track progress and prepare for the impacts of climate change. As a signatory of the GCoM in 2015, the City of Chicago pledged to conduct a GHG emission inventory in 2016. The City's 2015 GHG inventory satisfied the Covenant requirement and provided the City with data to continue monitoring progress toward its 2020, 2025, and 2050 GHG reduction goals. This 2017 GHG inventory update provides further data to support target monitoring.

Over the past decade, Chicago has implemented a diverse suite of programs to deliver energy and GHG emission reductions in the CCAP target strategies, with initiatives in areas such as renewable energy, building retrofits and energy codes, energy benchmarking, street lighting upgrades, green roofs, bike sharing, bike and pedestrian-friendly streets, public transit efficiency and ridership, waste and water consumption, recycling, and green infrastructure. These efforts

⁹ "Mayor Emanuel Signs Executive Order Committing Chicago to Guidelines of Paris Agreement." Press Release, Mayor Rahm Emanuel. June 7, 2017.
<https://www.cityofchicago.org/city/en/depts/mayor/press_room/press_releases/2017/may/ParisAgreementExecOrder.html>

¹⁰ "Mayor Emanuel Announces City Buildings to be Powered by 100 Percent Renewable Energy by 2025." Press Release, Mayor Rahm Emanuel. April 9, 2017.
<https://www.cityofchicago.org/city/en/depts/mayor/press_room/press_releases/2017/april/RenewableEnergy2025.html>

are outlined and documented in the Chicago Climate Action Plan¹¹ and Sustainable Chicago 2015¹² program reports.

1.1 Components of Report

This report represents an update to the *City of Chicago 2015 Greenhouse Gas Inventory Report* to incorporate results of the 2017 GHG inventory. It is organized in the following four sections:

- **Introduction** – describes the City’s GHG emissions target setting context and the inventory process and components
- **Community Inventory** – presents results and analysis of the 2017 inventory update, including specific descriptions of the emissions sectors and sub-sectors
- **Emissions Trends** – compares the City’s communitywide emissions trends from 2005 through 2017
- **Recommendation for Future Emissions Inventory Updates** – summarizes the recommended actions for future inventory updates to continually improve the emissions analysis process and results

1.2 Greenhouse Gases and Climate Change

Gases in the atmosphere that trap heat radiated from the Earth’s surface are called greenhouse gases (GHGs). GHGs can be either naturally occurring or emitted due to human activities. The main GHGs are carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), and fluorinated gases.

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

Each gas’ effect on climate change depends on three main factors: the quantity of each gas in the atmosphere, how long they stay in the atmosphere, and how strongly they impact global temperatures. As the concentration of GHGs in the atmosphere increases beyond natural fluctuations largely as a result of human activities, particularly from the burning of fossil fuels, the

¹¹ The Climate Action Plan and related information can be found online at <https://www.chicago.gov/city/en/progs/env/climateaction.html>.

¹² Sustainable Chicago 2015 can be found online at https://www.cityofchicago.org/city/en/progs/env/sustainable_chicago2015.html.

global climate system shifts in ways that can have significant adverse impacts on environmental, economic, and social systems alike.

In Chicago, anticipated climate change risks include increasing numbers of extreme heat days in the summer and warmer winters, migrating seasons, and increasing numbers of intense, heavy rain storms as well as periods of drought, resulting in growing flood risks, stresses on the public health system and threats to the city's economy. For more information about how climate change will impact the Chicago region, visit the Chicago Climate Action website <https://www.chicago.gov/city/en/progs/env/climateaction.html>. Chicago also recently adopted a Resilient Chicago strategy, found online at: <https://resilient.chicago.gov/>

1.3 Overview of the GHG Emissions Inventory

1.3.1 The Emissions Inventory

The City of Chicago has developed a community-scale GHG emissions inventory update for calendar year 2017. A community-scale inventory represents estimated total GHG emissions from activities occurring within the city's geographical boundaries from all sectors of a city's economy, including residential, commercial, industrial, municipal, transportation, power, and waste sectors. This section provides background information about the purpose and process of GHG emissions inventories.

1.3.2 Purpose of Emissions Inventories

A GHG emissions inventory is an estimate of GHGs emitted to, or removed from, the atmosphere over a specific period (usually one year). Preparation of an emissions inventory provides the City with an understanding of where Chicago's emissions are coming from and serves as a basis for developing and monitoring strategies that can reduce GHG emissions. The City has previously developed preliminary estimated GHG emissions for the years 1990 and 2000, as well as more complete community-scale GHG emissions inventories for the calendar years 2005, 2010, and 2015. This report presents the results of the most recent community-scale inventory for calendar year 2017.

An emissions inventory or inventory update can help with the following tasks:

- Identifying the greatest emissions sources within a geographic region, department (when preparing a local government operations inventory), or community activity;
- Comparing emission trends over time;
- Establishing the basis for developing or updating a climate action plan;
- Tracking progress in emissions reductions; and
- Setting and/or revising emissions reduction targets.

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

1.3.3 Overview of the GHG Inventory Methodology

The 2017 community inventory adheres to guidance provided in the *Global Protocol for Community-Scale Greenhouse Gas Emission Inventories* (GPC).¹³ The GPC represents an emissions analysis protocol with established and well-vetted methodological guidelines. Prior to publication of the GPC in 2014, cities developed GHG emission inventories using a variety of protocols, making comparison of inventory results difficult, whether they were year-over-year results within the same city or between cities. The GPC “provides a robust framework for accounting and reporting city-wide GHG emissions.”¹⁴ The Compact of Mayors requires signatories, such as Chicago, to complete GHG emission inventories using the GPC.

As described in the *City of Chicago 2015 Greenhouse Gas Inventory Report*, the City’s pre-2015 inventories had been prepared prior to publication of the GPC and used a variety of protocols according to best practice at the time of completion. The City’s 2015 inventory was its first to follow the GPC guidance; and during the 2015 inventory analysis, the 2005 and 2010 inventories were updated to also follow the GPC. The City’s GHG inventories from 2015 and later (including the 2017 inventory presented in this report) will use the GPC to enable consistent, transparent, and comparable GHG inventories over time and support effective emissions monitoring for GHG reduction strategies implemented in Chicago.



The GPC provides guidance on how to standardize community-scale emissions inventories.

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

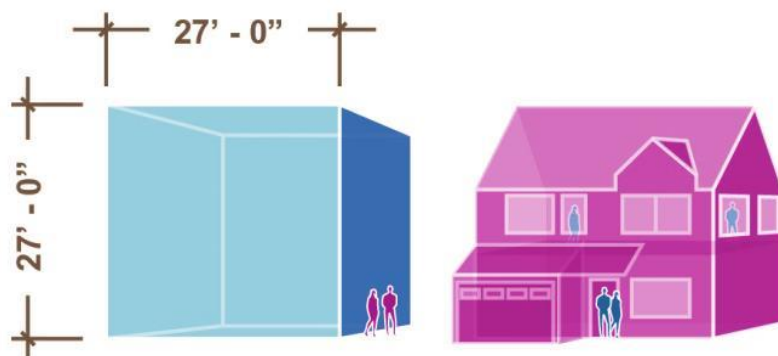
¹³ For more information about the GPC, visit the [Greenhouse Gas Protocol for Cities website](http://www.c40.org/gpc).

¹⁴ C40 Programmes Measurement & Planning. C40. <<http://www.c40.org/gpc>>, accessed October 2, 2019.

1.3.4 How Are Emissions Measured?

Emissions inventories are commonly expressed in metric tons (or tonnes¹⁵) of carbon dioxide (CO₂) equivalent per year (MT CO₂e/year). Figure 4 illustrates the scale of one metric ton of carbon dioxide as compared to a single-family house to help put a metric ton of CO₂ in context.

Figure 4 – How Large is One Metric Ton of CO₂?



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

Carbon dioxide equivalent (CO₂e) is the universal unit for comparing emissions of different GHGs to CO₂ based upon the varying global warming potentials (GWP) of each gas.¹⁶ GWPs were developed by the Intergovernmental Panel on Climate Change (IPCC) and describe how much heat a GHG can trap in the atmosphere compared to carbon dioxide, which has a GWP of 1 (because it is the gas being used as the reference). The intent is to express the impact of each different GHG in terms of the amount of CO₂ that would create the same amount of warming so that an emissions inventory consisting of many different greenhouse gases can be expressed as a single number. For example, methane has a GWP of 28, which means that 1 metric ton of methane will trap 28 times more heat than 1 metric ton of carbon dioxide, making it a more potent greenhouse gas. Some gases used in industrial applications can have a GWP thousands of times larger than CO₂.

To maintain consistency within each inventory and between the baseline and subsequent emission inventories, all GHG emissions have been quantified in units of MT CO₂e/year. To obtain CO₂ equivalent emissions, the mass of each GHG is multiplied by its respective GWP¹⁷ and then added together to give CO₂e.

The 2017 emissions inventory was prepared using a combination of empirical (measured) and estimated (modeled) data, depending on the availability of data. Data were collected from many

¹⁵ "tonne", also called a metric ton, is the standard international unit for measuring GHG emissions. It is different than a U.S. short ton (or "ton"). 1 U.S. short ton (ton) = 0.9072 metric tons (tonnes).

¹⁶ All seven GHGs that contribute to climate change covered by the Kyoto Protocol were included: carbon dioxide (CO₂), methane (CH₄), nitrous oxide (N₂O), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF₆) and nitrogen trifluoride (NF₃). However, activities within the City of Chicago emit only CO₂, CH₄, N₂O and HFCs. There were no emissions of PFCs or SF₆ identified in the emissions analysis as these emissions are generally associated with the transmission and distribution of electricity from generation facilities and/or the manufacture of semi-conductors. Fugitive emissions of HFCs are associated with refrigerant usage.

¹⁷ GWPs were sourced from the IPCC's 5th Assessment Report

sources, including City records, utility company reports, regional agencies (e.g., Chicago Metropolitan Agency for Planning), and private businesses. Activity data were then converted into greenhouse gas emissions estimates using relevant emissions factors. Emission factors represent the amount of greenhouse gases emitted by an action to a set amount of activity under that action. For example, burning a ton of coal releases different totals of carbon dioxide, methane, and nitrous oxide than burning a gallon of gasoline. The emission factors used in each equation define how much of each gas is released per a defined unit (e.g., ton, gallon, kilowatt) as a result of that activity (e.g., burning coal, burning gasoline).

Emissions were calculated using the following equation:

$$\text{Amount of Activity} \times \text{Emissions Factor} = \text{GHG Emissions for the Action}$$

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

1.3.5 What is Included in the Inventory?

The first step in developing a GHG inventory is to define the inventory boundary (i.e., the geographic area to be analyzed) and the gases and emission sources to be included in the inventory. GHG emissions can be characterized based upon where the emissions generation occurs. In GHG accounting there are three 'scopes' of GHG emissions:



SCOPE 1 Emissions from sources inside the boundary (e.g., natural gas combustion in buildings, transport fuel use in the community)



SCOPE 2 Emissions occur as a result of using grid-supplied energy inside the boundary (e.g., use of electricity in the community)



SCOPE 3 Emissions occurring outside the boundary from community activities inside the boundary (e.g., waste disposal at out-of-boundary landfills, electricity losses from transmission and distribution)

Scope 1 emissions are those where the source directly generates the emissions, such as combusting natural gas in a boiler for heating a building or an industrial process, or gasoline combustion by a bus. In a community inventory, the combustion takes place within the city boundary and the resulting emissions are a direct result of that consumption.

Scope 2 emissions are those where the activity causing the emissions takes place within the city boundary, but the actual emissions generation can occur outside of that boundary. Scope 2 emissions are limited to purchased electricity, steam, heat, and/or cooling. For example, a Chicago resident can consume electricity within their home, but that electricity may be generated outside of the city (e.g., power plants within Illinois).

Scope 3 emissions occur outside of the boundary as a result of activities within the boundary. Some Scope 3 emissions can be optionally reported within the GPC protocol, and others must be reported to provide a complete inventory. Scope 3 emissions represent sources that could be reported by other entities as Scope 1 emissions. For example, jet fuel combustion during the cruise portion of a flight would be reported by the airline as Scope 1 emissions because they are responsible for combusting the fuel. However, a city might also report these aviation emissions as Scope 3 because its citizens are responsible for using that mode of transportation and causing the emissions to occur.

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2 COMMUNITY INVENTORY

The City of Chicago 2017 community inventory estimates the total amount of GHG emissions generated from activities within the city boundary. The inventory represents emissions from residential, commercial, institutional, and industrial activities. This section introduces the emissions sectors used to organize the community inventory. It then presents the calendar year 2017 inventory results with emissions sector and sub-sector details to illustrate how emissions are generated in the City of Chicago.

2.1 Inventory Boundary

The boundary for the 2017 GHG inventory is the City of Chicago's jurisdiction within Cook County. The city occupies a 237-square-mile area and is home to approximately 2.7 million residents.¹⁸ The Chicago region has one of the world's largest and most diversified economies. Chicago is a transportation and distribution center and home to many major corporate headquarters, with manufacturing, printing, publishing, insurance and food processing contributing to the city's economy. Two major airports, O'Hare and Midway, are located within the city boundary.

2.2 GHG Emission Sources

The inventory is organized into sectors that represent the major emissions sources. These sectors are defined in the GPC and include sub-sector activities for more detailed emissions analysis. The City of Chicago's community inventory includes emissions from the following GPC Basic Level sectors and sub-sectors:

- Stationary Energy
 - Residential buildings
 - Commercial and institutional buildings and facilities
 - Manufacturing industries and construction
 - Energy industries
 - Non-specified sources – Calumet WRP biogas flare
 - Fugitive emissions from oil and natural gas systems
- Transportation
 - On-road transportation
 - Railways
 - Waterborne navigation
 - Aviation
 - Off-road transportation

¹⁸ US Census, ACS 2017 5-year estimate, Total Population. Available: https://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml

- Waste
 - Solid waste disposal
 - Biological treatment of waste
 - Wastewater treatment and discharge

2.3 Scope Limitations

The inventory presented in this report covers all GPC Basic level required emission sectors and sub-sectors. Due to data limitations, the inventory does not include emissions from the Industrial Process and Product Use (IPPU) and Agriculture, Forestry, and Other Land Use (AFOLU) sectors or scope 3 emissions in the Stationary Energy and Transportation sectors as outlined in the guidelines for GPC Basic+ level inventories. The difficulty in obtaining IPPU activity data makes this sector especially challenging to complete. Few peer cities have completed robust estimates of IPPU emission for this reason. Given the community's urban context, AFOLU emissions were determined to be negligible. In future emission inventories, the City will consider expanding the emissions inventory to include IPPU and the additional scope 3 Stationary Energy and Transportation emissions¹⁹ if the information would significantly benefit climate action planning and implementation efforts.

2.4 Emission Sectors and Sub-sectors

The community inventory is organized into the following sectors to describe the primary sources of emissions in the community. A supporting Technical Memorandum in Appendix A (provided under separate cover) provides additional details on these sectors, the emissions reporting methodology, and data sources used to guide preparation of this inventory.

2.4.1 Stationary Energy

The Stationary Energy sector includes emissions generated as a result of energy consumption in homes, offices, schools, stores, manufacturing facilities and other buildings within the community. Emissions result from the consumption of electricity from the local utility grid, as well as the direct (non-mobile) combustion of natural gas and other stationary fuel source (e.g., fuel oil). The Stationary Energy sector is organized into six sub-sectors: residential buildings, commercial and institutional buildings, manufacturing and construction industries, energy industries, non-specified sources, and fugitive emissions from oil and natural gas systems.

2.4.2 Transportation

The Transportation sector represents mobile emissions associated with different transportation modes and equipment types. The sector is organized into five sub-sectors: on-road transportation, railways, waterborne navigation, aviation, and off-road transportation. The community's on-road transportation emissions come from vehicle trips that begin and/or end within the City's

¹⁹ If included, the Scope 3 stationary emissions would represent transmission and distribution (T&D) losses from grid-supplied energy consumption (e.g., electricity), and the Scope 3 transportation emissions would represent T&D losses and emissions from transboundary journeys that are occurring outside the city boundary.

boundaries. Pass-through trips (for example, non-local drivers on the Interstate) are not included within the emissions inventory because they do not occur as a result of community activity (e.g., jobs, retail or housing in Chicago). Railway emissions estimate fuel use within the city's boundary from Amtrak, Metra Rail, CTA Rail, and the Northern Indiana Commuter Transportation District. Waterborne navigation emissions are estimated based on fuel use by private vessel operators in city. Aviation emissions are estimated from aircraft landing and takeoff activity at the city's airports. And, the community's off-road transportation emissions account for mobile sources from equipment associated with activities such as construction, landscaping, industrial manufacturing, and commercial uses.

2.4.3 Waste

The Waste sector includes emissions associated with solid waste disposal and process emissions resulting from wastewater treatment (i.e., energy use at wastewater treatment plans is included in the Energy sector). Solid waste collected by the Chicago Department of Streets and Sanitation (DSS) (for single-family residences) and by commercial haulers (for multi-family residences and commercial customers) in the community is sent to landfills outside of the City boundaries. No solid waste generated in the City of Chicago is sent to an incineration facility. Compared to solid waste collection, a minor amount of green waste collected in the city is composted.

It should be noted that waste collection activities also generate emissions from collection vehicles and landfill facility equipment. However, these emissions are represented within the Transportation sector (i.e., on-road transportation and off-road transportation). Recycling also produces emissions through collection, transport, and processing. As with waste collection, emissions from recycling collection vehicles are represented (in part) in the City's on-road transportation emissions. Emissions associated with recycling processes are only included in the City's inventory to the extent that these activities occur within the city's boundary.

2.5 Calendar Year 2017 GHG Emissions Inventory Results

As shown in Table 3 and Figures 5 through 8 on the following pages, community activities in the City of Chicago generated approximately 31,035,000 MT CO₂e in 2017. Stationary energy emissions were the largest contributor to the community inventory, accounting for 69% of total emissions. Transportation emissions contributed an additional 24%, with the waste sector responsible for the remaining 7% of community emissions.

Table 3 – 2017 Chicago GPC BASIC Community Greenhouse Gas Emissions Inventory by Sector and Sub-Sector

Sector	Emissions MT CO ₂ e/year				% of Total
	Scope 1 ^a	Scope 2 ^b	Scope 3 ^c	BASIC Total	
Stationary Energy	8,632,724	12,804,413	-	21,437,137	69%
Residential Buildings	4,893,822	3,468,411	-	8,362,233	27%
Commercial and Institutional Buildings and Facilities	2,586,242	5,119,282	-	7,705,525	25%
Manufacturing Industries and Construction	943,836	4,216,720	-	5,160,556	17%
Energy Industries	22	-	-	22	<1%
Non-Specified Source – Calumet WRP Biogas Flare	127	-	-	127	<1%
Fugitive Emissions from Oil and Natural Gas Systems	208,674	-	-	208,674	1%
Transportation	7,258,208	246,761	-	7,504,969	24%
On-road Transportation	4,795,501	-	-	4,795,501	15%
Railways	106,179	246,761	-	352,940	1%
Waterborne Navigation	2,674	-	-	2,674	<1%
Aviation	1,569,375	-	-	1,569,375	5%
Off-road Transportation	784,479	-	-	784,479	3%
Waste	2,326	-	2,090,953	2,093,279	7%
Solid Waste Generated in the City	-	NA	1,995,387	1,995,387	6%
Biological Waste Generated in City	-	NA	103	103	<1%
Wastewater Treatment and Discharge	2,326	NA	95,463	97,789	<1%
TOTAL	15,893,258	13,051,174	2,090,953	31,035,386	100%

Key:

- ^a Scope 1 emissions are GHG emissions from sources located within the city boundary
- ^b Scope 2 emissions are GHG emissions resulting from the use of grid-supplied electricity, heat, steam and/or cooling within the city boundary
- ^c Scope 3 emissions are all other GHG emissions that occur outside the city boundary as a result of activities taking place within the city boundary

Figure 5 – 2017 GPC BASIC Community GHG Emissions Inventory – Percent of Total Emissions by Sector

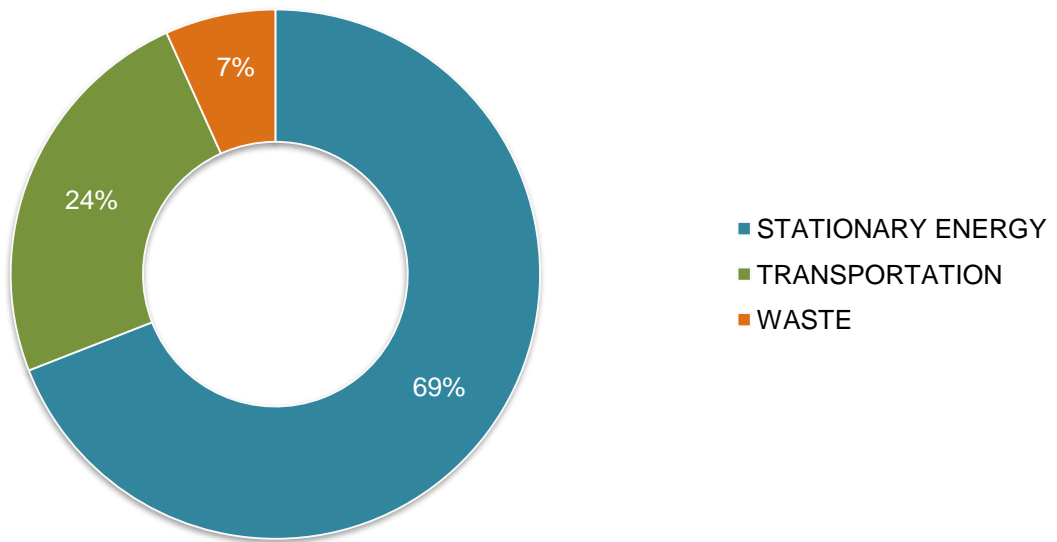


Figure 6 – 2017 GPC BASIC Community GHG Emissions Inventory – Total Emissions by Sector

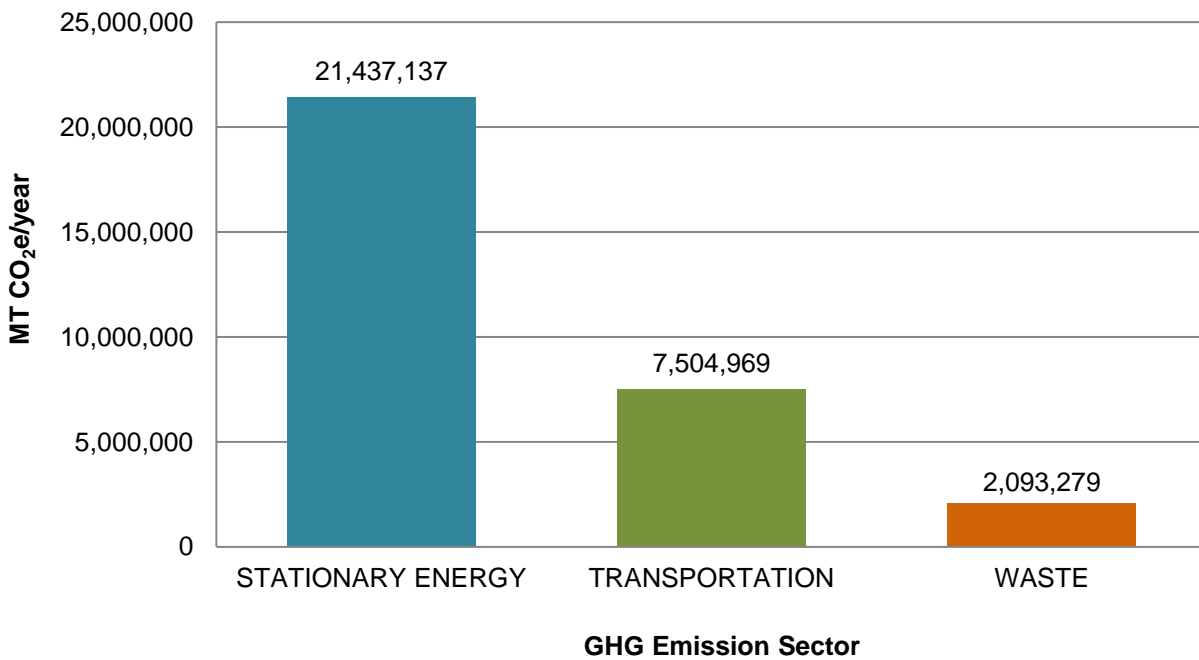


Figure 7 – 2017 GPC BASIC Community GHG Emissions Inventory – Percent of Total Emissions by Sub-Sector

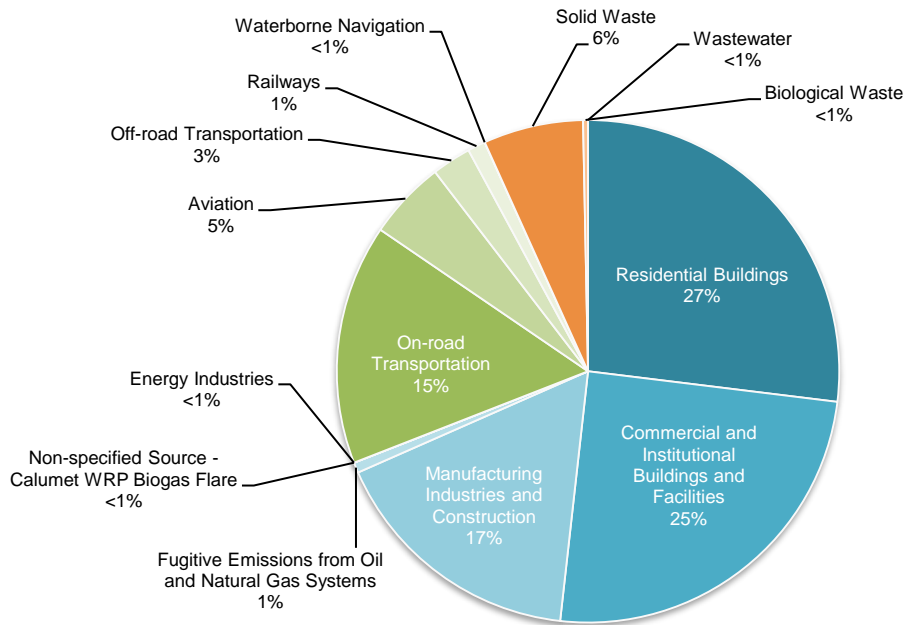
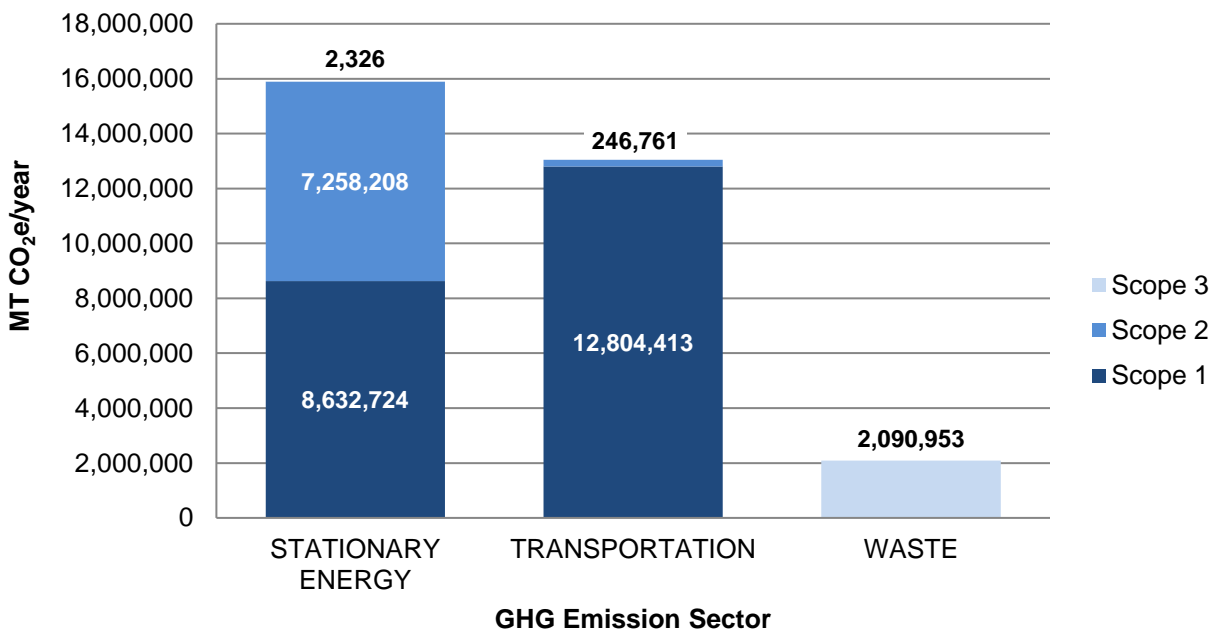


Figure 8 – 2017 GPC BASIC Community GHG Emissions Inventory – Total Emission by Sector and Scope

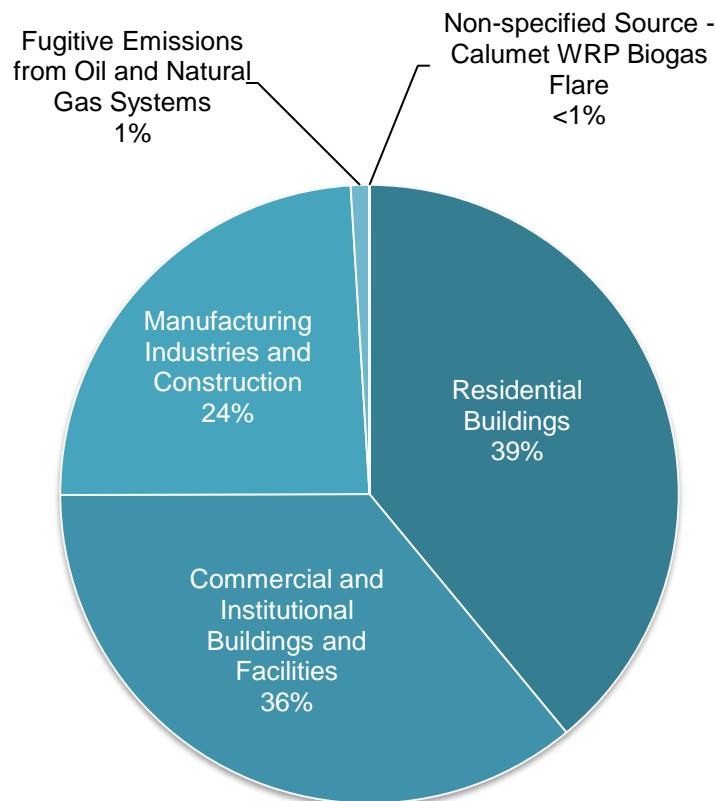


The following sections provide greater detail on the distribution of emissions within each sector. Emissions are represented according to sectors, sub-sectors, and fuel-type.

2.6 Stationary Energy

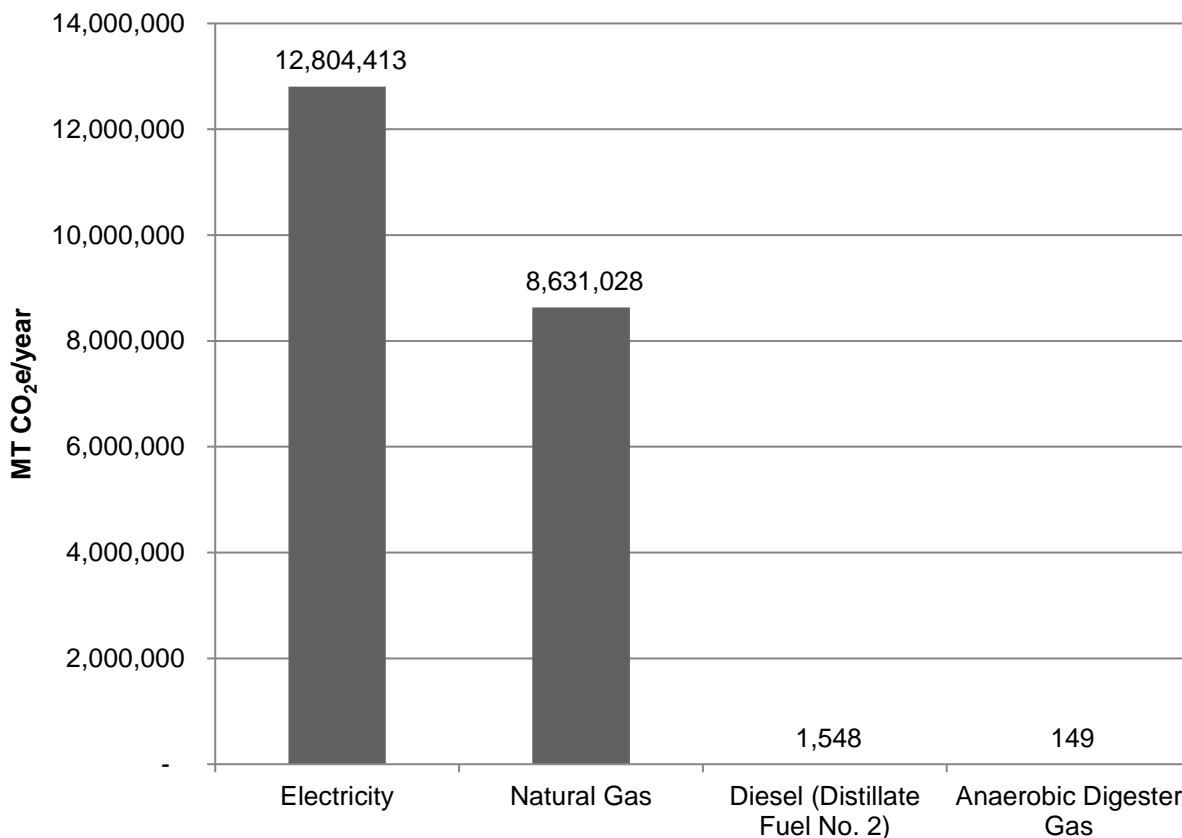
Stationary energy emissions from buildings account for 69% of total community emissions. Residential buildings generate 39% of the stationary energy sector emissions, commercial and institutional buildings provide an additional 36%, and manufacturing and construction industries contribute 24% of the sector total. The remaining stationary energy sector emissions include fugitive emissions from oil and natural gas distribution systems (1%), biogas flaring at the Calumet water reclamation plant (<1%), and energy industries (<1%), as shown in Figure 9.

Figure 9 – 2017 GPC BASIC Community GHG Emissions Inventory – Percent of Total Stationary Energy Sector GHG Emissions by Sub-Sector



The stationary energy sector can also be analyzed according to the type of energy used (Figure 10). Electricity use (Scope 2) was the largest source of GHG emissions in the stationary energy sector, generating approximately 60% of the sector's emissions. Natural gas combustion and fugitive emissions (Scope 1) contributed 40%. The remaining emissions (<0.01%) were the result of combusting distillate fuel oil No. 2 and anaerobic digester gas at the Calumet WRP.²⁰

Figure 10 – 2017 Stationary Energy Emissions by Fuel Type



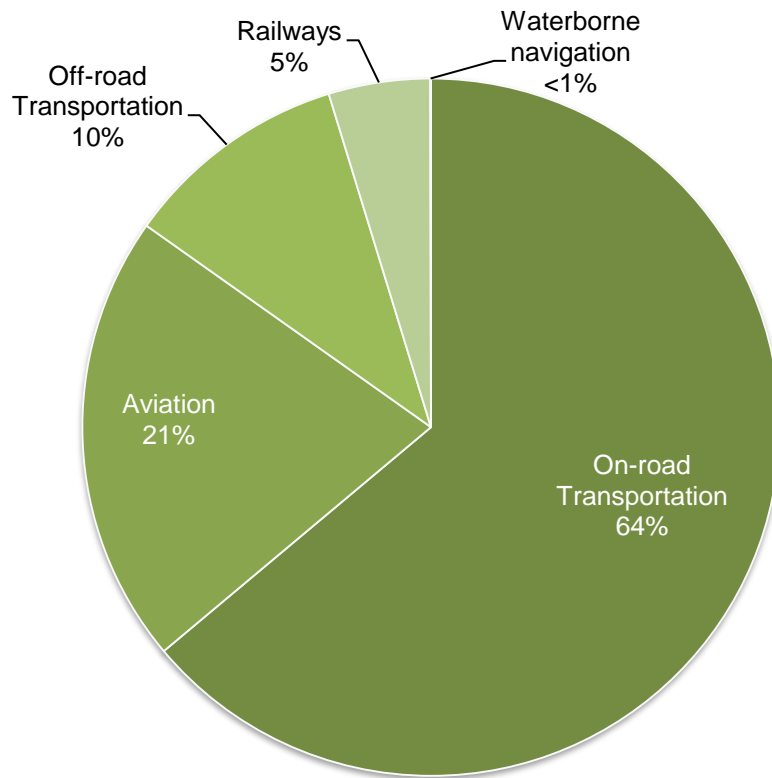
Electricity use by the commercial and institutional sub-sector contributed 24% of the total stationary energy sector emissions, while the manufacturing industries and construction sub-sector contributed approximately 20% and residential buildings contributed 16%. Natural gas use in the residential sub-sector contributed 23% of total sector emissions, while commercial and institutional buildings contributed 12% and manufacturing industries and construction contributed an additional 4% of emissions.

²⁰ In previous inventory years, this sector also included emissions from LPG fuel use, which was associated with facilities subject to the EPA's Mandatory Reporting Rule. The EPA FLIGHT database was queried for each inventory year to identify sources of stationary fuel use that would not otherwise be reported through the utility data collection process. In the 2017 reporting year, no applicable facilities reported use of LPG fuel within the city's boundary, and therefore LPG emissions were not identified as a stationary fuel emissions sources in the 2017 inventory.

2.7 Transportation

Transportation sector emissions account for 24% of total community emissions. As shown in Figure 11, most transportation emissions come from on-road vehicles driving on roadways within the community (64%). Aviation accounts for 21% of transportation emissions. Off-road equipment, such as lawnmowers, forklifts, and construction equipment provide an additional 10% of sector emissions. Railway operations within the community, including Amtrak, CTA Rail, Metra Rail, and Northern Indiana Commuter Transportation District, contribute approximately 5% of sector emissions. Waterborne navigation represents the remainder (<1%).

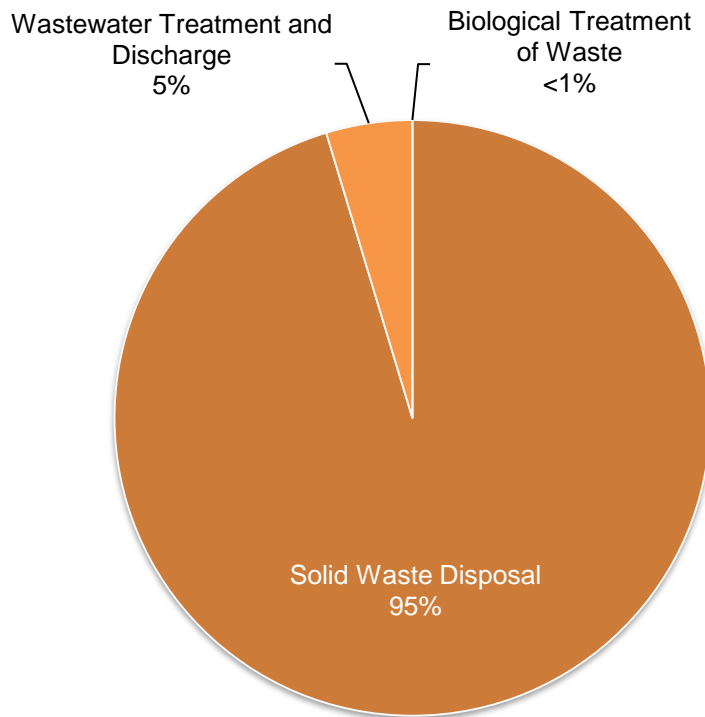
Figure 11 – 2017 GPC BASIC Community GHG Emissions Inventory – Percent of Total Transportation Sector GHG Emissions by Sub-Sector



2.8 Waste

Accounting for 7% of total community emissions, the Waste sector includes emissions from solid waste landfilling, biological treatment of waste (e.g., composting) and process emissions resulting from wastewater treatment. The majority of waste sector emissions result from landfilling solid waste collected in the community (95%). Process emissions from wastewater treatment plants contribute 5% of the sector total, while biological treatment of green waste contributes <1% of emissions, as shown in Figure 12.

Figure 12 – 2017 GPC BASIC Community GHG Emissions Inventory – Percent of Total Waste Sector GHG Emissions by Sub-Sector



3 EMISSIONS TRENDS

The City of Chicago’s community greenhouse gas emissions have decreased from 2005 to 2017 as shown in Figure 13, with the rate of reductions increasing between each inventory period. Table 4 on the following page presents the four emissions inventory results by sector and sub-sector. While emissions from interim years have not been quantified, the four inventories indicate a relatively steady decline in emissions during this analysis period. Between 2005 and 2010, total emissions decreased by 4.6% or by 0.9% per year. From 2005 to 2015, total emissions decreased by 11.0% while the rate of emissions reductions between 2010 and 2015 was 1.4% per year. Between 2005 and 2017, emissions decreased by 15.4%, accelerating to a rate of 2.5% per year between the 2015 and 2017 inventories.

Figure 13 – Community GHG Emissions Trends 2005 to 2017

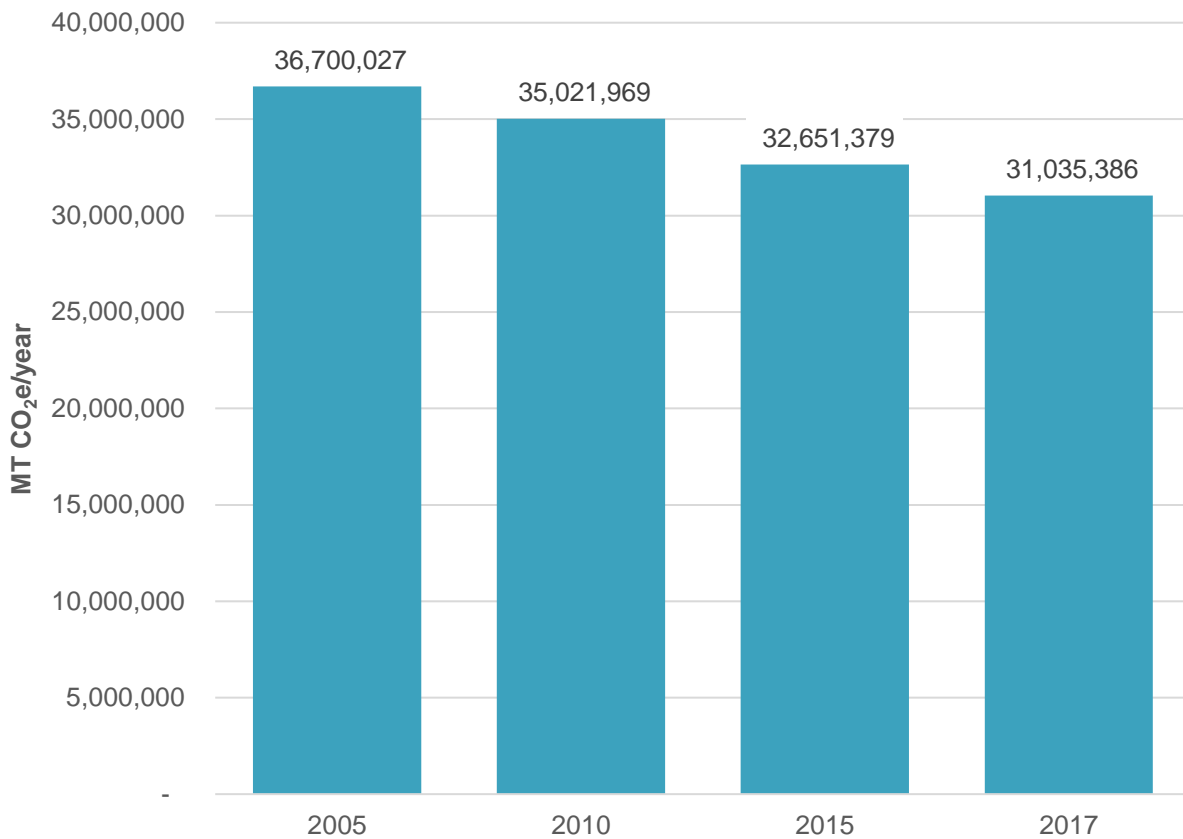


Table 4 – Emissions Inventory 2005 to 2017

Sector	2005 (MT CO₂e/year)	2010 (MT CO₂e/year)	2015 (MT CO₂e/year)	2017 (MT CO₂e/year)
Stationary Energy	26,982,932	25,362,795	23,500,082	21,437,137
Residential Buildings	8,785,240	9,815,020	9,127,835	8,362,233
Commercial and Institutional Buildings and Facilities and Manufacturing Industries and Construction ²¹	17,868,978	15,088,042	13,972,283	12,866,081
Energy Industries	30	21	28	22
Water Conveyance and Treatment ²²	Included Elsewhere	145,262	98,327	Included Elsewhere
Non-Specified Sources – Calumet WRP Energy Use ²³	77,708	91,359	77,482	127
Fugitive Emissions from Oil and Natural Gas Systems	250,975	223,091	224,126	208,674
Transportation	8,197,126	7,948,817	8,048,463	7,504,969
On-road Transportation	5,230,518	5,081,092	5,100,066	4,795,501
Railways	407,750	408,206	394,207	352,940
Waterborne Navigation	4,566	4,343	4,366	2,674
Aviation	1,736,673	1,551,247	1,551,941	1,569,375
Off-road Transportation	817,618	903,930	997,883	784,479
Waste	1,519,970	1,710,357	1,102,834	2,093,279
Solid Waste Generated in the City	1,317,550	1,542,561	998,888	1,995,387
Biological Waste Generated in the City	0	25	112	103
Wastewater Treatment and Discharge	202,420	167,771	103,835	97,789
Total	36,700,027	35,021,969	32,651,379	31,035,386
% Reduction below 2005 Levels	-	4.6%	11.0%	15.4%

Figure 14 on the following page charts the City's 2025 GHG target trajectory from the 2005 base year through the 2025 target year, illustrating the 26% reduction below 2005 target as a dashed line. The solid blue line illustrates the City's four GHG inventories (i.e., 2005, 2010, 2015, and 2017) and interpolates the line between each to show how the emissions declines in Figure 13

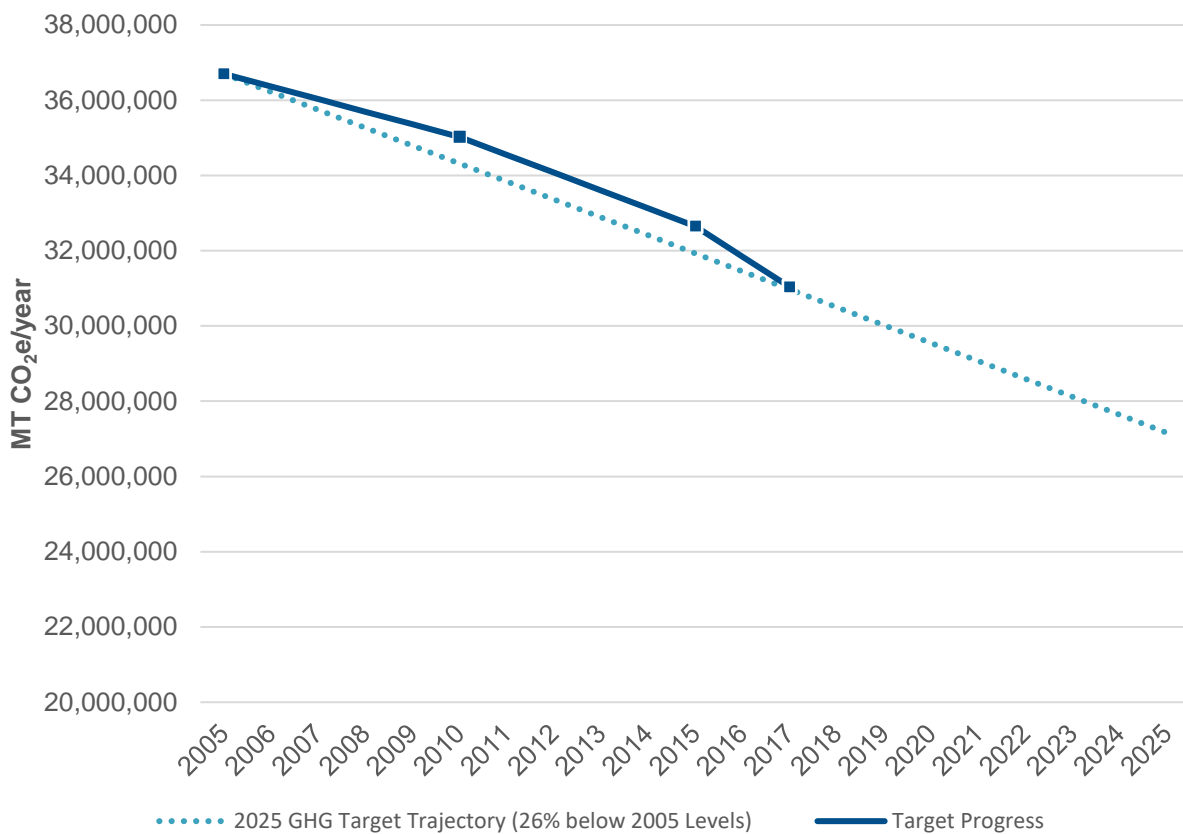
²¹ The 'Commercial and Institutional Buildings and Facilities' and 'Manufacturing Industries and Construction' subsectors are combined in this table because emissions in these subsectors are not reported separately in all inventory years due to how utility data was reported at the time each inventory was prepared.

²² The GPC protocol does not require cities to report water conveyance emissions as a separate emissions subsector. The 2010 and 2015 inventories had identified these emissions separately, though the 2005 inventory did not. At the time the 2017 inventory was prepared, the City and project team decided to discontinue this additional analysis step in the 2017 and future inventories, and simply report the water conveyance-related emissions within the I.2 Commercial and Institutional Buildings and Facilities subsector.

²³ As with water conveyance emissions described in the preceding note, the GPC protocol does not require cities to separately report energy use from wastewater treatment facilities. The 2005, 2010, and 2015 inventories had separately reported natural and electricity emissions from the Calumet WRP, which is within the city's boundary. At the time the 2017 inventory was prepared, the City and project team decided to discontinue this additional analysis step in the 2017 and future inventories, and simply report wastewater treatment energy use emissions within the I.2 Commercial and Institutional Buildings and Facilities subsector. The remaining emissions shown in 2017 in the Non-Specified Sources subsector are associated with anaerobic digester biogas flaring at the Calumet WRP that is not used to generate energy.

above compare to the City’s near-term GHG target. As shown, actual emissions in 2010 and 2015 were slightly higher than the GHG target levels, but community emissions returned to the necessary target trajectory in the 2017 inventory update.

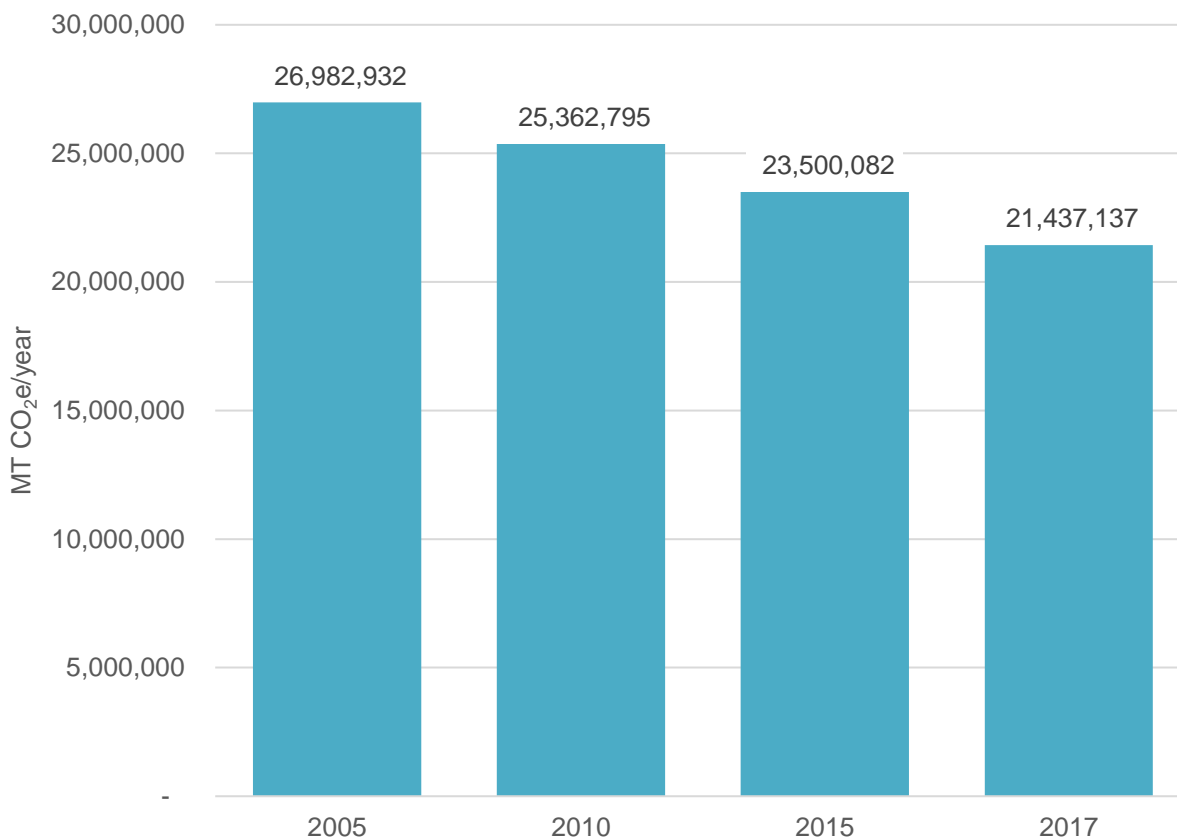
Figure 14 – 2025 GHG Target Trajectory and Progress



3.1 Stationary Energy

As shown in Figure 15 on the following page, the city’s stationary energy sector emissions decreased in each inventory period from 2005 to 2017, achieving reductions below 2005 levels of 6.0%, 12.9%, and 20.6% in 2010, 2015, and 2017, respectively. The following sections present a description of the changing electricity emissions factors in each inventory year, and then detailed emissions trends within the stationary energy sub-sectors.

Figure 15 – Stationary Sector Emissions Trends 2005 to 2017



3.1.1 Electricity Emissions Factor

Emissions are calculated by multiplying the amount of activity (e.g., total kilowatt hours consumed per year) occurring in a community by an activity-specific emission factor (e.g., tonnes of carbon dioxide equivalent per kWh). A change in emissions can be achieved through a change in activity and/or a change in the emission intensity of the emission factor. As is common practice in community-scale inventories, the City chose to hold the stationary energy sector fossil fuel combustion-related emission factors constant for all inventories. For this reason, changes in fossil fuel combustion-related emissions since 2005 result solely from changes in activity levels.

The emission factor for electricity is variable, however. An electricity emission factor is an aggregate emission factor that reflects the diversity of generation sources (fuel and technologies) used to produce the community's electricity. To ensure comparability among the inventories, the City chose to use the United States Environmental Protection Agency's (U.S. EPA) electricity emission factor for the grid region within which Chicago is located. Table 5 demonstrates the decline in carbon emissions intensity of Chicago's electricity based on this source, which decreased below 2005 levels by 2.2%, 10.0%, and 19.5% in 2010, 2015, and 2017, respectively. These lower electricity emission factors are an important driver for the stationary energy sector emissions reductions shown in Table 4.

Table 5 – U.S. EPA eGrid for RFCW Sub-region Electricity Emission Factor 2005-2017

Metric	2005	2010	2015	2017	Unit
Electricity Emission Factor	1,545.16	1,510.55	1,390.95	1,243.54	lbs CO ₂ e/MWh
% Change from 2005	-	-2.2%	-10.0%	-19.5%	percentage

Source: US EPA eGRID electricity emissions factors for RFCW sub-region, with IPCC AR5 global warming potential values for methane and nitrous oxide.

3.1.2 Residential Buildings

As shown in Table 6, total residential energy emissions decrease by 4.8% from 2005 to 2017. Tables 7 and 8 demonstrate that while electricity emissions and consumption decreased during this period, natural gas consumption and emissions increased in the sub-sector.

It should be noted that Table 6 shows that residential energy emission intensity was higher in 2010 (3.64 MT CO₂e/capita) and 2015 (3.36 MT CO₂e/capita) than in 2005 (3.09 MT CO₂e/capita), before falling below 2005 levels in the 2017 inventory (3.07 MT CO₂e/capita). Residential energy continues to represent a large portion of the community's total emissions, so this trend may indicate an area that requires additional analysis as household natural gas consumption and the related emissions have trended higher (with some variation) since 2005.²⁴ Determining the cause(s) of this increase could assist in future emission reduction efforts.

Table 6 – Residential Energy GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	8,785,240	9,815,020	9,127,835	8,362,233
Change from 2005 (MT CO ₂ e/year)	-	1,029,780	342,595	-423,007
% change from 2005	-	11.7%	3.9%	-4.8%
Emission Intensity (MT CO ₂ e/capita)	3.09	3.64	3.36	3.07

Table 7 – Residential Energy GHG Emissions by Activity Type 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Natural Gas (MT CO ₂ e/year)	4,004,082	5,301,154	5,264,148	4,893,822
Electricity (MT CO ₂ e/year)	4,781,158	4,513,865	3,863,687	3,468,411

Table 8 – Residential Energy Activity Data by Activity Type 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Natural Gas (therms/years)	753,858,547	998,061,613	991,094,385	921,372,194
Electricity (kWh/years)	6,821,722,949	6,587,894,578	6,123,852,602	6,149,008,543

²⁴ The observed increase in natural gas consumption occurred in each inventory year since 2005 even though 2005, 2010, and 2015 had similar numbers of heating degree days (HDD); 2017 had noticeably fewer. 2005 had 6,037 HDD; 2010 had 6,028 HDD; 2015 had 6,102 HDD; and 2017 had 5,469 HDD. All four years were below the annual average of 6,339 heating degree days. Source: ENERGY STAR Portfolio Manager Degree Days Calculator for O'hare Airport Weather Station: <https://portfoliomanager.energystar.gov/pm/degreeDaysCalculator>

3.1.3 Commercial and Manufacturing Buildings and Facilities

Due to the aggregation of commercial and manufacturing activity data by natural gas and electricity utilities in 2005, the City is unable to compare commercial (I.2) and manufacturing (I.3) emissions separately. As whole, commercial and manufacturing emissions decreased below 2005 levels by 15.6%, 21.8%, and 28.0% in 2010, 2015, and 2017, respectively. As demonstrated in Table 9, natural gas and electricity-related emissions decreased by approximately 3 million MT CO₂e in 2010, 4 million MT CO₂e in 2015, and 5 million MT CO₂e in 2017, from 2005 levels. These reductions made the commercial and manufacturing sub-sectors the largest sources of reductions in each inventory year. Tables 10 and 11 show that during this analysis period, natural gas emissions and consumption decreased substantially from 2005 to 2010 (42%) and then slightly increased through 2017 (4% from 2010 to 2017). Electricity consumption decreased each inventory year since 2005 for total reductions of 3.2% from 2005 to 2017. The corresponding electricity emissions decreased 22.1% over the same period. In addition to natural gas, several other stationary fuels have been consumed within these sub-sectors during the analysis period, including gas oil, LPG, and kerosene. However, these other fuel types represent insignificant emissions sources compared to natural gas and electricity use.

Table 9 – Commercial and Manufacturing Energy GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	17,868,978	15,088,042	13,972,283	12,866,081
Change from 2005 (MT CO ₂ e/year)	-	-2,780,936	-3,896,696	-5,002,897
% change from 2005	-	-15.6%	-21.8%	-28.0%
Emission Intensity (MT CO ₂ e/capita)	6.29	5.60	5.14	4.73
GDP (\$100,000 in 2019 dollars)	\$4,698,541	\$5,144,260	\$6,277,343	\$6,598,550
Economic Efficiency (MT CO ₂ e/\$100k GDP) ²⁵	3.80	2.93	2.23	1.95

Table 10 – Commercial and Manufacturing Energy GHG Emissions by Activity Type²⁶ 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Natural Gas (MT CO ₂ e/year)	5,882,303	3,393,877	3,468,593	3,528,531
Gas Oil (MT CO ₂ e/year)	288	304	5,865	1,548
Liquefied Petroleum Gas (LPG) (MT CO ₂ e/year)	39	9	6,612	-
Kerosene (MT CO ₂ e/year)	102	397	-	-
Electricity (MT CO ₂ e/year)	11,986,247	11,693,455	10,491,213	9,336,002

²⁵ Calculated based on the total Chicago metropolitan statistical area GDP values from the U.S. Department of Commerce Bureau of Economic Analysis. Accessed December 2019. Available: <<https://apps.bea.gov/itable/iTable.cfm?ReqID=70&step=1>>

²⁶ The variation in commercial and manufacturing gas oil, LPG, and kerosene activity is based on facilities reporting under the US EPA mandatory emission reporting requirements. From inventory year to year, some facilities discontinue reporting while new facilities begin; the fuel types and volumes used in these facilities also varies. As shown in Table 10, these additional emissions sources represent less than 1% of stationary fuel use in each inventory year.

Table 11 – Commercial and Manufacturing Energy Activity Data by Activity Type 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Natural Gas (therms/year)	1,107,475,838	638,973,741	653,040,645	664,325,349
Gas Oil (gallons/year)	28,069	29,647	572,556	151,107
LPG (scf/years)	255,100	60,144	42,741,383	-
Kerosene (gallons/year)	10,006	38,975	-	-
Electricity (kWh/year)	17,101,892,743	17,066,360,331	16,628,324,976	16,551,430,085

3.1.4 Non-Specified Sources – Water and Wastewater Infrastructure

The GPC protocol does not require cities to separately report energy emissions associated with water conveyance or wastewater treatment. Energy use associated with these activities would commonly be represented in sub-sector I.2 Commercial and Institutional Buildings and Facilities. However, cities may separately report these emissions types if desired. The City’s 2005, 2010, and 2015 inventories did report these emissions separately to varying degrees (e.g., the 2005 inventory did not report water conveyance separately, while the 2010 and 2015 inventories did), as shown in Table 12. However, during preparation of the 2017 inventory, the City and project team decided to discontinue this additional analysis step in the 2017 and future inventories, and simply report these emissions activities within the Commercial and Institutional Buildings and Facilities subsector. All four inventories do report emissions associated with flaring anaerobic digester biogas captured at the City’s Calumet Water Reclamation Plant. All wastewater treatment facility process emissions are reported in the inventories’ Waste sectors.

Given the change in reporting approach to be implemented in future inventories, the results shown in Tables 12 and 13 are provided for informational purposes only. Moving forward, the natural gas and electricity emissions from these tables will be combined with the previous section, where the emissions will represent a minor increase to the Commercial and Manufacturing sub-sector emissions currently shown (e.g., combining these tables would increase the 2015 emissions shown in Table 9 by approximately 1.3%).

Table 12 – Wastewater and Water Energy GHG Emissions 2005-2017

Total Sub-Sector Emissions	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	77,708	236,622	175,810	127
Change from 2005 (MT CO ₂ e/year)	-	158,914	98,102	-77,581
% change from 2005	-	204.5%	126.2%	-99.8%
Emission Intensity (MT CO ₂ e/capita)	0.03	0.09	0.06	0.00

Table 13 – Wastewater and Water Energy GHG Emissions by Activity Type 2005-2017

Emissions by Fuel	2005	2010	2015	2017
Natural Gas (MT CO ₂ e/year)	3,627	81,888	48,940	-
Sludge Gas (MT CO ₂ e/year)	573	638	223	127
Electricity (MT CO ₂ e/year)	73,507	154,095	126,646	-

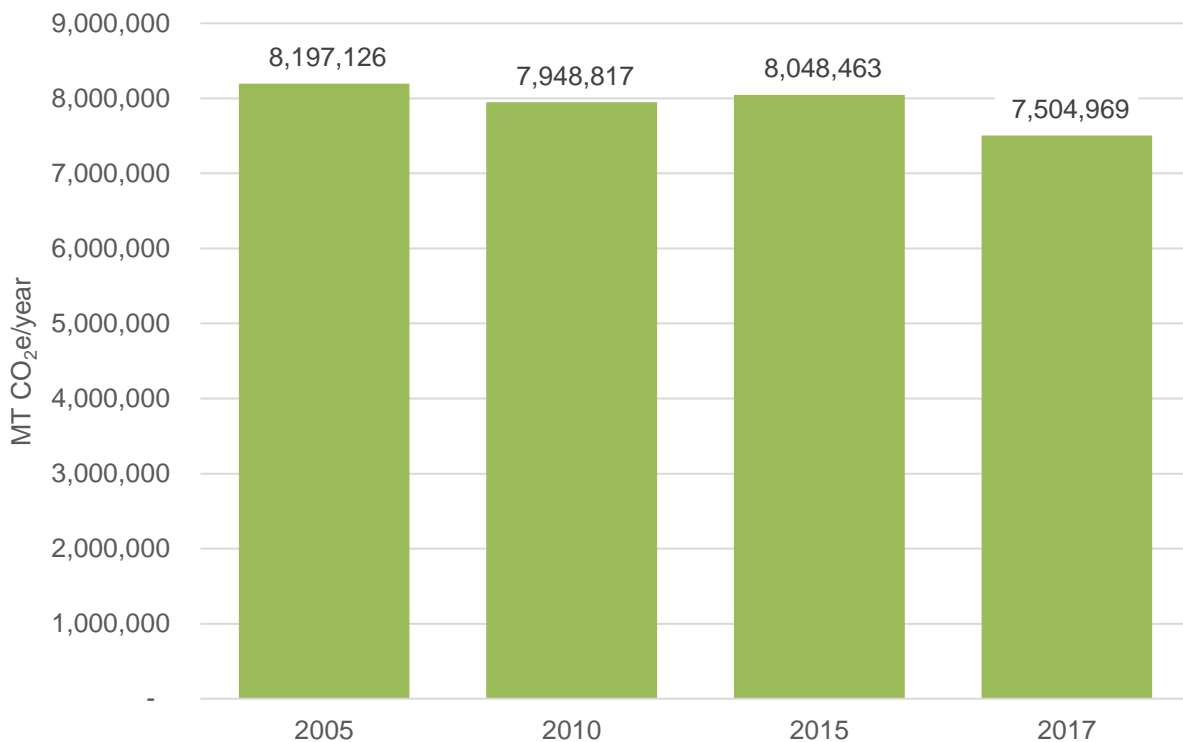
3.1.5 Fugitive Natural Gas

Fugitive natural gas emissions are calculated in relationship to the amount of natural gas consumption. Total natural gas emissions decreased from 250,975 MT CO₂e in 2005 to 223,091 MT CO₂e in 2010, 224,126 MT CO₂e in 2015, and 208,674 MT CO₂e in 2017. Emissions in 2017 were approximately 16.9% below 2005 levels.

3.2 Transportation

Transportation sector emissions decreased in each inventory year since the 2005 base year, as shown in Figure 16. Emissions decreased below 2005 levels by 3.0%, 1.8%, and 8.4% in 2010, 2015, and 2017, respectively. The following sections present a description of the emissions trends within each transportation sub-sector.

Figure 16 – Transportation Sector Emissions Trends 2005 to 2017



3.2.1 On-Road Transportation

Emissions from on-road vehicles have decreased gradually between 2005 and 2017 as shown in Table 14. Total on-road emissions decreased by 2.9% from 2005 to 2010, by 2.5% from 2005 to 2015, and by 8.3% from 2005 to 2017. At the same time emission intensities on a per capita basis has varied within the sub-sector, increasing in 2010 from 2005 levels and then decreasing through 2017.

Table 14 – On-Road Transportation GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	5,230,518	5,081,092	5,100,066	4,795,501
Change from 2005 (MT CO ₂ e/year)	-	-149,426	-130,452	-435,017
% change from 2005	-	-2.9%	-2.5%	-8.3%
Emission Intensity (MT CO ₂ e/capita)	1.84	1.88	1.87	1.76

Table 15 shows that most emission reductions since 2005 came from passenger cars and passenger trucks. Emissions increased from motorcycles, transit buses, and commercial trucks. Table 16 shows that vehicle miles traveled increased from 2005 to 2017 among all vehicle types, with the largest increases from commercial trucks operating in the city. Passenger vehicle and truck activity data increases were more gradual during that time period.

Table 15 – On-Road Transportation GHG Emissions (MT CO₂e/year) by Vehicle Type in 2005-2017

Vehicle Type	2005	2010	2015	2017	% Change 2005-2017
Motorcycle	54,697	53,479	55,430	55,637	1.7%
Passenger Car	2,661,279	2,544,172	2,535,798	2,434,313	-8.5%
Passenger Truck	1,622,157	1,551,376	1,551,684	1,384,846	-14.6%
Light Commercial Truck	120,391	124,301	125,037	110,777	-8.0%
Transit Bus	60,059	64,422	66,511	64,213	6.9%
Single Unit Short-haul Truck	243,541	248,941	263,712	249,936	2.6%
Combination Short-haul Truck	440,759	465,231	472,283	466,528	5.8%
Combination Long-haul Truck	27,635	29,170	29,612	29,251	5.8%

Table 16 – On-Road Transportation Activity Data (vehicle miles traveled/year) by Vehicle Type in 2005-2017

Vehicle Type	2005	2010	2015	2017	% Change 2005-2017
Motorcycle	149,071,602	145,341,345	150,474,692	150,979,313	1.3%
Passenger Car	6,577,842,775	6,411,765,447	6,635,312,030	6,657,165,927	1.2%
Passenger Truck	2,963,938,867	2,889,105,359	2,989,834,189	2,999,681,432	1.2%
Light Commercial Truck	219,972,944	231,483,296	240,925,040	239,951,105	9.1%
Transit Bus	60,758,821	65,324,071	67,010,401	64,822,866	6.7%
Single Unit Short-haul Truck	207,395,590	213,710,546	222,173,642	221,332,445	6.7%
Combination Short-haul Truck	233,721,111	246,759,230	254,503,450	257,114,045	10.0%
Combination Long-haul Truck	14,654,140	15,471,620	15,957,177	16,120,859	10.0%

Table 17 on the following page shows that despite increases in vehicle miles traveled, improved fuel efficiency within the vehicle fleet contributed to emissions reductions among certain vehicle types. Passenger cars and trucks and light commercial trucks experienced the most significant

fuel efficiency increases since 2005, based on the EPA's MOVE travel model outputs provided by staff at Chicago Metropolitan Agency for Planning (CMAP). In the past, these changes have been caused, in part, by Federal fuel efficiency requirements (CAFE standards).

Table 17 – On-Road Transportation Emission Factor (g/mile) by Vehicle Type in 2005-2017

Vehicle Type	2005	2010	2015	2017	% Change 2005-2017
Motorcycle	366.9	368.0	368.4	368.51	0.4%
Passenger Car	404.6	396.8	382.2	365.67	-9.6%
Passenger Truck	547.3	537.0	519.0	461.66	-15.6%
Light Commercial Truck	547.3	537.0	519.0	461.66	-15.6%
Transit Bus	988.5	986.2	992.5	990.59	0.2%
Single Unit Short-haul Truck	1,174.3	1,164.8	1,187.0	1,129.23	-3.8%
Combination Short-haul Truck	1,885.8	1,885.4	1,855.7	1,814.48	-3.8%
Combination Long-haul Truck	1,885.8	1,885.4	1,855.7	1,814.48	-3.8%

It should be noted that the emission factor and vehicle miles traveled data shown above includes both gasoline and diesel vehicles within the same vehicle class. The CMAP regional travel model does not analyze gasoline and diesel separately, so the data represents an aggregation of the two fuels. Gasoline and diesel vehicle miles traveled were then multiplied by a weighted composite (gasoline and diesel) emission factor (grams CO₂e/mile).

3.2.2 Railways

Railway emissions are a relatively minor contributor to total communitywide emissions and remained relatively stable on a per capita basis from 2005 to 2017 as shown in Table 18. Tables 19 and 20 (on the following page) show that minor increases in diesel consumption and corresponding emissions were offset by slightly lower electricity consumption and lower electricity emissions factors. Between 2005 and 2017 emissions fell by 13.4%, which can be primarily attributed to the improved electricity emissions factor.

Table 18 – Railways GHG Emissions (MT CO₂e/year) in 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	407,750	408,206	394,207	352,940
Change from 2005 (MT CO ₂ e/year)	-	455	-13,543	-54,810
% change from 2005	-	0.1%	-3.3%	-13.4%
Per capita Emission (MT CO ₂ e/capita)	0.14	0.15	0.14	0.13

Table 19 – Railways GHG Emissions (MT CO₂e/year) by Activity Type in 2005-2017

Emissions by Fuel	2005	2010	2015	2017
Diesel (MT CO ₂ e/year)	97,112	101,741	109,459	106,179
Electricity (MT CO ₂ e/year)	310,639	306,465	284,748	246,761

Table 20 – Railways Activity Data in 2005-2017

Activity by Fuel	2005	2010	2015	2017
Diesel (gallons/year)	9,427,141	9,876,524	10,625,785	10,307,342
Electricity (kWh/year)	443,216,926	447,278,878	451,318,520	437,473,398

3.2.3 Waterborne Navigation

Waterborne navigation-related emissions decreased slightly from 2005 to 2015, and more significantly by 2017, as shown in Table 21. However, this emissions source is a minor contributor to total community emissions. The decrease in emissions by fuel type shown in Table 22 is a result of the varied responses to requests for information the City made to various boat operators. The set of operators represented (i.e., those who responded to the data request) in each inventory year varies slightly, with a lower response rate noticed in 2017. There is currently no central database to be queried for this activity data.

Table 21 – Waterborne GHG Emissions (MT CO₂e/year) in 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	4,566	4,343	4,366	2,674
Change from 2005 (MT CO ₂ e/year)	-	-223	-201	-1,892
% change from 2005	-	-4.9%	-4.4%	-41.4%
Per capita Emission (MT CO ₂ e/capita)	<0.01	<0.01	<0.01	<0.01

Table 22 – Waterborne GHG Emissions (MT CO₂e/year) by Activity Type in 2005-2017

Emissions by Fuel	2005	2010	2015	2017
Diesel (MT CO ₂ e/year)	3,428	3,260	4,366	2,247
Biodiesel (MT CO ₂ e/year)	-	-	-	427
Motor gasoline (MT CO ₂ e/year)	1,138	1,083	-	-

3.2.4 Aviation

Aviation landing and takeoff (Scope 1) emissions decreased by approximately 10% from 2005 to 2017 as shown in Table 23. Aviation emissions per capita remained relatively stable during the same period. The aviation emissions reduction was the result of reduced flight operations at

O'Hare and Midway airports compared to the previous inventory years and the corresponding reduction in jet kerosene consumption as shown in Tables 24 and 25.

Table 23 – Aviation GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	1,736,673	1,551,247	1,551,941	1,569,375
Change from 2005 (MT CO ₂ e/year)	-	-185,426	-184,732	-167,298
% change from 2005	-	-10.7%	-10.6%	-9.6%
Emission Intensity (MT CO ₂ e/capita)	0.61	0.58	0.57	0.58

Table 24 – Airport Operations Activity Data 2005-2017

Activity by Airport	2005	2010	2015	2017
O'Hare Airport (total arrivals/departure per year)	972,246	882,617	875,136	867,049
Midway Airport (total arrivals/departures per year)	290,756	245,533	253,519	251,341

Table 25 – Aviation Activity Data 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Jet Kerosene (gallons/year)	180,304,277	161,053,007	161,125,100	159,659,684

3.2.5 Off-Road Vehicles

The off-road vehicles category includes vehicles and equipment that do not travel on local roadways, such as forklifts, lawn mowers, and backhoes. Emissions in this sub-sector showed an increasing trend from 2005 to 2015, and then decreased from 2015 to 2017. The result is a decrease of 4.1% in this sub-sector from 2005 to 2017, as shown in Table 26 on the following page. Due to the difficulty in estimating off-road emissions at the community scale, activity data was obtained from the U.S. EPA Motor Vehicle Emission Simulator (MOVES) model for all of Cook County and then downscaled for Chicago. The 2017 inventory used the most recent version of the MOVES model (MOVES2014b), which according to the EPA MOVES website “incorporates significant improvements in calculating nonroad equipment emissions”. This change to the underlying estimation model likely explains the directional changes in emissions in the 2017 inventory.

Table 26 – Off-Road GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	817,618	903,930	997,883	784,479
Change from 2005 (MT CO ₂ e/year)	-	86,312	180,265	-33,139
% change from 2005	-	10.6%	22.0%	-4.1%
Per capita Emission (MT CO ₂ e/capita)	0.29	0.34	0.37	0.29

Table 27 shows the activity data by fuel type from each inventory year.

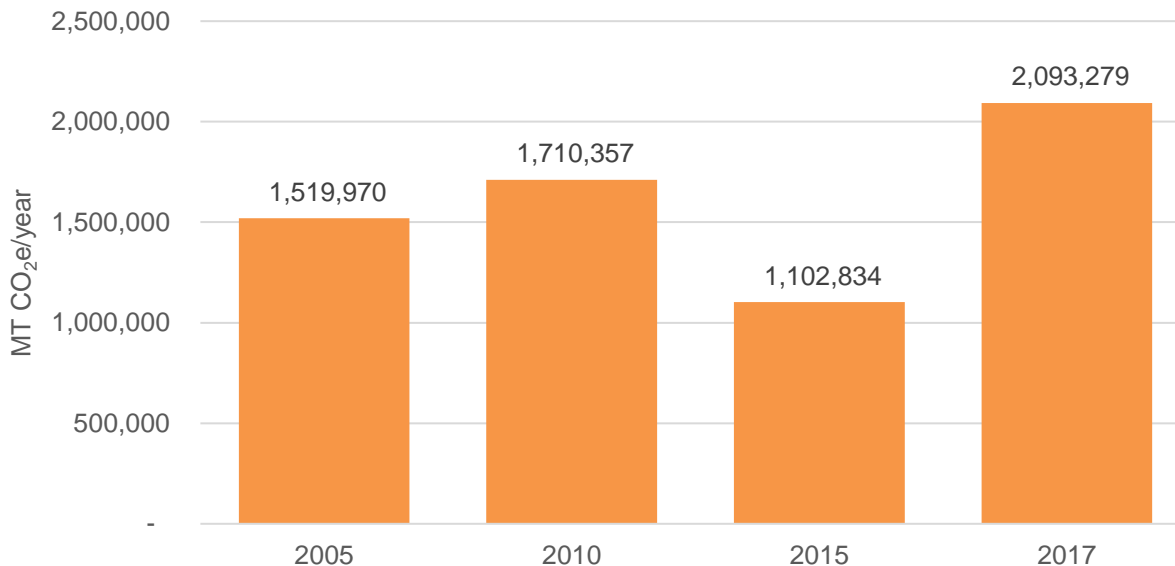
Table 27 – Off-Road GHG Emissions by Activity Type 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Diesel (MT CO ₂ e/year)	486,356	552,571	618,633	449,381
Gasoline (MT CO ₂ e/year)	204,917	220,322	240,933	221,705
LPG (MT CO ₂ e/year)	117,740	121,382	130,214	104,822
CNG (MT CO ₂ e/year)	8,605	9,655	8,103	8,571

3.3 Waste

Waste sector emissions increased 37.7% from 2005 to 2017. However, emissions varied substantially among the inventory years, as shown in Figure 17, primarily as a result of the solid waste disposal sub-sector. Emissions increased 12.5% from 2005 to 2010, decreased 35.5% from 2010 to 2015, and then increased 89.9% from 2015 to 2017. The following sections present a description of the emissions trends within each waste sub-sector.

Figure 17 – Waste Sector Emissions Trends 2005 to 2017



3.3.1 Solid Waste Disposal

Between 2005 and 2010 solid waste disposal emissions from material sent to landfills increased by 17.1% (see Table 28). Between 2005 and 2015 these emissions fell by 24.2%. Based on the 2017 inventory, solid waste disposal emissions increased 51.4% since 2005. These fluctuations in sub-sector emissions are based on the underlying waste disposal activity data shown in Table 29. The inventories developed prior to 2015 were each calculated by a different project team with

access to different data sources. The primary distinction between those two years was the destination of the solid waste collected in the city; the 2010 inventory estimated that 2% of total waste was sent to a landfill with no methane capture system in place, which resulted in higher emissions in 2010 than 2005 even though total waste disposed decreased. The data collected for the 2015 and 2017 inventories show that all waste is sent to landfills with methane capture systems, which contributed to the lower emissions in 2015 compared to 2010. The reported waste disposal data was also substantially lower in 2015 than 2010.

Variability in the reported waste disposal activity data from 2005 to 2015 is largely due to self-reporting from the City's private waste haulers that collect waste from non-residential properties and multi-family residential properties (the City is responsible for collection among single family residential customers and multifamily properties with two, three, or four units, and provided collection data for each inventory year). The 2017 inventory shows a significant emission increase due to a corresponding increase in reported disposal data, which is based on recent improvements to the City's solid waste data collection efforts to provide a more complete dataset of private haulers. Continued implementation of this system should result in future disposal data that more closely aligns with the 2017 data.

Table 28 – Solid Waste GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	1,317,550	1,542,561	998,888	1,995,387
Change from 2005 (MT CO ₂ e/year)	-	225,011	-318,662	677,837
% change from 2005	-	17.1%	-24.2%	51.4%
Emission Intensity (MT CO ₂ e/capita)	0.46	0.57	0.37	0.73

Table 29 – Solid Waste Activity Data 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Municipal Solid Waste (short tons)	3,111,920	2,901,689	2,373,832	4,325,409

3.3.2 Biological Treatment

Emissions related to composting (biological treatment) of organic waste materials is a negligible source relative to the total communitywide inventory, representing approximately 100 MT CO₂e in 2017 as shown in Table 30. The 2005 inventory did not estimate emissions from this sub-sector. The 2010 inventory includes data from the Chicago Park District, while the 2015 and 2017 inventories also include data from the Streets and Sanitation Department. As such, the activity data shown in Table 31 (see following page) is relatively consistent from 2015 to 2017.

Table 30 – Biological Treatment GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	-	25	112	103

Table 31 – Biological Treatment Activity Data 2005-2017

Metric and Unit	2005	2010	2015	2017
Organic material composted (kg/year)	-	132,676	582,594	539,067

3.3.3 Wastewater

Wastewater emissions are directly correlated to the number of persons served, the types of technologies used in treatment, and the facility operation conditions. As shown in Table 32, wastewater emissions decreased in each inventory year, with reduction of 51.7% from 2005 to 2017. The decrease can be partially explained by improvements made to treatment processes and treatment volumes. Table 33 shows a decline in nitrogen emissions resulting from improved processes that remove nitrogen pollutants from wastewater effluent. Changes in systems and operations led to a decrease in fugitive methane emissions from 2005 to 2017 as well.

Table 32 – Wastewater GHG Emissions 2005-2017

Metric and Unit	2005	2010	2015	2017
Emissions (MT CO ₂ e/year)	202,420	167,771	103,835	97,789
Change from 2005 (MT CO ₂ e/year)	-	-34,649	-98,585	-104,631
% change from 2005	-	-17.1%	-48.7%	-51.7%
Emission Intensity (MT CO ₂ e/capita)	0.07	0.06	0.04	0.04

Table 33 – Wastewater Activity Data 2005-2017

Activity Type and Unit	2005	2010	2015	2017
Nitrogen (MT CO ₂ e/year)	38,626	36,348	30,692	30,764
Fugitive Methane (MT CO ₂ e/year)	163,794	131,423	73,142	67,026

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