CITY OF BOULDER COMMUNITY-WIDE GREENHOUSE GAS EMISSIONS SUMMARY REPORT

DECEMBER 2022

CITY OF BOULDER

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), N~~ʉ~~m~~ʉ~~n~~ʉʉ~~ (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.

"IN 2035, I WANT TO LIVE IN A CITY WHERE PEOPLE TALK OF CLIMATE JUSTICE WITH PRIDE, BECAUSE WE CAN SEE IT IN THE WAY WE SHOP, DO BUSINESS, SUPPORT ORGANIZATIONS AND BUILD POLICIES."

"WHEN WE TALK ABOUT THE FUTURE, WE TALK WITH HOPE ABOUT HOW TO MAINTAIN ALL OF THE GOOD WE'VE ALREADY BUILT."

"WE'VE TAKEN ADVANTAGE OF THE INCREDIBLE LOCAL SCIENTIFIC AND ENGINEERING COMMUNITY, CAPTURING EXCESS ENERGY AND USING RENEWABLE RESOURCES TO POWER OUR BEAUTIFUL CITY."

-CITY OF BOULDER

SOUNDS OF HOPE PROJECT

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Glossary of Terms

Note that the following terms are sourced from the Global Protocol for Community-scale Greenhouse Gas Emission Inventories (GPC).[1]

Biogenic emissions ($CO_{2(b)}$)

Emissions produced by living organisms or biological processes, but not fossilized or from fossil sources.

Carbon Sequestration

Process by which atmospheric carbon dioxide is taken up by plants through photosynthesis and stored as carbon in biomass and soils.

Consumption-based Emissions Inventory

A consumption-based emissions inventory (CBEI) is a calculation of all of the greenhouse gas emissions associated with producing, transporting, using, and disposing of products and services consumed by a particular community or entity in a given time period (typically a year). A CBEI is a way to tally up a comprehensive emissions 'footprint' of a community.

Emission Factor

A factor that converts activity data into GHG emissions data (e.g., kg CO_2e emitted per liter of fuel consumed, kg CO_2e emitted per kilometer traveled, etc.).

Fugitive Emissions

A small portion of emissions from the energy sector frequently arises as fugitive emissions, which typically occur during extraction, transformation, and transportation of primary fossil fuels. Where applicable, cities should account for fugitive emissions from the following subsectors: 1) mining, processing, storage, and transportation of coal; and 2) oil and natural gas systems.

Greenhouse gas emissions

Gases that trap heat in the atmosphere. For the purposes of the GPC, GHGs are the seven gases covered by the UNFCCC: carbon dioxide (CO_2); methane (CH_4); nitrous oxide (N_2O); hydrofluorocarbons (HFCs); perfluorocarbons (PFCs); sulfur hexafluoride (SF_6); and nitrogen trifluoride (NF_3).

Global Warming Potential

A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GHG relative to one unit of CO_2.

GPC

The Global Protocol for Community-scale Greenhouse Gas Emission Inventories (GPC) is a greenhouse gas protocol that provides extensive guidance on emissions calculations and reporting for local, subnational, and national governments.

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[1] For more information see: https://ghgprotocol.org/sites/default/files/standards/GPC_Full_MASTER_RW_v7.pdf.

In-boundary transportation

Includes all transportation of people and freight occurring within the city boundary.

Mode Shift

A shift in the way residents travel to and from locations. This often presents itself as a shift away from driving fossil-fuel powered vehicles to using public transport or other forms of carbon-free transportation like walking or biking.

Transboundary Emissions

Emissions from sources that cross the geographic boundary.

Transboundary trips

There are typically four types of transboundary trips:

1. Trips that originate in the city and terminate outside the city.
2. Trips that originate outside the city and terminate in the city.
3. Regional transit (typically buses and trains) with an intermediate stop (or multiple stops) within the city.
4. Trips that pass through the city, with both origin and destination outside the city. These trips are not attributed to Boulder for the purposes of the inventory.

Waste Characterization/Composition

Is the result of a study solid waste composition study, using survey data and a systematic approach to analyze the waste stream and determine the waste source (paper, wood, textiles, garden waste, etc.).

INTRODUCTION

Since 2016, the City of Boulder has contracted with Lotus Engineering and Sustainability, LLC (Lotus) to complete an annual greenhouse gas (GHG) inventory as a means of measuring the effectiveness of the city's efforts to mitigate the community's contribution to global emissions. The inventory is prepared following the Global Protocol for Community-Scale Greenhouse Emission Inventories (GPC). The GPC protocol provides a robust framework for accounting and reporting city-wide GHG emissions. The inventory results should not be considered an absolute measure of the community's emissions, but rather a tool to track and evaluate year-to-year trends.

The results presented here are for the year 2021, on the heels of the city's transition away from state-wide shutdowns and other effects of the COVID-19 pandemic. The COVID-19 pandemic effects on the city, which began on March 16, 2020, may continue to impact the 2021 results. While some of the effects, both reduce and increase emissions, may carry forward, it will be years before any conclusion can be drawn as to the sustained impact on global and local emissions.

This report also marks the end of another transition: reporting progress against the revised baseline year of 2018. In the fall of 2020, the United Nations Framework Convention on Climate Change (UNFCCC) began the Race to Zero campaign.[2] The Race to Zero campaign spurred the city to adopt an updated methodology for setting science-based targets, recommending that cities use an updated baseline year between 2016 and 2019 to set an interim target towards the achievement of Net Zero emissions. The city adopted 2018 as its new baseline in 2021 and simultaneously developed an updated set of emissions-related targets. From this point forward, the city will track its progress using the 2018 baseline. The city will still use the phased-out 2005 baseline as a tool to evaluate long-term progress and the efficacy of prior emissions-reduction efforts.[3]

The purpose of this greenhouse gas (GHG) emissions inventory is to report on the sources and magnitude of territorial GHG emissions and short-term and long-term trends so the Boulder community is better able to take informed actions to combat the climate crisis. While the responsibility for emissions reductions rests with the entire community, tracking emissions across the buildings, transportation, industrial, and waste sectors helps the city develop effective programs and policies designed to reduce our climate impacts. Boulder's historical climate leadership has resulted in progressive energy efficiency policies and a robust public transit network which in turn has helped us achieve one of the lowest per-capita territorial emissions rates compared to North American peer cities. What this shows is that Boulder's climate actions started off in the right direction. However, as Boulder's population and economy continue to grow, a greater degree of reductions is needed to achieve its climate goals.

As Boulder prepares for a future that will be fundamentally shaped by an increasing frequency and intensity of climate-change-caused disruptions, both resilience and equity must now be considered integral elements in all climate action. As the primary provider of local public services, local governments will now have to turn an increasing amount of attention and resourc-

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[2] See: https://unfccc.int/climate-action/race-to-zero-campaign.

[3] In addition to this published report, the city regularly reports and updates its progress on its "Boulder Measures" citywide dashboard see: https://bouldercolorado.gov/boulder-measures.

es towards addressing climate change impacts. At the same time, climate change disproportionately affects those who are both least responsible and most vulnerable to its impacts.

Black, Indigenous, or People of Color (BIPOC) communities worldwide, unequally bear the burden of climate change, air pollution, and environmental degradation. BIPOC communities continue to be increasingly concerned about climate change, yet historically, environmental decisions on policy, communications and programming have been siloed and within a vacuum made by those with race and class privilege. It is therefore imperative that Boulder center this context when analyzing the results of this inventory and prioritize partnering with BIPOC communities to shape equitable climate policy for the city. Therefore, all climate actions —both mitigation and adaptation/resilience — must now also integrate considerations to address these intrinsic, structural inequities.

EXECUTIVE SUMMARY

Boulder's Climate Targets

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 of Boulder 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 around reducing the GHG emissions covered in this inventory. These updated targets and goals are:

- Reduce emissions 70% by 2030 (against a 2018 baseline)
- Become a net-zero city by 2035
- Become a carbon positive[4] city by 2040

In the pursuit of achieving these ambitious targets, the city has embedded quantitative and qualitative targets across energy, natural climate solutions, materials systems, transportation, land use and financial systems work, including becoming a zero-waste city by 2025 and achieving a 100% renewable electricity supply by 2030.

The community will likely remember 2021 as the year in which the Marshall Fire swept through neighboring communities becoming Colorado's most destructive fire to date. It was also another year in which the COVID-19 pandemic played a major role in the lives of the community and, consequently, its emissions. In line with global trends, the City of Boulder saw its emissions rebound as the community navigated returning to work, travel, and recreation. The events of 2021 highlighted both the local urgency and the global context surrounding emissions, as well as the increasingly urgent need to prepare for significant climate change disruptions and to address the inequities that climate change perpetuates.

[4] Carbon-Positive means that an activity goes beyond achieving net zero carbon emissions to create an environmental benefit by removing additional carbon dioxide from the atmosphere.

2021 Results

Emissions increased 9% from 2020 due to a rebound towards pre-pandemic activity levels. Emissions still remain 15.5% below the 2018 baseline (pre-pandemic). Compared to the original 2005 baseline, community emissions have reduced by 30%. See Figure 1 for more information.

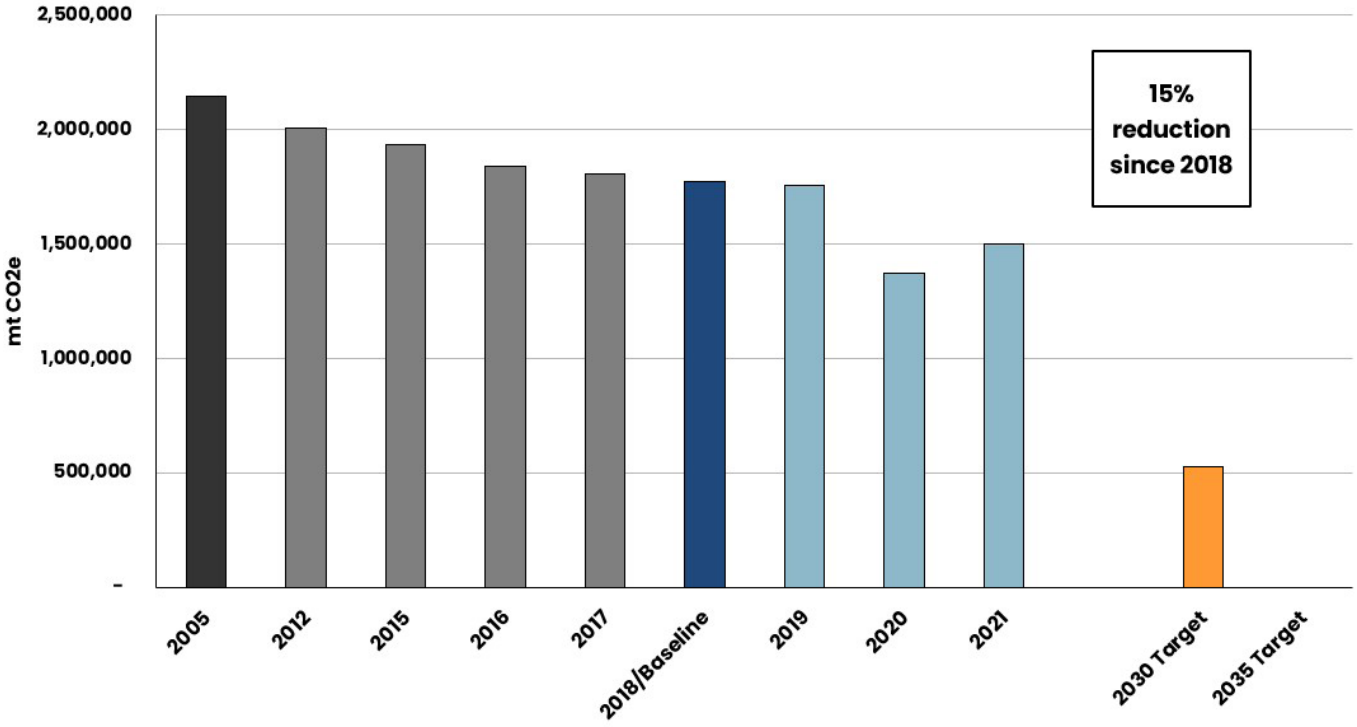

Figure 1. Total Community GHG Emissions.

Emissions Snapshot

In 2021, the biggest contributors to emissions come from:

- Building electricity use (38%)
- Building natural gas use (23%)
- On-road transportation fuels (27%)
- Aviation fuels (10%)

Figure 2 provides an overview of the total emissions including transboundary travel (1,499,314 mt CO_2e) reported by Boulder broken out by sector and source. Additional detail can be found in the Current Emissions Snapshot section.

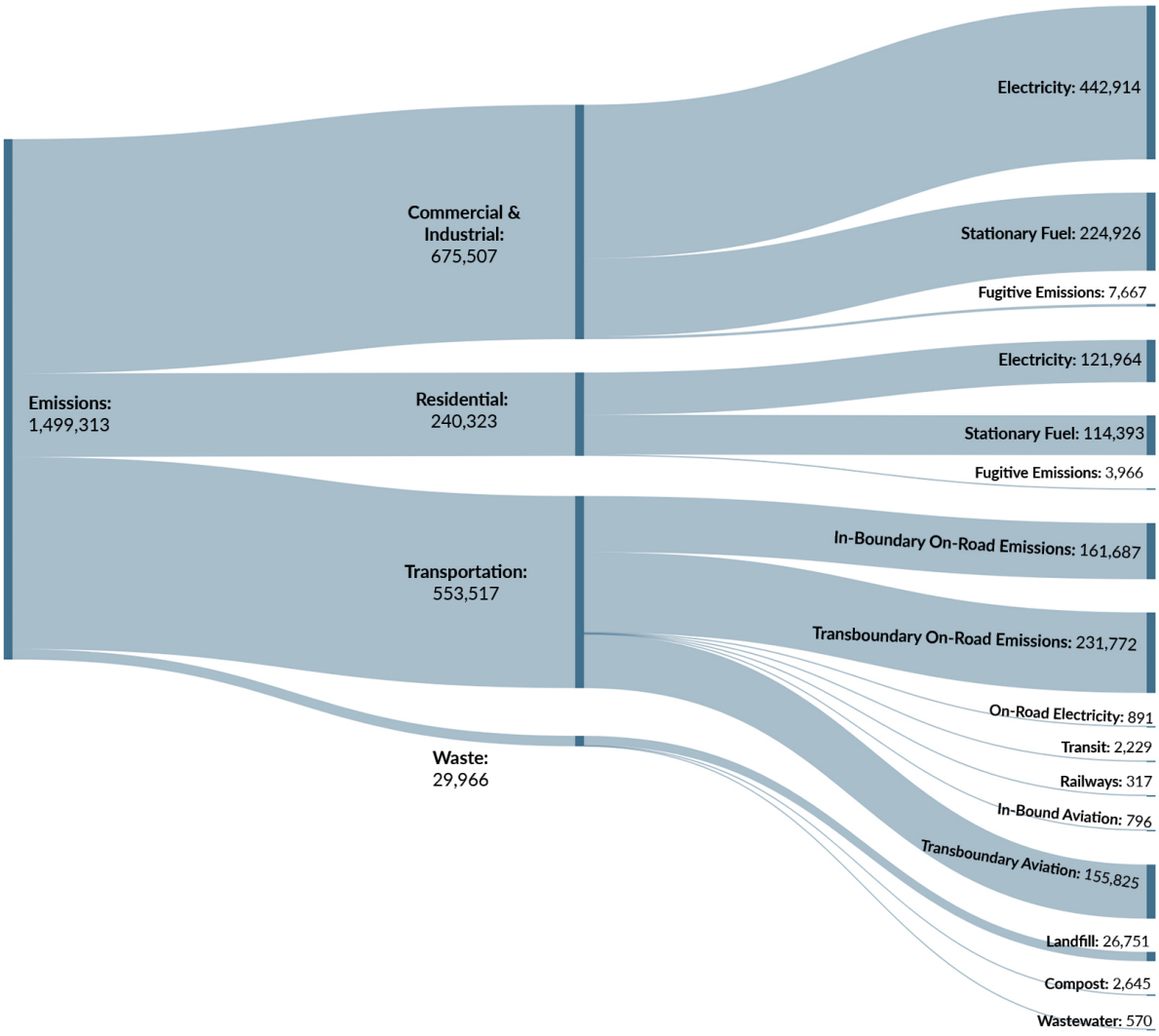

Figure 2. Snapshot of Boulder's 2021 GHG Emissions (mt CO_2e).

Core Emissions Changes from 2020-2021

The biggest contributor to the overall increase in emissions came from the transportation sector, but smaller increases in other sectors contributed as well.

- Transportation (up 23%)
  - In-boundary on-road transportation (up 5%)
  - Transboundary on-road transportation (up 21%)
  - Aviation (up 53%)
- Commercial and Industrial Buildings (up 2%)
  - Building electricity emissions (up 1%)
  - Natural gas emissions (up 2%)
- Waste (up 22%)

Key Takeaways from the 2021 Inventory

Some key takeaways from the 2021 greenhouse gas emissions inventory include:

- Emissions rebounded slightly (up 9% since 2020) but are still significantly below 2018 levels (down 15%).
- Compared to the prior baseline (2005), emissions have decreased by 30%.
- The largest emissions sources in Boulder are electricity use, natural gas use, on-road transportation, and aviation.
- Boulder needs to continue to find durable solutions to reduce emissions necessary to meet the 2030 and 2035 emissions reductions targets, but they are still within reach.

The Impact of COVID-19

While emissions increased from 2020 to 2021, it is important to note the unique circumstances in 2020 that appear to make it an outlier. State-wide shutdowns led most of the population to spend a sizeable amount of time in their homes and vastly less time on the road, dramatically reducing vehicle miles traveled in 2020. Many commercial businesses had reduced operations, with some even closing operations all together due to the economic effects of the pandemic. As noted in the 2020 report, while these impacts presented significant emissions reduction for 2020, they did not necessarily represent a persistent systemic change that would carry forward post-pandemic.

At this point, it is too soon to say whether some of the norms that formed during the pandemic (i.e., increase in remote work, reduction in leisure travel, etc.) are durable. Similarly, it is unlikely that 2021 is fully representative of the post-pandemic condition. The city will continue to track the trends of the pandemic to determine their persistence into the future and how the city will adjust its own strategies in response.

The rapid drop and subsequent rise in transportation emissions is a clear example of systems change, brought on by the COVID-19 pandemic. Unfortunately, this type of systems change came at great cost, and the associated decline in emissions has not been durable.

METHODOLOGY

The 2021 GHG inventory was completed using the same protocol as previous community inventories - the Global Protocol for Community-Scale Greenhouse Emission Inventories (GPC).[5] The GPC protocol provides a robust framework for accounting and reporting citywide GHG emissions. This protocol is required for cities committed to the Global Covenant of Mayors for Climate & Energy. Boulder signed onto this covenant in 2015.[6] By completing a GPC-compliant inventory, Boulder can report emissions to the Carbon Disclosure Project (CDP),[7] which outwardly demonstrates Boulder's climate change commitments to a global audience. The following report reviews how the 2021 inventory was completed, 2021 GHG emissions sources, and trends in emissions.

[5] For more information see: https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities.
[6] For more information see: https://www.globalcovenantofmayors.org/.
[7] For more information see: https://www.cdp.net/en/info/about-us.

Changes to the Methodology and Available Data in 2021

Propane

In 2021, Boulder received data on propane consumption by residential and commercial users from a major provider in the community. These data were added to the inventory, but no other data were reported and no data from previous years exist to determine a baseline. This source will be included in all future inventories, so it will be possible to study trends, such as the impact of covid on the use of propane for outdoor dining.

Global Warming Potentials

The IPCC releases global warming potentials with each new release of its Assessment Reports. The latest Assessment Report, AR6, was released August of 2021. The 2020 and 2021 community greenhouse gas emissions inventories both use the most up-to-date global warming potentials for CH_4, N_2O, and HFCs.

Other Data Sources and Methodology

VMT

As previously reported, Boulder changed its VMT methodology in 2020 to leverage more accurate cell phone data. Previous inventories relied on a model developed by DRCOG combined with city traffic count data and commuter survey information. The new cell phone data source was used again in 2021 and will continue to be used for future inventories.

Utility Emissions

Electricity and natural gas in Boulder are provided by Xcel Energy. Xcel Energy releases annual Community Energy Reports for the communities it serves, which detail the amount of electricity and natural gas used within a community's boundaries. Xcel also provides an annual emissions factor for its electricity and natural gas supply, which is verified externally by the Climate Registry.

Stationary Diesel

The Colorado Department of Public Health and the Environment (CDPHE) collects data diesel used in industrial boilers and generators. CDPHE provided this data for entities in Boulder.

Jet Fuel

Boulder Municipal Airport provides data on fuel used by planes at the airport. Transboundary aviation emissions from Denver International Airport (DEN) are calculated using fuel use data provided by DEN. The city estimates that 4% of all DEN traffic can be attributed to the City's residents. This accounts for likelihood of the population traveling more often than other communities around Colorado.

Transit

RTD operates several bus routes within the city. Additionally, the city owns and operates the HOP route, which has recently added electric buses to the fleet. Emissions from transit are a combination of the electricity used by the HOP buses and the fuel used by RTD's buses.

Railways

There are just over 2 miles of railways that run through Boulder. The US EPA tracks fuel use data for all freight trains in the US. The EPA reports the fuel used by trains within the city's boundaries and emissions are calculated from that fuel use.

Waste

Boulder requires waste haulers to report data on waste, recycling, and compost collected within city boundaries. This data is tracked through a system called ReTRAC. Based on total tonnage of waste landfilled, the most recent Boulder County Waste Characterization (2019), and emission factors from the EPA's Waste Reduction and Materials tool, emissions can be calculated.

Wastewater

The city owns and operates the 75th Street Wastewater Treatment Plant. The plant tracks data on annual wastewater treatment processes, such as denitrification and anaerobic digestion. Emissions from wastewater treatment are calculated using this data.

Other Emissions Inventories

Consumption Based Emissions Inventory

Boulder is in the process of conducting its first consumption-based emissions inventory (CBEI). This will be a calculation of the greenhouse gas emissions associated with producing, transporting, using, and disposing of products and services consumed by the City of Boulder.

The main purpose of a CBEI is to gain understanding into where "embedded" emissions generated outside Boulder's boundaries constitute a significant portion of the carbon footprint of the community. By conducting a CBEI, the City of Boulder hopes to gain insights about where local consumption gives rise to emissions outside a city's borders, and suggest additional opportunities for reducing emissions.

CURRENT EMISSIONS SNAPSHOT

While Boulder's climate action includes efforts towards environmental justice and increasing resilience, the purpose of this inventory is to better understand the community's emissions.

In 2021, the results of the inventory show a total of 1,499,314 mt CO_2e, which equates to a 15% reduction when compared to 2018 baseline year emissions. These emissions include emissions from transboundary transportation (Boulder-based flights out of Denver International Airport (DEN) and transboundary vehicle trips). Of these emissions, a total of 1,111,718 mt CO_2e were generated within Boulder's boundary, which equates to a 16% reduction as compared to the 2018 baseline year.

Emissions Snapshot

Emissions by Sector

At 45% of total emissions (675,507 mt CO_2e), the commercial and industrial building energy sector made up the largest share of Boulder's emissions, followed by transportation emissions at 37% (553,517 mt CO_2e) and residential building emissions at 16% (240,323 mt CO_2e), with the remaining 2% of emissions generated from solid waste (29,396 mt CO_2e) and wastewater treatment (571 mt CO_2e). Of the total transportation emissions, transboundary transportation (flights out of DEN by Boulder residents and vehicle trips that do not fully take place within Boulder's boundary) emissions accounted for 387,596 mt CO_2e in 2021, or 70% of the total emissions associated with the transportation sector. See Figure 3.

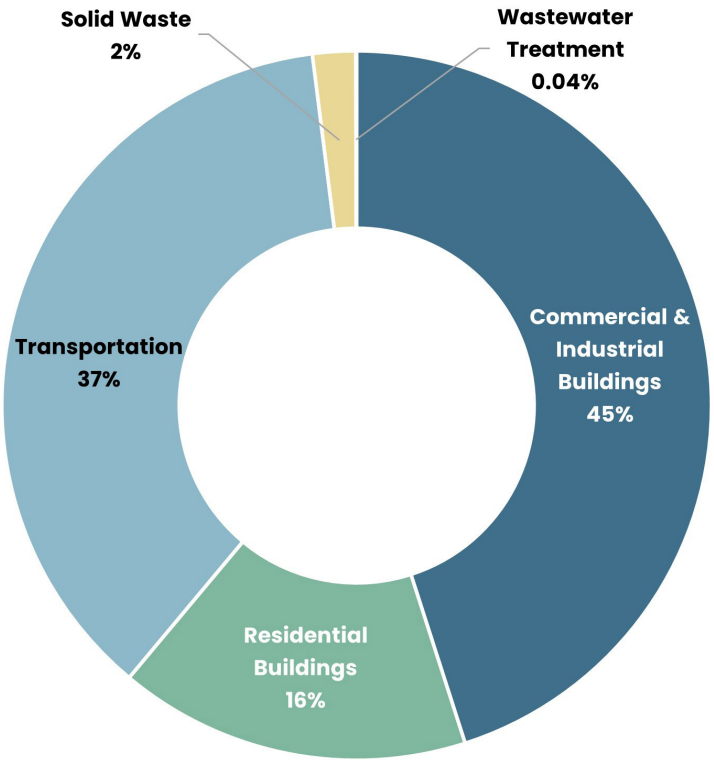

Figure 3. Emissions by sector including transboundary transportation emissions (mt CO_2e).

Emissions by Source

The largest sources of emissions in order are electricity (38% or 564,879 mt CO_2e), transportation fuels (37% or 553,517 mt CO_2e), natural gas (23% or 346,786 mt CO_2e), and waste (2% or 29,966 mt CO_2e). See Figure 4.

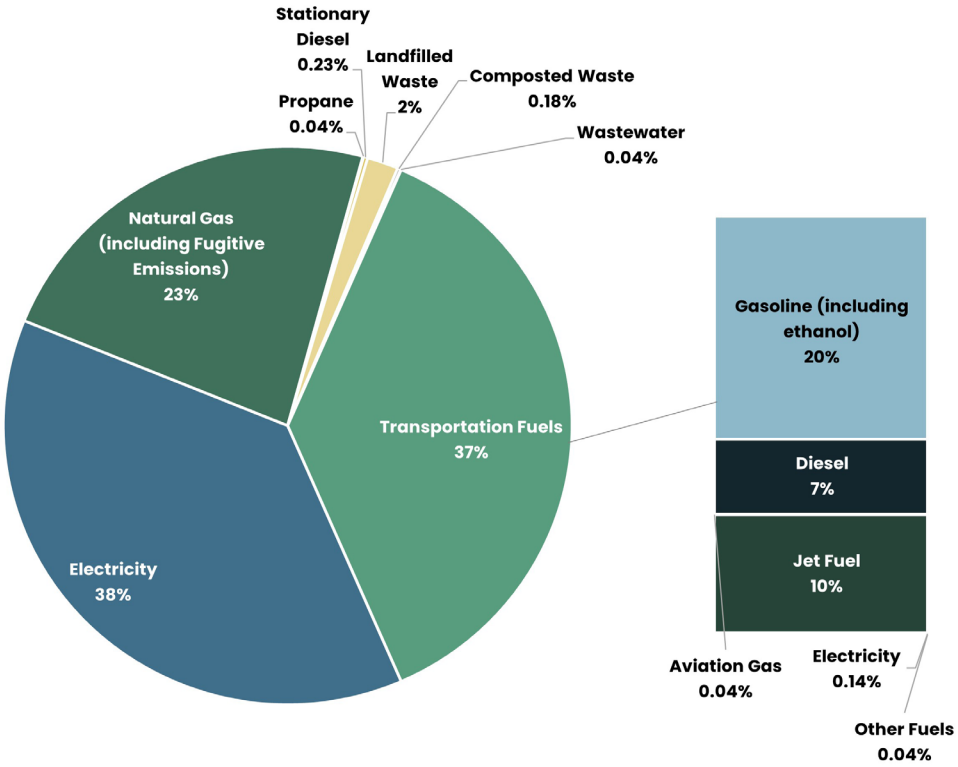

Figure 4. Emissions by source including transboundary transportation emissions (mt CO_2e).

IS BOULDER ON TRACK TO MEET NEW TARGETS?

As discussed in the Executive Summary, the City of Boulder updated its emissions reduction targets in 2021. These are:

- Reduce emissions 70% by 2030 (against a 2018 baseline)
- Become a net-zero city by 2035
- Become a carbon positive city by 2040

In order to reach the target of a 70% reduction by 2030, Boulder's emissions need to be reduced by an average of 5.83% (of the 2018 total) per year. Figure 5 shows that emissions have reduced by 15% between 2018 and 2021, which is an average of 5% per year. This may lead to the belief that Boulder is close to on track, but looking historically provides a more sobering view. Figure 5 shows that emissions dropped at a much slower rate between 2005 and 2019, and it is important to recognize that 2021 is not likely representative of a post-pandemic norm.

Net Zero Emissions

As close to zero carbon emissions as possible. Any remaining emissions sources can be sequestered naturally through the biosphere.

Carbon Positive

Above and beyond net-zero emissions. A carbon positive community takes in, or sequesters, more carbon than it emits.

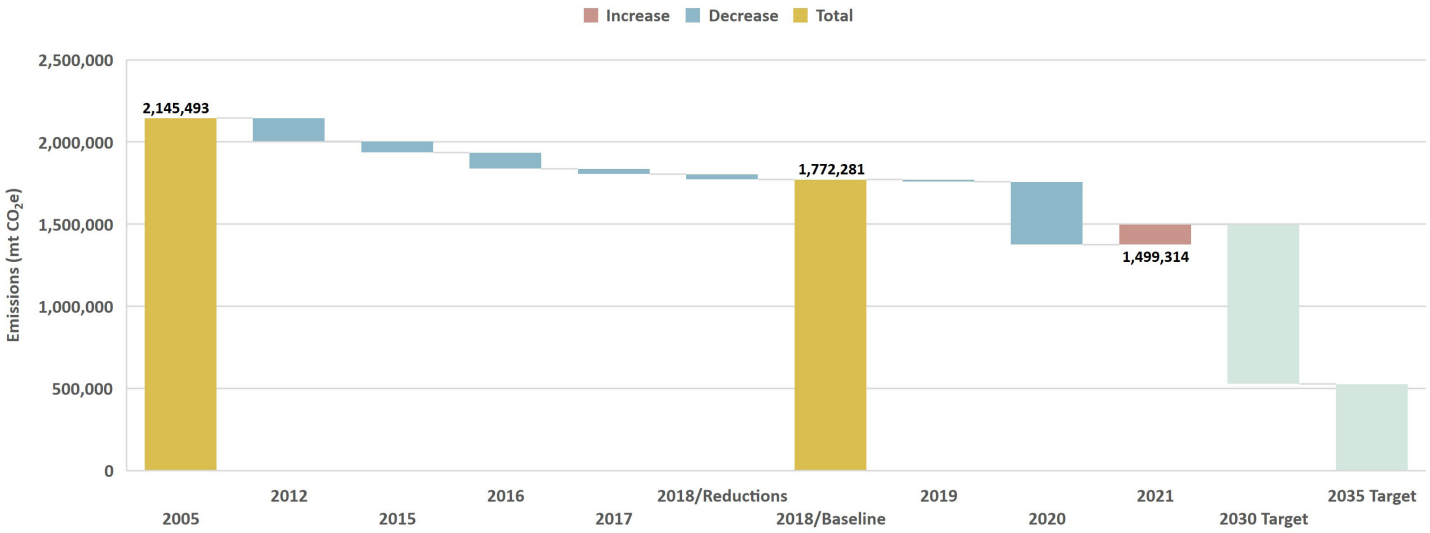

Figure 5. Tracking emissions reductions since 2005 and 2018 (new baseline).

In order for Boulder to meet its 2030 and 2035 targets, emissions reductions will need to accelerate faster than they have historically. However, there are several trends headed in the right direction. Purchases of electric vehicles have been increasing even throughout the pandemic, and the city has one of the highest adoption rates of EVs in the state. Xcel Energy also has a target of 80% emissions reduction in the electricity it provides by 2030 (compared to 2005), which will help to reduce emissions in building and transportation electricity use. There are ample incentives that will soon be available to help fuel the acceleration of emissions reductions, especially with the passage of the Inflation Reduction Act and the Infrastructure Investment and Jobs Act. Rebates for solar, heat pumps and electric vehicles are now available at the federal level in addition to the state and utility level. It is imperative that the city as well as its residents take part in climate action so that the 2030 and 2035 targets can be met.

KEY TRENDS DRIVING EMISSIONS IN 2021

For the first time since Boulder began conducting inventories, emissions increased as compared to the previous year. This is reflective of the unprecedented events of 2020 and the transition to recovery from those events that was underway in 2021. The inventory showed an increase of 9% (125,763 mt CO_2e) between 2020 and 2021, but this is still a reduction of 15% (272,966 mt CO_2e) compared to the 2018 baseline.

Changes in Emissions

The slight increase in 2021 emissions over 2020 has been driven by one main source: transboundary travel, both on-road and aviation, consistent with the easing of COVID-19 restrictions and return of both workforce and recreational travelers. However, emissions from all sources still dropped in comparison to 2018 emissions.

The COVID-19 Rebound

The global response to the COVID-19 pandemic generated unprecedented restrictions on travel; as these restrictions eased throughout 2021, transboundary travel rose significantly. Emissions from on-road transportation and aviation both showed substantial increases, while

commercial and industrial electricity and natural gas rose modestly. It is important to note that 2021 was the year of the Great Resignation, where many left their jobs for other companies or remote positions. It is unclear if this trend will continue or what the impact will be on workforce norms and patterns. Trends are detailed below.

- **Overall reduction in building emissions:** Both commercial and industrial buildings and residential buildings have reduced emissions by 17% and 4% respectively since 2018 but rose 3% and 0.1% over 2020. Electricity usage across all buildings increased by 32.5 million kWh between 2020 and 2021 but decreased by just under 104 million kWh between 2018 and 2021. Emissions from natural gas usage in buildings have risen by approximately 2.3% since 2018, or 1.5 million therms.

  A key and likely persistent outcome of the pandemic is an increased focus on indoor air quality in commercial/office spaces. Increased use of air filtration and higher and more frequent air flow equate to increased building energy use. The building emissions increases between 2020 and 2021 can likely be attributed to adoption of air quality best practices and to workforce and visitor return to commercial spaces. Energy use in 2021 also reflects the effects of Winter Storm Uri and the associated extreme cold in February. Increases in commercial electricity usage were greater than the increase in residential electricity usage as many businesses were able to reopen as COVID-19 restrictions eased. Retail sales in Boulder recorded a 13% increase between 2020 and 2021.

- **Reduced emissions from transportation:** Emissions from the transportation sector have decreased overall by 25% since 2018. This decrease can be seen in the increased fuel efficiency of vehicles and reduction in VMT. Transportation emissions increased between 2020-2021, which can be attributed to post-pandemic recovery to include workforce return and increases in recreational visitation.

Cleaner Electricity

Since 2005, the electricity emission factor for metric tons of carbon dioxide equivalent (mt CO_2e) per megawatt-hour (MWh) has decreased by 44% due to additional renewable energy resources and the reduction of coal and natural gas on the grid. Since 2018, the electricity emissions factor has decreased by 15%. In the last year (2020 to 2021), the electricity emission factor for mt CO_2e decreased by 1%. Looking forward, Xcel Energy is subject to the requirements of Colorado House Bill 19-1261, which puts into law an emissions reduction target for the power sector of 80% by 2030 compared to 2005 emissions.[8] Should Xcel meet that goal in 2030, the electricity emissions factor would be expected to decrease an additional 36% over the next 9 years.

Increases in Emissions/Activity since 2018 Baseline

While most emission sources have decreased, two sources increased since 2018.

[8] See: https://leg.colorado.gov/bills/hb19-1261.

Solid Waste

Both solid waste emissions and tonnage were higher in 2021 as compared to the 2018 baseline. Emissions rose by 47% while tonnage increased by 22%, partially reflected in the change in the IPCC estimate of the global warming potential of methane in 2020.

Fugitive Emissions from Natural Gas

Fugitive emissions occurs when natural gas leaks from the distribution system. Between 2018 and 2021, natural gas use by commercial buildings increased 3% and increased 1% in residential buildings. Correspondingly, fugitive emissions from natural gas also rose 3% for commercial buildings and 1% for residential buildings from the 2018 baseline year.

On-Road Electric Vehicles

Electricity use, and associated emissions, from miles driven in Boulder by electric vehicles have increased by 93% and 54%, respectively. However, this is one source where activity increases are a positive sign. Boulder has been working on supporting alternatives to internal combustion engine (ICE) vehicles in the city, and both the City and Boulder County are amongst the leaders in the state in adoption of electric vehicles.[9] Adding more electric vehicles in future years will help the city get closer to its climate goals, improve air quality, and provide resilience in the form of battery backup.

Normalized Metrics

Normalized metrics[10] indicate significant emission reductions, as shown in Table 1 below. After normalizing total emissions for indicating growth factors, notable trends are revealed. It is important to note that the advent of increased work-from-home policies due to COVID-19 restrictions appear to mark a shift in some historical trends. For example, the increased residential electricity usage per capita first noted in 2020 has continued into 2021 in conjunction with the integration of work-from-home policies. Waste landfilled per person has also increased since 2018; one potential reason could be the increase in single-use items and takeout containers associated with the pandemic. However, per capita emissions and emissions per GDP continue to fall despite the post-COVID-19 pandemic restrictions economic rebound. Similarly, the reduction in VMT per capita associated with the COVID shutdowns and stay-at-home orders has largely endured, hovering around 25% lower than 2018 numbers.

Another interesting trend to note is that natural gas use per housing unit has decreased slightly since the 2018 baseline, potentially indicating an increase in residential households switching out their natural gas-powered furnaces for electric heat pumps. This trend does not translate to commercial buildings, as the natural gas use per commercial floor space has remained the same between 2018-2021. Finally, the biggest increase is seen in the percent of registered vehicles as electric vehicles, which has increased 141% since 2018. In 2021, 3.5% of all vehicles on the road in Boulder were electric vehicles, one of the highest rates in Colorado.

[9] See: https://atlaspolicy.com/evaluateco/.
[10] Normalized metrics are intensity ratios that can be used in GHG emissions accounting to scale the net generated emissions by business metrics or other financial or community indicators, such as emissions per person or emissions per job.

The aim is that the city will be able to hold on to a significant portion of these reductions into the future through a variety of strategies.

Table 1. Normalized metrics.

Emission Metrics	2018 Baseline	2021	Change since 2018
Total emissions per capita ($mtCO_2e$/resident)	16.3	13.9	-15%
Total emissions per Gross Domestic Product (GDP) ($mtCO_2e$ / $)	0.00007	0.00005	-28%
Residential electricity per person (kWh/Person)	2,226	2,392	7%
Residential natural gas use per housing unit (therms/housing unit)	460	456	-1%
C&I natural gas per building floor space (dekatherm/sqft)	0.088	0.088	0%
In-boundary VMT per capita (VMT/resident)	4,900	3,691	-25%
% of Registered Vehicles that are Electric	1.45%	3.50%	141%
Landfill tons per capita (tons/resident)	0.79	0.96	22%

STATIONARY ENERGY

Building energy use made up 61% of Boulder's 2021 emissions inventory and is a key focus for Boulder in achieving its GHG emissions reduction goals.

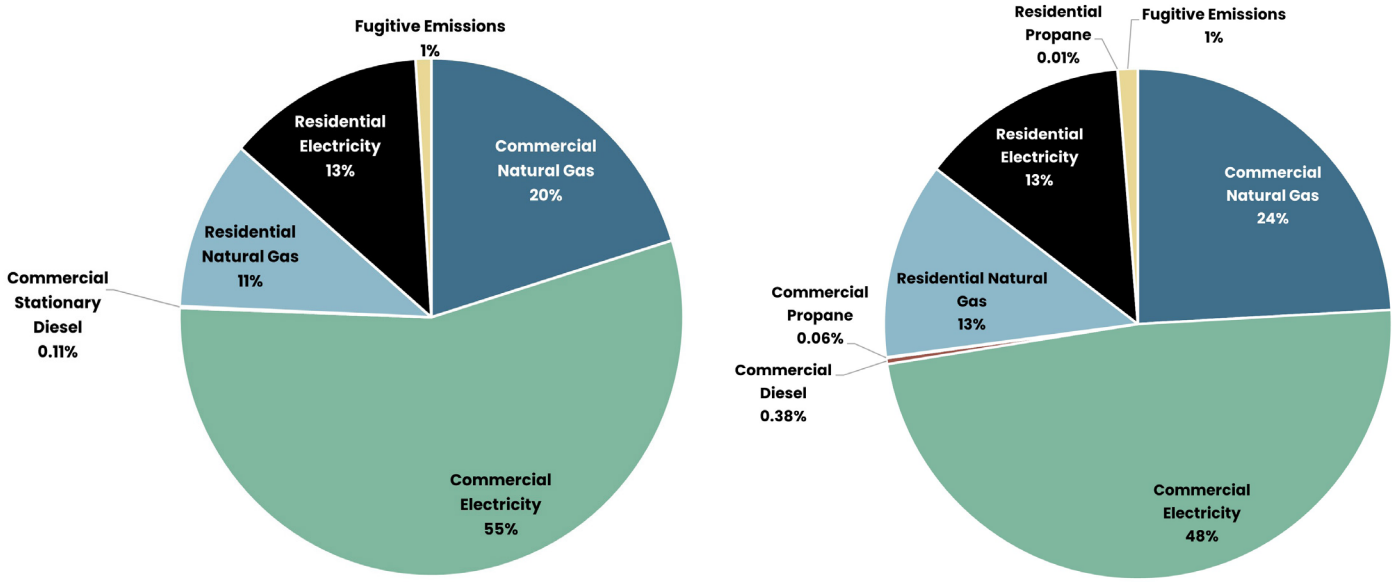

Figure 6. Stationary energy emissions by source in 2018 (left) and 2021 (right).

Overall, commercial electricity (48%) comprises the largest percentage of total stationary energy emissions. The next greatest source of emissions is commercial natural gas followed by residential electricity and residential natural gas making up 24%, 13%, and 13% of the total, respectively. The proportion of emissions from electricity and natural gas have shifted since the 2018 baseline, and in the residential sector emissions are now beginning to shift where soon emissions from natural gas will exceed emissions from electricity. This shift is also evident in the commercial sector. Emissions from natural gas will decrease if more homes and businesses convert from natural gas furnaces, stoves, and boilers to electric heat pumps. Much of the decrease in electricity emissions has been possible due to Xcel's work to add renewable energy to the electric grid. See Figure 6.

Emissions from electricity have been lower each year compared to a 2018 baseline, although results show a slight rebound in 2021 emissions. On the other hand, emissions from natural gas and stationary diesel have been higher than the 2018 baseline. Natural gas emissions experienced a similar slight rebound over 2020 numbers while emissions from stationary diesel have consistently risen through the pandemic years.

Electricity Trends

The consistent reduction in electricity emissions can be attributed to:

- **Reduction in residential electricity emissions:** Total residential electricity usage has increased by 7% since the baseline year of 2018. However, residential electricity emissions have decreased by 4% since 2018. Even though residential electricity use has increased over time, local solar adoption, along with cleaner electricity on the grid, result in lower total emissions. It is expected that the trend of increasing electricity use per person will continue as more homes become electrified and more households adopt electric vehicles and charge them at home. With continued efforts around energy efficiency and greening the grid, electricity emissions from the residential sector can be expected to reduce over time.
- **Decrease in Commercial and Industrial (C&I) Electricity Use per GDP:** Increases in overall C&I electricity are a function of economic growth. Growth in some of the normalized C&I electricity metrics (such as electricity use per employee) may be primarily driven by the addition of high energy density buildings which consume significant amounts of energy within small footprints. Because of this, the most accurate metric for the C&I sector is electricity use per GDP, which in 2021 was approximately 25% lower than in 2018. Once again, the lingering impacts of the pandemic and the rebounding economy may have contributed to at least part of the overall decrease in electricity use over 2018 numbers. However, GDP also increased 17% since 2018 indicating that industry has identified some greater efficiencies in their practices. Refer to Table 1.
- **Cleaner Electricity:** A cleaner electricity grid supplying energy to the community has contributed to emissions reduction since 2005. Colorado's Renewable Energy Standard[11] and the state's Clean Air Clean Jobs Act[12] required Xcel Energy, Boulder's electricity pro-

[11] For more information, see: https://www.xcelenergy.com/staticfiles/xe/Corporate/CRR2013/environment/renewable-energy.html.
[12] For more information, see: https://www.xcelenergy.com/environment/system_improvements/colorado_clean_air_clean_jobs.

vider, to increase the efficiency of its operations and procure increasing amounts of energy from low- to zero-carbon sources (i.e., renewable energy, recycled energy, etc.). Further, House Bill 1261, passed in 2019, requires a reduction in GHG emissions within all sectors of the state's economy, including electricity generation.[13] The state government continues to support renewable energy generation through executive and legislative action. Xcel Energy's Colorado Energy Plan maps the utility's work to reduce emissions to meet its own goal of an 80% reduction in electricity generation emissions by 2030.[14] The mix of energy sources that supply Xcel Energy's electric grid changes every year, and the resulting electricity emission factor decreases every year. Based on data from Xcel Energy, in 2021 the electricity emission factor for mt CO_2e has decreased by 44% from 2005, and by 1% from 2020.[15] See Figure 7.

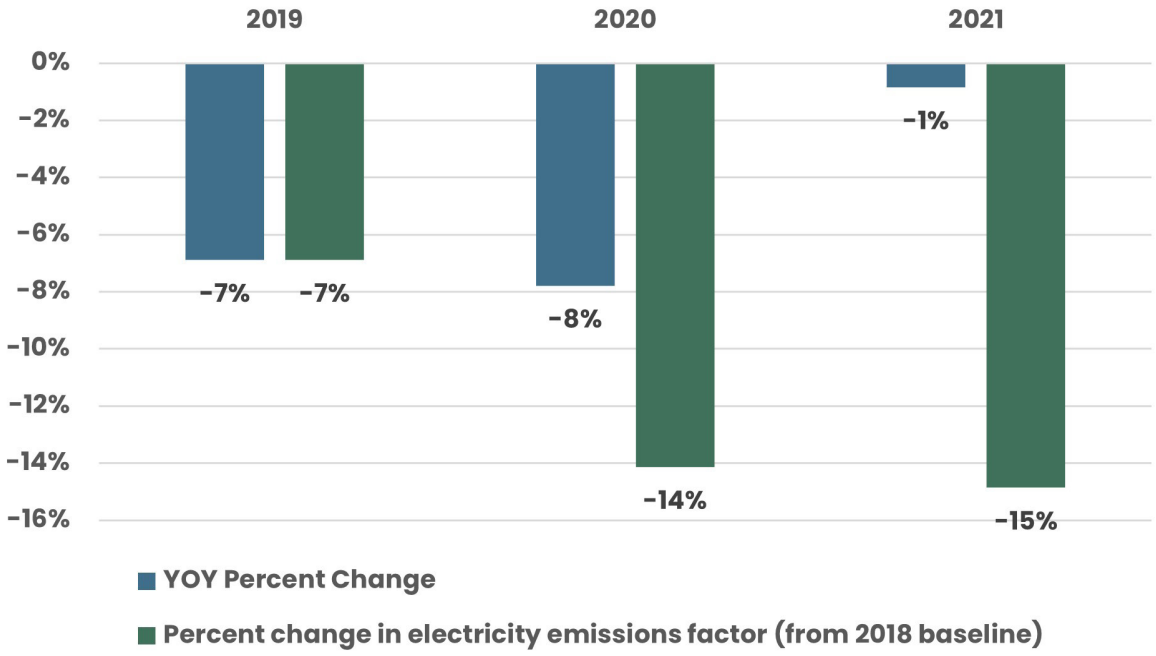

Figure 7. Change in electricity emission factors since 2018.

- **Increase in Local Renewable Energy Generation:** Boulder aims to generate at least 100MW of renewable energy locally by 2030. In 2021, 79,219,377 kWh of renewable energy through municipal-owned hydrogeneration and on-site solar were consumed by the community.[16] This is a 15% increase from 2018 and a 6% decrease from 2020. It is important to note that this local generation is factored into Xcel's annual electricity emissions factor, and increasing local generation can help Xcel, and the city, to reach its emissions reductions goals.

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[13] For more information see https://leg.colorado.gov/bills/hb19-1261.
[14] For more information see https://www.xcelenergy.com/staticfiles/xe-responsive/Company/Rates%20&%20Regulations/Regulatory%20Filings/CO%20Recent%20Filings/Colorado%20Energy%20Plan%202020.pdf.
[15] Xcel Energy does not report emission factors for methane and nitrous oxide. These values are sourced from U.S. Environmental Protection Agency's (EPA) eGRID and are not expected to change annually.
[16] See: https://www.xcelenergy.com/community_energy_reports.

Other Stationary Energy Trends

Natural gas consumption has increased by 2.4% since the 2018 baseline, driven largely by commercial and industrial (C&I) consumption which increased by 3% between 2021 and 2018. Also in 2021, emissions from residential and commercial propane use were included for the first time. Natural gas and stationary diesel emissions trends can be attributed to:

- **Increased housing:** Residential natural gas usage on a per capita or per housing unit basis has remained approximately the same since 2018. However, the number of housing units has increased by 2%, contributing to the 1% increase in natural gas usage between 2018 and 2021.
- **Increased C&I square footage:** C&I natural gas consumption per square foot has flatlined between 2018 and 2021. However, growth in square footage (2%) closely follows the increase in overall natural gas consumption (3%) between 2018 and 2021.

Action Plan

Strategies such as reducing energy emissions through shifting energy generation from fossil fuels to renewables, electrifying transportation and making buildings more efficient, have long been central to the city's strategies to mitigate the climate crisis. In recent years, Boulder's work on systems change in the energy sector has focused significantly on clean energy sources. Electricity generation has consistently comprised more than half of Boulder's emissions, making it a key target for climate action. Between 2010 and 2020, the city combined policy action at the state level with pursuing local control of electricity through municipalization.

On Nov. 3, 2020, the community voted to enter a new franchise with Xcel Energy, with a core goal of the relationship to achieve 100% renewable electricity for the community by 2030. With such efforts underway as part of the partnership, Boulder has reframed its focus beyond just achieving a renewable electricity supply, ensuring that energy affordability, resilience, and reliability become cornerstones to the transition to a clean energy system. Strategies also recognize the substantial progress made in eliminating electricity-sourced emissions, not just locally, but statewide, and the foundation this creates for accelerating the move away from natural gas and transportation fuels.

At a high level, this systems-change work in the energy sector is focused on:

» **High-performance emissions-free healthy buildings:** developing innovative financing solutions for efficiency and electrification that will provide increased affordability and access for residents with lower incomes, ensuring use of low carbon building materials in construction, enhancing workforce and market development for affordable HVAC retrofits and new builds, determining the optimal placement and pairing of local generation and storage to optimize resilience and demand management.

» **Clean mobility:** maximizing vehicle electrification and providing greater access for community to be able to utilize clean, affordable transportation across various platforms.

» **Clean energy sources:** ensuring a 100% renewable electricity supply, providing affordable access to solar and storage.

With the commitment to new overarching emission mitigation goals for the community, Boulder also established a set of new objectives, targets, and short-term progress measures (next one-to-five years) which are detailed below to track progress towards a clean, affordable, and resilient energy transition.

Table 2. Objectives, targets, and progress measures for the Stationary Energy sector.

Objectives	Targets	Progress Measure
Ensure equitable and affordable access to energy.	100% of our community members will have unburdened access to basic heating, cooling, and energy needs by 2035.	By 2023, develop a resilience strategy to meet heating and cooling needs of frontline communities.
		By 2023, provide new opportunities for low-income households to engage in efficiency or electrification solutions.
		By 2025, no member of our community will meet the definition of energy impoverished (10%+ of income spent on energy needs).
Establish a safe, healthy, and resilient fossil-fuel-free energy system.	Our energy system will deliver 100% renewable electricity by 2030 and strive to meet the resiliency and reliability needs of the community.	By 2023, develop a community informed strategic roadmap toward achieving 100% renewable energy supply and identify interim targets.
		By 2023, develop a strategic framework detailing the amount, placement, and pairing of local generation and storage to optimize resilience and demand management.
		By 2030, our electricity grid is emissions free

Objectives	Targets	Progress Measure
Transform existing building stock to mitigate their environmental impacts and ensure they provide affordable, healthy, and resilient spaces for their occupants.	Our existing building stock will promote health and wellbeing of occupants and have zero operational emissions by 2040.	By 2023, advocate for state level science-based air quality guidelines for combustion appliances that protect the safety of sensitive populations.
		By 2025, eliminate natural gas from 15% of existing residential building stock and 5% of existing commercial buildings.
		By 2025, all commercial buildings larger than 20,000 sq. ft. will be engaged in performance-based standards such that the Energy Use Intensity (EUI) of our building stock is reduced 20% against a 2015 baseline.
Ensure all newly constructed buildings have the lowest possible carbon footprint and provide affordable, healthy, and resilient spaces for their occupants.	Achieve zero operational emissions in all new buildings with a 40% reduction in embodied carbon by 2031.	By 2023, 100% of new residential and commercial construction will be built electric ready.
		By 2023, require all new construction to conduct an analysis of embodied carbon intensity of the project structure.
		By 2024, stand up a regional embodied energy roundtable of developers, architects, and contractors.
		By 2026, average EUI of commercial construction will be reduced 60% compared to a 2016 baseline.
		By 2026, partner with other communities and community stakeholders to collaborate on purchasing low carbon building materials for all future city operations.

TRANSPORTATION

Transportation emissions can be looked at in two ways: in-boundary and transboundary (sometimes called cross-boundary). In-boundary emissions include all emissions that happen from transportation within Boulder's city limits. This includes trips that start and end in Boulder, as well as the portion of miles that occur within the city boundary for trips that originate or end outside the boundary. Transboundary emissions include emissions from miles that occur outside the city boundary, but that are induced by Boulder residents (commuting out of the city and/or taking a flight from DEN) or commuters coming into to Boulder. As noted in the Current Emissions Snapshot section of this report, Boulder includes transboundary transportation emissions in its GHG goals.

Figure 8 shows the breakdown of transportation emissions.

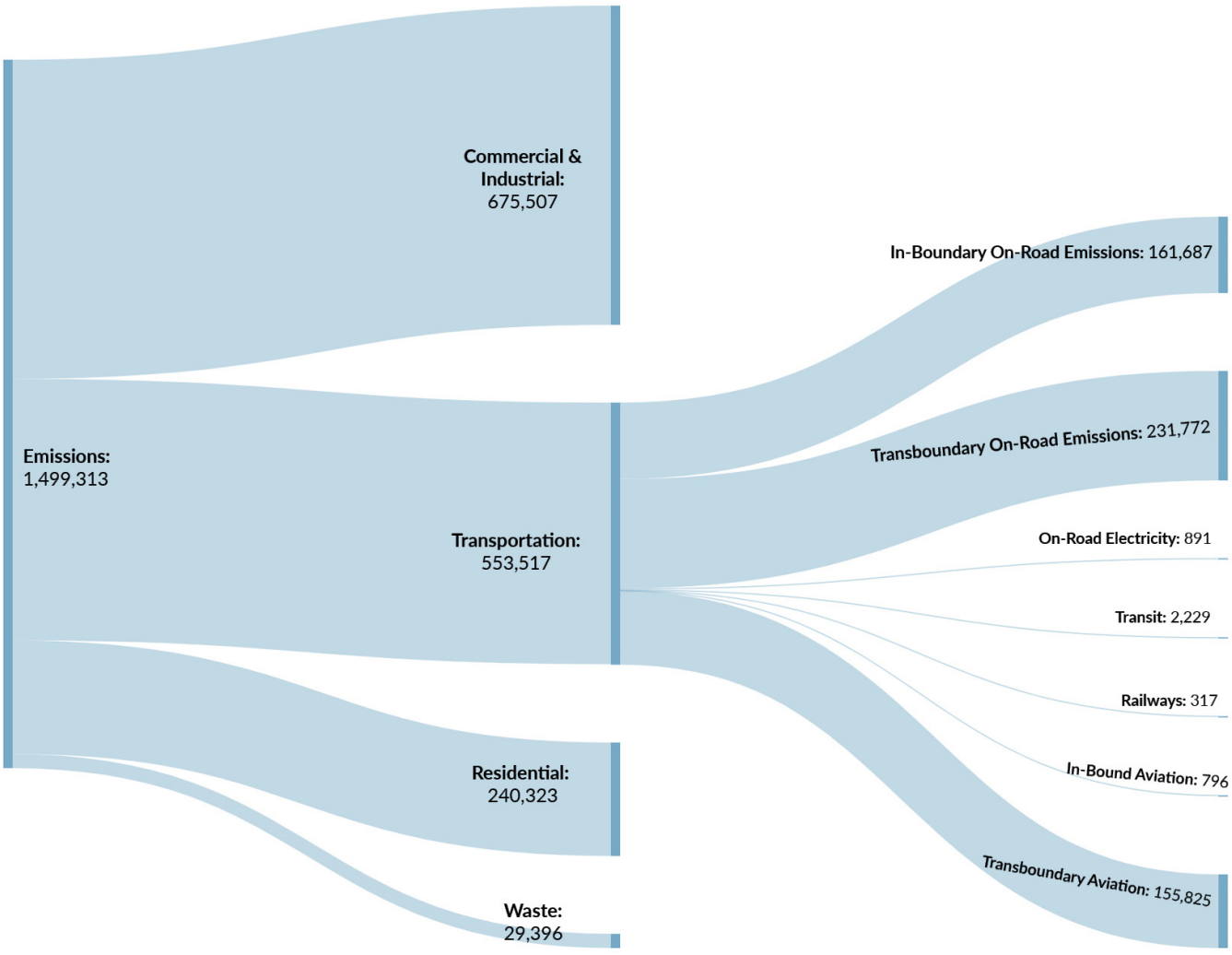

Figure 8. Transportation sector emissions breakdown (2021).

Emissions from transboundary transportation (70% of total transportation emissions) include:

- Transboundary on-road transportation includes 42% of miles that occur outside the Boulder boundary where the city is the origin or destination of the trip.
- Transboundary aviation - flights out of DEN (28% of total transportation emissions). Boulder estimates that 4% of all DEN traffic can be attributed to the City's residents. This accounts for likelihood of the City's population traveling more often than other communities around Colorado.

In-boundary transportation emissions (30% of total transportation emissions) are made up of multiple sources including:

- In-boundary on-road transportation includes all vehicles traveling within Boulder's boundaries (29.7% of total transportation emissions), which are broken up between two types of miles:
  - Miles for trips that start and end within Boulder
  - Miles that occur within the Boulder boundary for trips that originated or ended outside the boundary. See Figure 10 for breakout of miles by type.
- In-boundary railways (0.06% of total transportation emissions).
- In-boundary aviation - flights out of Boulder Municipal Airport (0.14% of total transportation emissions).

Transportation Trends

As the community emerged from the COVID-19 pandemic of 2020, emissions from transportation showed an increase in 2021. Since the 2018 baseline, in-boundary transportation emissions have decreased 30% and since 2020, in-boundary transportation emissions have increased by 5%. In 2021, transboundary emissions increased from the previous year by 32%, but have decreased since the baseline of 2018 by 15%. Emissions from all the transportation sources (including in-boundary and transboundary) showed meaningful reductions against the 2018 baseline (21%). While there were significant reductions in transportation emissions in 2020, the sharp decline experienced in 2020 is almost entirely attributable to COVID and rebounded in 2021, with all emissions increasing by 5%.

Figure 9 shows the change in transportation emissions since 2018. Emissions from both in-boundary and transboundary on-road transportation are lower compared to a 2018 baseline, while emissions from aviation (in-boundary and transboundary) and railways have been consistently higher than the 2018 baseline.

The largest source of emissions reduction is attributable to improvements in average vehicle fuel economy and emission factors, including increased adoption of electric vehicles. As Figure 10 conveys, overall VMT increased more than 10% between 2018 and 2019, then dropped dramatically in 2020 due to the COVID-19 pandemic. VMT increased in 2021 but remained below 2018 levels. It is unlikely that 2021 is fully representative of the post-COVID rebound. Globally, travel remained surpressed for much of 2021 due to ongoing transmission and hospitalization rates, and associated restrictions and requirements. Businesses and workers are still defining

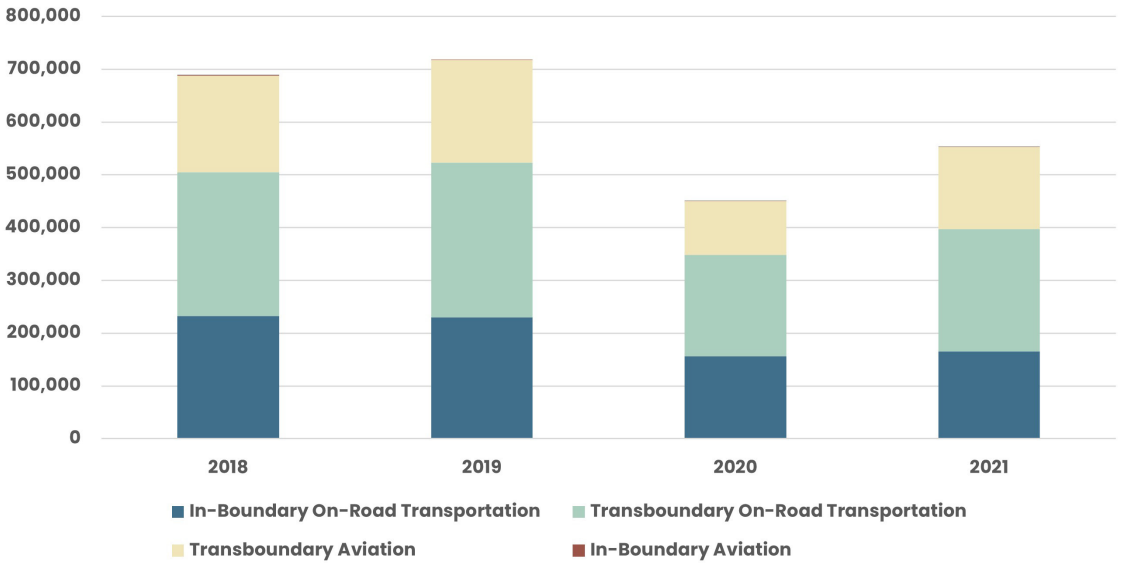

Figure 9. Change in emissions since 2018.

new norms in term of telework. Ridership decline, driver shortages, COVID-exposure fears and changes in commute requirements have shifted travel modes back to the single occupancy vehicle. It could be several more years before the full impact of the pandemic is understood in terms of the community's GHG inventory. One area of note, however, is in-boundary VMT. Despite population growth and growth in GDP, both current and past inventories show that in-boundary VMT has held steady or declined from year to year. This is an indicator that mode shift is occurring within the city boundaries.

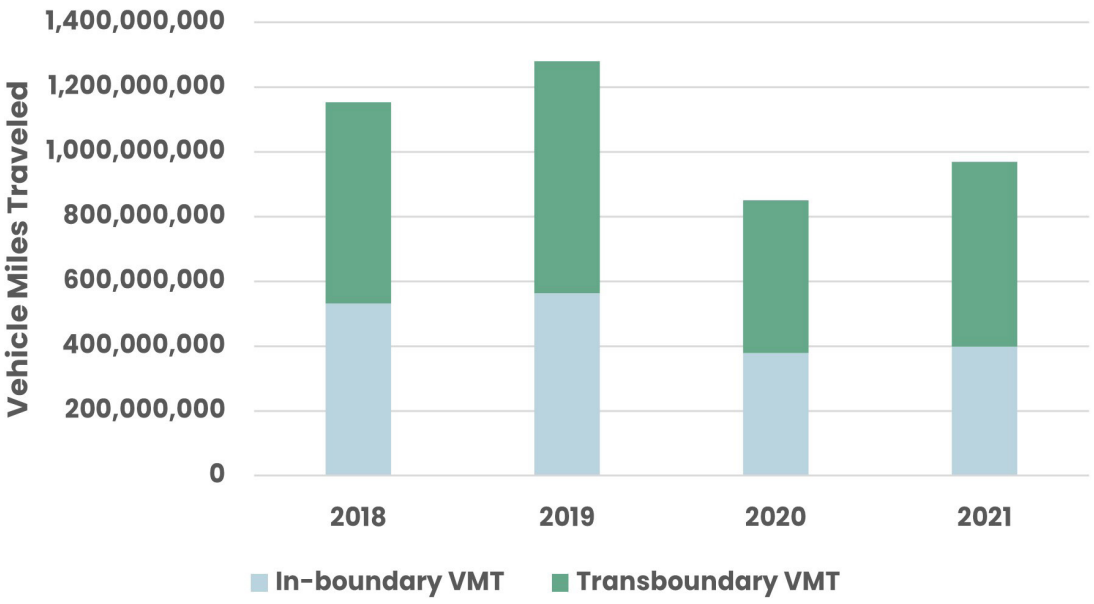

Figure 10. In-boundary and transboundary VMT between 2018-2021.

The COVID-19 Rebound

- **Increase in Vehicle Miles Traveled (VMT).** In 2021, in-boundary vehicle miles traveled (VMT) went back up by 5% and transboundary VMT went back up 22% compared to 2020.

More travel associated with the removals of COVID-19 restrictions are the likely cause of the increase in the VMT, as well as the shift away from public transportation. Overall, however, VMT is still down 16% from the 2018 baseline (see Figure 10).

- **Rebound in aviation travel:** Within the aviation sector, gallons of jet fuel increased 54% between 2020 and 2021. Gallons of aviation gasoline similarly increased by 53% from 2020 to 2021. Jet fuel is used in airplanes with turbine engine jets (commercial airliners) while aviation gas is used in airplanes using propellers or piston-engines.[17] The removal of travel restrictions due to the COVID-19 pandemic are the cause of the dramatic increase in fuel use. Boulder estimates that 4% of all DEN traffic can be attributed to the City's residents, which has remained consistent since 2018. Air traffic at DEN increased from 2020 to 2021, but still remains lower in 2021 than it was in 2018. Compared to the 2018 baseline, at both DEN and Boulder Municipal Airport, jet fuel use decreased by 16% and aviation gasoline use decreased by 6% from 2018.
- **Impacts from the shift to working from home:** Many people work within Boulder's borders but live elsewhere. Many of the individuals employed within Boulder commute from outside the city and traffic is a daily issue for many residents. Prior to the pandemic, it is estimated that between 50,000-60,000 individuals commuted into Boulder daily. With the onset of COVID-19 a shift to more telework, the amount of daily traffic reduced drastically, and it is unclear how many workers will return to full time work in the office. In addition, Boulder is a tourism and student hub for Colorado. Both industries were deeply affected by the COVID-19 travel restriction. The shift to working from home continued in 2021. From 2020 to 2021 emissions from transportation within the city increased only 5% and transboundary emissions from transportation in the city increased by 21%.
- **Slight rebound in Transit:** Gallons of diesel from buses increased slightly (10%) from 2020-2021 due to a restoration of bus routes that were stopped during 2020.

Shifts in Fuel and Vehicle Type and Efficiency Gains

- **Increase in Fuel Efficiency:** CAFE standards have increased the fuel efficiency of vehicles since 2005. Since 2005, the average fuel economy for a new light-duty vehicle has increased by 29%.[18] As more efficient vehicles are driven the amount of fuel used per mile (MPG) has decreased. Additionally, as more states adopt California's Clean Car Standards, the more likely it is that automakers will move to producing more efficient, less carbon-intense vehicles which may lead to additional fuel sand consequently emissions savings.
- **Increase in electric vehicles:** The community saw 650 additional EV registrations in 2021, even amidst numerous supply chain issues that stemmed from the COVID-19 pandemic. The city's adoption rate of over 3.5% of all registered vehicles is over four times higher than the statewide average. Additionally, the city is working to electrify the buses that operate the HOP route. There were 4 total electric buses in the fleet in 2021, and the city has ordered 6 more electric buses to hopefully join the fleet in 2023. See Figure 11.

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[17] See: https://ijet.aero/ijet-blog/different-types-aviation-fuel-jet-fuel#:~:text=AVGAS%2C%20or%20aviation%20gasoline%2C%20is,the%20thrust%20of%20expelled%20air.

[18] See: https://www.energy.gov/eere/vehicles/articles/fotw-1177-march-15-2021-preliminary-data-show-average-fuel-economy-new-light.

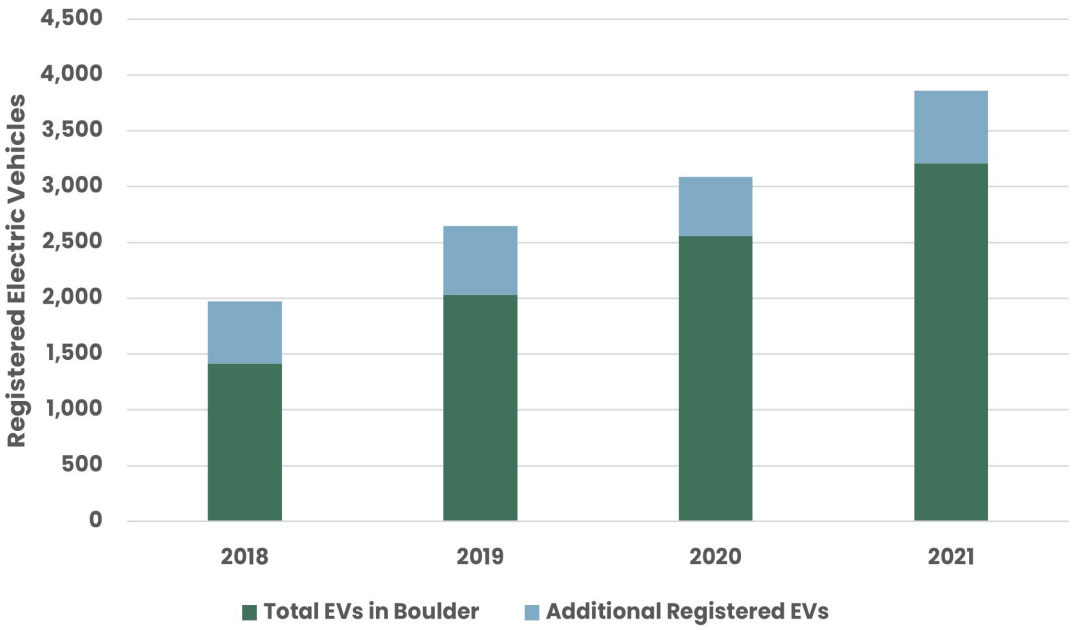

Figure 11. Trends in EVs over time.

The transportation area that had no change in emissions in 2021 was railways:

- **Railway Emissions:** Between 2018 and 2021 railway emissions increased by 227% due to new emission factors and updated global warming potentials for methane and nitrous oxides from the Sixth IPCC Assessment Report. Even with this increase, railways make up very little of Boulder's overall emissions.

Action Plan

The comprehensive overview of Boulder's transportation policies, plans and actions going forward can be found in the most recent Transportation Master Plan (TMP) and the 2020 TMP Progress Report. The report details the city's efforts to address transportation emissions (with a target of reducing transportation emissions 50% by 2030 against a 2005 baseline) through a set of aggressive, city-funded programs and services. The city will be updating the TMP Progress Report in 2023. Residents and businesses in Boulder can also help the City reach the goals in the TMP by reducing their own vehicle miles traveled and working to use carbon-free modes of transportation more frequently. Regarding emissions reductions, transportation-related efforts include:

- **Regional Multimodal Investments and Coordination:** Continue to coordinate with regional partners on multimodal corridor investments including bus rapid transit (BRT) service and regional bikeways. Regional BRT investments are critical to changing non-resident employee travel behavior by providing regional travel options that can compete against the personal vehicle in terms of travel time and cost.
- **VMT Reduction:**
  - **Multimodal Transportation Investments:** Continue investing in multimodal infrastructure and programs outlined in Boulder's Transportation Master Plan (TMP) to achieve SOV vehicle trip and GHG reduction goals as well as broader community sustainability goals.

    - **Vision Zero:** The city has adopted a Vision Zero policy that aims at eliminating severe and fatal traffic crashes and has an Action Plan to implement safety improvements in the areas of engineering, enforcement, education, and evaluation. Safer travel conditions can increase the number of biking and walking trips and shift trips away from motor vehicles.
    - **Micromobility Program:** Expand electric bikeshare program and the pilot e-scooter programs. Micromobility trips can replace vehicle trips for many trips around the city and provides a critical first and final mile solution for transit users.
    - **Transportation Demand Management (TDM):** Continue to work with local employers and Boulder Transportation Connections to implement TDM programs that provide employee commute benefits such as the EcoPass or Parking Cash-Out. As a model employer. The city will continue to provide commute benefits and telework options to city employees.
- **Electrification strategy:** Continue to coordinate the multi-departmental working group on EV and alternative fuels strategy development with a community goal of 30% EV adoption by 2030. This includes pursuing funding opportunities for public charging infrastructure, developing low-income access opportunities, pairing EV charging with solar and electrifying RTD, city, BVSD and CU bus fleets. While RTD provides most of the transit service to and within Boulder, the city contracts with Via Mobility, the city's paratransit provider, to operate the HOP service. The city's aims to electrify the HOP fleet, with 4 buses already electrified, the goal is to have an entirely electric fleet by 2030.
- **Emerging Transportation Policies and Technologies:** Research and evaluate emerging mobility options including expanded micromobility programs, rideshare systems, connected/automated vehicles, and new heavy transport options (e.g., renewable natural gas or diesel fleet vehicles). Develop policies on more effective curbside management better manage access to the curb for Transportation Network Companies, like Uber or Lyft, and freight deliveries, and rethink use of public right-of-way to increase multimodal access.

With the commitment to new overarching emission mitigation goals for the community, Boulder also established a set of new objectives, targets, and short-term progress measures (next one to five years) which are detailed below to track progress towards the city's collaborative climate transportation work.

Table 3. Objectives, targets, and progress measures for the Transportation sector.

Objectives	Targets	Progress Measure
Provide clean mobility solutions that meet community needs.	All Boulder residents will have access to clean mobility options by 2035.	By 2023, identify neighborhoods in greatest need of transportation solutions and design solutions around micromobility, electric car sharing and micro transit platforms
		By 2025, all residents will have access to convenient, accessible, and affordable charging infrastructure.
		By 2025, 50% of shared fleets such as taxis, rideshare, and carshare companies in Boulder will be electric.
	30% vehicle miles travelled in Boulder will be electric by 2030.	By 2023, all EV owners will be engaged in charging management programs.
		By 2025, 40% of new vehicles purchased in Boulder will be electric.
		By 2025, meet World Health Organization Air Quality Guidelines for particulate matter, nitrogen dioxide, ozone, and sulfur dioxide, with a particular focus on transportation corridors and burdened communities.

WASTE AND WASTEWATER

Waste and Wastewater Trends

Overall waste and wastewater emissions make up a small amount of Boulder community emissions in 2021 at 1.96% and 0.04%, respectively. However, these emissions are limited to treatment of waste and do not include the emissions associated with the production of goods and services consumed in Boulder, or "embodied emissions." New methods of measuring consumption emissions that are under development show that urban consumption is a key driver of global greenhouse gas emissions. Boulder is committed to reducing embodied emissions by advancing a circular economy, discussed in the Action Plan.

Figure 12 shows the difference in waste and compost tonnage from 2018-2021. Emissions from wastewater have been consistently lower each year compared to a 2018 baseline, while emissions from waste have been consistently higher than the 2018 baseline. Composting emissions reduced every year between 2018-2020 and then increased in 2021. These trends can be attributed to:

- **Waste:** The amount of waste being landfilled has increased since 2018 due to a variety of factors, including population growth and increased visitation, construction in the community, and the continued increase in single-use items and takeout containers associated with the COVID-19 pandemic.
- **Composting Emissions:** Composting emissions are lower than the baseline year likely because composting rates dropped before and during the COVID-19 pandemic and have not fully recovered to 2018 levels. The tonnage of compost composted, and associated emissions, increased in 2021 which is a positive trend.
- **Wastewater:** Several efficiency improvements have been made to the wastewater treatment process, the largest being a significant reduction in nitrogen discharge.

Figure 12. Annual change in waste and compost tonnage 2018-2021.

What Happened in 2021

Only the wastewater sector continued to reduce emissions between 2018 and 2021, and 2020 and 2021. Solid waste emissions increased by 47% from 2018 to 2021 (8,518 mt CO_2e) and 25% from 2020 to 2021 (5,304 mt CO_2e). Emissions from composting have decreased between 2018-2021 by 14% (438 mt CO_2e) and increased between 2020-2021 by 2% (50 mt CO_2e). Several notable trends are driving these emission trends:

- **Increase in Composting post-COVID:** Composted waste decreased by 16% from 2018 to 2020 and increased by 2% between 2020 and 2021.
- **Wastewater:** There has been a decrease (-19%) in emissions from the city's wastewater treatment plant (WWTP) between 2018 and 2021. Wastewater treatment emissions primarily stem from treatment volumes and population. Additionally, it should be noted that emissions from the wastewater treatment plant are also attributable to electricity used to treat the effluent, and these emissions, which are captured in the commercial electricity use emissions, have been decreasing over time with Xcel's greening of the grid.

- **Updated GWP:** in 2020, the global warming potentials were updated with the latest GWPs in the IPCC AR6 report. This is likely a contributing factor to the large increase in waste emissions between 2018-2021 (47%).

Action Plan

Boulder's circular economy work is transitioning beyond traditional zero waste goals of diverting waste for recycling to a broader set of actions that change the system of consumption and keep materials in circulation as long as possible. As a first step, the city, via consulting firm Metabolic, produced the Circular Boulder analysis and roadmap. Metabolic examined the current level of circularity in Boulder by performing an in-depth Material Flow Analysis. They also identified hotspots and opportunities that exist throughout the local materials economy and summarized the impacts of some of those hotspots. This innovative work is informing the development of Boulder's strategic plan for a circular materials economy, the next evolution of reducing waste.

At a high level, this circular economy systems-change work is focused on:

- **Consumer goods:** reducing consumption-based emissions through lower carbon choices (local, etc.), minimizing single use plastics, maximizing reuse and repair through clinics and stores, promoting sharing platforms over direct ownership, and supporting market development for recyclables.
- **Built environment:** understanding the opportunity for and promoting adoption of low-carbon construction materials, maximizing reuse of building materials and designing buildings for reuse in deconstruction, supporting market development for construction waste diversion.
- **Organics materials:** Minimizing food waste while maximizing the production on clean compost and biochar products that can be reapplied within our community.

With the commitment to new overarching emission mitigation goals for the community, Boulder also established a set of new objectives, targets, and short-term progress measures (next one to five years) which are detailed below to track progress towards our transition to a circular materials economy.

Table 4. Objectives, target, and progress measures for the Waste sector.

Objectives	Targets	Progress Measure
Minimize waste production per capita and maximize diversion from landfills.	Become a zero-waste city by 2025.	By 2023, reduce waste per capita 10% against a 2015 baseline.
		By 2025, divert 85% of waste from landfills.
		By 2026, all food waste will be eliminated from landfills and will instead go toward feeding people, animals, and soils.

Objectives	Targets	Progress Measure
Reduce the carbon footprint of production cycles we have the greatest ability to affect	Reduce community consumption-based emissions 50% by 2030 against a 2018 baseline.	By 2022, complete a consumption-based inventory to understand the product supply chains our community has the greatest ability to impact.
		By 2023, host multiple annual education outreach events to inform community on how they can reduce consumption-based emissions.
		By 2025, host educational and outreach sessions with large actors in our region on implementing low carbon procurement strategies and policies.
Employ circular principals in building construction and demolition.	By 2025, host educational and outreach sessions with large actors in our region on implementing low carbon procurement strategies and policies.	By 2022, 75% of deconstruction waste will be recycled or reused.
		By 2023, require a building materials inventory for all new construction.
		By 2025, develop a plan and location for storing recovered building materials for reuse.
		By 2026, require new residential and commercial construction to use non-toxic recyclable and recycled products in the selection of construction materials.

Objectives	Targets	Progress Measure
Make the repair reuse and remanufacture of components and materials easier and more accessible.	Materials and products are designed to last with the ability to recycle, reuse, repair, or remanufacture at the end of product life by 2030.	By 2023, 50% restaurants in Boulder adopt use of reusable take out containers.
		By 2025, fund and fuel development of reusable e-commerce and consumer good packaging solutions.
		By 2025, eliminate use of single use plastics.
	Increase participation in sharing platforms 30% over a 2020 baseline to foster equitable access to goods and services over ownership by 2030.	By 2023, complete analysis determining areas and neighborhoods with gaps in access to essential goods and services.
		By 2025, increase sharing economy platform use 30% from 2020 baseline, targeting neighborhoods and resources in greatest need.
Establish an economic basis for circular entrepreneurship and innovation.	Create a closed loop system that reduces fire risk in our community, converts biomass to biochar, and generates clean energy to fuel buildings by 2030.	By 2023, complete a city biomass assessment.
		By 2025, 20% of biomass collected in community to be converted to compost or biochar.
		By 2025, bioenergy is derived from locally sourced "waste"; biomass is used to displace methane (natural gas) at 10 locations.
		By 2025, wildland urban interface thinning materials are integrated into bioenergy-biochar systems.
	Foster community and entrepreneurial partnerships and platforms to promote repair and reuse by 2030.	By 2023, develop a network of online resources that facilitate the market for reusable or shareable goods such as catalog of items at thrift stores, tool libraries, etc.
		By 2024, initiate a funding structure to support circular business platforms.
		By 2028, establish a community innovation park.

NATURE-BASED CLIMATE SOLUTIONS

In the city's 2016 Climate Action Plan (the "Climate Commitment") the city established a new action area focusing on the role of ecosystems in climate action. In the following year, 2017, the city and Boulder County both initiated their first carbon sequestration initiatives, both on agricultural holdings. Land plays an important role with regards to climate change: it can act as a sponge and absorb carbon from the atmosphere or it can contribute to the climate crisis

through forest and grassland destruction and the increased expansion of cities. The city has been working to quantify the impacts of its lands.

One of the first areas in which the climate benefits of natural climate solutions are being quantified is urban forestry. In 2020, the city participated in the piloting of a new ICLEI protocol--Appendix J to the U.S. Community Protocol. This appendix on Forests and "Trees outside Forests", establishes guidance for communities to integrate such sequestration and emission values of city managed/influenced forests into their inventories.

Currently there are not established protocols for capturing carbon sequestration benefits in land management other than forests. The city is working with a broad consortium of organizations to develop these protocols. This would enable the city to start capturing the soil-based sequestration efforts it is engaged in along with other potential natural climate solutions. These efforts and their developments will be reported on in subsequent reports. This report will focus solely on forests as the only area in which there are currently established and accepted quantification methods of nature-based sequestration actions.

Forests and Trees Outside Forests

In 2020, the city participated in ICLEI's cohort to calculate the total GHG emissions, removals (i.e., sequestration or sinking potential), and carbon storage (i.e., sink) from land use and land use changes in the city and its Open Space and Mountain Parks (OSMP) lands, with the aim of integrating the results into the city's annual inventory process.

The results show that the total amount of carbon stored in Boulder's forests and trees within the city boundary are ~350,000 metric tons as of the latest period of analysis (2016-2019), with the large majority (69%) stored in urban tree canopy with the remaining 31% stored in forest. When including the city's OSMP lands within the boundary of analysis, the amount of carbon stored is ~2.3 million metric tons, with the vast majority (75%) within forested lands (Figure 13).

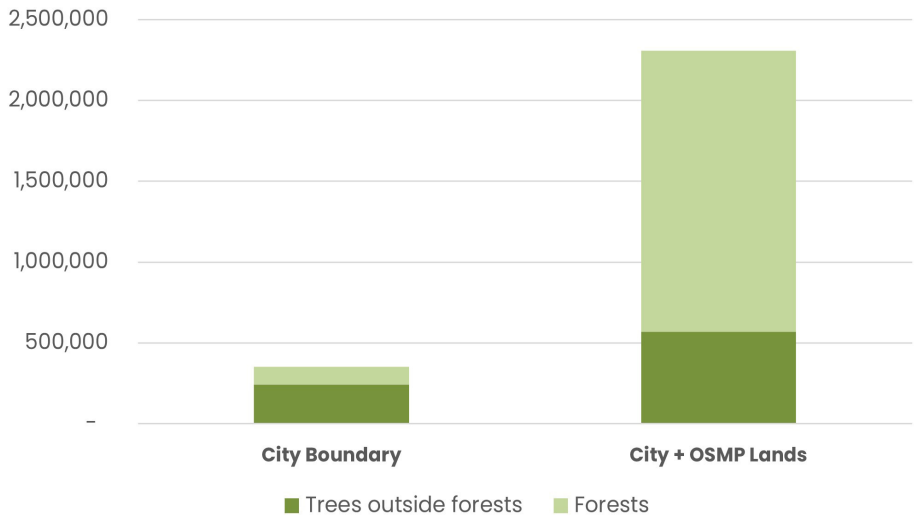

Figure 13. Total Carbon Stored in Boulder's Forests and Trees Outside Forests in 2020 (Urban Trees).

In addition to calculating the total carbon stock held within Boulder's trees and forests, the Appendix J analysis provided guidance on calculating the annual emissions and removals (sequestration) that those trees and forests yield. When summing the total emissions produced

by trees that were lost or damaged with the amount of carbon removed from the atmosphere from existing and new trees, a net annual GHG change figure was calculated, **with negative values representing removals and positive values representing emissions**. For more details on the Forest and Trees Outside of Forests analysis, refer to the 2020 Community Greenhouse Gas Emissions Inventory Report.

Emissions Snapshot

Boulder did not recalculate annual carbon removals from forests and urban trees for 2021. The city is currently exploring methods to allow this analysis to be completed on an annual basis. Therefore, estimates from 2020 were used to estimate total net emissions from emissions and removals. When using 2020 removals estimates, total net emissions including transboundary transportation and emissions removals in Boulder in 2021 are 1,478,541 mt CO_2e (Table 5).

Table 5. GHG emissions including annual carbon emissions and removals of forests and urban trees in the annual GHG inventory.

Emission Type by Sector	Emissions ($mtCO_2e$)		
	2005	2020	2021
Commercial and Industrial Buildings	977,220	658,541	675,507
Residential Buildings	311,427	240,013	240,323
Transportation (with transboundary aviation)	801,206	451,104	553,517
Transportation (without transboundary aviation)	320,257	157,307	165,921
Solid Waste	53,840	24,042	29,396
Wastewater Treatment	1,800	658	571
Total Gross Emissions (with transboundary emissions)	**2,145,493**	**1,373,552**	**1,499,314**

Land Use Sequestration: City Only	Emissions ($mtCO_2e$)		
	2005	2020	2021
Forests Remaining Forests	(1,073)	(1,041)	(1,041)
Forests Converted to Other Lands & Disturbances	748	641	641
Other Lands Converted to Forests	(6)	(2)	(2)
Sequestration from Urban Trees	(8,795)	(8,898)	(8,898)
Emissions from Urban Trees	2,688	58	58
Total Net GHG Removals	**(6,403)**	**(9,243)**	**(9,243)**
Total (Net) GHG Emissions without transboundary emissions and removals	**1,658,141**	**1,070,511**	**1,102,475**

Land Use Sequestration: City + OSMP Lands	Emissions (mt CO_2e)		
	2005	2020	2021
Forests Remaining Forests	(16,685)	(16,542)	(16,542)
Forests Converted to Other Lands & Disturbances	11,759	16,611	16,611
Other Lands Converted to Forests	(20)	(14)	(14)
Sequestration from Urban Trees	(21,055)	(20,962)	(20,962)
Emissions from Urban Trees	995	10	10
Total Net GHG Removals	**(26,001)**	**(20,773)**	**(20,773)**
Total (Net) GHG Emissions with transboundary emissions and removals	**2,119,492**	**1,352,779**	**1,478,541**

Action Plan

Building on the city's legacy as a leader in open space and environmental protection, the city's climate action program has also been a leader in advancing and mainstreaming ecosystems as a core focus area for climate action. Over the next three to five years, Boulder's major actions will take place in the following areas:

- **Urban Forests for Life** — A multi-year campaign will be initiated to mobilize both public and private sector entities to plant over 10,000 trees in the Boulder area.
- **Cool Landscapes** – This initiative has both urban and working lands components.
  - **Cool Corridors (urban)** – Design and implement a network of corridors throughout the city that can act as both critical habitat and carbon-rich vegetative networks that support urban cooling and other green infrastructure benefits.
  - **Cool and Absorbent Landscapes (working lands)** – Analyze the larger working land network owned by the city to assess the potential of using vegetative and water management systems to support both cooling and storm water management objectives.
- **Urban Drawdown Initiative (UDI)** – Building on the two years of development work that has taken place with UDI, begin implementing the planning and implementation systems both in Boulder and in communities across the US that intersect mitigation, adaptation/resilience, and equity objectives.
- **Green Jobs**– Working in collaboration with Boulder County and the State, support the placement of State and Federally supported CCC crews in support of actions developed in the initiatives outlined above.

With the commitment to new overarching emission mitigation goals for the community, Boulder also established a set of new objectives, targets, and short-term progress measures (next 1-5 years) which are detailed below to track progress towards the city's nature-based climate solutions work:

Table 6. Objectives, target, and progress measures for the Natural Climate Solutions.

Objectives	Targets	Progress Measure
Foster community resilience through carbon enhanced ecosystems.	Reach 20% tree canopy by 2035, targeting growth of canopy cover in areas of greatest need.	By 2022, determine planting plan to maximize tree canopy and ecosystem service benefits to the community across both public and private lands.
		By 2025, plant 20,000 additional trees on public and private lands.
		By 2030, increase city-wide tree canopy coverage from 14% to 20%.
	Increase water absorption capacity by 25% in high flood risk areas by 2030.	By 2025, increase soil moisture retention capacities in targeted areas by 30%.
	Create connected "cool corridors" across 10% of urban land area by 2030.	By 2025, establish cooling corridor projects in 5 neighborhoods by 2023, and an additional 10 neighborhoods/areas.
	Develop landscape cooling/ absorption zones in 25% of the peri-urban areas surrounding the city by 2030.	By 2025, increase soil cover/ canopy by 10% in targeted areas.
		By 2025, increase moisture retention capacities in targeted sites by 30%.
	Reduce fire hazards in urban-wildland interface and other high fire risk zones by 50% by 2030.	By 2027, complete 50% risk reduction in all "high risk" wildland urban interface areas.

Objectives	Targets	Progress Measure
Increase natural carbon sequestration within and beyond our boundaries.	Remove 50,000 tons of CO_2 annually by 2030 through forest, urban tree, and soil landscape restoration.	By 2025, have 1,500 acres of agricultural lands in carbon management.
		By 2025, increase soil organic carbon by 25% in lands managed through restoration and regeneration practices.
		By 2025, increase urban forest carbon capture capacity by 10,000 MT.
		By 2027, 50% of organics diverted by the city are applied as compost within city boundaries and on city-controlled properties.
Design actions to maximize equitable ecosystem benefits.	Achieve tree planting capable of achieving 30% canopy cover in 100% of high vulnerability neighborhoods by 2030.	By 2022, identify neighborhoods vulnerable to urban heat island effect and energy burden.
		By 2025, reach annual targeted plantings in all vulnerable neighborhoods as identified by analysis.
Support the growth of economic sectors that sustain critical ecosystem services.	Support Climate Conservation Corps establishment in Boulder/ Boulder County.	By 2022, support 5 CCC placements working on urban forestry projects in Boulder.
	Strive to ensure 40% of new employment comprises equity-based green sector jobs.	By 2023, provide training and outreach that engage BIPOC in urban forestry opportunities.
		By 2025, increase the number of BIPOC operators engaging in land management/stewardship leases/contracts with the city by 20%.
		By 2025, work with BIPOC landscape contractors to promote offering of organic or other sustainable landscape services by 20%.

Objectives	Targets	Progress Measure
Advance the field of natural climate solutions beyond Boulder.	Develop globally accessible tools for carbon management and optimal ecosystem services planning by 2025.	By 2022, publish and disseminate urban drawdown planning tools and systems in 10 cities/ counties/nationally.
		By 2022, participate in the formation of a "vanguard" cities network around urban landscape climate action.
		By 2023, develop tools that are being used in 25 cities and counties across North America.
		By 2023, coordinate the first national urban forests carbon offset sale of 200,000 MT of carbon.
		By 2025, engage in active collaboration with 4 or more cities internationally in urban drawdown activities.