BOULDER COUNTY'S 2016 GREENHOUSE GAS EMISSIONS INVENTORY AND MODELING REPORT

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lotus
engineering & sustainability

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ACRONYMS

CACTIS	Colorado Air Compliance Tracking and Inventory System
CDD	Cooling Degree Days
CDPHE	Colorado Department of Public Health and the Environment
C&I	Commercial and Industrial
CO_2e	Carbon Dioxide Equivalent
DIA	Denver International Airport
DRCOG	Denver's Regional Council of Governments
eGRID	Emissions and Generation Resource Integrated Database
FLIGHT	Facility Level Information on Greenhouse Gases Tool
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GPC	Global Protocol for Community-Scale Greenhouse Gas Emission Inventories
GWP	Global Warming Potentials
HDD	Heating Degree Days
IPCC	Intergovernmental Panel on Climate Change
kWh	Kilowatt Hour
$mtCO_2e$	Metric Tons of Carbon Dioxide Equivalent
MWh	Megawatt Hour
RECs	Renewable Energy Credits
SAR	Second Assessment Report
VMT	Vehicle Miles Traveled
WWTP	Wastewater Treatment Plants

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Executive Summary

Boulder County is committed to addressing climate change by reducing greenhouse gas (GHG) emissions in accordance with levels specified by the Paris Climate Agreement Goal, which will help prevent a global temperature increase of 1.5 to 2°C. In 2012, Boulder County committed to reduce countywide GHG emissions by 40% by 2020 based on a 2005 baseline, and in 2018, the county committed to reduce GHG emissions by 45% by 2030 and by 90% by 2050 based on a 2005 baseline.[1]

To understand how to reduce GHG emissions, Boulder County completed GHG emission inventories in 2005, 2011, and 2016 and modeled the GHG emission reduction potential for GHG emission reduction strategies. The initial inventories provide a baseline of activity, and the subsequent inventories provide insight into Boulder County's performance and ability to meet its carbon reduction goals. The identification and quantification of GHG emission reduction strategies provides insights as to how certain programs and policies may affect the county's GHG emissions and recommendations as to where the county should focus its efforts.

Boulder County contracted with Lotus Engineering and Sustainability, LLC (Lotus) to complete their 2016 GHG emission inventory and model potential reductions in GHG emissions based on selected strategies.

Key Findings from 2016 Inventory

Boulder County is committed to addressing climate change at the local level by reducing GHG emissions. To meet GHG reduction goals, Boulder County needs to understand and track community-wide emissions by completing GHG inventories that highlight emissions from each municipality, source, and sector.

To date, Boulder County has completed three GHG inventories (2005, 2011, and 2016), which provide a picture of GHG emissions created by the activities of Boulder County residents, businesses, and industries. This report includes a comparison of Boulder County's 2011 and 2016 inventories; specifically, changes in actual emissions by sector and source, as well as changes in factors that influence emissions, such as Boulder County's demographics and utility emission factors. By reviewing and comparing the 2011 GHG inventory to the current 2016 GHG inventory, Boulder County can begin to track and understand trends in emissions from specific sectors, and where Boulder County should focus its efforts to successfully meet GHG reduction goals. This comparison creates a dynamic feedback loop that can inform and shape future improvement strategies.

In recent years, Boulder County experienced significant economic growth that is expected to continue for the foreseeable future. Even with this growth, between 2005 and 2016, countywide

[1] Countywide includes emissions from all municipalities as well as unincorporated Boulder County.

GHG emissions decreased by 3%. The template from which communities can complete comparable and standard emission inventories changed since Boulder County completed the last two inventories. Therefore, if we compare only the emission sources that were in both 2005 and 2016 GHG inventories, Boulder County-wide emissions have been reduced by 18% between 2005 and 2016.

However, Boulder Counties growth will lead to an increase in population and building square footage that in turn will inevitably increase the amount of demand for electricity, natural gas, gasoline, diesel, and goods. As a result, Boulder County, the municipalities, and all community members will need to take effective action to continue to reduce GHG emissions countywide.

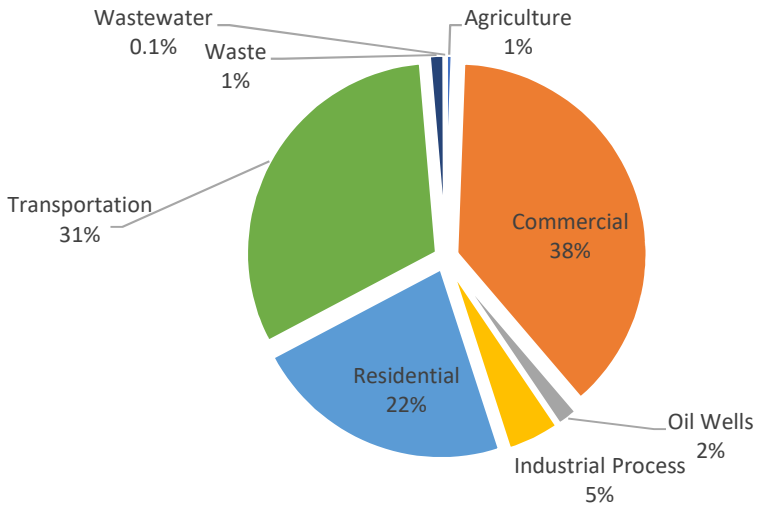
The 2016 inventory was completed using the framework provided by the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), which is a global standard for GHG emission accounting and reporting. The GPC was developed and launched in 2014 through the collaboration of key stakeholders across the world and provides a template from which communities can create comparable and standard emission inventories.

Overview of 2016 Emissions by Sector, Source, and Municipality

The 2016 Boulder County GHG inventory shows a total emission value of 4,873,034 metric tons of carbon dioxide equivalent ($mtCO_2e$).

Emissions from commercial and residential building energy use account for 60% of emissions county-wide and emissions from transportation account for 31% of emissions county-wide. Emissions from industrial processes, oil wells, agriculture, solid waste, and wastewater account for the remaining 9% of emissions. Emissions for all sectors are shown in Figure ES- 1.

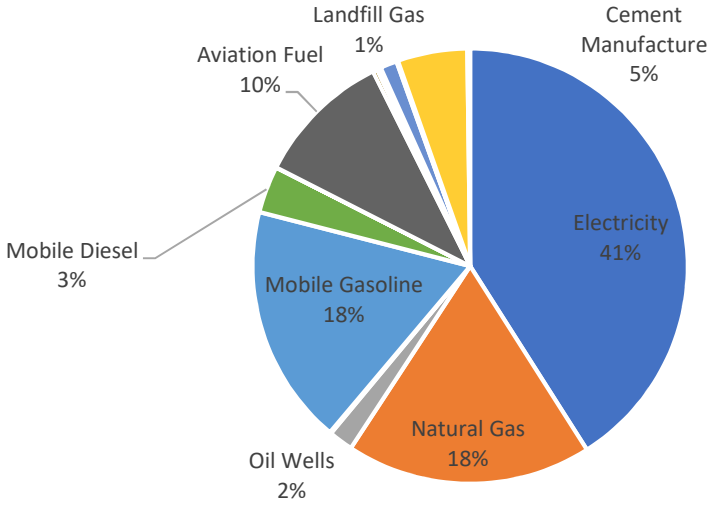
Figure ES- 1. 2016 Emissions by Sector



Emissions from electricity use and production comprised the highest proportion of emissions by source (41%). Emissions from natural gas (excluding mobile usage) accounts for 18% of emissions.

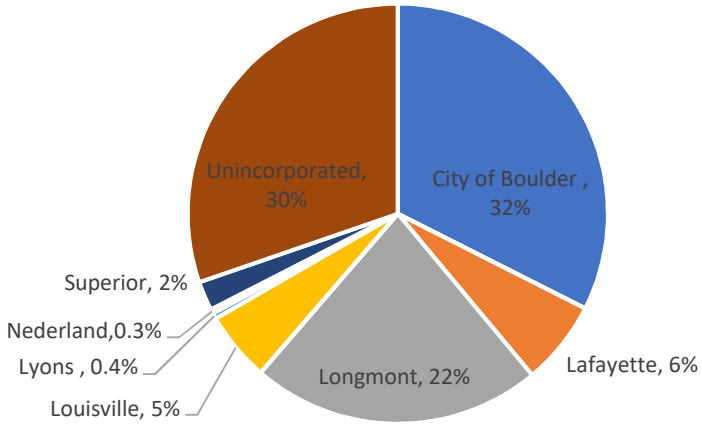
Mobile gasoline also accounts for 18% of emissions while aviation fuel accounts for 10% of total emissions. The remaining 13% of emissions are produced through various processes and activities, including cement manufacturing, mobile diesel, oil wells, waste, and agriculture. Emissions for all sources are shown in Figure ES- 2.

Figure ES- 2. 2016 Emissions by Source



Together the Cities of Boulder and Longmont, as well as unincorporated/other[2], account for approximately 32%, 22%, and 30%, respectively, of Boulder County's total GHG emissions. Lafayette and Louisville accounted for approximately 6% and 5%, respectively. Superior, Lyons, and Nederland together accounted for the remaining 3% of emissions (see Figure ES- 3).

Figure ES- 3. 2016 Emissions by Municipality



[2]Unincorporated/other includes all unincorporated areas (i.e. Gunbarrel, Hygiene, Niwot, etc.) and a few incorporated municipalities (i.e. Erie, Jamestown, and Ward) in Boulder County that are not explicitly disaggregated in the GHG inventory.

Notable Highlights from the 2016 GHG Emission Inventory

The 2016 inventory showed a very slight (0.4%) decrease in emissions since the 2011 inventory: the 2011 value was 4,890,832 $mtCO_2e$ and the 2016 value was 4,873,034 $mtCO_2e$.

The slight decrease in GHG emissions experienced by Boulder County to date is partly a result of the different calculation methodologies and emission sources tracked in the 2011 and 2016 inventories. The GPC requires Boulder County to track an additional eight emission sources that were not tracked in 2011. These new emission sources alone account for 14% of Boulder County's GHG emissions in 2016. ***If we compare only the emission sources that were in both 2011 and 2016 GHG inventories, Boulder Countywide emissions have been reduced by 16% between 2011 and 2016.*** For more information on the different inventory methodologies see the subsection *Inventory Methodology.*

Also, unlike the 2011 inventory, the 2016 inventory does not include renewable energy credits (RECs) or offsets which accounted for a reduction in emissions in the 2011 inventory. In addition, the emissions from the Denver International Airport were also included in the 2016 GHG inventory. The result of the various changes in inventory methodology is that the new 2016 inventory added 770,041 $mtCO_2e$ in emissions that were not accounted for in the 2011 inventory.

This report describes and compares the absolute emissions covered by the respective inventories of 2011 and 2016. Where appropriate, differences in the methodologies are described.

The following highlights and trends in the 2016 inventory are worth noting:

- Total GHG emissions in 2016 for Boulder County is 4,873,034 $mtCO_2e$. This includes emissions from all municipalities as well as unincorporated Boulder County.
    - Emission reductions from 2011 to 2016 can be compared to growth and economic activity, by normalization, as follows: 6% reduction of emissions per job and 33% reduction in commercial and industrial emissions per square foot.
    - Emissions per capita varied by municipality, ranging from 8.3 $mtCO_2e$ per person to 26.6 $mtCO_2e$ per person; the average emissions per capita for all of Boulder County was 15.1 $mtCO_2e$ per person.
- Emissions due to electricity consumption accounted for 41% of the overall 2016 GHG inventory. Between 2011 and 2016, electricity usage decreased by 1% while emissions from electricity decreased by 25%. This emissions reduction from electricity is caused by significantly lower electricity emission factors due to a cleaner grid from the increase in renewable energy.
    - Electricity emission reductions (625,850 $mtCO_2e$) were the single largest source of GHG reductions overall between 2011 and 2016.

  - Between 2011 and 2016, Boulder County's per household residential electricity consumption decreased 8%, while the number of households increased by 3%. The commercial and industrial (C&I) electricity consumption per square foot decreased by 33% while C&I square footage increased by 23%.
- Emissions due to natural gas consumption accounted for 18% of the overall 2016 GHG inventory. Natural gas consumption can track closely with cold weather since natural gas is the most common fuel used for heating in Boulder County. Since heating degree days (HDD) (i.e. number of days when heating was required) decreased between 2011 and 2016 by 17%, it would be expected that natural gas usage would also decrease; however, natural gas consumption increased slightly.
- Emissions due to transportation accounted for 31% of the overall 2016 GHG inventory.
  - Emissions from on-road transportation decreased by just over 5% between 2011 and 2016.
  - Emissions from aviation fuel use at Denver International Airport (DIA), which was not included in prior inventories but is required by the GPC, accounted for 10% of Boulder County's emissions.

Community Trends

Between 2011 and 2016, Boulder County saw population increase by 8%, the number of jobs increase by 7%, and the number of households increase by 3%. During this period, Boulder County's economy also grew with a 24% increase in Gross Domestic Product (GDP).

In general, a larger population and stronger economy results in increased emissions due to more emission-producing activities and materials being consumed. However, in Boulder County, emissions per resident decreased by 8% and emissions per job decreased by 6%. This is due in large part to both county-supported programs and policies to reduce emissions, and to a greater degree, the decrease in electricity emissions factors (i.e. a decrease in electricity emission factor indicates the grid is increasing the amount of power provided by clean energy as compared to fossil-fuel energy). Emissions factors for all electrical utilities serving Boulder County (with the exception of the Town of Lyons) decreased between 10% and 31%; the emissions factor for the Town of Lyons electrical service increased by 0.6%. Emissions factors for other sources (i.e. natural gas, gasoline, etc.) remained the same or decreased slightly between 2011 and 2016.

Boulder County's Potential to Reduce Greenhouse Gas Emissions

Lotus researched a variety of plans and policies and worked with local experts to identify an initial list of GHG emission reduction strategies that have the greatest potential to reduce GHG emissions. The initial list of recommendations was reviewed with Boulder County staff, who provided guidance on a final list of recommended strategies. The list of final GHG emission reduction strategies along with estimated contributions towards overall reductions in GHG emissions is presented in Table ES - 1.

Table ES - 1. Summary of GHG Emission Reduction Potentials by Sector

Sector	Objective	Specific Strategy
Building Energy	Implement deep carbon reductions in buildings to reduce energy consumption	Adhere to and Enforce Current Building Code
		Implement Beyond Code Requirements
		Accelerate Fuel Switching
		Impose Mandatory Benchmarking
		Increase the State's Energy Efficiency Resource Standard
		Continue Boulder County's Suite of Energy Efficiency Programs
Renewable Energy	Accelerate solar energy adoption: all-of-the-above strategy	Continue Boulder County's Suite of Renewable Energy Programs
		Expand Rooftop Solar
		Expand Community Solar
		Additional Efforts
Transportation	Increase the adoption of electric vehicles	Accelerate Electric Vehicles: All-of-the-Above Strategy
	Reduce carbon intensity of vehicle travel	Support Federal and/or State Clean Car Policies
	Reduce single-occupancy vehicle travel	Expand Public Transit
Oil and Gas	Support regional and state efforts to control methane leaks	Adopt and Enforce Leak Detection and Repair
Waste	Strive for zero waste	Reduce Food Waste
		C&D and Composting Waste to Local Transfer Facility
		Promote Zero Waste Education
		Strive for Municipal Zero Waste
		Conduct Other Efforts as Needed
Other Carbon Reduction Strategies	Implement community-wide comprehensive carbon reduction programs	Pursue Carbon Sequestration
		Implement Carbon Tax
		Carbon Intensive Industries Carbon Impact Offset Fund

Boulder County's GHG Reduction Goals

In 2012, Boulder County committed to reduce countywide GHG emissions 40% by 2020 based on a 2005 baseline. With the additional new GHG reduction strategies described in this report, Boulder County is estimated to achieve 24% emission reductions by 2020.

It is expected that emissions will increase by 7% or 345,387 mtCO2e from 2016 to 2050, in a business-as-usual scenario if no aggressive action is taken by Boulder County and the community. Boulder County is committed to addressing climate change by reducing greenhouse gas (GHG) emissions in accordance with levels specified by the Paris Climate Agreement Goal, which will help prevent a global temperature increase of 1.5 to 2°C. In 2018, the county committed to the following GHG reduction goals based on a 2005 baseline:

1. reduce countywide GHG emissions by 45% by 2030; and
2. reduce countywide GHG emissions by 90% by 2050.

If all strategies were to be implemented, Boulder County can expect to achieve the GHG emission reductions listed in Table ES - 2.

Table ES - 2. Comparison of Model Predictions Against County's GHG Emission Reduction Goals

Year	Boulder County's GHG Emission Reduction Goal	Model Predictions	Additional Reductions Needed
2030	45%	52%	0%
2050	90%	59%	31%

Figure ES - 4, and Figure ES - 5 show the relative contribution from each sector's respective GHG reduction strategies towards the overall GHG emission reduction goal.

Figure ES - 4. 2030 GHG Emission Reduction Potential Projections[3]

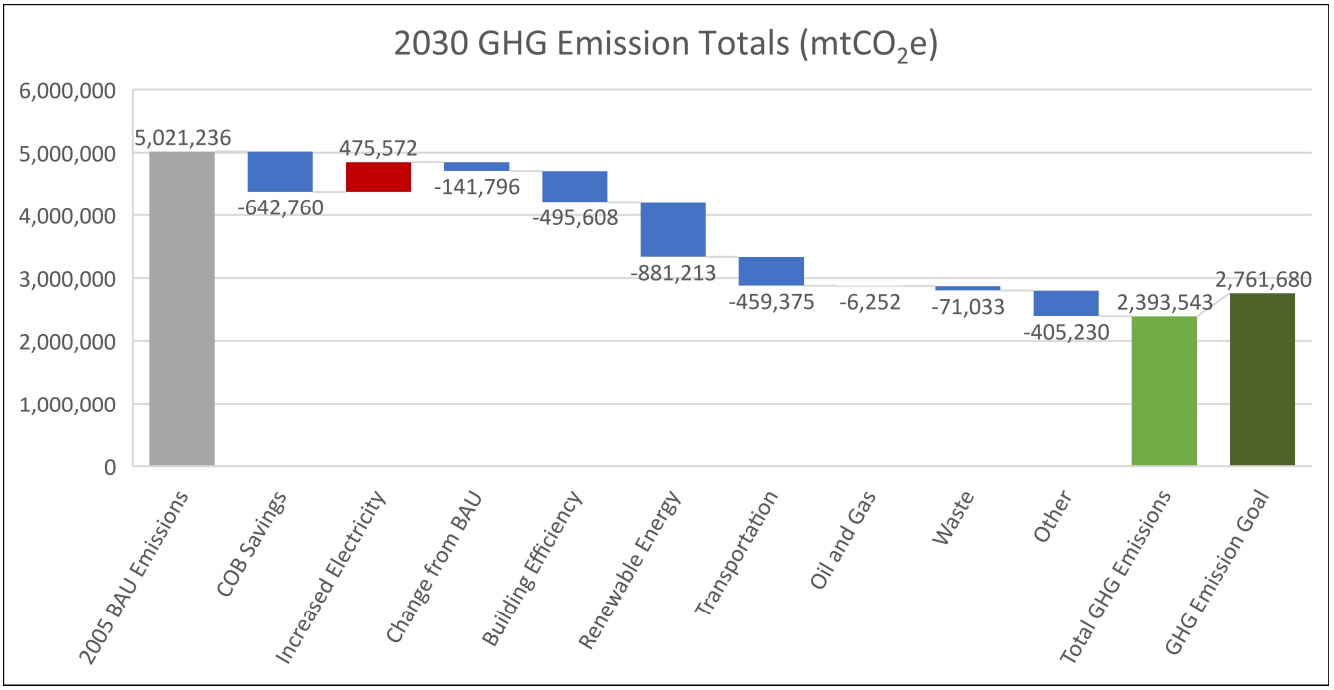
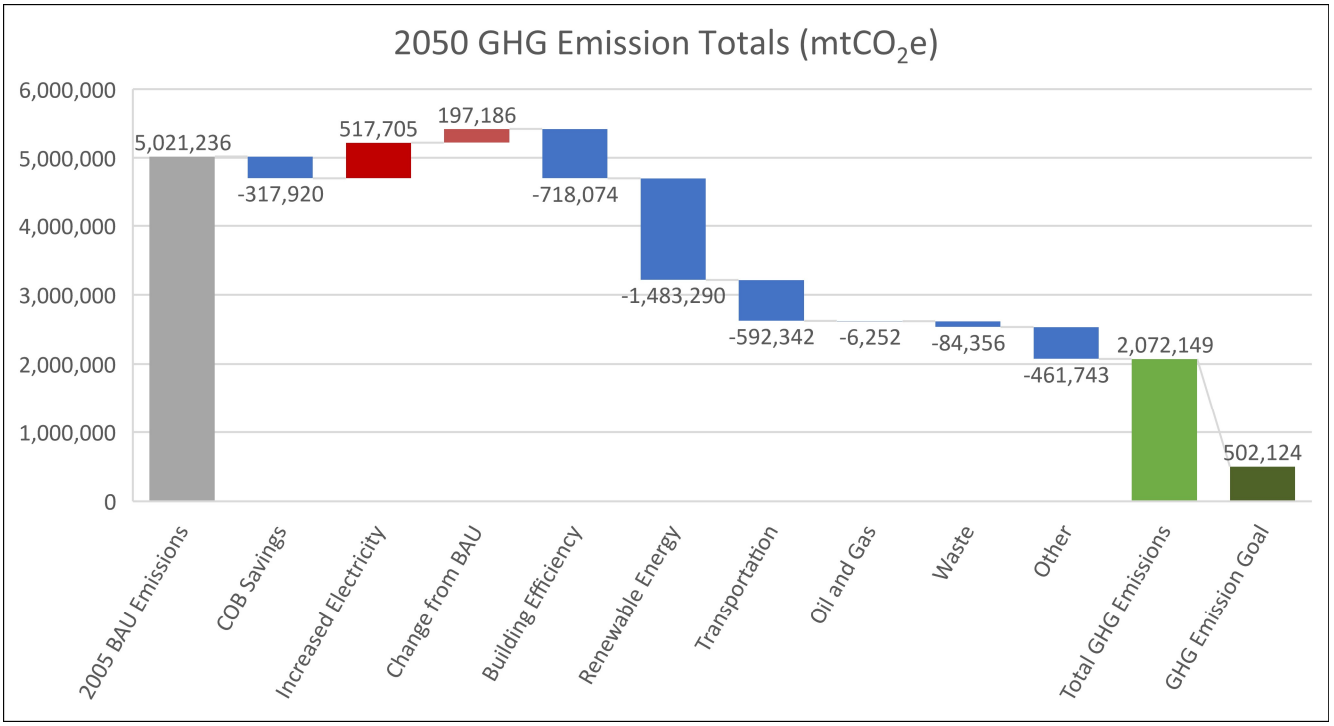


Figure ES - 5. 2050 GHG Emission Reduction Potential Projections



[3] Note that COB stands for City of Boulder GHG savings that they have estimated from their GHG reduction strategies. In addition, increased electricity accounts for the electricity demands that will be created through the increase in

The largest contribution in GHG emission reductions comes from renewable energy, which must overcome electricity consumption not already offset by efficiency measures and additional electricity put on to the grid from stationary fuel switching and electric vehicles. Having a robust and aggressive plan to increase the amount of renewable energy on the grid is essential if Boulder County is to meet its GHG reduction goals.

Contributions from all other sectors vary in each goal year. In 2050, after renewable energy, the next largest contribution comes from building efficiency, followed by transportation, other sector improvements, expected reductions from waste, and oil and gas. If the City of Boulder, and all other municipalities in Boulder County, achieve their GHG reduction goals and implementation plans, it will greatly help in achieving countywide goals. The City of Boulder's GHG reduction estimates are included in the above charts, as the city has quantified the estimates for 2030 and 2050.

The 2030 interim goal is achievable according to model predictions; however, the longer term, 2050 goal, is more difficult to achieve. This is because the business-as-usual (BAU) projections continue to grow due to expected increases in population and will surpass the 2005 baseline value while the 2030 BAU value is less than the 2005 baseline value. In addition, the strategies tackle key emission sources: electricity, transportation, waste, and oil and gas, but do not affect other emission sources that may be less influenced by Boulder County programs and policies such as airplane travel out of Denver International Airport. Following 2030, Boulder County will need to adopt aggressive actions to further reduce its carbon footprint.

electric vehicles and fuel switching. Lastly, "Change from BAU" accounts for the increase in emissions expected due to increased population and square footage.

Introduction

Boulder County is committed to addressing climate change by reducing greenhouse gas (GHG) emissions. To understand how to effectively reduce GHG emissions, Boulder County completed GHG emission inventories for calendar years 2005, 2011, and 2016 and modeled the GHG emission reduction potential for numerous GHG emission reduction strategies. Boulder County contracted with Lotus Engineering and Sustainability, LLC (Lotus) to complete their 2016 GHG emission inventory and model potential reductions in GHG emissions based on selected strategies (see Appendix D: Detailed Descriptions of GHG Emission Reduction Strategies).

In 2012, Boulder County committed to reduce countywide GHG emissions 40% by 2020 based on a 2005 baseline. With existing initiatives and partnerships, and additional new strategies described later in this report. Boulder County is estimated to achieve 23% emission reductions by 2020. In 2018, the county committed to reduce countywide GHG emissions 45% by 2030 and 90% by 2050 based on a 2005 baseline.

The initial inventories provide a baseline of activity, and the subsequent inventories provide insight into Boulder County's performance and ability to meet its carbon reduction goals.

Inventory Methodology

2016 Inventory Methodology

The 2016 inventory was completed using the framework provided by the Global Protocol for Community-Scale Greenhouse Gas Emission Inventories (GPC), which is a global standard for GHG emission accounting and reporting. The GPC, which was released in 2014, defines what emissions must be reported and how they are measured and analyzed. The 2016 community GHG inventory was completed to be GPC compliant and will enable Boulder County to track, record, and report their emissions within one workbook. GPC draws on methods from ICLEI-Local Governments for Sustainability's (ICLEI) *U.S. Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions*, which provides more detailed methodology specific to U.S. communities.[4]

There are two reporting methodologies for the GPC community framework:

- **BASIC**: The BASIC methodology covers stationary energy, in-boundary transportation, and community-generated waste.
- **BASIC+:** The BASIC+ methodology includes BASIC emission sources, as well as a more comprehensive coverage of emissions sources such as trans-boundary transportation; energy transmission and distribution losses; industrial processes and product use; and agriculture, forestry and other land uses.

[4] For more information regarding the US Community Protocol for Accounting and Reporting of Greenhouse Gas Emissions see. http://icleiusa.org/us-community-protocol/

Based on the available data, Boulder County has chosen the BASIC+ reporting level.[5] A full list of sectors, sources, and municipalities that are included in the GHG inventory are listed below in Table 1.

Table 1. Sector, Source, and Municipality List

Sector	Source	Municipality
Agriculture	Electricity	Boulder
Commercial	Transmission Losses	Lafayette
Oil Wells	Natural Gas	Longmont
Industrial Process	Natural Gas Leakage	Louisville
Residential	Oil Wells	Lyons
Transportation	Stationary Diesel	Nederland
Waste	Mobile Gasoline	Superior
Wastewater	Mobile Diesel	Unincorporated/Other
	Mobile Electricity	
	Railways	
	Boulder County Airports	
	Denver International Airport	
	Enteric Fermentation	
	Manure Management	
	Soil Management	
	Landfill	
	Compost	
	Wastewater	
	Cement Manufacture	
	Refrigerants	

GPC does not account for emission reductions based on recycling or the use of renewable energy. In the 2016 inventory, emissions from these items are included as information-only items, which was a different approach from previous inventories. See Table 2 for an overview of sources recorded in the 2005, 2011, and 2016 GHG inventories.

[5] For more information regarding GPC see https://www.compactofmayors.org/resources/tools-for-cities/

Table 2. GHG Emission Sources

Emissions Source	2005	2011	2016
Electricity	X	X	X
Transmission Loses			X
Natural Gas	X	X	X
Natural Gas Leakage			X
Oil Wells			X
Stationary Diesel	X	X	X
Voluntary Renewable Energy Credits	X	X	Info Only
Mobile Gasoline	X	X	X
Mobile Diesel	X	X	X
Mobile Electricity	Included in Electricity Source		Split Out
Railways			X
Boulder County Airports	X	X	X
Denver International Airport			X
Enteric Fermentation	X	X	X
Manure Management	X	X	X
Soil Management	X	X	X
Landfilled Waste	X	X	X
Compost			X
Wastewater			X
Cement Manufacture	X	X	X
Refrigerant	X	X	X
Muni-Renewable Energy*	X	X	Info Only
* 'Muni-Renewable Energy' refers to renewable energy assets owned by municipalities only.			

Per the GPC protocol, the sources listed above can be organized into the following scopes:

- Scope 1: GHG emissions from sources located within the county boundary, including:
  - energy and transportation fuel combustion;
  - fugitive emissions (includes active oil wells and leakage of natural gas);
  - solid waste (including compost) treated within the county;
  - wastewater treated within the county;
  - industrial processes and product use inside the county; and
  - agriculture, forestry, and land use inside the county.
- Scope 2: GHG emissions occurring as a consequence of the use of grid-supplied electricity, heat, steam and/or cooling within the county boundary.
- Scope 3: GHG emissions that occur outside the county boundary as a result of activities taking place within the county boundary, including:
  - transmission and distribution losses;

- solid waste (including compost) treated outside the county; and
- transportation activities for which fuel combustion occurs outside the county.

The GPC protocol does not recognize emissions avoided through the purchase of renewable energy credits (RECs), local installation of renewable energy systems (including solar and hydrogeneration), or recycling. However, communities frequently want to understand the potential impact of these activities. For Boulder County, these items are calculated as "information-only" and include:

- recycling;
- RECs; and
- local renewable energy production (solar and hydrogeneration).

Sources of Data

Lotus collected all data by reaching out to a variety of people and resources. The list of resources will need to be researched and updated every year. All data resources and contacts can be found in the *Boulder County Inventory Management Report* and in the *2016 Boulder County Greenhouse Gas Inventory* spreadsheet.

The inventory considers the predominant greenhouse gases – carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) – as well as refrigerants. For ease of reporting and comparing the absolute effects of different gases, all GHGs have different, defined global warming potentials (GWP). The GWP of a GHG defines its contribution to global warming (i.e. the ability of each gas to trap heat in the atmosphere), whereas a GWP of one is equal to the impacts of one unit of CO_2. The effect of a non-CO_2 GHG or the combination of different GHGs is expressed as carbon dioxide equivalents or CO_2e.

In 2016, GWPs have been sourced from the Intergovernmental Panel on Climate Change (IPCC) Fifth Assessment Report (see Table 3). Methane, nitrous oxide, HCFC 123, HFC-134A, and R-114 are converted to CO_2e by multiplying their value by the 100-year GWP coefficient.

Table 3. Global Warming Potentials, 2016

Common Name	Formula	GWP (2016)
Carbon Dioxide	CO_2	1
Methane	CH_4	28
Nitrous Oxide	N_2O	265
2,2-Dichloro-1,1,1-trifluoroethane	HCFC 123	77
1,1,1,2-Tetrafluoroethane	HFC-134A	1,430
1,2-dichloro-1,1,2-trifluoroethane	R-114	10,000

Previous Inventory Methodologies

For the 2005 and 2011 inventories, Boulder County used the *GHG Protocol Corporate Accounting and Reporting Standard,* developed by the World Resources Institute and the World Business Council for Sustainable Development. Results from the 2005 inventory were published in a comprehensive report titled *Boulder County, Colorado Greenhouse Gas Inventory Final Report*[6], and results from the 2011 inventory were published in the *GHG Inventory & SEP Analysis.*[7]

Boulder County's geopolitical organizational boundary was used as the boundary for both previous emission inventories. Whenever possible, the 2011 inventory attempted to prioritize emissions estimates based on available activity data for Boulder County over modeled data; however, in some cases the data was estimated or modeled.

Overview of Boulder County's 2016 GHG Emissions

GHG emissions are a product of emission factors and activity data. Emission factors represent the amount of GHGs emitted into the atmosphere by a specific activity (see *Appendix B* for more information on emission factors). Activity data refers to the data measured for the community GHG emission inventory calculations, such as fuel consumed, electricity consumed, tons of waste generated, and vehicle miles traveled. Activity data is influenced by community indicators (i.e. population, economic growth, etc.), energy consumption, and other generation behaviors. Changes in emissions result from the interplay of activity data and emission factors. Boulder County can influence positive changes in emissions through various programs, policies, and outreach efforts. A regular review of emission changes and the factors that influence those changes will inform how well Boulder County's climate-change initiatives are working and may inform where the county should focus future efforts.

The following is an overview of 2016 GHG emissions and the drivers that affected the GHG emissions throughout the years. If applicable, comparisons are made between the 2011 and 2016 GHG inventories.

Community Indicator Trends

Community Indicators reflect how the countywide community is changing over time. Between 2011 and 2016, the population grew and the area experienced economic growth (see Table 4). During this time the county has seen an 8% increase in population and a 7% increase in the number of people employed.

[6] For more information see: https://assets.bouldercounty.org/wp-content/uploads/2017/03/greenhouse-gas-inventory-2006.pdf

[7] For more information see: https://assets.bouldercounty.org/wp-content/uploads/2017/03/greenhouse-gas-inventory-2012.pdf

Table 4. Changes in Community Indicators

Community Indicators	2011	2016	Change since 2011
Boulder County Population	297,814	322,226	8%
Number of Households	118,545	122,516	3%
Number of Housing Units	126,444	133,773	6%
Number of Jobs	238,388	254,340	7%
C&I Building Floor Space (ft^2)	73,386,167	90,608,049	23%
GDP (million dollars)	$18,832	$23,400	24%
Heating Degree Days[8]	4,526	3,756	-17%
Cooling Degree Days	1,424	1,386	-3%

Boulder County has also seen a 48% increase in the amount of retail sales within the county, and a 24% increase in its Gross Domestic Product (GDP), which represents significant growth in economic activity for the community.

Although growth can benefit the community, it makes the task of achieving significant reductions in GHG emissions more challenging. Fortunately, Boulder County is reducing overall GHG emissions as it grows, and in some cases normalized metrics present drastic reductions.

Overall 2016 emissions have decreased by 0.4% since 2011. When normalized by community indicators (i.e. population, households, employees, GDP, etc.), we see a larger reduction in emissions: from a 6% reduction of emissions per job to a 33% reduction in commercial and industrial emissions per square foot (see Table 5). These numbers show that Boulder County is successfully reducing emissions as the county's economy continues to grow.

[8] A Heating Degree Day (HDD) and Cooling Degree Day (CDD) are roughly proportional to the energy used for heating and cooling a building. They are calculated by taking the difference between the average daily temperature and the balance point temperature. The balance point temperature is the average daily outside temperature at which a building maintains a comfortable indoor temperature without heating or cooling. When the average daily temperature is above the balance point temperature, the result is cooling degree days (i.e., a building must be cooled to maintain the balance point temperature). When the average daily temperature is below the balance point temperature the result is heating degree days (i.e., the building must be heated to maintain the balance point temperature). HDD and CDD were taken from: http://www.weatherdatadepot.com/ using at 60-degree Fahrenheit balance point.

Table 5. Normalized Emissions Data

Normalized Emissions	Units	2011	2016	% Change Between 2016 and 2011
Emissions per Resident	$mtCO_2e$/person	16.4	15.1	-8%
Residential Emissions per Household	$mtCO_2e$ /HH	11.3	8.7	-23%
C&I Emissions per Employee	$mtCO_2e$ /FTE	8.6	7.2	-16%
C&I Emissions per Square Foot (ft^2)	$mtCO_2e$ /ft^2	0.03	0.02	-33%
Emission per Job	$mtCO_2e$ /FTE	20.5	19.2	-6%

Energy Source Emissions

The energy sector accounted for 61% of Boulder County's 2016 GHG emissions and included the following emission sources:

- electricity consumption (including transmission and distribution losses);
- natural gas consumption;
- stationary diesel consumption;
- fugitive emissions from natural gas consumption; and
- fugitive emissions from oil well extraction.

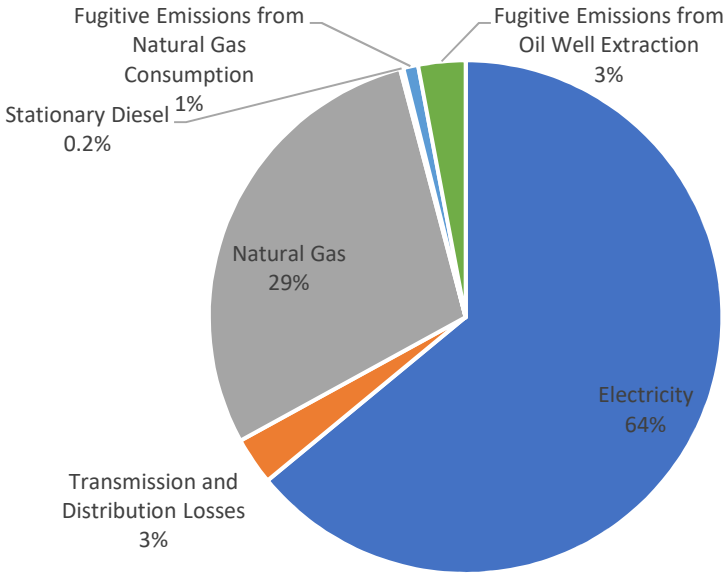
Trends and Key Takeaways

The following are the major takeaways and trends from the energy sources:

- Electricity consumption (including transmission and distribution losses) accounted for 41% of Boulder County's 2016 GHG emissions.
- Between 2011 and 2016, electricity consumption has decreased by 1%; however, the GHG emissions from electricity has decreased by 25% due to significantly lower electricity emission factors (see *Appendix B* for more information).
- Electricity emission reductions (625,850 $mtCO_2e$) were the single largest source of GHG reductions overall between 2011 and 2016.
- Between 2011 and 2016, Boulder County's per person and per household residential electricity consumption decreased by 15% and 11%, respectively, while the county's population grew by 8% and the number of households increased by 3%.
- The commercial and industrial (C&I) electricity consumption per square foot decreased by 17%, while C&I square footage increased by 23%.
- Natural gas consumption accounted for 18% of Boulder County's 2016 GHG emissions, and between 2011 and 2016, emissions from natural gas have increased by 0.8%.
- Fugitive emission from active oil wells and natural gas accounted for 2% of Boulder County's GHG emissions.

As shown in Figure 1, the majority of emissions from energy came from electricity (64%) followed by natural gas at 29%. The remaining energy sources made up less than 7% of Boulder County's 2016 GHG emissions.

Figure 1. Energy Emissions Sources, 2016



Electricity Usage

Electricity consumption accounted for 41% of Boulder County's 2016 GHG emissions. As shown in Table 6, residential electricity consumption between 2011 and 2016 decreased by 8%, while commercial electricity use increased by 3%. Altogether electricity usage decreased by 1%. Although consumption was reduced by only 1%, the GHG emissions from electricity decreased by 25% due to significantly lower electricity emission factors (for more information on emission factors see *Appendix B: Overview of Emission Factors*). Electricity emission reductions were the single largest source of GHG reductions between 2011 and 2016.

Table 6. Electricity Consumption and Emissions

Electricity Data	2011	2016	% Change since 2011
Residential Electricity Use (kWh)	1,080,416,815	992,059,503	-8%
C&I Electricity Use (kWh)	1,982,026,066	2,040,232,459	3%
Total Electricity Use (kWh)	**3,062,442,881**	**3,032,291,962**	**-1%**
Residential Electricity Use Emission ($mtCO_2e$)	893,984	628,073	-30%
C&I Electricity Use Emission ($mtCO_2e$)	1,640,014	1,280,074	-22%
Total Electricity Emissions ($mtCO_2e$)	**2,533,998**	**1,908,148**	**-25%**

If you normalize electricity consumption for growth factors, residential electricity usage decreased by 11% per household and 15% per person since 2011. At the same time, C&I electricity consumption decreased per square foot by 17%.

Table 7. Normalized Electricity Data

Normalized Energy Data	Units	2011	2016	% Change since 2011
Residential Electricity per Person	kWh/person	3,628	3,079	-15%
Residential Electricity per Household	kWh/HH	9,114	8,097	-11%
C&I Electricity per Square Foot	kWh/ft^2	27	22.5	-17%

Between 2011 and 2016, Boulder County's per person and per household residential electricity consumption decreased while the county's population grew by 8% and the number of households increased by 3%.

As the community grows, its normalized electricity consumption continues to trend downwards; this indicates a higher level of efficiency in both the residential and the C&I building sectors for electricity consumption. The people living in and employed within Boulder County are using less electricity to perform the same tasks. The reduction in normalized electricity usage can likely be attributed to growing end-user awareness as well as demand side management programs from the utilities and Boulder County (i.e. EnergySmart, Weatherization Assistance Program, and Partners for a Clean Environment (PACE)).

When electricity is transmitted from large power plants to consumers, a portion of the electricity is inherently lost due to resistance. The GPC BASIC+ protocol requires calculating transmission and distribution losses. The loss factor of 4.67% was determined using data from the U.S. Energy Information Administration. This factor showed that 89,077 $mtCO_2e$ were created due to the loss of electricity via utility transmission and distribution and represented 1% of Boulder County's total 2016 GHG emissions.

As Boulder County continues to grow, policies and programs that increase end-user awareness and demand side management will play a key role in ensuring that the share of emissions from stationary electricity continues to track downwards.

Natural Gas Usage

Natural gas consumption accounted for 18% of Boulder County's 2016 GHG emissions. Since 2011, total natural gas consumption increased by 0.5%, while natural gas usage decreased by 14% per household and decreased 8% per square foot in the commercial sector over the same time period (see Table 8 and Table 9 for more information).

Table 8. Natural Gas Consumption

Natural Gas Data	2011	2016	% Change since 2011
Residential Natural Gas Use (therms)	83,797,986	74,077,642	-12%
C&I Natural Gas Use (therms)	77,278,544	87,832,319	14%
Total Natural Gas Use (therms)	**161,076,530**	**161,909,961**	**0.5%**
Residential Natural Gas Use Emission ($mtCO_2e$)	444,297	393,877	-11%
C&I Natural Gas Use Emission ($mtCO_2e$)	409,731	467,012	14%
Total Natural Gas Emissions ($mtCO_2e$)	**854,028**	**860,889**	**0.8%**

Table 9. Normalized Natural Gas Data

Normalized Natural Gas Data	Units	2011	2016	Change since 2011
Residential Natural Gas per Person	th/person	281.4	229.9	-18%
Residential Natural Gas per Household	th/HH	706.9	604.6	-14%
C&I Natural Gas per Square Foot	th/ft^2	1.1	0.9	-8%

Natural gas consumption can track closely with cold weather since natural gas is the most common fuel used for heating in Boulder County. Since HDD (i.e. number of days when heating was required) decreased between 2011 and 2016 by 17%, it would be expected that natural gas usage would also decrease; however, natural gas consumption increased slightly.

These numbers highlight the need for Boulder County to focus on natural gas consumption since it may result in increasing emissions moving forward.

Stationary Diesel Usage

Stationary diesel usage accounted for 0.1% of Boulder County's GHG emissions. Between 2011 to 2016, stationary diesel consumption and emissions both decreased by 96% (134,000 $mtCO_2e$). The reduction was almost entirely driven by one location in Louisville no longer consuming any stationary diesel for their emergency diesel generator.

Fugitive Emissions

Active oil wells and natural gas distribution systems cause methane leakage and fugitive emissions, which must be accounted for in the GPC protocol.[9] Fugitive emission accounted for more than 2% of Boulder County's GHG emissions.

[9] Fugitive emissions and natural gas leakage rates were not calculated in the 2011 inventory; therefore, there are no comparable emissions between 2011 and 2016.

Boulder County had nearly 300 active oil wells within county limits in 2016. During the natural gas extraction process, these wells emit small amounts of methane that add up over time to comprise a significant amount of emissions. Fugitive emissions from active wells accounted for 2% of Boulder County's GHG emissions.

Further, natural gas distribution systems have methane leaks which accounted for 0.6% of Boulder County's total GHG emissions.

Information-Only Renewable Energy Generation

Per the GPC protocol, renewable energy generation is calculated as an information-only item. While no emission reductions can be included from renewable energy and Renewable Energy Credits (RECs) in a GPC inventory, many cities and counties track this data to monitor the success of their renewable energy programs and policies.

In 2016, businesses and residents installed and consumed over 11 megawatts of power generated by solar photovoltaic panels and community solar gardens. RECs allow electricity users to purchase the environmental benefits of renewable energy that is generated somewhere else. In 2016, businesses and residents in Boulder County purchased over 115 megawatts of RECs (approximately 4% of total Boulder County's electricity) from Renewable Choice Energy and various utility REC programs.

Transportation Source Emissions

The transportation sector accounted for 31% of all Boulder County's 2016 GHG emissions and included the following emission sources:

- mobile gasoline;
- mobile diesel;
- mobile electricity;
- railways; and
- aviation fuel.

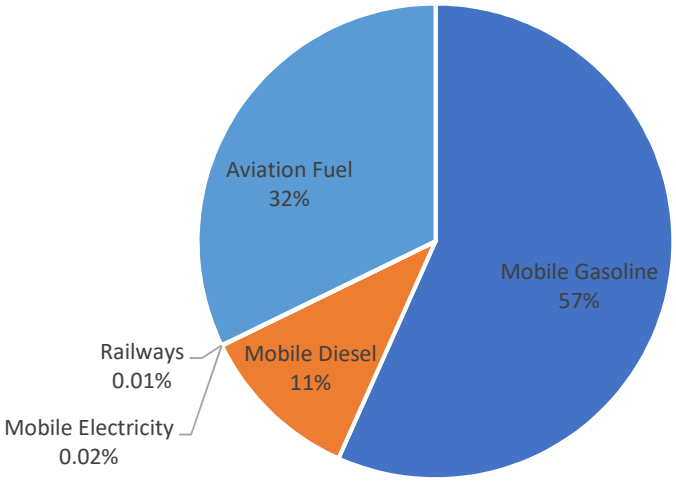
Trends and Key Takeaways

The following are the major takeaways and trends from the transportation sources:

- On-road transportation emissions from gasoline, ethanol, and diesel usage accounted for 21% of Boulder County's total 2016 GHG emissions.
- Emissions from on-road transportation decreased by 5% between 2011 and 2016.
- Aviation fuel consumption from the three airports that serve Boulder County residents accounted for 10% of Boulder County's total 2016 GHG emissions. These airports include: Denver International Airport (DIA) (located in the City and County of Denver), Boulder Municipal Airport (located in the City of Boulder), and Vance Brand Municipal Airport (located in the City of Longmont).

As shown in Figure 2, the majority of transportation emissions came from mobile gasoline (57%) followed by aviation fuel at 32% and mobile diesel at 11%. The remaining transportation sources made up less than 0.03% of Boulder County's transportation emissions.

Figure 2. Emissions from Transportation Sector, 2016



Gasoline, Ethanol, and Diesel Usage

On-road transportation emissions from gasoline, ethanol, and diesel usage accounted for 21% of Boulder County's total 2016 GHG emissions. As shown in Table 10, emissions from on-road transportation decreased by 5% between 2011 and 2016. On-road emission data is based on several factors: emission factors, fuel efficiencies, vehicle miles traveled (VMT), and vehicle type distribution by vehicle fuel (diesel and gasoline).

Table 10. On-road Transportation Trends

Transportation Data	Units	2011	2016	% Change since 2011
On-road transportation total emissions	$mtCO_2e$	1,097,941	1,039,423	-5%
On-road transportation	gallons fuel	121,826,342	124,542,743	2%
VMT	miles	2,390,243,903	2,208,590,205	-8%

While the gallons of fuel used increased slightly (2%), the emission decreased by 5% due to the inclusion of ethanol in the gasoline mixture. If you normalize transportation consumption for growth factors, emissions per person decreased by 14%, gallons per person decreased by 5% per person, and VMTs decreased by 15% per person.

Table 11. Normalized Transportation Data

Normalized Transportation Data	Units	2011	2016	% Change since 2011
On-road transportation emissions per person	$mtCO_2e$/person	3.7	3.2	-14%
Gallons per person	gallons/person	409	387	-5%
VMT per person	VMT/person	8,026	6,854	-15%

As the community grows, its normalized fuel consumption continues to trend downwards; this could indicate a higher level of efficiency in vehicles, less people driving single-occupied vehicles, and an increase in alternative transportation such as biking, walking, and mobility options. In addition, it could indicate an increase in end-user awareness on the impact of transportation on the environment.

As Boulder County continues to grow, policies and programs that increase end-user awareness and reduce vehicle miles traveled will play a key role in ensuring that the share of emissions from on-road emission continue to track downwards.

Railways Diesel Usage

Railways accounted for 0.004% of Boulder County's total 2016 GHG emissions. Burlington Northern Santa Fe operates a diesel freight train that travels approximately 30 miles through unincorporated Boulder County and the Cities of Boulder, Longmont, and Louisville.

Aviation Fuel Usage

In 2016, emissions from aviation fuel accounted for 10% of Boulder County's total 2016 GHG emissions and 32% of the emissions from transportation. There are three airports that serve Boulder County residents: DIA (located in the City and County of Denver), Boulder Municipal Airport (located in the City of Boulder), and Vance Brand Municipal Airport (located in the City of Longmont). Emissions from DIA accounted for almost 100% of the total GHG emissions from aviation.

The 2011 GHG inventory included the Boulder Municipal Airport and Vance Brand Municipal Airports, but not the Denver International Airport. This lead to a large increase in the reported aviation emissions between 2011 and 2016.

Waste Source Emissions

The waste sector accounted for just over 1% of all Boulder County's 2016 GHG emissions and included the following emission sources:

- landfill gas;
- compost; and
- wastewater.

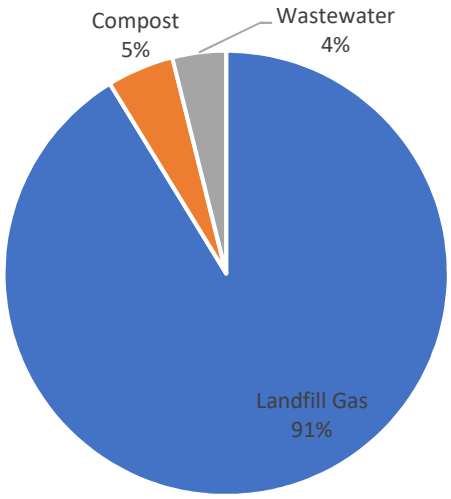
Trends and Key Takeaways

The following are the major takeaways and trends from waste sources:

- Landfill gas accounts for 1% of Boulder County's total GHG emissions and composted waste accounts for 0.1% of Boulder County's total GHG emissions.
- In 2016, 36% of countywide waste was diverted through recycling and composting.
- Between 2011 and 2016, the amount of landfilled waste per person increased by 18%.
- Wastewater emissions accounted for 0.05% of Boulder County's total GHG emissions.

As shown in Figure 3, the majority of waste emissions came from landfill gas (91%) followed by compost at 5% and wastewater at 4%.

Figure 3. Emissions from Waste Sector, 2016



Landfilled, Recycled, and Composted Waste

Emissions from landfilled waste accounted for approximately 1% of Boulder County's total GHG emissions. Between 2011 and 2016, the amount of landfilled waste increased by 27% and the amount of landfilled waste per person increased by 18% (see Table 12).

Table 12. Landfilled, Composted and Recycling Tonnage

Waste Data	Units	2011	2016	% Change since 2011
Landfilled waste	Tons	223,361	284,093	27%
Composted waste*	Tons	-	46,351	-
Recycled waste*	Tons	-	112,475	-
Total Waste Created	**Tons**	**223,361**	**442,919**	**-**
Diversion Waste	**% Waste Diverted**	**-**	**36%**	
Landfill tons per person	Tons/Person	0.8	0.9	17%
Composted tons per person*	Tons/Person	-	0.1	-
Recycled tons per person*	Tons/Person	-	0.4	-
Total Waste Created Per Person	**Tons/Person**	**0.8**	**1.4**	**-**
** Sources that were reported in 2016 but not reported in 2011. Still recycling and composting climate impacts are reported as information-only as the GPC protocol doesn't include them in the inventory.*				

In 2016, 36% of waste was diverted from the landfill. In 2016, on average, 0.1 tons of compost and 0.4 of recycling was created per person per year. Per GPC protocol, emission reductions resulting from materials being recycled is not counted and the amount of recycled waste is reported as information-only in Boulder County's inventory. However, Boulder County has identified recycling as a top GHG reduction strategy due to the life-cycle GHG emission savings achieved through recycling a material instead of landfilling the material. Utilizing the life-cycle emission factors from ICLEI's Recycling and Composting protocol, it is estimated that Boulder County avoided 153,289 $mtCO_2e$.

Wastewater Treatment

In 2016, wastewater treatment plant (WWTP) emissions accounted for 0.05% of Boulder County's 2016 GHG inventory.[10] Each municipality has its own WWTP. In addition, some residents residing in Nederland and unincorporated Boulder County are served by septic systems. The 2016 inventory calculated WWTP emissions from process nitrous oxide and from fugitive emissions from nitrification and denitrification.

Industrial Processes and Product Use Source Emissions

The IPPU sector accounted for 5% of all Boulder County's 2016 GHG emissions and included the following emission sources:

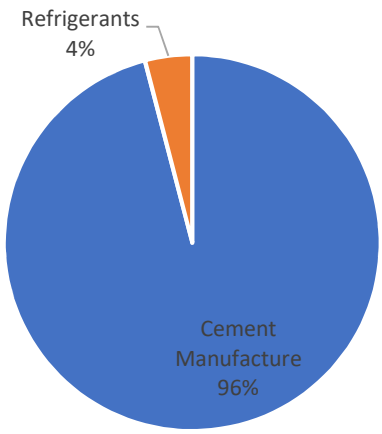
- industrial processes (cement manufacturing); and
- industrial product use (refrigerants).

[10] Wastewater emissions were not calculated in the 2011 inventory; therefore, there are no comparable emissions from 2011 to 2016.

Trends and Key Takeaways

Emissions from industrial processes in Boulder County are primarily generated by cement manufacturing activities and, to a much smaller degree, refrigerant use in buildings. As shown in Figure 4, the majority of IPPU emissions came from cement manufacturing (96%) followed by refrigerants at 4%.

Figure 4. Emissions from IPPU Sector, 2016



Industrial Processes

Industrial processes accounted for 5% of Boulder County's total GHG emissions. The main emission sources from industrial processes are releases that chemically or physically transform materials (e.g. the blast furnace in the iron and steel industry, cement, etc.). During these processes different GHGs can be produced. The only industrial process noted within Boulder County is the cement plant located in unincorporated Boulder County.

Industrial Product Use

Industrial product use of refrigerants accounted for 0.2% of Boulder County's total GHG emissions. Products such as refrigerants, foams or aerosol cans can release potent GHG emissions. Earlier generations of refrigerants—chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs)—contributed significantly to the depletion of stratospheric ozone and are being phased out due to the Kyoto Protocol. CFCs and HCFCs largely have been replaced with hydrofluorocarbons (HFCs) but many of these HFCs have high global warming potentials and are starting to be restricted or phased out.

Agriculture, Forestry, and Other Land Use Source Emissions

The Agriculture, Forestry, and Other Land Use (AFOLU) sector accounted for 0.6% of Boulder County's 2016 GHG emissions and included the following emission sources:

- emissions from enteric fermentation;
- emissions from manure management;
- emissions from forest fires; and
- emissions from soil management.

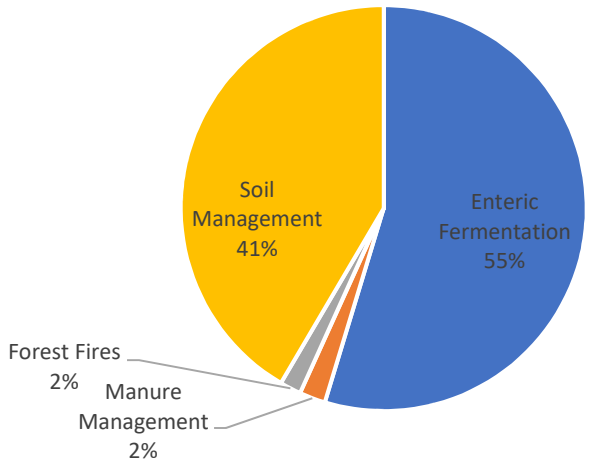
Trends and Key Takeaways

The following are the major takeaways and trends from Agriculture, Forestry, and Other Land Use (AFOLU) sources:

- Emissions from livestock, which include those created by both enteric fermentation and manure management, comprise nearly 57% of AFOLU emissions for Boulder County and 0.4% of total emissions for Boulder County.
- Activities related to managed soils account for approximately 42% of AFOLU emissions and 0.3% of Boulder County's total emissions.

As shown in Figure 5, the majority of AFOLU emissions came from enteric fermentation (55%) followed by soil management (42%), manure management (2%), and forest fires (2%).

Figure 5. Emissions from AFOLU Sector, 2016



Emissions from Livestock

Total agricultural emissions from livestock comprise 0.4% of 2016 emissions for Boulder County and nearly 57% of AFOLU emissions. Emissions from livestock are created through enteric fermentation and manure management. Enteric fermentation is the process of microbial fermentation through which methane is produced during animal digestion. Enteric fermentation is one of the largest sources of methane in the United States but only makes up a very small percentage of the total Boulder County 2016 GHG emissions.

Between 2011 and 2016, emissions from enteric fermentation and manure management increased by 26% due to the increased number of reported livestock (see Table 13).

Table 13. Livestock Data (Number of Animals in Boulder County)

Livestock Category	2011	2016	% Change since 2011
Dairy Cattle	0	59	100%
Beef Cattle	10,771	9,887	-9%
Sheep	1,343	922	-46%
Goat	206	694	70%
Pig	235	286	18%
Horse	3,915	3,796	-3%
Poultry*	-	35,100	-
Total	**16,470**	**50,744**	**68%**
** Data was not provided for poultry in 2011*			

Emissions from Land

As data was not available over the required 20-year time period, and land use changes were minimal, emissions associated with land use changes were not included in the 2016 inventory.

Emissions from Aggregate Sources and Non-CO2 Emission Sources

Emissions from managed soils and forest fires represent 0.3% of Boulder County's 2016 GHG emissions. GPC recognizes several types of emissions resulting from aggregate sources and non-CO_2 emissions sources in the BASIC+ inventory. While several of these aggregate sources are not occurring (i.e. rice cultivation) in Boulder County, there are both direct and indirect emissions resulting from managed soils and forest fires in the county. Between 2011 to 2016, emissions from managed soils in Boulder County decreased by 63%—this is in large part due to the county's aggressive pursuit of organic land management practices.

Based on the Boulder County Parks and Open Space 2015 Agricultural Resources Division Annual Report[11], 15% of open space and grassland owned by Boulder County is organically managed. As Boulder County continues to increase organic management practices and reduce the use of synthetic fertilizers, the emissions from managed soils in Boulder County will continue to trend downwards.

In 2016, Boulder County experienced the Cold Springs fire which burned 528 acres. Emissions resulted from the fire accounted for 0.01% of Boulder County's GHG emission in 2016.

[11] Boulder County Parks and Open Space 2015 Agricultural Resources Division Annual Report can be found at: https://assets.bouldercounty.org/wp-content/uploads/2017/03/agriculture-annual-report.pdf

Boulder County's Potential to Reduce Greenhouse Gas Emissions

GHG Emission Reduction Strategies

Lotus researched sustainability reports, plans, and policies and worked with local energy, transportation, waste, carbon sequestration and oil and gas experts and staff to identify an initial list of GHG emission reduction strategies that have the greatest potential to reduce GHG emissions. Only those strategies with a high potential to reduce GHG emissions were considered; additional benefits such as air quality improvements were not considered during this analysis. For more information refer to Appendix D: Detailed Descriptions of GHG Emission Reduction Strategies.

The initial list of recommendations was reviewed with Boulder County staff, who provided guidance on a final list of recommended strategies. The list of GHG reduction strategies is presented in Table 14. These strategies fall under six sectors: building energy, renewable energy, transportation, oil and gas, waste, and other. Strategy definitions are based off industry best practices and are tailored based on existing actions underway by the county. In some cases, strategies may overlap or may be dependent on one another.

Table 14. GHG Reduction Strategies by Sector

Sector	Objective	Specific Strategy
Building Energy	Implement deep carbon reductions in buildings to reduce energy consumption	Adhere to and Enforce Current Building Code
		Implement Beyond Code Requirements
		Accelerate Fuel Switching
		Impose Mandatory Benchmarking
		Increase the State's Energy Efficiency Resource Standard
		Continue Boulder County's Suite of Energy Efficiency Programs
Renewable Energy	Accelerate solar energy adoption: all-of-the-above strategy	Continue Boulder County's Suite of Renewable Energy Programs
		Expand Rooftop Solar
		Expand Community Solar
		Additional Efforts
Transportation	Increase the adoption of electric vehicles	Accelerate Electric Vehicles: All-of-the-Above Strategy
	Reduce carbon intensity of vehicle travel	Support Federal and/or State Clean Car Policies
	Reduce single-occupancy vehicle travel	Expand Public Transit
Oil and Gas	Support regional and state efforts to control methane leaks	Adopt and Enforce Leak Detection and Repair
Waste	Strive for zero waste	Reduce Food Waste
		C&D and Composting Waste to Local Transfer Facility
		Promote Zero Waste Education
		Strive for Municipal Zero Waste
		Conduct Other Efforts as Needed
Other Carbon Reduction Strategies	Implement community-wide comprehensive carbon reduction programs	Pursue Carbon Sequestration
		Implement Carbon Tax
		Carbon Intensive Industries Carbon Impact Offset Fund

It should be noted that there is a direct relationship between increasing renewable energy and all strategies that effect electricity use (through either increases or decreases in use), particularly stationary fuel switching and the addition of electric vehicles.

These strategies will help set Boulder County on a path to achieve the Paris Climate Agreement Goal which will help prevent a global temperature increase of 1.5 to 2°C.

Community-Wide GHG Reduction Goals

From 2016 to 2050, it is expected that emissions will increase by 7% or 345,387 mtCO2e in a business-as-usual scenario where no aggressive actions are taken by Boulder County and the community. Boulder County is committed to addressing climate change by GHG emissions in accordance with levels specified by the Paris Climate Agreement Goal, which will help prevent a global temperature increase of 1.5 to 2°C. In 2018, the county committed to the follow GHG reduction goals based on a 2005 baseline:

1. reduce GHG emissions by 45% by 2030; and
2. reduce GHG emissions by 90% by 2050.

If all strategies were to be implemented, Boulder County is estimated to achieve the GHG emission reductions listed in Table 15.

Table 15. Comparison of Model Predictions Against Boulder County's GHG Emission Reduction Goals

Year	Boulder County's GHG Emission Reduction Goal	Model Predictions	Additional Reductions Needed
2030	45%	52%	0%
2050	90%	59%	31%

Figure 6 and Figure 7 show the relative contribution from each sector towards the overall GHG emission reduction goal.

Figure 6. 2030 GHG Emission Reduction Potential Projections

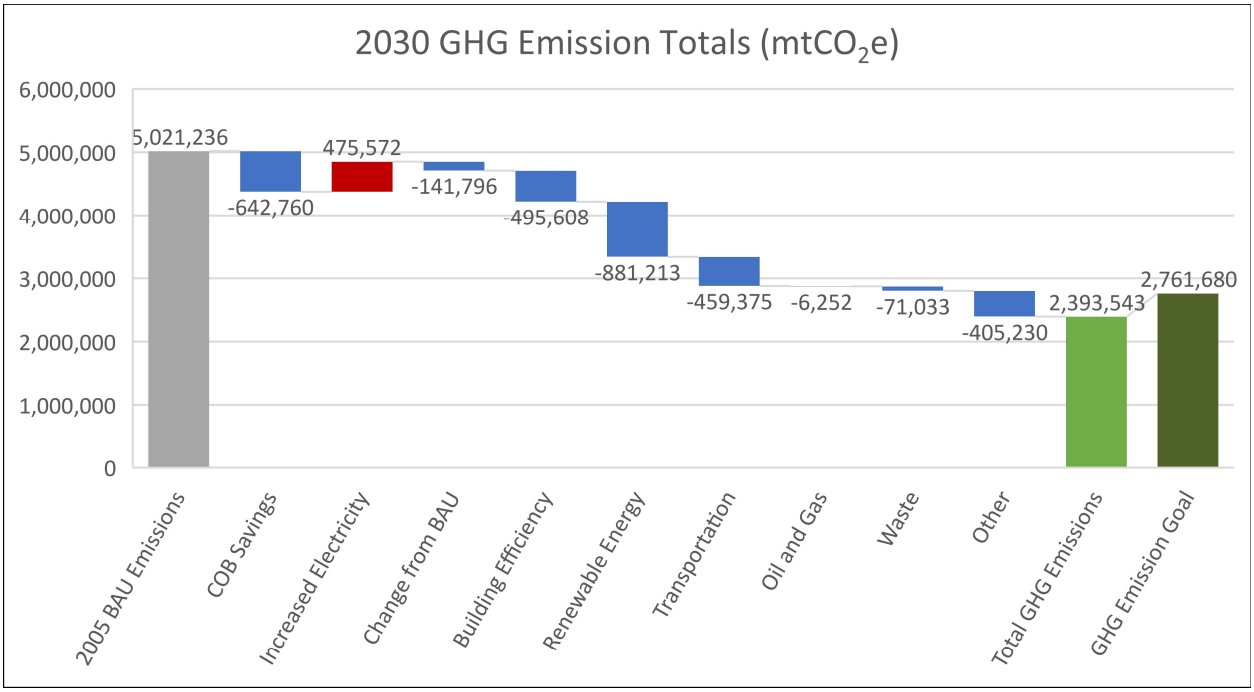
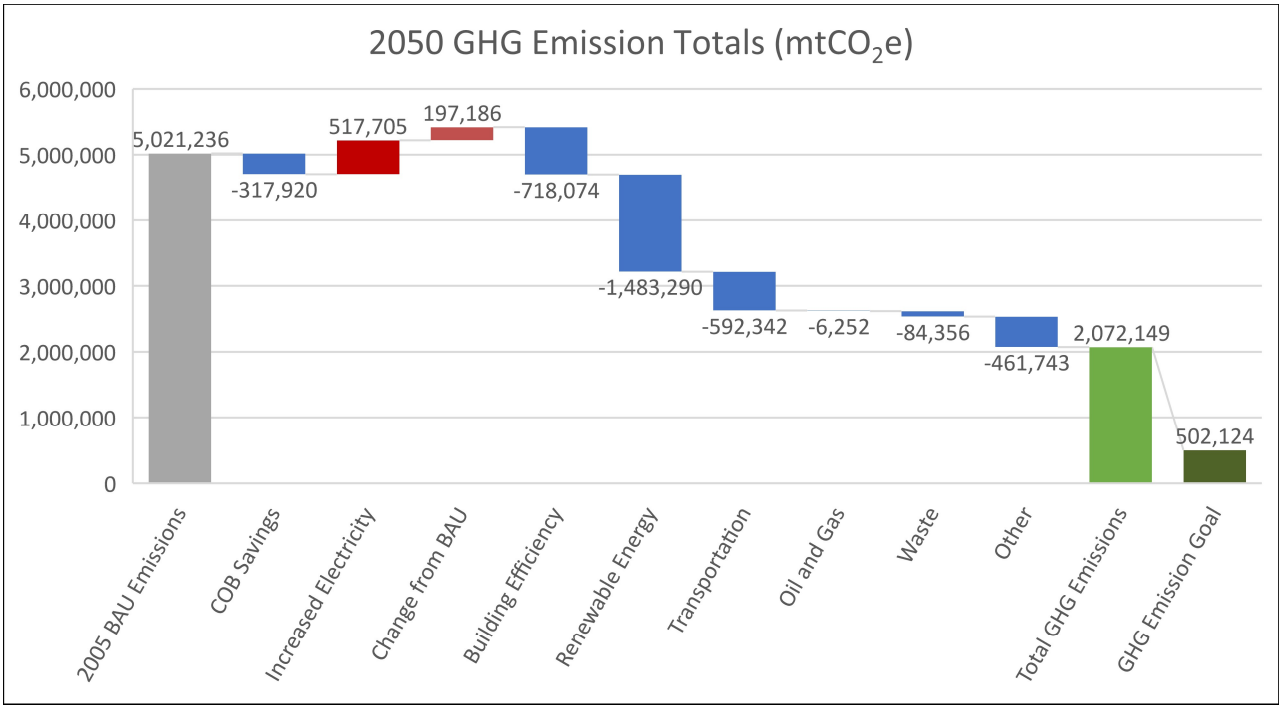


Figure 7. 2050 GHG Emission Reduction Potential Projections



The contributions to lower emissions from the GHG reduction strategies, grouped by category, varies each goal year. The largest contribution in GHG emission reductions comes from renewable energy, which must provide electricity not only for current demand, but any additional electricity demanded due to stationary fuel switching and electric vehicles.

In 2050, after renewable energy, the next largest contribution comes from building efficiency, followed by transportation, other carbon reduction strategies, expected reductions from the City of Boulder, waste, and oil and gas.

From 2030 to 2050, it becomes more challenging to achieve the GHG emission reduction goal. There are a few reasons as described:

1. The business-as-usual (BAU) projection in GHG emissions continues to grow each year due to expected increases in population. The GHG reductions from the proposed strategies need to exceed the increase in BAU projections.
2. The GHG emission reduction strategies affect key emission sources in these sectors: electricity, on-ground transportation, waste, and oil and gas. Boulder County's GHG emissions include additional sources that are not as easily influenced by Boulder County programs and policies, such as airline travel from the Denver International Airport. The GHG emission reduction savings that result from the key emission sources need to be large enough to overcome sources that are not directly impacted by the list of recommended strategies.

It should be noted that the contributions from each sector (and therefore strategy) are highly dependent on data inputs and data assumptions. Refer to the spreadsheet titled *Boulder County GHG Modeling Spreadsheet_060618*.

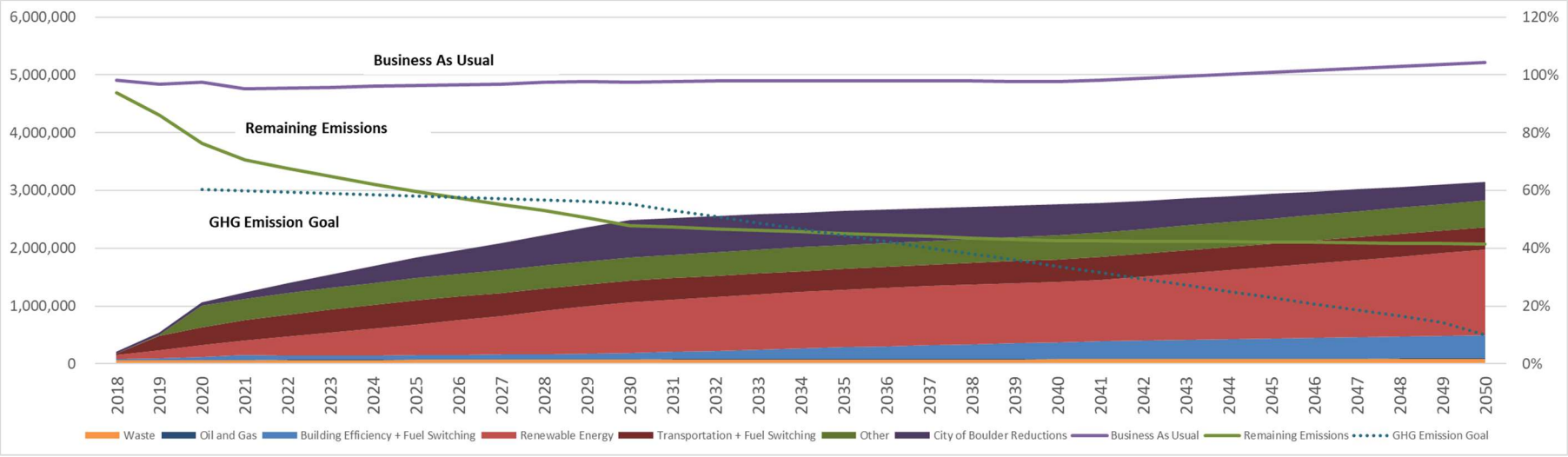
Because the inputs used in this model are specific to Boulder County and further assumptions were derived during multiple conversations and through research, comparing the results of this model to other communities should be approached with care. Likewise, the assumptions used in the model predict the potential reductions in GHG emissions and the successful implementation of the strategies depends on the level of resources provided to each initiative. If assumed inputs, such as participation or savings values, do not occur, then the potential for GHG emission reductions will change accordingly. Data inputs and assumptions can be referenced in the spreadsheet titled *Boulder County GHG Modeling Spreadsheet_060618*

GHG Savings Over Time

The impact of GHG emission reduction potential over time is shown in Figure 8. If Boulder County does not pursue more aggressive GHG reduction strategies, it is expected that GHG emissions will increase over time and will be affected by changes in population, emission factors, and other exogenous factors. This is shown as the BAU projection. Each colored "wedge" represents the amount of savings predicted by a specific sector, with GHG emission savings from renewable energy dominating the potential for savings. The difference between the BAU and the cumulative GHG savings from all strategies is shown as "Remaining Emissions". Boulder County's GHG emission reduction goals for 2030 and 2050 are included in the "GHG Emission Goal" line.

The GHG emission reductions shown in Figure 8 represent the potential if all recommended GHG reduction strategies were pursued.

Figure 8. Impacts from GHG Emission Reduction Strategy Savings Over Time



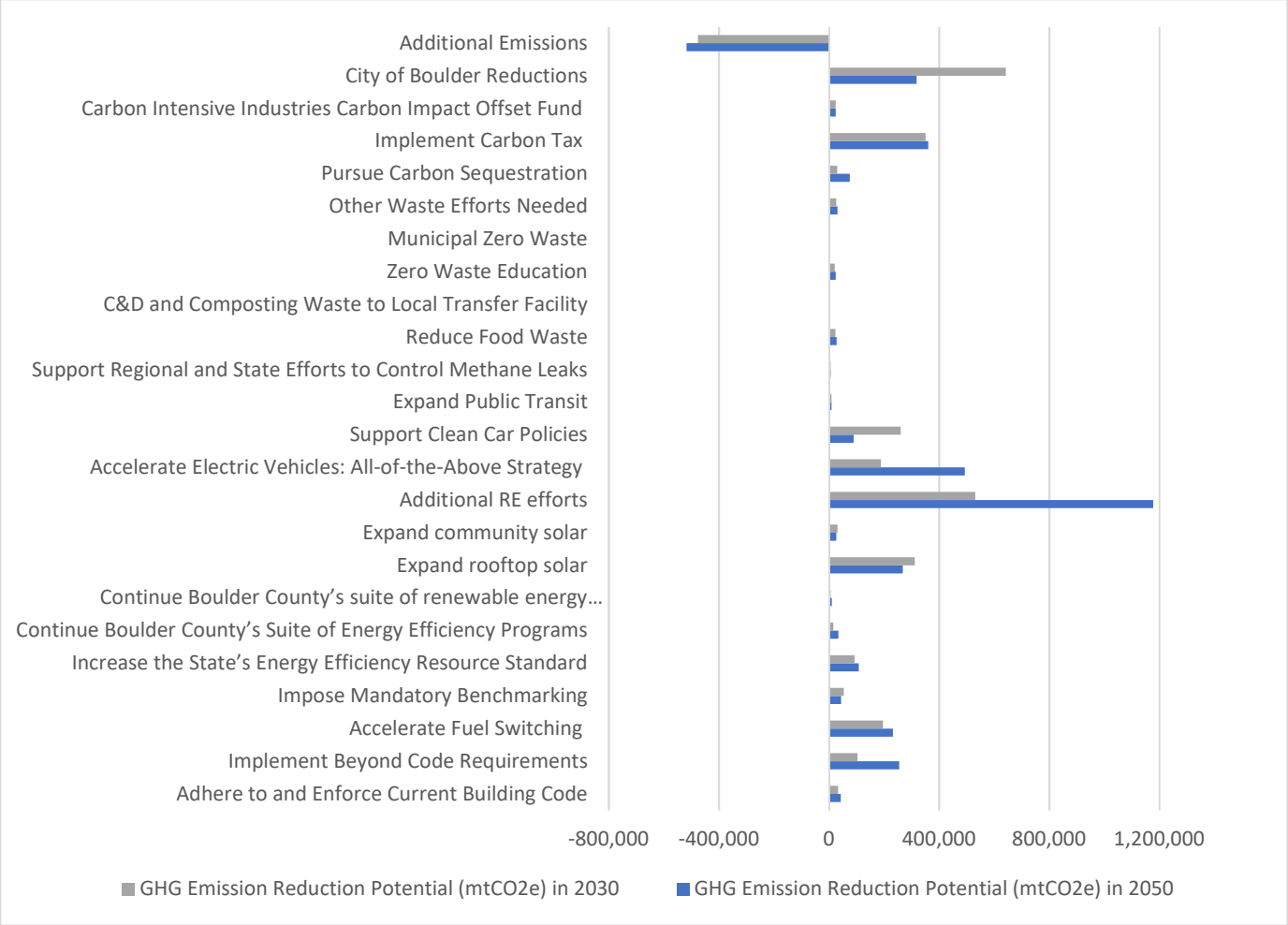
Many of the strategies are expected to reach their full potential of participation and/or savings in the year 2030; therefore, there is a steep incline of potential savings from 2018 until 2030 and the savings begin to incline at a more gradual rate following the year 2030 until 2050.

The BAU captures the already-committed-to increases in renewable energy by the utilities, while the renewable energy wedge captures the additional reduction in GHG emission resulting from additional renewable energy commitments.

Contributions from Different Strategies

Contributions from each strategy in 2030 and 2050 are shown in Figure 9.

Figure 9. GHG Emission Reduction Potential from Each Strategy



The reduction potential of each individual strategy is presented in Table 16. It should be noted that both stationary and mobile fuel switching are only effective if the additional electricity that

they generate is supplied by renewable energy (assuming that renewable energy has an emission factor of 0 lbs. CO_2e/MWh).

Table 16. GHG Reductions by Strategy [12]

	GHG Emission Reduction Potential ($mtCO_2e$) in 2030	GHG Emission Reduction Potential ($mtCO_2e$) in 2050
BUILDING EFFICIENCY		
1. Adhere to and Enforce Current Building Code	33,013	42,907
2. Implement Beyond Code Requirements	103,746	255,412
3a. Accelerate Fuel Switching (savings from natural gas)	196,063	232,839
3b. Accelerate Fuel Switching (increased electricity emissions)	(389,461)	(318,031)
4. Impose Mandatory Benchmarking	54,271	43,994
5. Increase the State's Energy Efficiency Resource Standard	92,858	108,597
6. Continue Boulder County's Suite of Energy Efficiency Programs	15,657	34,323
TOTAL	106,147	400,042
RENEWABLE ENERGY		
1. Continue Boulder County's Suite of Renewable Energy Programs	5,936	10,362
2. Expand rooftop solar	311,733	267,940
3. Expand community solar	31,389	26,979
4. Additional efforts	532,154	1,178,009
TOTAL	881,213	1,483,290
TRANSPORTATION		
1a. Accelerate Electric Vehicles: All-of-the-Above Strategy (savings from using less fossil fuel)	189,172	493,079
1b. Accelerate Electric Vehicles: All-of-the-Above Strategy (increased electricity emissions)	(86,111)	(199,674)
2. Support Clean Car Policies	261,166	90,369
3. Expand Public Transit	9,037	8,893
TOTAL	373,263	392,668
OIL AND GAS		
1. Support Regional and State Efforts to Control Methane Leaks	6,252	6,252
TOTAL	6,252	6,252
WASTE		
1. Reduce Food Waste	23,054	27,378
2. C&D and Composting Waste to Local Transfer Facility	257	305
3. Zero Waste Education	21,170	25,141
4. Municipal Zero Waste	86	109
5. Other Efforts Needed	26,466	31,424
TOTAL	71,033	84,356
OTHER		
1. Pursue Carbon Sequestration	29,861	75,800
2. Implement Carbon Tax	350,571	361,145
3. Carbon Intensive Industries Carbon Impact Offset Fund	24,798	24,798
TOTAL	405,230	461,743
TOTAL	**1,843,137**	**2,828,352**

[12] Further detail on each strategy, data inputs and assumptions, and the source of each assumption can be referenced in the corresponding tab in the spreadsheet titled Boulder County GHG Modeling Spreadsheet_060618.

Appendix A: Upstream Emission Benefits from Waste

The GPC Protocol, in which Boulder County's greenhouse gas (GHG) emissions inventory is based, requires local governments to report GHG emissions from landfilled waste but precludes local governments from reporting certain emissions avoided when recycling and composting materials. However, the "upstream" benefit can be reported separately, as an information-only item.

The GPC Protocol accounts for the methane released from landfills, while most of the products the community purchases also have emissions associated with their collection and manufacture outside of Boulder County. Waste reduction efforts contribute to significant emissions reductions by avoiding "upstream" GHGs emitted in the extraction, manufacturing, and transportation of raw materials, food, and goods. Hence, upstream-waste emissions must be calculated and shown separately from landfill emissions.

What is included in the GHG inventory:

The GHG inventory includes the emissions associated with landfilling waste. Direct emissions from recycling and composting are captured within the modeling and emissions inventory since recycling and composting—decreases landfilled waste, thus decreasing associated waste emissions.

The primary greenhouse gas emissions from waste disposal result from the natural decay of biological waste, the transport of solid waste to treatment and disposal facilities, incineration, and combustion of biologic and non-biologic waste. Recycling and composting can create emissions from the natural decay of biological waste (i.e. composting), collection vehicles, energy use at a material recovery facility, energy use to operate compost facility equipment, and the long-distance transport of recyclables and compost outside the community.

What is not included in the GHG inventory yet provided here for informational purposes:

Waste reduction efforts contribute to significant emissions reductions by avoiding "upstream" GHGs emitted in the extraction, manufacturing, and transportation of raw materials, food, and goods. These "upstream" emissions avoided cannot be included in the county inventory, yet they can be reported separately as an information-only item, per the GPC protocol.

This appendix has been included as information-only to highlight the upstream emission savings from recycling and composting and its importance to the overall sustainability of Boulder County. The upstream emissions of waste provide a holistic representation of Boulder County and its stakeholder's efforts in waste reduction.

Emission reductions occur by:

- avoiding raw material acquisition and manufacturing;
- avoiding the transport of the raw materials;

- increasing carbon stored in forests;
- reducing emissions associated with landfilling and combusting;
- improving water retention capacity, thus conserving water and reducing emissions associated with pumping and applying water; and
- reducing the application of synthetic fertilizers.

With the exception of reducing the amount of landfilled waste, these reductions are considered "upstream."

Upstream GHG Emission Savings from GHG Emission Reduction Strategies:

As shown in the table below, Boulder County has the potential for significant upstream waste-related GHG emissions savings with a projection of 774,351 $mtCO_2e$ by 2025 through the diversion of 358,902 tons of waste from the landfill thanks to recycling and composting. This is in addition to the already reported GHG emission savings from reduced landfilled waste, which can be found in the previous waste section of this report.

Figure 10. Upstream GHG Emission Savings from Waste

Strategy	Target Diversion	Target Year	Total Tonnage Savings (tons) in 2025	Total GHG Emission Savings in 2025 ($mtCO_2e$)
Increase Recycling and Composting	100%	2025	314,551	612,024
Divert All Food Waste from the Landfill	100%	2025	44,352	162,327
		TOTAL	**358,902**	**774,351**

Local government plays an important role in the development of waste diversion infrastructure, which helps lead to a healthier environment and a prospering economy. According to the 2016 EPA's Recycling Economic Information Study, the national average for recycling has led to 1.57 jobs and $14,101 in tax revenue for every 1,000 tons of material recycled.[13] That means for Boulder County, by meeting the 2025 goal to become a zero waste community, diversion from increased recycling and composting may lead to 563 jobs and $5,060,877 (though it should be clarified that the entire benefit may not be realized within the county).

[13] For more information see: https://www.epa.gov/recycle/recycling-basics.

Appendix B: Municipality Overviews

Overview of Municipalities GHG Emissions

The following is an overview of each municipality's 2016 GHG emissions. See each municipality's subsection for more detailed information on their 2016 GHG emissions. The methodology used by Boulder County to calculate emissions for each municipality may differ from how individual municipalities may have calculated their respective GHG inventories.

Figure 11. GHG Emissions by Municipality, 2016

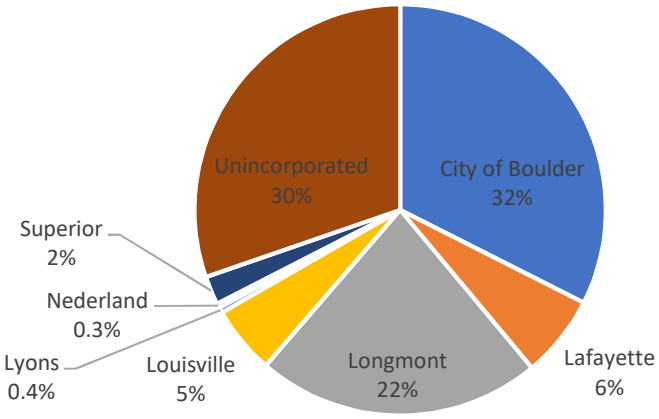
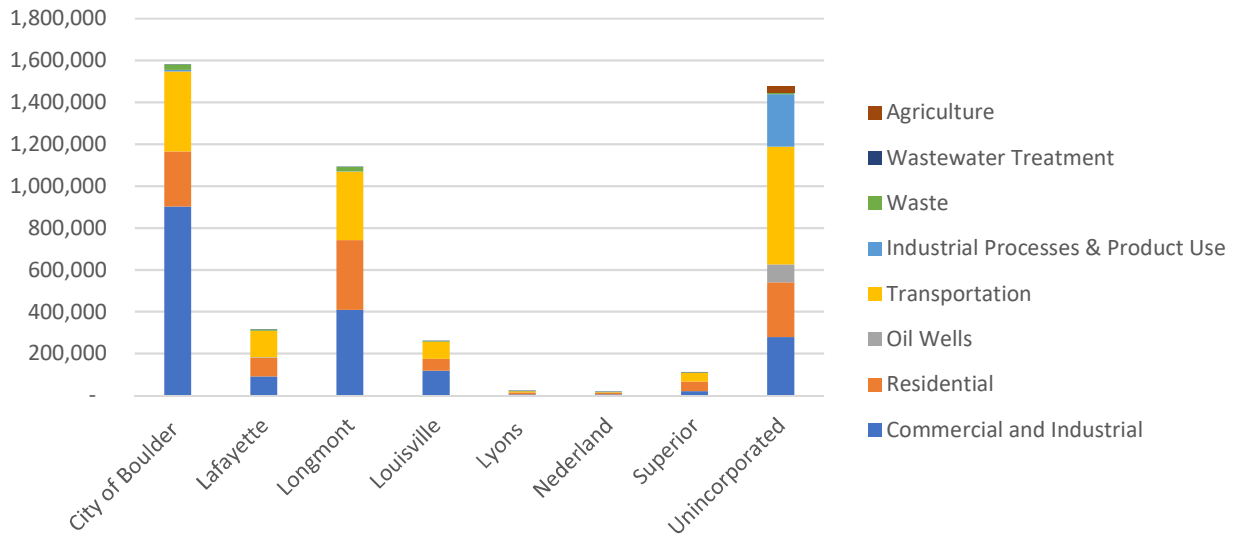
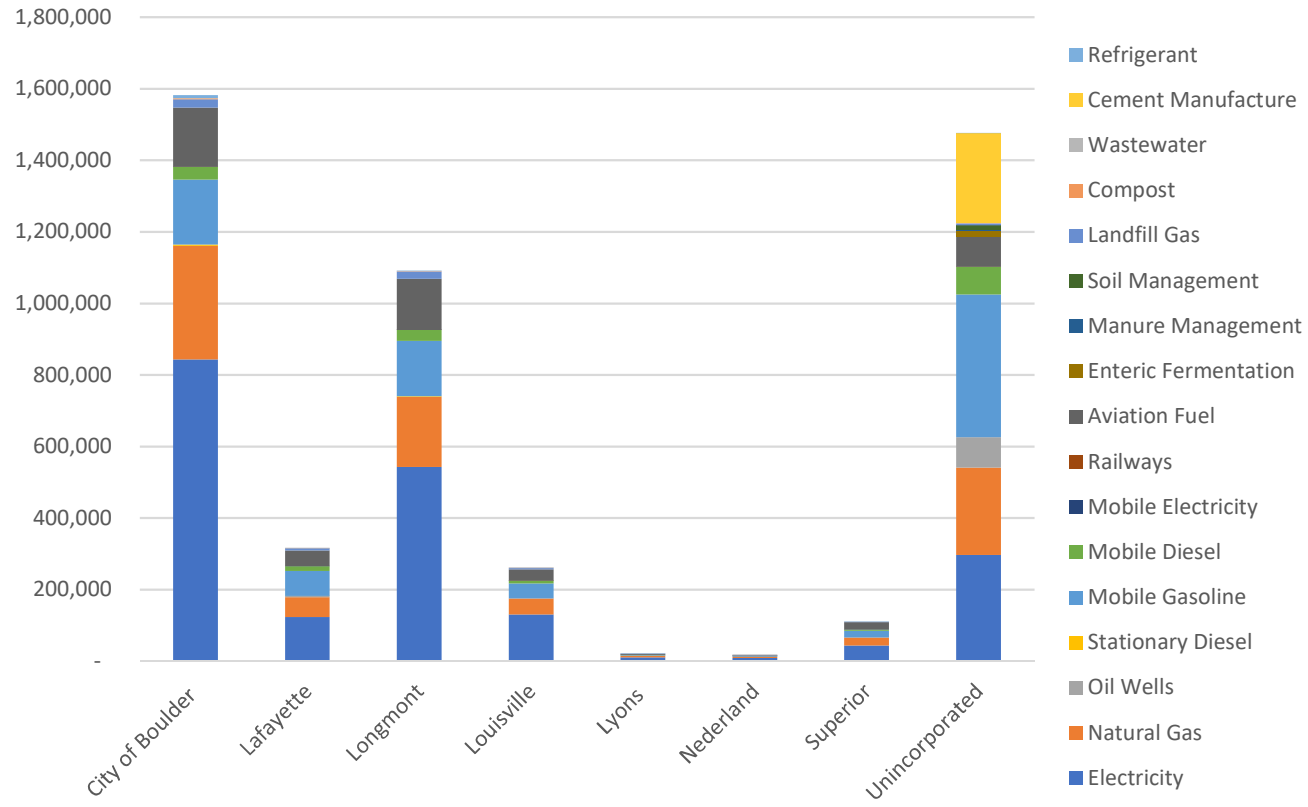


Figure 12. Emissions by Sector by Municipality, 2016[14]



[14] All GHG emissions occurring from industrial processes, product use, and non-energy uses of fossil fuel, are reported under Industrial Processes and Product Uses (IPPU). Energy use from industrial companies is reported under energy emissions.

Figure 13. Emissions by Source by Municipality, 2016



The following table provides an overview of each municipality's 2016 population, total emissions percent of total Boulder County emissions, and emissions per capita.

Table 17. Overview of Emissions per Municipality

Municipality	2016 Population	Total $mtCO_2e$	% of Total Emissions	Emissions per Capita
City of Boulder	108,020	1,581,618	32%	14.6
Lafayette	28,278	315,818	6%	11.2
Longmont	92,858	1,091,533	22%	11.8
Louisville	20,801	260,795	5%	12.5
Lyons	2,148	21,008	0.4%	9.8
Nederland	1,534	16,644	0.3%	10.9
Superior	13,155	109,834	2%	8.3
Unincorporated	55,432	1,475,786	30%	26.6
Boulder County Total	**322,226**	**4,873,034**	**100%**	**15.1**

City of Boulder

In 2016, the City of Boulder experienced the following GHG and economic trends:

- The City of Boulder was the most populous municipality in Boulder County with 108,020 residents.
- The total GHG emissions in 2016 for the City of Boulder was 1,581,618 $mtCO_2e$, which accounts for 32% of Boulder County's total GHG emissions.
- The average per capita emissions for the City of Boulder was 14.6 $mtCO_2e$ per resident, which is the second highest emissions per capita for a municipality in Boulder County.
- As shown in Figure 14, the commercial and industrial sector was the largest emitter of GHG emissions at 57%, followed by transportation at 24%, and the residential sector at 16%. The remaining sectors made up less than 3% of total emissions.
- As shown in Figure 15, electricity was the largest source of emissions at 53%, followed by natural gas at 20%, mobile gasoline at 11% and aviation fuel at 10%. The remaining sources accounted for less than 5% of total emissions.

Note: The methodology used by Boulder County to calculate emissions for each municipality may differ from how individual municipalities may have calculated their respective GHG inventories.

Figure 14. GHG Emissions by Sector for the City of Boulder, 2016

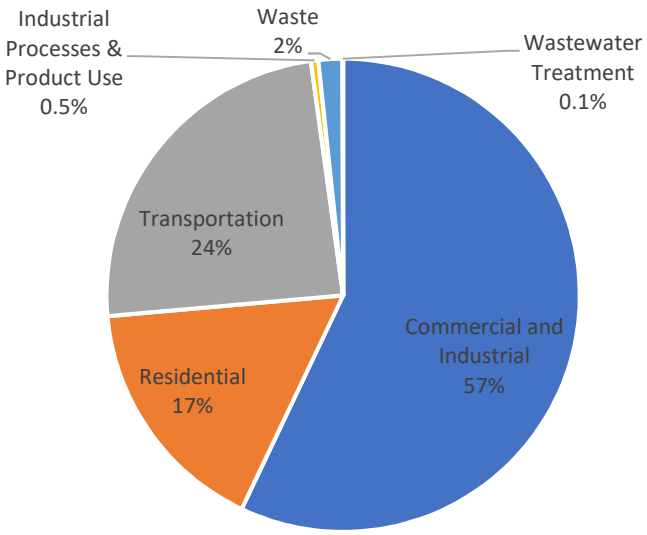
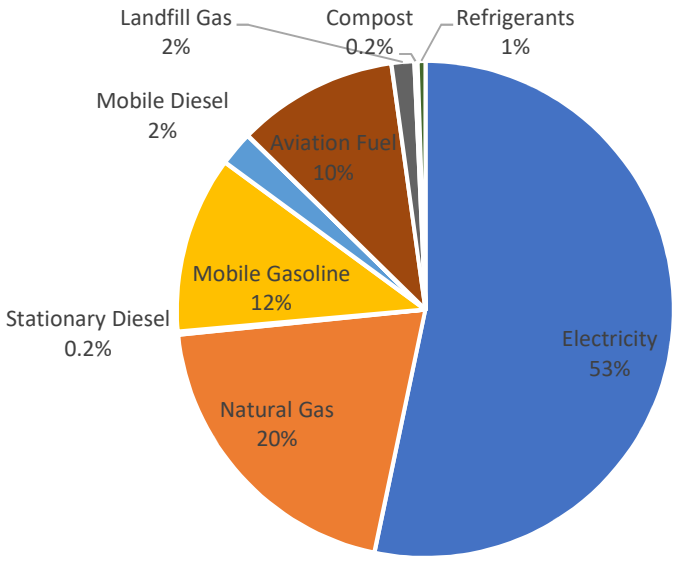


Figure 15. GHG Emissions by Source for the City of Boulder, 2016



City of Lafayette

In 2016, the City of Lafayette experienced the following emissions trends:

- The City of Lafayette had a population of 28,278 residents.
- The total GHG emissions in 2016 for the City of Lafayette was 315,818 $mtCO_2e$, which accounts for 6% of Boulder County's total GHG emissions.
- The average per capita emissions for the City of Lafayette was 11.2 $mtCO_2e$ per resident.
- As shown in Figure 16, the transportation sector was the largest emitter of GHG emissions at 40%, followed by the commercial and industrial sector at 28%, and the residential sector at 28%. The remaining sectors made up approximately 3% of total emissions.
- As shown in Figure 17, electricity was the largest source of emissions at 39%, followed by mobile gasoline at 22%, natural gas at 18% and aviation fuel at 14%. The remaining sources accounted for 8% of total emissions.

Note: The methodology used by Boulder County to calculate emissions for each municipality may differ from how individual municipalities may have calculated their respective GHG inventories.

Figure 16. GHG Emissions by Sector for the City of Lafayette, 2016

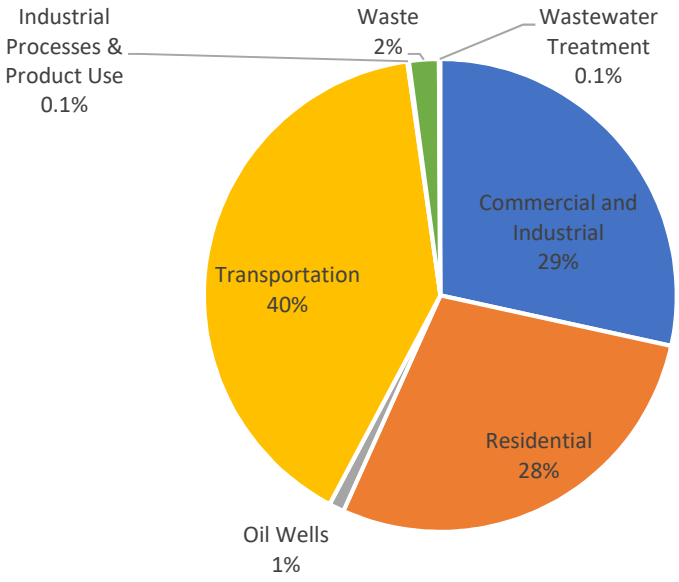
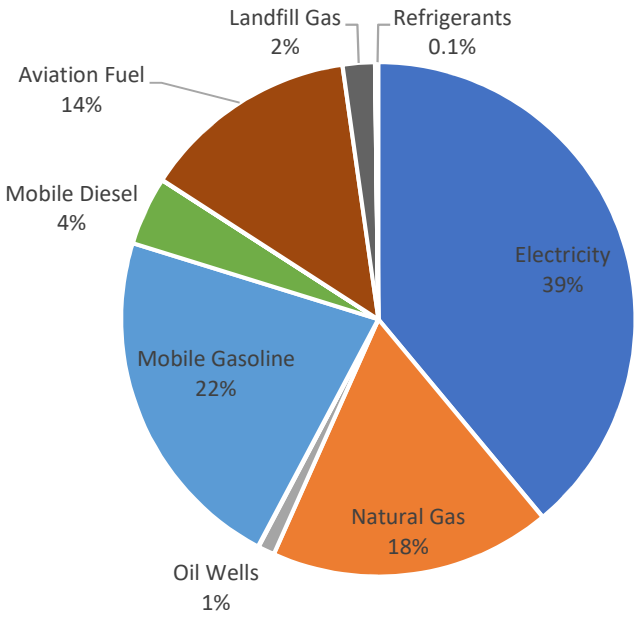


Figure 17. GHG Emissions by Source for the City of Lafayette, 2016



City of Longmont

In 2016, the City of Longmont experienced the following emissions trends:

- The City of Longmont had a population of 92,858 residents, making it the second most populous municipality in Boulder County.
- The total GHG emissions in 2016 for the City of Longmont was 1,091,533 $mtCO_2e$, which accounts for 22% of Boulder County's total GHG emissions.
- The average per capita emissions for the City of Longmont was 11.8 $mtCO_2e$ per resident.
- As shown in Figure 18, the commercial and industrial sector was the largest emitter of GHG emissions at 37%, followed by the residential sector at 30%, and the transportation sector at 30%. The remaining sectors made up less than 3% of total emissions.
- As shown in Figure 19, electricity was the largest source of emissions at 50%, followed by natural gas at 18%, mobile gasoline at 14%, and aviation fuel at 13%. The remaining sources accounted for approximately 5% of total emissions.

Note: The methodology used by Boulder County to calculate emissions for each municipality may differ from how individual municipalities may have calculated their respective GHG inventories.

Figure 18. GHG Emissions by Sector for the City of Longmont, 2016

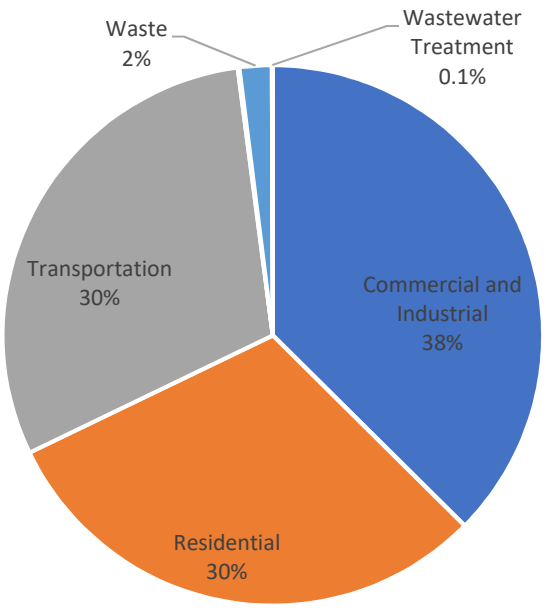
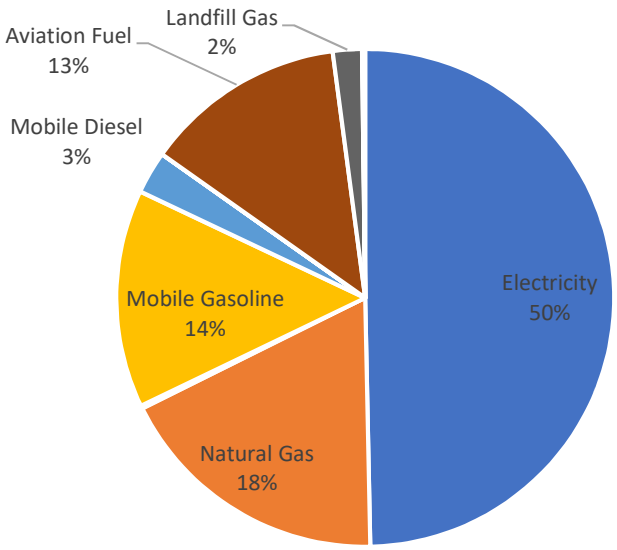


Figure 19. GHG Emissions by Source for the City of Longmont, 2016



City of Louisville

In 2016, the City of Louisville experienced the following emissions trends:

- The City of Louisville had a population of 20,801 residents.
- The total GHG emissions in 2016 for the City of Louisville was 260,795 $mtCO_2e$, which accounts for 5% of Boulder County's total GHG emissions.
- The average per capita emissions for the City of Louisville was 12.5 $mtCO_2e$ per resident.
- As shown in Figure 20, the commercial and industrial sector was the largest emitter of GHG emissions at 45%, followed by the transportation sector at 31%, and the residential sector at 22%. The remaining sectors made up less than 2% of total emissions.
- As shown in Figure 21, electricity was the largest source of emissions at 50%, followed by natural gas at 17%, mobile gasoline at 16%, and aviation fuel at 12%. The remaining sources accounted for less than 5% of total emissions.

Note: The methodology used by Boulder County to calculate emissions for each municipality may differ from how individual municipalities may have calculated their respective GHG inventories.

Figure 20. GHG Emissions by Sector for the City of Louisville, 2016

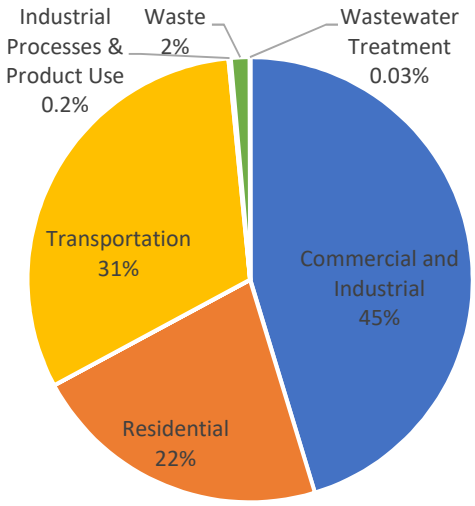
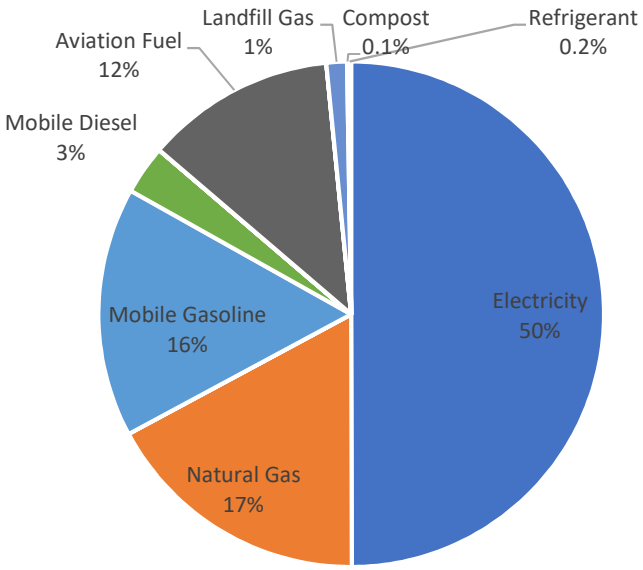


Figure 21. GHG Emissions by Source for the City of Louisville, 2016



Town of Lyons

In 2016, the Town of Lyons experienced the following emissions trends:

- The Town of Lyons had a population of 2,148 residents.
- The total GHG emissions in 2016 for the Town of Lyons was 21,008 $mtCO_2e$, which accounts for 0.4% of Boulder County's total GHG emissions.
- The average per capita emissions for the Town of Lyons was 9.8 $mtCO_2e$ per resident.
- As shown in Figure 22, the residential sector was the largest emitter of GHG emissions at 44%, followed by the transportation sector at 29%, and the commercial and industrial sector at 26%. The remaining sectors made up less than 3% of total emissions.
- As shown in Figure 23, electricity was the largest source of emissions at 49%, followed by natural gas at 20%, aviation fuel at 16%, and mobile gasoline at 11%. The remaining sources accounted for less than 5%.

Figure 22. GHG Emissions by Sector for the Town of Lyons, 2016

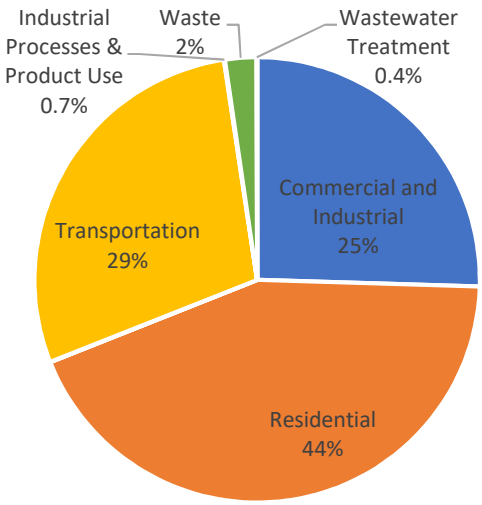
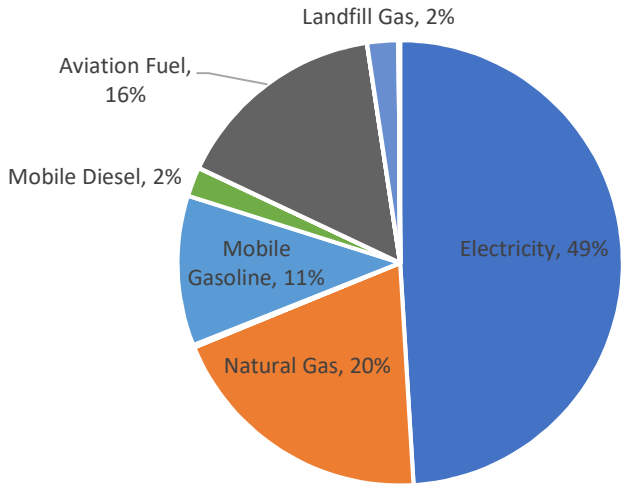


Figure 23. GHG Emissions by Source for the Town of Lyons, 2016



Town of Nederland

In 2016, the Town of Nederland experienced the following emissions trends:

- The Town of Nederland had a population of 1,534 residents.
- The total GHG emissions in 2016 for the Town of Nederland was 16,644 $mtCO_2e$, which accounts for 0.3% of Boulder County's total GHG emissions.
- The average per capita emissions for the Town of Nederland was 10.9 $mtCO_2e$ per resident.
- As shown in Figure 24, the residential sector was the largest emitter of GHG emissions at 46%, followed by the commercial and industrial sector at 27%, and the transportation sector at 24%. The remaining sectors made up less than 3% of total emissions.
- As shown in Figure 25, electricity was the largest source of emissions at 50.5%, followed by natural gas at 23 %, aviation fuel at 14%, and mobile gasoline at 8%. The remaining sources accounted for less than 5% of total emissions.

Figure 24. GHG Emissions by Sector for the Town of Nederland, 2016

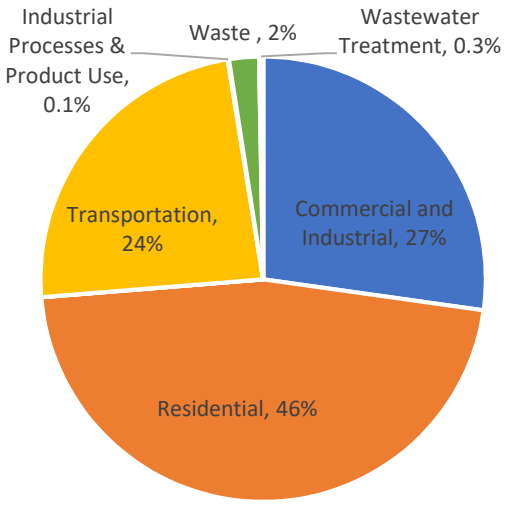
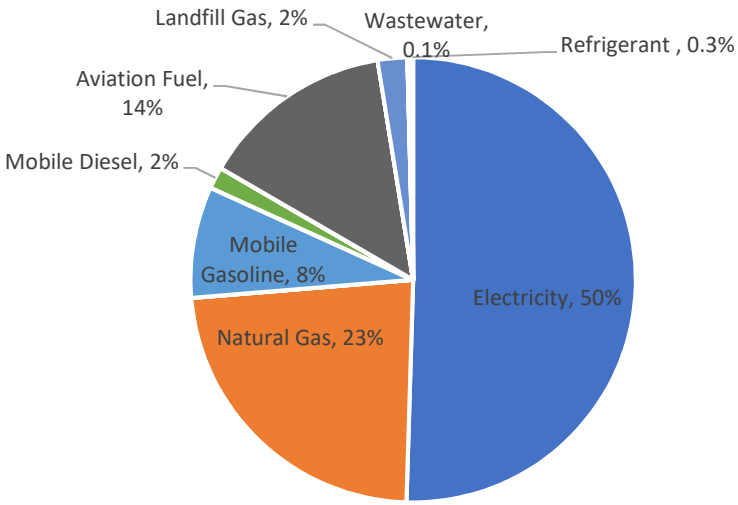


Figure 25. GHG Emissions by Source for the Town of Nederland, 2016



Town of Superior

In 2016, the Town of Superior experienced the following emissions trends:

- The Town of Superior had a population of 13,155 residents.
- The total GHG emissions in 2016 for the Town of Superior was 109,834 $mtCO_2e$, which accounts for 2% of Boulder County's total GHG emissions.
- The average per capita emissions for the Town of Superior was 8.3 $mtCO_2e$ per resident, the lowest for all municipalities in Boulder County.
- As shown in Figure 26, the residential sector was the largest emitter of GHG emissions at 41%, followed by the transportation sector at 39%, and the commercial and industrial sector at 19%. The remaining sectors made up approximately 1% of emissions of total emissions.
- As shown in Figure 27, electricity was the largest source of emissions at 39.4%, followed by natural gas at 20%, aviation fuel at 18%, and mobile gasoline at 17%. The remaining sources accounted for less than 5% of total emissions.

Figure 26. GHG Emissions by Sector for the Town of Superior, 2016

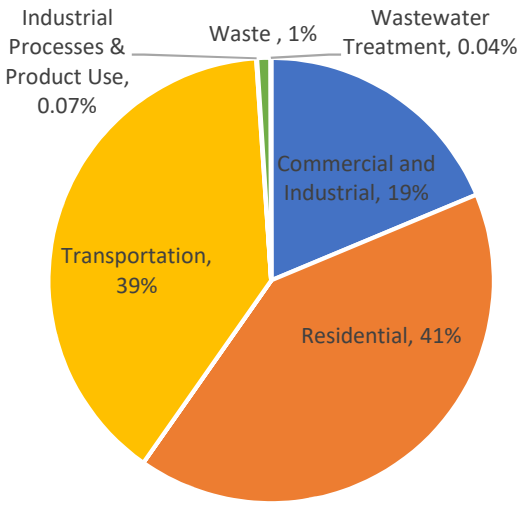
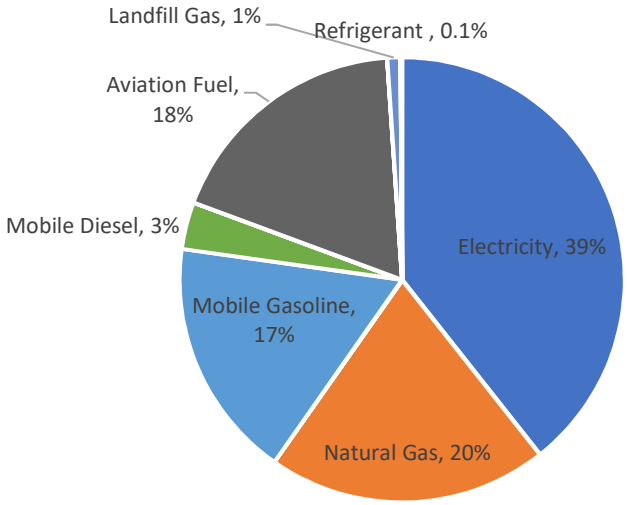


Figure 27. GHG Emissions by Source for the Town of Superior, 2016



Unincorporated Boulder County

In 2016, the areas of unincorporated Boulder County experienced the following emissions trends:

- The unincorporated areas had a population of 55,432 residents.
- The total GHG emissions in 2016 for the unincorporated areas was 1,475,786 $mtCO_2e$, which accounts for 30% of Boulder County's total GHG emissions.
- The average per capita emissions for unincorporated Boulder County was 26.6 $mtCO_2e$ per resident, the highest for all disaggregated areas of Boulder County.
- As shown in Figure 28, the transportation sector was the largest emitter of GHG emissions at 38%, followed by the commercial and industrial sector at 19%, the residential sector at 18%, and the IPPU sector at 17%. The remaining sectors made up approximately 8% of emissions.
- As shown in Figure 29, mobile gasoline was the largest source of emissions at 27%, followed by electricity at 20%, cement manufacturing at 17%, and natural gas at 17%. The remaining sources accounted approximately 14% of total emissions.

Figure 28. GHG Emissions by Sector for Unincorporated Boulder County, 2016

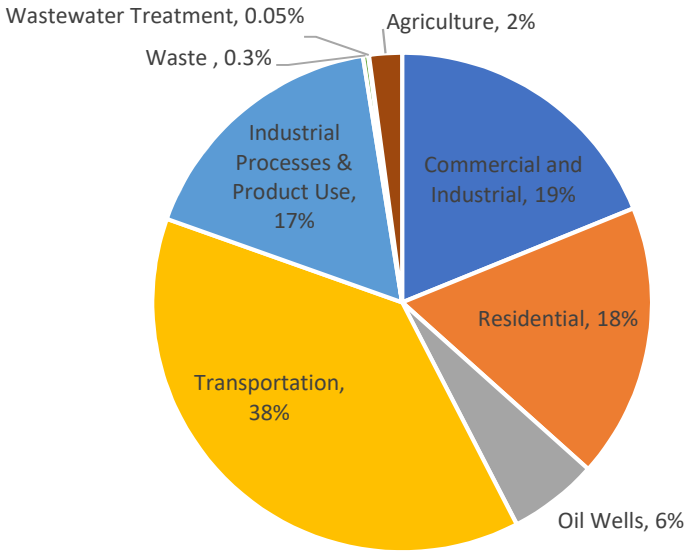
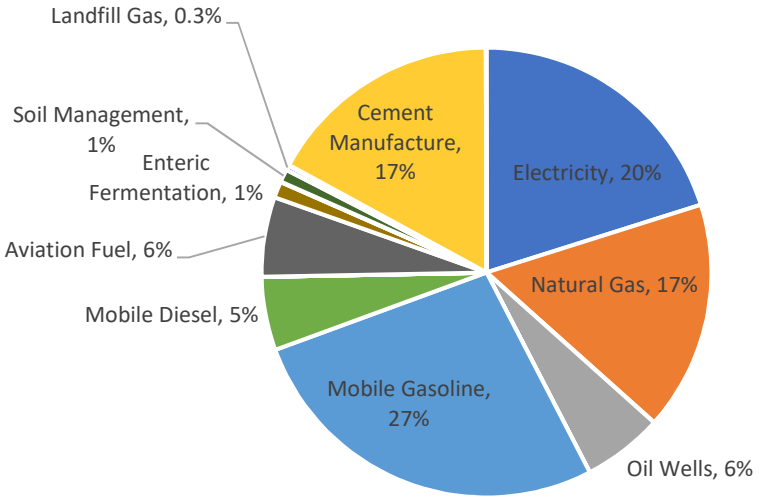


Figure 29. GHG Emissions by Source for Unincorporated Boulder County, 2016



Appendix C: Overview of Emission Factors

Boulder County is served by six utilities: Xcel Energy, Estes Park Light and Power, Longmont Power and Communications, Poudre Valley Rural Electric Association, Lyons, and United Power. Each electric utility has a different resource mix (i.e. renewable energy, natural gas, coal, nuclear) and therefore a different emission factor. Emission factors are represented in units of carbon dioxide equivalent (CO_2e), which combines the respective global warming potentials (GWP) of the various GHGs.

Colorado's Renewable Energy Standard[15] and the state's Clean Air Clean Jobs Act[16] require all Colorado utilities to increase their efficiency in their own operations and procure increasing amounts of energy from low- to zero-carbon sources (i.e. renewable energy, recycled energy, etc.) through 2020. As a result, the mix of energy sources that utilities supply the electric grid changes every year, and the resulting electricity emission factor decreases every year.

The 2011 emission inventory used Environmental Protection Agency's Emissions & Generation Resource Integrated Database (eGRID) emission factors for electricity. These factors are based off the Rocky Mountain Power Authority sub-region called WECC Rockies.[17] The 2016 inventory electricity emission factors ($mtCO_2e/MWh$) were based on emission factor or resource mix data from the six utilities providing service in Boulder County. As shown in Table 18, five of the utilities electricity emission factors used in the 2011 and 2016 GHG inventories decreased between 2% and 31% between 2011 and 2016. The Town of Lyons utilities emission factor increased by 0.6% during the same time period.

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

[16] For more information, see: https://www.xcelenergy.com/environment/system_improvements/colorado_clean_air_clean_jobs.

[17] For more information see: https://www.epa.gov/energy/emissions-generation-resource-integrated-database-egrid

Table 18. Changes in Electricity Emission Factors

	Utility	Locations Served	2011	2016	Change since 2011
Electricity Emission Factors ($mtCO_2e$/ MWh)	Xcel Energy	Boulder, Louisville, Lafayette, Longmont, Nederland, Superior, Unincorporated/other	0.8278	0.6044	-26.9%
	Longmont Power and Communications and Estes Park Light and Power	Longmont	0.8278	0.7452	-9.9%
	Poudre Valley REA	Unincorporated/other, Lyons	0.8278	0.7404	-10.6%
	Lyons	Lyons	0.8278	0.8330	0.6%
	United Power	Unincorporated/other	0.8278	0.5700	-31.1%

Emission factors for other emission sources (natural gas, gasoline, etc.) were minor or stayed consistent between 2011 and 2016.

The reduction in the electricity emission factors for five of the six utilities serving Boulder County is the largest cause of reduced emissions from electricity use in the residential and C&I sectors.

Appendix D: Detailed Descriptions of GHG Emission Reduction Strategies

The following is an overview of top strategies and policies identified by Lotus that have the potential to considerably reduce GHG emissions. The analysis was completed by looking only through the lens of GHG reductions. Secondary benefits or risks were not considered during this analysis. The strategies will help set the County on a path to achieve the Paris Climate Agreement Goal which will help prevent a global temperature increase of 1.5-2 degrees C. This review was completed by performing the following tasks:

- Reviewing numerous reports and studies completed on behalf of Boulder County regarding potential GHG reduction strategies, policies, and regulations including:
    - Boulder County's Sustainable Energy Plan (SEP) developed by Boulder County in partnership with many other cities/towns in 2008
    - Boulder County's Environmental Sustainability Plan adopted in 2013
    - Boulder County's 2012 GHG Inventory developed by WSP
    - Boulder County's 2015 Sustainability Impact Analysis Report by Natural Capitalism Solutions
- Reviewing the current policy efforts being considered by Boulder County including:
    - The Colorado Community for Climate Action (CC4CA) Policy Agenda
    - An updated House Bill 07-1146 which requires all local governments to adopt and enforce an International Energy Conservation Code (IECC) Code that meets or exceeds a minimum version (i.e. the original bill states that they will enforce or exceed the IECC 2003 standard).
- Reviewing comparable city's and county's sustainability goals, including: Boulder, Denver, Fort Collins, Broomfield, Longmont, Marin County, CA, Sonoma County, CA, King County, WA, Miami-Dade, FL and Summit County, UT.
- Identifying GHG reduction strategies based off Lotus's deep expertise working with dozens of municipalities on their climate action plans.

This work was reviewed and supplemented by the following experts:

- Taryn Finnesey with the Colorado Department of Public Health and Environment
- Tom Plant with the Center for the New Energy Economy
- Will Toor with the Southwest Energy Efficiency Project
- Amelia Myers with Conservation Colorado
- Stacy Tellinghuisen with Western Resource Advocates (WRA)

Overview of GHG Emissions

To understand which GHG emission reduction policies and strategies to select, it is important to have a strong understanding of which sectors and sources are attributing the highest GHG emissions. Emissions by sector are especially important to look at since many programs and policies specifically target sectors. For example, Boulder County's EnergySmart program focuses solely on the commercial and residential sectors. In 2016, the commercial, transportation, and residential sectors made up almost 92% of Boulder County's total GHG emissions. Industrial process and oil wells together made up 5% with the remaining sectors representing approximately 2%. In addition, it is important to note which sector's emissions are increasing. Of the top four emitters, commercial and residential energy building use is decreasing (mostly due to decreased emission factors for electricity), while transportation and industrial process emission are increasing.

It is also important to understand GHG emissions by source. For example, Boulder County's renewable energy policies focus only on electricity; while the county's sustainable agricultural practices program focus on manure management. In 2016, electricity, natural gas, gasoline, and aviation fuel made up 89% of the total GHG emissions. Of the top four emitters, electricity emissions and mobile gasoline emissions are decreasing, while natural gas and aviation fuel emissions are increasing.

Though it is important for Boulder County to address all GHG emissions, Lotus recommends focusing the majority of Boulder County's staff time, money, and political capital on top GHG emitters where they have significant or moderate control. As such, our recommendations focus on the commercial, transportation, and residential sectors and electricity, natural gas, and gasoline sources. Note that some sectors and sources will be affected indirectly due to these policies.

Note: Aviation/jet fuel accounts for 10% of the counties GHG emissions. Air traffic management practices, new aircraft technology, and developing sustainable alternative fuels are helping reduce GHG emissions per flight; however, each of those strategies are unlikely to be achieved through a county's policies or programs. Therefore, we have not provided any strategies for aviation fuel.

Summary of Strategies, Programs, and Policies

Many of the current programs and policies that are occurring in Boulder County that help reduce GHG reductions are not listed below; however, it does not mean that they are not valuable in reducing GHG emissions or providing secondary benefits such as reduced costs or improved air quality. Instead the following are meant to highlight the most impactful GHG strategies. Also, it should be noted that some of the strategies might be better accomplished on a state, regional, or city level. However, we believe it is possible for

Boulder County to play a role in starting, leading, bolstering, or lobbying for these strategies. Table 19 shows the recommended strategies for Boulder County.

Table 19. GHG Reduction Strategies by Sector

Sector	Objective	Specific Strategy
Building Energy	Implement deep carbon reductions in buildings to reduce energy consumption	Adhere to and Enforce Current Building Code
		Implement Beyond Code Requirements
		Accelerate Fuel Switching
		Impose Mandatory Benchmarking
		Increase the State's Energy Efficiency Resource Standard
		Continue Boulder County's Suite of Energy Efficiency Programs
Renewable Energy	Accelerate Solar Energy Adoption: All-of-the-Above Strategy	Continue Boulder County's Suite of Renewable Energy Programs
		Expand Rooftop Solar
		Expand Community Solar
		Additional Efforts
Transportation	Increase the adoption of electric vehicles	Accelerate Electric Vehicles: All-of-the-Above Strategy
	Reduce carbon intensity of vehicle travel	Support Federal and/or State Clean Car Policies
	Reduce single-occupancy vehicle travel	Expand Public Transit
Oil and Gas	Support regional and state efforts to control methane leaks	Adopt and Enforce Leak Detection and Repair
Waste	Strive for zero waste	Reduce Food Waste
		C&D and Composting Waste to Local Transfer Facility
		Promote Zero Waste Education
		Strive for Municipal Zero Waste
		Conduct Other Efforts as Needed
Other Carbon Reduction Strategies	Implement community-wide comprehensive carbon reduction programs	Pursue Carbon Sequestration
		Implement Carbon Tax
		Carbon Intensive Industries Carbon Impact Offset Fund

Building Energy

Electricity is currently the top GHG emitter for Boulder County (41%) and is expected to continue to be top emitter for the near future. Although GHG emissions from electricity have reduced by 25% since 2011, usage has decreased by only 1%. The large emission reductions are due to the increase in renewable energy on the grid. Due to competitive renewable energy prices and growing consumer demand, it is expected that demand for renewable energy will rapidly increase; however, there is inconsistency between Boulder County's five utilities on how quickly they are moving towards renewable energy.

In addition, it is also expected that the demand for electricity will increase or stay flat over time due to the increase in population, square footage, electric vehicles, and fuel switching (switching from natural gas to electricity). Together these trends show that electricity should be a top priority for Boulder County's GHG reduction strategy.

Natural gas is currently the second largest GHG emitter for Boulder County (18%) and could potentially be the top emitter in the near future, surpassing electricity. GHG emissions from natural gas have increased by 0.8% between 2005 and 2016. Unlike electricity, the emission factor is likely to stay flat (i.e. natural gas is not becoming cleaner). Boulder County has the potential to reduce GHG emissions from natural gas through demand for natural gas at the site (where it is being used (i.e. buildings)) and stricter regulations on natural gas wells.

Strategies 1 and 2: Adhere to and Enforce Current Code and Implement Beyond Code Requirements

Between 2011 and 2016, commercial square footage increased in Boulder County by over 23%, population rose by 8%, and the number of housing units rose by 6%. All of these trends lead to an increased amount of new and remodeled square footage. The following would drastically reduce GHG emissions:

- Encourage or require (if possible) all Boulder County communities to have codes that match the most recent IECC codes
- Continually improve codes (ideally on a three-year basis each time a new IECC code is released) by creating new policies or ordinances
- Enforce energy codes
- Continue to increase building codes to require net-zero energy consumption for new buildings and to be significantly more stringent for existing buildings, through policy or ordinance

Note that Boulder County would need to figure out the best way for them to influence this strategy since cities are the primary enforcers of building codes.

- **Plans That Agree:** SEP Plan, NREL City Policies report, Boulder County's Environmental Sustainability Plan, WSP GHG Inventory, House Bill 07-1146
- **Other Cities/Counties with Similar Goals:** Denver, King County, WA, Sonoma County, CA, Cleveland, OH, Summit County, UT, and Miami-Dade County, FL

Strategy 3: Fuel Switching

As the grid continues to become cleaner, Boulder County should start to convert commercial and residential buildings from natural gas heating to electric heating. This will significantly reduce natural gas emissions, by providing electric heat from a no- to low-carbon source.

Specific policies and programs could include: building code requirements and targeted rebates.

- **Plans That Agree:** N/A
- **Other Cities/Counties with Similar Goals:** Denver, Fort Collins, City of Boulder, Sonoma County, CA, Cleveland, OH, and Vancouver, BC

Strategy 4: Impose Mandatory Benchmarking

According to research completed for the Energize Denver project, benchmarking and transparency requirements have resulted in a 2-3% energy savings each year. Some cities have seen even higher reductions ranging from 5-11%.[18]

Boulder County could require all commercial buildings in Boulder County over a certain size to publicly benchmark and report energy consumption.

- **Plans That Agree:** NREL City Policies
- **Other Cities/Counties with Similar Goals:** Denver, State of California

[18] Source: https://www.denvergov.org/content/denvergov/en/environmental-health/environmental-quality/Energize-Denver/CommercialMultifamilyBuildingBenchmarking.html

Strategy 5: Increase the State's Energy Efficiency Resource Standard

House Bill 1227, signed in June 2017, extends electric efficiency programs to 2028 and requires the Public Utilities Commission to set goals of at least 5% peak demand reduction and 5% energy savings by 2028 for demand-side management programs implemented during 2019 through 2028 when compared to 2018. However, many experts believe this bill was not stringent enough.

Boulder County could lobby for the Energy Efficiency Resource Standard to increase and potentially be expanded to co-operative and municipal utilities.

- **Plans That Agree:** CC4CA
- **Other Cities/Counties with Similar Goals:** Denver and Sonoma County, CA

Strategy 6: Continue Boulder County's Suite of Energy Efficiency Programs

Boulder County currently offers numerous residential and commercial programs and policies. Since 2011, GHG emissions from residential sector buildings have decreased, while GHG emissions from the commercial sector have increased. While both residential and commercial sectors must be addressed in energy efficiency programs and policies, commercial programs might need to be prioritized in the short run to start reversing the trend of increased GHG emissions. We recommend continuing to be aggressive in energy efficiency programs and policies but focus in on carbon reductions.

Boulder County could continue to support their energy efficiency and renewable energy programs (e.g. Partners for a Clean Environment, EnergySmart, BuildSmart, Weatherization, etc.) with additional funding and emphasis on GHG reductions.

- **Plans That Agree:** NREL City Policies, NCS Analysis, Boulder County's Environmental Sustainability Plan, and SEP Plan
- **Other Cities/Counties with Similar Goals:** All cities and counties reviewed

Renewable Energy

Many of Boulder County's utilities have increased their renewable energy due to Colorado's Renewable Portfolio Standard (RPS). The RPS requires Investor-Owned Utilities to acquire 30% of their energy mix from renewable energy sources by 2020, co-operative utilities over 100,000 meters to acquire 20% of their energy mix from renewable energy sources by 2020, and co-operative utilities under 100,000 meters and municipal utilities serving more than 40,000 meters to acquire 10% of their energy mix from renewable energy

sources by 2020. This policy will sunset in 2020; a utility would not have to increase their renewable energy allocation over their mandated percentage past 2020.

Strategy 7: Continue Boulder County's Suite of Renewable Energy Programs

Boulder County currently offers numerous residential and commercial programs and policies. We recommend continuing to be aggressive in renewable energy programs and policies.

Boulder County could continue to support their renewable energy programs (e.g. Partners for a Clean Environment, EnergySmart, BuildSmart, Weatherization, etc.) with additional funding and emphasis on GHG reductions.

- **Plans That Agree:** NREL City Policies, NCS Analysis, Boulder County's Environmental Sustainability Plan, and SEP Plan
- **Other Cities/Counties with Similar Goals:** All cities and counties reviewed

Strategies 8-10: Expand Rooftop Solar, Community Solar, and Additional Renewable Energy Efforts

Three specific strategies were added to the analysis after conversation with the experts had concluded:

- Expand rooftop solar on viable rooftops.
- Expand community solar to viable land areas.
- Pursue additional renewable energy strategies to help achieve 100% renewable energy by 2030.

These efforts were highlighted by Boulder County as options to help drastically reduce GHG emissions.

Transportation

Generally, emissions from gasoline are on a downward trajectory due to more efficient vehicles. As more businesses and people move to Boulder County, it is expected that gasoline emissions will remain constant or potentially increase due to the growth in number of vehicles and vehicle miles traveled from longer commutes. It is very possible that the ground transportation sector will become the largest emitter in the near future surpassing residential and commercial buildings; however, if transportation policy, programs, and strategies are pursued correctly it is possible that ground transportation emissions will drastically reduce in the near and mid-term.

Note that each of the recommended policies below will most likely reduce mobile diesel as well.

Also, a note about biodiesel and compressed natural gas: historically many cities have recommended the usage of biodiesel and compressed natural gas due to potential GHG reductions; however, in recent years many cities are no longer considering these strategies due to costs, availability, and minimal GHG reduction potential (over the long run compared to electric vehicles). Therefore, we did not consider biofuels or CNG in our analysis. Note that Will agreed with this statement that alternative fuels are good for niche vehicles but are not scalable.

Strategy 11: Electric Vehicles (EV): All-of-the-above Strategy

The Colorado Energy Office's 2015 *Colorado Electric Vehicle Market Implementation Study* estimated that each individual electric light duty vehicle accounts for an average annual reduction in GHG emissions of approximately 37%, compared to the typical gasoline-powered light duty vehicle in 2015.[19] As the energy mix becomes increasingly cleaner, the emissions reductions will continue to improve (potentially to a 100% reduction in emissions if 100% renewable energy is supplied to grid). However, according to the report even in a high electric vehicle growth scenario, by 2030 EVs will only account for 15.5% of all light duty vehicles on the road in Colorado (assumes a 44.2% year-over-year growth in electric vehicle sales). To reach significant GHG reductions in the transportation sector, electric vehicle penetration must increase rapidly.

Potential options for Boulder County to pursue: Bulk Buying Programs, Tax Free Purchasing, Feebates (one-time fee on buyers who purchase higher emission vehicles), and regulations.

- **Plans That Agree:** SEP Plan, NCS Analysis, Boulder County's Environmental Sustainability Plan, CC4CA, and NREL City Policies
- **Other Cities/Counties with Similar Goals:** All cities and counties reviewed

Strategy 12: Support Clean Car Policies

The Corporate Average Fuel Economy, or CAFE standard, is a federal regulation that requires vehicle manufacturers to improve gas mileage and decrease emissions. As the vehicle fleet turns over, more efficient vehicles will replace less efficient ones, and as a result, the carbon intensity of the miles traveled by vehicles will continue to drop. This represents an enormous opportunity for Boulder County to capitalize on these federal regulations. Clean car standards can help ease the per-capita emissions of all drivers. CAFE standards are currently being debated at the national level and could potentially be eliminated. If so, Colorado will need to help with the reductions.

[19] For more information see: https://www.colorado.gov/pacific/energyoffice/atom/14086

Boulder County could encourage clean car standards for Colorado or the region.

- **Plans That Agree:** SEP Plan, Boulder County's Environmental Sustainability Plan, Western Resource Advocates
- **Other Cities/Counties with Similar Goals:** City and County of Denver, Sonoma County, CA, Cleveland, OH

Strategy 13: Expand Public Transit

A top priority to reduce GHG emissions must include decreasing single-occupant vehicles (SOVs). Developing a countywide rapid public transit network that includes buses, light rail, and first- and last-mile connections will help reduce GHG emissions while increasing quality of life.

Boulder County could include numerous strategies and policies including expanded rapid transit and free/reduced cost eco-passes.

- **Plans That Agree:** SEP Plan, NCS Analysis, Boulder County's Environmental Sustainability Plan CC4CA, and NREL City Policies
- **Other Cities/Counties with Similar Goals:** All cities and counties reviewed

Oil and Gas

Currently natural gas wells currently account for only 1.8% of Boulder County's emissions but that could quickly rise with the recent end of the moratorium on oil and gas development in Boulder County. For example, in March 2017, Crestone Peak Resources proposed opening up to 216 new wells in Boulder County. This application alone, if permitted, would increase the number of active wells in Boulder County by 73% (in 2016 there were 298). In addition, oil and gas extraction is a large GHG and volatile organic compound (VOC) emitter for the State of Colorado and is expected to increase annually with the increase in drilling and pipelines.

Strategy 14: Support regional and state efforts to control methane leaks

In Colorado, the amount of methane leaked from oil and gas sector is expected to rise as more wells are drilled and infrastructure for oil and gas is increased. Oil and gas accounts for less than 2% of Boulder County's GHG emissions but that number is expected to rise.

Boulder County should support an additional round of methane regulations through PUC or legislator.

- **Plans That Agree:** Western Resource Advocates
- **Other Cities/Counties with Similar Goals:** Longmont

Waste

Strategies 15-19: Waste Reduction and Diversion Rates

Five specific strategies were added to the analysis after conversation with the experts had concluded including:

- Reduce Food Waste: Reduce all food waste through source reduction campaign.
- C&D and Composting Waste to Local Transfer Facility: Develop a construction and demolition (C&D) local processing facility. Divert all C&D waste produced in the county to the facility.
- Promote Zero Waste Education: Educate the residential and commercial sectors on ways to reduce waste using existing infrastructure.
- Strive for Municipal Zero Waste: Reduce waste produced in all municipal buildings.
- Conduct Other Efforts as Needed: Represents remaining emissions that must be reduced through existing efforts that may be hard to quantify and/or new efforts.

These efforts were highlighted by Boulder County as options to help drastically reduce GHG emissions.

Other Carbon Reduction Strategies

Carbon sequestration through forestry, land management, and agricultural practices can play a large role in helping reduce GHG emissions. It should be noted that the GHG protocol currently used by Boulder County (i.e. GPC) does not count carbon sequestration towards overall GHG emissions. However, this may change. In addition, even though carbon sequestration is not counted, it does not mean that is not reducing GHG emissions.

Strategy 20: Pursue Carbon Sequestration

Boulder County could create a carbon sequestration program that encourages or requires carbon sequestration strategies.

- **Plans That Agree:** NCS Analysis, Boulder County's Environmental Sustainability Plan, Western Resource Advocates
- **Other Cities/Counties with Similar Goals:** City and County of Denver, Marin County, CA, Sonoma County, CA, and Miami-Dade County, FL

Strategy 21: Implement Carbon Tax

A carbon tax is a fee imposed on the burning of carbon-based fuels (e.g. coal, oil, and gas). A carbon tax can act as the core policy for reducing GHG emissions, while helping account for the externalities of fossil fuels.

Boulder County could impose a carbon tax to help incentivize a reduction in fossil fuels to help provide funding for the aforementioned strategies.

- **Plans That Agree:** N/A
- **Other Cities/Counties with Similar Goals:** Denver, all municipalities in California already effected by cap-and-trade.

Strategy 22: Carbon Intensive Industries Carbon Impact Offset Fund

The creation of a Carbon Intensive Industries Carbon Impact Offset Fund was added to the analysis after conversations with the experts had concluded. The strategy would impose a carbon tax on energy intensive industries including marijuana and oil and gas industries. For example, marijuana growers could be required to offset 100% of electricity consumed by a no-carbon source. Oil and gas industries would be required to achieve a certain level of efficiency and would be taxed on methane released that exceeds the pre-determined level of efficiency.

Note that this effort was highlighted by Boulder County as an option to help drastically reduce GHG emissions after conversations with experts were concluded.