# City of Bozeman 2020 Community Greenhouse Gas Emissions Inventory Report

BOZEMAN MT
City Sustainability

Prepared by LOTUS Engineering & Sustainability

# Table of Contents

**Executive Summary** .......... **ES-1**

**Introduction** .......... **1**

**An Overview of 2020 Emissions** .......... **5**

**Year-Over-Year Comparison** .......... **21**

**Carbon Sequestration** .......... **32**

**Summary** .......... **37**

**Appendix A: Data Sources** .......... **38**

**Appendix B: Emissions Factors** .......... **40**

## Table of Tables

Table 1. Annual greenhouse gas emission intensities in Bozeman, the US, and globally. .......... 7
Table 2. Bozeman's 2020 greenhouse gas emissions by sector and source. .......... 19
Table 3. Detailed contributing factors to GHG emissions increases and decreases between 2018 and 2020. .......... 30
Table 4. Annual carbon flux within the Bozeman city boundary. .......... 35
Table 5. Emissions data sources and if they were calculated or estimated in this report. .......... 38
Table 6. Summary of greenhouse gas emissions factors. .......... 40

# Table of Figures

Figure ES 1. 2020 greenhouse gas emissions by sector. ES-1
Figure ES 2. Total GHG emissions between 2008-2020 and the City of Bozeman's 2025 emissions reduction goal (mt $CO_2$e). ES-2
Figure ES 3. Annual per capita greenhouse gas emissions and population growth from 2008-2020. ES-3
Figure ES 4. US greenhouse gas emissions over time (via New York Times). ES-4
Figure ES 5. Progress towards the 2020 Bozeman Climate Plan goals.. ES-5

Figure 1. Bozeman City Limits. 3
Figure 2. 2020 greenhouse gas emissions by scope. 6
Figure 3. Bozeman's 2020 stationary energy use sector greenhouse gas emissions. 10
Figure 4. Bozeman's 2020 transportation sector greenhouse gas emissions. 12
Figure 5. Bozeman's 2020 waste sector greenhouse gas emissions. 14
Figure 6. Bozeman's 2020 greenhouse gas emissions by sector and source. 18
Figure 7. Changes in GHG emissions between inventories. 22
Figure 8. Progress towards the 2020 Bozeman Climate Plan goals. 23
Figure 9. Year-over-year greenhouse gas emissions by sector (2008-2020). 25
Figure 10. Year-over-year per capita greenhouse gas emissions and population (2008-2020). 26
Figure 11. Population increases between 2010-2020 in select Montana cities and unincorporated areas. 27
Figure 12. Contributing factors to GHG emissions increases and decreases between the 2018 and 2020 inventories. 29
Figure 13. National trends in greenhouse gas emissions between 2005-2021. 31

# Executive Summary

The natural surroundings of Bozeman are integral to the community's quality of life and economy; the clean environment benefits residents and visitors alike. While climate disruption continues to impact southwest Montana's ecosystems, water resources, public health, agriculture, and tourist economy, the City of Bozeman's 2020 Climate Plan offers a path forward to ensure a more vibrant future for all residents. Bozeman has set a community-wide goal of reaching carbon neutrality by 2050, and the pathway to this goal includes reducing greenhouse gas (GHG) emissions 26% below 2008 levels by 2025 and transitioning to 100% net clean electricity by 2030. Bozeman measures greenhouse gas emissions bi-annually to monitor progress towards these goals and to better understand effective interventions. The following report summarizes the City of Bozeman's greenhouse gas emissions in 2020, including an analysis of emission sources, trends, and an estimate of terrestrial carbon sequestration.

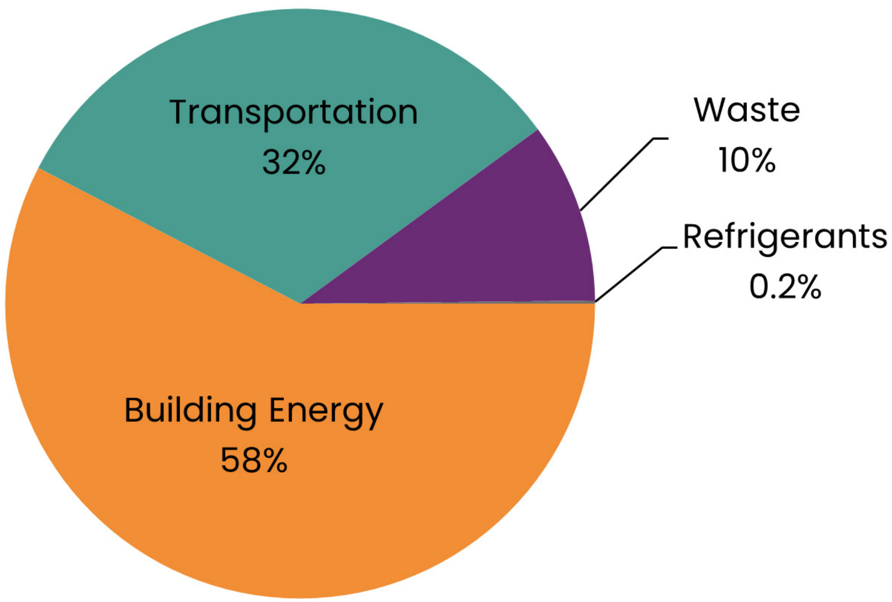


*Figure ES 1. 2020 greenhouse gas emissions by sector.*

**Bozeman developed a 2020 greenhouse gas emissions inventory to track progress toward reduction goals. Bozeman's 2020 GHG emissions totaled 548,746 metric tons of carbon dioxide equivalent (mt $CO_2$e) inclusive of all GHG emissions generated in Bozeman from building energy use, transportation, and waste.**

In 2020, building energy emissions were the largest contributor to Bozeman's GHG emissions, comprising 58% of total emissions. Transportation emissions comprised 32% of total emissions, waste emissions comprised 10%, and refrigerant leakage emissions comprised 0.2%. See Figure ES 1. National trends follow a similar pattern with building energy representing the largest emissions sector followed by the transportation sector.

Bozeman's total emissions have increased 5% from the baseline year of 2008. See Figure ES 2. A key contributing factor to the overall increase in emissions since 2008 is population growth within the City of Bozeman and surrounding areas. Bozeman's per capita emissions have decreased 30% from 2008 while population has increased 50%. See Figure ES 3.

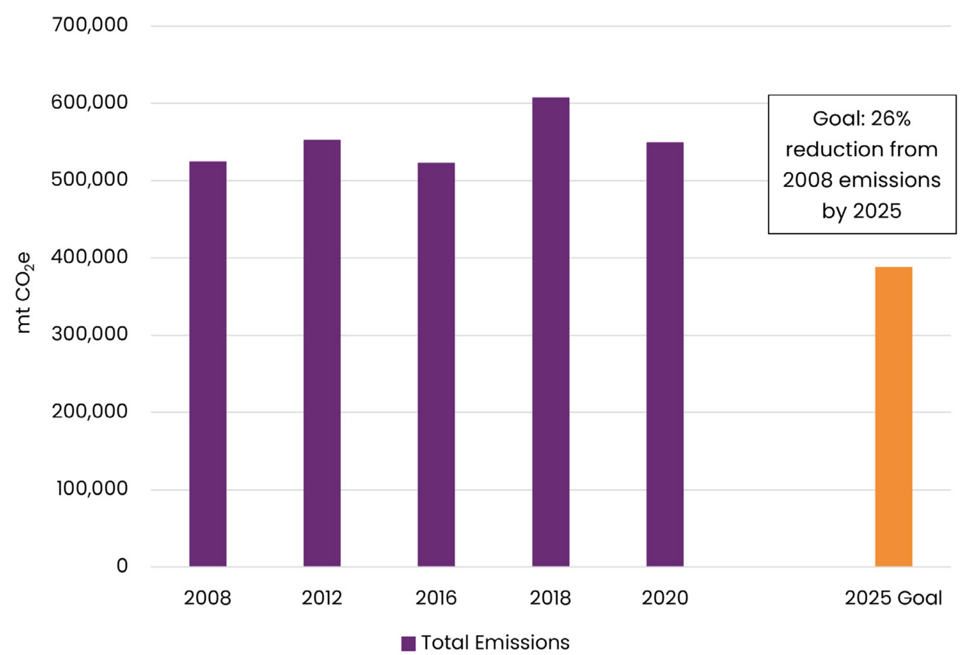


*Figure ES 2. Total greenhouse gas emissions between 2008-2020 and the City of Bozeman's 2025 emissions reduction goal (mt $CO_2$e).*

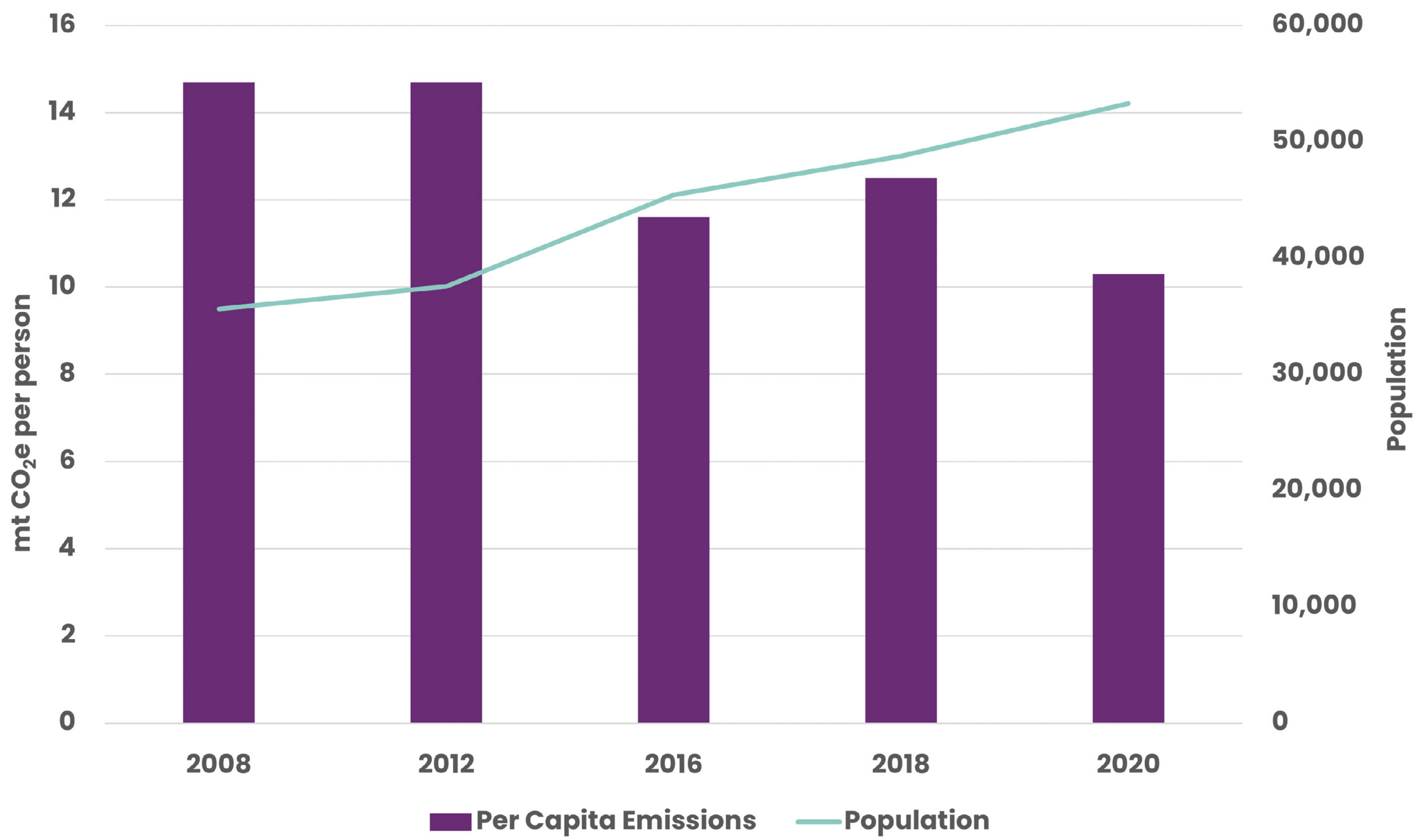


*Figure ES 3. Annual per capita greenhouse gas emissions and population growth from 2008-2020.*

Total emissions in Bozeman decreased by 10% in 2020 from the recent inventory in 2018. See Figure ES2. Changes between 2018 and 2020 reflect similar shifts in emissions patterns across the country. As shown in Figure ES 4, trends in US emissions decreased between 2018 to 2020 in the transportation, electricity, and buildings sectors. These decreases are believed to be strongly influenced by the COVID-19 pandemic.

The 2020 GHG inventory reflects the City's advancement toward its 2020 Bozeman Climate Plan goals. However, continuous action is needed to meet the City's goals and secure a more sustainable future (Figure ES 5).

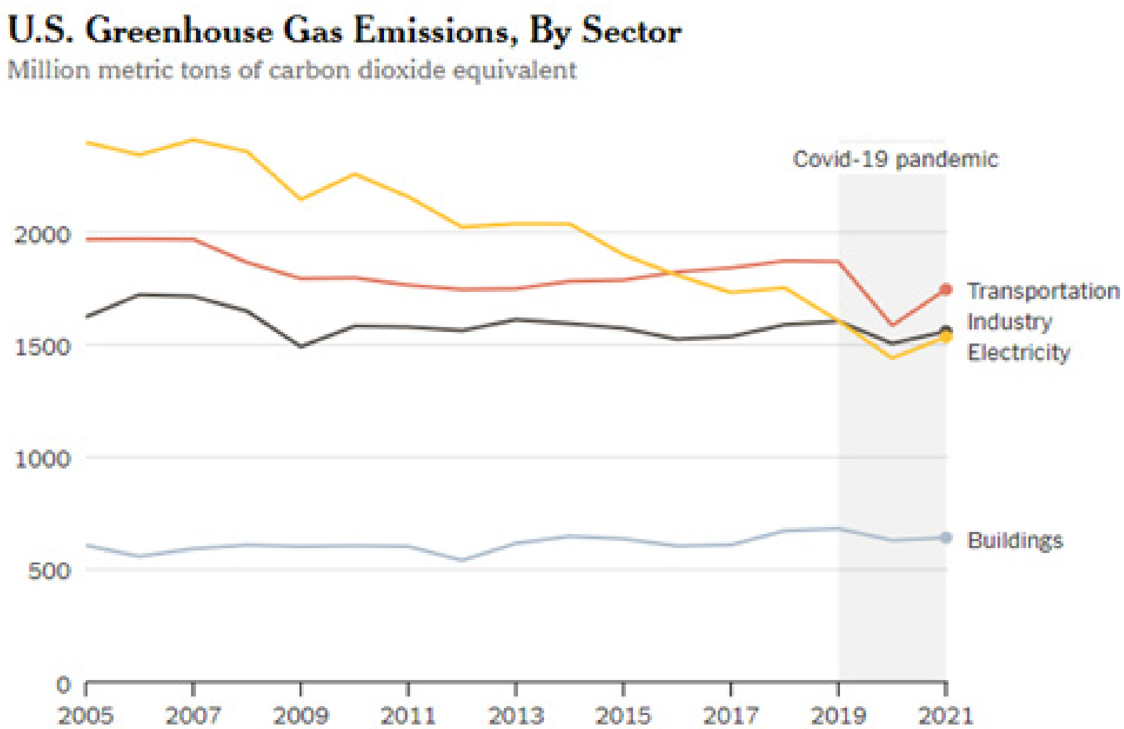


*Figure ES 4. US greenhouse gas emissions over time (via [New York Times](#)).*

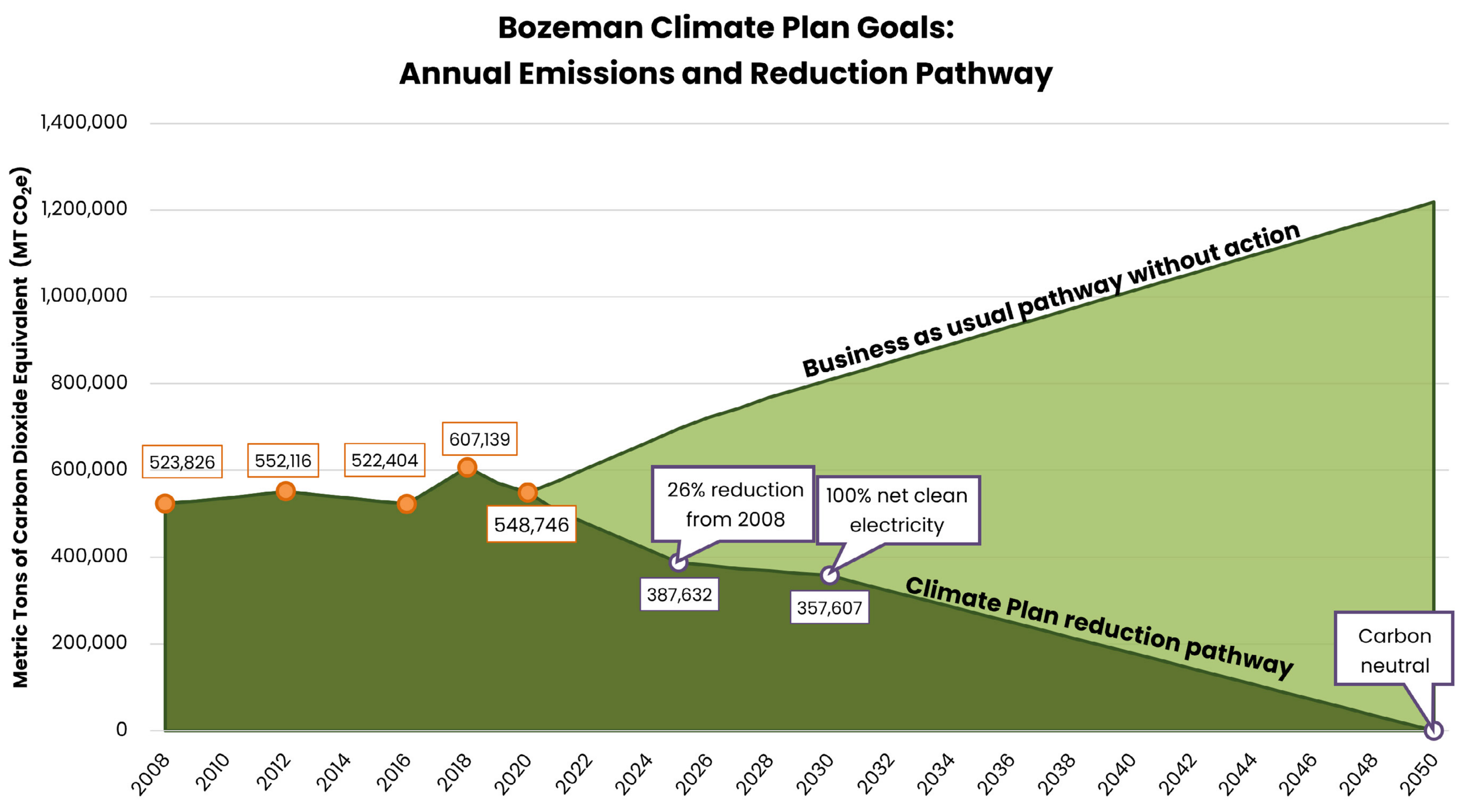


*Figure ES 5. Progress towards the 2020 Bozeman Climate Plan goals.*

# Introduction

To help Bozeman reach its carbon neutrality goals, the City has completed a community wide greenhouse gas (GHG) emissions inventory to measure and identify sources of emissions within the community.

GHG emissions are heat-trapping gases that contribute to climate change through atmospheric warming. The primary GHG emissions are carbon dioxide ($CO_2$), methane ($CH_4$), nitrous oxide ($N_2O$) and fluorinated gases – hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulfur hexafluoride ($SF_6$), and nitrogen trifluoride ($NF_3$). While carbon dioxide, methane, and nitrous oxide come from a variety of natural sources, human-related emissions of these gases are responsible for the substantial increase that has occurred in the atmosphere since the Industrial Revolution. Today, global greenhouse gas emissions are higher than at any time during the last 650,000 years.[*] Human-related GHG emissions are often produced as a result of burning fossil fuels (coal, natural gas, oil) for buildings and transportation, industrial activity, agriculture, solid waste decomposition, wastewater treatment, and other activities.

Lotus Engineering and Sustainability, LLC (Lotus) was hired to complete the 2020 calendar year community wide GHG emissions inventory. The inventory was developed using the standard methodology outlined in the Global Protocol for Community-Scale GHG Inventories (GPC) for a BASIC inventory. BASIC inventories include emissions generated from building energy, transportation, and waste.

Additional emission sources (sometimes referred to as BASIC+ sources), such as electricity transmission and distribution (T&D) losses and transboundary aviation,[**] were included in the 2020 inventory. Unless otherwise noted, all emission totals in this report include BASIC+ sources. See the subsection titled BASIC+ Emissions for more information. This report also estimates the

* ACS Climate Science Toolkit

** Per the GPC protocol, "The transportation emissions from large regional transit hubs (e.g., airports or seaports) serving the city, but outside of the geographic boundary, should be counted in scope 3. These emissions are driven by activities within the city and should be included to provide a more holistic view of the city's transportation sector."

average annual net carbon flux from Bozeman's land and forests within the city boundary. See subsection Carbon Sequestration for more information.

The following report reviews 2020 GHG emissions sectors and sources, and progress toward Bozeman's climate goals.

## Inventory Boundary

Per the GPC, communities shall establish a geographic boundary that identifies the spatial dimensions or physical perimeter of the inventory's boundary. The boundary for the Bozeman inventory reflects the physical City limits (Figure 1).

**Moving forward the City has committed to publicly reporting emissions every two years with the next inventory reflecting 2022. Greenhouse gas inventories help the City monitor emissions trends and recognize reduction opportunities.**

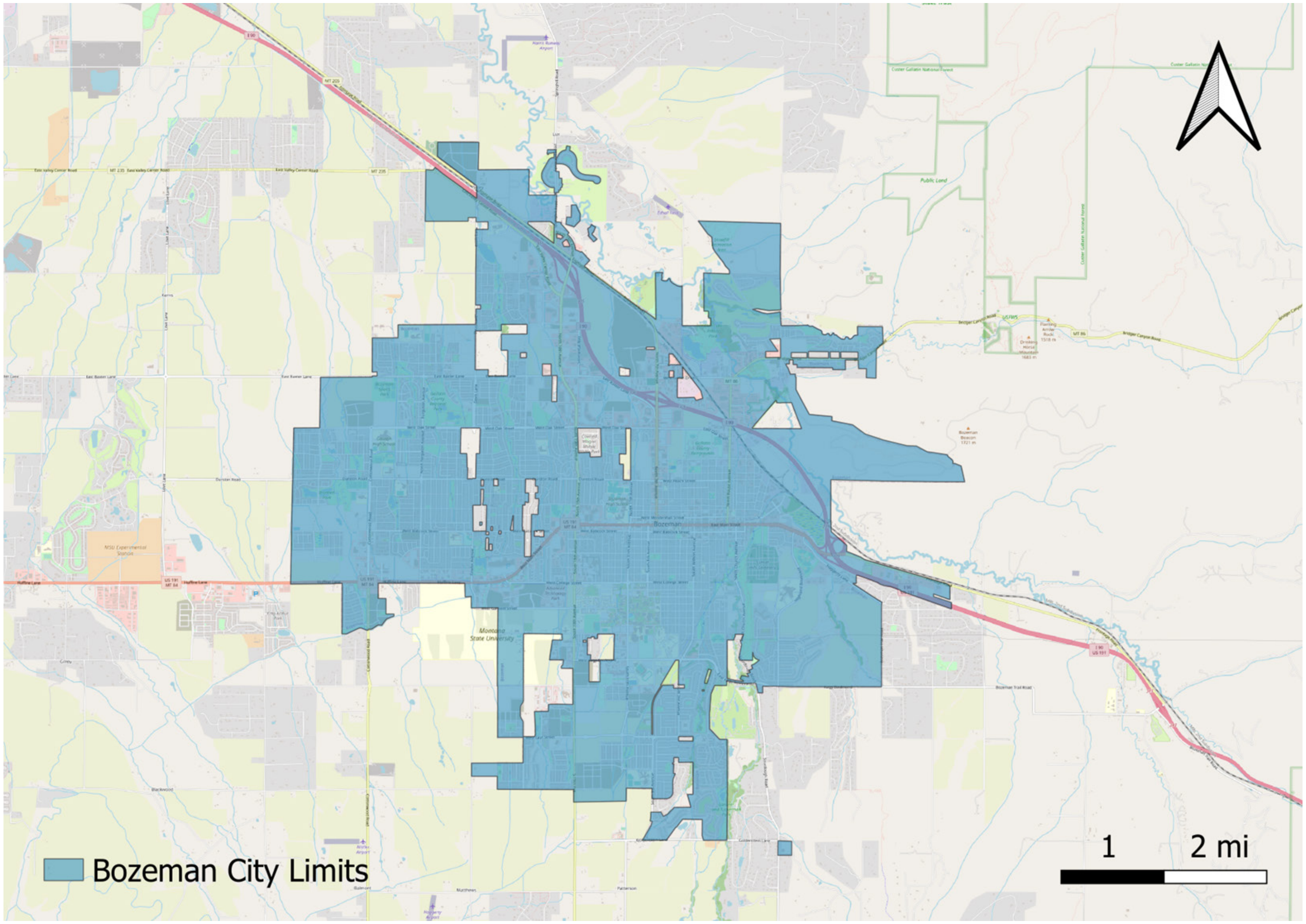


*Figure 1. Bozeman City Limits.*

## Note on COVID-19 Impacts

While Bozeman's total emissions decreased from 2018 to 2020, it is important to note that 2020 is an outlier year due to the COVID-19 pandemic. National trends saw reduced travel, decreased commercial energy usage, and increased waste disposal. With more people working from home and traveling less, there were fewer commuting and air travel emissions. As businesses slowed and closed operations, commercial building energy emissions decreased. Increased use and disposal of single-use items significantly increased waste emissions. The 2020 drop in national and local emissions does not necessarily represent a new normal and it is unlikely these reductions will be durable without sustained systemic change.

# An Overview of 2020 Emissions

## Emissions By Scope

Emission sources fall into one of three scope categories, which vary depending on the emissions point of release in relation to the city boundary.

**Scope 1 includes GHG emissions from sources within the city boundary, such as building fuel use (other than electricity), vehicle activity within the City, and compost deposited within city limits.**

**Scope 2 includes emissions from the use of grid-supplied electricity, heat, steam, and cooling within the city boundary.**

The only scope 2 emission source for Bozeman is grid-supplied electricity, including electric use by electric vehicles.

**Scope 3 emissions include all other GHG emissions occurring outside the city as a result of activities within the City boundary.**

For example, landfilled waste is a scope 3 emission for Bozeman, as waste generated in Bozeman is taken to be disposed of outside the city boundary.

Scope 1 emissions accounted for 58% of Bozeman's total emissions (317,702 mt $CO_2e$). On-road vehicle fuel combustion, residential natural gas usage, and commercial and industrial electricity usage were the three largest contributors to scope 1 emissions in 2020. Scope 2 emissions from grid-supplied electricity made up 26% of total emissions from the City (142,096 mt $CO_2e$). Scope 3 emissions made up 16% of Bozeman's emissions (88,949 mt $CO_2e$), with landfilled waste and emissions from the Yellowstone/Bozeman International Airport making up the majority of scope 3 emissions. Figure 2 shows the percentage of emissions from each scope.*

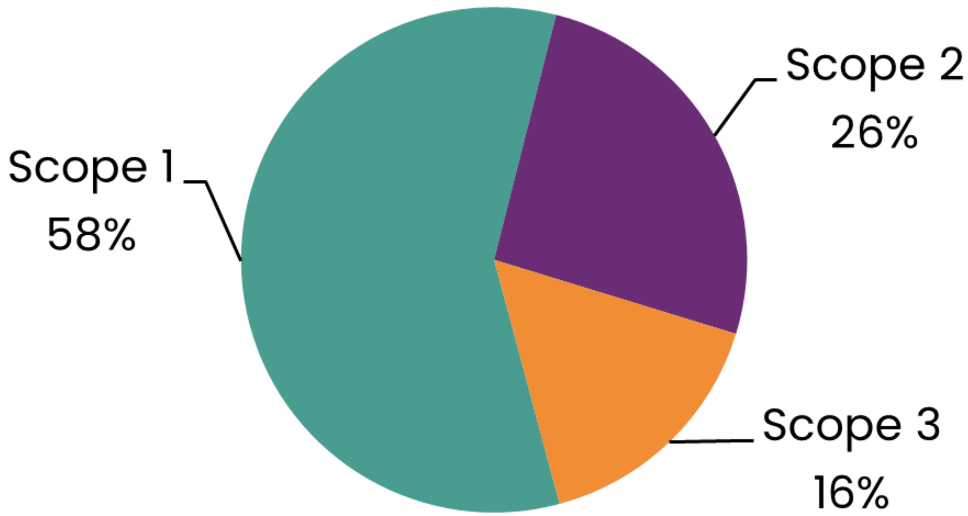


*Figure 2. 2020 greenhouse gas emissions by scope.*

* As noted above, additional Scope 3 emission sources (sometimes referred to as BASIC+ sources) from transmission and distribution (T&D) losses and transboundary aviation were calculated for the 2020 inventory. See the subsection titled BASIC+ Emissions for more information.

# Normalized Emissions

Bozeman's population of 53,293 in 2020, emissions per resident were approximately 10.3 mt $CO_2e$. Bozeman per capita emissions are lower than US average emissions per capita by approximately 30%. The lower per capita emissions rate is driven by lower industry-related emissions compared to other cities, as well as newer and more efficient buildings. Per capita emission intensities are shown in Table 1.

*Table 1. Annual greenhouse gas emission intensities in Bozeman, the US, and globally.*

| Metric | 2018 Annual Greenhouse Gas Emissions (mt $CO_2e$) | 2020 Annual Greenhouse Gas Emissions (mt $CO_2e$) |
|---|---|---|
| Bozeman per capita | 12.5 | 10.3 |
| National per capita[*] | 15.8 | 13.5 |
| International per capita[4] | 4.8 | 4.5 |

* National and international annual per capita emissions data are from Statista; data are from 2018 & 2020.

Emissions sectors are the broad categories of activities that result in GHG emissions. Bozeman's inventory is split into the following emissions sectors:

**Stationary Energy:** emissions sourced from buildings (electricity and natural gas usage), propane and diesel combustion, and transmission and distribution losses (T&D).

**Transportation:** emissions originating from gas and diesel vehicles, aviation, transit and electric vehicles, and T&D losses from electric vehicles.

**Solid Waste and Wastewater Treatment:** emissions released from organic material, solid waste this is inclusive of transportation, collection, and processing of waste.

**Industrial Processes and Product Use:** emissions stemming from refrigerant leaks in building heating, ventilation, and air conditioning (HVAC) systems.

Each sector contains individual sources, which represent the specific activities resulting in the emissions. Emissions sectors and the sources within them are further discussed in the following subsections. A summary of emissions from BASIC+ emissions, which captures all scope 1, 2, and 3 emissions sources, is included following the emission sector summaries.

## Stationary Energy

**Emissions from stationary energy accounted for 57 percent of Bozeman's total GHG emissions (315,412 mt $CO_2e$).**

The stationary energy sector includes emissions from buildings, primarily from electricity and natural gas usage. Other sources of stationary energy emissions include propane and diesel combustion, as well as T&D losses. Fugitive emissions, or emissions from the sourcing, transport, and leakage of natural gas, are also included.

Figure 3 breaks down the specific sources of stationary energy emissions. Overall, electricity use, including T&D losses, accounted for 48% (150,733 mt $CO_2e$) of stationary energy emissions, and natural gas use, including fugitive emissions, made up 51% (160,645 mt $CO_2e$). Propane, residential wood, and stationary diesel together accounted for the remaining stationary energy emissions (see Table 2).

Splitting energy use by building type provides a more detailed understanding of the sources contributing to stationary energy emissions. In 2020, commercial buildings (e.g., shops, offices, hotels, warehouses, and other places of business) accounted for 56% of Bozeman's stationary energy emissions (175,646 mt $CO_2e$), while homes made up 44% of stationary energy emissions (139,765 mt $CO_2e$). Commercial natural gas usage was the largest source of stationary energy emissions (91,589 mt $CO_2e$). Commercial building emissions decreased by 13% from 2018 while residential building emissions decreased by 3% over the same period. This is largely due to COVID-19 impacts and restrictions that prevented employees from working from the office and students from attending school and forced them to work and learn from home instead.

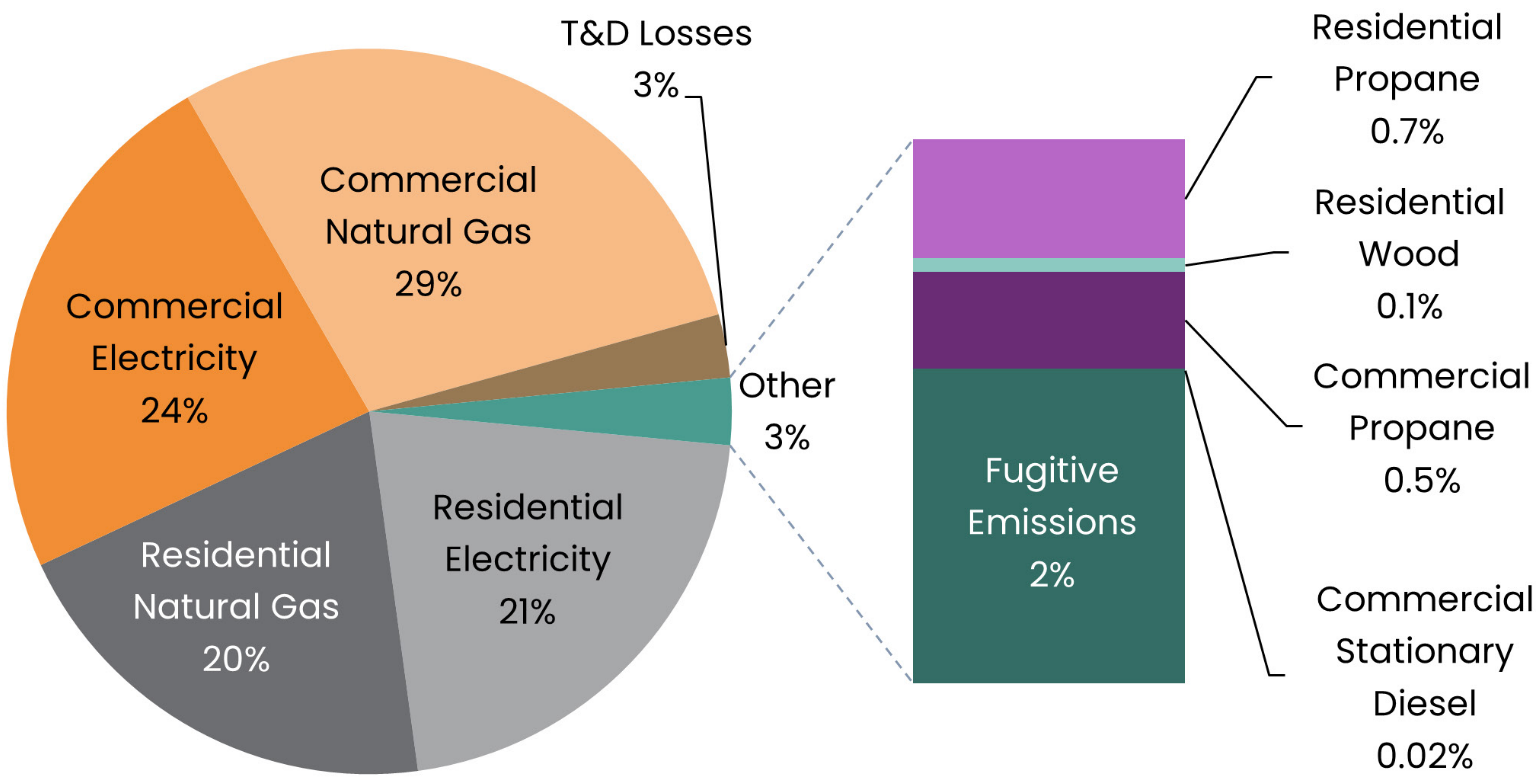


*Figure 3. Bozeman's 2020 stationary energy use sector greenhouse gas emissions.*

# Transportation

**The transportation sector accounted for 32 percent of Bozeman's total GHG emissions (177,593 mt $CO_2e$).**

Figure 4 provides a breakdown of the contributing sources to emissions from the transportation sector. Emissions from gasoline vehicles (including emissions from ethanol) made up 53% of transportation emissions (95,008 mt $CO_2e$) and diesel vehicles made up 24% (41,932 mt $CO_2e$). Aviation emissions made up 23% of transportation emissions (39,999 mt $CO_2e$).* Together, transit vehicles, electric vehicles, and T&D losses from electric vehicle charging made up under one percent of total transportation emissions. See Table 2 for more detail. Between 2018 and 2020, transportation emissions decreased by 23%. These reductions can be attributed to COVID-19 impacts and restrictions that limited travel within Bozeman and across the country. This trend mirrors the National trend in transportation emissions between 2018 and 2020, see Figure 13. The high emissions stemming from gas and diesel vehicles (77%) mirrors national trends, the data conveys an opportunity for more sustainable travel.

* Per the GPC protocol, transboundary aviation is defined as "The transportation emissions from large regional transit hubs (e.g., airports or seaports) serving the city, but outside of the geographic boundary, should be counted in scope 3. These emissions are driven by activities within the city and should be included to provide a more holistic view of the city's transportation sector."

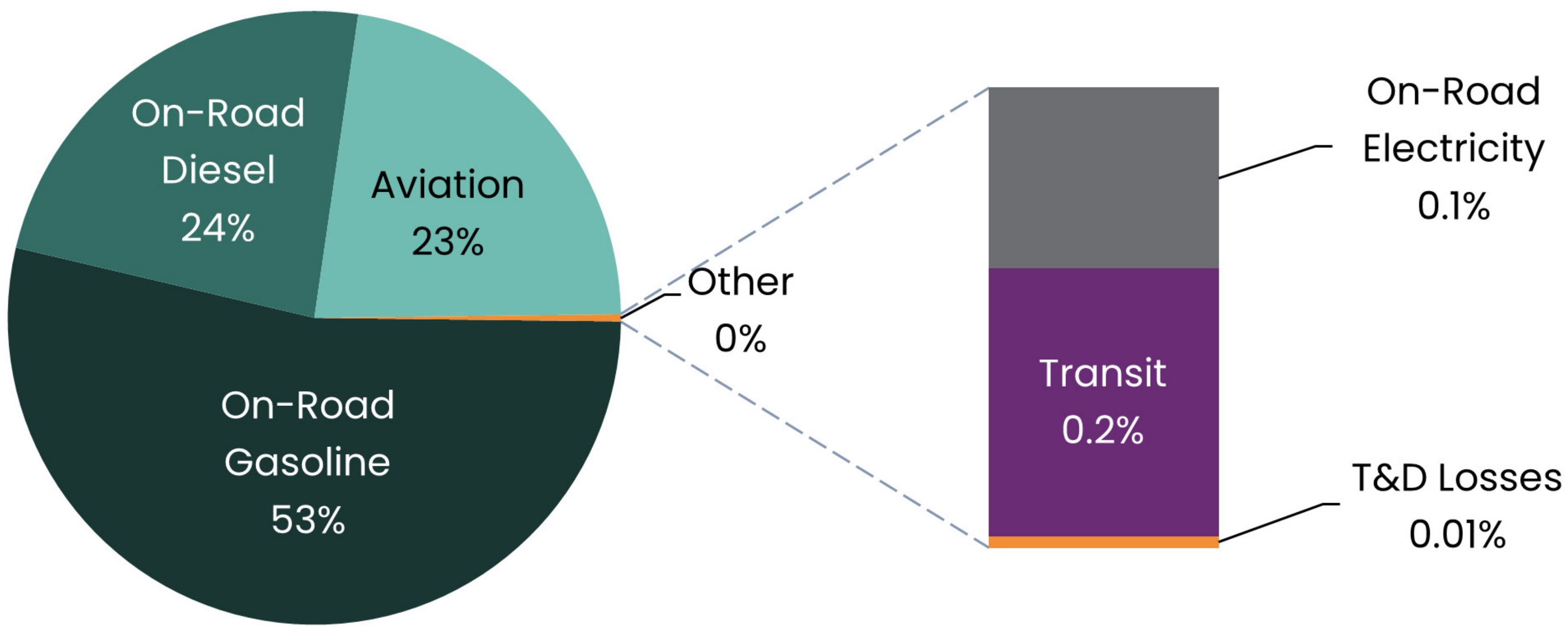


*Figure 4. Bozeman's 2020 transportation sector greenhouse gas emissions.*

# Waste and Wastewater

**Waste and wastewater emissions made up nine percent of Bozeman's total 2020 emissions (54,856 mt $CO_2e$).**

The solid waste generated in Bozeman is disposed of outside the City boundary at Logan Landfill. Some organic material is taken outside of the City boundary for composting, while other organic material is composted within City limits. Solid waste from residential, commercial, and industrial sources made up 67% of total waste and wastewater emissions (36,733 mt $CO_2e$). The closed Story Landfill comprised 26% of total waste and wastewater emissions (14,388 mt $CO_2e$) where methane from historically landfilled organic materials is captured, flared, and converted to $CO_2$ before it is emitted into the atmosphere. Emissions from the transport, collection, and processing of waste made up 5% of total waste emissions (2,952 mt $CO_2e$) and compost made up 1% of total waste emissions (501 mt $CO_2e$). See Table 2. Composting organic materials, like yard residuals and kitchen scraps, reduces emissions compared to landfilling. Solid waste emissions increased in 2020 from 2018 by 70% due to several changes. The largest driver in the emissions change was the updated global warming potential for methane, which increased the impact of methane emissions by 6%. The global warming potential of methane is the amount of impact that one metric ton of the greenhouse gas methane has on global warming compared to one metric ton of the greenhouse gas carbon dioxide. Every metric ton of methane emitted creates the same amount of atmospheric warming as 29.8 metric tons of carbon dioxide. Methane is the primary greenhouse gas emitted when solid waste decomposes. Other smaller factors  including COVID-19 impacts on the landfilling of waste and the increase in population also contributed to the emissions rise in 2020.

Wastewater treatment was negligible in terms of total emissions (0.5% of waste emissions and 280 mt $CO_2e$, Figure 5). All wastewater produced in Bozeman is treated at the Bozeman Water Reclamation Facility within the city boundaries. Wastewater treatment emissions are mostly impacted by population, the volume of wastewater treated, and treatment processes at the facility.

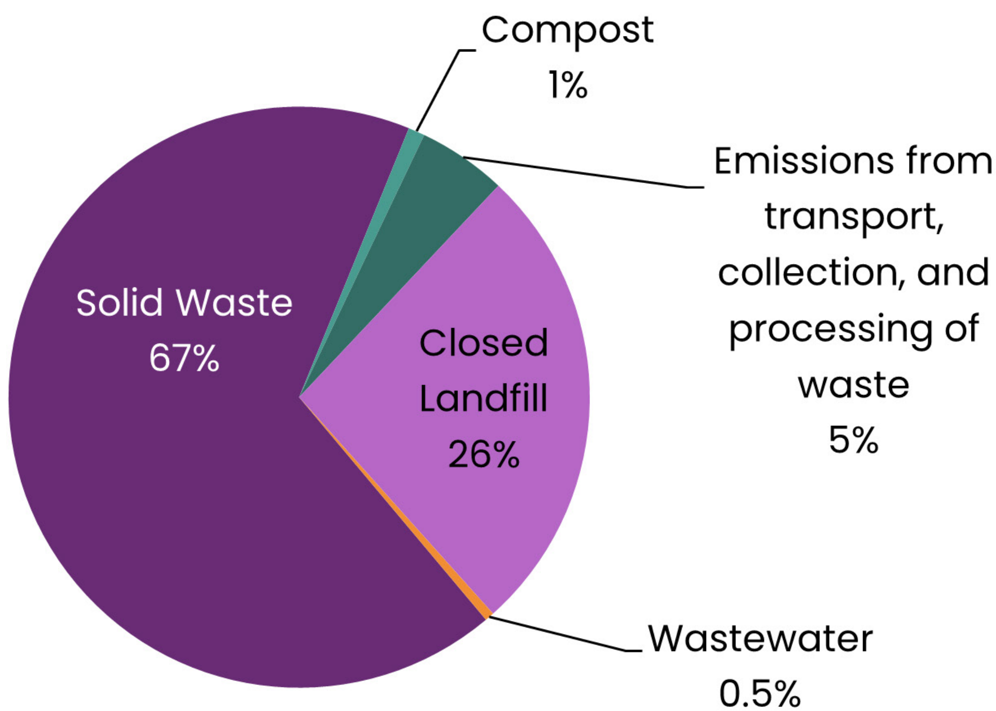


*Figure 5. Bozeman's 2020 waste sector greenhouse gas emissions.*

# Industrial Processes and Product Use

**In 2020, emissions from refrigerant leaks made up 0.2% of Bozeman's total emissions (886 mt $CO_2e$).**

Emissions from refrigerant leaks in building HVAC systems are the only source included in the industrial processes and product use sector for Bozeman. These emissions were estimated assuming that 25% of Bozeman's commercial square footage is refrigerated and a standard 5% leakage rate based on IPCC refrigerant leakage emissions methodologies. Refrigerant leaks in building HVAC systems, beyond their emissions impact, can have significant negative effects on human health as harmful chemicals and substances are released with leaks.

## BASIC+ Emissions

As noted in the introduction, BASIC+ sources from electricity transmission and distribution (T&D) losses and transboundary aviation were calculated for the 2020 inventory. Together these sources accounted for 48,908 mt $CO_2e$, approximately 9% of overall emissions.

## Transmission and Distribution Losses

T&D losses represent electricity that is generated but does not reach intended customers due to inefficiencies in the transmission and distribution systems. The T&D loss rate is estimated by the utility, NorthWestern Energy. These losses can range year-to-year and can be reduced through the utility making upgrades to the grid. In 2020, it was estimated that 6.27% of electricity did not make it to the intended customer resulting in approximately 21 million kWh lost on the way to Bozeman. The total emissions from these losses are 8,909 mt $CO_2e$.

## Transboundary Aviation

Emissions from Bozeman Yellowstone International Airport are considered transboundary aviation emissions due to the airport being outside the City boundary. Per the GPC protocol, "The transportation emissions from large regional transit hubs (e.g., airports or seaports) serving the city, but outside of the geographic boundary, should be counted in scope 3. These emissions are driven by activities within the city and should be included to provide a more holistic view of the city's transportation sector."[*] Of the airport's total 2020 emissions, 39,999 mt $CO_2e$ were attributable to the City of Bozeman (7% of total emissions). Traditionally, Bozeman has worked with the airport to determine the proportion of the airport's activity that occurs as a result of Bozeman's residents. For this inventory, Bozeman assumes that 46.7% of Bozeman Yellowstone International Airport emissions are attributable to residents of the city.

* See page 72 of the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories.

# Emissions by Source

Figure 6 shows the percentage of emissions produced by each sector and source, while Table 2 displays the quantity of emissions. Emissions from each sector are described in more detail in the previous sections. The largest sources of Bozeman's emissions are on-road gasoline and commercial natural gas use, each comprising 17% of total emissions. The next largest emissions source is commercial electricity usage, comprising 14% of total emissions.

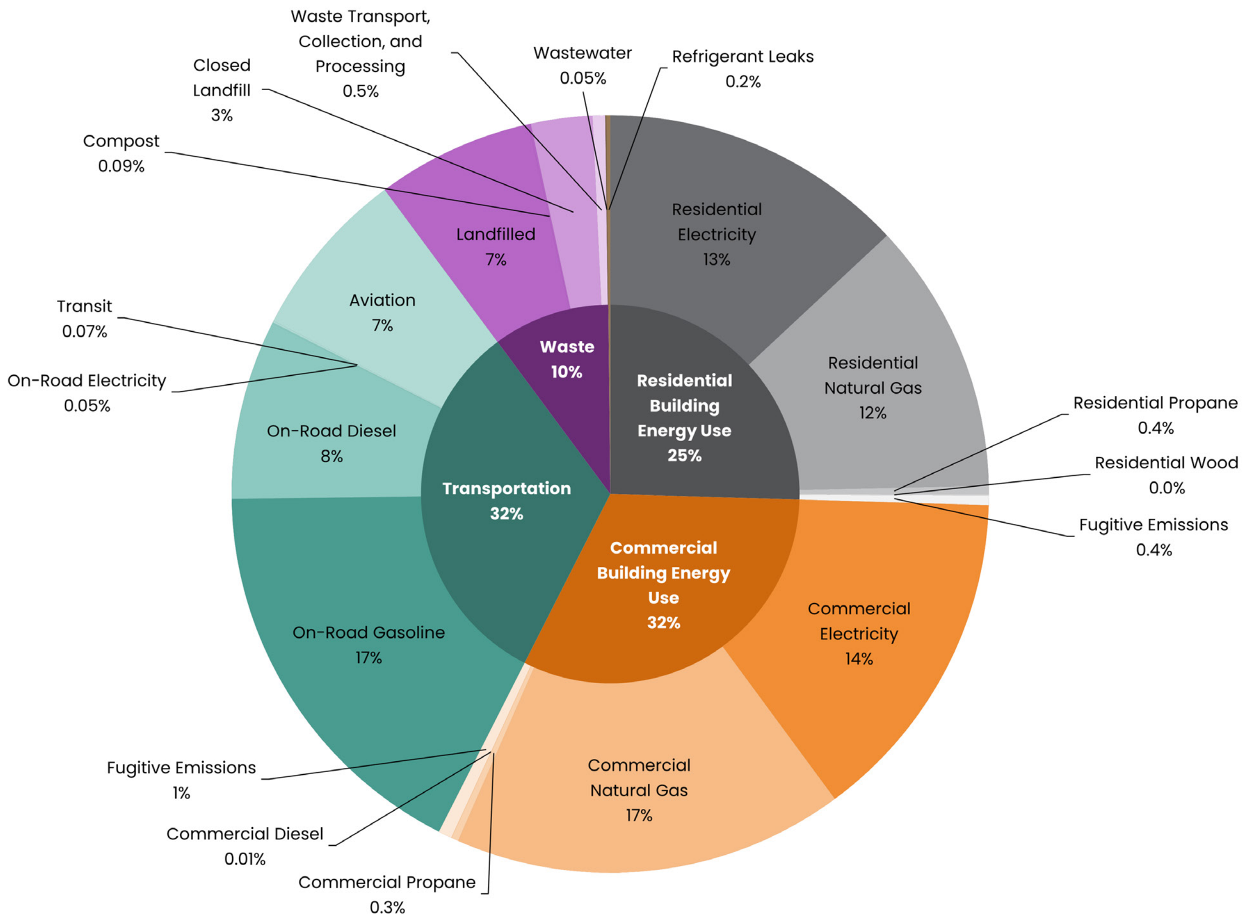


*Figure 6. Bozeman's 2020 greenhouse gas emissions by sector and source.*

*Table 2. Bozeman's 2020 greenhouse gas emissions by sector and source.*

| Emissions Sources | Scope | Emissions ($mtCO_2e$) | Percent |
|---|---|---|---|
| **Residential Fuel Use** | **1, 2,3** | **139,765** | **25%** |
| Residential Electricity | 2 | 67,369.0 | 12% |
| Residential Natural Gas | 1 | 63,666.9 | 12% |
| Residential Propane | 1 | 2,062.3 | 0.4% |
| Residential Wood | 1 | 233.1 | 0.04% |
| Fugitive Emissions | 1 | 2,209.9 | 0.4% |
| Transmission/Distribution Losses | 3 | 4,224.0 | 1% |
| **Commercial Energy** | **1, 2,3** | **175,646** | **32%** |
| Commercial Electricity | 2 | 74,470.3 | 13.5% |
| Commercial Natural Gas | 1 | 91,588.8 | 17% |
| Commercial Propane | 1 | 1,670.9 | 0.3% |
| Commercial Diesel | 1 | 68.0 | 0.01% |
| Fugitive Emissions | 1 | 3,179.0 | 1% |
| Transmission/Distribution Losses | 3 | 4,669.3 | 0.5% |

| Emissions Sources | Scope | Emissions ($mtCO_2e$) | Percent |
|---|---|---|---|
| **Transportation** | **1, 2, 3** | **177,593** | **32%** |
| On-Road Gasoline | 1 | 95,007.7 | 17% |
| On-Road Diesel | 1 | 41,932.5 | 8% |
| On-Road Electricity | 2 | 272.4 | 0.05% |
| Transit | 1 | 381.3 | 0.1% |
| Aviation | 3 | 39,998.8 | 7% |
| **Waste** | **1, 3** | **54,856** | **10%** |
| Landfilled | 3 | 36,733.1 | 7% |
| Compost | 1,3 | 501.1 | 0.1% |
| Closed Landfill | 1 | 14,388.3 | 3% |
| Waste Transport, Collection, and Processing | 3 | 2,952.7 | 0.5% |
| Wastewater | 1 | 280.5 | 0.05% |
| **Industrial Processes and Product Use** | **1** | **886** | **0.2%** |
| Refrigerant Leaks | 1 | 886.3 | 0.2% |
| **Total** | | **548,746** | **100%** |

# Year-Over-Year Comparison

## New Emissions Sources in 2020

For this iteration of the inventory, new emissions data was available for the following sources: commercial stationary diesel use and refrigerant use. The methodology for estimating residential and commercial propane was modified from previous inventories that used national and statewide statistical data to estimate usage. In 2020, propane consumption was estimated based on usage estimates from one of the primary propane providers in Bozeman. Data from these sources was found to be reliable and replicable and was therefore included in the 2020 inventory. See Appendix A for specific data sources. It should be noted that this inventory uses the most recent global warming potentials (GWP) for methane and nitrous oxide from the Intergovernmental Panel on Climate Change's Sixth Assessment Report. The methane GWP increased from 28 to 29.8 and nitrous oxide GWP increased from 265 to 273.

## Year-Over-Year Emissions

Bozeman has faced the local challenge of rapid population growth and development, along with the national challenge of COVID-19, which influenced emissions in 2020. Year over year comparisons help Bozeman better understand patterns overtime to create effective change (Figure 7). Bozeman's total emissions have increased 5% since the baseline year of 2008, but the trend has fluctuated. Bozeman saw increased emissions from 2008 to 2012, which was followed by decreased emissions from 2012 to 2016. This was largely due to a reduction in the carbon intensity of grid supplied electricity and commercial building efficiency improvements. The increase in emissions from 2016 to 2018 was largely related to population growth, and the decrease in emissions from 2018 to 2020 was influenced by the COVID-19 pandemic. Continued work to reduce Bozeman's contribution to climate change, through City-led programs, community initiatives, and individual actions, is needed to meet the emissions reduction goals identified in the 2020 Bozeman Climate Plan (Figure 8).

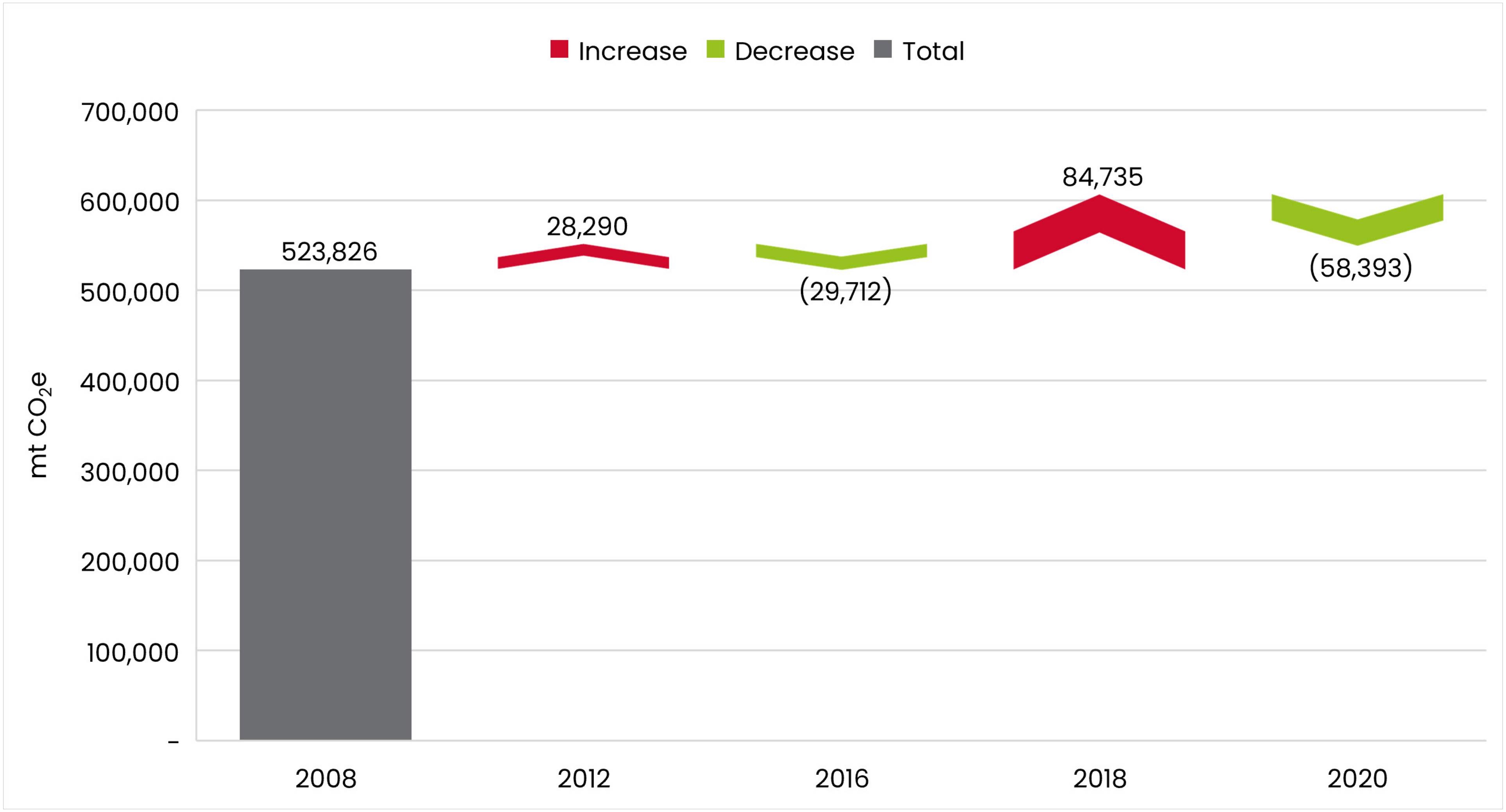


*Figure 7. Changes in GHG emissions between inventories. Red arrows indicate an increase in emissions from the previous inventory, while green arrows indicate a decrease in emissions from the previous inventory.*

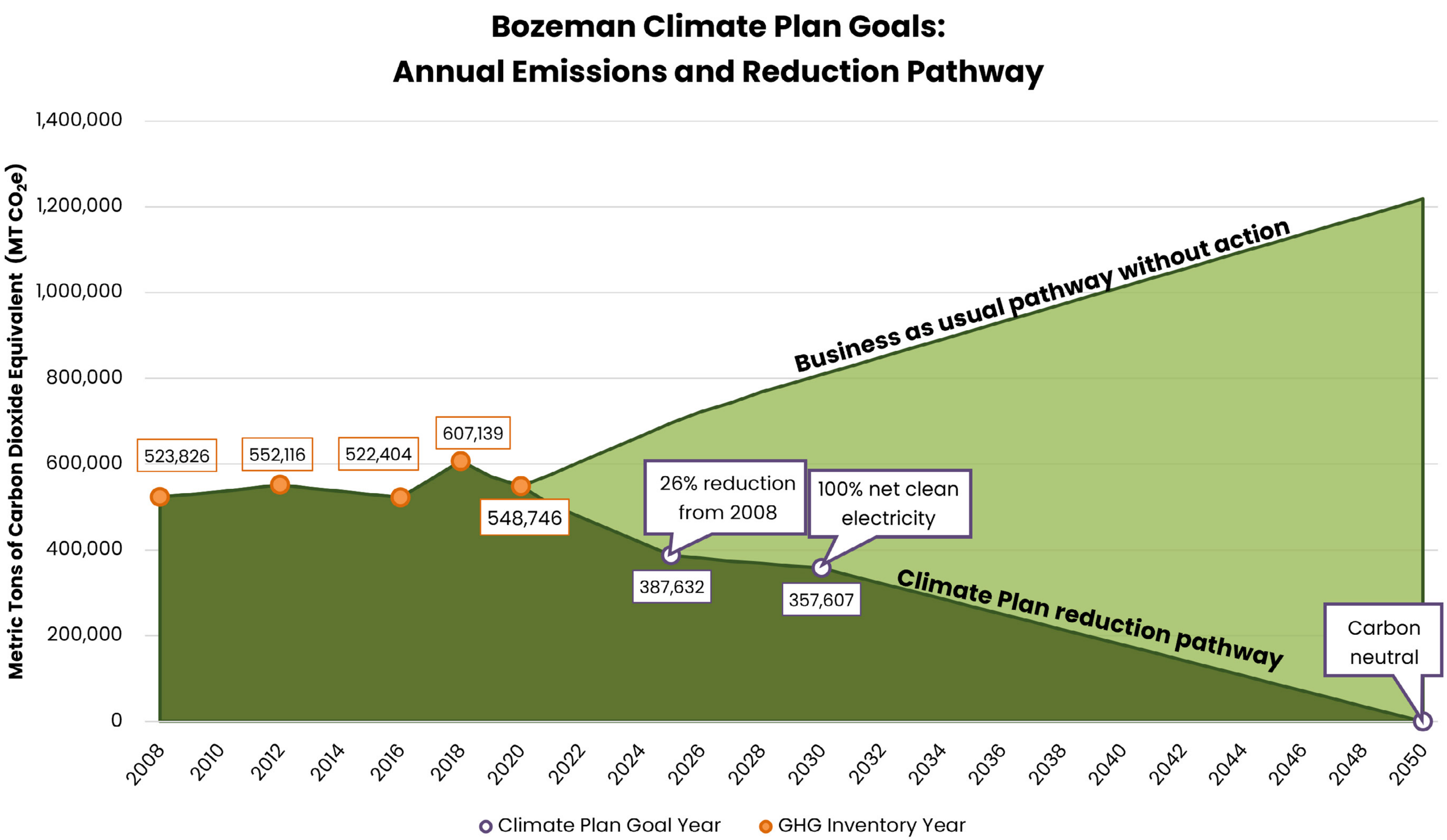


*Figure 8. Progress towards the 2020 Bozeman Climate Plan goals.*

## Year-Over-Year Emissions by Sector

Since 2008 solid waste emissions increased 69% and transportation emissions increased 16%, primarily due to the increased Global Warming Potential (GWP) of methane and increase of Vehicle Miles Traveled within the City boundary. Other sectors have been decreasing overtime including: wastewater treatment emissions decreased 70%, commercial and industrial building energy usage emissions decreased 6%, and residential building energy usage emissions decreased 18% (Figure 9). The decreasing emissions are largely attributed to more efficient commercial buildings and the reduced use of commercial buildings during the COVID-19 pandemic.

Compared to the most recent inventory year of 2018, Bozeman's total emissions have decreased 10%. Between these two years, solid waste emissions increased 70%, while residential building energy usage emissions decreased 3%, commercial and industrial building energy usage emissions decreased 13%, wastewater treatment emissions decreased 7%, and transportation emissions decreased 23%. The fluctuations since 2018 follow national trends of emissions reductions due to COVID-19 in each sector.

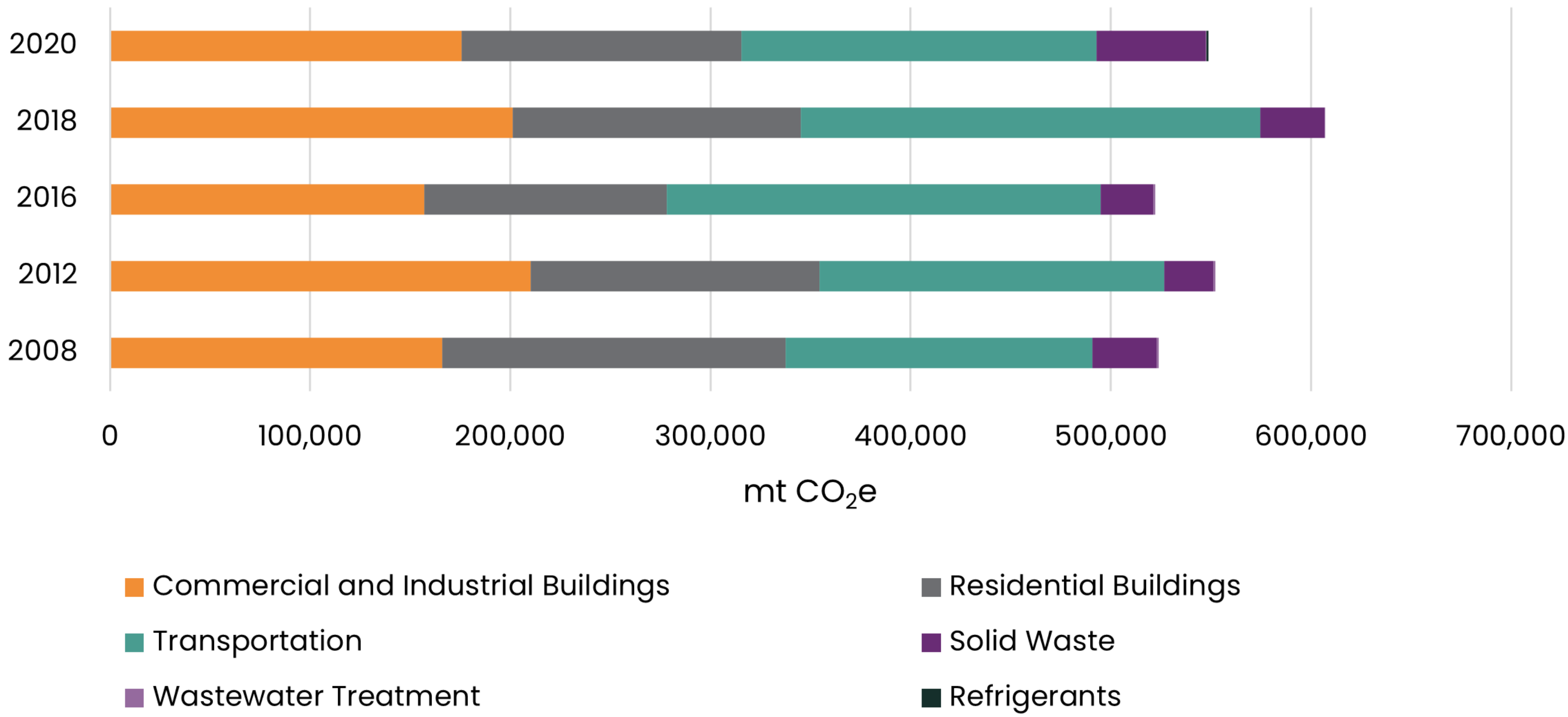


*Figure 9. Year-over-year greenhouse gas emissions by sector (2008 to 2020).*

# Per Capita Emissions

In contrast to total emissions, Bozeman's per capita emissions have decreased 30% from the baseline year (Figure 10). Between 2018 and 2020, per capita emissions have decreased 18% while Bozeman's population increased by 9% (48,751 to 53,293). This means that residents are generating fewer emissions per person in 2020 compared to 2018.

Since Bozeman's 2008 baseline inventory year, the City of Bozeman's population has experienced sustained and rapid growth. The City's population increased 50% between 2008 and 2020 (Figure 10). During this same period, the cities and unincorporated areas surrounding Bozeman grew at a comparable rate or faster. This regional growth contributes directly to traffic and economic activity in Bozeman, which influence emissions. Other major cities in Montana, such as Missoula, Helena, and Whitefish, have also experienced significant growth, but at a comparatively lower rate.

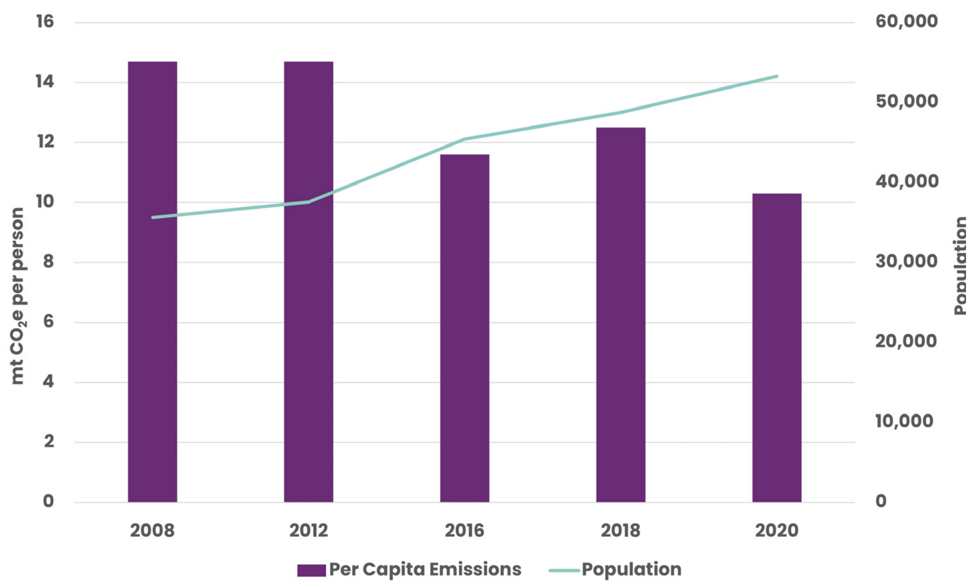


*Figure 10. Year-over-year per capita greenhouse gas emissions and population (2008-2020).*

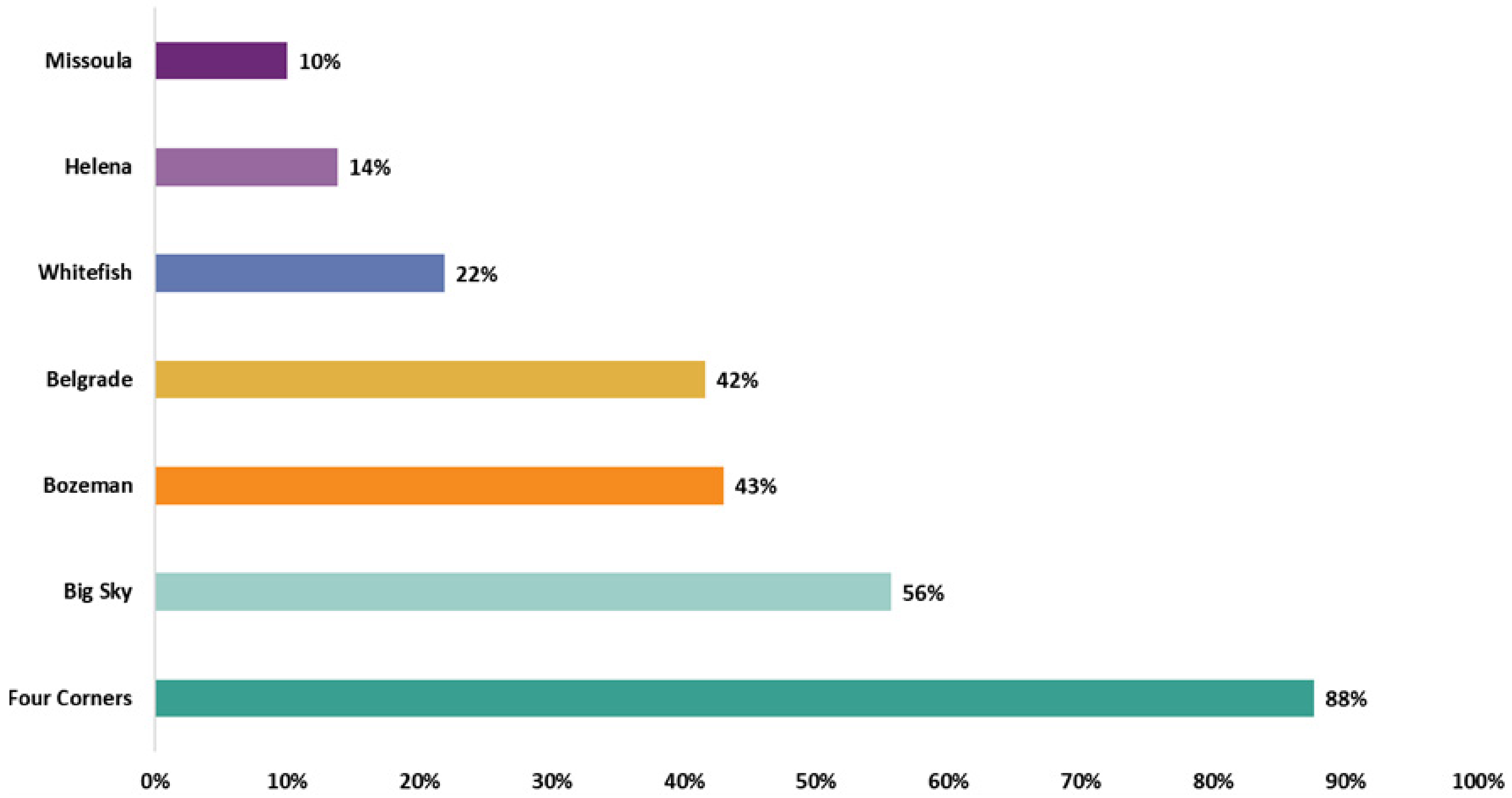


*Figure 11. Population increases between 2010-2020 in select Montana cities and unincorporated areas.**

* Montana Department of Commerce Census & Economic Information Center

## Other Drivers of Emissions Changes

While COVID-19 pandemic impacts drove a large portion of the emissions reductions between 2018 to 2020, there were other forces at play which also contributed to changes in emissions. Energy use and other input data were analyzed using the ICLEI Contribution Analysis tool for their influence on emissions changes. Between 2018 and 2020, larger drivers of emissions increases were the growth in population, increase in number of jobs, increases in waste generation, and a slightly warmer summer. Drivers of emissions reductions between the two years include decreased vehicle miles traveled per person, a cleaner electric fuels mix, and a warmer winter. See Figure 11 and Table 3. Note that several emissions sources were not analyzed by the ICLEI Contribution Analysis tool, such as aviation, transit, and wastewater treatment, as these sources are more nuanced and require a more complex analysis to determine their impact on emissions trends.

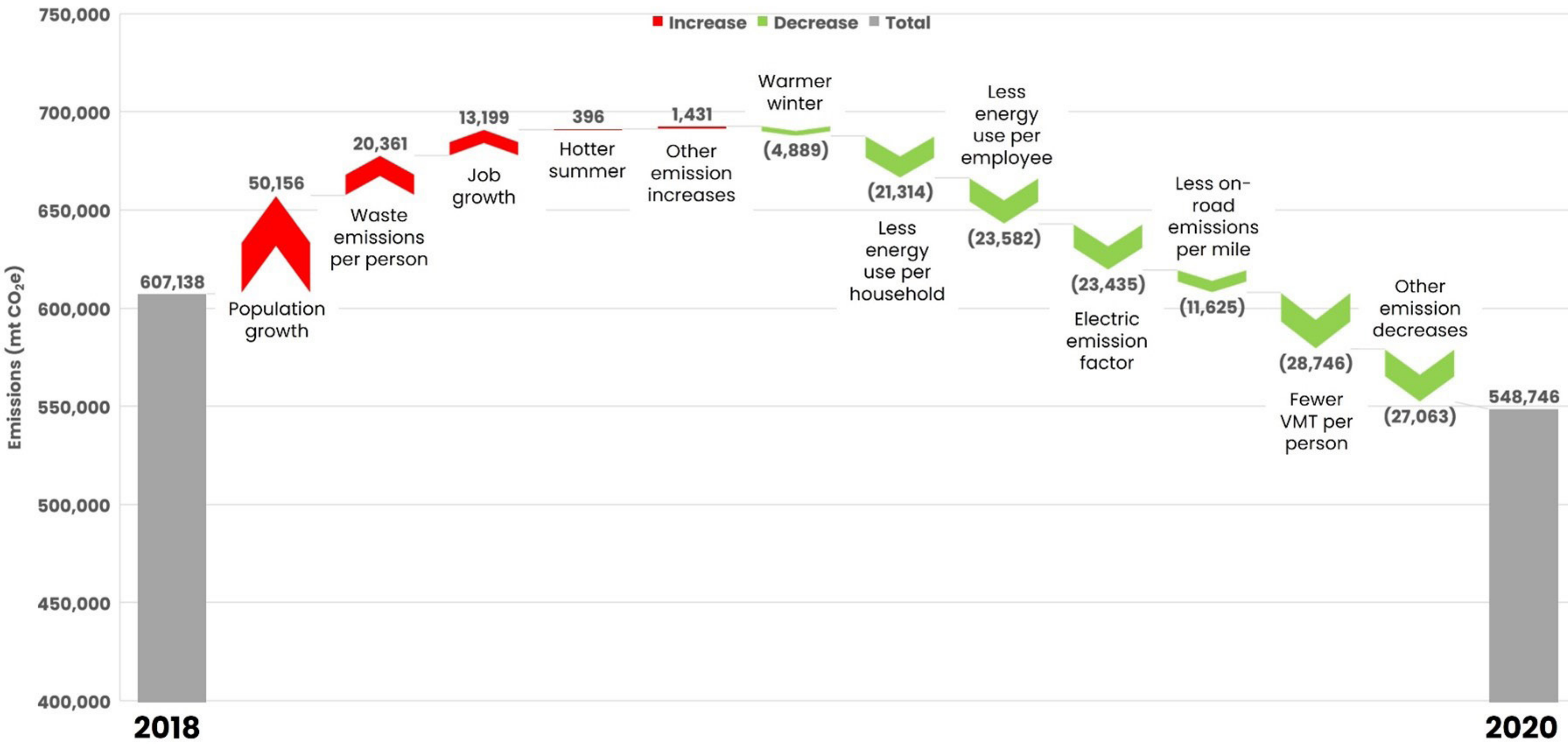


*Figure 12. Contributing factors to GHG emissions increases and decreases between the 2018 and 2020 inventories.*

*Table 3. Detailed contributing factors to GHG emissions increases and decreases between the 2018 and 2020 inventories.*

| Contributing Factor | Emissions Change (mt $CO_2e$) |
|---|---|
| Emissions Change (mt $CO_2e$) | 50,156 |
| Waste model difference | 33,678 |
| Growth in employment | 13,199 |
| Increased therms per household | 2,217 |
| Refrigerants | 886 |
| Hotter summer | 396 |
| EVs | 256 |
| Fugitive Emissions | 210 |
| Stationary Diesel | 68 |
| Compost | 12 |

| Contributing Factor | Emissions Change (mt $CO_2e$) |
|---|---|
| Wastewater | -23 |
| Aviation | -848 |
| Residential Wood | -1,082 |
| T&D Losses | -1,404 |
| Heating fuels mix | -2,064 |
| More households using electric heat | -2,322 |
| Warmer winter | -4,889 |
| Decreased commercial therms per job | -9,491 |
| Decreased on-road emissions per mile | -11,625 |
| Decreased waste generation per person | -13,317 |
| Decreased commercial kWh per job | -14,091 |
| Decreased kWh per household | -21,209 |
| Electricity fuel mix | -21,371 |
| Off-road | -25,178 |
| Decreased VMT per person | -28,746 |

# Comparison with National Trends

City of Bozeman emissions were reduced by 10% between 2018 to 2020. The building energy and transportation sectors decreased emissions while the waste sector emissions increased. These trends mirror trends at the National level. In the US, emissions also decreased between 2018 to 2020 and saw significant COVID-related decreases to the transportation sector and positive impacts of the greening of the electricity grid on electricity sector emissions (Figure 12). National data from 2021 suggests that GHG emissions will likely increase as the world recovers from the COVID-19 pandemic.

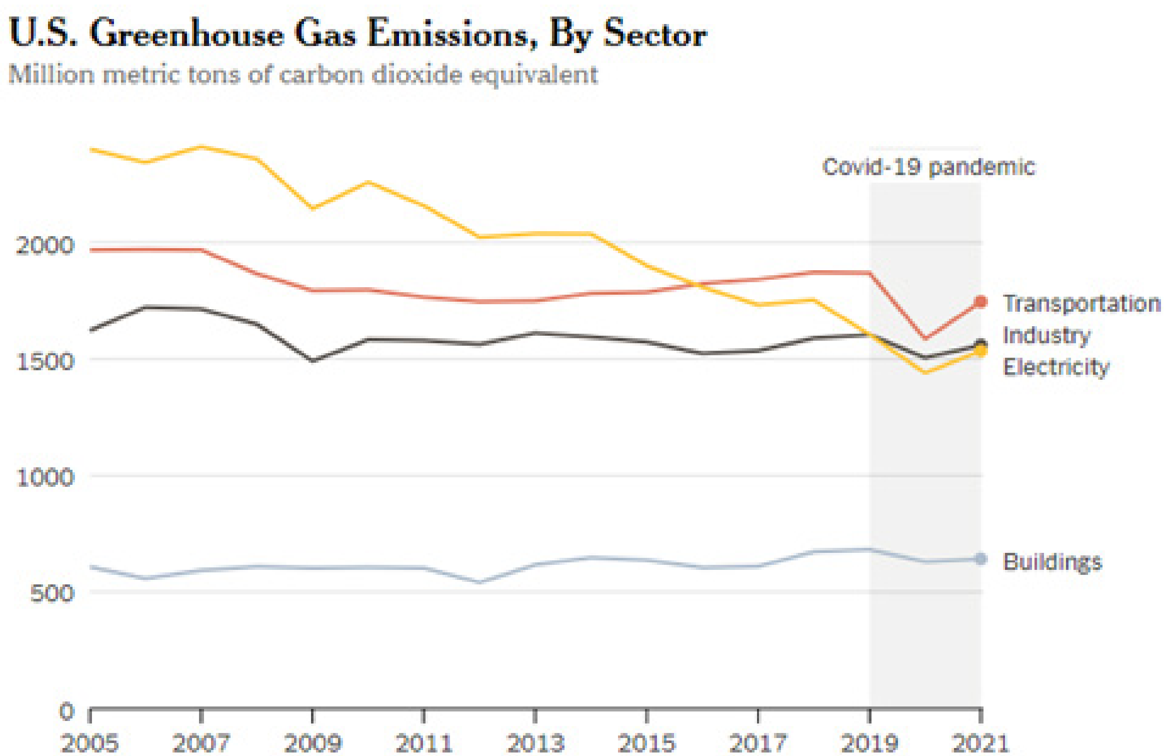


*Figure 13. National trends in greenhouse gas emissions between 2005-2021.*

# Carbon Sequestration

**Bozeman's parks and urban forests provide a myriad of ecosystem benefits and services. Urban forests help filter air and water as well as provide cooling and public health benefits. They also perform a vital function of removing carbon dioxide out of the air, which is commonly referred to as sequestration.**

## Terms and Definitions

**Terrestrial carbon sequestration** is the process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils. The plants and soil that hold the carbon taken from the atmosphere make up a carbon sink. The quantity of carbon stored in the plants and soil is the **carbon stock**. Plants are continually taking in the carbon from the atmosphere and storing it. But when plants senesce, decompose, burn, or land changes from one cover type to another (i.e., from grassland to developments), carbon gets released back into the atmosphere, known as the carbon cycle. Emissions are the loss of carbon to the atmosphere (positive value) and removals are the carbon sequestered from the atmosphere (negative value); **net carbon flux** is the sum of emissions and removals. Ecosystems provide a natural carbon sink through trees, soils, grasslands, etc. Emissions from land and forests occur as part of the natural carbon cycle, but emissions can occur following disturbance events, such as fire, insects and diseases, or land-use changes. Typically, in the United States, land and forests are a net carbon sink, rather than a source of greenhouse gas emissions.*

## Methodology

To estimate Bozeman's greenhouse gas emissions and removals from Bozeman's land and forests, the ICLEI, Local Governments for Sustainability (ICLEI) Land Emissions and Removal Navigator (LEARN) tool was used across Bozeman city limits. The ICLEI LEARN tool estimates the average annual emissions and removals from forests and trees outside forests based on geospatial and cover type data (i.e., forest land, grassland, cropland, wetland, settlement, and other lands). Comparing two time periods provides an estimation of changes in both emissions and removals of carbon, the carbon flux.

The boundary of the carbon flux analysis includes Bozeman city limits The ICLEI LEARN tool applies emission and removal factors for both forests and trees outside of forests (urban tree canopy). Forest factor sets are applied to large tracts of trees that may be present in parks, flood plains, or other areas. Trees outside of forest factor sets are applied to the more sparsely spaced trees typical of residential streets. For Bozeman, only trees outside of forest factor sets were used, as there are no extensive forested areas within the city limits. Default trees outside forests emission and removal factors are provided from a benchmark city that is selected based on geography and climate. Casper, WY, was identified as the most similar benchmark city, though it is comparatively drier and warmer than Bozeman. The land cover layer sourced data from the National Land Cover Dataset (NLCD) for the years 2011, 2013, 2016, and 2019 are at 30-meter resolution, and an overall accuracy of 86.6% at the Anderson Classification System,** Level I vegetation classification. The tree canopy layer sourced data from the NLCD of those same years is also at 30-meter

* Carbon Stocks, Fluxes and the Land Sector, Michgan State Univeristy (2022).
** A Land Use and Land Cover Classification System for Use with Remote Sensor Data, GEOLOGICAL SURVEY PROFESSIONAL PAPER 964 (1976).

resolution, and the data contains percent tree canopy estimates as a continuous variable for each pixel across all land covers and types and are generated by the United States Forest Service (USFS). Gain or loss of tree canopy within the city limits is then applied to the appropriate emissions and removal factors to determine the carbon flux.

## Results

Bozeman's trees and forests removed over a nine-year period on average removed -1,559 metric tons of $CO_2e$ per year. The average emissions from Bozeman's urban tree canopy forested land were 21 metric tons of $CO_2e$ per year. When carbon dioxide emissions are deducted from removals, the balance is -1,548 metric tons of carbon dioxide sequestered per year (Table 4).

The LEARN tool reports uncertainty in the net greenhouse gas balance as high as +/- 45% with a 95% confidence interval (CI) largely attributed to the 30-meter resolution of the geospatial land cover data. In this dataset the confidence interval range for the net greenhouse gas balance on average ranges from -851 metric tons of $CO_2e$ per year to -2,204 metric tons of $CO_2e$ per year. In addition, the NLCD only contains trees outside of forest imagery for the years 2011 and 2016, thus the analysis of 2011 to 2013 and 2013 to 2016 have the same removals, emissions, and net balance numbers. The NLCD is expected to have 2019 trees outside of forest data soon, but was not available for this analysis. Other ways to improve the data is to obtain high resolution tree canopy data from a third party, but that would still require two time periods of identical analysis to apply the change in urban tree canopy to the trees outside of forests emissions and removal factors.

*Table 4. Annual carbon flux within the Bozeman city boundary.*

| City Boundary | Total Removals (t $CO_2e$/yr) | Total Emissions (t $CO_2e$/yr) | Net GHG Balance (Carbon Flux) |
|---|---|---|---|
| Average (2011-2019) | -1,559 | 21 | -1,548 |
| High end range of +45% error | -2,261 | 30 | -2,245 |
| Low end range of -45% error | -857 | 11 | -852 |

Based on current protocol guidance, Bozeman's net greenhouse gas average annual net flux of carbon of -1,548 metric tons of $CO_2e$ per year is provided for informational purposes and was not deducted from Bozeman's overall greenhouse gas emissions total of 548,746 metric tons $CO_2e$.

Beyond carbon sequestration, this analysis does not attempt to quantify the direct and indirect ecosystem benefits of parks and urban forests that create a healthy environment for residents and urban wildlife. Among the many co-benefits, trees intercept particulate matter and reduce air pollution, while providing shade that can reduce the urban heat island and the cooling load of buildings. Plants and soils also act as a filter before water enters streams and groundwater. These ecosystem benefits are interconnected to Bozeman's quality of life and economy but are not quantified within the LEARN tool.

Despite these limitations, the annual carbon sequestration estimates from the LEARN tool are a step towards quantifying the carbon flux of Bozeman's urban natural systems over time and provide an indication of the local carbon sequestration potential. Since climate change impacts can lead to a decline in carbon stock through disturbance events such as insects and disease or high-intensity wildfire, understanding these impacts improves our ability to manage and protect Bozeman's carbon stock. Examples of land management strategies to maintain carbon stocks may include enhancing species diversity of the urban forest and land use planning to minimize forest, grassland, and wetland conversion to other land cover types.

From the LEARN tool analysis, the results provide a preliminary estimate of Bozeman's carbon stock. In future years, the accuracy of the carbon stock estimate could be improved with higher resolution data and establishing urban forest emissions and removal factors specific to Bozeman. Knowledge of Bozeman's carbon stock can help inform land management practices and enhancements that support natural climate solutions to reduce emissions and improve community resilience. While annual removals may seem small, it is critical to maintain and enhance existing urban tree canopy whenever possible. Disturbances such as insect infestations and removal of healthy urban trees can create larger "pulses" of emissions. Trees remain an essential tool in conserving existing carbon stock and ensuring a carbon flux results in net removals.

# Summary

Bozeman's 2020 GHG inventory illustrates the City's progress toward its climate goals. Although Bozeman's emissions have increased by 5% since the 2008 baseline, the City's emissions decreased 10% from the most recent inventory in 2018 and per capita emissions declined by 18%. While this decrease may be attributable to the COVID-19 pandemic, the practical outcome is that the Bozeman community contributed fewer greenhouse gas emissions to the atmosphere in 2020.

Measuring emissions helps Bozeman track progress and understand new opportunities to reduce our contribution to climate change. Monitoring emissions also builds an understanding of areas where we have agency, and areas that may require partnerships and collaboration.

With accelerated emissions reductions, there is still an opportunity to achieve our community climate goals under the adopted framework of the 2020 Bozeman Climate Plan, which features solutions and actions to transition to low-carbon energy and transportation systems, pedestrian-oriented neighborhoods, and nature-based solutions for urban cooling and disaster resilience.

# Appendix A: Data Sources

*Table 5. Emissions data sources and if they were calculated or estimated in this report.*

| Emissions Source | Data Source | Were Emissions Calculated or Estimated? |
|---|---|---|
| Building Electricity Use | NorthWestern Energy | Calculated |
| Building Natural Gas Use | NorthWestern Energy | Calculated |
| Building Propane Use | Amerigas | Calculated |
| Building Stationary Diesel Use | US Census ACS House heating Fuel Survey data, Bozeman commercial square footage data, CBECS data, and US EIA unit conversions | Estimated |
| Fugitive Emissions from Natural Gas Leakage | GPC Protocol default leakage rate (0.3%) | Calculated |
| Transmission & Distribution Losses | NorthWestern Energy loss rate | Calculated |
| Vehicle Miles Traveled | City of Bozeman and Montana Dept or Transportation | Calculated |
| Vehicle Registrations | EPA State Inventory Tool Mobile Combustion Module | Calculated |
| Electric Vehicle Registrations | Atlas EV Dashboard | Calculated |
| EV Transmission & Distribution Losses | NorthWestern Energy loss rate | Calculated |
| Transit Fuel Use | Human Resources Development Council | Calculated |

| Emissions Source | Data Source | Were Emissions Estimated or Calculated? |
|---|---|---|
| Aviation Fuel Use | Bozeman/Yellowstone International Airport | Calculated |
| Waste and compost tonnage | Gallatin County Solid Waste, City of Bozeman | Calculated |
| Closed landfill emissions | Estimated emissions depreciation rate via ICLEI | Estimated |
| Waste transport, collection, and processing emissions | GPC Protocol methodology | Calculated |
| Wastewater | City of Bozeman data for Bozeman WRF | Calculated |
| Refrigerant Leaks | Estimated from commercial square footage and standard assumptions and methodology from IPCC | Estimated |
| NorthWestern Energy Electric Emissions Factor | NorthWestern Energy | N/A |

# Appendix B: Emissions Factors

See Table 6 for an overview of the emission factors that were used for calculations throughout the inventory. The Notes column provides details as to which emission factors need updated regularly.

*Table 6. Summary of greenhouse gas emissions factors.*

| Stationary Energy Emission Factors—Electricity & Natural Gas | | | | | |
|---|---|---|---|---|---|
| Emission Source | GHG | Value | Unit | Source | Notes |
| Electricity | $CO_2$ | 0.419 | mt $CO_2$/ MWh | Shown in NorthWestern Energy's ESG/ Sustainability Template under Montana Generation Statistics: Montana Owned + Long Term Contracts for 2020. See line 7.3.2.3 on page 10. | Verify with each inventory. Likely that the $CO_2$ emission factor will change annually. |
| | $CH_4$ | 0.00003 | mt $CH_4$/ MWh | EPA's eGrid: eGRID 2020 summary tables, table 1, sub region NWPP. | Verify with each inventory. |
| | $N_2O$ | 0.000004 | mt $N_2O$/ MWh | | |

| Stationary Energy Emission Factors—Electricity & Natural Gas | | | | | |
|---|---|---|---|---|---|
| Emission Source | GHG | Value | Unit | Source | Notes |
| Natural Gas | $CO_2$ | 0.0053 | mt $CO_2$/ therm | 2013 ICLEI US Community Protocol, Appendix C. | Verify with each inventory. |
| | $CH_4$ | 0.0000005 | mt $CH_4$/ therm | | |
| | $N_2O$ | 0.00000001 | mt $N_2O$/ therm | | |
| Stationary Diesel | $CO_2$ | 0.01 | mt $CO_2$/ gallon | ICLEI's U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol) – Appendix C: Built Environment Emission Activities and Sources, Version 1.1, July 2013. Assumes distillate fuel oil number 2 and that diesel is primarily used in generators by the industrial sector. | |
| | $CH_4$ | 0.0000004 | mt $CH_4$/ gallon | | |
| | $N_2O$ | 0.0000001 | mt $N_2O$/ gallon | | |
| Propane | $CO_2$ | 0.006 | mt $CO_2$/ gallon | ICLEI's U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol) – Appendix C: Built Environment Emission Activities and Sources, Version 1.1, July 2013. | |
| | $CH_4$ | 0.000001 | mt $CH_4$/ gallon | | |
| | $N_2O$ | 0.0000001 | mt $N_2O$/ gallon | | |

| Transportation Emission Factors—Ethanol, Gasoline, and Diesel | | | | | |
|---|---|---|---|---|---|
| Emission Source | GHG | Value | Unit | Source | Notes |
| Gasoline | $CO_2$ | 0.00878 | mt $CO_2$/gal | EPA estimates as recommended by ICLEI. Based on vehicles that are 2008 to present or 2009 to present. Past years utilized ICLEI Appendix D numbers. | Should remain constant but verify with each inventory. |
| | $CH_4$ | Varies by vehicle | g/mile | | |
| | $N_2O$ | | | | |
| Diesel | $CO_2$ | 0.01 | mt $CO_2$/gal | | |
| | $CH_4$ | Varies by vehicle | g/mile | | |
| | $N_2O$ | | | | |
| Ethanol | $CO_2$ | 0.006 | mt CO2/gal | | |
| | $CH_4$ | Varies by vehicle | g/mile | | |
| | $N_2O$ | | | | |

| Transit Emission Factors | | | | | |
|---|---|---|---|---|---|
| Emission Source | GHG | Value | Unit | Source | Notes |
| Diesel | $CO_2$ | 0.01 | mt $CO_2$/ gal | EPA estimates as recommended by ICLEI. | Should remain constant but verify with each inventory. |
| | $CH_4$ | 0.001 | g $CH_4$/ mile | | |
| | $N_2O$ | 0.0015 | g $N_2O$/ mile | | |
| **Aviation Emission Factors** | | | | | |
| Jet fuel | $CO_2$ | 9.75 | Kg $CO_2$/ gal | Per guidance from ICLEI on emissions factors used in the ClearPath tool. | Should remain constant but verify with each inventory. |
| | $CH_4$ | 0.41 | g $CH_4$/ gal | | |
| | $N_2O$ | 0.08 | g $N_2O$/ gal | | |
| Aviation Gasoline | $CO_2$ | 8.31 | kg $CO_2$/ gal | | |
| | $CH_4$ | 0.36 | g $CH_4$/ gal | | |
| | $N_2O$ | 0.07 | g $N_2O$/ gal | | |

| Waste Emission Factors | | | | | |
|---|---|---|---|---|---|
| **Emission Source** | **GHG** | **Value** | **Unit** | **Source** | **Notes** |
| Municipal Solid Waste | $CH_4$ | Varies by waste type | mt $CH_4$/ ton waste | 2013 ICLEI US Community Protocol, Appendix E. | Should remain constant but verify with each inventory. |
| Recycled Waste | $CH_4$ | Varies by waste type | mt $CH_4$/ ton waste | CLEI's U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions (Community Protocol) – Appendix C: Built Environment Emission Activities and Sources, Version 1.1, July 2013. | |
| | $N_2O$ | | mt $N_2O$/ wet short ton waste | | |
| Composted Waste | $CH_4$ | 0.00047 | mt $CH_4$/ ton waste | Documentation for Greenhouse Gas Emissions and Energy Factors Used in the Waste Reduction Model (WARM). **Assumes green waste.** Values are adjusted to $CH_4$ and $N_2O$ emission factors. | |
| | $N_2O$ | 0.00022 | mt $N_2O$/ ton waste | | |
| | $CH_4$ | 0.00018 | mt $CH_4$/ ton waste | Documentation for Greenhouse Gas Emissions and Energy Factors Used in the Waste Reduction Model (WARM). **Assumes biowaste.** Values are adjusted to CH4 and $N_2O$ emission factors. | |
| | $N_2O$ | 0.00013 | mt $N_2O$/ ton waste | | |
| Wastewater | $CH_4$ | Varies by treatment | Varies | 2013 ICLEI US Community Protocol, Appendix F. | |
| | $N_2O$ | | | | |

## Photo Credits

Page ES-1 Trevor Vannoy on Unsplash

Page 1 Lee Peters on Unsplash

Page 4 Chris Montgomery on Unsplash

Page 5 Jennifer Horstmann on Unsplash

Page 15 Matthew Lancaster on Unsplash

Page 17 Anna Gur on Unsplash

Page 21 Bobby Stevenson on Unsplash

Page 28 Matthew Lancaster on Unsplash

Page 32, 40 Olena Sergienko on Unsplash

Page 36 Malachy Marshall on Unsplash

Page 37 Trevor Vannoy on Unsplash