Boulder's Municipal

Greenhouse Gas Inventory Report

Calendar Year 2022

LOTUS
Engineering & Sustainability

We acknowledge with respect and gratitude that this report was created on the ancestral homelands and unceded territory of Indigenous Peoples who have traversed, lived in and stewarded lands in the Boulder Valley since time immemorial. Those Indigenous Nations include the: Di De'i (Apache), Hinono'eiteen (Arapaho), Tsistsistas (Cheyenne), Nʉmʉnʉʉ (Comanche), Kiowa, Čariks i Čariks (Pawnee), Sosonih (Shoshone), Oc'eti S'akowin (Sioux) and Núuchiu (Ute). We honor and respect the people of these Nations and their ancestors. We also recognize that Indigenous knowledge, oral histories, and languages handed down through generations have shaped profound cultural and spiritual connections with Boulder-area lands and ecosystems — connections that are sustained and celebrated to this day.

TABLE OF CONTENTS

Table of Figures

Table of Tables

INTRODUCTION

The City of Boulder has been engaged in climate action for over two decades, becoming one of the first cities to sign on to the Kyoto Protocol in 2002 and officially adopting carbon reduction goals in 2006. Since those early years, Boulder has consistently kept up with updating targets in accordance with the scientific consensus on the level of carbon reduction necessary to stabilize the climate. In April 2021, the city took the next step by becoming one of 21 US cities to join the ICLEI 150 Race to Zero campaign. The initiative encourages bold emissions reduction policies and rallies US cities to lead the fight against climate change. Boulder strengthened its Climate Action Plan in 2021 to include ambitious mitigation goals and targets:

<table>
<tr><th>Community-wide</th><th>City Organization</th></tr>
<tr><td>Reduce emissions 70 percent by 2030 using a 2018 baseline</td><td>Reduce emissions 50 percent by 2020 using a 2008 baseline</td></tr>
<tr><td>Become a Net-Zero City by 2035.[1]</td><td rowspan="2">Reduce emissions 80 percent by 2030 using a 2008 baseline</td></tr>
<tr><td>Become a Carbon-Positive City by 2040.[2]</td></tr>
</table>

To support progress towards these targets, Boulder's city organization has been working to reduce greenhouse gas (GHG) emissions from its operations. Boulder conducted its first municipal operations GHG inventory in 2008 and utilized the Climate Registry's Local Government Operations Protocol[3] (LGOP) framework. Inventory results were uploaded into the ICLEI-Local Governments for Sustainability (ICLEI) ClearPath tracking system.[4] In 2011, the city began conducting annual GHG inventories to track our progress towards emission reduction goals and in 2016, the city adopted formal targets for reducing emissions from its municipal operations. See Figure 1 below for a timeline of the city's emission tracking milestones.

As of 2022, Boulder has reduced its emissions from municipal operations by 43 percent since 2008.

[1] To be a Net-Zero City, Boulder will reduce its emissions to the highest extent possible by 2035. Any remaining emissions sources can be sequestered naturally through the biosphere.

[2] To be a Net-Zero City, Boulder will absorb more GHGs than it emits. Examples of how Boulder may do this include regenerative agricultural practices and initiatives to dramatically increase urban forest plantings. Please see https://bouldercolorado.gov/news/boulders-new-climate-targets-explained.

[3] For more information on the Local Government Operations Protocol please see http://www.theclimateregistry.org/tools-resources/reporting-protocols/local-goverment-operations-protocol/. The inventory considers emissions generated from activities within the operational control of the city of Boulder. 'Operational control' is defined as those operations, facilities, or sources that are wholly owned by the city of Boulder, as well as those in which the city of Boulder has full authority to introduce and implement operational health, safety, and environmental policies. See: https://www.arb.ca.gov/cc/protocols/localgov/pubs/lgo_protocol_v1_1_2010-05-03.pdf.

[4] For more information in ICLEI's ClearPath tool please see http://icleiusa.org/clearpath/.

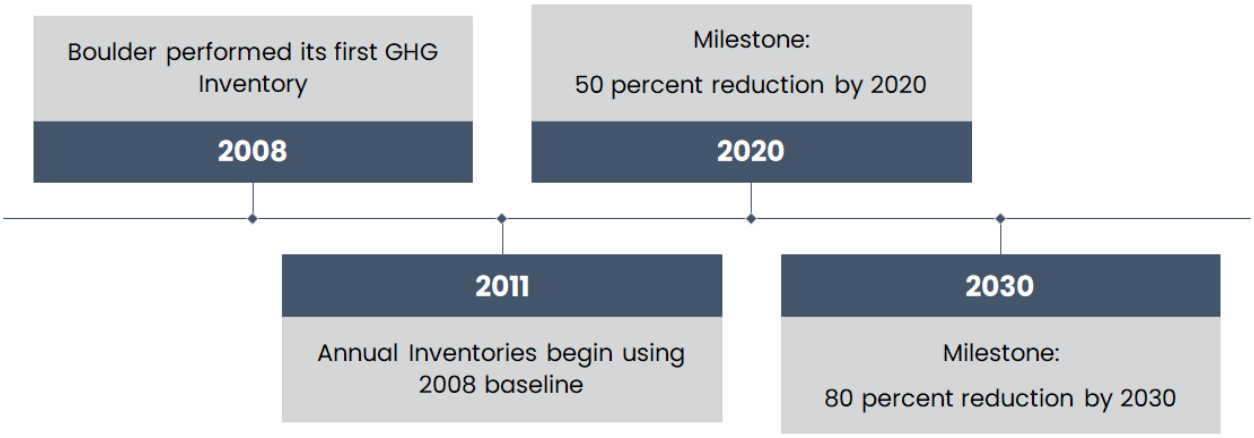

Figure 1. Timeline of Boulder's municipal emission reductions goals.

CURRENT EMISSIONS SNAPSHOT

Boulder's city operations have made significant progress in recent years, narrowly missing their 2020 target by three percent, and reducing emissions 54 percent from 2008 levels in 2021. However, due to likely consequences of the pandemic easing in severity, as well as new methodology changes and upgraded data, municipal emissions increased in 2022. See Figure 2. Moving forward, reductions of approximately 5 percent per year will be needed to meet the 2030 target of an 80 percent reduction in emissions.

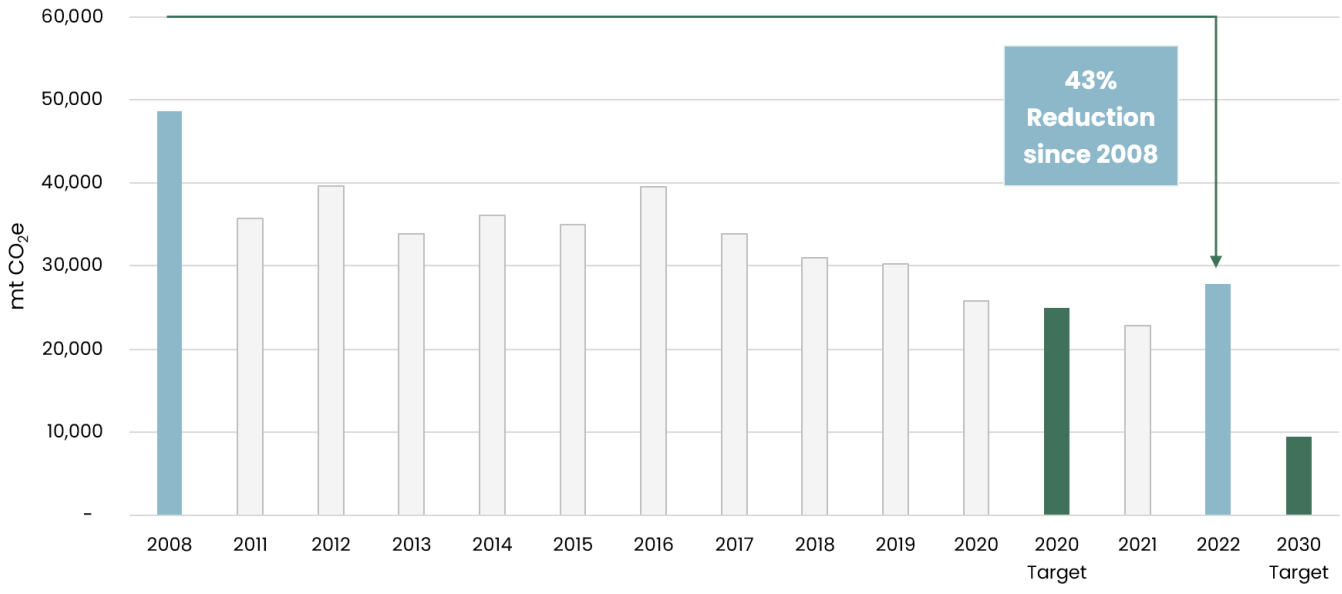

Figure 2. Total annual emissions (mt CO_2e) 2008-2022 and 2020/2030 targets.

In 2022, Boulder's municipal operations generated a total of 27,809 metric tons of carbon dioxide equivalent (mt CO_2e) including well-to-wheel emissions.

At 56 percent of total emissions (15,689 mt CO_2e), the stationary energy (i.e., building energy) sector made up the largest share of the city's operational emissions, followed by transportation emissions at 21 percent (5,773 mt CO_2e) and consumption-based emissions at 19 percent (5,293 mt CO_2e). Consumption-based emissions sources include well-to-wheel emissions (773 mt CO_2e). The remaining 4 percent of emissions were generated from wastewater treatment (2 percent), solid waste (1 percent), and the use of industrial processes and products (i.e., refrigerant use, 1 percent). See Figure 3.

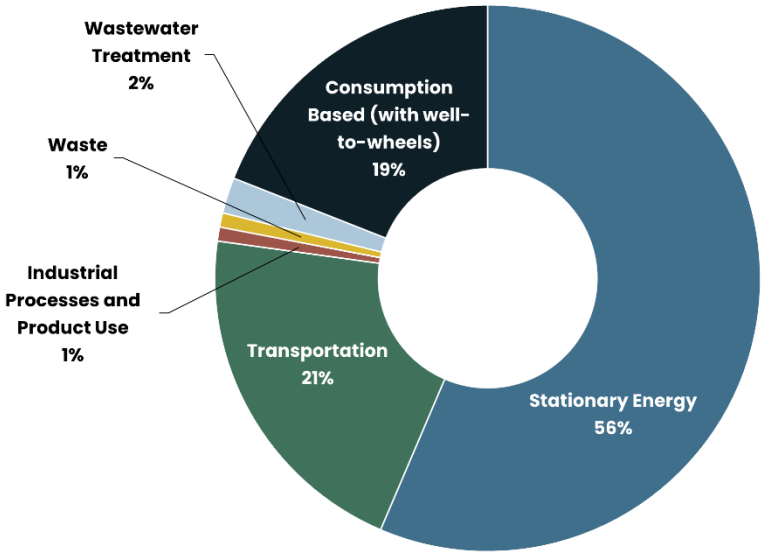

Figure 3. Municipal emissions by sector, 2022.

In terms of emissions by source (Figure 3), without well-to-wheel, the breakdown is:

- **Highest: Electricity** at 41 percent of municipal emissions (11,517 mt CO_2e).
    - Grid-supplied electricity (i.e., electricity used in streetlights, facilities, water transport, and wastewater treatment) and those associated with emissions from grid-supplied electricity consumed in the city for on-road transportation (i.e., electric vehicles in the municipal vehicle fleet and used for employee commuting).
- **Second Highest: Natural gas** usage at municipal facilities accounted for 15 percent of municipal emissions (4,072 mt CO_2e).
- **Third Highest: Consumption-based sources** accounted for 19 percent of municipal emissions (5,293 mt CO_2e). Cement usage itself accounted for 12 percent of overall municipal emissions (3,466 mt CO_2e).

For more in-depth breakdowns of emissions by source, see Table 1 and Figure 4[5] below.

[5] Other emissions include: asphalt, wastewater, food purchases, solid waste, refrigerants, propane, business air travel, paper purchases, computer purchases, ethanol, and fertilizer use.

Table 1. Municipal emissions by source detail including consumption emissions, 2022.[6]

Emission Source	Emissions (mt CO_2e)	Percent of Total
Electricity	11,517	41%
Natural Gas	4,072	15%
Cement	3,466	12%
Gasoline	3,198	12%
Diesel	2,342	8%
Well-to-wheel[7]	773	3%
Asphalt	726	3%
Wastewater	589	2%
Food	282	1%
Solid Waste	234	1%
Refrigerants	230	1%
Propane	173	1%
Aviation	151	1%
Paper	26	0.1%
Computers	17	0.1%
Ethanol	8	0.03%
Fertilizer	3	0.01%
Biodiesel	1	0.01%
Total	**27,809**	**100%**

[6] Numbers in data tables may not add up to exactly 100 percent due to rounding.

[7] Well-to-wheel emissions include all emissions related to fuel production, processing, distribution, and use. For example, emissions from gasoline are produced while extracting petroleum from the earth, refining it, distributing the fuel to stations, and burning it in vehicles. Boulder's city operations use the well-to-wheel estimates to better understand the environmental impact from their vehicle fleet and equipment.

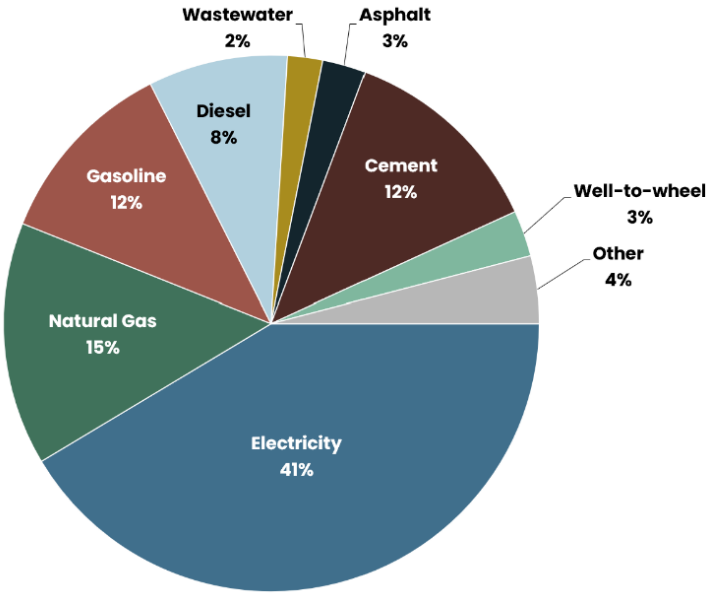

Figure 4. Boulder municipal emissions by source in 2022.

How Close is Boulder Municipality to Reaching its Goals?

With the exception of 2009 and 2010, Boulder has been tracking emissions from municipal operations since 2008. These inventories are vital in helping the city organization understand its progress towards emission reduction goals. Inventory results are also helpful in determining new sustainability programs and policies, as well as identifying where to focus certain strategies and funding.

As discussed in the introduction, Boulder's city organization set two municipal emission reduction goals. The first goal was to reduce municipal emissions by 50 percent by 2020 and the second goal is to reduce emissions by 80 percent by 2030. Both goals are set against a 2008 baseline.

As seen below in Figure 5, city operations surpassed their 2020 goal in 2021, reducing their emissions 54 percent from 2008 levels. However, municipal emissions increased once again in 2022. With this increase in emissions, city operations have now decreased their emissions 43 percent from the 2008 baseline.

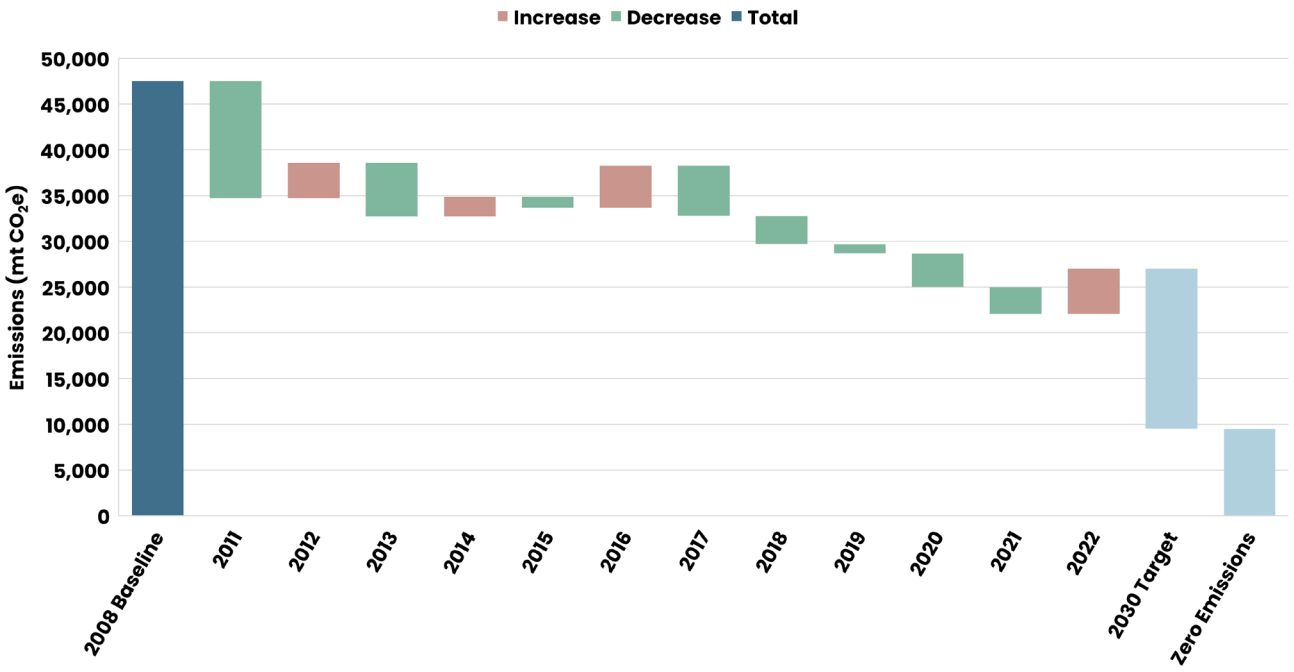

Figure 5. Year-over-year change in mt CO_2e, 2008-2022 with targets.

What Happened in 2022

Total municipal emissions increased 23 percent between 2021 and 2022 but remain below pre-pandemic levels. Between the two years, scope 1 sources increased 26 percent, scope 2 sources increased 4 percent, and scope 3 sources increased 60 percent. Except for a few years, emissions have largely been declining since 2008.

Some notable factors and trends between 2021 and 2022 include:

- **Fleet vehicle and equipment methodology updates**: for the 2022 inventory, more granular data for Boulder's municipal fleet and equipment fuel usage was available and analyzed; this update is important for future data analysis and emissions tracking. However, it is likely the cause for increased scope 1 emissions from the municipal fleet is because emissions may have been underestimated in the past.
- **Updated employee commute survey and increased VMT**: The city organization completed an updated Boulder Valley Employee Survey in 2022—the first one that has been completed since 2017. The 2017 survey was used to calculate employee commuting emissions from 2017 to 2021. Between 2017 and 2022, vehicle miles traveled (VMT) by commuters increased 23 percent—this increase has a significant emissions impact. This jump in VMT, coupled with the updated survey and methodological changes, is contributing to emissions changes between 2021 and 2022. In other words, we may not have been fully accounting for these emissions previously. We continue to refine our methodology to ensure accurate measurements.
- **COVID-19 easing and commuting patterns changing:** as the pandemic continues to ease, activity levels are realigning with pre-pandemic conditions. For Boulder, this is most evident in

2022 employee commuting data. Commuting habits and patterns are changing in several ways: more people are driving single-occupancy vehicles and fewer people are taking public transit, Boulder residents use a larger variety of transportation options and drive shorter distances to work, and non-residents primarily drive SOVs and commute much farther to work. Additionally, 60 percent of employees live outside of Boulder while 40 percent reside in the city, and those residing outside of the City were driving farther to get to work in 2022.[8] Read more about commuting trends in the Transportation Emissions section.

EMISSION TRENDS BY SCOPE

Comparing emissions by scope is important as each scope presents a different level of municipal control over emissions. Scope 1 emissions are direct emissions from owned or controlled sources (e.g., fuel used in buildings and fleet vehicles). Scope 2 emissions primarily consist of grid-supplied electricity. Scope 3 emissions are other indirect emissions (e.g., consumption-based sources).

The following is an overview of all the sources that are included in the 2022 inventory,[9] classified by scope.

- **Scope 1:** GHG emissions from sources owned and operated by the City.
  - Stationary fuel used in municipal buildings and facilities including natural gas, propane, diesel, and biodiesel.
  - Municipal vehicle fleet and equipment fuel use including gasoline, ethanol, diesel, and biodiesel.
  - Wastewater treatment by the city-owned facility.
  - Refrigerant usage in municipal buildings and facilities.
- **Scope 2:** GHG emissions occurring as a result of the use of grid-supplied electricity, heat, steam, and/or cooling within the boundary.
  - Grid-supplied electricity used in municipal buildings, facilities, and vehicle fleet.
- **Scope 3:** All other GHG emissions that occur as a result of activity by City employees as well as consumption-based sources.
  - Employee commuting fuel use (includes diesel and gasoline).
  - Reimbursed business travel (on-road) fuel use including gasoline.
  - Business travel (aviation).
  - Solid waste and compost from municipal buildings and facilities.
  - Consumption-based sources including asphalt, cement, paper, food, fertilizer, and computers.

Since the 2008 baseline, scope 1 emissions have decreased nine percent, scope 2 emissions have decreased 55 percent, and scope 3 emissions have decreased 43 percent. See Figure 6. Scope 1 emissions have not decreased significantly because natural gas usage in buildings has not decreased significantly.

[8] See: https://bouldercolorado.gov/media/4807/download?inline.

[9] Note that Boulder was interested in understanding the avoided emissions from activities such as recycling, composting, and renewable energy (i.e., on-site solar and hydro generation). These activities are not included in the standard LGOP reporting and are therefore reported as information-only.

Fleet vehicles and equipment still mostly use fossil fuels but the city has switched some fleet vehicles over to hybrid and electric options—another contributor to the small decrease over time. The city organization is working on electrifying its fleet and buildings, so scope 1 emissions will decrease and become scope 2 emissions. Scope 2 emissions have decreased significantly, largely due to the greening of Xcel Energy's electric grid. Although electrification will bring more electricity usage and emissions, scope 2 emissions will still benefit from Xcel Energy's decreasing emission factor. Scope 3 emissions have fluctuated annually since the 2008 baseline, mostly due to the inconsistency of capital projects and purchasing.

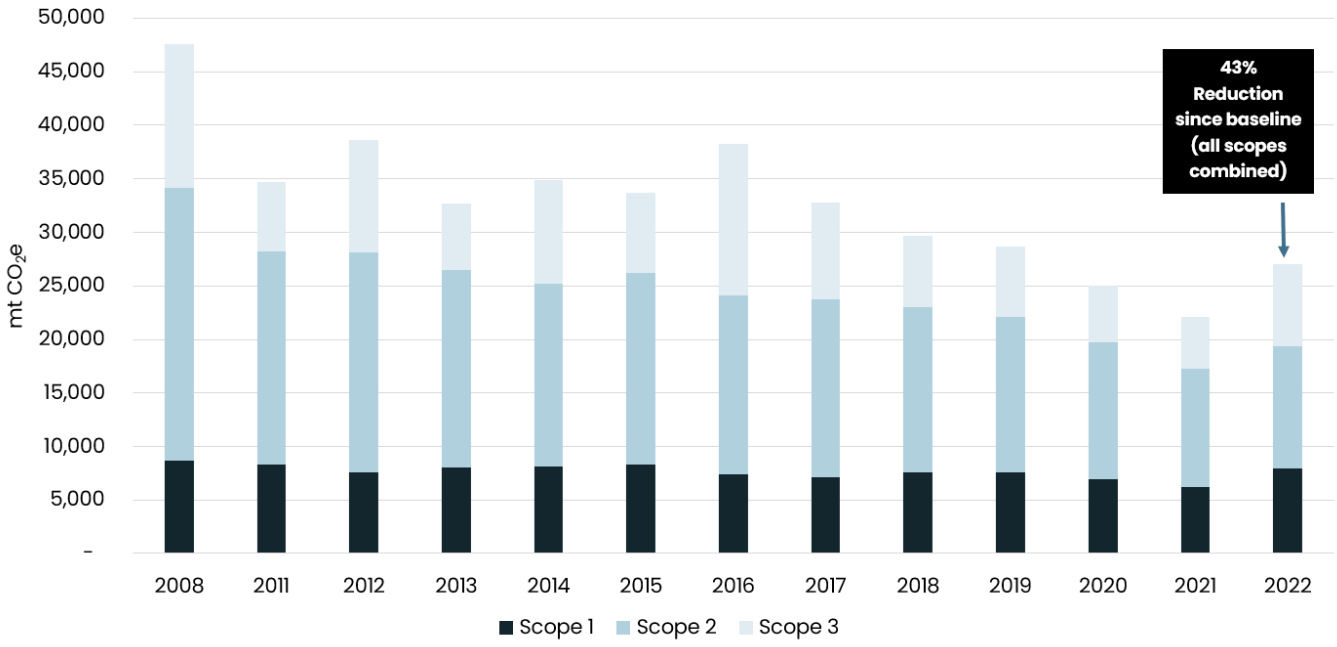

Figure 6. Emissions by scope (mt CO_2e), 2008-2022.[10]

[10] The inventory also estimated Scope 3 emissions resulting from well-to-wheel activities, which include emissions from extracting and transporting the primary fuel source to the point at which it is used in the vehicle. Well-to-wheel activities produce 770 mt CO_2e, resulting in a total emissions value of 24,705 mt CO_2e. Well-to-wheel numbers are not included in the 2008-2022 trends.

EMISSION TRENDS BY SECTOR

Figure 7 and Figure 8 highlight emission trends by sector over time. Reductions since 2008 came from consumption-based sources (down 61%), streetlights and traffic signals[11] (down 53%), buildings and facilities (down 52%), and waste and wastewater treatment activity (down 45%). Increases since 2008 came from employee commuting activity and jet fuel usage related to business travel (up 58%), solid waste disposal (up 58%), and vehicle fleet and equipment fuel usage (up 25%). See Figure 7.

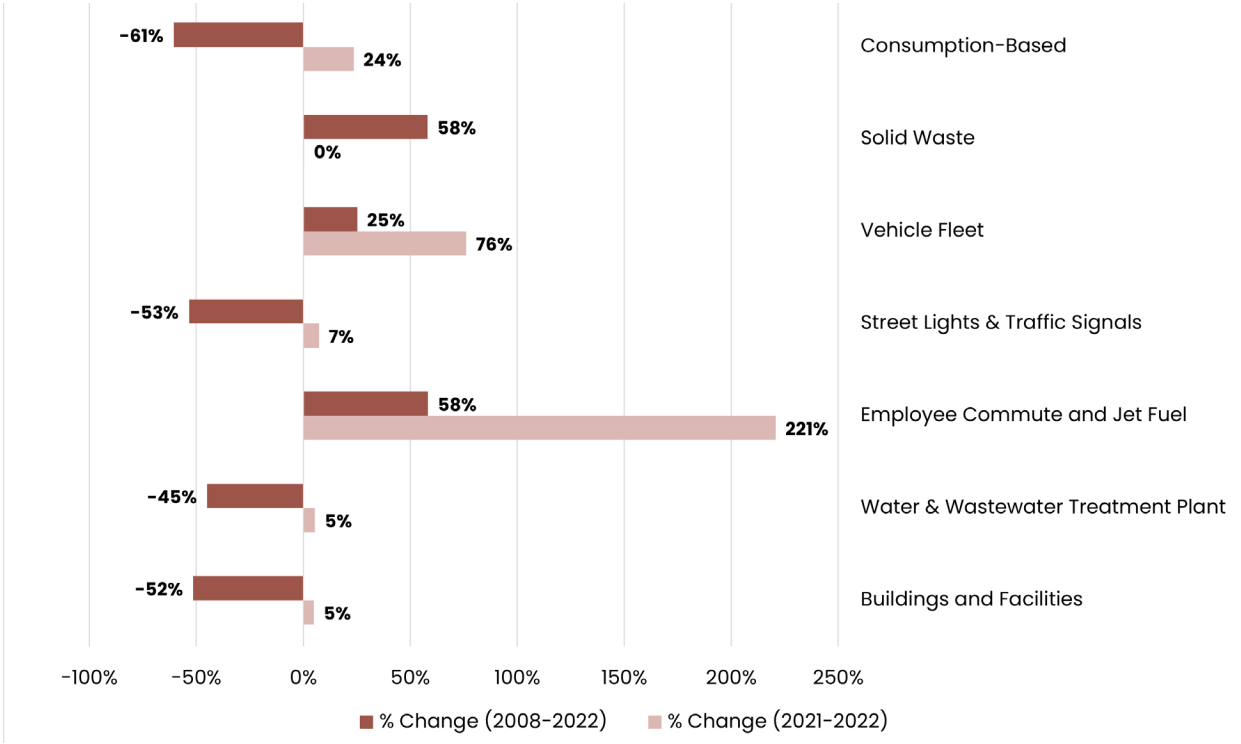

Figure 7. Percent Change in Emissions by Sector 2008-2022, 2021-2022.[12]

Emissions from all sectors increased between 2021 and 2022. The largest increases came from employee commuting activity and business-travel induced jet fuel usage (up 221 percent), vehicle fleet and equipment fuel usage (up 76 percent), and consumption-based sources (up 29 percent).[13] See Figure 8.

[11] Due to incomplete 2021 streetlight and traffic signal data, there appears to be an emissions increase between 2021 and 2022; however, these emissions likely did not change between years.

[12] Note that refrigerants are not included in this figure; they have shown a 584% increase between 2008 and 2022 due to better data collection efforts, updated global warming potentials, and additional square footage to cool. Excluding them from this figure provides a better scale for visualizing the increases and decreases of other sectors. Despite the large increase, refrigerant emissions make up only 0.8 percent of total municipal emissions.

[13] The "Other" category for Figure 8 contains emissions from solid waste and refrigerant leakage.

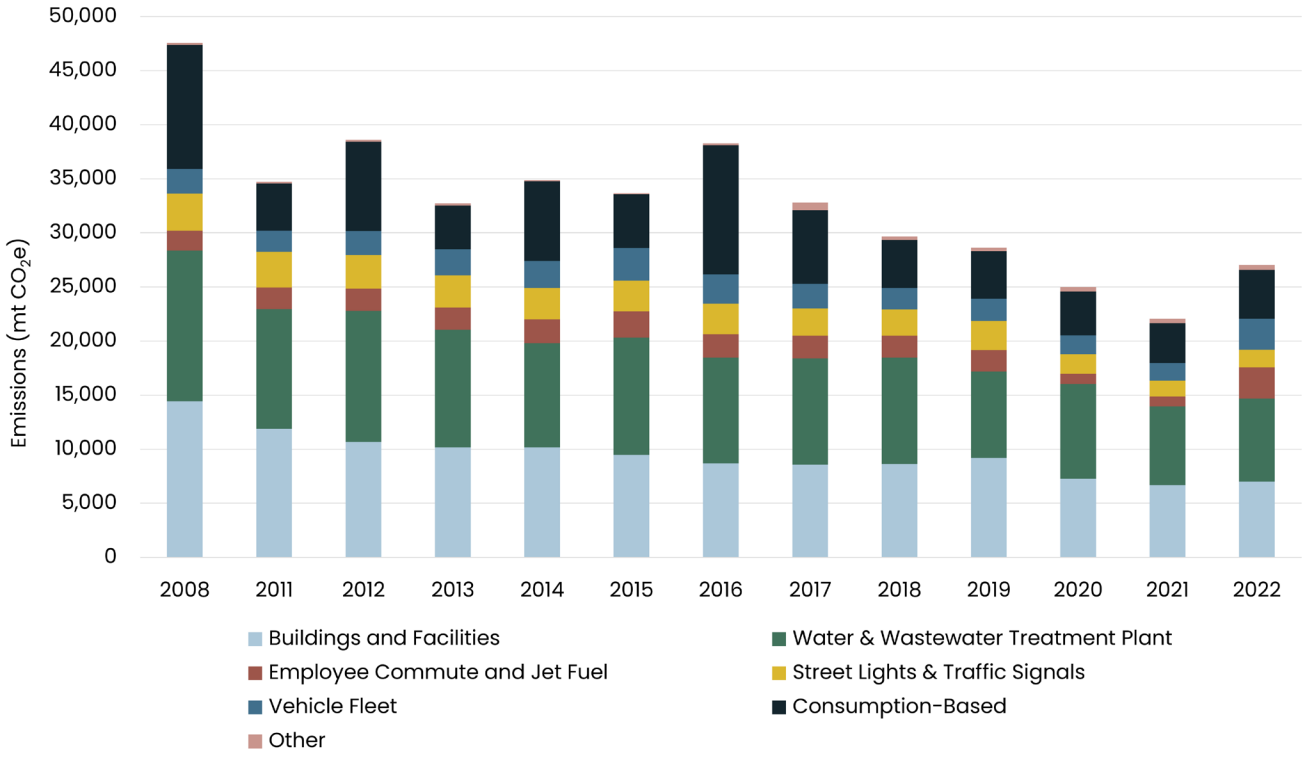

Figure 8. Emissions by sector (mt CO_2e), 2008-2022.

Stationary Energy Emissions

The largest source of emissions from municipal operations in the stationary energy sector is water and wastewater treatment ("Utilities") electricity usage[14] at 36 percent (5,693 mt CO_2e), followed by facilities electricity use at 26 percent (4,134 mt CO_2e), facilities stationary fuel usage at 18 percent (2,868 mt CO_2e), streetlights electricity usage at 10 percent (1,596 mt CO_2e), water treatment stationary fuel usage at eight percent (181 mt CO_2e), and wastewater treatment stationary fuel usage at one percent (6 mt CO_2e). Stationary fuels, such as natural gas, stationary diesel, and propane, differ from other fuels in that they are used in stationary objects, such as buildings, generators, and pumps rather than in mobile objects. Refer to Table 2.

[14] Utilities include Public Works and Wastewater Treatment.

Table 2. Stationary energy emissions detail (mt CO_2e), 2022.

Emission Source	Emissions (mt CO_2e)	Percent of the Total
Utilities Electricity	5,693	36%
Facilities Electricity	4,134	26%
Facilities Natural Gas	2,868	18%
Streetlights Electricity	1,596	10%
Utilities Natural Gas	1,212	8%
Water Treatment Propane and Diesel	181	1%
Wastewater Treatment Propane	6	0.04%
Total	**15,689**	**100%**

Electricity use comprises a significant source of emissions—it is helpful to distinguish between usage trends and emission trends. Generally, over time, electricity use at municipal facilities has decreased alongside emissions. This is largely driven by energy efficiency measures and more renewable energy sources on the grid. See Figure 9.

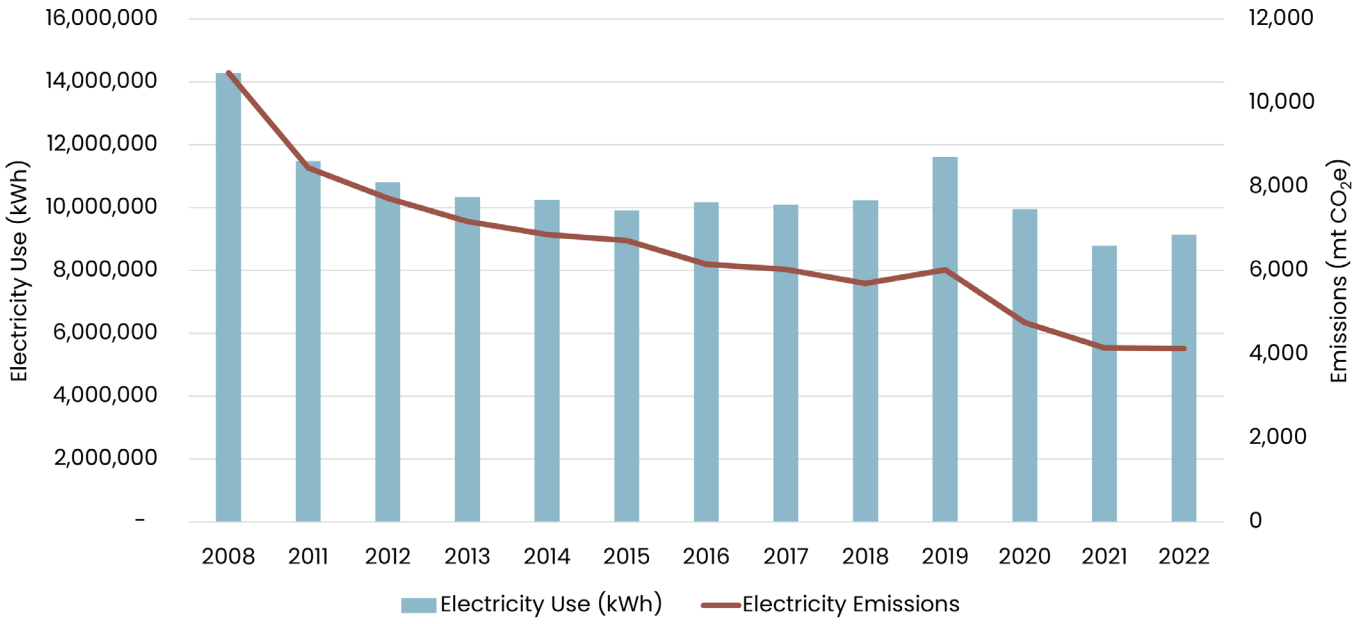

Figure 9. Total electricity usage and change in electricity emissions from the 2008 baseline.

What Happened in 2022

The city's official return to work happened in August of 2022, which resulted in a number of emissions sources rebounding towards pre-pandemic levels. Stationary energy emissions, including both electricity and natural gas, increased five percent in municipal facilities between

2021 and 2022. Usage of almost all stationary energy sources were higher in 2022. Electricity emissions increased four percent, natural gas emissions increased 10 percent, propane emissions increased four percent, stationary diesel emissions increased 29 percent, and stationary biodiesel emissions did not change.

Some notable trends include:

- **Building Electrification**: The city organization has been working on converting some of its municipal buildings to run fully on electricity. Without significant investment in building infrastructure to aid electrification, scope 1 emissions are unlikely to decrease significantly in coming years. Additionally, without electrifying space and water heating in municipal buildings, there will still be emissions from buildings when Xcel Energy achieves 100% renewable energy on the grid.
- **Solar:** Many new solar projects have been installed across the city in recent years. In 2021, there were several solar systems that did not record a full year's worth of solar generation data. This year, those systems did record data for the entire calendar year, so avoided emissions from solar generation increased. It should be noted that the city does NOT retain the renewable energy credits (RECs) for these systems and therefore cannot count the renewable energy avoided emissions against the total local government operations emissions. It is important that the city continues to explore and add renewable energy systems to their facilities for resilience and grid-wide emissions reductions impacts.
- **Renewable Energy on the Grid:** Colorado House Bill 19-1261 requires that investor-owned utilities like Xcel Energy reduce emissions 80% from 2005 levels by 2030. Xcel Energy's emission reduction goals are even more ambitious. Xcel Energy also has a carbon-neutrality goal for 2050. Assuming that Xcel Energy stays on track with their goals, the city organization can expect electricity emissions to continue decreasing annually. Table 3 shows the overall change in the electricity emissions factor between 2008 and 2022.

Table 3. Electricity emission factor over time, 2008-2022.

	2008	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022
Electricity Emission Factor (mt CO2 / MWh)	0.747	0.732	0.7	0.69	0.657	0.676	0.599	0.593	0.552	0.514	0.474	0.470	0.449
Year over Year Change		-2%	-4%	-1%	-5%	3%	-11%	-1%	-7%	-7%	-8%	-1%	-4%
Change Since 2008		-2%	-6%	-8%	-12%	-10%	-20%	-21%	-26%	-31%	-37%	-37%	-40%

TRANSPORTATION EMISSIONS

Emissions from transportation-related sources are outlined in Table 4.

Table 4. Transportation emissions detail (mt CO_2e), 2022.

Emission Source	Emissions (mt CO_2e)	Percent of Total
Employee Commuting	2,737	47%
Municipal Owned Vehicles	2,457	43%
Municipal Owned Equipment	416	7%
Business Air Travel	151	3%
On-Road Business Travel[15]	12	0.2%
Total	**5,773**	**100%**

What Happened in 2022

Transportation emissions increased by 116 percent between 2021 and 2022. Vehicle fleet (municipally-owned vehicles and equipment) emissions increased by 66 percent,[16] business travel (on-road and air travel) emissions increased by 277 percent, and employee commuting emissions increased by 205 percent.

Some notable trends include:

- **Employee Commute Shift:** An updated set of survey results was available for the 2022 municipal operations inventory. When compared to the previous survey results from 2017, a mode shift is evident in Boulder's 2022 employee commuting data. The "return-to-work" following the pandemic happened later for city employees than it did for the broader community. Several interesting trends were evident in the data, such as:
    - According to the most recent 2022 City of Boulder (Government) Employee Transportation Survey[17] (Transportation Survey), 79 percent of the city organization's workforce is non-residents. These non-resident employees are commuting farther and are more likely to use SOVs. Employees who reside in Boulder commute an average of 3.9 miles, whereas non-residents commute an average of 19.7 miles. Fifty-one percent of resident employees drive to work in an SOV, while 73 percent of non-resident employees do the same. In addition, the percentage of total commuters driving SOVs increased from 42 percent to 62 percent between 2017 and 2022.
    - Overall commuting distances are increasing, especially for non-residents. Between 2017 and 2022, the percentage of employees who commute zero to two miles dropped from

[15] On-Road Business Travel includes reimbursements for employees that drove a fleet vehicle and needed to refill at a non-Boulder owned fueling station.
[16] The 66% increase in vehicle fleet and equipment emissions is due to methodology changes and higher quality activity data.
[17] See: 2022 City of Boulder Employee (Government) Transportation Survey. Published January 2023.

18 percent to 7 percent. In the same years, the percentage of employees who commute over 20 miles, exclusively non-residents, has increased from 13 percent to 27 percent.
    - According to the Transportation Survey, employee transit use dropped from 5.6 percent to 2.5 percent between 2017 and 2022. Also, only two percent of non-resident employees take the bus, bike, or walk to work, whereas 7 percent of resident employees do the same. Despite the increase in popularity of micromobility options within Boulder, such as BCycle and scooters, RTD is still operating at 65% of pre-pandemic levels and DASH buses now come every 30 minutes instead of every 15 minutes, which hinders employees' ability to take transit to the office.
- **Business Travel Shift:** Because "return-to-work" appeared to happen in 2022 instead of 2021 for Boulder, business travel increased significantly during 2022 as work trips resumed to pre-pandemic frequency.
- **Extra Snow Plowing:** In conversations with the fleet department, snowplows were used more often in 2022 due to more snowfall in the winter of 2021/2022. Additional snowfall events caused increased equipment emissions from the additional snowplow fuel usage.
- **Fleet Methodology Update:** As previously mentioned, Boulder provided newly available and higher quality fleet vehicle and equipment fuel usage data for 2022. This methodology change increased emissions; data in previous years were likely underestimated. In the 2022 iteration of the GHG inventory, the fleet was able to be split out by vehicle and fuel type for the first time, leading to a more nuanced picture of Boulder's fleet vehicle and equipment emissions. This data will be available going forward and trends will be assessed more clearly in future years.

Waste and Wastewater Treatment Emissions

Emissions from the treatment of wastewater have decreased by 63 percent since 2008 and increased by 3% between 2021-2022. In the 2022 inventory, it was recommended by wastewater treatment plant officials that the service area population be used in emissions calculations for 2022, whereas the 2021 inventory utilized the city population. This is a primary cause for the increase in wastewater emissions between 2021-2022.

The decrease in wastewater treatment emissions from 2008-2022 is an important trend to note and deserves recognition. There have been concerted efforts to reduce the emissions impact of treating wastewater and implementing processes that help to bring down emissions. Processes to reduce treatment emissions include utilizing nitrification/denitrification, which reduces the quantity of process nitrogen emitted in the treatment of wastewater and discharged effluent, and the use of a digester on the treatment plant to capture and flare methane gas created during treatment. Flaring methane gas converts emissions from methane to carbon dioxide, which is 30 times less intensive in terms of global warming potential. Wastewater treatment emissions are an important source to target in this sector—they are a bigger source of emissions than solid waste collected at municipal facilities and comprise 3 percent of the municipality's total emissions. It is also important to note that this sector includes emissions just from the treatment processes themselves; emissions from electricity and other stationary fuels to operate the facility are included in the Stationary Energy sector emissions.

Emissions from solid waste collected at municipal facilities have increased by 58 percent since 2008, and between 2021 and 2022 emissions increased by less than one percent. Compared to 2021, however, solid waste emissions remained nearly the same. The tonnage of compost collected at facilities increased slightly between 2021 and 2022; this is likely due to employees returning to the office and creating additional food waste. Tonnages of waste, recycling, and composting collected since 2008 are shown in Figure 10.

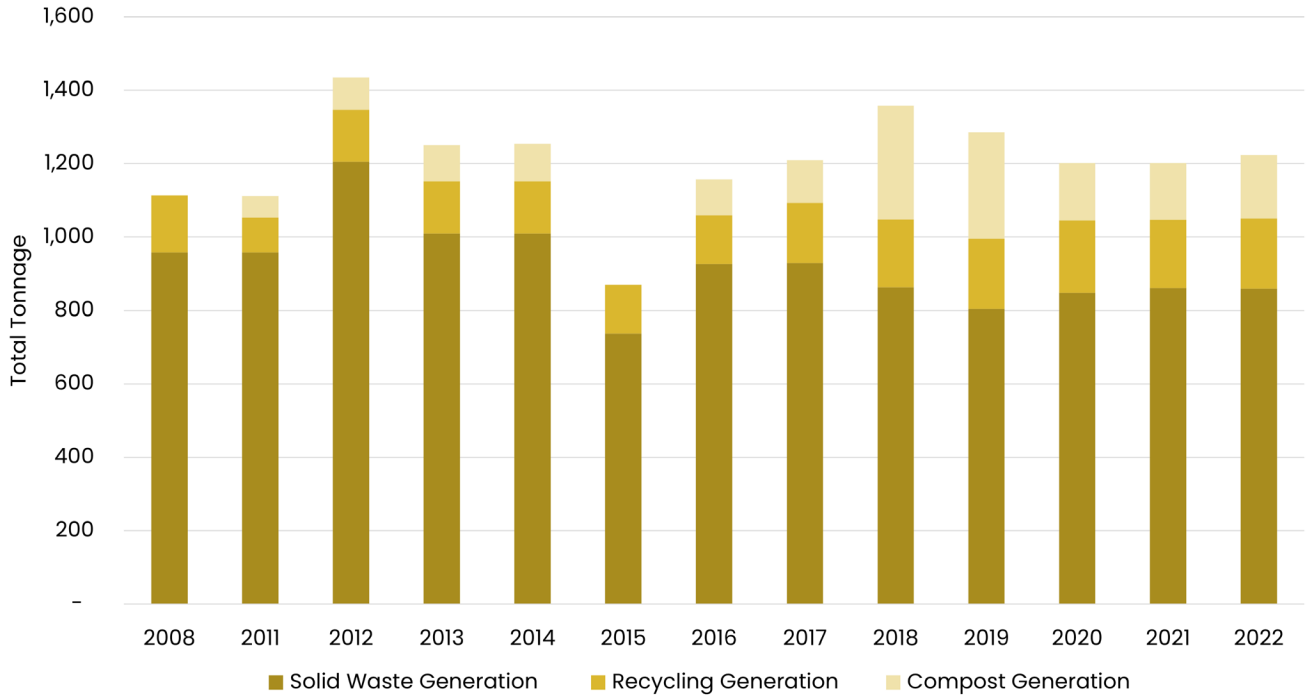

Figure 10. Reported Waste, Recycling, and Composting Tonnage

What Happened in 2022

Neither wastewater emissions nor solid waste emissions changed significantly between 2021 and 2022.

Refrigerant Emissions

Since 2008, reported refrigerant emissions have increased by 584 percent. Since 2021, they have increased by 19 percent. Despite this increase, it is important to note that refrigerants make up less than one percent of the city organization's total 2022 emissions.

What Happened in 2022

Some notable trends include:

- **More building refrigerant refills:** In 2022, more refrigerants refills in building HVAC equipment were reported by MTech, the City's HVAC contractor, compared to 2021 (5 lbs in 2021 compared to 51 lbs in 2022).
- **New lower GWP refrigerant:** Boulder now uses a low global warming potential refrigerant in some of its fleet vehicles (R-1234yf). This refrigerant has a GWP of 4, which is substantially lower than other refrigerants used previously by city operations in their buildings and fleet vehicles. Using lower GWP refrigerants in vehicles and buildings will help to lower emissions from refrigerant use in the future.

CONSUMPTION-BASED EMISSIONS

The consumption-based sector is highly variable year-to-year. Due to the importance of sources in this sector to maintaining infrastructure and serving daily operational needs, it is and will continue to be challenging to eliminate these emissions. Sources in this sector, such as asphalt and concrete use in infrastructure projects, paper use, food purchases and consumption, and technology purchases, can change significantly each year due to a variety of factors. Some of these factors include planned (or unexpected) infrastructure projects; adoption of new technologies or municipality-wide computer upgrades; or the need to print out updated plans (such as a comprehensive plan). Another important note is that the city organization owns large amounts of land through its Open Space and Mountain Parks Department (OSMP). Neither emissions nor carbon sequestration benefits from OSMP lands are included in this inventory, both of which could further influence emissions. Boulder has chosen to include consumption-based emissions in the setting of its municipal GHG reduction targets, and the inclusion of these sources of emissions are a significant factor in choosing not to have a net-zero emissions target for the municipality and can pose challenges for meeting the current goal of 80 percent emissions reductions from 2008 levels by 2030.

What Happened in 2022

Some notable trends include:

- **Concrete**: Concrete emissions made up 65 percent of total consumption-based emissions in 2022 and increased 102 percent between 2021 and 2022. These emissions alone account for just under 13 percent of the municipality's overall GHG emissions in 2022. There were two major roadway construction projects that occurred in 2022: the 30th & Colorado and North Broadway projects. There was also an increase in concrete used as a part of the Pavement Management Program in 2022 compared to 2021. In years where no major construction projects occur, concrete emissions could be much lower, which would significantly lower total consumption-based emissions. The high year-to-year variability makes it challenging to predict and reduce future emissions, however it should be noted that Boulder will not stop attending to and pursuing infrastructure projects to reduce these emissions. It is important to explore ways to use concrete more efficiently in projects and to find lower embodied carbon concrete options for use in these projects. Despite its initially high emissions, concrete roads have a longer average lifetime than asphalt ones; thus, concrete roads have a lower total lifetime carbon footprint.

EMISSIONS TRENDS BY SOURCE

As shown in Figure 11, emissions over the years can be largely attributed to the following sources: electricity, natural gas, gasoline, and consumption-based sources. Emissions from all four of these sources have decreased since 2008 due to sustainability policies initiated by the city and Xcel Energy's continuously-decreasing emission factor for electricity. The emissions by source for 2008, 2021, and 2022 are provided in Table 5.

Between 2021 and 2022, electricity emissions increased 4 percent, natural gas emissions increased ten percent, gasoline emissions increased 142 percent, and consumption-based emissions sources increased 20 percent. See Figure 12 for year-over-year trends of the city's four largest emission sources.

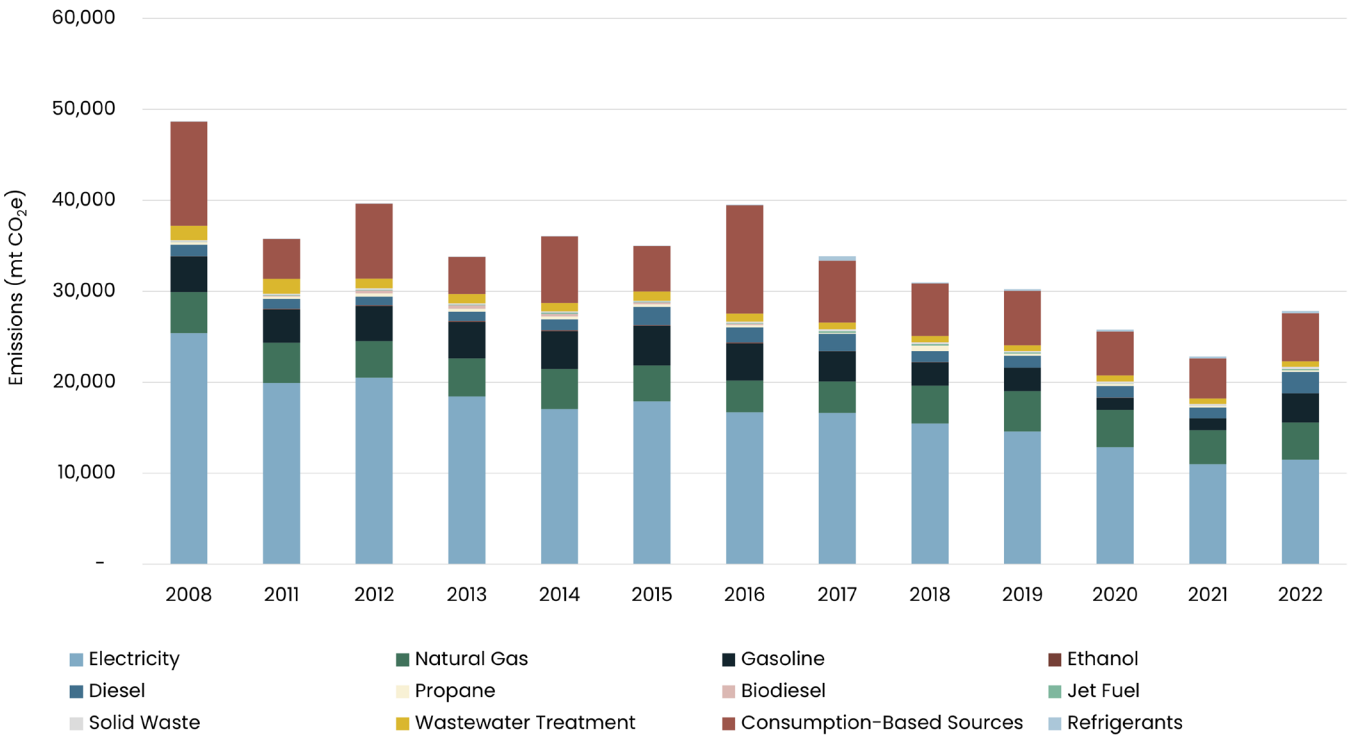

Figure 11. Emissions by source, 2008-2022.

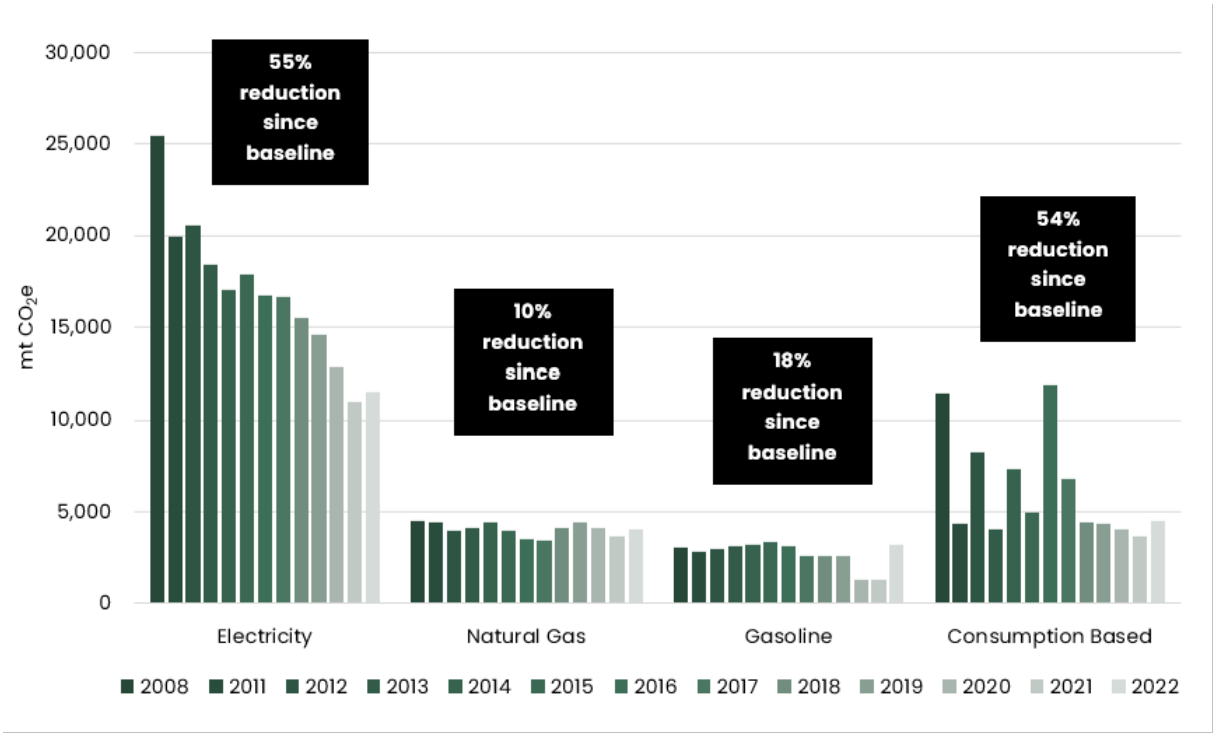

Figure 12. Emissions from Boulder's four largest emissions sources, 2008-2022.

Table 5. Emissions by source comparison between 2008, 2021, and 2022 (mt CO_2e).

Source	2008	2021	2022	Percent Change (2008-2022)	Percent Change (2021-2022)
Electricity	25,409	11,027	11,517	-55%	4%
Natural Gas	4,520	3,694	4,072	-10%	10%
Gasoline[18]	3,025	1,321	3,198	6%	142%
Ethanol	35	4	8	-78%	111%
Diesel (Mobile and Stationary)	1,026	1,193	2,342	128%	96%
Propane	292	166	173	-41%	4%
Biodiesel	12	1	1	-88%	172%
Jet Fuel	30	4	151	401%	3,998%
Solid Waste	148	233	234	58%	0.1%
Wastewater Treatment	1,579	571	589	-63%	3%
Consumption Based	11,445	3,659	4,520	-61%	24%
Refrigerants	34	194	230	584%	19%
Totals	**47,555**	**22,066**	**27,036**	**-43%**	**22%**

[18] Fuel emissions from gasoline, ethanol, and diesel reflect usage by Boulder fleet vehicles and equipment as well as employee commuting fuel use.

CONCLUSION

Consistent with the Community GHG inventory, the 2022 municipal inventory shows a post-pandemic rebound effect. While the city organization has made notable progress in reducing emissions compared to its 2008 baseline, much more work will need to be done if the goal of 80 percent emissions reduction by 2030 is to be reached. The city's Facilities Master Plan[19] (FMP) lays out the decision framework for targeted improvements, consolidation, deep retrofits, and new builds. Implementation of this plan will position the city organization to continue to lead by example. The city's continued commitment to transitioning its fleet of over 500 vehicles will also play a key role in reducing emissions.[20] Successful implementation of these two strategies, combined with Xcel Energy's requirement to reduce emissions from the electricity it provides 80 percent by 2030 will help city operations achieve their 2030 target.[21]

[19] See: https://bouldercolorado.gov/media/5927/download?inline.

[20] See:https://bouldercolorado.gov/news/city-install-19-new-electric-vehicle-chargers-across-six-city-facilities#:~:text=The%20City%20of%20Boulder%20is,chargers%20across%2016%20city%20facilities.

[21] See: https://leg.colorado.gov/sites/default/files/2019a_1261_signed.pdf.