City of Boulder Community Greenhouse Gas Inventory Report

Calendar Year 2020

LOTUS
Engineering & Sustainability

"From the conservation of our vast open space to the enactment of the first municipal carbon tax in the country, for decades, the City of Boulder has served as a North Star for other environmentally-conscious communities. As the young climate activist Greta Thunberg once said, 'The bigger your platform the bigger your responsibility…' and Boulder is poised to act."[1]

[1] https://bouldercolorado.gov/news/action-beyond-boundaries-citys-proposed-climate-action-evolves-attack-systemic-drivers-climate

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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).[2]

Biogenic emissions (CO2(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.

Emission Factor

A factor that converts activity data into GHG emissions data (e.g., kg CO2 e emitted per liter of fuel consumed, kg CO2 e 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); sulphur hexafluoride (SF6); 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.

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

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.

In-boundary transportation

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

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 accounted for in 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 and the progress towards its climate goals. 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 by which year-to-year changes can be tracked and evaluated.

The results presented here are for the year 2020 and should be taken within the context that this was an extraordinary year and may not reflect persistent progress towards the city's goals. The COVID-19 pandemic effects on the city began March 16, 2020, with the state-wide shutdown and have continued through the publication of this report. While some of the effects, both positive and negative, may carry forward, it will be years before any conclusion can be drawn as to the sustained impact on global emissions.

This report also marks a shift in the city's mitigation goals and tracking methodology. In the fall of 2020, the Race to Zero campaign was established, creating a coalition of cities, businesses, and industries to commit to setting science-based targets to achieve a net zero future. As such, ICLEI updated its methodology for setting science-based targets, recommending that cities use an updated baseline year between 2016 – 2019 to set an interim target towards the achievement of Net Zero emissions. To follow this reporting methodology while keeping track of all our climate work to date, going forward, the city's inventory will report progress against two baselines – the historical baseline year of 2005 and the revised baseline year of 2018.

Finally, in addition to this published report, the city regularly reports and updates its progress on its "Boulder Measures" citywide dashboard.[3]

[3] For more information see https://bouldercolorado.gov/boulder-measures.

EXECUTIVE SUMMARY

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.

"The City of Boulder is proud to stand with other cities in the Race to Zero. We know that cities acting alone won't come close to the action needed to stabilize our climate, so we are grateful for the chance to collaborate," said Sam Weaver, City of Boulder Mayor. "Cities are where integrated solutions, backed up by ambitious policy and urban planning, will be critical in creating the systemic change needed to create a more sustainable, equitable and prosperous world."

Boulder has continually been a leader in climate action, not only by setting ambitious goals but by implementing progressive policies to ensure these targets are met. Through collaboration with partners, cities, and government agencies, Boulder hopes to take "action beyond boundaries" to address not only citywide emissions but also tackle the climate issues that permeate municipal borders.

In accordance with these new commitments, the City of Boulder adopted more aggressive community climate action targets. The new targets aim to:

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

In the pursuit of achieving these ambitious targets, the city remains committed to reaching the community's numerous quantitative and qualitative targets embedded across their energy, natural climate solutions, materials systems, land use, and financial systems work including becoming a zero-waste city by 2025 and achieving a 100% renewable electricity supply by 2030.

Since Boulder started completing an annual GHG inventory, the city has experienced year-over-year reductions in emissions. As of 2020, the Boulder community reduced emissions by 36% compared to the original 2005 baseline and 22% since the new 2018 baseline. Despite growth in Boulder's population, gross domestic product (GDP), and square footage since 2005 (by 10%, 87%, and 12% respectively), Boulder continues to reduce its emissions year over year. See Figure 1 for more information.

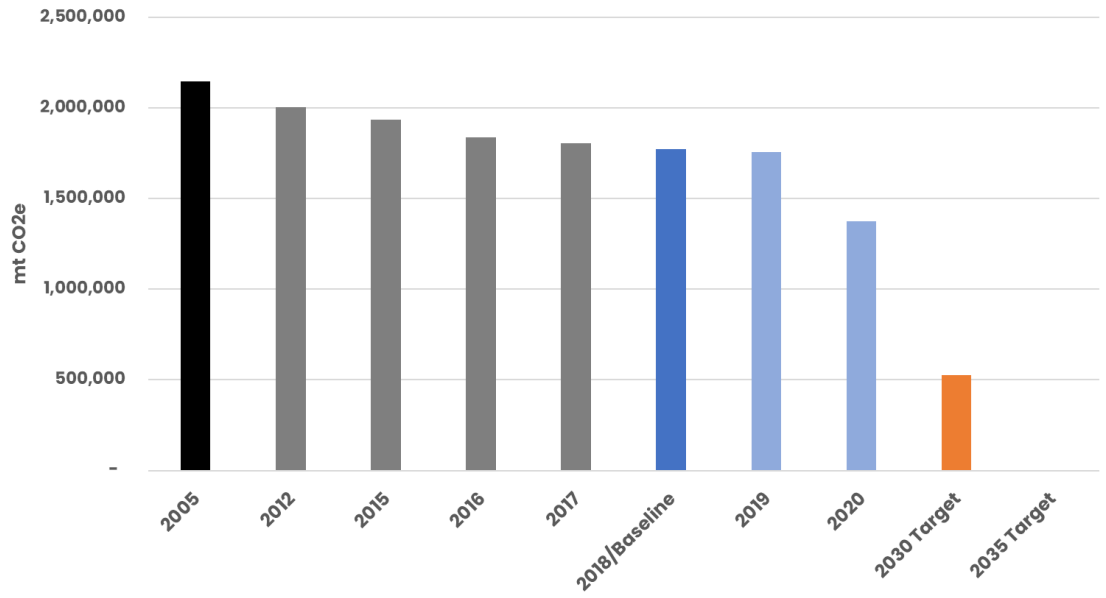


Figure 1. Total Community GHG Emissions.

Given the unprecedented circumstances that 2020 yielded, with state-wide shutdowns leading to most of the population spending a sizeable amount of time in their homes and vastly less time on the road, Boulder recognizes the uniqueness of the GHG results presented in this analysis and that while some of the reductions seen in 2020 are durable, others are relatively unique to the circumstances of the COVID shutdowns. The most significant reductions noted in 2020 were driven by:

- Vehicle Miles Traveled (VMT) and associated transportation emissions
- Commercial and Industrial electricity and natural gas consumption
- Aviation travel

While many emission sources decreased during 2020, some emissions and activity levels have increased since 2018 including:

- Residential electricity and natural gas consumption
- Waste related emissions

With COVID creating many unique trends in our emissions that we have an opportunity to leverage, such as higher levels of telecommuting that have a significant impact on non-resident employee commuting and its associated emissions, we also recognize that it brought about some potentially negative environmental trends. For example, there was a shift away from public transit in favor of single occupant vehicles. This signifies a setback in our overall strategy of VMT reduction that could yield long term effects on service reductions. Similarly, a sharp increase in e-commerce likely resulted in increased truck deliveries into the community that may have persistence beyond COVID, and an uptick in takeout food items from restaurants yielded increased use of disposable containers and utensils which our waste

programs sought to address via subsidizing sustainable food service ware items and launching a reusable takeout container program. The city will continue to track these trends to determine their persistence into the future.

Figure 2 provides an overview of the total emissions (1,373,552 mt CO_2e) reported by Boulder broken out by sector and source. Additional detail can be found in the *Current Emissions Snapshot* section.

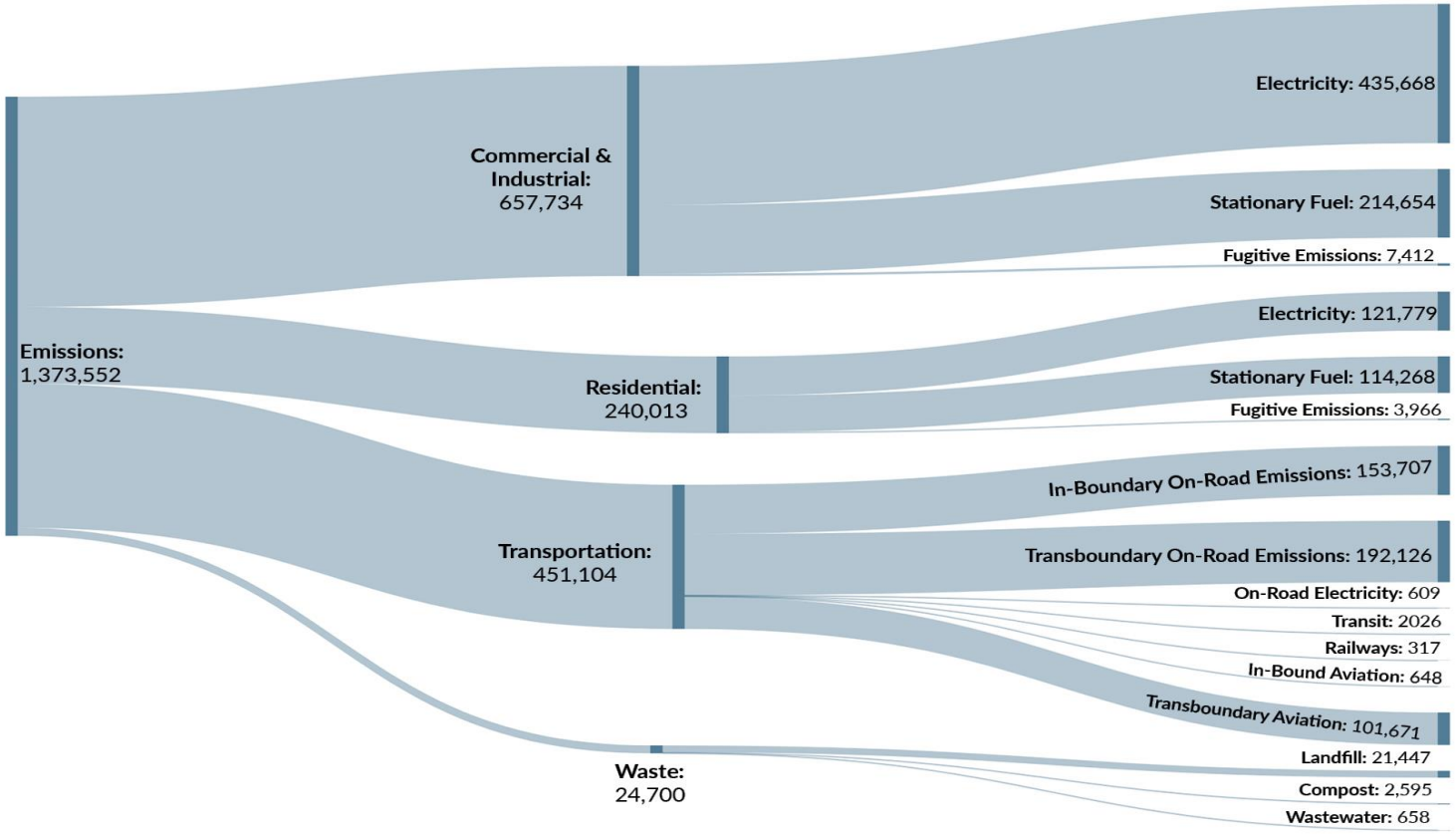


Figure 2. Snapshot of Boulder's 2020 GHG Emissions

METHODOLOGY

The 2020 GHG inventory was completed using the same protocol as previous community inventories - the Global Protocol for Community-Scale Greenhouse Emission Inventories (GPC).[4] 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.[5] By completing a GPC-compliant inventory, Boulder can report emissions to the Carbon Disclosure Project (CDP),[6] which outwardly demonstrates Boulder's climate change commitments to a global audience. The following report reviews how the 2020 inventory was completed, 2020 GHG emissions sources, and trends in emissions between 2005 and 2020 and 2018 and 2020.

Changes to the Methodology and Available Data in 2020

Transportation

Prior to 2020, the city used DRCOG's Regional Travel Model, a "gravity-based" transportation model[7] that calculated the total Vehicles Miles Traveled (VMT) for the city using a system of traffic analysis zones with population, employment, and estimated traffic based on average trip length by trip purpose. The city transportation model refined the DRCOG regional transportation model and validated it against existing vehicular counts. There were limitations to this approach that impacted estimations of annual VMT. The model did not include the distance of trips outside the city plan area boundary for trips that began or ended outside the boundary.

This year, Boulder has updated its analysis to use anonymized smartphone data to estimate the volume of vehicle traffic traveling within, into, and out of the city daily based on origin and destination.[8] Alongside this data which for the first time delineates the transboundary miles traveled to and from the city, mostly attributable to in-commuters, Boulder has also been able to take into account a more detailed vehicle type breakout, updated emission factors, and additional fuel types (i.e., Compressed Natural Gas and E-85) which impacted our transportation emission calculations.

With this change, Boulder now takes responsibility for all miles travelled within the city boundary, while taking responsibility for 50% of miles that occur outside the boundary for trips that start or end in Boulder. This methodology change does not include VMT from pass through

[4] For more information see: https://ghgprotocol.org/greenhouse-gas-protocol-accounting-reporting-standard-cities.
[5] For more information see: https://www.globalcovenantofmayors.org/.
[6] For more information, see https://www.cdp.net/en/info/about-us.
[7] For more information see: http://www.princeton.edu/~alaink/Orf467F12/The Gravity Model.pdf.
[8] For more information see: https://www.streetlightdata.com/..

trips where a car does not stop in Boulder. Figure 3 shows the breakdown of types of miles that are included in the analysis.

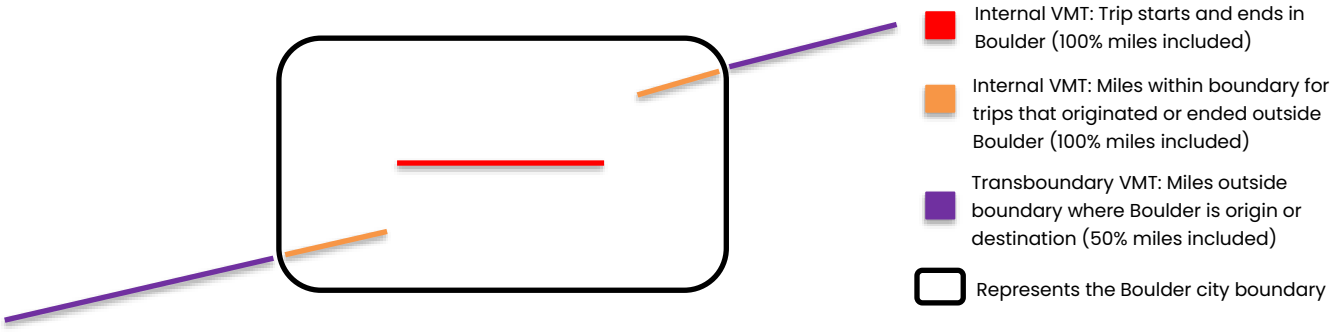


Figure 3. Breakdown of Vehicle Miles by Type.

To ensure an apples-to-apples comparison of 2020 data to past years, the updated methodology was applied to all years going back to 2005. Raw VMT data was used for 2018 – 2020, while prior years were calculated using a combination of the Regional Travel Model output figures and CDPHE VMT trends.

Waste

In 2020, Boulder County released a new waste composition study. This study provided new estimates of the waste stream make up. These new estimates were applied to Boulder's landfilled waste estimates. Additionally, the global warming potential for methane, the prominent GHG emitted from waste disposed at landfills, increased in the latest IPCC Assessment Report. The global warming potential increased by 6 percent, and while the overall tonnage of landfilled waste decreased in Boulder in 2020, emissions went up due to this increase in the global warming potential.

Sequestration of Forests and Trees Outside Forests

Guidance for calculating GHG fluxes from land use and land use change is currently being developed under the GPC Protocol, building upon the guidance developed under the U.S. Community Protocol Appendix J: Forest Land and Trees. In 2020, the City of Boulder participated in the 2020 ICLEI Cohort for estimating emissions and removals associated with our forests and urban trees according to the Appendix J protocol, which will be adapted for the GPC in coming years.

Boulder chose to include the sequestration results as part of our annual GHG reporting as a signal of the importance of quantifying and tracking these emissions as part of a comprehensive approach to climate action. Given the significant challenges in eliminating all emissions, drawdown actions will play a pivotal role in achieving community net zero goals. By measuring and managing carbon drawdown as a mechanism for addressing climate change, the city is helping pioneer a city-based approach to development of this critical sector.

The analysis was conducted on two sets of boundaries: one looking at net annual sequestration of trees and forests within our city boundary which will be compared against our total internal city emissions (1,079,755 $mtCO_2e$), and a boundary level that includes all Open Space and Mountain Lands under the city's management control which will be compared against our transboundary total emissions (1,373,552 $mtCO_2e$).

A detailed description of all methods used in calculating the annual net sequestration of forests and urban trees can be found here and is comprised largely of calculating loss/gain of forest lands over periods of time, assessing amount of tree area damaged by insects, fire, or other disturbances, and estimating the area of trees outside of forests (urban trees), while assigning relevant emission and removal factors to each.

New IPCC Global Warming Potential (GWP) Estimates

GWP is a measure of how much energy the emissions of 1 ton of a gas will absorb over a given period of time, relative to the emissions of 1 ton of carbon dioxide (CO_2). The larger the GWP, the more that a given gas warms the Earth compared to CO_2 over that time period. With the updated IPCC 6th Assessment report, several of the GHG emissions that Boulder reports received increased GWP:

- Methane (CH_4): 29.8 (before it was 28).
- Nitrous Oxide (N_2O): 273 (before it was 265).

CURRENT EMISSIONS SNAPSHOT

In 2020, the results of the inventory show a total of 1,079,755 mt CO_2e generated within Boulder's boundary. When including transboundary transportation (flights out of Denver International Airport (DEN) and transboundary vehicle trips), the analysis shows emissions of 1,373,552 mt CO_2e.

Emissions snapshot

At 48% of total emissions (657,734 mt CO_2e), the commercial and industrial building energy sector made up the largest share of Boulder's emissions, followed by transportation emissions at 33% (451,104 mt CO_2e) and residential building emissions at 22% (240,013 mt CO_2e), with the remaining 2% of emissions generated from solid waste (24,042 mt CO_2e, and wastewater treatment (658 mt CO_2e). Transboundary transportation (flights out of DEN by Boulder residents and transboundary vehicle trips) emissions accounted for 293,797 mt CO_2e in 2020. See Figure 4.

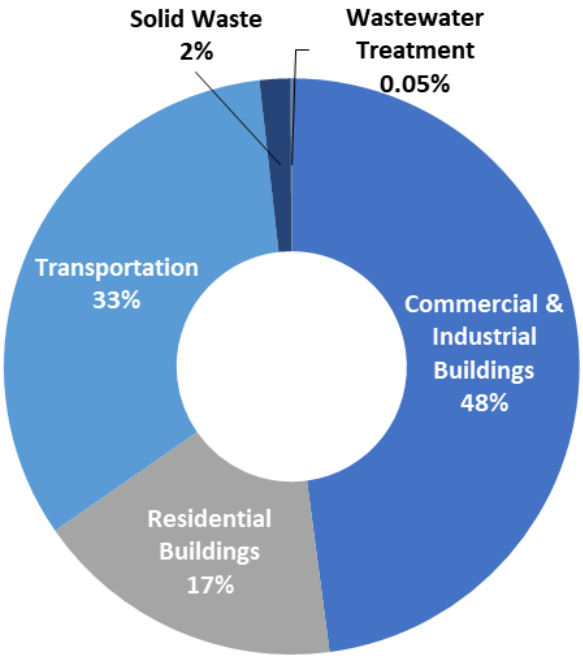


Figure 4. Emissions by Sector including transboundary transportation emissions (mt CO2e).

Within each of the sectors, there are several sources of emissions, and some sources are attributed to multiple sectors. For example, electricity is a source of emissions that is captured within the Commercial and Industrial (C&I) building sector, the residential sector, the transit sector (via electric buses), and the transportation sector (via electric passenger vehicles). The

largest source of emissions is electricity (41% or 557,447 mt CO_2e). Natural gas (including fugitive emissions) is the second-largest source (25% or 339,195 mt CO_2e). Transportation Fuels make up 33% of emissions with gasoline at 19% (259,312 mt CO_2e), jet fuel at 7.41% (101,829 mtCO_2e), diesel at 6.51% (89,462 mtCO_2e), and aviation gasoline at less than 0.05%. Together, waste (compost and landfilled waste) and wastewater (process emissions, effluent discharge, flared gas, and combustion gas) accounted for just over 2%. See Figure 5.

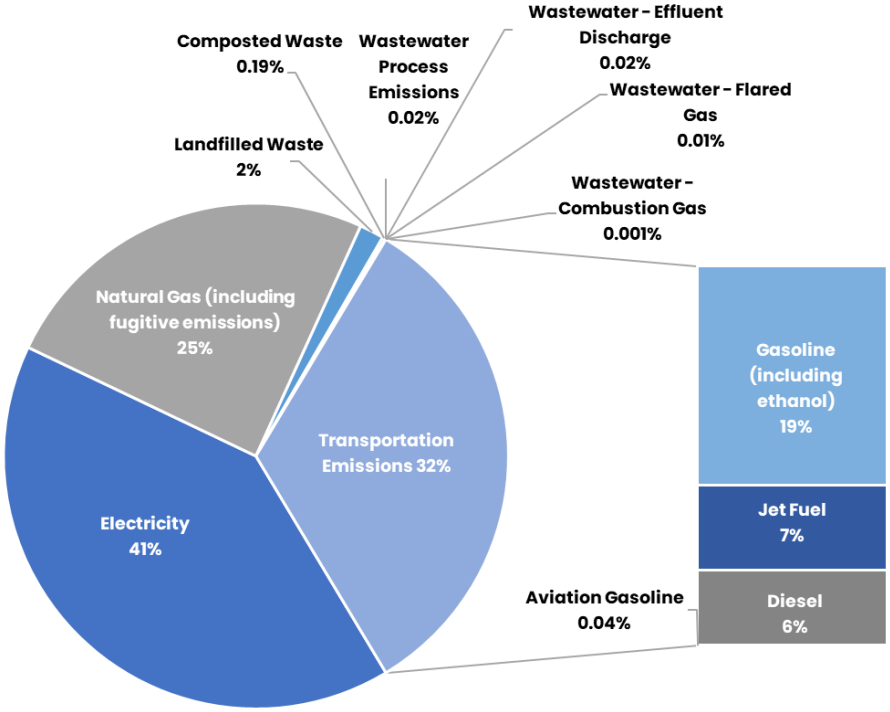


Figure 5. Emissions by source including transboundary transportation emissions (mt CO2e).

Boulder's emissions excluding transboundary activities totals 1,079,755 mt CO_2e. To visualize, producing this many emissions is similar to driving nearly 3 billion miles on the road,[9] or driving the circumference of the earth over 100,000 times! See Figure 6 for a visual comparison of Boulder's GHG emissions.

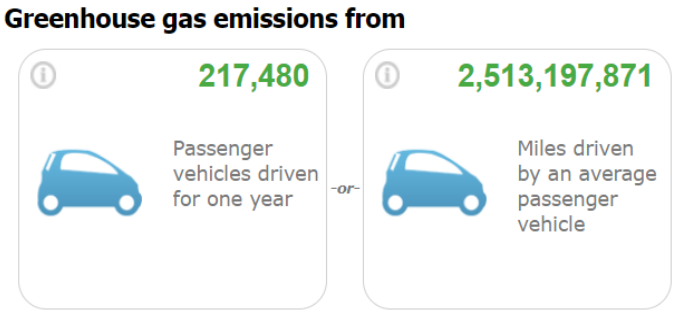


Figure 6. Visual Comparison of Boulder's GHG Emissions.

[9] See: https://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

IS BOULDER ON TRACK TO MEET NEW TARGETS?

As shown in Figure 7, the analysis shows that Boulder's emissions have reduced by 22% between 2018 and 2020 (see blue line). While this suggests that Boulder is currently ahead of its emission reduction goals (see green line), much of those reductions are likely temporary due to the COVID-19 pandemic. Moving forward, Boulder will need to reduce its emissions by approximately 5.83% per year to meet the 2030 goals of a 70% reduction in emissions (2018 baseline) and 5.88% per year to meet the 2035 goal of net-zero emissions.

Historically Boulder has reduced emissions at a slower rate at an average of 2.4% a year (if you include 2020). If you look at the average reduction per year prior to 2020, Boulder has reduced emissions by approximately 1.3% per year. See the orange line.

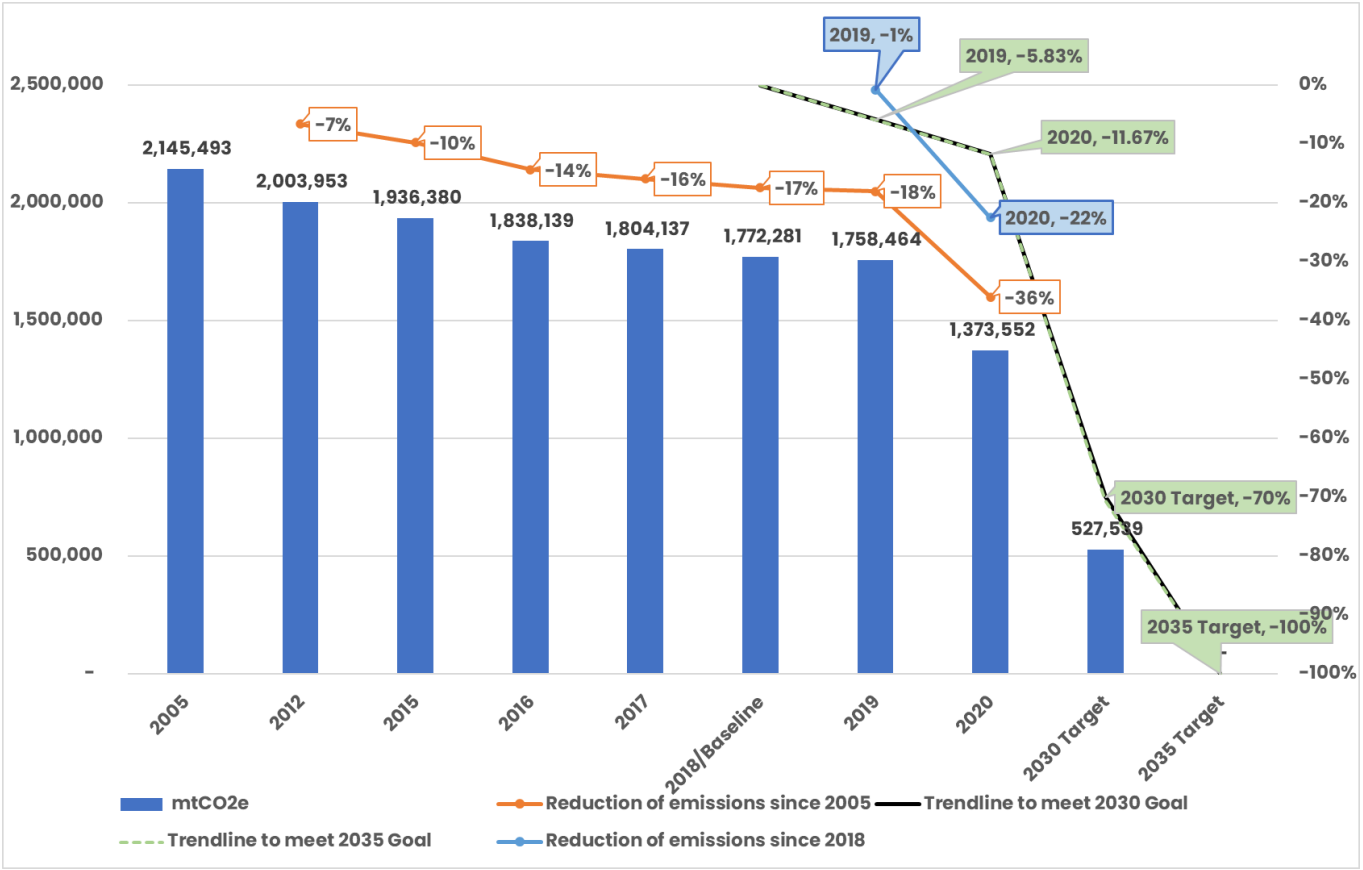


Figure 7. Tracking Emission Reductions since 2005 and 2018.

KEY TRENDS DRIVING EMISSIONS IN 2020

The unprecedented events of 2020 led to significant changes in the 2020 inventory compared with past inventories. Between 2018 and 2019 emissions were reduced by 13,817 mtCO_2e, while between 2019 and 2020, emissions were reduced by 398,729 mtCO_2e.

Reductions in Emissions

The reduction in 2020 emissions has been driven by two main sources: COVID-19 and cleaner electricity.

COVID-19

The global pandemic led to significant reductions in GHG emissions in 2020. Emissions from on-road transportation, aviation, and commercial and industrial electricity all showed substantial decreases. These are detailed below.

- **Reduction in building emissions:** Both commercial and industrial buildings and residential buildings have reduced emissions by 19% and 5% respectively since 2018 and 13% and 7% since 2019. Total natural gas usage in buildings decreased by over 5 million therms between 2019 and 2020. Electricity usage across all buildings decreased by about 88 million kWh between 2019 and 2020. Building emissions dropped between 2019 and 2020 largely due to the COVID-19 pandemic. Reductions in commercial electricity usage were greater than the increase in residential electricity usage as residents spent more time working from home and were advised against working from their offices for the majority of 2020.
- **Reduced emissions from transportation:** Emissions from the transportation sector have decreased by 33% since 2018. Between the 2019 and 2020 inventory, transportation emissions were reduced by 32%. Much of the reduction in transportation emissions, particularly between 2019-2020, can be attributed to the pandemic. However, more efficient vehicles and the increase in the number of electric vehicles have also played a vital role in emissions reduction since 2018.
- **CU enrollment:** Another factor that may have contributed to emissions reductions is a decline in CU Boulder enrollment due to COVID-19. In Fall 2020, total CU Boulder enrollment levels declined 1.6% from 2019, and freshman undergraduate enrollment fell 11%. Many enrolled students completed their studies virtually, instead of on campus. In mid-November 2020, the school shifted the remainder of the Fall semester to entirely remote learning in response to rising COVID-19 cases. All of these factors led to fewer students on campus and potentially played a role, though minor, in 2020 emissions reductions.

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 42% due to additional renewable energy

resources and the reduction of coal and natural gas on the grid. In the last year (2019 to 2020), the electricity emission factor for mt CO_2e decreased by 7%.

Increases in Emissions/Activity

While most emission sources have decreased several sources increased.

Residential electricity use

Residential electricity use has increased by 4% since 2019 and 6% since 2018, largely due to the stay-at-home orders during 2020. Even with these increases in electricity consumed, the emission factor for electricity supplied by Xcel has decreased at a greater rate than the consumption of electricity, which results in emissions decreasing rather than increasing over these time periods.

Solid Waste

Opposite to residential electricity use which saw lower emission factors with higher rates of activity, solid waste emissions increased in 2020 even though solid waste tonnage has declined since 2005. The 13% increase in solid waste emissions from the 2018 baseline was not due to an increase in landfilled tonnage (the number of landfilled tons decreased by 1,828 tons between 2018 and 2020) but instead due to the following two trends:

- **Updated waste characterization:** See the Changes to the Methodology and Available Data in 2020 section for more information.
- **New IPCC Global Warming Potential (GWP) Estimates:** The global warming potential for methane, the prominent GHG emitted from waste disposed at landfills, increased in the latest IPCC Assessment Report. See the Changes to the Methodology and Available Data in 2020 section for more information.

Normalized Metrics

Normalized metrics[10] indicate significant emission reduction achievements, as shown in Table 1 below. After normalizing total emissions for indicating growth factors, notable savings are revealed. It is important to note that the COVID pandemic affected some of the historical trends that we would have expected to see. For example, prior to 2020, we saw residential electricity use per capita reducing year over year, and the increase noted in 2020 can be partly attributed to the increased time spent in residential buildings (at home) during the pandemic. Similarly, while we had noted a reduction in VMT per capita since 2005 to date, the sharp 29% reduction we see between 2018 and 2020 is mostly related to the COVID shutdowns and stay-at-home

[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.

orders. The aim is that the city will be able to hold on to a significant portion of these reductions into the future through more comprehensive hybrid work policies and reduced need for multiple vehicles per household.

Table 1. Normalized Metrics

Emission Metrics	2005 Baseline	2018 baseline	2020	Change Since 2005	Change Since 2018
Total emissions per capita ($mtCO_2e$/resident)	21.8	16.3	12.7	-42%	-22%
Total emissions per Gross Domestic Product (GDP) ($mtCO_2e$ / $)	0.00013	0.00007	0.00005	-66%	-35%
Residential electricity per person (kwh/ Person)	2,483	2, 226	2,359	-5%	6%
C&I natural gas per building floor space (dekatherm/sqft)	0.093	0.088	0.085	-8.6%	-3.4%
Internal VMT per capita (VMT/resident)	5,547	4,900	3,502	-63.1%	-28.5%
Landfill tons per capita (tons/resident)	0.85	0.79	0.77	-9.4%	-2.5%

Energy Trends

Building energy made up 65% of Boulder's 2020 emissions and, therefore, is a key focus for Boulder in achieving its GHG emissions reduction goals.

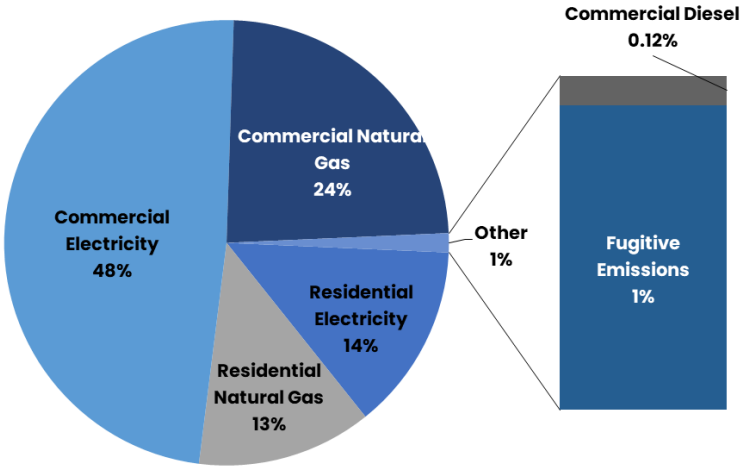


Figure 8. Energy emissions by source.

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%, 14%, and 13% of the total, respectively. See Figure 8.

Figure 9 shows the difference in mt CO_2e each sector has experienced compared to 2005. Any bars that are in the negative show a reduction in emissions since 2005, while anything in the positive shows an increase in emissions since 2005. Emissions from electricity have been consistently lower each year compared to a 2005 baseline, while emissions from natural gas and stationary diesel have been consistently higher than the 2005 baseline.

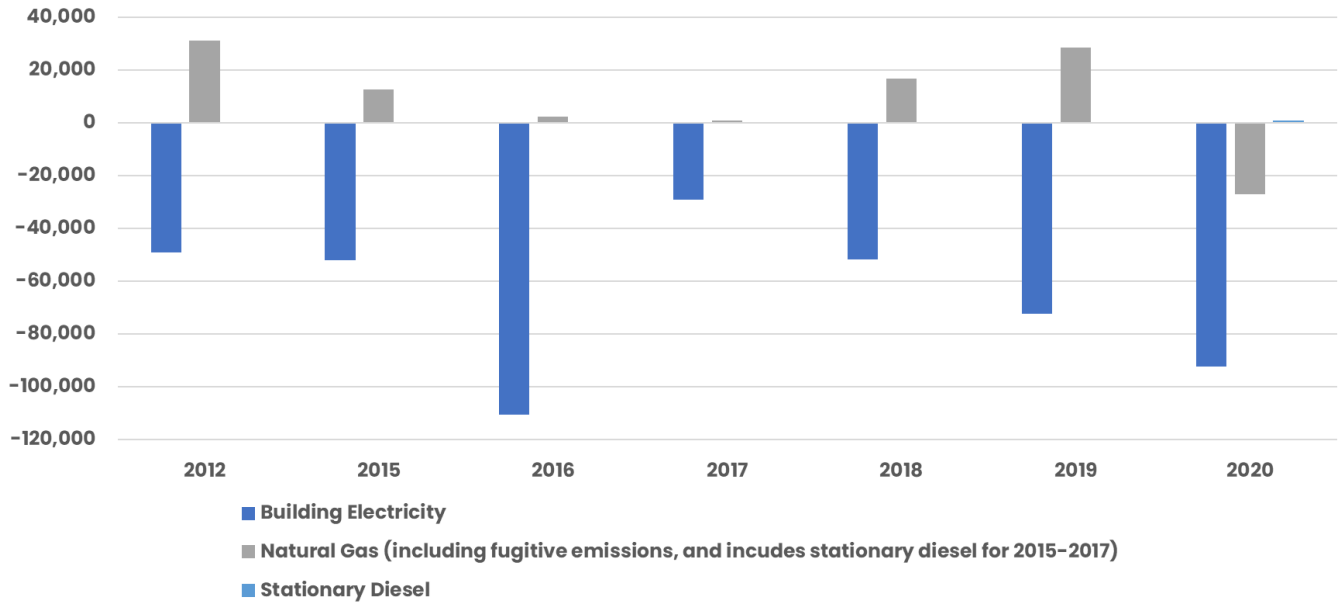


Figure 9. Annual change in building energy emissions since 2005 (mt CO2e).

Electricity Trends

The consistent reduction in electricity emissions can be attributed to:

- **Reduction in residential electricity emissions:** Total residential electricity usage increased by 4% since 2005 and 6% since the baseline year of 2018. However, residential electricity emissions have decreased 40% since 2005 and 9% since 2018. Even though residential electricity use has increased over time, the electricity provided by Xcel has steadily become greener as more renewable energy is added to the grid. Growing end-user awareness, aggressive building codes, and demand-side management programs from the city, the county, and the energy utility, including Boulder's EnergySmart Program, SmartRegs, and solar incentive programs, have contributed to the overall reduction in energy usage per person since 2005, though this increased between 2019 and 2020 due to the COVID-19

pandemic and the lockdowns that had most residents spending significantly more time at home than they normally would.

- **Decrease in 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 has decreased by 41% since 2005 and 17% since 2018. Once again, the pandemic may have contributed to the decrease in electricity use as many commercial and industrial buildings closed for significant periods in 2020 while GDP also increased 19% since 2018 and 87% since 2005. 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] require Xcel Energy, Boulder's electricity provider, 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] 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 2020 the electricity emission factor for mt CO_2e has decreased by 42% from 2005, and by seven% from 2019.[15] See Figure 10. While this trend is largely expected to continue, it should be noted that in 2020 Xcel Energy experienced reduced demand due to the pandemic impacts. One of their coal units, Comanche III also did not operate during the year.
- **Reduction in Electricity Emission Factors:** The electricity emission factor mt CO_2e decreased by 7% between 2019 and 2020.

[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.
[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.

- **Increase in Solar Energy:** In 2020, 1,392 kW of on-site (non-solar*rewards) solar energy was installed across the C&I and residential sectors as noted by Xcel Energy Community Energy Reports.[16] This is a 21% increase from 2019.

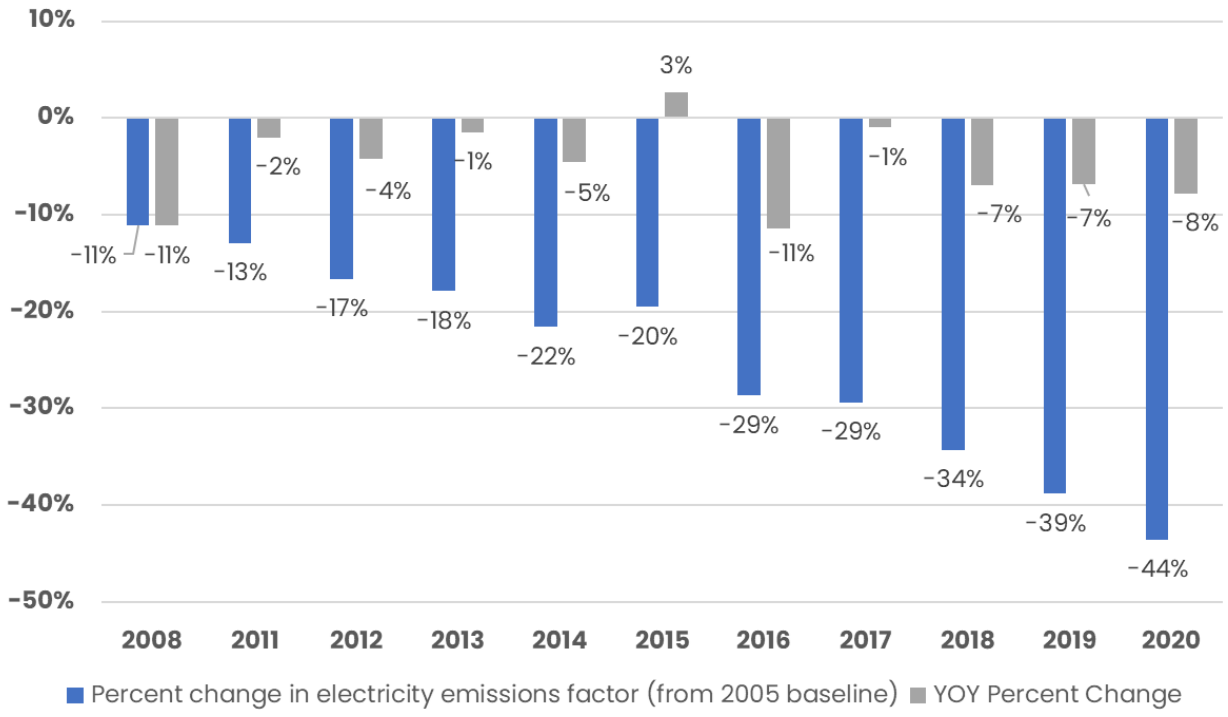


Figure 10. Change in electricity emission factors

Natural Gas and Stationary Diesel Trends

Natural gas consumption has increased by 2% since the 2005 baseline and very slightly since 2018 (0.13%). Natural gas and stationary diesel emissions can be attributed to:

- **Increased housing and population:** Residential natural gas usage has decreased per housing unit and capita since 2005 and remained the same since 2018. However, the number of housing units has increased by 12% and the number of residents has increased by 10% leading to an increase in natural gas usage.
- **Increased C&I square footage:** C&I natural gas has decreased significantly when looking at usage per square foot. Since 2005, C&I natural gas per square foot has decreased by 8.6% and just in the last two years decreased 3.4%. However, growth in square footage has outpaced these reductions with an increase of C&I square footage of 12% since 2005 and 3% since 2008.

[16] See: https://www.xcelenergy.com/community_energy_reports.

- **Decrease in Stationary Diesel emissions:** Total stationary diesel consumption has decreased in Boulder since being added to the inventory in 2018. As well, Stationary Diesel emissions have decreased since 2018 by 3% and decreased by 6% between 2019 and 2020. Stationary diesel is primarily used in emergency generators, and it is likely that the use of these generators has declined over the past few years.

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's primary strategy to change how the community's energy was generated was to bring local control of electricity to the community 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 our partnership, Boulder has reframed our 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.

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

- **High-performance emissions free 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 our community to be able to utilize clean, affordable transportation across various platforms.
- **Clean energy sources:** ensuring that we provide 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 1-5 years) which are detailed below to track progress towards our clean, affordable, and resilient energy transition.

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

Objectives	Targets	Progress Measures
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 2022, 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 2022, 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
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 2022, 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 the report, Boulder is counting transboundary transportation emissions in its GHG goals.

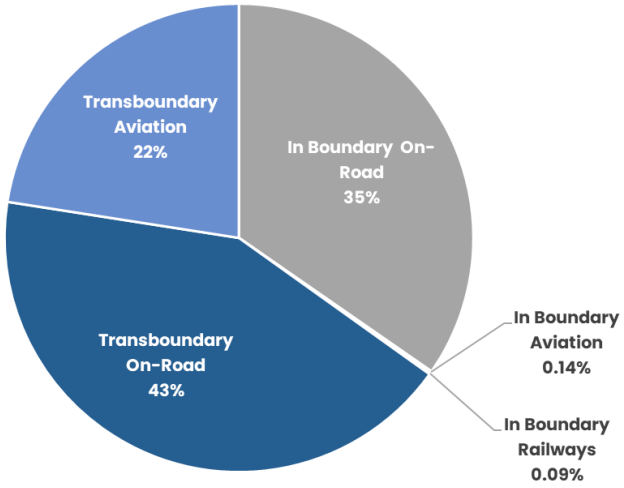
As shown in Figure 11, in-boundary transportation emissions (35% of total transportation emissions) are made up of multiple sources including:

- In-boundary on-road transportation includes all vehicles traveling within Boulder's boundaries (34.7% 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 13 for breakout of miles by type.
- In-boundary railways (0.09% of total transportation emissions).
- In-boundary aviation - flights out of Boulder Municipal Airport (0.14% of total transportation emissions).

Emissions from transboundary transportation (65% of total transportation emissions) include:

- Transboundary on-road transportation includes 50% of miles that occur outside the Boulder boundary where the city is the origin or destination of the trip.
    - Over half of all Boulder's transboundary miles are attributable to trips that begin or end in the following five cities by order of VMT: Denver (23%), Longmont (14%), Broomfield (9%), Louisville (7%), Lafayette (5%).
- Transboundary aviation - flights out of DEN (22% of total transportation emissions).

Figure 11. Transportation emissions by sector



Transportation Trends

Largely due to the impacts of COVID shutdowns during 2020, emissions from transportation showed significant reductions against the 2005 and 2018 baseline. Since 2005, in-boundary transportation emissions have decreased 51% and since 2018, in-boundary transportation emissions have decreased by 33%. Emissions from all the transportation sources (including in-boundary and transboundary) showed significant reductions against the 2005 (44%) and 2018 baseline (35%). While we did note emission reduction trends in transportation prior to 2020 of approximately 2% per year, the sharp decline experienced in 2020 is almost entirely attributable to COVID. Lasting impacts from telecommuting and hybrid work practices may retain some of these reductions into the future.

Figure 12. shows the change in transportation emissions since 2005. Emissions from both in-boundary and transboundary on-road transportation have been consistently lower each year compared to a 2005 baseline, while emissions from aviation (in-boundary and transboundary) and railways have been consistently higher (except for in 2020) than the 2005 baseline.

Figure 12. Change in Emissions since 2005

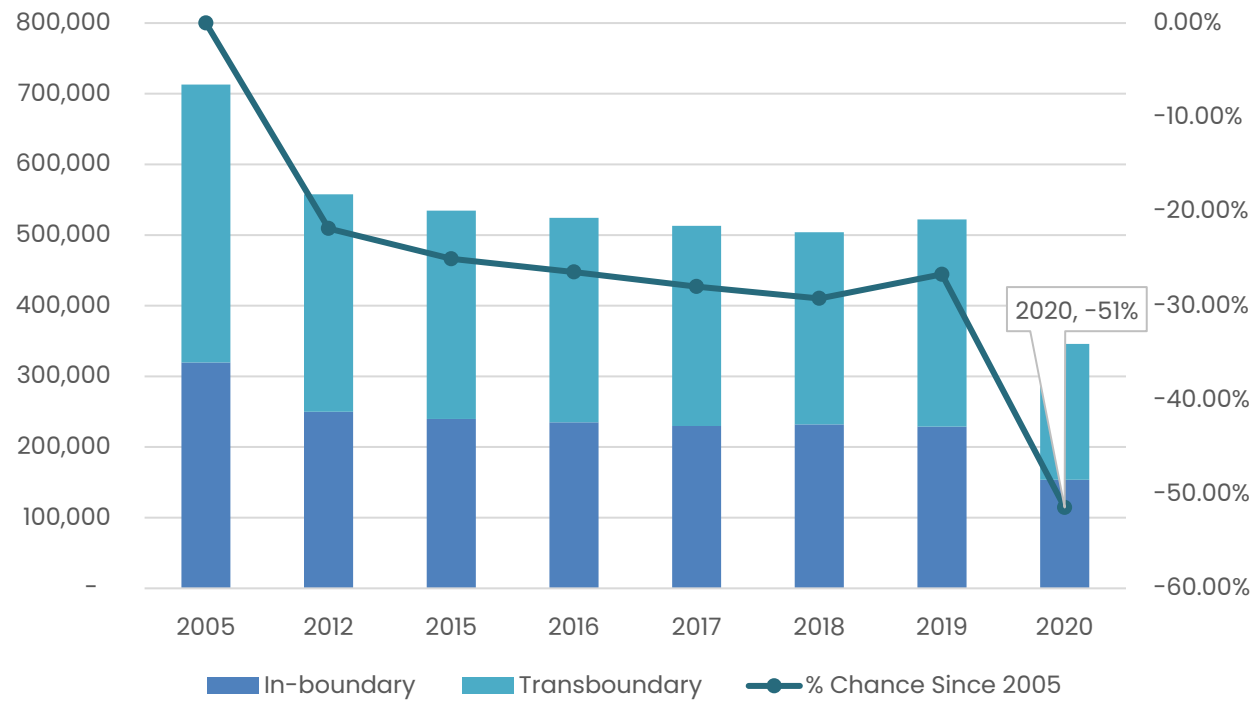
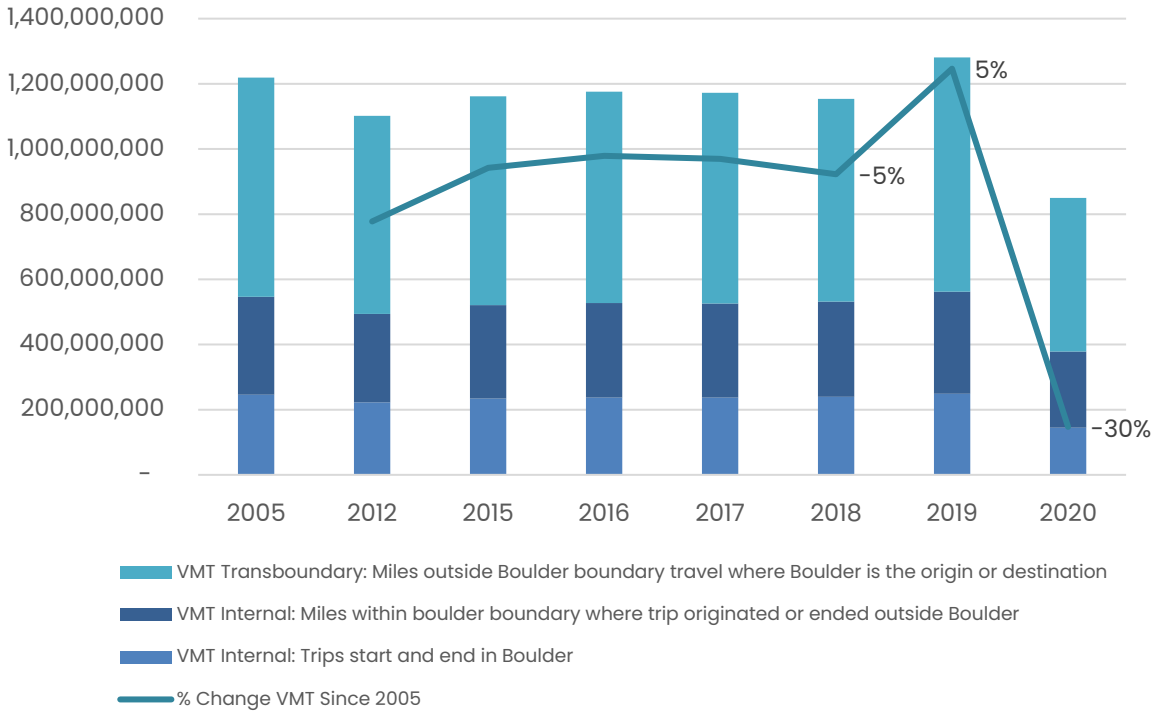


Figure 13. Change in VMT since 2005



Despite the trend noted in Figure 12. regarding emission reductions in the transportation sector over the years, it is important to note that this was largely due to improvements in average vehicle fuel economy and emission factors. As Figure 13. conveys, VMT remained relatively stagnant between 2005 and 2018, despite a 10% growth in both population and jobs, and a 57% increase in GDP, showing the impact of Boulder's multimodal investments. This trend was broken in 2019, however, which experienced a 5% increase in VMT compared to 2005 levels. While this uptick was starkly reversed with the 2020 impacts which saw a 30% decrease in VMT from 2005 levels, and a 26% reduction from 2018 levels – it remains to be seen what degree of COVID-related transportation reductions will persist into the future, such as that of telecommute and hybrid work policies.

As an anomalous year, the decrease in emissions for on-road transportation in 2020 can be largely attributed to COVID-19 impacts, while the general trend of transportation emission reductions over the years is due largely to fuel and vehicle type shifts and efficiency gains.

COVID-19 Impacts

- **Decrease in Vehicle Miles Traveled (VMT).** Total vehicle miles traveled (VMT) decreased 30% since 2005 and 26% since 2018. While the majority of the reduction in VMT in 2020 can be attributed to the pandemic, an increase in multi-modal transportation has also helped decrease the number of single-occupied vehicle trips within the city since 2005.

- **Significant decrease in aviation travel:** Within the aviation sector, gallons of jet fuel decreased 45%. Not surprisingly, these dramatic reductions in emissions are largely attributable to the pandemic. The percent change from 2019 to 2020 for each sector exhibits the significant impact of COVID-19 on transportation emissions. In just a year, gallons of jet fuel were nearly cut in half (from 20,213,175 gallons of fuel in 2019 to 10,407,59 gallons of fuel in 2020).
- **Lockdown:** As a community, Boulder has many people that work within its 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. With the onset of COVID-19 and lock down, the amount of daily traffic reduced drastically with the switch to teleworking for many employees. In addition, Boulder is a tourism and student hub for Colorado. Both industries were deeply affected by the COVID-19 travel restriction. From 2019 to 2020 emissions from fuel combustion within the city decreased 33% and transboundary emissions from fuel combustion in the city were reduced by 35%.
- **Reduction in Transit:** Gallons of diesel from buses decreased 59% from 2019-2020 due to reduced bus service due to COVID-19.

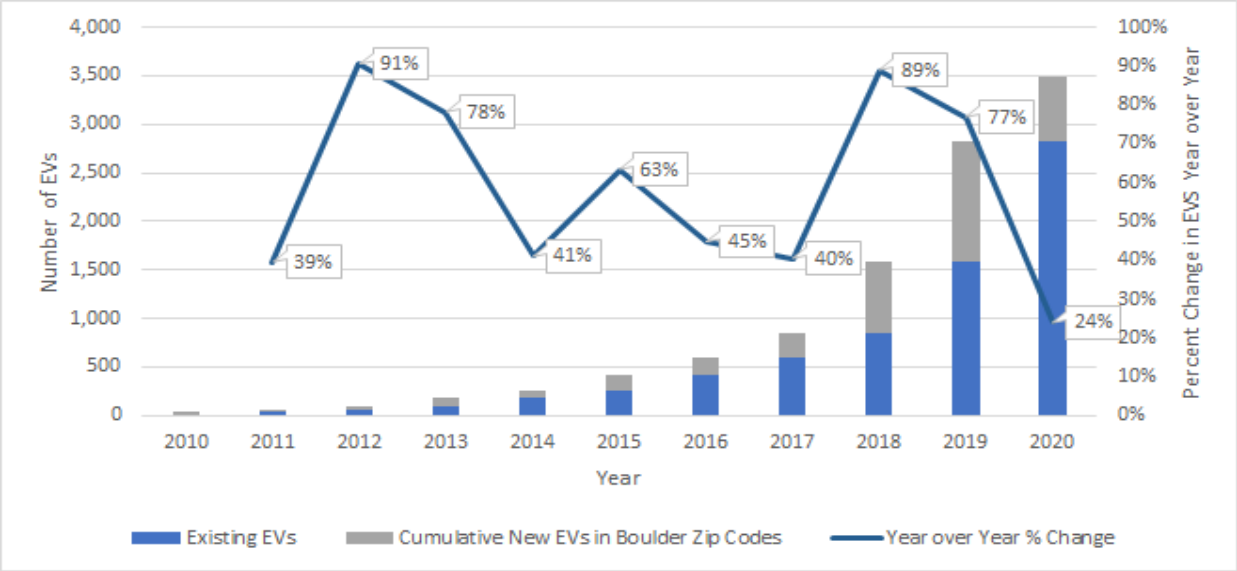
Fuel and vehicle type shifts and efficiency gains

- **Increase in Fuel Efficiency:** CAFE standards have drastically increased the fuel efficiency of vehicles since 2005. As more efficient vehicles are driven the amount of fuel used per mile (MPG) has decreased.
- **Increase in Alternative Fuels:** Since 2005, additional alternative fuels have become more common including biodiesel, compressed natural gas (CNG), and electric vehicles. The increase in these fuels helps reduce emissions.
- **Increase in electric vehicles:** Boulder has demonstrated leadership and a commitment to transportation electrification by installing 46 public EV charging stations,[17] completing a Fleet Electrification Assessment and purchasing 23 electric fleet vehicles, installing solar panels and charging stations at city facilities to charge EVs with clean energy, and working with Via Mobility, Boulder Valley School District, and the University of Colorado to electrify their bus fleets. Boulder County has the highest rate of EV adoption in the state, and the city's adoption rate of over 3% of all registered vehicles is over four times higher than the statewide average. Through the city's commitment to becoming a "GoEV City", Boulder will work with the community on programs, policies, incentives, and regulatory approaches to transition 30% of all vehicles within the city to zero emissions by 2030, and 100% of all vehicles by 2050.[18] See Figure 14.

[17] For more information see: https://bouldercolorado.gov/public-works/electric-vehicles-and-charging-stations.

[18] For more information see: https://www.goevcity.org/.

Figure 14. EV Purchasing Trends.



The transportation area that did see an increase in emissions in 2020 was railways:

- **Railway Emissions:** Railway emissions are higher for the simple reason that these emissions were not captured in the 2005 GHG inventory. Between 2018 and 2020 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.

Other Notable Trends in 2020

Some notable projects and trends include:

- **Electric Vehicles growth slows:** Interestingly, in 2020, the year-over-year increase in EV purchases dropped to 24%. This is the lowest year-over-year percent increase since 2010. One reason for this may be economic uncertainty amid the 2020 pandemic. See Figure 13.

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). 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 updates their TMP every five years, and a new update is

scheduled to begin in 2022. Regarding emissions reductions, transportation-related efforts include:

- **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 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 strategy, and electrifying the bus fleet. 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 aims to electrify the HOP fleet, with 4 buses already electrified, the goal is to have an entirely electric fleet by 2030.
- **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.
- **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 1-5 years) which are detailed below to track progress towards our collaborative climate transportation work.

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

Objectives	Targets	Progress Measures
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 sulphur 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 at 1.75% and 0.05%, respectively. However, both sectors are important to the citizens of Boulder and the city continues to implement sustainability initiatives to guide the community toward zero waste, and therefore reduce landfill emissions, as identified in the Action Plan.

Figure 15 shows the difference in mt CO_2e each sector has experienced compared to 2005. Any bars that are in the negative show a reduction in emissions since 2005, while anything in the positive shows an increase in emissions since 2005. Emissions from waste and wastewater have been consistently lower each year compared to a 2005 baseline, while emissions from composting have been consistently higher than the 2005 baseline. These trends can be attributed to:

- **Waste:** The amount of waste being landfilled has decreased since 2005 due to recycling and composting programs reducing the amount of waste being landfilled.
- **Composting Emissions:** Composting emissions are higher for the simple reason that composting was not captured in the 2005 GHG inventory.
- **Wastewater:** A number of efficiency improvements have been made to the wastewater treatment process, the largest being a significant reduction in nitrogen discharge.

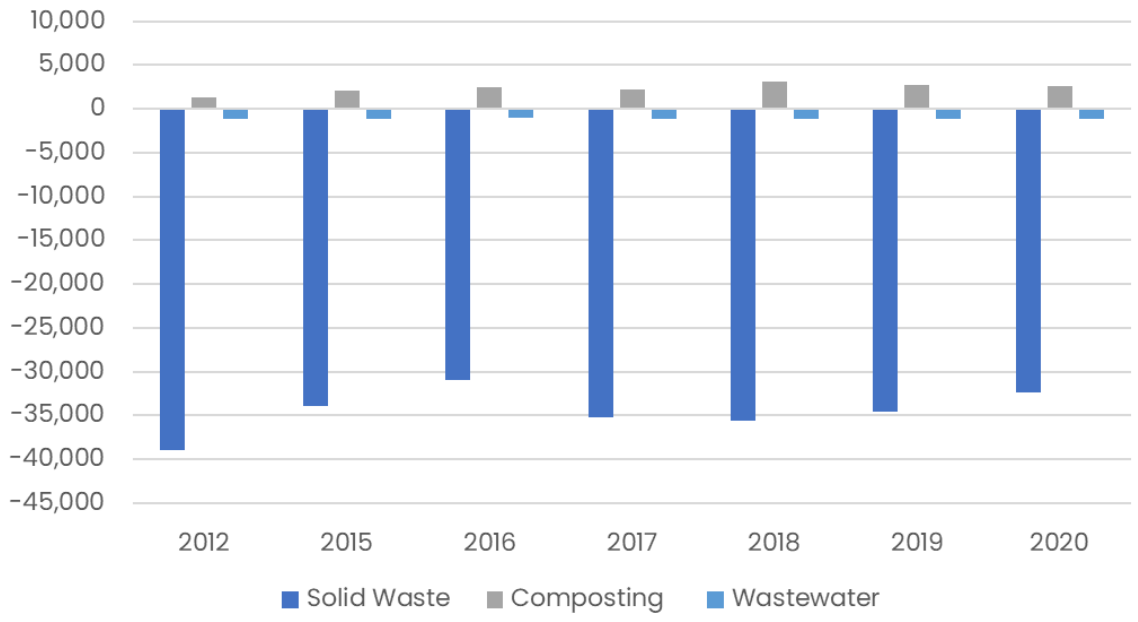


Figure 15. Annual change in waste and wastewater emissions since 2005 (mt CO2e).

What Happened in 2020

Both the composting and wastewater sectors continued to reduce emissions between 2018 and 2020 and 2019 and 2020, however, solid waste emissions increased by 18% from 2018 to 2020 (3,213 mt CO_2e) and 11% from 2019 to 2020 (2,108 mtCO_2e). Several notable trends are driving these emission trends:

- **Reduction in Composting:** Composted waste decreased by 16% from 2018 to 2020 and 7% between 2019 and 2020.
- **Wastewater:** The table below shows a decrease (-6%) in emissions from the city's wastewater treatment plant (WWTP) between 2018 and 2020.
- **Updated waste characterization:** See the *Changes to the Methodology and Available Data in 2020* subsection for more information.
- **Updated GWP:** See the *Changes to the Methodology and Available Data in 2020* subsection for more information.

Action Plan

Boulder's zero waste 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. 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 work in zero waste.

At a high level, this systems-change work in the energy sector 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 1-5 years) which are detailed below to track progress towards our transition to a circular materials economy.

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

Objectives	Targets	Progress Measures
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.
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.
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 2022, 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	Create a closed loop system that reduces fire risk in our community,	By 2022, complete a city biomass assessment.
		By 2025, 20% of biomass collected in community to be converted to compost or biochar.

Objectives	Targets	Progress Measures
entrepreneurship and innovation.	converts biomass to biochar, and generates clean energy to fuel buildings by 2030.	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.

In 2019, the city launched additional carbon sequestration "drawdown" efforts. With the Urban Sustainability Director's Network, it jointly established a new organization called the Urban Drawdown Initiatives (UDI) intended to promote natural climate solutions in urban landscapes. As part of this effort, the city has been working with a broad consortium of partners to explore strategies for managing both rural/agricultural and urban landscapes to both capture carbon and to enhance urban ecosystem services — shade, storm water infiltration, air quality, biodiversity. One of the core aspects of this work is in developing ways to baseline, track, and measure progress towards work in this realm, an area that has historically proven very difficult to measure success due to lack of standardized guidance and accessible tools.

While cities worldwide have been hard at work in developing climate-based targets, mitigation plans, and inventories of their greenhouse gas emissions (GHGs), vastly, the sequestration impact of their natural environment has been excluded from such plans, targets, tactics, and inventories – largely because there was a lack of guidance on how to account for and include emissions impacts of this sector in inventories and mitigation workplans. However, based on the recent climate science as conveyed by both the IPCC's 2018 Special Report on Global Warming on 1.5°C and the 2021 AR6 Climate Change Sixth Assessment Report, there is no realistic way of achieving our global goal of remaining under 1.5°C without protecting and increasing our forests and tree canopy. Carbon sequestration is a necessary player that needs to be recognized and built up in future climate plans as a key tactic in mitigating climate change.

Given this finding, ICLEI worked together with the World Resources Institute (WRI) and Woodwell Climate Research Center to develop Appendix J to the U.S. Community Protocol, an appendix on Forests and "Trees outside Forests", establishing guidance for communities to integrate such sequestration and emission values into their inventories.

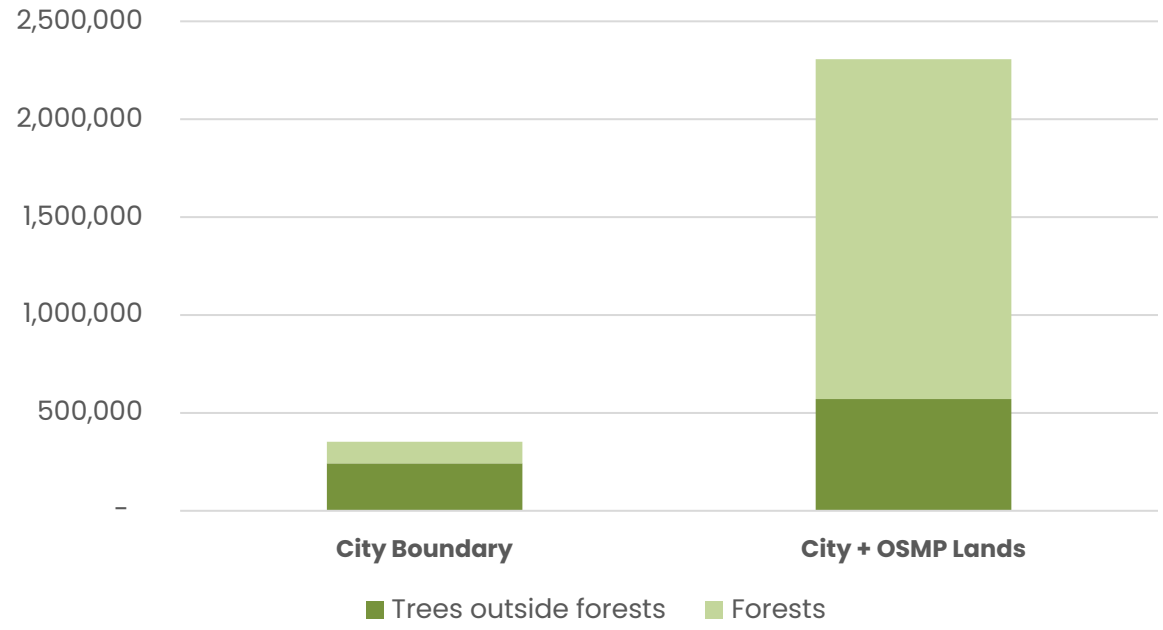
Currently there are not established protocols for capturing carbon sequestration benefits in land management other than forests. The city is working with a broad consortium of organizations to develop these protocols. This would enable the city to start capturing the soil-based sequestration efforts 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 it's OSMP lands, with the aim of integrating the results into our annual inventory process.

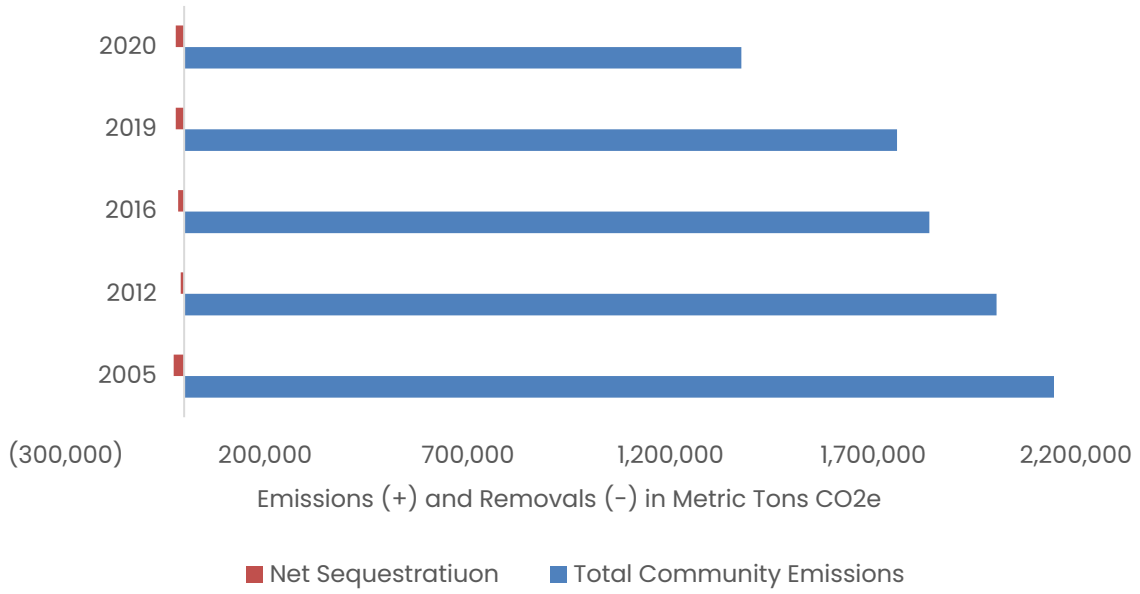
The results show that the total amount of carbon stored in Boulder's forests and trees within the city boundary are ~350,000 metric tons as of the latest period of analysis (2016-2019), with the large majority (69%) stored in urban tree canopy with the remaining 31% stored in forest. When including the 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 15).

Figure 16. Total Carbon Stored in Boulder's Forests and Trees Outside Forests (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**.

Figure 17. Total Community Emissions and Net Sequestration by Year (mt CO2e).



Currently, Boulder is annually sequestering (in net) approximately 6,000 to 10,000 mt CO2e annually within our city boundary, and about 9,000 – 26,000 mt CO2e annually when including OSMP lands within the boundary of analysis. In contrast, in recent years, the city has been emitting 1,350,000 to 1,750,000 mt CO2e annually. The impact that the city's nature-based sequestration is having in tackling local emissions therefore makes up about 1-2% of the emissions we produce. This is an issue that many highly urbanized cities face, as the lack of forested lands within our boundary means that Boulder is reliant on urban trees, of which the city only has management control over about 8% (50,800) of urban trees. By including the forested Open Space and Mountain Park lands into the analysis, our sequestration impacts increase, yet we also see periods of significant emissions produced by those forested lands due to impacts of fire damage, insects, and harvests.

An important consideration in assessing the sequestration value of forests is the "removal factor". This means the amount of carbon associated with the transfer of GHGs from atmosphere to the land per hectare of tree cover, and this figure changes depending on geography, age of trees, and tree/forest type. Urban tree canopy in Boulder was found to have a greater removal factor than that of forested areas due to the greater control exerted over such urban trees (more watering, planned soil health, choice of species by speed of growth). Based on this factor, the sequestration analysis found that an optimal strategy for the city to improve sequestration potential would include the following:

- focus management of forests for resilience against disturbances such as fire and insects: and

- expand urban forest cover, particularly in areas at the highest risk of heat extremes and/or in areas that have historic inequity challenges—lower income, higher proportion of non-white residents.

In this way, Boulder will seek to protect optimize the climate benefits of its existing forested lands by attributing greater resources to resilience and forest protection. The city is also planning a significant, decade-long urban forestry-as-climate action campaign that will direct new planting programs in the urban center where trees will likely grow faster, yield greater sequestration values, and bring equitable community values of shade, urban cooling, wind mitigation, air quality, and aesthetics.

Emissions snapshot

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

Emission Type by Sector	Emissions (mtCO2e)	
	2005	2020
Commercial and Industrial Buildings	977,220	658,541
Residential Buildings	311,427	240,013
Transportation (with transboundary aviation)	801,206	451,104
Transportation (without transboundary aviation)	320,257	157,307
Solid Waste	53,840	24,042
Wastewater Treatment	1,800	658
Total Gross Emissions (with transboundary emissions)	**2,145,493**	**1,373,552**
Total Gross Emissions (without transboundary emissions)	**1,664,544**	**1,079,755**

Land Use Sequestration: City Only	Emissions (mtCO2e)	
	2005	2020
Forests Remaining Forests	(1,073)	(1,041)
Forests Converted to Other Lands & Disturbances	748	641
Other Lands Converted to Forests	(6)	(2)
Sequestration from Urban Trees	(8,795)	(8,898)
Emissions from Urban Trees	2,688	58
Total Net GHG Removals	**(6,403)**	**(9,243)**

Total (Net) GHG Emissions without transboundary emissions and removals	**1,658,141**	**1,070,511**

Land Use Sequestration: City + OSMP Lands	Emissions (mtCO2e)	
	2005	2020
Forests Remaining Forests	(16,685)	(16,542)
Forests Converted to Other Lands & Disturbances	11,759	16,611
Other Lands Converted to Forests	(20)	(14)
Sequestration from Urban Trees	(21,055)	(20,962)
Emissions from Urban Trees	995	10
Total Net GHG Removals	**(26,001)**	**(20,773)**

Total (Net) GHG Emissions with transboundary emissions and removals	**2,119,492**	**1,352,779**

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 our nature-based climate solutions work:

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

Objectives	Targets	Progress Measures
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%

Objectives	Targets	Progress Measures
	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
Increase natural carbon sequestration within and beyond our boundaries.	Remove 50,000 tons of CO2 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%.
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 200,000MT of carbon
		By 2025, engage in active collaboration with 4 or more cities internationally in urban drawdown activities

ACTION BEYOND BOUNDARIES

In July of 2019, the Boulder City Council declared a climate emergency, recognizing the accelerating rate and intensifying effects of climate change. [19] Many of these effects are already visible in Boulder city limits. The floods in 2013 and the 2020 fire season exemplify climate change's real-time threat to the natural environment, public health, city infrastructure, and peoples' livelihoods.

However, these climate threats are not contained to Boulder city limits, therefore, the City of Boulder decided their action plan should not be either. The city amended the Climate Action Plan to incorporate broader systemic changes.

The plan includes a two-pronged approach covering individual and community-based action and collaboration with partners, other cities, and government agencies to facilitate action beyond city boundaries.[20] Elements of the new plan include:

- Act beyond boundaries: Collaborate with partners, other cities and government agencies to achieve impact at larger scale, on topics within the city's sphere of influence.
- Achieve regional and national climate targets:
    - Reduce emissions 70% by 2030 against a 2018 baseline.
    - Become a net-zero city by 2035.
    - Become a carbon-positive city by 2040.
- Center Equity: Allocate necessary time and resources to address the impacts of climate change in an equitable manner.
- Build Resilience: Strengthen community capacity to survive and thrive.
- Count all the emissions: Account for the full scope of emissions in our community, including emissions associated with land use changes and the creation and purchase of goods and food.
- Expand our focus: Address new focus areas for climate action including land use and financial/economic systems.
- Work with community: Bring the community together with renewed urgency to address the climate emergency and achieve clarity on the required next steps.

[19] https://bouldercolorado.gov/news/action-beyond-boundaries-citys-proposed-climate-action-evolves-attack-systemic-drivers-climate.
[20] Ibid.