2007 Chaffee County, Colorado Greenhouse Gas Inventory Report

Prepared by:
Alexander Dismore

Supervised by:
Dr. Anu Ramaswami, Alison Culpen, and Luann Rudolph

Center for Sustainable Infrastructure Systems
University of Colorado Denver
www.cudenver.edu/IGERT

Executive Summary

As climate mitigation and adaptation move to the forefront of local and state policies, many local governments are beginning to assess their greenhouse gases (GHG) emissions. One tool for policymakers is a greenhouse gas inventory in which all of the emissions in an area are quantified by sector and source. Greenhouse gas inventories allow local governments to target specific sectors for emission reductions as well as to benchmark their emissions against similar areas, set quantifiable reduction goals, and measure progress.

Chaffee County is a rural area with significant agricultural activity, located in a mountainous region of central Colorado. This report uses a comprehensive inventory method based on Ramaswami et. al's demand-centered method,[1] incorporating elements from other accepted protocols, to develop a greenhouse gas emissions footprint for Chaffee County. Although the sources of the emissions are very different, this report finds that citizens of Chaffee County have similar per-capita greenhouse gas emissions to those of the nearest large city, Denver.

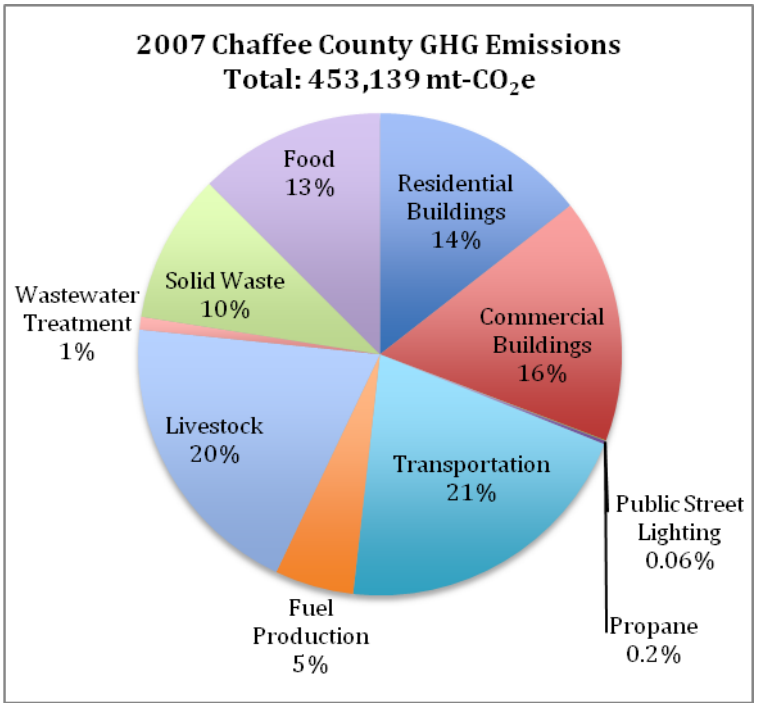

Figure ES 1: Chaffee County 2007 GHG Emissions

1: Ramaswami, A., T. Hillman, B. Janson, M. Reiner, and G. Thomas. "A Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories." *Environmental Science & Technology* 42 (September 2008): 6455-6461.

Table of Contents

Greenhouse Gas Accounting

In recent years, increasing interest in sustainability and the protection of the global climate has lead to an increased awareness of the impact of human activities on our environment. One such impact is the release of gases that have the potential to trap heat from the sun within the atmosphere, collectively dubbed "greenhouse gases" or GHGs. In sufficient quantities these chemicals have the potential to alter the Earth's climate, so it has become a priority to substantially reduce GHG emissions caused by human activity. However, before we can take steps to reduce emissions of GHGs, it is necessary to understand their sources.

Greenhouse Gases

The major greenhouse gases are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and several industrial compounds called "chlorofluorocarbons." Of these, the first three are the most important, are released in substantial quantities, and have the greatest impact on the planet, and will be considered in this report. CO_2 is produced primarily from burning fossil fuels and is the largest contributor to global warming. CH_4 is produced largely from waste decomposition (naturally or in landfills) and from fugitive emission in natural gas pipelines and wastewater treatment. Chlorofluorocarbons may be omitted unless significant production occurs in the region of interest. The different GHGs have different global warming potential (ability to trap heat in the atmosphere); their emissions are reported together on a common standardized basis as metric tons of carbon dioxide equivalent, or mt-CO_2e. For example, one ton of methane can trap 21 times as much heat in the atmosphere as a ton of carbon dioxide.[2] Therefore 1 mt-CH_4 is equal to 21 mt-CO_2e.

GHGs and Sustainability

Almost every facet of modern life emits greenhouse gases. Carbon dioxide is emitted wherever and whenever fossil fuels are burned including when we drive

2: "2009 U.S. Greenhouse Gas Inventory Report." U.S. Environmental Protection Agency http://www.epa.gov/climatechange/emissions/usinventoryreport.html

our cars, heat our houses, and generate our electricity. Methane is emitted from farms that raise the animals we eat. Nitrous oxide is emitted from landfills and wastewater treatment plants. Factories that produce all of the products we use in our daily lives all emit greenhouse gases, and the trucks that transport these items to our cities emit more still.

Many governments are currently making it a priority to reduce greenhouse gas emissions, but there is no strong consensus regarding which steps we should take to safely and effectively reduce our greenhouse gas emissions and which steps will needlessly cripple our productivity. Part of the reason no consensus has emerged is that every part of the globe is different and will require taking different actions in order to reduce greenhouse gas emissions while maintaining productivity and a high standard of living. Greenhouse gas accounting is just one of many effective tools that policymakers can use to ensure that environmental policies are effective.

Greenhouse Gas Accounting

Greenhouse gas accounting is the practice of accounting for every GHG emission within a boundary (anything from a single home to an entire country) and those emitted on behalf of the area within that boundary (for example, electricity that is produced in a neighboring county but used in the county of interest). The end product is a greenhouse gas inventory specifying how many metric tons of carbon dioxide equivalent (mt-CO_2e) were emitted in a given year, broken down by sector and source and expressed in simple terms that are comparable over time.

GHG emissions inventories are an incredibly useful tool for policymakers for three reasons. If it is apparent which sector of a community is producing the majority of emissions, policies can be targeted at specific sectors where easy improvements can be made with little investment; inventories can help to identify the "low-hanging fruit." Second, each sector can be compared on a per-user basis (per household, per employee, per square foot, etc) to the same sector in a nearby region having similar demographics and climate in order to identify if there are

specific local practices that can be modified or if there are even any improvements to be made.

Third, and most importantly, once policies have been implemented, their effectiveness can be tracked over time by performing a new inventory every year or two and comparing the results. For this reason alone, it is vitally important that any government interested in reducing its environmental impact have a "baseline" inventory to which they can make comparisons in the future.

Objectives for the Chaffee County Inventory

The objective of this GHG emissions inventory is three-fold:

- Design an inventory method based on the principles of demand-centered hybrid life-cycle analysis.[3] This inventory method should be consistent, accurate, transparent, and replicable in future years.
- Provide a baseline greenhouse gas footprint for Chaffee County incorporating all of the activities of the community including residential, commercial, industrial, agricultural, and governmental; this is known as a "community-wide GHG footprint."
- Establish concise tracking metrics to be updated in future years to assess progress over time.

This inventory is being compiled in order to facilitate climate action planning and provide tools for outcomes assessment in the future. In order to accomplish this goal, it is necessary to establish a set of procedures used to calculate the footprint that can be easily repeated in future years, or by other neighboring communities; this is known as the "inventory method." The method used in this inventory is described further in the GHG Accounting Method section.

Most of the other communities in Colorado that have performed community-wide inventories have been high-density urban areas with intense commercial or industrial activity. Chaffee County does not fit this profile so this inventory will also establish some basic results to which other similar communities in Colorado can compare.

3: The methodology is further explained in the GHG Accounting Method section.

Overview of Chaffee County

Chaffee County is a predominately rural, sparsely populated county located in the Rocky Mountains in central Colorado. Nestled between the Sawatch Range on the west and the Mosquito Range on the east, Chaffee County is an extremely mountainous region with elevations reaching up to 14,000 feet.[4] In 2007, the population was estimated by the U.S. Census Bureau to be 16,733 persons, making it the 28th most populous of Colorado's 64 counties. During the same time period, population density was estimated to be 16 persons per square mile, compared to 46.9 persons per square mile for the State of Colorado and an average density of 86.2 for the entire United States.[5] The Census Bureau estimates the population growth between 2000 and 2007 to be 3.0%, substantially behind the 12.5% growth rate for the state of Colorado.[6]

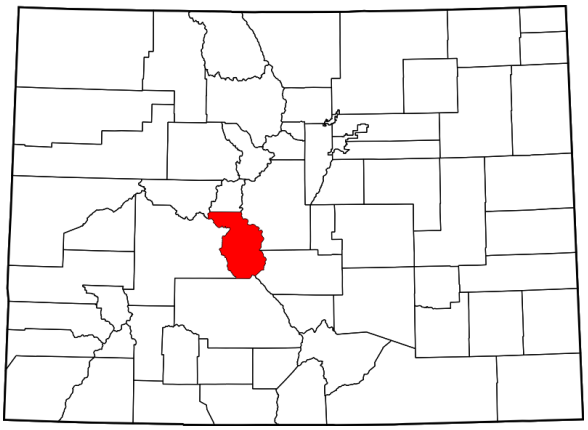

Figure 1: Location and Size of Chaffee County. Source: Wikimedia Commons

Several characteristics of Chaffee County are important to consider when performing a greenhouse gas emissions inventory. The climate is substantially cooler than other lower-lying areas of Colorado,[7] which means that the average home will use substantially more heating fuel during more parts of the year. Many homes in Chaffee County are heated with propane that is stored on-site: 25% of

4: "Chaffee in brief…" http://www.chaffeecounty.org/Page.aspx?PageID=250
5: "Chaffee County, Colorado." Wikipedia, http://en.wikipedia.org/wiki/Chaffee_County,_Colorado
6: "County Population Estimates." U.S. Census Bureau, http://www.census.gov/popest/counties/CO-EST2008-01.html
7: Between February and December 2007 (no data available for January), Chaffee County experienced 7,245 heating and cooling degree days compared to 5,979 for Denver for the same period. Heating and cooling degree days measure the variation from a baseline temperature and approximate the amount of heating or cooling needed to maintain a stable temperature in a home. Data from http://www.degreedays.net/ using weather stations KCOBUENA2 and KCODENVE11.

occupied homes, or about 1,700.[8] Using propane for heating has a different effect on the environment that must be taken into account. Propane is delivered by private companies instead of state-regulated utilities, and comprehensive data on propane sales were not available for this report; estimates have been used instead.

Agricultural area in Chaffee County comprises over 79,000 acres, or 12% of the total area of the County. Livestock activities, which have a substantial carbon footprint, represent 62% of the economic activity in the agricultural sector. Due to the substantial presence of animal agriculture in Chaffee County, the impact of livestock has been included in this report.

8: "DP-4. Profile of Selected Housing Characteristics: 2000." U.S. Census Bureau State and County QuickFacts, http://quickfacts.census.gov/qfd/states/08/08015lk.html

GHG Accounting Method

Method and Scopes

This GHG inventory is conducted using the demand-centered hybrid life-cycle analysis method developed by Ramaswami et al.[9] The method uses the standard Local Government Operations Protocol (LGOP, released by ICLEI) to report GHG emissions from in-boundary activities. Out-of-boundary activities critical for a community such as the provision of food, water, fuels and shelter are added to the in-boundary activities to yield a more comprehensive GHG footprint. The inclusion of additional out-of-boundary activities is highly recommended by the Climate Leaders Program of the U.S. Environmental Protection Agency (EPA).

The Ramaswami inventory-footprint method for GHG accounting was pioneered by the University of Colorado Denver along with the City and County of Denver in 2008, and has since been utilized by other cities such as Portland, Oregon, Seattle, Washington, Arvada, Colorado, Austin, Texas and Minneapolis, Minnesota. This inventory is the first application of the methodology to a rural area with significant agricultural activity, such as Chaffee County.

In-boundary activities

The following energy uses are considered "in-boundary" and are required to be reported as per the Local Government Operations Protocol (LGOP)[10] and World Resources Institute (WRI) protocol[11]:

- **Buildings Energy Use** – Use of electricity, natural gas, and propane in residential, commercial and industrial sectors in a community
- **Transportation Energy Use** – Includes tailpipe emissions from operating personal and commercial vehicles associated with a community

9: Ramaswami, A., T. Hillman, B. Janson, M. Reiner, and G. Thomas. "A Demand-Centered, Hybrid Life-Cycle Methodology for City-Scale Greenhouse Gas Inventories." *Environmental Science & Technology* 42 (September 2008): 6455-6461.
10: Local Government Operations Protocol v 1.0, September 2008: http://www.icleiusa.org/action-center/tools/lgo-protocol-1
11: WRI Corporate Standard Protocol: http://www.ghgprotocol.org/standards/corporate-standard

- **Emissions from Waste Disposal** – Under LGOP, emissions from solid waste landfilling and wastewater treatment by residential and commercial sectors are also included in the in-boundary accounting.

Formally, the GHGs emitted directly from burning natural gas in buildings and gasoline and diesel fuels in vehicles are termed "Scope 1" while emissions from power plants to produce electricity used within the community are termed "Scope 2." Scopes 1+2 emissions are included in the "in-boundary" activities; LGOP requires that these emissions be reported in a GHG inventory.

Out-of-boundary activities

WRI designates all emissions not included in Scopes 1+2 as Scope 3; including these emissions is optional, but highly recommended by the EPA. Including Scope 3 emissions produces a much more complete and accurate inventory. Although a community may report a larger GHG footprint by including Scope 3 emissions there may also be easier, more cost-effective actions that can be taken to reduce these Scope 3 emissions. Communities that use a comprehensive inventory including all scopes are more likely to make greater reductions over time.

The following out-of-boundary activities, when added to in-boundary activities, yield a more holistic account of a community's CO_2e footprint:

- **Embodied Energy of Critical Urban Materials** – The energy use and associated GHG emissions from producing key urban materials such as water, fuels, and food, necessary to support life in cities. Some inventories also include concrete.

- **Waste Management –** Emissions relating to the collection, processing, and storage of solid and liquid wastes, including the operation of landfills and wastewater treatment plants and direct emissions from the waste itself.

- **Livestock** – Chaffee County differs from most other communities because there is significant agricultural activity within the County. Animal agriculture

has a tremendous impact on GHG emissions due to the digestive process, so this inventory will include a component missing from most inventories.

Some of the emission sources listed above are not included in this inventory, either because it was determined the source was not a major contributor in Chaffee County during the reporting year (such as concrete), or the data were not available in the baseline year. Future GHG inventory projects should seek to include these sources if they become relevant or data becomes available.

Energy Use Sectors and Data

To better communicate a community's overall energy use and GHG emissions, classifying end-use of energy in three different sectors is more useful. In this report, we consistently report energy use and GHG emissions in the following four sectors:

- **Buildings Sector** – GHG emissions from residential, commercial, and government buildings and industrial facilities.
- **Transport Sector** – GHG emissions from operating cars, trucks and airplanes, termed Pump-to-Wheels (P2W) emissions.
- **Agricultural Sector** – GHG emissions from agricultural activities, specifically raising livestock.
- **Materials Sector** – GHG emissions from producing critical urban materials (food, water, cement) and fuel production (termed Wells-to-Pump, W2P) and from landfilling and wastewater treatment.

For energy (or materials use) in each sector, the following data were gathered:

- **Annual Materials or Energy Consumption –** Total kWh of electricity consumed annually, total water consumed annually, total natural gas use, etc. The annual Material/Energy Flow Analysis indicates how much is consumed as a community. Benchmarking these consumption data on a per-person or

per-household basis represents how efficient the community is its consumption patterns.

- **GHG Emissions factors –** GHG emissions factors express how much CO_2e is emitted per unit of energy or material consumed. For example: kilograms of carbon dioxide equivalent emitted per kilowatt-hour of electricity consumed, or kg-CO_2e/kWh.

Total emissions are computed as the product of how much is consumed and the GHG emissions per unit of the product consumed, using the following simple equation:

Material/Energy Flow x Emissions factor = GHG Emissions

In the next section, consumption data and emissions factors for all three sectors are reported and overall community-wide GHG footprint is developed.

Chaffee County Greenhouse Gas Inventory

Reporting year

This section reports energy (or materials) consumption data and associated GHG emissions for 2007 for the three main sectors:

- Buildings
- Transportation (tailpipe emissions)
- Materials and Waste

For each sector, raw consumption data are collected, the data are multiplied by an emissions factor (in an equivalent unit) and the results are totaled. The total GHG emissions from each sector are consolidated and reported in an overall community-wide summary table. GHG emissions are reported in terms of metric tons (mt) of carbon-dioxide equivalents, or mt-CO_2e.

Buildings Sector

Buildings Energy Consumption and Energy Intensity: This sector includes electricity, natural gas, and propane consumed in residential, commercial, government, and industrial facilities. Consumption data were obtained from Xcel Energy (commercial and residential electricity and natural gas), Atmos Energy (commercial and residential natural gas) and Sangre de Cristo Electric Association (residential and commercial electricity) for the year 2007. Data regarding the number of households and the square footage of commercial spaces in the County were obtained from the Chaffee County Assessor's Office.

Sangre de Cristo Electric Association was unable to provide specific consumption data or number of premises for Chaffee County, but did provide this data for their total service area. In order to determine the energy consumption in Chaffee County it was assumed that electricity was distributed evenly between all premises in the service area, so the consumption in Chaffee County would be proportional to the percentage of Sangre de Cristo premises in the County. The number of premises was determined by subtracting the number of residential customers receiving electricity from Xcel energy from the total number of

households in Chaffee County, taken from the Colorado Division of Local Government.

Additionally, many homes in Chaffee County are heated by propane instead of natural gas. Exact data regarding propane sales were not obtained due to the proprietary nature of this data. Therefore, an estimation was utilized for this report.[12] See Table 1 for a summary of electricity and natural gas energy consumption and resulting emissions in the buildings sector.

The term "energy use intensity" (or EUI) refers to the amount of energy used per consumer. EUI is useful for comparing consumption rates between different areas. Although Denver and Chaffee counties have vastly different numbers of households, the amount of energy used per household can be compared. EUI is usually expressed in thousands of British Thermal Units, or "kBTU," a measurement that includes electricity and heating fuel use. The energy use intensity for buildings in Chaffee County can also be benchmarked with similar energy intensity metrics reported by the Energy Information Agency (EIA) for homes and commercial spaces in the Rocky Mountain region.

- Including electricity and natural gas or propane, the average home in Chaffee County used 6,721 kBTU of energy in 2007. The Residential Energy Consumption Survey (RECS) published by the EIA reports that the average home in the Mountain West region used 7,483 kBTU in 2005 (the latest year for which data is available).[13]
- Businesses in Chaffee County used 136.95 kBTU per square foot in 2007, compared with 91.9 kBTU per square foot for office buildings in the Mountain West in 2003 (the latest year for which data is available). [14]

12: Propane consumption estimate of 6.25 million cu. ft. in 2007 was provided to UC Denver and is used in this report.
13: Table US1. Total Energy Consumption, Expenditures, and Intensities, 2005. "Residential Energy Consumption Survey – Detailed Tables." U.S. Energy Information Administration.
http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html
14: Table C9. Consumption and Gross Energy Intensity by Census Division for Sum of Major Fuels: Part 3. "Commercial Buildings Energy Consumption Survey," 2003. U.S. Energy Information Administration.
http://www.eia.doe.gov/emeu/cbecs/cbecs2003/detailed_tables_2003/2003set9/2003pdf/c9.pdf

Emissions factors for Electricity & Natural Gas**: Xcel Energy provided the GHG emissions factors for emissions factors for electricity and natural gas. Atmos Energy provides only natural gas, which has gas, which has the same emissions factor regardless of provider because it is burned on-site. Sangre on-site. Sangre de Cristo Electric Association (SdC) did not provide an emissions factor so the factor so the average emissions factor for electricity generation in Colorado was used instead.[15] used instead.[15] Emissions factors are shown in**

Table 2.

Table 1: Energy Consumption and GHG Emissions in the Buildings Sector

Residential Energy	**Xcel Energy**	**SdC**	**Atmos Energy**
Number of Electricity Customers	4,114	2,766	0
Total Grid Electricity Used (MWh)	27,213[A]	27,748	0
Electricity/household/month (kWh/hh/mo)	525.43	835.97	0
Number of Natural Gas Customers	2	0	4,716
Total Natural Gas Used (therms)	2,318	0	3,511,691
Natural Gas/household/month (therms/hh/mo)	97	0	62
Total Residential GHG emissions (mt-CO_2e)	**20,912**	**25,528**	**18,963**
Total Residential GHG Emissions (mt-CO_2e)	**65,402**		
Commercial-Industrial Energy	**Xcel Energy**	**SdC**	**Atmos Energy**
Number of Electricity Customers	1,009	0	0
Total Commercial-Industrial Area (sq. ft.)	7,123,599		
Total Electricity Used (MWh)	35,412	0	0
Number of Natural Gas Customers	7	0	774
Total Natural Gas (therms)	6,628,830	0	1,918,398
Total energy use per square foot (kBtu/s.f.)	136.95		
Commercial–Industrial GHG emissions (mt-CO_2e)	**63,802**	**0**	**10,359**
Total Commercial-Industrial GHG Emissions (mt-CO_2e)	**74,161**		

Notes: MWh = Megawatt-hours of electricity. 1MWh = 1,000 kWh. Both electricity and natural gas use can be combined and represented as kBtu: 1 kWh = 3.412 kBtu; 1 therm = 100 kBtu).
A. Includes 698 MWh of electricity from Xcel's Windsource program with zero GHG emissions in 2007.

15: Emissions factors and Energy Prices for Leonardo Academy's Cleaner and Greener® Program, Page 8. Leonardo Academy, Inc. (April 21, 2009) Available: http://www.cleanerandgreener.org/download/2009-4-21%20C&G%20Program%20Emission%20Factors%20and%20Energy%20Prices.pdf

Table 2: Electricity and Natural Gas Emissions Factors

Emissions factors	Xcel	SdC[16]	Atmos
Electricity (kg-CO_2e/kWh)	0.788	0.92	N/A
Natural Gas (kg-CO_2e/therm)	5.4		

Public Street and Highway Lighting: Xcel Energy also delivered 295 MWh for use in public streets and highway lighting during 2007. GHG emissions resulting from this consumption totaled 233 mt-CO_2e.

Propane Consumption: Many homes in Chaffee County do not receive natural gas via a pipeline from an energy utility company, but purchase propane to be delivered and stored on-site. A propane consumption estimate of 6.25 million cubic feet was provided. Of the 6,880 households in Chaffee County, the U.S. Census Bureau reports that 25.3%, or 1,740 homes, heat with propane.[17] Average propane consumption for these homes would be 99.8 gallons per year. The Residential Energy Consumption Survey released by EIA reports that the average propane-burning home in the mountain west region used 501 gallons of propane during 2005.[18] Considering this benchmark, the propane consumption figure used in this report is likely an underestimation. Securing accurate data about residential propane consumption should be a priority for future GHG inventory reports.

Based on the estimate given here, a conversion factor of 0.0278 gallons per cubic foot[19] and an emissions factor of 5.74 kg-CO_2e per gallon[20] were applied, bringing the total emissions from propane to 997 mt-CO_2e in 2007.

16: Emissions factors and Energy Prices for Leonardo Academy's Cleaner and Greener® Program, Page 8. Leonardo Academy, Inc. (April 21, 2009) Available: http://www.cleanerandgreener.org/download/2009-4-21%20C&G%20Program%20Emission%20Factors%20and%20Energy%20Prices.pdf
17: "DP-4. Profile of Selected Housing Characteristics: 2000." U.S. Census Bureau State and County QuickFacts, http://quickfacts.census.gov/qfd/states/08/08015lk.html
18: Table US8. Average Consumption by Fuels Used, 2005. "Residential Energy Consumption Survey – Detailed Tables." U.S. Energy Information Administration. http://www.eia.doe.gov/emeu/recs/recs2005/c&e/detailed_tables2005c&e.html
19: Connecticut Department of Revenue website, http://www.ct.gov/DRS/cwp/view.asp?a=1511&q=267170
20: Local Government Operations Protocol v 1.0, September 2008: http://www.icleiusa.org/action-center/tools/lgo-protocol-1

Transportation Sector

Surface Travel and Fuel Consumption: Fuel consumption for Chaffee County was calculated from total statewide vehicle fuel sales data maintained by the Colorado Department of Revenue. Based on the assumption that citizens of Chaffee County will travel, on average, as much as other residents of the state, fuel sales were allocated based on the proportion of the population of Chaffee County to the State of Colorado. In 2007, statewide fuel sales totaled 2,193 million gallons of gasoline and 702 million gallons of diesel fuel.[21] The population of Chaffee County comprised 0.35% of the population of the state during this period,[22] so 7.58 million gallons of gasoline and 2.43 million gallons of diesel were allocated to Chaffee County.

Airline trips: Because there are no commercial airports in Chaffee County, airline trips were not included in this inventory. It is likely that Chaffee County residents make use of airports in other areas, thus future inventories could include an air travel component.

Emissions Factors: Diesel and gasoline emissions factors were obtained from Argonne National Laboratory's Greenhouse Gas, Regulated Emissions and Energy Use in Transportation (GREET[23]) model for pump-to-wheels analysis, appropriate for vehicle operations. The emissions factors of 9.12 kg-CO_2e for gasoline and 10.2 kg-CO_2e for diesel are in line with those used by ICLEI and the Intergovernmental Panel on Climate Change (IPCC), although they have been changed recently and may not exactly match emissions factors used in other inventories in Colorado. GHG emissions from the transport sector totaled 93,850 mt-CO_2e. See Table 3 for a summary of fuel consumption and resulting emissions in the transportation sector.

21: "Motor Fuel Taxes." Colorado Department of Revenue, http://www.colorado.gov/cs/Satellite/Revenue-Main/XRM/1213954144067
22: "County Population Estimates." U.S. Census Bureau, http://www.census.gov/popest/counties/CO-EST2008-01.html
23: "Argonne GREET Model." Argonne National Laboratory Transportation Technology R&D Center. http://www.transportation.anl.gov/modeling_simulation/GREET/

Table 3: Fuel Consumption and GHG Emissions in the Transportation Sector

Colorado Statewide Fuel	**2007**
Gasoline (Million Gallons)	2,193
Diesel (Million Gallons)	702

Chaffee County Population Proportion	0.35%

Chaffee County Fuel	**2007**
Gasoline (Million Gallons)	7.58
Diesel (Million Gallons)	2.43

GHG Emissions from Transport	**2007**
Gasoline (mt-CO_2e)	69,101.80
Diesel (mt-CO2e)	24,748.95
Total (mt-CO_2e)	**93,850.74**

Materials and Waste Sector

This sector includes many relevant out-of-boundary activities that produce GHG emissions, including the production of food and fuels and treatment of wastewater. These results are shown in Table 4.

Fuel Production: Consumption of transportation fuels was determined from statewide fuel consumption as summarized in Table 3. When fuels are burned they release emissions directly into the air- this process is covered in the Transportation Sector section above. However, there are also emissions associated with the recovery, processing, and refinement of these fuels as they are transported to the County. These emissions are referred to as "wells-to-pumps," or W2P, and the emissions factors are taken from the GREET model. W2P emissions for gasoline, diesel, and propane in 2007 totaled 23,995 mt-CO_2e in 2007.

Food Production: The consumption of food was tracked in terms of money spent on food expenditures as reported in the Consumer Expenditure Surveys for residents released by the U.S. Bureau of Labor Statistics. In 2007, the average expenditure for food prepared at home was $3,091 per home[24] in rural areas. The emissions factor for food was derived from the Economic Input-Output Life Cycle Analysis tool (maintained by Carnegie Mellon University[25]). The EF was found to be 2.67 kg-CO_2e per dollar of food expenditure. GHG emissions from food production in 2007 totaled 56,674 mt-CO_2e.

Municipal Waste and Recycling: The Chaffee County landfill reported the amount of waste landfilled during 2007, broken down by type (i.e. municipal solid waste (MSW), construction, yard, tires, etc). Most amounts were reported in short tons (2,000 lbs), but a few were reported in terms of cubic yards (some elements of household waste) or number (tires). For these items, conversion factors were located to provide total short tons. Additionally, the amount of recycled material (cardboard and metal) was reported in tons. The number of short tons in each category was entered into the EPA's Waste Reduction Model[26] (WaRM), which evaluates multiple waste disposal scenarios. In this case, waste disposal was evaluated with and without recycling. GHG emissions from solid waste totaled 45,303 mt-CO_2e in 2007. Without recycling, this number would have been higher by 1,848 mt-CO_2e, or about 4%.

Wastewater Treatment: The Local Government Operations Protocol has outlined a methodology through which average emissions for wastewater treatment can be estimated without specific knowledge of the treatment process used in a specific area, based on typical treatment plants and the population being served.[27] The analysis for this report includes methane emissions from anaerobic digestion of biosolids and treatment lagoons, but not fugitive emissions from septic tanks or N_2O

24: U.S. Bureau of Labor Statistics Consumer Expenditure Survey, Series ID CXUFH000809 (available: http://data.bls.gov/cgi-bin/srgate)
25: Carnegie Mellon University Green Design Institute. (2010) Economic Input-Output Life Cycle Assessment (EIO-LCA) US 1997 (491) model [Internet], Available from: <http://www.eiolca.net/> [Accessed 13 Jan, 2010]
26: Waste Reduction Model, U.S. Environmental Protection Agency. http://www.epa.gov/climatechange/wycd/waste/calculators/Warm_home.html
27: ICLEI Local Governments Protocol v1.0, September 2008

emissions from nitrification and denitrification. Based on this methodology, GHG emissions from wastewater treatment totaled 3,897 mt-CO_2e in 2007.

Table 4: Material Flow and GHG Emissions in the Material Sector

Material	Annual Material Flow	GHG Emissions
Fuel Production	7.6, 2.4 and 0.2 million gallons[28]	23,995 mt-CO_2e
Wastewater Treatment	16,733 users	3,897 mt-CO_2e
Food Production	$21.26 million	56,674 mt-CO_2e
MSW and Recycling	19,730 short tons	45,303 mt-CO_2e
Total GHG Emissions for Producing Urban Materials		**129,869 mt-CO_2e**

Agricultural Sector

Agricultural activities, specifically animal agriculture, emit a great deal of greenhouse gases. Livestock emit methane during the digestive process (referred to as "enteric fermentation") and their wastes release additional methane and nitrous oxide while being collected, stored, and treated. Please note that this sector will include only emissions directly related to livestock and not from farm operations, which are already covered in the commercial buildings energy and transportation fuel sections.

The head of livestock in each category were taken from the 2007 Census of Agriculture[29] for Chaffee County, released by the U.S. Department of Agriculture. Emissions factors were taken from the 2007 U.S. Greenhouse Gas Inventory Report, released by the EPA;[30]specifically from Chapter 6 and are based on protocols released by the IPCC. GHG emissions from livestock total 88,626 mt-CO_2e for 2007. The data supporting these calculations are shown in

28: Gasoline, diesel, and propane respectively.
29: Received in a Personal Communication with Kathryn Wadsworth, December 23 2009
30: "2007 Draft U.S. Greenhouse Gas Inventory Report." U.S. Environmental Protection Agency. http://www.epa.gov/climatechange/emissions/downloads07/07Agriculture.pdf

Table 5.

Table 5: Emissions factors and GHG Emissions in the Agricultural Sector

Type	Number	Enteric Fermentation kg-CO_2/animal/year	Manure Management kg-CO_2e/animal/year	GHG Emissions mt-CO_2e/year
Cattle	7,928	9,019	2,157	88,603.3
Goat	259	5	N/A[31]	1.3
Horse	963	15	N/A[31]	14.4
Layers	362	N/A[31]	21	7.6
			Total GHG Emissions, Livestock Sector:	**88,626.7**

Community-Wide and Per-Capita GHG Footprint

All three sectors described in the previous sections are added together in Table 6. The result is the total community-wide GHG footprint shown in the form of a pie chart by sector in Figure 2. The community-wide GHG footprint for Chaffee County in 2007 was 453,139 mt-CO_2e. Unfortunately, this number by itself is not helpful- it can't be compared to any other footprint due to differences in population size and composition; the per-capita GHG footprint is much more useful.

The per-capita GHG footprint for Chaffee County in 2007 was 27.08 mt-CO_2e per person. This is similar to the per-capita emissions of 24.25 mt-CO_2e for the City and County of Denver for the same period. It is important to recognize that the inventory for Chaffee County includes some sectors that were not included in the inventory for Denver, either because they weren't relevant (agriculture) or because data were not available at the time (solid waste disposal); due to all of this, the per-capita footprint is expected to be slightly higher. Some basic tracking metrics are shown in Table 7 below to illustrate the differences and similarities between the two areas.

31: No emissions factor could be found.

Table 6: Community-Wide GHG Emissions for Chaffee County

	Sector/use	Community-wide annual urban material/energy flows, MFA	GHG emissions factor (EF)	total GHG emitted = MFAxEF
Scopes 1 & 2 plus waste	Buildings Electricity Use	90,373 MWh (Xcel Energy, Sangre de Cristo Electric Assoc.) 295 MWh (Pub. Streetlights)	0.78 (Xcel) 0.92 (SdC) kg CO_2e/kWh	74,665 mt-CO_2e
	Buildings Natural Gas	12.06 million therms (Xcel Energy, Atmos Energy)	5.4 kg-CO_2e/therm	65,130 mt-CO_2e
	Fuel Consumption	7.58 million gallons (gasoline) 2.43 million gallons (diesel) 173,750 gallons (propane)	Gasoline PTW: 9.1 kg-CO_2e/gal Diesel PTW: 10.2 kg-CO_2e/gal Propane tailpipe: 5.74 kg-CO_2e/gal	94,847 mt-CO_2e
	Solid Waste	19,730 short tons	Varies: ~1 mt-CO_2e/short ton	45,303 mt-CO_2e
Scope 3	Wastewater Treatment	16,733 persons served	257.9 kg-CO_2e/person/year	3,897 mt-CO_2e
	Fuel Production	Fuel Flow in million gallons: Gasoline: 7.58 Diesel: 2.43 Propane: 0.17	Gasoline: 2.5 Diesel: 2.0 Propane: 1.15 kg-CO_2e/gal	23,995 mt-CO_2e
	Livestock	7,928 Cows 259 Goats 963 Horses 362 Layers	11,716 kg-CO_2e/cow (+ others)	88,626 mt-CO_2e
	Food Purchases	$21.26 million	2.65 kg-CO_2e/$	56,674 mt-CO_2e
		Total Community Wide Emissions:		**453,139 mt-CO_2e**

Figure 2: Chaffee County GHG Emissions by Sector

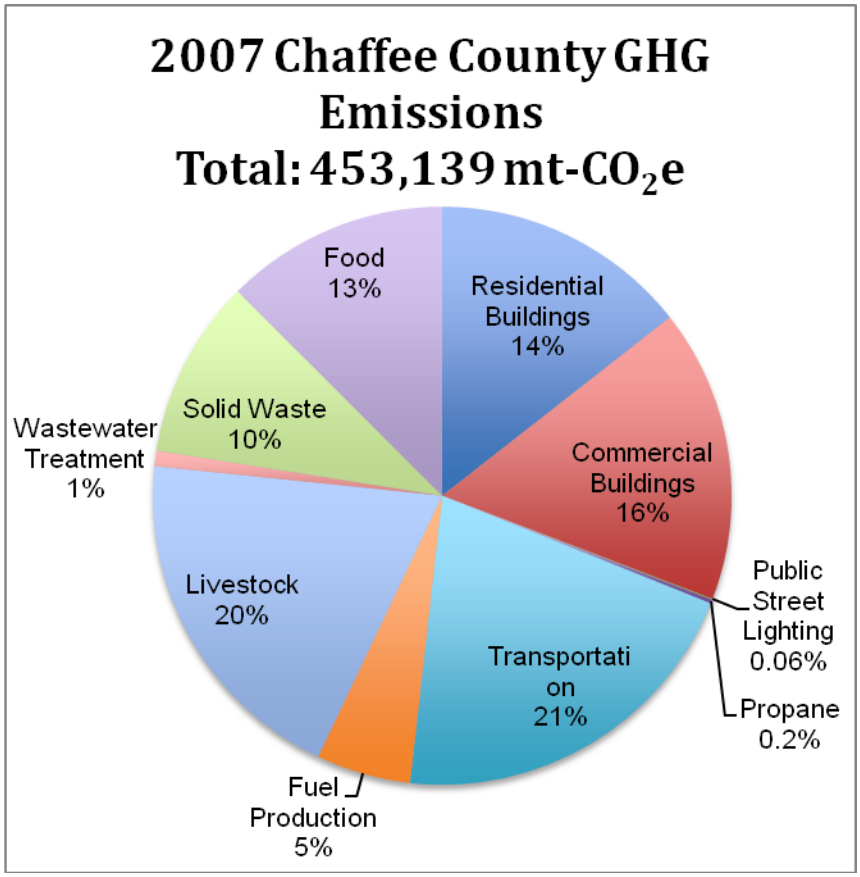

Table 7: Benchmark Comparison Between Chaffee County and Denver

	Chaffee County, 2007	Denver, 2007
Residential Buildings	665 kWh/hh/mo	528 kWh/hh/mo
	44.5 therms/hh/mo	65 therms/hh/mo
Commercial Buildings	137 kBTU/s.f.	179 kBTU/s.f.
Transportation	598 gal/person/year	638 gal/person/year
Food Purchases	$3,091/household	$3,000/household
Livestock	5.3 mt-CO_2e/person	0 mt-CO_2e/person