# GHG INVENTORY & SEP ANALYSIS

Boulder County, Colorado

2012 Edition of the 2007 Report

Version 1, May 23, 2013

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## Client

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# EXECUTIVE SUMMARY

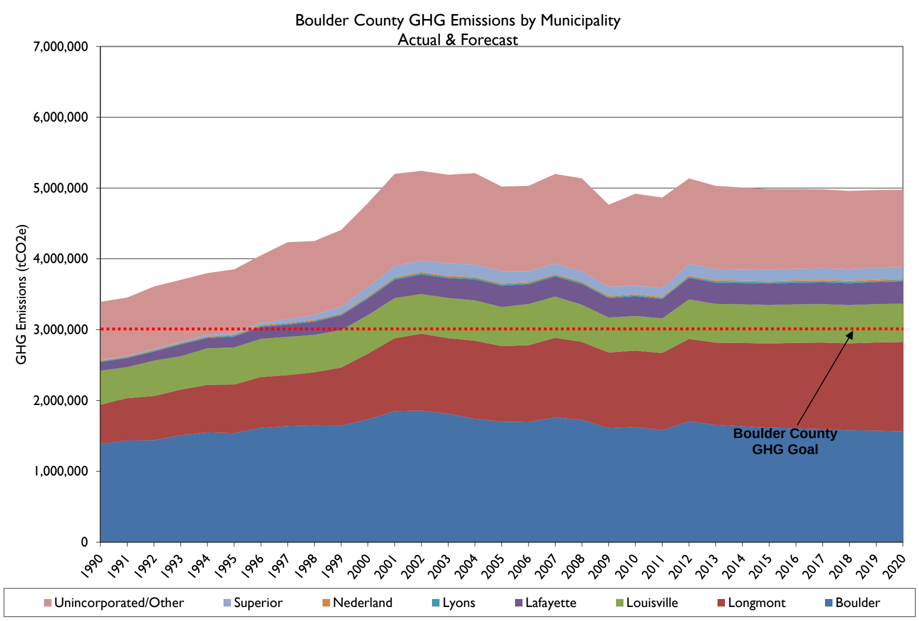
In 2006 and 2007, Econergy International Corporation was engaged by Boulder County to develop an inventory of GHG emissions produced by the entire county economy and to assist the County in developing a comprehensive plan for mitigating emissions to a level representing pro rata compliance with the US commitment under the United Nations Kyoto Protocol. The report on the inventory and recommended mitigation actions issued by Econergy in late 2007 served as a guidance resource that helped inform the creation of the Boulder County Sustainable Energy Plan (SEP). Boulder County engaged WSP (formerly Econergy) in 2012 to update and augment the previous body of Econergy work.

## Analysis Results

Comparison of the 2005 and 2011 inventories reveals that substantial progress has been made toward the GHG mitigation goal. However, a substantial gap appears to remain between the economy's current Business-as-Usual (BAU) trajectory and the 2020 target. Thus, it remains the case that meeting this goal will be a daunting enterprise requiring substantial community mobilization, County and municipality commitment, and dedicated budgets. In addition, efforts must focus on aggressively promoting renewable energy technologies, particularly those producing electricity and biofuels.

The following graph presents the updated BAU trajectory out to 2020 in emissions units of metric tonnes/year of carbon dioxide-equivalent (mtCO2e/yr).

**Business-As-Usual GHG Emissions Projections by Municipality, 2011**

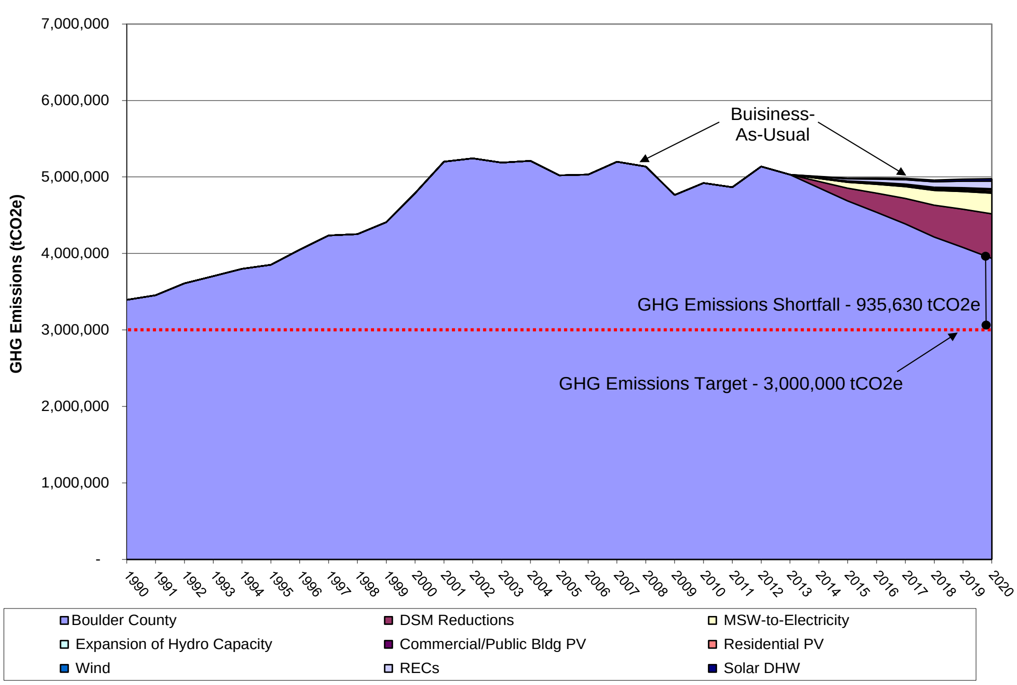


## Emissions Mitigation Strategies

A broad range of emissions mitigation strategies was analyzed by WSP in 2007, including energy demand-side measures (DSM; mostly energy efficiency) and energy supply-side measures (mostly renewable energy, RE). These analyses were updated using 2013 energy costs and estimated implementation costs. Detailed results are presented in Chapters 3 – 6 of the report. The following table summarizes some of the most promising GHG emissions reductions strategies identified by these analyses, including approximate Marginal Abatement Cost (MAC):

| Reduction Measure | 2020 REDUCTION ($mtCO_2e$) | FRACTION OF GOAL ACHIEVED | MAC ($/$mtCO_2$) |
|---|---|---|---|
| Commercial Buildings Bundle 2 | 145,420 | 7.3% | -91 |
| Residential Buildings Bundle 2 | 219,000 | 10.9% | -11 |
| E15 & E85 | 19,000 | 1% | 0 |
| Plug-In Hybrid Electric Vehicle | 12,400 | 0.6% | +66 |
| Solar PV | 33,700 | 1.7% | +195 (residential<br>+132 (commercial) |
| Solar DHW | 30,740 | 1.5% | +85 |
| MSW-to-Electricity | 270,000 | 13.5% | -124 |
| RECs at $13/MWh | 100,000 | 5.1% | +20 |

Achieving aggressive but achievable market penetrations in the implementation of these strategies will reduce county-wide GHG emissions by 20% in 2020, relative to the updated BAU, thereby achieving more than 50% of the projected gap-to-goal. These measures are estimated to deliver $128 million/yr in energy cost savings and energy sales revenues in 2020, at a total implementation cost of $1.1 billion. Over the 25-year lifetime of the energy efficiency and renewable energy measures, the Benefit:Cost ratio is about 2.2.



These results make it apparent that the original set of DSM and RE measures evaluated are inadequate to the task of achieving the County's GHG goal. Additional creative and aggressive strategies need to be developed to boost emissions reductions, especially via DSM in the Commercial Buildings and Residential Buildings sectors.

## CLOSING THE REMAINING GAP-TO-PLAN

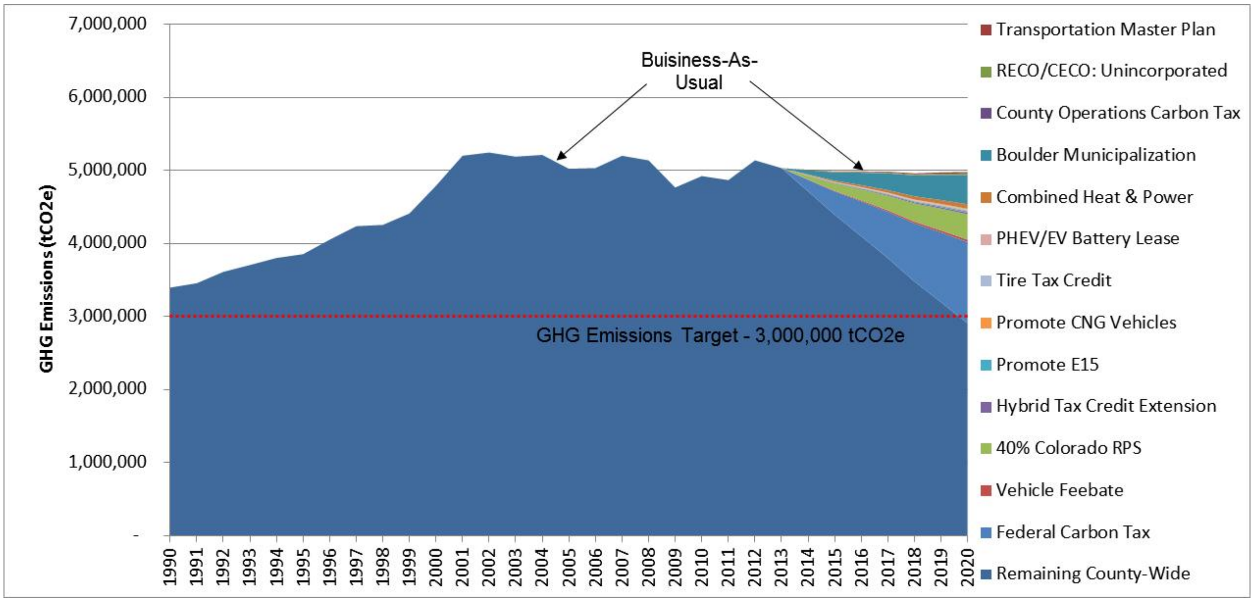
As part of WSP's 2012 – 2013 work scope, new initiatives were evaluated that could be pursued within the SEP context to increase programmatic impacts and thereby reduce the projected gap-to-plan.

The menu of gap-closing initiatives was parsed into three 'buckets' – 1) those actions over which Boulder County has direct control; 2) those actions over which Boulder County can exert influence; and 3) those actions requiring legislation at the state or federal level.

The following table summarizes the estimated mitigation impact of the specific actions evaluated for each bucket.

| **Bucket** | **Project** | **GHG Savings in 2020 (tCO2e)** | |
|---|---|---|---|
| Control | Transportation Master Plan | 19,000 | |
| | RECO/CECO: Unincorporated | 19,400 | |
| | County Operations Internal $CO_2$ Tax | 3,130 | 41,530 |
| Influence | Boulder Municipalization | 400,000 | |
| | Combined Heat & Power | 62,000 | 462,000 |
| State/ Federal | Colorado $CO_2$ Tax | 1,113,500 | |
| | Vehicle Feebate | 33,000 | |
| | 40% Colorado RPS | 348,081 | |
| | Hybrid Electric Tax Credit Extension | 21,000 | |
| | Promote E15 | 19,000 | |
| | Promote CNG Vehicles | 13,000 | |
| | Hi-Efficiency Tire Tax Credit | 10,000 | |
| | PHEV/EV Battery Lease | 12,000 | 1,569,581 |
| **Total** | | | **2,073,111** |

These mitigation actions, if fully realized, would completely close the gap that the updated BAU trajectory projects for 2020. The wedge diagram below depicts the potential of each mitigation action. Note that interactions among these measures have not been quantified since this is beyond the WSP scope of work.




## SEP BASELINE ESTABLISHED WITH REGRESSION ANALYSIS

Also in 2012 – 2013, WSP investigated whether it is possible to discern the county-wide SEP programmatic impacts on electricity and natural gas usage and GHG emissions in the commercial and residential sectors. The inherent low resolution of sector-level data leads, at best, to a rough estimate of SEP impacts. WSP determined that post-SEP implementation data must be accumulated over a few years to roughly calculate programmatic impacts. More accurate impact evaluation must involve evaluation of individual premise-level data across samples of building types, using well-known programmatic impact-evaluation techniques. In the future, with sufficient post-SEP implementation data, it may be possible to discern approximate SEP impacts using sector-level data, via the data normalization methodology developed by WSP and presented in this report.

The analysis indicates that, among the independent variables of weather, population, and GDP, weather most influences natural gas usage, and GDP most influences electricity usage in both sectors. Normalized pre-SEP baseline values for natural gas and electricity usage for both sectors are summarized below, expressed as annual average per-capita values.  For comparison, actual historical annual average per-capital values are also presented.

| | Residential Buildings Sector | Commercial Buildings Sector |
|---|---|---|
| **Natural Gas Usage, therms/person-yr** | 291.68 Baseline | 294.23 Baseline |
| | 277.56 Actual | 276.36 Actual |
| **Electricity Usage, kWh/person-yr** | 3684.41 Baseline | 4938.05 Baseline |
| | 3632.16 Actual | 4902.53 Actual |

## DETAILED SUMMARY

In 2006 and 2007, Econergy International Corporation was engaged by Boulder County to develop an inventory of GHG emissions produced by the entire county economy and to assist the County in developing a comprehensive plan for mitigating emissions to a level representing pro rata compliance with the US commitment under the United Nations Kyoto Protocol. The report on the inventory and recommended mitigation actions issued by Econergy in late 2007 served as a guidance resource that helped inform the creation of the Boulder County Sustainable Energy Plan (SEP).

In 2009, the Econergy consulting division was acquired by WSP. Boulder County engaged WSP in 2012 to update and augment the previous body of Econergy work. This report is essentially a 2012 edition of the 2007 report, embodying updates of the economy-wide GHG inventory and mitigation analysis. This 2012 edition of the original 2007 report includes new elements – 2005 versus 2011 inventory comparisons; evaluation of the benefits and costs of additional emissions mitigation actions; and a methodology based on data normalization techniques by which SEP impacts can be roughly estimated in the future.

The overarching philosophical framework within which Boulder County's SEP has been developed is that the Commission recognizes and acknowledges the environmental imperative that man-made climate change is real, it is happening now, and decisive action must be taken to mitigate it. For some time, man-made climate change has been recognized as a direct threat to the very lifeblood of our home, as capsulated in statements contained in the USEPA's report on climate change submitted summer 2002 to the United Nations: "…Snow-fed streams in the USA will be permanently diminished" and "alpine meadows in the US Rocky Mountains will permanently disappear" as the result of man-made climate change. Clearly, Boulder County's water supply, quality of life, and tourism industry are threatened by climate change.

On the bright side of this very sobering outlook, it is now widely recognized that climate change mitigation could become one of the world's biggest growth industries. The response to the threat, as embodied in Boulder County's SEP, is framed within the perspective that aggressive GHG mitigation is not a burden but rather an opportunity. The "economic costs" associated with GHG management are actually investments in the local economy that will return quite substantial dividends in the form of numerous co-benefits. These co-benefits include overall improvement in the health of Boulder County's local environment, substantial improvements in public health, significant reductions in local traffic congestion, substantial energy cost savings in every sector of the local economy, insulation against energy price shocks, generation of new local economic activity and creation of new businesses, leading to net increases in jobs and net new revenue to the County and local municipal governments.

### ANALYSIS RESULTS

Comparison of the 2005 and 2011 inventories reveals that substantial progress has been made toward the GHG mitigation goal. However, a substantial gap appears to remain between the economy's current Business-as-Usual (BAU) trajectory and the 2020 target. Thus, it remains the case that meeting this goal will be a daunting enterprise requiring substantial community mobilization, County and municipality commitment, and dedicated budgets. In addition, efforts must focus on aggressively promoting renewable energy technologies, particularly those producing electricity and biofuels.

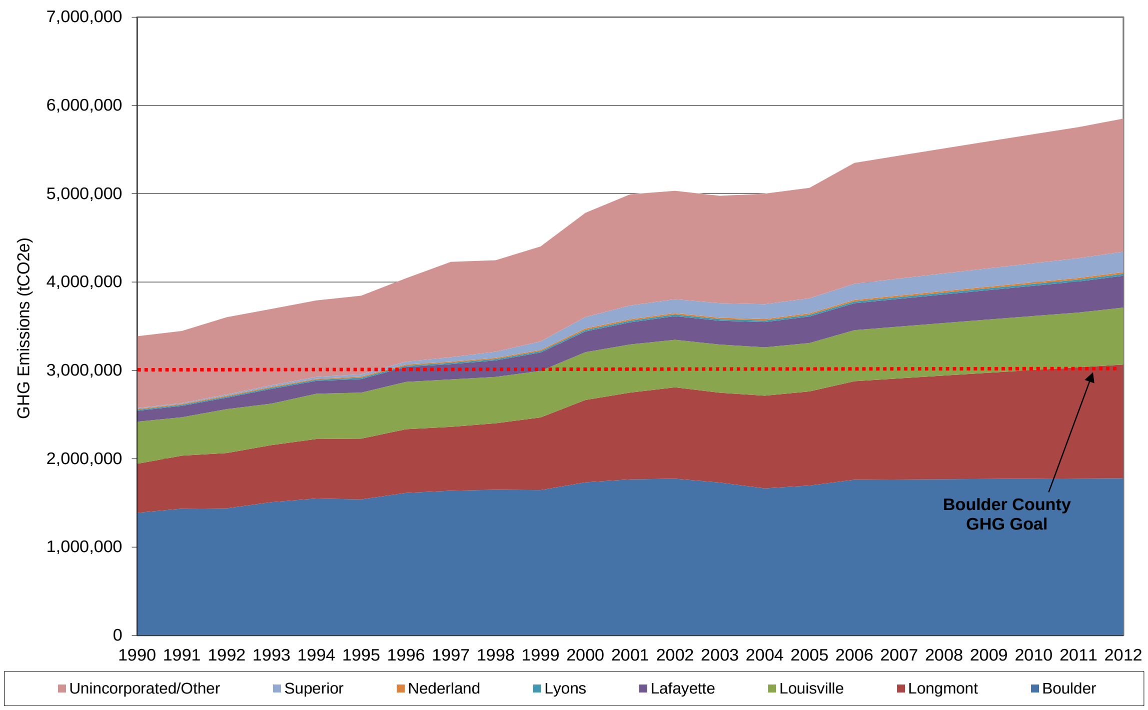
## Boulder County's GHG Inventory

The work involved in developing a comprehensive GHG plan for Boulder County is organized around the sectors within the County's economy: commercial buildings, residential buildings, transportation, industry, and agriculture. The first step in the planning process is to develop a clear picture of historical and current sources and magnitudes of Boulder County's GHG emissions. This is accomplished by developing a GHG inventory of each of the economic sectors outlined above. Amalgamating the sectoral inventories into an aggregated county-wide inventory provides the context in which to compare and contrast the emissions produced by each sector. Thus, a comprehensive picture of the problem guides limited resources to be focused on those emissions-intensive individual sectors and, within those sectors, specific mitigation strategies.

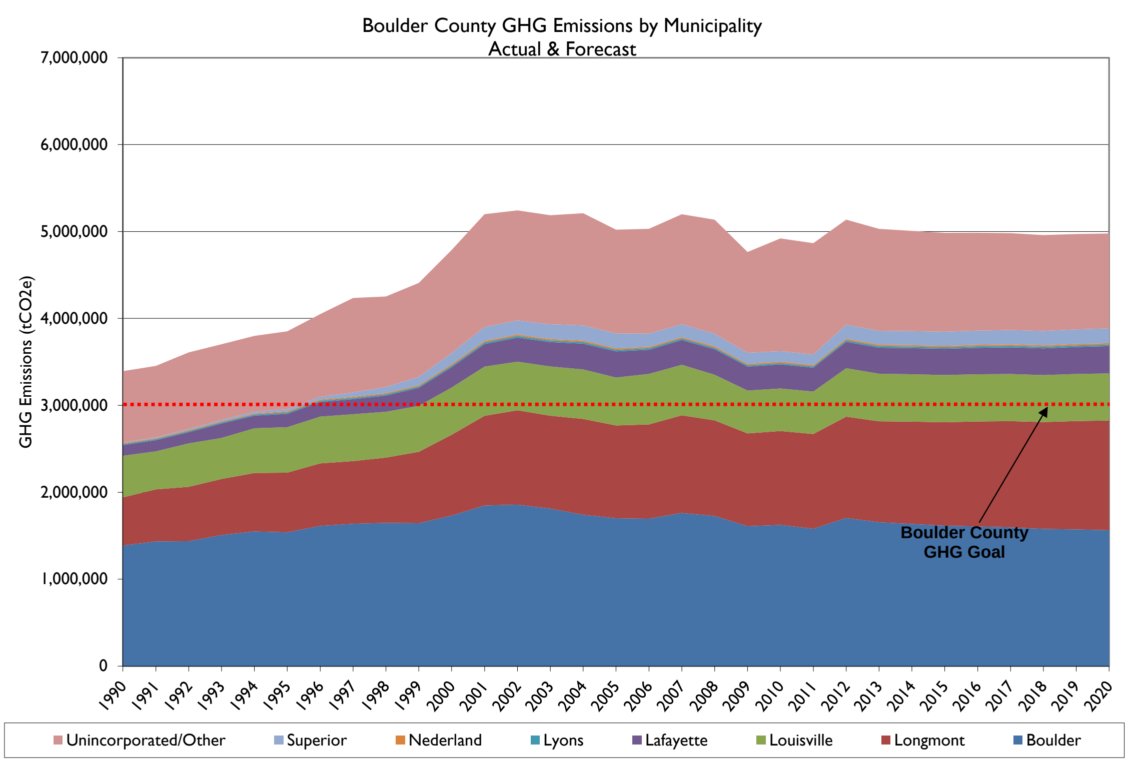
The following graphs present comparisons of the Boulder County inventory, based on 2005 data versus the inventory based on 2011 data. The 2005 BAU trajectory predicted that the 2012 economy-wide inventory would total about 5,851,000 mtCO2e, while the 2011 trajectory suggests that 2012 emissions will total only about 5 million tonnes. While this comparison demonstrates that substantial progress has been made, the 2011 trajectory predicts that a substantial gap will remain in 2020 between BAU and the 3 million mtCO2e target. Details of the updated inventory are presented in Chapter 2 of this report. A complete set of 2005 vs 2011 comparisons is presented in Appendix A.

Note that the BAU projection probably represents a conservative estimate of GHG emissions trends. Since it is impossible to forecast many crucial variables, such as conventional energy prices and federal and state policies and regulations, to which emissions trends are highly sensitive, forecasts have been based on extrapolations of historical energy usage trends and policies/regulations that are known at this time. Consequently, it is believed that the resulting BAU projections comprise a "worst-case" scenario. While this conservative BAU picture may overstate the magnitude of the challenge facing Boulder County, it is clear that the 3 million tonne target is a stretch goal.

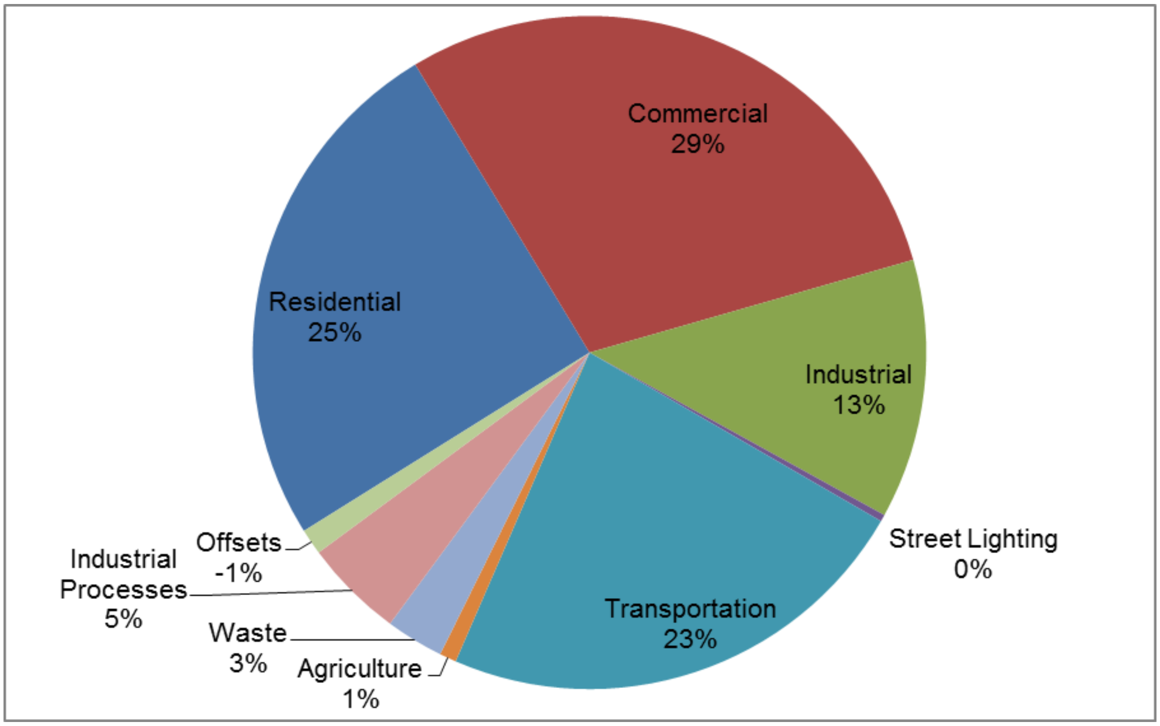
## Business-As-Usual GHG Emissions Projections by Municipality, 2005



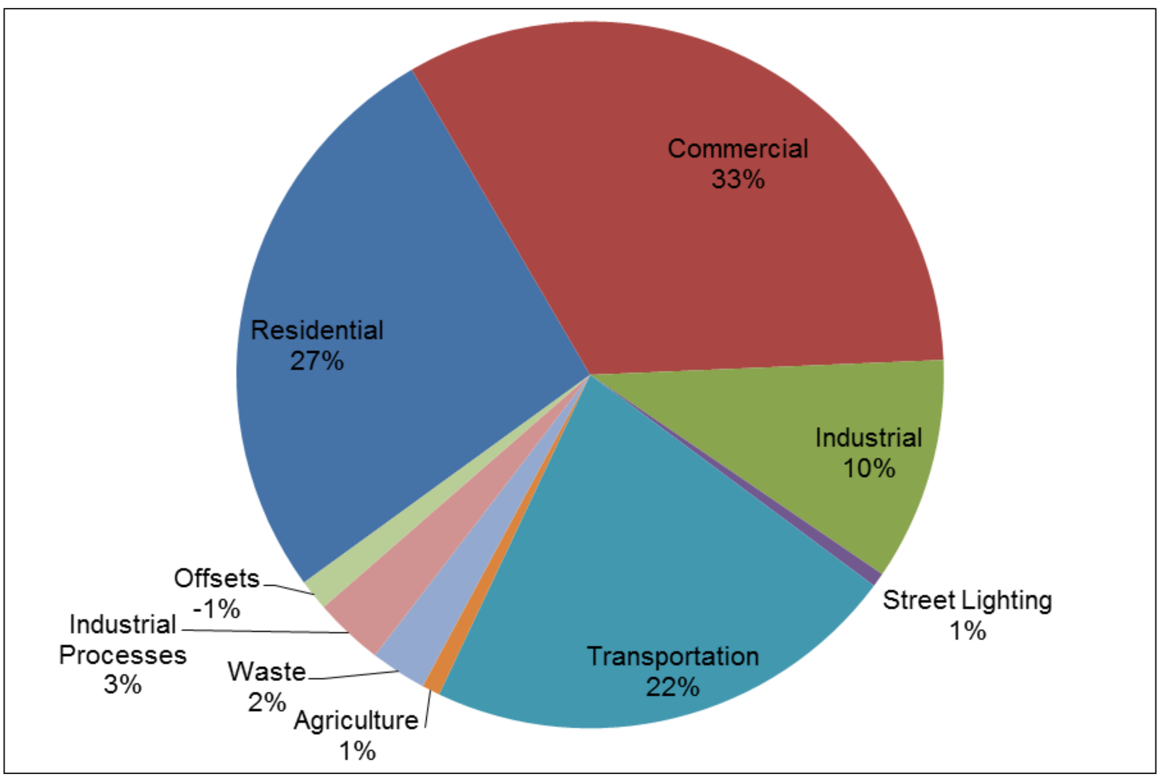

## Business-As-Usual GHG Emissions Projections by Municipality, 2011



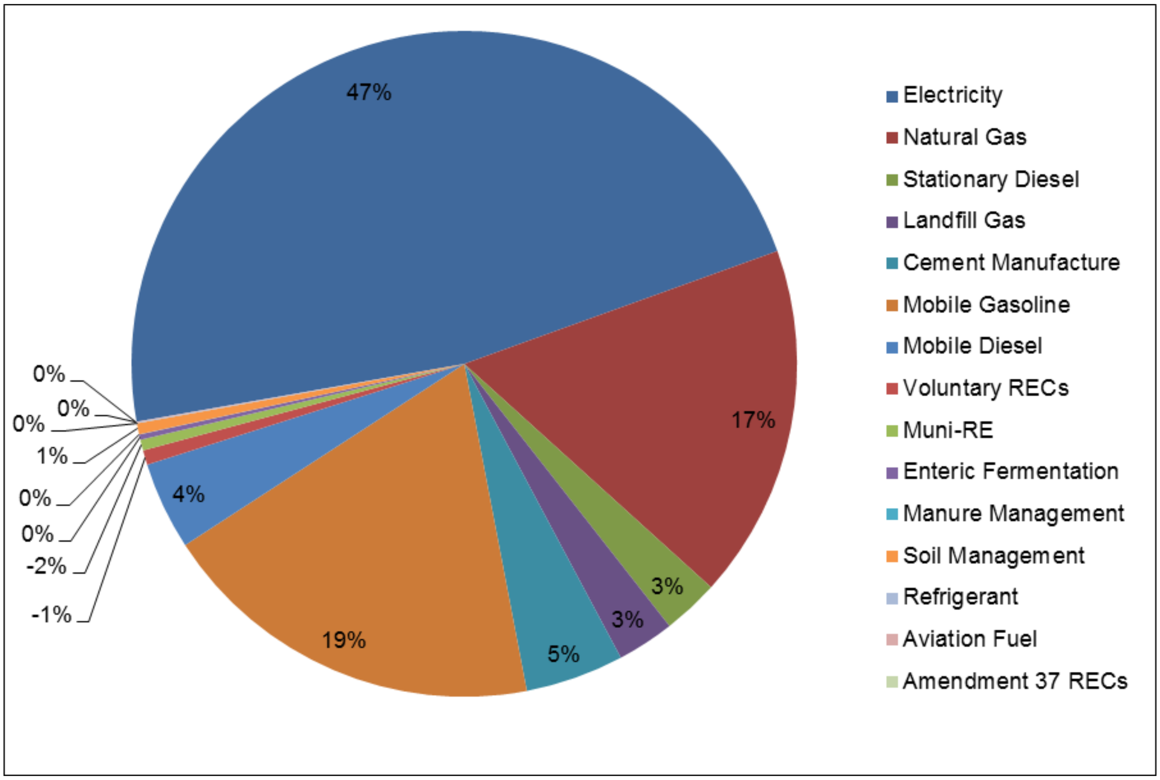
**County-Wide Emissions by Economic Sector, 2005**



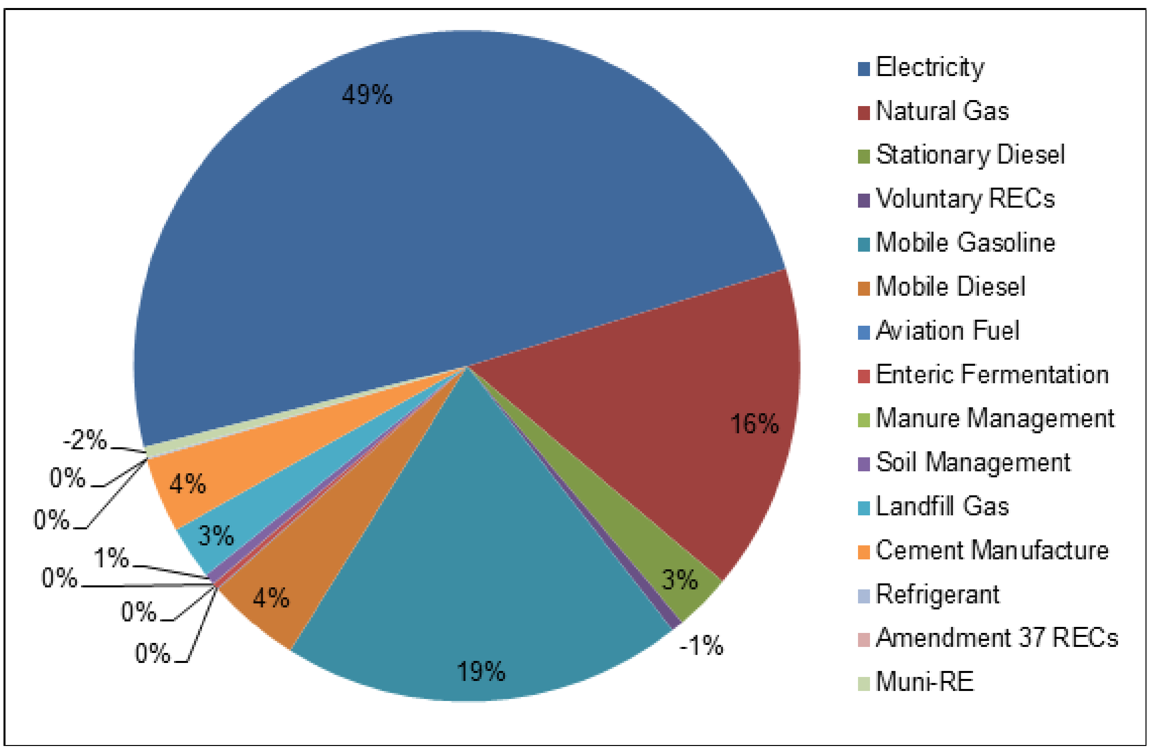

**County-Wide Emissions by Economic Sector, 2011**



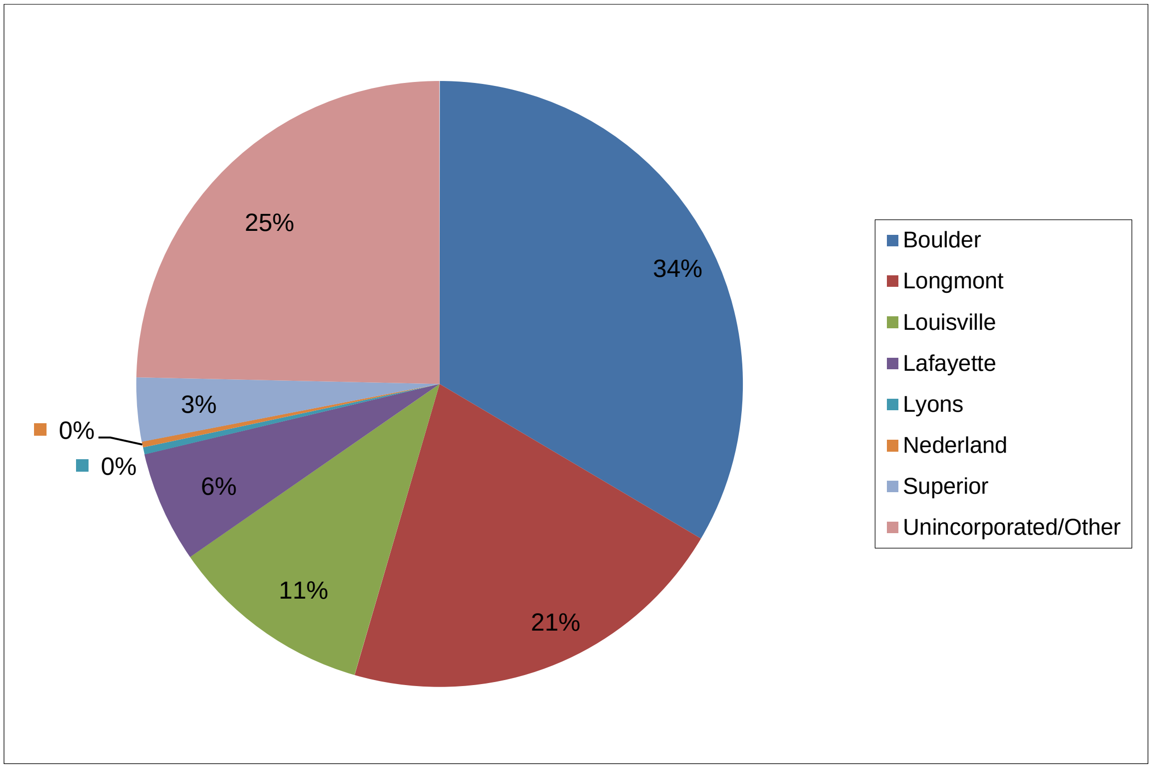
**County-Wide Emissions by Source, 2005**



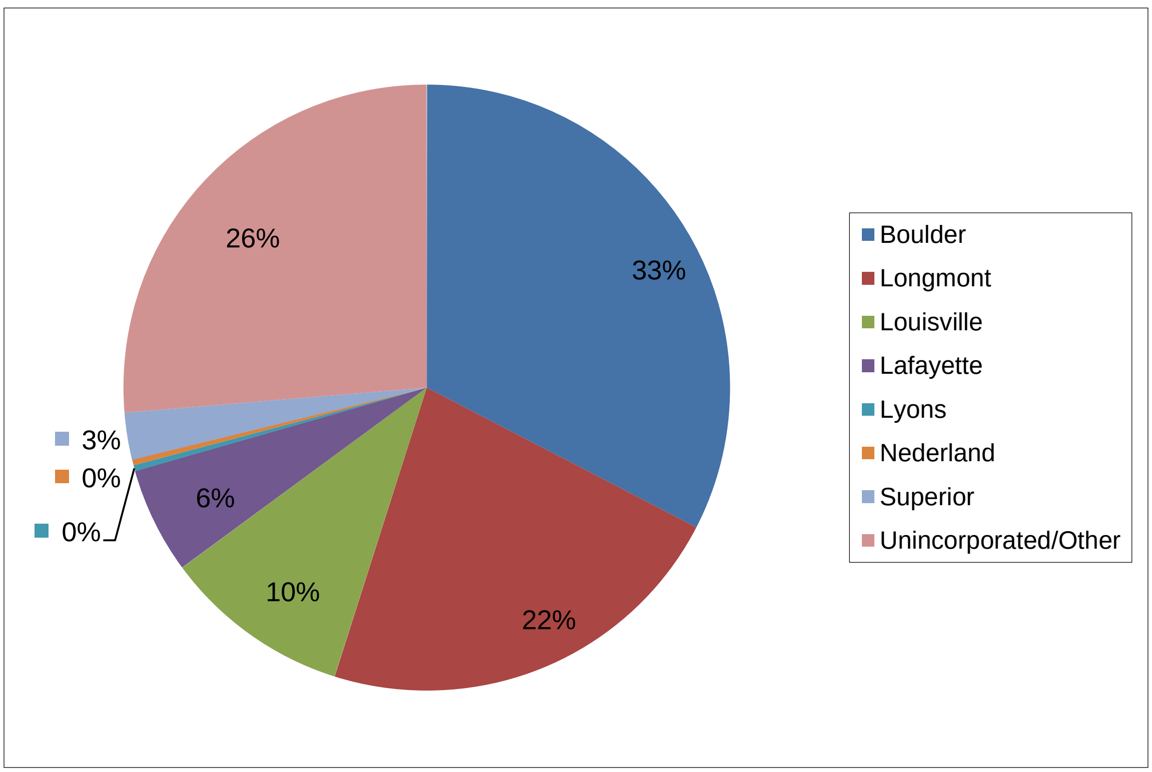

**County-Wide Emissions by Source, 2011**



**County-Wide Emissions by Municipality, 2005**




**County-Wide Emissions by Municipality, 2011**



Note that there are several explanations for the surprising size of the Unincorporated/Other slice of the pie. The unexpected result that Unincorporated/Other is the second-largest source of emissions in the County has to do with the "Other" and not with the "Unincorporated". "Other" includes all incorporated municipalities in Boulder County that are not explicitly disaggregated in the GHG inventory. These include but are not limited to Erie, Gunbarrel, Niwot, and Ward, and comprise 10% of the Unincorporated/Other total.

In addition, note that Cemex is a large contributor to the Unincorporated/Other total as "cement manufacture" (industrial process emissions) is 12% of the Unincorporated/Other total. Furthermore, Cemex natural gas use is estimated to contribute roughly 5% of the Unincorporated/Other total. Next note that "Other" includes county-wide agriculture-related emissions. Lastly note that transportation emissions for Unincorporated/Other are more than double those of Longmont.

If Cemex and "Other" were removed, the Unincorporated/Other total would drop behind Longmont in the County's Inventory. The following table compares the 2011 emissions components of Unincorporated/Other versus Longmont to help illustrate why the former has totals that are larger than the latter.

**2011 GHG Emissions (tCO2e)**

| Source | Longmont | Unincorporated/Other |
|---|---|---|
| Electricity | 679,200 | 378,174 |
| Natural Gas | 209,313 | 170,477 |
| Stationary Diesel | 270 | 153 |
| Mobile Gasoline | 135,110 | 421,321 |
| Mobile Diesel | 30,480 | 95,047 |
| Landfill Gas | 38,085 | 20,402 |
| Cement Manufacture | - | 159,879 |
| Enteric Fermentation | - | 13,723 |
| Manure Management | - | 415 |
| Soil Management | - | 27,562 |
| Aviation Fuel | 916 | - |
| **Grand Total** | **1,093,374** | **1,287,151** |

Another factor driving Unincorporated/Other emissions is simply demographics. The table below presents the population data for the various municipalities over time. Note that Unincorporated/Other comprises about 18% of total county population in 2010.

<table>
<tr><th>Population</th><th>1990</th><th>2000</th><th>2006</th><th>2007</th><th>2010</th></tr>
<tr><td>Boulder</td><td>85,127</td><td>99,093</td><td>101,918</td><td>102,569</td><td>97,385</td></tr>
<tr><td>Longmont</td><td>51,976</td><td>71,069</td><td>83,937</td><td>87,249</td><td>86,270</td></tr>
<tr><td>Louisville</td><td>12,363</td><td>18,937</td><td>19,379</td><td>19,488</td><td>18,376</td></tr>
<tr><td>Lafayette</td><td>14,708</td><td>23,197</td><td>24,557</td><td>25,091</td><td>24,453</td></tr>
<tr><td>Lyons</td><td>1,227</td><td>1,585</td><td>1,769</td><td>1,951</td><td rowspan="4">68,083</td></tr>
<tr><td>Nederland</td><td>1,099</td><td>1,394</td><td>1,511</td><td>1,444</td></tr>
<tr><td>Superior</td><td>255</td><td>9,008</td><td>10,789</td><td>10,703</td></tr>
<tr><td>Unincorporated/Other</td><td>58,584</td><td>45,531</td><td>53,143</td><td>54,030</td></tr>
<tr><td>County</td><td>225,339</td><td>269,814</td><td>297,003</td><td>302,525</td><td>294,567</td></tr>
</table>

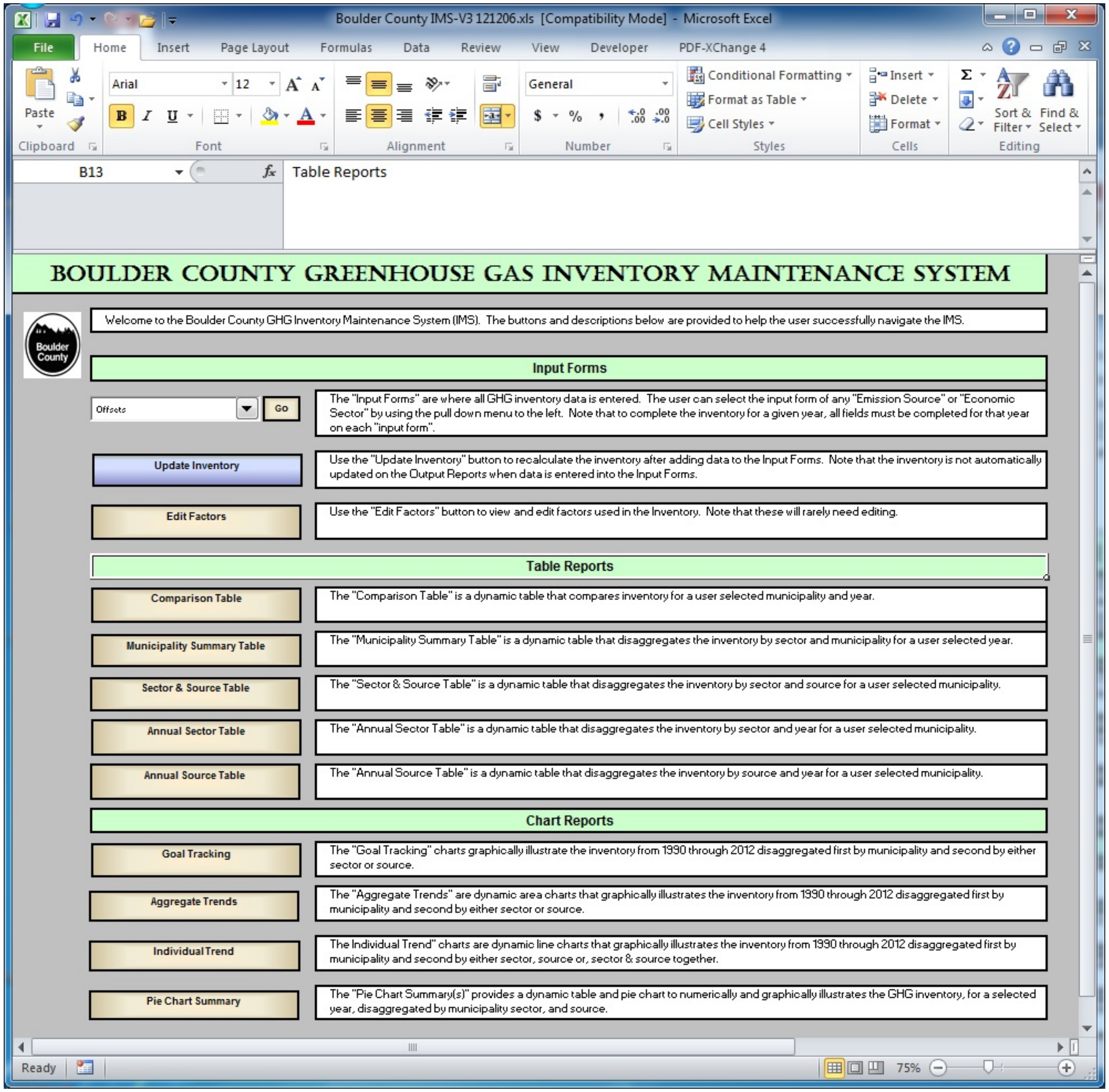
*Source: City of Boulder, Colorado, Population Growth & Projections*

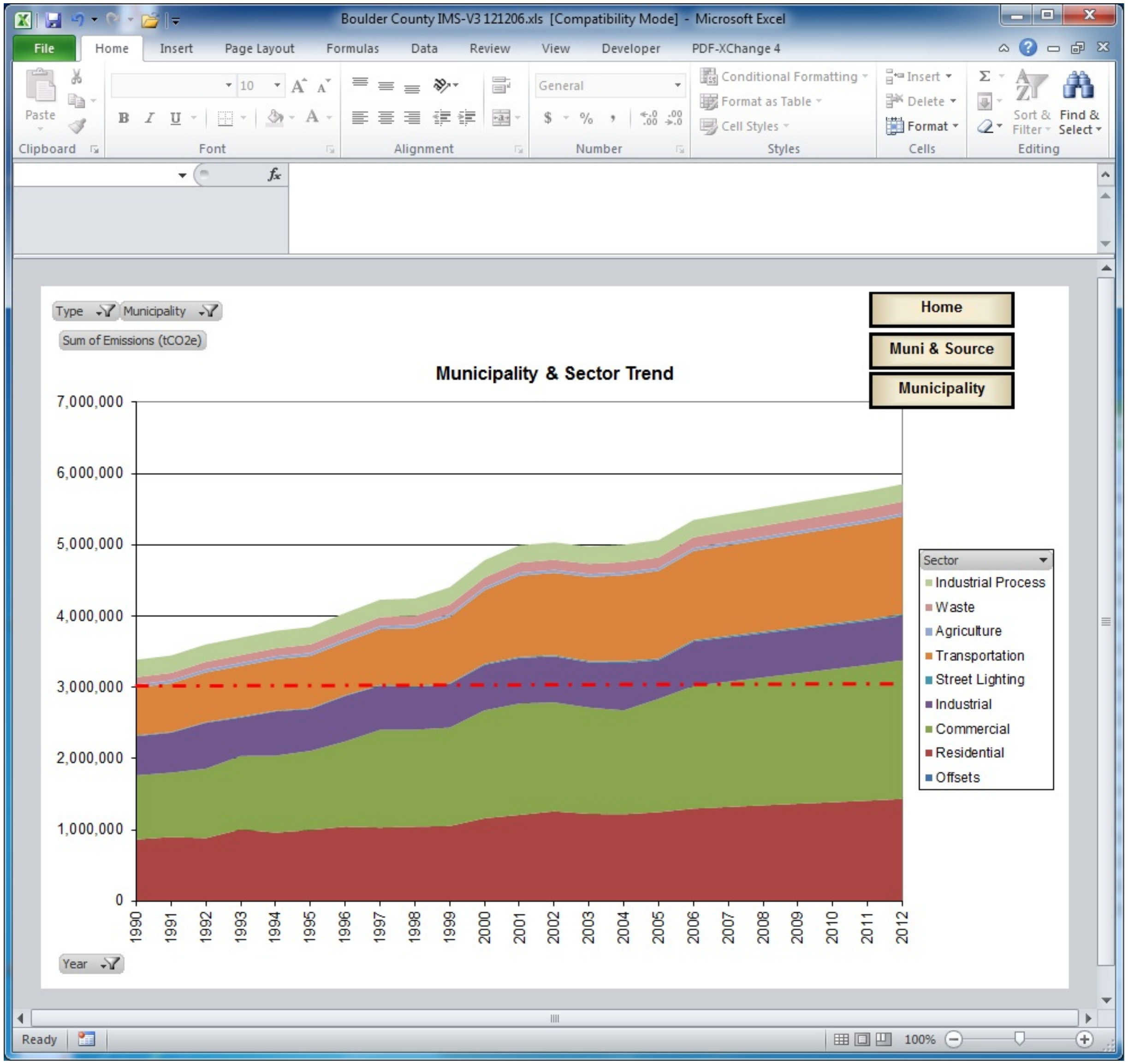
*Note: 2010 Data is from the County of Boulder, and reports Lyons, Nederland, Superior and Unincorporated/Other as "Other"*

## Boulder County Inventory Maintenance System

WSP (formerly Econergy) created an Excel workbook-based tool, containing all the raw data that underlie the county-wide inventory, which can be easily updated to maintain an up-to-date inventory over time. This tool, called the Inventory Maintenance System (IMS), also has a good deal of data-analysis capability. As new data become available, they are entered into the IMS which automatically updates the inventory and automatically generates a range of useful tabular and graphical presentations of inventory details.

In 2012, WSP updated the Boulder County IMS with the most recent data set available, for 2011. The following are a few selected screen shots from the IMS.


Boulder County IMS-V3 121206.xls [Compatibility Mode] - Microsoft Excel
File
Home
Insert
Page Layout
Formulas
Data
Review
View
Developer
PDF-XChange 4
B13
Table Reports
BOULDER COUNTY GREENHOUSE GAS INVENTORY MAINTENANCE SYSTEM
Boulder County
Welcome to the Boulder County GHG Inventory Maintenance System (IMS). The buttons and descriptions below are provided to help the user successfully navigate the IMS.
Input Forms
Offsets
Go
The "Input Forms" are where all GHG inventory data is entered. The user can select the input form of any "Emission Source" or "Economic Sector" by using the pull down menu to the left. Note that to complete the inventory for a given year, all fields must be completed for that year on each "input form".
Update Inventory
Use the "Update Inventory" button to recalculate the inventory after adding data to the Input Forms. Note that the inventory is not automatically updated on the Output Reports when data is entered into the Input Forms.
Edit Factors
Use the "Edit Factors" button to view and edit factors used in the Inventory. Note that these will rarely need editing.
Table Reports
Comparison Table
The "Comparison Table" is a dynamic table that compares inventory for a user selected municipality and year.
Municipality Summary Table
The "Municipality Summary Table" is a dynamic table that disaggregates the inventory by sector and municipality for a user selected year.
Sector & Source Table
The "Sector & Source Table" is a dynamic table that disaggregates the inventory by sector and source for a user selected municipality.
Annual Sector Table
The "Annual Sector Table" is a dynamic table that disaggregates the inventory by sector and year for a user selected municipality.
Annual Source Table
The "Annual Source Table" is a dynamic table that disaggregates the inventory by source and year for a user selected municipality.
Chart Reports
Goal Tracking
The "Goal Tracking" charts graphically illustrate the inventory from 1990 through 2012 disaggregated first by municipality and second by either sector or source.
Aggregate Trends
The "Aggregate Trends" are dynamic area charts that graphically illustrates the inventory from 1990 through 2012 disaggregated first by municipality and second by either sector or source.
Individual Trend
The Individual Trend" charts are dynamic line charts that graphically illustrates the inventory from 1990 through 2012 disaggregated first by municipality and second by either sector, source or, sector & source together.
Pie Chart Summary
The "Pie Chart Summary(s)" provides a dynamic table and pie chart to numerically and graphically illustrates the GHG inventory, for a selected year, disaggregated by municipality sector, and source.
Ready
75%


Boulder County IMS-V3 121206.xls [Compatibility Mode] - Microsoft Excel
Home
Muni & Source
Municipality
Type
Municipality
Sum of Emissions (tCO2e)
Municipality & Sector Trend
7,000,000
6,000,000
5,000,000
4,000,000
3,000,000
2,000,000
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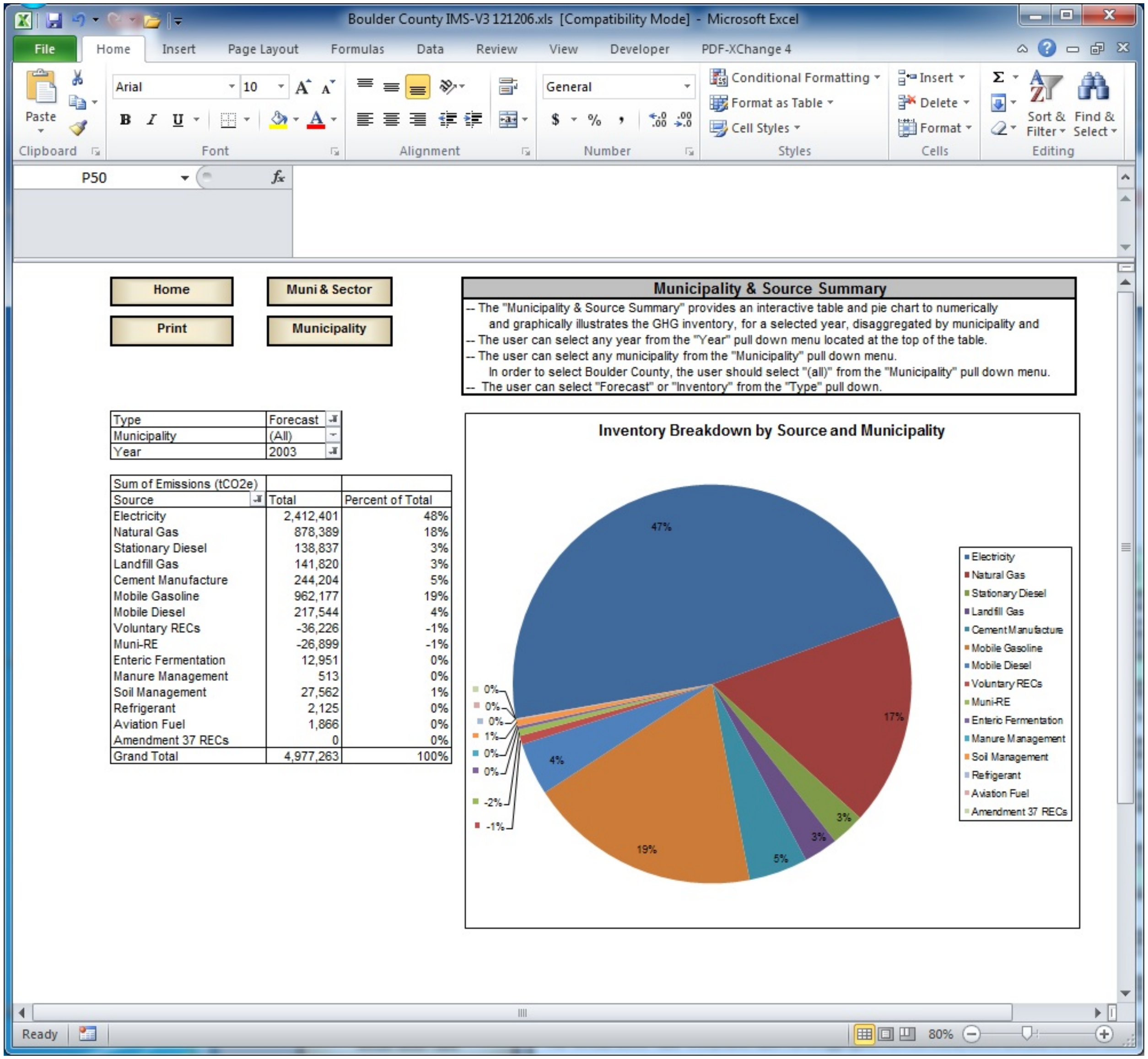
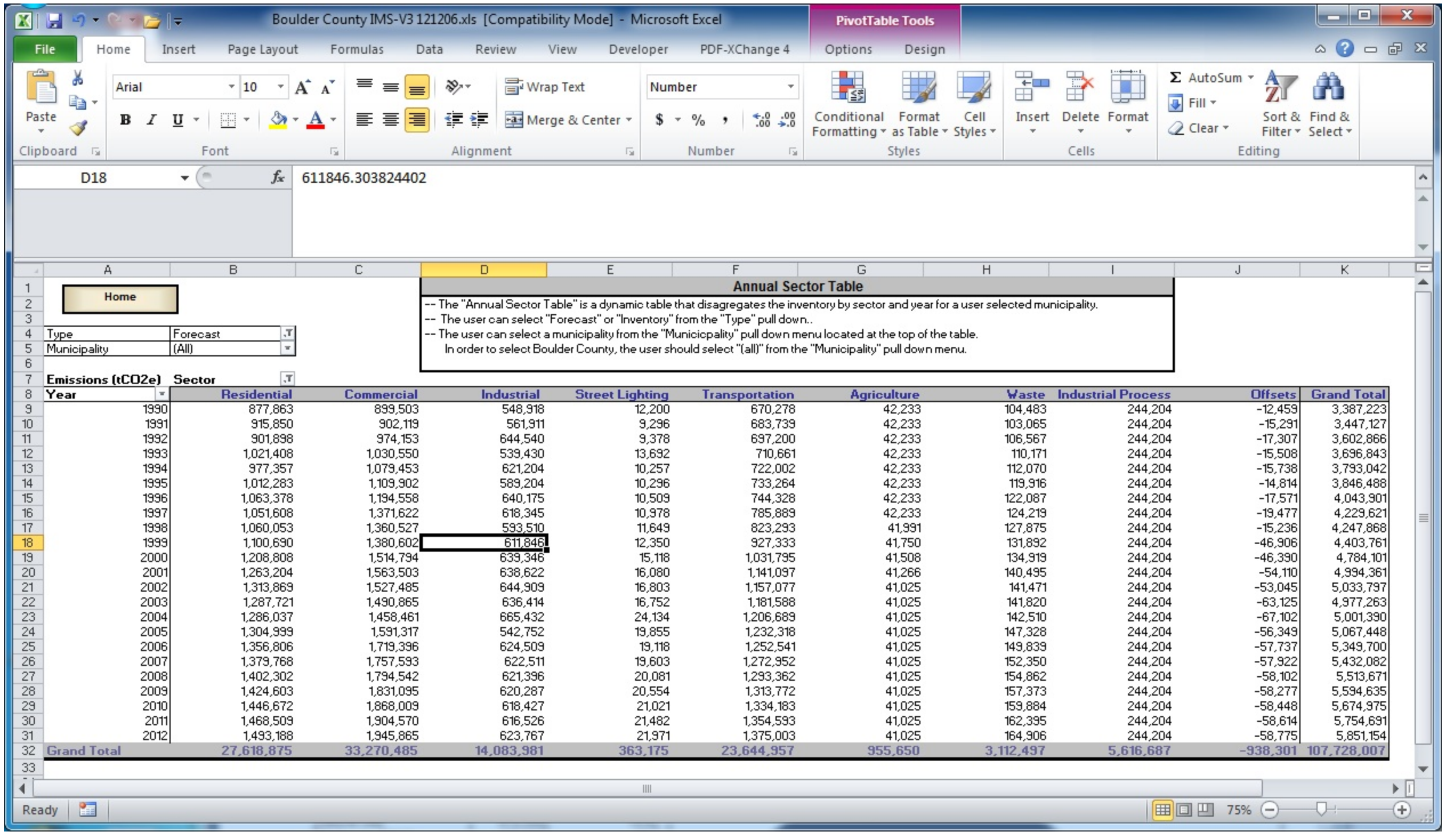
Industrial
Commercial
Residential
Offsets




| | |
|---|---|
| Type | Forecast |
| Municipality | (All) |
| Year | 2003 |

| Sum of Emissions (tCO2e) | | |
|---|---|---|
| Source | Total | Percent of Total |
| Electricity | 2,412,401 | 48% |
| Natural Gas | 878,389 | 18% |
| Stationary Diesel | 138,837 | 3% |
| Landfill Gas | 141,820 | 3% |
| Cement Manufacture | 244,204 | 5% |
| Mobile Gasoline | 962,177 | 19% |
| Mobile Diesel | 217,544 | 4% |
| Voluntary RECs | -36,226 | -1% |
| Muni-RE | -26,899 | -1% |
| Enteric Fermentation | 12,951 | 0% |
| Manure Management | 513 | 0% |
| Soil Management | 27,562 | 1% |
| Refrigerant | 2,125 | 0% |
| Aviation Fuel | 1,866 | 0% |
| Amendment 37 RECs | 0 | 0% |
| Grand Total | 4,977,263 | 100% |



Annual Sector Table

-- The "Annual Sector Table" is a dynamic table that disagregates the inventory by sector and year for a user selected municipality.
-- The user can select "Forecast" or "Inventory" from the "Type" pull down..
-- The user can select a municipality from the "Municicpality" pull down menu located at the top of the table.
In order to select Boulder County, the user should select "(all)" from the "Municipality" pull down menu.

Type: Forecast
Municipality: (All)

| Emissions (tCO2e) Year | Residential | Commercial | Industrial | Street Lighting | Transportation | Agriculture | Waste | Industrial Process | Offsets | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 877,863 | 899,503 | 548,918 | 12,200 | 670,278 | 42,233 | 104,483 | 244,204 | -12,459 | 3,387,223 |
| 1991 | 915,850 | 902,119 | 561,911 | 9,296 | 683,739 | 42,233 | 103,065 | 244,204 | -15,291 | 3,447,127 |
| 1992 | 901,898 | 974,153 | 644,540 | 9,378 | 697,200 | 42,233 | 106,567 | 244,204 | -17,307 | 3,602,866 |
| 1993 | 1,021,408 | 1,030,550 | 539,430 | 13,692 | 710,661 | 42,233 | 110,171 | 244,204 | -15,508 | 3,696,843 |
| 1994 | 977,357 | 1,079,453 | 621,204 | 10,257 | 722,002 | 42,233 | 112,070 | 244,204 | -15,738 | 3,793,042 |
| 1995 | 1,012,283 | 1,109,902 | 589,204 | 10,296 | 733,264 | 42,233 | 119,916 | 244,204 | -14,814 | 3,846,488 |
| 1996 | 1,063,378 | 1,194,558 | 640,175 | 10,509 | 744,328 | 42,233 | 122,087 | 244,204 | -17,571 | 4,043,901 |
| 1997 | 1,051,608 | 1,371,622 | 618,345 | 10,978 | 785,889 | 42,233 | 124,219 | 244,204 | -19,477 | 4,229,621 |
| 1998 | 1,060,053 | 1,360,527 | 593,510 | 11,649 | 823,293 | 41,991 | 127,875 | 244,204 | -15,236 | 4,247,868 |
| 1999 | 1,100,690 | 1,380,602 | 611,846 | 12,350 | 927,333 | 41,750 | 131,892 | 244,204 | -46,906 | 4,403,761 |
| 2000 | 1,208,808 | 1,514,794 | 639,346 | 15,118 | 1,031,795 | 41,508 | 134,919 | 244,204 | -46,390 | 4,784,101 |
| 2001 | 1,263,204 | 1,563,503 | 638,622 | 16,080 | 1,141,097 | 41,266 | 140,495 | 244,204 | -54,110 | 4,994,361 |
| 2002 | 1,313,869 | 1,527,485 | 644,909 | 16,803 | 1,157,077 | 41,025 | 141,471 | 244,204 | -53,045 | 5,033,797 |
| 2003 | 1,287,721 | 1,490,865 | 636,414 | 16,752 | 1,181,588 | 41,025 | 141,820 | 244,204 | -63,125 | 4,977,263 |
| 2004 | 1,286,037 | 1,458,461 | 665,432 | 24,134 | 1,206,689 | 41,025 | 142,510 | 244,204 | -67,102 | 5,001,390 |
| 2005 | 1,304,999 | 1,591,317 | 542,752 | 19,855 | 1,232,318 | 41,025 | 147,328 | 244,204 | -56,349 | 5,067,448 |
| 2006 | 1,356,806 | 1,719,396 | 624,509 | 19,118 | 1,252,541 | 41,025 | 149,839 | 244,204 | -57,737 | 5,349,700 |
| 2007 | 1,379,768 | 1,757,593 | 622,511 | 19,603 | 1,272,952 | 41,025 | 152,350 | 244,204 | -57,922 | 5,432,082 |
| 2008 | 1,402,302 | 1,794,542 | 621,396 | 20,081 | 1,293,362 | 41,025 | 154,862 | 244,204 | -58,102 | 5,513,671 |
| 2009 | 1,424,603 | 1,831,095 | 620,287 | 20,554 | 1,313,772 | 41,025 | 157,373 | 244,204 | -58,277 | 5,594,635 |
| 2010 | 1,446,672 | 1,868,009 | 618,427 | 21,021 | 1,334,183 | 41,025 | 159,884 | 244,204 | -58,448 | 5,674,975 |
| 2011 | 1,468,509 | 1,904,570 | 616,526 | 21,482 | 1,354,593 | 41,025 | 162,395 | 244,204 | -58,614 | 5,754,691 |
| 2012 | 1,493,188 | 1,945,865 | 623,767 | 21,971 | 1,375,003 | 41,025 | 164,906 | 244,204 | -58,775 | 5,851,154 |
| Grand Total | 27,618,875 | 33,270,485 | 14,083,981 | 363,175 | 23,644,957 | 955,650 | 3,112,497 | 5,616,687 | -938,301 | 107,728,007 |

## Emissions Mitigation Strategies

A broad range of emissions mitigation strategies was analyzed by WSP in 2007. Demand-side measures (DSM) were first investigated to gauge the opportunities presented by energy efficiency technologies. Supply-side measures were then evaluated to quantify the mitigation potential of renewable energy (RE) technologies. These analyses were updated in 2012/2013. The updated results are summarized below and the details are presented in Chapters 3 – 6 of the report.

Achieving aggressive market penetrations in the implementation of these strategies will produce 53% of the overall GHG emissions reductions county-wide that are needed to hit the Commission's target in 2020. This level of emissions mitigation will require investments by building owners and vehicle owners of about $1.1 billion through 2020. By 2020, these investments are estimated to deliver $128 million/yr in energy cost savings and energy sales revenue. The overall Benefit:Cost ratio of this mix of measures is 2.2. This means that, over the equipment lifetime, each $1 of investment in DSM and RE will produce $2.20 in energy cost savings and energy sales revenue (constant 2013 $$).

### *Emissions Reductions from Commercial Buildings*

The table below presents the results of the updated in-depth analysis of GHG emissions mitigation opportunities from DSM in commercial buildings. Analysis details are contained in Chapter 4.

| | 2020 REDUCTION ($TCO_2E$) | FRACTION OF COMMERCIAL GOAL ACHIEVED (%) | SIMPLE PAYBACK (YRS) |
|---|---|---|---|
| Commercial retrofit – Bundle 1 | 48,101 | 7% | 2.7 |
| Commercial retrofit – Bundle 2 | 145,419 | 21% | 4.8 |
| Commercial retrofit – Bundle 3 | 166,988 | 24% | 10.5 |
| Commercial new construction | 49,913 | 7% | na |

All things considered, Bundle 2 was judged to be the most-aggressive package that offers economic performance that can realistically appeal to the market. The marginal abatement cost (MAC) of Bundle 2 is (-91)$/mtCO2, indicating it is an excellent investment. To achieve the reductions presented here will require investment by building owners of approximately $102 million through 2020.

Impacts for solar PV are accounted for separately in the Renewable Energy chapter.

### *Emissions Reductions from Residential Buildings*

In-depth analysis was performed of emissions mitigation opportunities from DSM in residential buildings. The table below presents the updated residential results. Analysis details are contained in Chapter 3.

| | 2020 REDUCTION ($TCO_2E$) | FRACTION OF RESIDENTIAL GOAL ACHIEVED (%) | SIMPLE PAYBACK (YRS) |
|---|---|---|---|
| Residential retrofit – Bundle 1 | 117,231 | 21% | 3.9 |
| Residential retrofit – Bundle 2 | 219,000 | 39% | 10.8 |
| Residential retrofit – Bundle 3 | 265,413 | 48% | 16.0 |
| Residential new construction | 61,216 | 7% | Na |

All things considered, Bundle 2 was judged to be the most-aggressive package that offers economic performance that can realistically appeal to the market. The MAC of the residential Bundle 2 is (-11)$/mtCO2, indicating it is a worthwhile investment. To achieve the reductions presented here will require investment by building owners of approximately $352 million through 2020.

Impacts for solar DHW and PV are discussed in the Renewable Energy chapter.

### *Emissions Reductions from Transportation*

The most dramatic change in the county-wide inventory, from 2005 to 2011, is the inventory of the Transportation sector. Historical data show that transportation emissions peaked and flattened in 2005 and 2006 and then established a decidedly downward trend through 2011, the last year of historical data analyzed. More stringent federal vehicle fuel economy standards took effect in calendar year 2010 (when 2011 model year vehicles became available), which likely contributed to the downward trajectory of the sector trend line.

If this Business-As-Usual (BAU) trend continues, 2020 forecasts show that the transportation sector emissions will decrease to 729,400 $tCO_2e$. The County's goal is to be 40% below 2005 emissions, which establishes the nominal Transportation sector target at a level of 738,601 $tCO_2e$. Thus the 2020 emissions level is projected to be 9,224 $tCO_2e$ below the target.

Emissions mitigation opportunities in the transportation sector were analyzed in-depth. The table below presents the 2007 transportation sector results that have been updated with 2012 energy and vehicle costs. Details of the analysis are contained in Chapter 5.

| Strategy Description | GHG Emissions Reduction ($mtCO_2e$) |
|---|---|
| 10% E85 & 30% E15 market penetrations | 19,000 |
| 20% B20 biodiesel market penetration | 9,600 |
| 5% PHEV market penetration | 12,400 |
| Transportation Master Plan | 19,400 |
| | |
| Total Reduction | 60,600 |
| **Reduction Required to Meet Goal** | **-9,200** |
| **Over-achieved Reduction** | **69,200** |

The MACs of key transportation emissions reduction strategies range from (0)$/mtCO2 for E15 and E85 to (+20)$/mtCO2 for B20 to (+66)$/mtCO2 for plug-in hybrid electric vehicles (with tax credits). To achieve the reductions presented here will require investment by vehicle owners of approximately $60 million, after accounting for tax credits but not including implementation costs for the TMP.

### *Emissions Reductions from Renewable Energy*

Results from the updated analysis of renewable energy measures are presented below. Analysis details are contained in Chapter 6.

| Strategy Description | GHG Emissions Reduction ($mtCO_2e$) | % of Gap-to-Plan after DSM & Transportation Measures |
|---|---|---|
| MSW-to-electricity | 270,000 | 19.4% |
| Expansion of hydro capacity | 7,430 | 0.5% |
| PV on commercial & public bldgs | 13,500 | 1.0% |
| PV on residential buildings | 20,200 | 1.4% |
| Wind | 17,000 | 1.2% |
| Bulk purchase CERs, VERs, RECs | 100,000 | 7.2% |
| Solar DHW | 30,740 | 2.2% |
| **Total reduction** | **458,870** | **33%** |

The MACs of key RE strategies range from (-124) $/mtCO2 for municipal solid waste (MSW) gasification-to-electricity, to +20 $/mtCO2 for RECs, to +85 $/mtCO2 for solar DHW, to +132 $/mtCO2 for solar PV on commercial buildings. To achieve the reductions presented here will require investment of approximately $445 million through 2020.

## Summary of Updated Results

Aggregated results of the updated analysis indicate that cost-effective energy efficiency and renewable energy measures have the potential to reduce county-wide GHG emissions by about 1,041,500 mtCO2e/yr in 2020, a reduction of about 21%, relative to the updated BAU. This represents about 54% of the reduction required to hit the 2020 target. These measures are estimated to deliver $128 million/yr in energy cost savings and energy sales revenues in 2020, at a total implementation cost of about $1.1 billion. Over the 25-year lifetime of the energy efficiency and renewable energy measures, the Benefit:Cost ratio is about 2.2.

The following table summarizes the updated GHG impacts of the demand-side measures examined by this study.

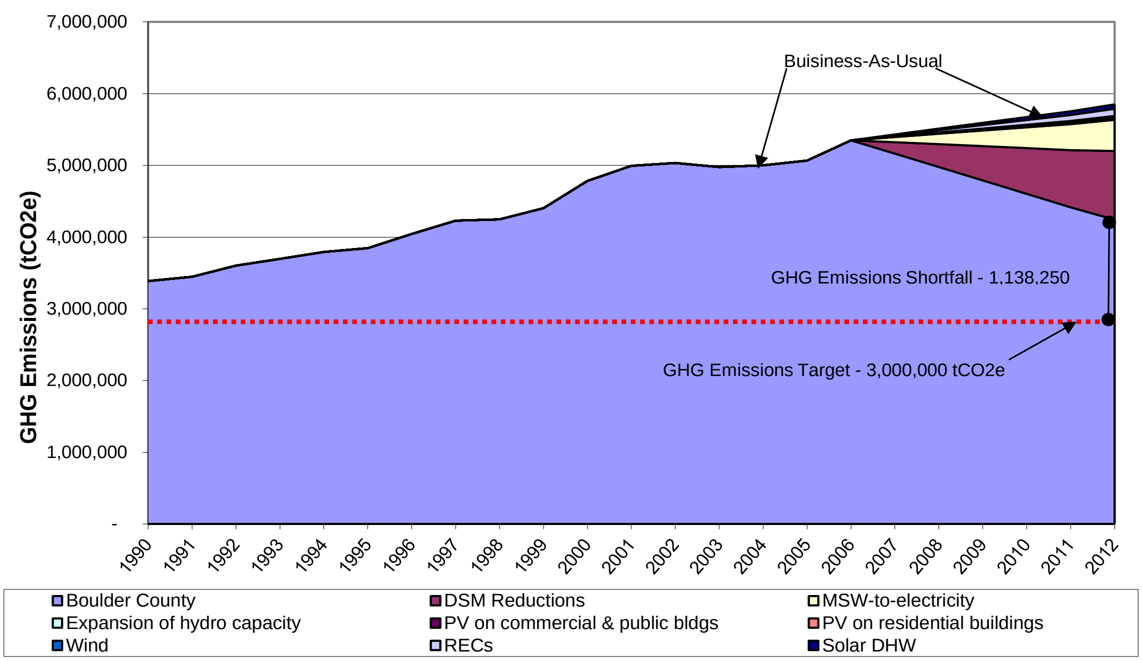
| | Required Reduction in 2020 | Expected GHG Reduction in 2020 | Reduction Goal Shortfall |
|---|---|---|---|
| | (mtCO2e) | (mtCO2e) | (mtCO2e) |
| Residential Buildings (retrofits + new construction) | 693,058 | 268,900 | 424,158 |
| Commercial Buildings (retrofits + new construction) | 865,328 | 206,635 | 658,693 |
| Transportation | 0 | 60,600 | -60,600 |
| Industrial Energy | 243,607 | 24,766 | 218,841 |
| Industrial Process | 67,588 | 8,092 | 59,496 |
| Agriculture | 16,790 | 1,961 | 14,829 |
| Solid Waste | 64,547 | 6,792 | 57,755 |
| Street Lighting | 26,253 | 4,939 | 21,314 |
| **Total** | **1,977,200** | **582,700** | **1,394,500** |

Clearly, demand-side strategies by themselves will not achieve the GHG goal. Therefore, supply-side strategies and/or emissions offsets will be needed to close the GHG reduction gap. Several renewable energy supply-side strategies were evaluated in Chapter 6. These consist of MSW-to-energy, PV, wind energy, carbon offsets, green tags or RECs, and solar hot water. The following table summarizes the emissions reductions the updated analysis estimates are achievable with this mix of RE supply-side measures. It shows the expected shortfall in 2020 to be 935,630 mtCO2e/yr after implementation of both DSM and RE measures evaluated here.

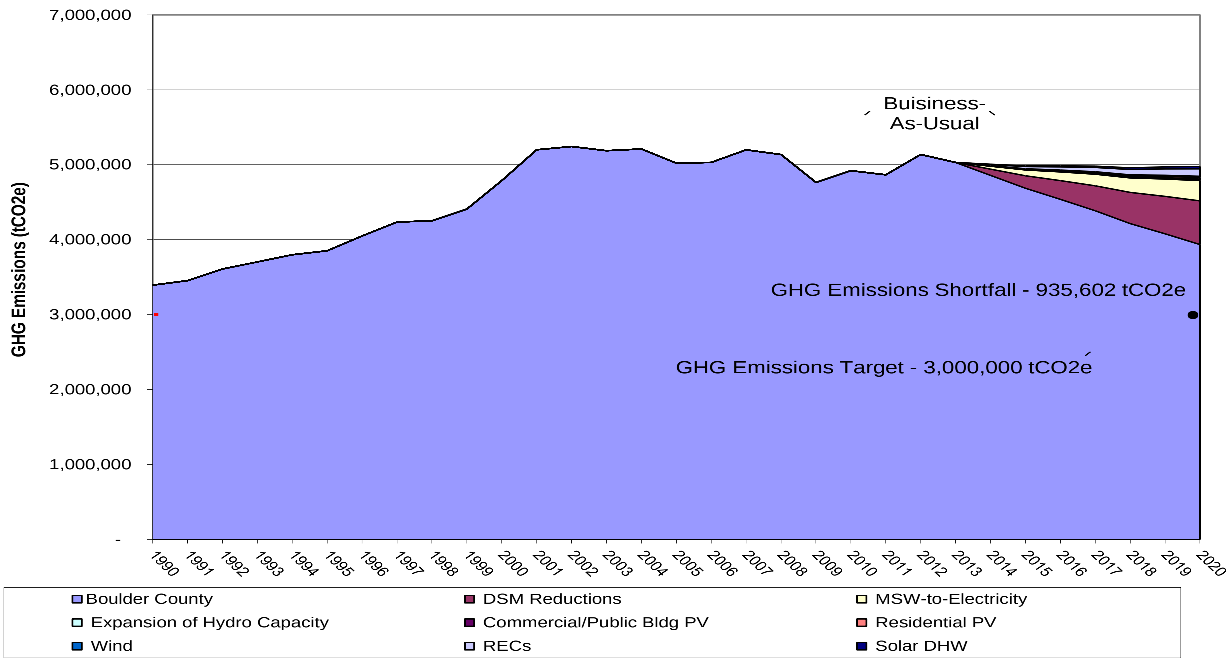
| | Reduction Shortfall after DSM ($mtCO_2e$) | Expected RE GHG Reduction ($mtCO_2e$) | Remaining Reduction Shortfall after RE ($mtCO_2e$) |
|---|---|---|---|
| | 1,394,500 | | |
| MSW-to-electricity | | 270,000 | |
| Expansion of hydro capacity | | 7,430 | |
| PV on commercial & public bldgs | | 13,500 | |
| PV on residential buildings | | 20,200 | |
| Wind | | 17,000 | |
| Bulk purchase CERs, VERs, RECs | | 100,000 | |
| Solar DHW | | 30,740 | |
| **Total reduction** | | **458,870** | **935,630** |

The following graphs compare the deflection of the BAU emissions trend line over time in response to the mitigation impacts quantified by the 2007 analysis versus the updated analysis.

**Projected Mitigation Impacts, 2007 Edition**



**Projected Mitigation Impacts, 2012 Edition**




## Phased Implementation Approach

Energy efficiency (demand-side measures) almost always have a lower Cost of Saved Energy ($/kWh) than the cost of energy provided by new supply measures, including renewable energy. The preliminary results of this work indicate that energy efficiency is more cost-effective and should, therefore, be implemented aggressively before aggressive implementation of renewable energy measures. Also, energy efficiency and renewable energy implementation mechanisms will need time to ramp up. For these reasons, it is anticipated that a phased approach to the implementation of new initiatives of Boulder County's SEP will make sense.

## CONCLUSIONS

These results make it apparent that the DSM and RE measures evaluated are inadequate to the task of achieving the County's GHG goal. According to this updated analysis, the suite of DSM and RE measures will get the county only about 54% of the way to the goal line. Additional creative and aggressive strategies need to be developed to boost emissions reductions, especially via DSM in the Commercial Buildings and Residential Buildings sectors.

The updated MACs for the key emissions reduction strategies are summarized in the following table.

| Reduction Measure | MAC ($/mtCO2) |
|---|---|
| Commercial Buildings Bundle 2 | -91 |
| Residential Buildings Bundle 2 | -11 |
| Plug-in Hybrid Electric Vehicle | +66 |
| Solar PV Residential | +195 |
| Solar PV Commercial | +132 |
| Solar DHW | +85 |
| MSW-to-Electricity | -124 |
| RECs at $13/MWh | +20 (varies depending on project location) |
| Carbon Offsets at $10/mtCO2 | +10 |

Commercial and residential buildings must achieve emissions reductions in 2020 of about 47%, relative to 2011 actual emissions, in order for these sectors to hit their nominal targets. This updated analysis assumes reductions of only about 39% and 24% respectively, for these sectors relative to 2011 actuals, reflecting the anticipated difficulty of achieving deep market penetrations for building DSM.

The results presented here represent market penetrations of 35% for DSM packages that achieve about 30% energy savings on average. Based on historical DSM program performance experienced by electric and natural gas utilities in the US over the past 25 years, it is believed that even a 35% market penetration is a high bar. Achieving this will require either substantial increases in the cost of conventional electricity and natural gas or substantial financial incentives for building owners, or both. Xcel and Longmont Power & Communications currently offer financial incentives for building DSM that should be aggressively pursued. However, these incentives are unlikely to be sufficient to realize the Boulder County Commission's GHG goal for the county's commercial buildings.

It is important to bear in mind that the vast majority (about 93%) of the Commercial Buildings sector emissions that would be produced in 2020 under BAU emanate from the building stock existing as of 2011, as opposed to new construction that will be added during the 2012 – 2020 period. Further, it is important to note that the vast majority of existing commercial buildings are small buildings that are too small to attract the interest of the energy services performance contracting industry (ESCOs). WSP has recommended that a project performance guarantee facility be established to mitigate ESCO contractual risk to a level that would attract the active engagement of the ESCO industry in order to bring substantial private capital to bear on Boulder County's existing small commercial buildings subsector.

Similar conclusions can be drawn for the Residential Buildings sector. The vast majority (about 94%) of the residential buildings emissions that would be produced in 2020 under BAU emanate from the building stock existing as of 2011, as opposed to new construction added during the 2012 – 2020 period. Thus, the key challenge for county and municipal leaders will be figuring out how to effect rapid and dramatic change in behaviors of building owners. While home owners may be willing to accept longer paybacks of investments than commercial building owners, the owners of residential rental properties will behave more like the latter.

The results for the Transportation sector highlight the crucial role that vehicle fuel economy and low-carbon vehicle fuels play in acquiring substantial GHG emissions reductions. The Commissioners must consider whether it is acceptable policy to initiate programmatic activities that will aggressively promote public awareness of E15 and E85 benefits with the aim of encouraging motorists to use these fuels. Every effort should be made to leverage E85 programs already offered by the Colorado Biofuels Coalition.

The analysis also spotlights the substantial potential for the county's MSW resource to be exploited for important GHG emissions reductions. Since this potential represents as much as 27% of the total prospective reductions that are enumerated in this report, MSW gasification warrants serious investigation and consideration.

Finally, the purchase of Carbon Offsets should be seriously considered as one of the more cost-effective mitigation strategies. Offsets can be purchased through several sources including online "carbon calculators" and offset brokers. Attention must be paid to offset quality, however. Generally, the higher the offset quality, the higher the price. If the County finds value in fostering support for clean economic development in emerging economies, it could promote the purchase of Verified Emissions Reductions (VERs) or Certified Emissions Reductions (CERs). Alternatively, if the County wishes to foster development of US-based emissions mitigation projects, it could promote the purchase of VERs generated by US projects. The Colorado Carbon Fund is another potential channel through which Colorado-based offsets could be purchased. However, the caveat to bear in mind with respect to carbon offsets and RECs is that these are strictly costs incurred by the buyer; they offer no return on investment. In contrast, even though PV has a very high MAC it nevertheless eventually recovers the investment via avoided grid electricity costs.

Several ballot initiatives approved by voters are having significant impacts on the county's GHG emissions and must, therefore, be taken into account by the SEP. These include Colorado Renewable Portfolio Standard, RTD's FasTracks, the City of Boulder carbon tax, fuel switching some Xcel power plants from coal to natural gas, and the County's sustainability fee. Finally, the ballot initiative that has led to investigation of the prospective creation of a municipal utility to serve the City of Boulder has great potential to substantially affect the county-wide GHG footprint, since Boulder represents one-third of that footprint.

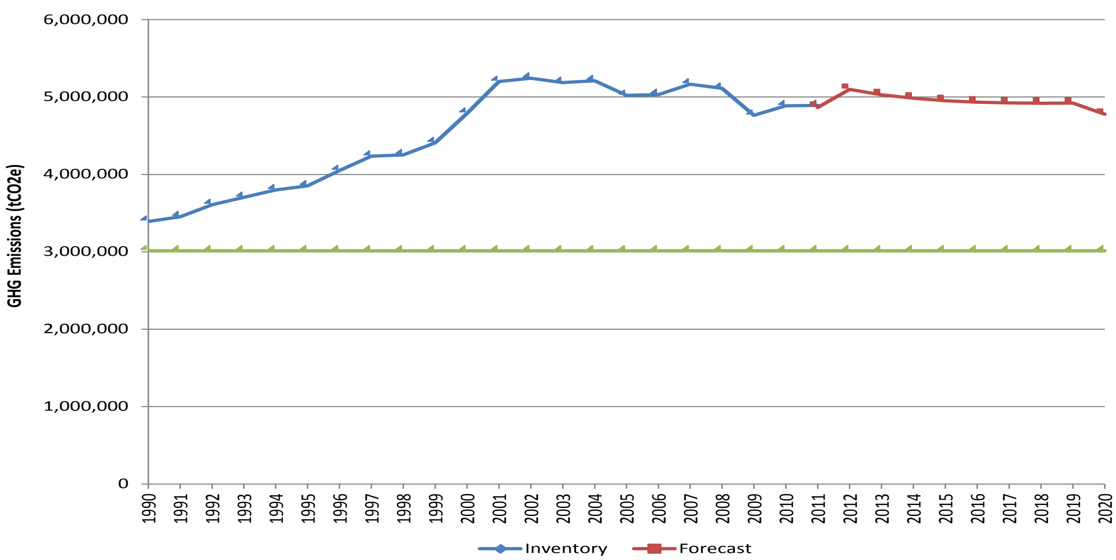
In addition, Boulder County voters may be asked to approve a new tax increase to generate additional funds for the Commission's sustainability initiative.

## CLOSING THE REMAINING GAP-TO-PLAN

WSP's 2012 update of the inventory of GHG emissions emanating from within the county economy produced an updated future Business as Usual emissions trajectory. This BAU trajectory incorporates anticipated future changes including: 1) reductions in the regional electricity grid carbon intensity; 2) improvements in average fuel efficiency of the vehicle fleet; 3) on-going impacts of existing SEP and Xcel programs. Each of these emissions drivers are now part of the future BAU.

This recast BAU emissions trajectory is depicted in the following graph. In 2020 it estimates that economy-wide GHG emissions will be about 4,977,200 mtCO2e/yr. Compared to the goal of 3 million this leaves a gap of about 2 million mtCO2e/yr in 2020.

**Emissions Trajectory, 1990 - 2020**

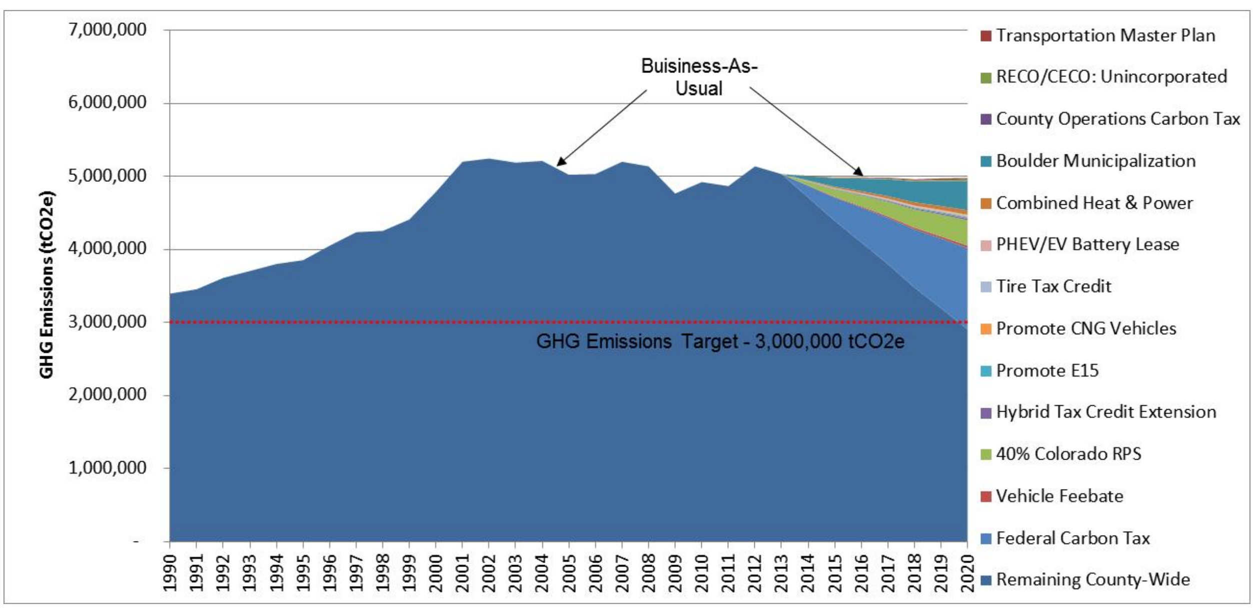



As part of WSP's 2012 – 2013 work scope, new initiatives were evaluated that could be pursued within the SEP context in order to increase programmatic impacts and thereby reduce the projected gap-to-plan.

Toward this end, WSP investigated several initiatives that have potential to capture substantial emissions mitigation if designed well and implemented properly. Some of these are new initiatives while some are existing initiatives that warrant redoubled effort to capture their mitigation potential. Some of these can be pursued by Boulder County independent of local governments, the State of Colorado, and federal government while others will require collaboration with these other players. Therefore, the menu of gap-closing initiatives was parsed into three 'buckets' – 1) those actions over which Boulder County has direct control; 2) those actions over which Boulder County can exert influence; and 3) those actions requiring legislation at the state level. The following table summarizes the potential mitigation achievable with several specific gap-closing actions.

| Bucket | Project | GHG Savings in 2020 (tCO2e) | |
|---|---|---|---|
| Control | Transportation Master Plan | 19,000 | |
| | RECO/CECO: Unincorporated | 19,400 | |
| | County Operations Internal $CO_2$ Tax | 3,130 | 41,530 |
| Influence | Boulder Municipalization | 400,000 | |
| | Combined Heat & Power | 62,000 | 462,000 |
| State/ Federal | Colorado $CO_2$ Tax | 1,113,500 | |
| | Vehicle Feebate | 33,000 | |
| | 40% Colorado RPS | 348,081 | |
| | Hybrid Electric Tax Credit Extension | 21,000 | |
| | Promote E15 | 19,000 | |
| | Promote CNG Vehicles | 13,000 | |
| | Hi-Efficiency Tire Tax Credit | 10,000 | |
| | PHEV/EV Battery Lease | 12,000 | |
| | | | 1,569,581 |
| **Total** | | | **2,073,111** |

These mitigation actions, if fully realized, would completely close the gap that the updated BAU trajectory projects for 2020. The wedge diagram below depicts the potential of each mitigation action. Note that interactions among these measures have not been quantified since this is beyond the WSP scope of work.



## SEP BASELINE ESTABLISHED WITH REGRESSION ANALYSIS

Also in 2012 – 2013, WSP investigated whether it is possible to discern the county-wide SEP programmatic impacts on electricity and natural gas usage and GHG emissions in the commercial and residential sectors. The inherent low resolution of sector-level data leads, at best, to a rough estimate of SEP impacts. WSP determined that post-SEP implementation data must be accumulated over a few years to roughly calculate programmatic impacts. More accurate impact evaluation must involve evaluation of individual premise-level data across samples of building types, using well-known programmatic impact-evaluation techniques. In the future, with sufficient post-SEP implementation data, it may be possible to discern approximate SEP impacts using sector-level data, via the data normalization methodology developed by WSP and presented in this report.

The analysis indicates that, among the independent variables of weather, population, and GDP, weather most influences natural gas usage, and GDP most influences electricity usage in both sectors. Normalized pre-SEP baseline values for natural gas and electricity usage for both sectors are summarized below, expressed as annual average per-capita values. For comparison, actual historical annual average per-capital values are also presented.

Best-fit algorithms from the normalization exercise were driven with long-term average values for the independent variables to establish normalized baselines for natural gas and electricity usage in the pre-SEP period. In the future, with sufficient data from the post-SEP implementation period, this methodology can be applied to establish normalized post-SEP values. The difference between pre- and post-SEP will be a rough estimate of the SEP impact.

| | Residential Buildings Sector | Commercial Buildings Sector |
|---|---|---|
| **Natural Gas Usage, therms/person-yr** | 291.68 Baseline | 294.23 Baseline |
| | 277.56 Actual | 276.36 Actual |
| **Electricity Usage, kWh/person-yr** | 3684.41 Baseline | 4938.05 Baseline |
| | 3632.16 Actual | 4902.53 Actual |

# 1. INTRODUCTION

In 2006 and 2007, Econergy International Corporation was engaged by Boulder County to develop an inventory of GHG emissions produced by the entire county economy and to assist the County in developing a comprehensive plan for mitigating emissions to a level representing pro rata compliance with the US commitment under the United Nations Kyoto Protocol. The report on the inventory and recommended mitigation actions issued by Econergy in late 2007 served as a guidance resource that helped inform the creation of the Boulder County Sustainable Energy Plan (SEP).

In 2009, the Econergy consulting division was acquired by WSP Environment & Energy. Boulder County engaged WSP in 2012 to update and augment the previous body of Econergy work. This report is a 2012 edition of the 2007 report, embodying updates of the economy-wide GHG inventory and mitigation analysis, and incorporating new elements such as 2005 versus 2011 inventory comparisons and a methodology based on data normalization techniques by which SEP impacts can be estimated in the future.

The overarching philosophical framework within which Boulder County's SEP has been developed is that the Commission recognizes and acknowledges the environmental imperative that man-made climate change is real, it is happening now, and decisive action must be taken to mitigate it. For some time, man-made climate change has been recognized as a direct threat to the very lifeblood of our home, as capsulated in statements contained in the USEPA's report on climate change submitted summer 2002 to the United Nations: "…Snow-fed streams in the USA will be permanently diminished" and "alpine meadows in the US Rocky Mountains will permanently disappear" as the result of man-made climate change. Clearly, Boulder County's water supply, quality of life, and tourism industry are threatened by climate change.

The response to the threat, as embodied in the SEP, is framed within the perspective that aggressive GHG mitigation is not a burden but rather an opportunity. The "economic costs" associated with GHG management are actually investments in the local economy that will return quite substantial dividends in the form of numerous co-benefits. These co-benefits include overall improvement in the health of Boulder County's local environment, substantial improvements in public health, significant reductions in local traffic congestion, substantial energy cost savings in every sector of the local economy, insulation against energy price shocks, generation of new local economic activity and creation of new businesses, leading to net increases in jobs and net new revenue to the County and Boulder County municipalities.

Boulder County's GHG emissions come predominantly from fossil fuel-based electricity consumption, natural gas used in buildings, and consumption of transportation fuel. The primary "sector" sources of emissions are commercial buildings, homes, and vehicles. GHG mitigation programs focus on energy efficiency and conservation in commercial buildings and homes, expand on the county's transportation goals to support high-efficiency and alternative-fuel vehicles, and increased use of renewable (no- or low-carbon) energy sources like wind and solar.

Accomplishing the goal of reducing GHG emissions by 2020 to a level that is 40 percent below 2005 levels will require substantial community effort and commitment to energy efficiency, and a transition to renewable energy sources for electricity and transportation. Because of the goal and vision, Boulder County will be a very different place in 2020.

The county will give the community the tools and resources to reduce their energy consumption and use renewable resources to the maximum practical extent. Commercial buildings and homes will be more energy efficient and comfortable, featuring the latest technologies and creating long-term value. Use of alternative-fuel vehicles by Boulder County businesses and residents will increase substantially. ENERGY STAR will become a household name and the county will have a high ENERGY STAR product-purchase rate. Boulder County will establish itself as one of the nation's leading users of renewable energy technologies, with solar PV and water heating panels covering substantial portions of county roofs, electricity and biofuels powering a significant fraction of total VMT, and county businesses and citizens investing substantial amounts of money into renewable energy projects through the purchase of RECs and/or carbon offsets.

Upcoming issues that affect the vision of the county's energy and GHG programs include renewable power sources added to Xcel Energy's portfolio, the City of Boulder's decision about municipalization, and expanded transportation programs that are predicted to reduce mileage and emissions. The vision and plan will be dynamic and will rely on the best available data and mechanisms to organically evolve as necessary to reach the county's GHG emissions reduction goal.

Preliminary analytical results are presented in this report for demand-side energy efficiency measures and supply-side renewable energy strategies. Chapter 2 presents details on the county's GHG inventory. Chapter 3 reports on the GHG analysis activities related to the Residential Buildings sector. Chapter 4 presents details on the analysis of the Commercial Buildings sector. The Transportation sector analysis is detailed in Chapter 5. Renewable energy is treated in Chapter 6. A summary and conclusions are presented in Chapter 7.

# 2. GREENHOUSE GAS EMISSIONS INVENTORY

## 2.1 OVERVIEW

To establish the context within which to assess GHG emissions reduction opportunities in Boulder County, a comprehensive county-wide inventory was first constructed. For the purposes of the Inventory and identifying areas in which the County can realize its climate change objectives, emissions were disaggregated on both a sector and emission source basis. Nine individual sector inventories were constructed: Residential, Commercial, Industrial, Transportation, Street lighting, Solid Waste, Agriculture, Industrial Process and Offsets. The Residential, Commercial, and Industrial were further broken down into the emissions from electricity and natural gas consumption. The Transportation sector was divided into emissions resulting from mobile gasoline, mobile diesel, and aviation fuel consumption. The street lighting sector quantifies emissions from electricity usage. Finally, the Solid Waste sector quantifies methane emissions resulting from disposal of solid waste in landfills.

## 2.2 BASIS FOR INVENTORY

The Inventory is based on accepted international protocols and emissions factors. Specifically, WSP has applied the GHG accounting principles of the World Resources Institute GHG Protocol, electricity grid emissions factors from the latest version of US EPA's eGrid database, and non-electricity emissions factors from The Climate Registry. The inventory is not meant to be precise GHG accounting, but it does provide a high-level examination of the County's GHG emissions. Utilizing the results of the Inventory, the County can develop policies and programs that will create the greatest reductions in emissions, while simultaneously generating increased economic activity and sales tax revenue and creating other important co-benefits.

The primary basis for the GHG inventory was the historical consumption of electricity and natural gas, disaggregated by sector. The necessary historical energy consumption data were acquired from Colorado Department of Transportation, Longmont Power and Communications, Poudre Valley Electric, and Xcel Energy. For the most part, annual data for the consumption of electricity and natural gas were available for the 1990 – 2011 period. Using standard methodologies provided by the WRI GHG Protocol, these historical consumption data were translated into GHG emissions on an annual basis. Thus an annual economy-wide GHG inventory was created for the County for the 1990 through 2011 period. Furthermore, the historical data were used to forecast annual Business-As-Usual (BAU) GHG emissions for the 2012 through 2020 period. BAU emissions are those that would occur in the absence of new emissions mitigation efforts.

The inventory considers only the predominant greenhouse gases – carbon dioxide and methane – together represented as units of $CO_2$-equivalent[1] ($CO_2e$), that result from the combustion of fossil fuel, from enteric fermentation in livestock, from cement manufacturing, and from anaerobic decay of solid waste.

Additionally, the Inventory does not cover emissions sources considered to be insignificant and/or not readily controlled by local government actions. These excluded emission sources include locomotive transportation, solvent use, land use, and forestry. Finally the inventory does not include the emissions related to the production of most goods bought or consumed[2] in the County.

The Inventory does credit municipalities for reductions achieved through the generation and purchase of renewable electricity. These credits are realized through the cities of Boulder, Longmont, and Lyons hydroelectric and wind generation, and public and private subscription to Xcel Energy's Windsource Program. Other green tag purchases by Boulder businesses and individuals, such as through Renewable Choice and other green tag retailers, have not been reflected in the current inventory, due to the difficulty of acquiring these data.

There is very little uncertainty surrounding electricity and natural gas usage, as these values are obtained directly from the utility providers. Some uncertainty arises through the extrapolation techniques used to estimate energy use for facilities where data is no longer available, which is prorated based on actual data for previous years. Only 1% of electricity data were estimated in 2011, and no natural gas usage was estimated. The aggregated uncertainty for the County's inventory is 6.7%.

There is considerable uncertainty surrounding waste and refrigerant emissions, as these are estimated based on other variables, such as building square footage, estimated percentage of refrigerants used, and estimated percentage of waste types. An uncertainty of 50% was assigned to these categories. However, these categories represent very small portions of the overall economy-wide GHG emissions. Therefore, the impacts of these sources of uncertainty are small.

A moderate amount of uncertainty arises from estimates of mobile fuels (diesel and gasoline), cement manufacturing and agricultural emissions. Of these, mobile fuels comprise the largest source of emissions, and thus contribute the most uncertainty to the inventory. An uncertainty of

1 The Global Warming Potential (GWP) for carbon dioxide and methane has been calculated to make relative comparisons between the two gases possible. Since methane is 21 times more potent a greenhouse gas than carbon dioxide, the relative global warming potential of carbon dioxide = 1, and methane = 21. When GHG emissions are summed for an inventory, they are commonly referred to as $CO_2e$, indicating that the gases have been converted to $CO_2$ equivalent.

2 To avoid double counting, emissions associated with the manufacture of goods bought or consumed in the county should be included in inventories done by the communities in which the goods were made.

30% was assigned to mobile diesel and gasoline usage, based on estimated VMT and proportion of each vehicle class.

## 2.3 BOULDER COUNTY ECONOMY-WIDE GHG INVENTORY

The following sub-sections provide the historical and forecasted GHG inventories for the county's aggregated Inventory as well as the seven individual sectors evaluated in this study. Information from the 2007 report, previously developed based on 2005 data, has been updated using 2011 data and presented in this 2012 edition of the report. Graphical and tabular comparisons between the 2005 and 2011 inventories are presented in detail in the Appendix.

The following tables summarize the specific GHG emissions factors used to develop the inventory.

| Category | Source | Emissions Factor | Units |
|---|---|---|---|
| Fuels | Natural Gas | 0.00530 | tCO2/therm |
| | Distillate Fuel Oil #2 | 0.01021 | tCO2/gal |
| | Residual Fuel Oil #6 | 0.01127 | tCO2/gal |
| | LPG/Propane | 0.00559 | tCO2/gal |
| | Mobile Gas | 0.00878 | tCO2/gal |
| | Mobile Diesel | 0.01021 | tCO2/gal |
| | Jet Fuel | 0.00975 | tCO2/gal |
| | Aviation Gas | 0.00831 | tCO2/gal |
| Enteric Emissions | Dairy Cattle | 2.68800 | tCO2/head/year |
| | Other Cattle | 1.11300 | tCO2/head/year |
| | Sheep | 0.16800 | tCO2/head/year |
| | Goat | 0.10500 | tCO2/head/year |
| | Swine | 0.03150 | tCO2/head/year |
| | Horse | 0.37800 | tCO2/head/year |
| | Poultry | - | tCO2/head/year |
| Manure Management | Dairy Cattle | 1.05000 | tCO2/head/year |
| | Other Cattle | 0.02100 | tCO2/head/year |
| | Sheep | 0.00399 | tCO2/head/year |
| | Goat | 0.00273 | tCO2/head/year |
| | Swine | 0.23100 | tCO2/head/year |
| | Horse | 0.03276 | tCO2/head/year |
| | Poultry | 0.02520 | tCO2/head/year |
| Soil Management | Ag Soil | 1.11989 | tCO2e/acre |
| Waste | Municipal Solid Waste, CH4 | 0.02747 | tCH4/ton waste |
| | Municipal Solid Waste, CO2 | 0.57697 | tCO2e/ton waste |
| Industrial Processes | Cement Production | 0.51115 | tCO2/t cement |
| Refrigerants | Commercial AC Leakage | 500.00 | ft2 per Ton |
| | Charge per Ton | 1.00000 | kg |
| | EPA Operating Loss Factor | 10% | % |

| Category | Source | Emissions Factor | Units |
|---|---|---|---|
| Electricity - eGRID WECC Rockies *note: values in red are estimates or projections, because no eGRID data was available* | 1990 | 0.81298 | lbCO2/MWh |
| | 1991 | 0.81298 | lbCO2/MWh |
| | 1992 | 0.81298 | lbCO2/MWh |
| | 1993 | 0.81298 | lbCO2/MWh |
| | 1994 | 0.81298 | lbCO2/MWh |
| | 1995 | 0.81298 | lbCO2/MWh |
| | 1996 | 0.81298 | lbCO2/MWh |
| | 1997 | 0.81298 | lbCO2/MWh |
| | 1998 | 0.81298 | lbCO2/MWh |
| | 1999 | 0.81180 | lbCO2/MWh |
| | 2000 | 0.84891 | lbCO2/MWh |
| | 2001 | 0.92343 | lbCO2/MWh |
| | 2002 | 0.92343 | lbCO2/MWh |
| | 2003 | 0.92343 | lbCO2/MWh |
| | 2004 | 0.92343 | lbCO2/MWh |
| | 2005 | 0.85415 | lbCO2/MWh |
| | 2006 | 0.85415 | lbCO2/MWh |
| | 2007 | 0.85415 | lbCO2/MWh |
| | 2008 | 0.85415 | lbCO2/MWh |
| | 2009 | 0.82758 | lbCO2/MWh |
| | 2010 | 0.82758 | lbCO2/MWh |
| | 2011 | 0.82758 | lbCO2/MWh |
| | 2012 | 0.81540 | lbCO2/MWh |
| | 2013 | 0.81134 | lbCO2/MWh |
| | 2014 | 0.80728 | lbCO2/MWh |
| | 2015 | 0.80321 | lbCO2/MWh |
| | 2016 | 0.79915 | lbCO2/MWh |
| | 2017 | 0.79509 | lbCO2/MWh |
| | 2018 | 0.79103 | lbCO2/MWh |
| | 2019 | 0.78697 | lbCO2/MWh |
| | 2020 | 0.74281 | lbCO2/MWh |

### 2.3.1. Aggregated Inventory

Table 2-1 presents the updated historical and forecasted Inventory for the 1990 – 2020 period. Comparison of the county-wide GHG inventory developed by WSP in 2006 (based on historical data through 2005 and projected out to 2012) with the 2012 update (based on historical data through 2011 and projected out to 2020) clearly shows the desired trending. Figure 2-1 and Figure 2-2 illustrate the 2005 and 2011 Inventory profiles, which show that in 2006, the trajectory out to 2012 had a decidedly upward trend, with projected GHG emissions of 5.85 million tCO2e/yr in 2012. Encouragingly, the 2011 trajectory out to 2020 flattens and actually starts to deflect downward, with projected GHG emissions of 5.14 million tCO2e/yr in 2012, dropping to 4.98 million tCO2e/yr in 2020. SEP impacts are no doubt contributing to this trend, but macroeconomic forces are likely the overwhelming drivers of this trajectory currently. While the desired trend of the historically upward-trending trajectory being flattened and then deflected downward over time is evident, the 2011 projection still leaves an estimated 2.14 million tCO2e/yr gap-to-goal in 2012 and a 1.98 million tCO2e/yr gap-to-goal in 2020. The current outlook is a substantial improvement over the 2.7 million tCO2e/yr gap-to-goal in 2012 predicted back in 2005, but clearly much additional progress is required.

**Figure 2-1: Boulder County GHG Inventory Profile, 1990 – 2012**

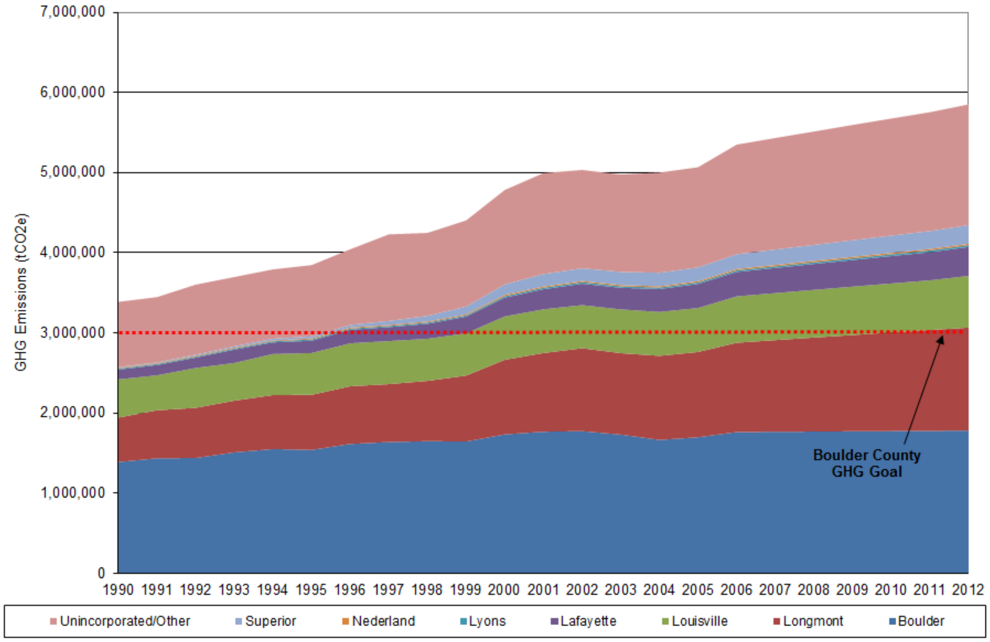
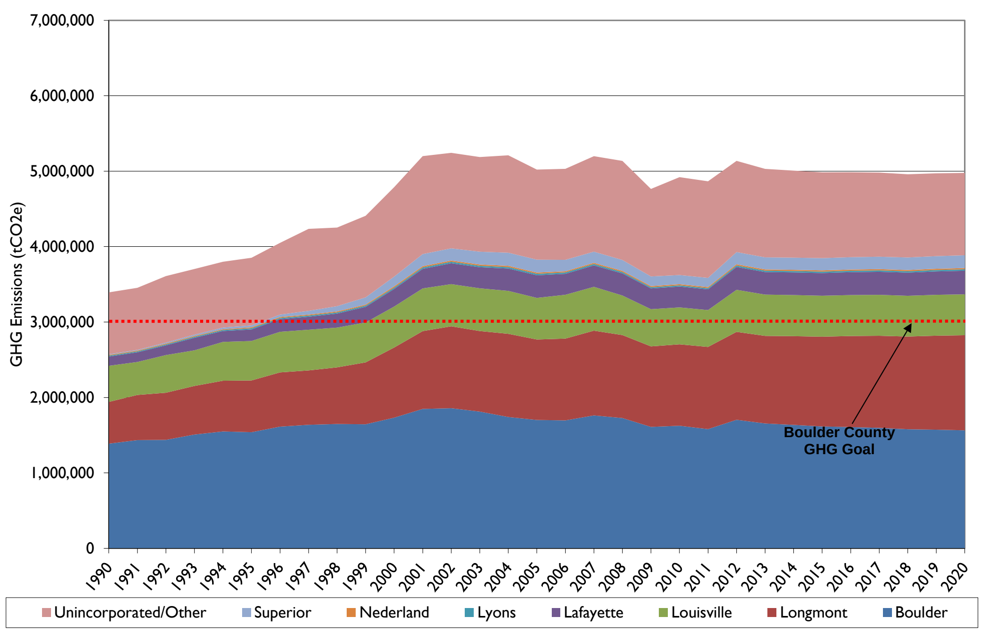



**Figure 2-2: Boulder County GHG Inventory Profile, 1990 – 2020**




Please see the Appendix for the full details on how the 2005 Inventory and future emissions trajectory compare to the 2011 Inventory and projected trajectory, including comparisons by sector, by municipality, and by emissions source.

**Table 2-1: Boulder County GHG Inventory, 1990 – 2020**

| Year | Residential | Commercial | Industrial | Street Lighting | Offsets | Transportation | Agriculture | Waste | Industrial Process | Grand Total |
|---|---|---|---|---|---|---|---|---|---|---|
| 1990 | 879,366 | 902,567 | 551,455 | 12,200 | -12,459 | 671,984 | 43,896 | 94,035 | 250,357 | **3,393,402** |
| 1991 | 917,450 | 905,295 | 564,497 | 9,296 | -15,291 | 685,479 | 43,896 | 92,759 | 250,357 | **3,453,738** |
| 1992 | 903,413 | 977,452 | 647,131 | 9,378 | -17,307 | 698,975 | 43,896 | 95,910 | 250,357 | **3,609,205** |
| 1993 | 1,023,229 | 1,033,998 | 542,007 | 13,692 | -15,508 | 712,470 | 43,896 | 99,154 | 250,357 | **3,703,296** |
| 1994 | 979,035 | 1,083,014 | 623,780 | 10,257 | -15,738 | 723,844 | 43,896 | 100,863 | 250,357 | **3,799,309** |
| 1995 | 1,014,034 | 1,113,411 | 591,783 | 10,296 | -14,814 | 735,140 | 43,896 | 107,924 | 250,357 | **3,852,027** |
| 1996 | 1,065,246 | 1,198,295 | 642,765 | 10,509 | -17,571 | 746,233 | 43,896 | 109,879 | 250,357 | **4,049,609** |
| 1997 | 1,053,311 | 1,375,762 | 620,978 | 10,978 | -19,477 | 787,715 | 43,896 | 111,797 | 250,357 | **4,235,318** |
| 1998 | 1,061,694 | 1,364,349 | 596,120 | 11,649 | -15,236 | 825,001 | 43,617 | 115,088 | 250,357 | **4,252,640** |
| 1999 | 1,102,380 | 1,384,375 | 614,480 | 12,350 | -46,906 | 929,583 | 43,339 | 118,703 | 250,357 | **4,408,661** |
| 2000 | 1,210,169 | 1,518,149 | 641,787 | 15,110 | -46,390 | 1,034,648 | 43,060 | 121,427 | 250,357 | **4,788,317** |
| 2001 | 1,336,747 | 1,663,760 | 676,472 | 17,482 | -58,829 | 1,144,615 | 42,781 | 126,445 | 250,357 | **5,199,832** |
| 2002 | 1,390,026 | 1,628,483 | 683,393 | 18,268 | -57,671 | 1,160,701 | 42,503 | 127,324 | 250,357 | **5,243,384** |
| 2003 | 1,364,518 | 1,592,659 | 674,921 | 18,213 | -68,630 | 1,185,298 | 42,503 | 127,638 | 250,357 | **5,187,476** |
| 2004 | 1,362,999 | 1,556,595 | 706,090 | 26,239 | -72,954 | 1,210,507 | 42,503 | 128,259 | 250,357 | **5,210,595** |
| 2005 | 1,311,814 | 1,602,002 | 547,182 | 19,967 | -56,667 | 1,236,230 | 42,503 | 132,595 | 185,611 | **5,021,236** |
| 2006 | 1,278,214 | 1,392,677 | 813,775 | 26,080 | -82,647 | 1,233,582 | 42,503 | 130,520 | 196,481 | **5,031,184** |
| 2007 | 1,364,132 | 1,476,763 | 829,248 | 26,777 | -74,198 | 1,200,200 | 41,699 | 132,867 | 201,558 | **5,199,044** |
| 2008 | 1,363,285 | 1,681,979 | 543,944 | 32,537 | -36,262 | 1,176,730 | 41,699 | 130,898 | 201,399 | **5,136,209** |
| 2009 | 1,256,639 | 1,585,960 | 509,128 | 31,007 | -39,144 | 1,166,687 | 41,699 | 126,872 | 85,806 | **4,764,654** |
| 2010 | 1,315,564 | 1,630,964 | 504,901 | 31,249 | -44,212 | 1,153,670 | 41,699 | 127,728 | 159,362 | **4,920,924** |
| 2011 | 1,338,281 | 1,647,722 | 513,882 | 32,065 | -95,977 | 1,099,548 | 41,699 | 128,873 | 159,879 | **4,865,971** |
| 2012 | 1,396,897 | 1,689,176 | 599,522 | 30,918 | -59,920 | 1,121,369 | 42,503 | 136,363 | 180,056 | **5,136,886** |
| 2013 | 1,392,041 | 1,687,153 | 589,521 | 31,411 | -58,760 | 1,029,207 | 42,509 | 137,431 | 180,060 | **5,030,573** |
| 2014 | 1,408,651 | 1,714,729 | 589,072 | 32,602 | -58,940 | 960,235 | 42,514 | 138,499 | 180,063 | **5,007,426** |
| 2015 | 1,420,692 | 1,735,254 | 587,343 | 33,640 | -58,842 | 904,336 | 42,520 | 139,568 | 180,066 | **4,984,579** |
| 2016 | 1,439,847 | 1,763,763 | 586,935 | 34,787 | -58,934 | 855,835 | 42,526 | 140,636 | 180,069 | **4,985,465** |
| 2017 | 1,454,199 | 1,785,264 | 584,787 | 35,768 | -58,746 | 816,124 | 42,532 | 141,705 | 180,073 | **4,981,705** |
| 2018 | 1,459,629 | 1,793,730 | 579,434 | 36,427 | -58,058 | 782,698 | 42,538 | 142,773 | 180,076 | **4,959,247** |
| 2019 | 1,475,682 | 1,817,641 | 577,983 | 37,457 | -57,984 | 754,485 | 42,544 | 143,841 | 180,079 | **4,971,729** |
| 2020 | 1,488,114 | 1,836,259 | 575,240 | 38,355 | -57,714 | 729,377 | 42,550 | 144,910 | 180,082 | **4,977,172** |

Figure 2-3 presents the Inventory disaggregated by sector for 2011. The figure shows that the Commercial Buildings sector is the largest source of GHG emissions. This reinforces the need to focus in detail on the existing Commercial Buildings sector for emissions mitigation. Contributing 29% of the 2005 Inventory and 33% of the 2011 Inventory, the Commercial sector continues to provide a large opportunity for the county to achieve GHG reductions. The results of detailed analysis, presented in Chapter 4, identify and quantify opportunities to reduce the Commercial Buildings slice of the Inventory pie.

**Figure 2-3: Breakdown of Inventory by Sector – 2011**

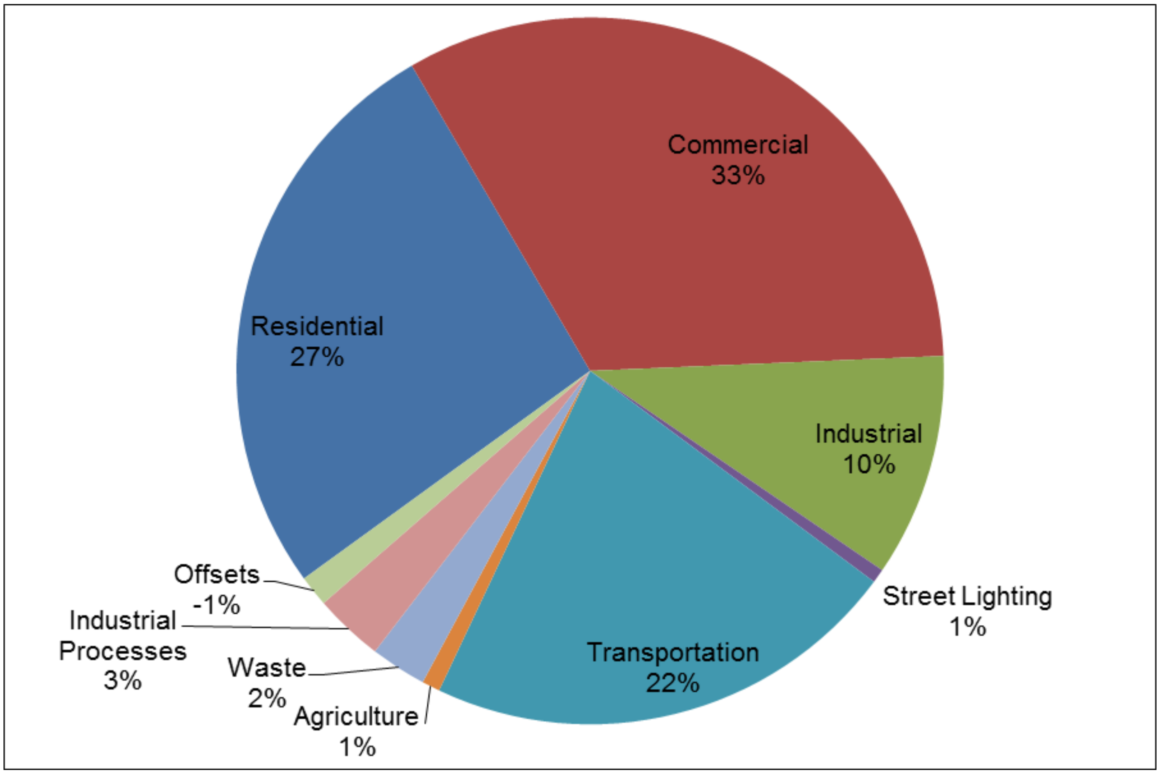
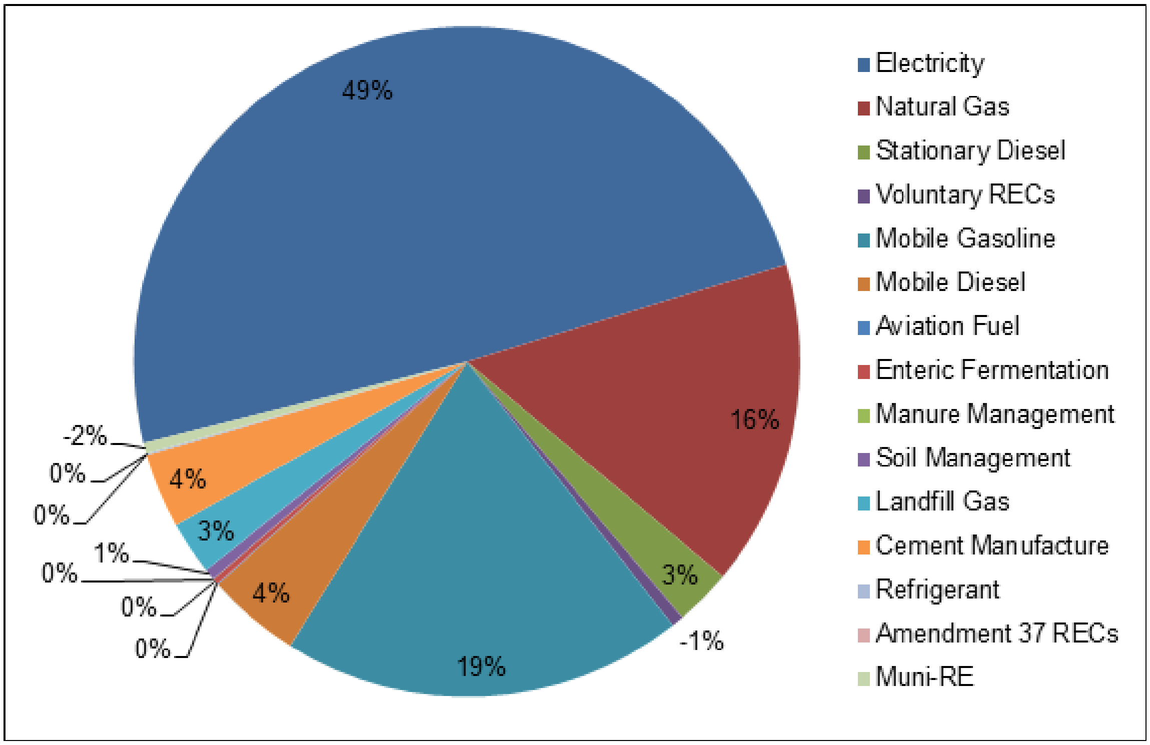



Figure 2-4 presents the Inventory disaggregated by energy source for 2011. The figure shows that Electricity is the foremost source of GHG emissions with Vehicle Fuel a distant second. It is instructive to recall that emissions resulting from electricity consumption are classified as an indirect emissions source. These indirect emissions result from consumption of electricity within the county's boundary. However, the actual direct emissions occur mostly outside of this boundary, at the individual fossil-fueled power plants that generate the electricity.

This figure draws attention to the importance of addressing electricity consumption and of accurately quantifying the GHG intensity of electricity supply. Furthermore, the figure highlights, to a lesser extent, the need to deal with emissions resulting from vehicle fuel (Mobile Gasoline and Mobile Diesel) and Natural Gas consumption. Finally, Figure 2-4 underscores the relatively insignificant role landfill gas, voluntary RECs, municipal renewable energy, enteric fermentation, manure management, soil management, refrigerants, aviation fuel, and amendment 37 RECs, collectively have on the Inventory.

**Figure 2-4: Breakdown of Inventory by Energy Source – 2011**




## 2.3.2. Residential Buildings

The Residential Buildings sector produced 25% of the county's GHG emissions in 2005 and 27% in 2011. Figure 2-5 illustrates the Residential Inventory profile and indicates that emissions increased from 879,366 to 1,338,281 tCO2e during the 1990 – 2011 period. Moreover, the figure illustrates that Residential sector emissions in 2020 are expected to be 1,488,114 tCO2e.

Figure 2-6 illustrates the breakdown of the Residential Inventory by emissions source for 2011. The figures highlight the primary role electricity plays in the sector's inventory.

**Figure 2-5: Residential GHG Inventory Profile, 1990 – 2020**

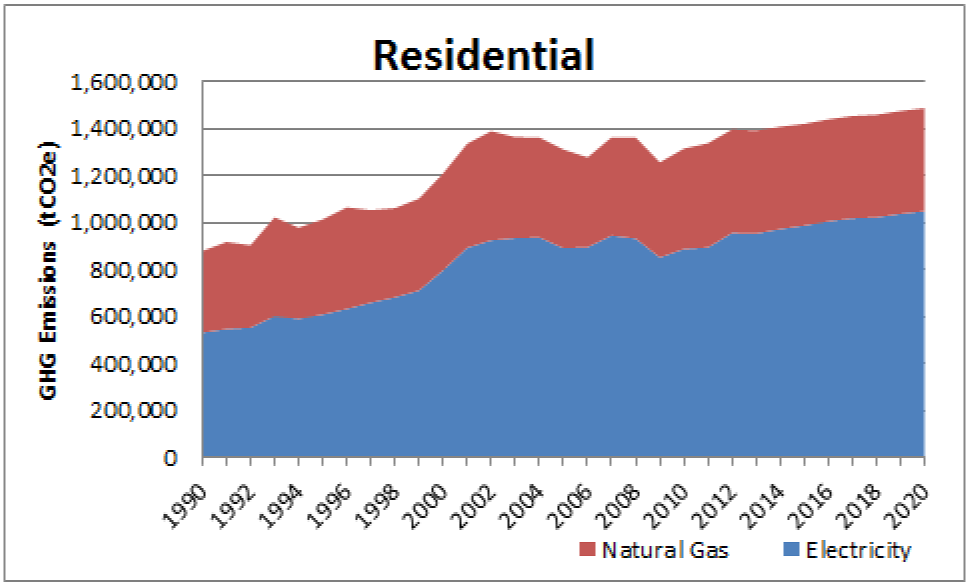
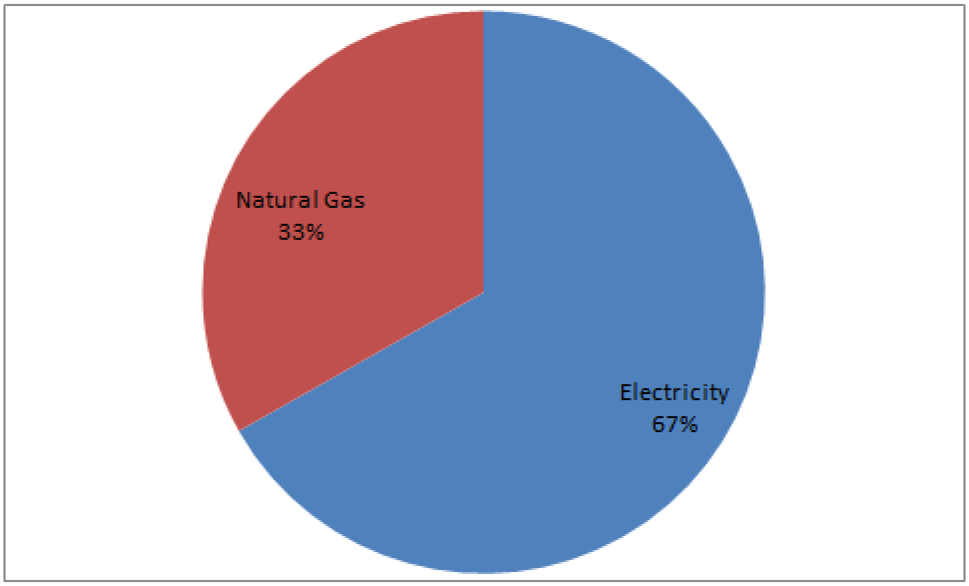



**Figure 2-6: Breakdown of Residential Emissions by Source - 2011**




## 2.3.3. Commercial Buildings

WSP has been engaged with Xcel Energy since 2004 in the context of acquiring economy-wide electricity and natural gas data for Boulder and Boulder County. Over this period, Xcel has changed their classification of customer classes on at least two occasions. Consequently, certain classes of customers were classified as commercial sector at one point in time but as industrial at another point, and vice versa. This has resulted in inconsistencies in the electricity and natural gas data over time and seeming anomalies in these data. This circumstance has forced WSP to combine the industrial and commercial sectors' energy data to force a semblance of consistency on irregular data for purposes of establishing discernible historical trends for the affected customer types. We then applied to the combined usage the historically predominant ratio of industrial to commercial energy usage during the anomalous period in order to estimate the industrial usage and the commercial usage during this period. While this is an unwanted process, we believe that it is necessary and that it does not introduce significant errors in the inventory or the mitigation analyses.

The bigger problem with data quality has been created by the so-called '15/15 Rule', promulgated in recent years by the Public Utilities Commission, as a well-intentioned move to protect utility customer privacy. This rule prohibits Xcel from providing to Boulder County electricity and natural gas consumption data of sufficient resolution to facilitate the level of analysis that the County desires. The 15/15 Rule states that an aggregation sample must have more than 15 customers and that no single customer's data may comprise more than 15 percent of the total aggregated data. This rule affects only the quality of data for the Commercial and Industrial sectors.

The Commercial Buildings sector produced 29% of the county's GHG emissions in 2005 and 33% of the county's GHG emissions in 2011. Figure 2-7 illustrates the Commercial Buildings Inventory profile and indicates that emissions increased from 902,567 to 1,647,722 tCO2e during the 1990 – 2011 period. This figure illustrates that Commercial sector emissions in 2020 are expected to be 1,836,259 tCO2e.

**Figure 2-7: Commercial GHG Inventory Profile, 1990 – 2020**

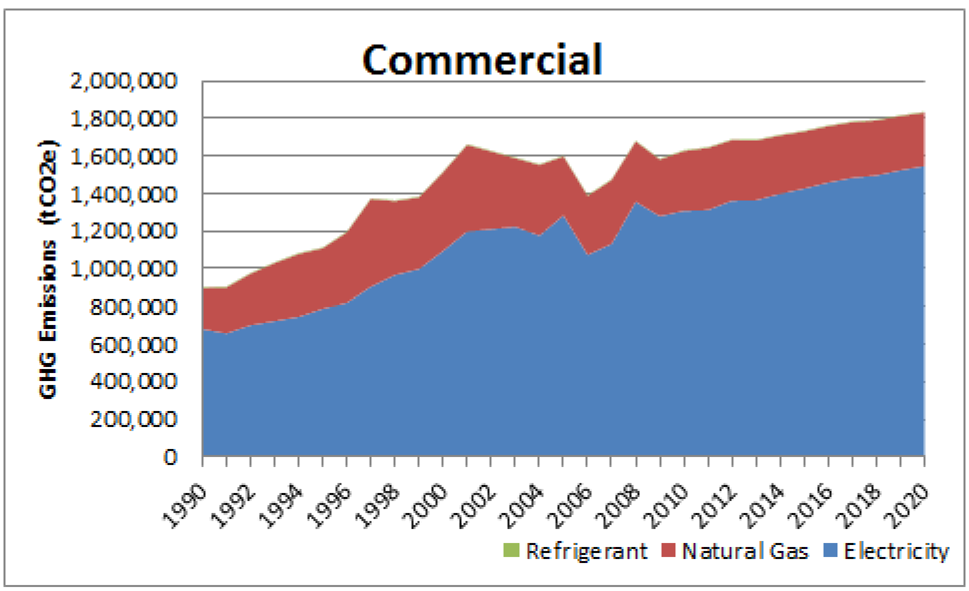
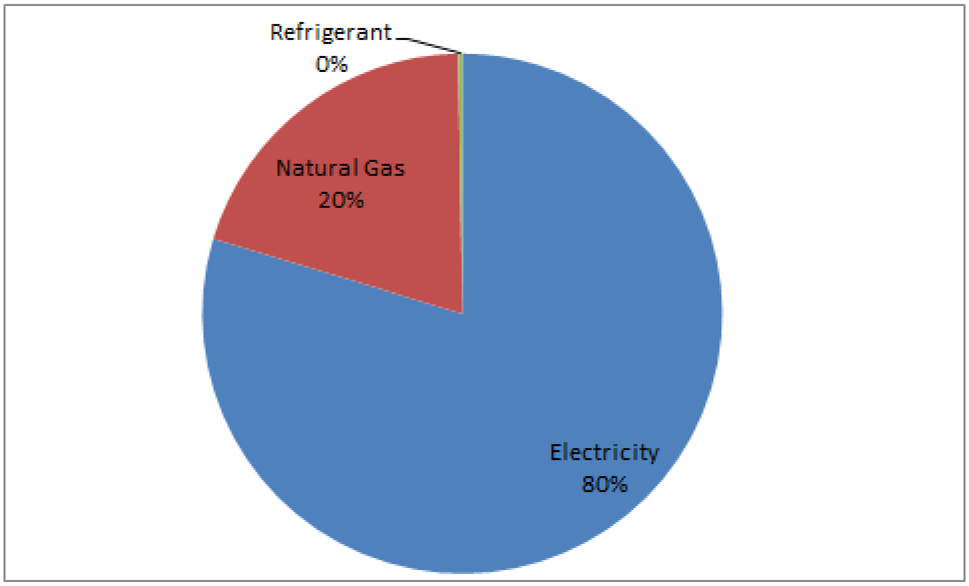



Figure 2-8 illustrates the breakdown of the Commercial Inventory by energy source for 2011. The figure highlights the primary role electricity has on the sector's inventory and thus highlights that electric energy efficiency actions remain key to future efforts for meeting the Commission's climate objectives.

**Figure 2-8: Breakdown of Commercial Emissions by Source – 2011**




### 2.3.4. Transportation

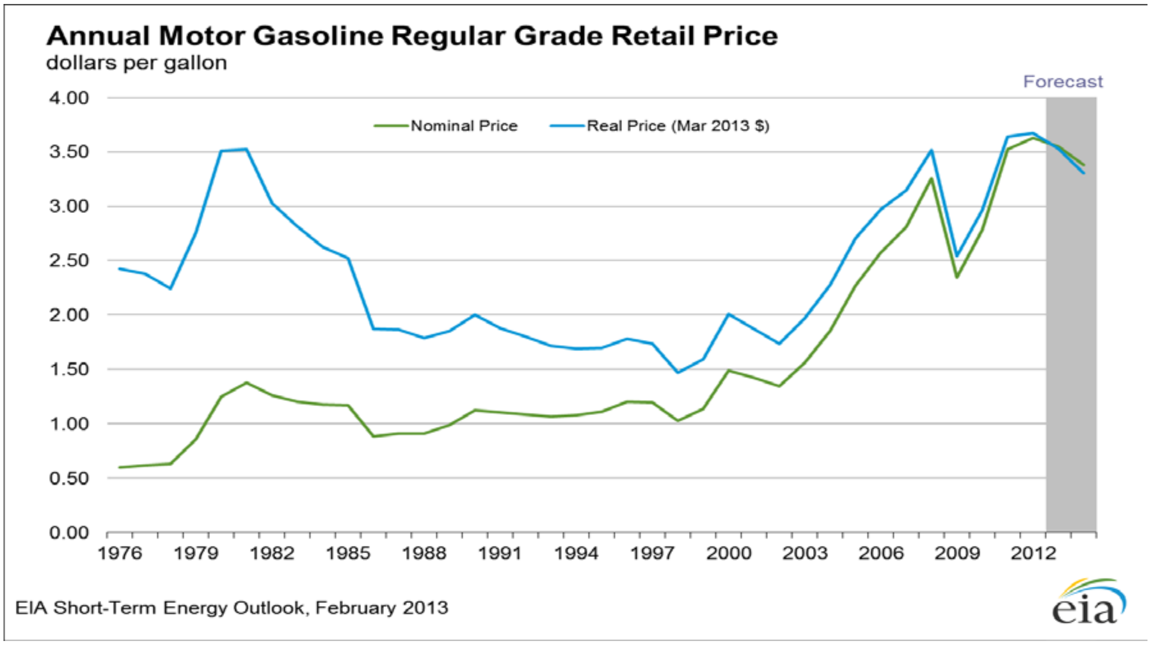
Unlike all other sectors, the Transportation sector has posted a downward-trending emissions profile in recent years. Possible explanations for this result are presented below.

Vehicle fuel usage accounted for 23% of the County's overall GHG emissions in 2005 and 24% in 2011. Figure 2-9 illustrates the Transportation Inventory profile and indicates that emissions increased from about 0.7 million metric tons in 1990 to a peak above 1.2 million metric tons in 2005 and then declined to about 1.1 million metric tons in 2011. This figure illustrates that Transportation sector emissions in 2020 are expected to be only about 0.73 million metric tons.

**Figure 2-9: Transportation GHG Inventory, 1990-2020**


Since actual fuel usage data are not available, fuel consumption was estimated on the basis of Vehicle Miles Traveled (VMT) and average vehicle fuel economy data, which are readily available from the Colorado Department of Transportation and Denver Regional Council of Governments. The forecasted fuel economy rates (miles traveled per gallon of fuel) reflect the effect of federal standards, resulting in a trend toward a higher percentage of miles traveled in future years by more efficient, lighter-weight vehicles relative to heavier vehicles. The VMT in the county peaked in 2005 and has trended downward since then. This is evidence of possible County program effects, but may be more likely to reflect the dramatic increase in vehicle fuel prices. For example, Figure 2-10 shows that during the 2002 – 2005 period, regular gasoline prices increased 55%. Prices increased a further 30% from 2005 to 2009.

**Figure 2-10: Gasoline price trends, 1976-2012**




Demand-elasticity models for VMT versus fuel price typically predict that VMT will fall 1% for each 5% increase in fuel price. This implies that VMT should have dropped 11% during 2002 – 2005 and should have dropped another 6% during 2005 – 2009. However, actual VMT data indicate total VMT *increased* 3% from 2002 to 2005 and decreased 10% from 2006 to 2009. Countervailing trends during this period were likely more influential than fuel price – from 2002 to 2005, county population remained flat and grew by nearly 4% from 2005 to 2009; GDP grew 16% from 2002 to 2005 and grew another 9% from 2006 to 2009. Taken together, these population and GDP trends may have outweighed the dampening effect of price increases during the 2002 – 2009 period, resulting in more modest reductions in Transportation sector GHG emissions than might otherwise be expected.

More stringent federal vehicle fuel economy standards took effect in calendar year 2010 (when 2011 model year vehicles became available), which likely contributed to the decidedly downward trajectory of the sector trend line.

## 2.3.5. Industrial

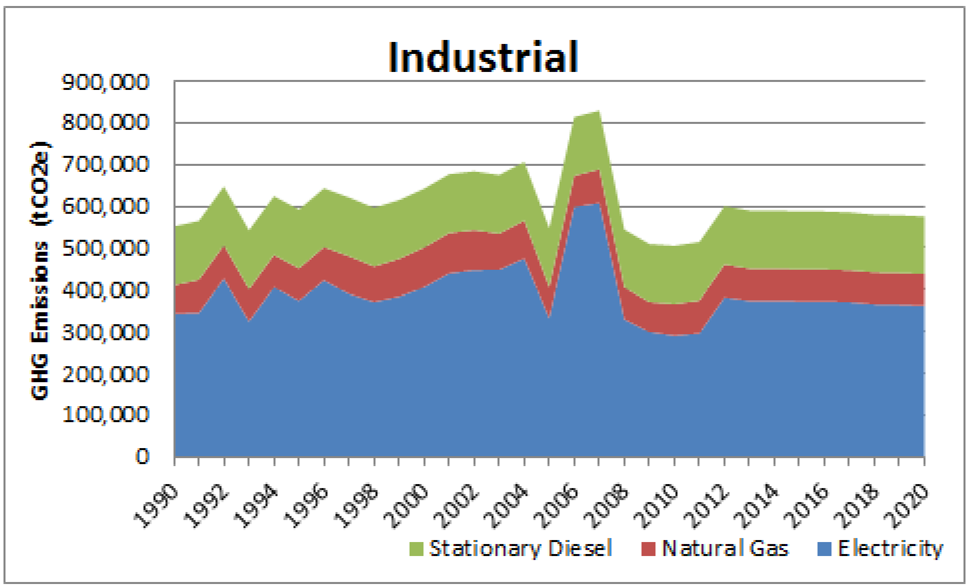
As discussed in 2.3.3, Xcel has over time changed their classification of customer classe. Consequently, certain classes of customers were classified as commercial sector at one point in time but as industrial at another point, and vice versa. This has resulted in inconsistencies in the electricity and natural gas data over time and seeming anomalies in these data. This circumstance has forced WSP to take steps to force a semblance of consistency on irregular data for purposes of establishing discernible historical trends for the affected customer types. While this is an unwanted process, we believe that it is necessary and that it does not introduce significant errors in the inventory or the mitigation analyses.

Industrial sector emissions are produced indirectly through the consumption of electricity and directly through the consumption of natural gas and stationary diesel fuel. This inventory does not include under Industrial Emissions the fugitive process emissions from industrial processes, which are accounted for separately as Industrial Process Emissions. Rather, this inventory assigns to Industrial only the emissions associated with the *energy consumption* of industrial buildings and processes.

In 1990, industrial energy usage accounted for 16% of total county-wide GHG emissions. Industrial energy consumption produced 13% of the overall county-wide GHG emissions in 2005 and 10% in 2011. The projected BAU trajectory for industrial energy usage was estimated in 2005 to be 11% of total county-wide emissions in 2012. The updated 2011 projection now predicts industrial emissions to be 12% in 2012 and 2020.

Louisville leads the county's non-process industrial energy emissions, accounting for 34% of the county-wide emissions for this sector in 2005 and 37% in 2011. Longmont contributed another 28% and Boulder was responsible for 34% of total GHG emissions attributable to 2011 industrial energy usage.

**Figure 2-11: Industrial GHG Emissions, 1990-2020**




## 2.3.6. Industrial Process

In the Industrial Process category, greenhouse gas emissions are produced as a by-product of various non-energy-related industrial activities. The sole industrial process that emits a significant quantity of emissions in Boulder County is the manufacture of cement. One step of cement production involves the conversion of calcium carbonate ($CaCO_3$) into lime ($CaO$), which releases $CO_2$ as a byproduct. There were no other industrial process emissions identified in the county that were large enough to quantify.

For the 2007 report, only one year of data was available for cement manufacturing process emissions. As a result, it was assumed that these industrial process emissions stayed constant from 1990 through 2005. Consequently, the projected BAU trend line assumed that there would not be any growth in industrial process emissions through 2012.

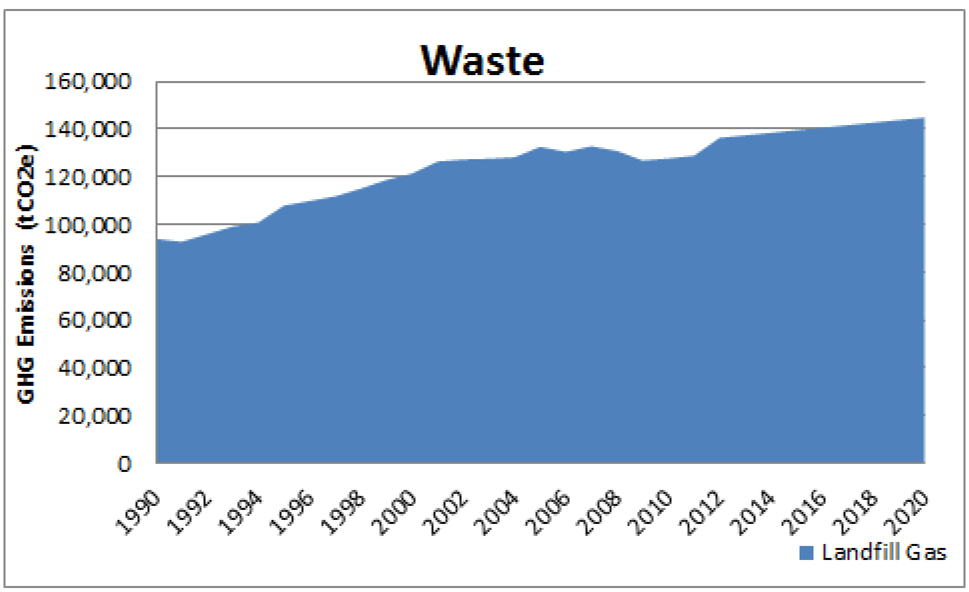
For the 2012 update, additional data show that Industrial Processes account for 3% of the County's overall GHG emissions in 2011, compared to 5% in 2005. Emissions decreased from 250,357 mtCO2e/yr in 2004 to 159,879 in 2011. Industrial Processes sector emissions are projected to be 180,082 in 2020.

### 2.3.7. Solid Waste

The municipal solid waste sector accounts for about 3% of the county's total GHG emissions, due to methane emissions from landfills. Figure 2-12 shows the total GHG emissions since 1990, with projections through 2020. Between 1990 and 2011, the emissions grew from 94,035 to 128,873 metric tons of carbon dioxide equivalent per year, an increase of about 37%. The emissions are projected to reach 144,910 metric tons in 2020, a 54% increase from 1990 levels.

For this forecast, the waste per capita is assumed to remain constant at current levels throughout the study: about 0.78 tons of MSW /year per person, according to recorded data taken by the City of Boulder from 1999 - 2003. An EPA model is used to convert rates of MSW landfilling into methane generation rates and GHG emissions are then calculated by converting the resulting $CH_4$ into equivalent metric tons of $CO_2$ emissions. Therefore, the trend is directly related to the projected population growth in the county.

**Figure 2-12: Sold Waste GHG Inventory, 1990-2020**



### 2.3.8. Offsets and RECs

Presently there are four main options for creating offsets within Boulder County: voluntary RECs, voluntary carbon offsets, regulatory RECs produced by Amendment 37 projects, and municipally owned renewable energy generation. Voluntary RECs and carbon offsets are available for purchase from a variety of suppliers. Amendment 37 Projects generate RECs produced by small-scale renewable electricity projects that have been mandated by law and are thus considered to be regulatory RECs. For purposes of the Boulder County GHG inventory, a regulatory REC is defined as a REC created by a project that is installed within the county political boundary and which contributes toward meeting the requirements of Amendment 37. An example of regulatory RECs is the RECs produced by a customer-owned photovoltaic system for which the customer receives a payment from Xcel. The final option for creating offsets is generation of renewable electricity by municipally owned power plants. Presently, the cities of Boulder, Longmont and Lyons own renewable power generation (hydro and wind).

More than 5 MW of small-scale solar systems have been installed in Boulder County since 2010, representing perhaps as much as 40% of total systems of this type in Xcel's Colorado territory. However, RECs and carbon offsets of all kinds taken together (and from here on referred to simply as Offsets) comprise such a small slice of the county-wide emissions pie that they do not show up in Figures 2-15 through 2-22, below.

### 2.3.9. Municipality-Specific Emissions

Table 2-2 presents the County's historical and forecast inventory grouped by municipality. Figure 2-13 presents the County's 2011 inventory disaggregated by municipality. The figure shows that, as in the 2005 inventory, Boulder and Unincorporated/Other are still the largest producers of emissions, contributing 33% and 26% of the County's overall emissions, respectively.

Figure 2-14 highlights the historical and forecast emissions by municipality. This figure illustrates the relative magnitude of each municipality as well the historical and forecast annual growth rate. It is instructive to note the significant growth expected for Unincorporated/Other regions of the County.

**Table 2-2: Historical and Forecast GHG Emissions by Municipality (tCO2e)**

| Municipality | 1990 | 1995 | 2000 | 2005 | 2010 | 2020 |
|---|---|---|---|---|---|---|
| Boulder | 1,387,380 | 1,539,248 | 1,732,024 | 1,701,646 | 1,624,788 | *1,564,243* |
| Lafayette | 122,236 | 152,834 | 233,408 | 300,286 | 276,813 | *313,237* |
| Longmont | 553,659 | 686,377 | 930,021 | 1,066,914 | 1,079,948 | *1,260,961* |
| Louisville | 478,779 | 523,262 | 543,376 | 551,559 | 489,299 | *542,188* |
| Lyons | 12,357 | 15,749 | 17,647 | 19,246 | 15,632 | *18,460* |
| Nederland | 10,180 | 12,631 | 16,726 | 15,809 | 14,950 | *16,231* |
| Superior | 8,954 | 25,586 | 129,168 | 171,590 | 121,773 | *169,876* |
| Unincorporated/Other | 819,857 | 896,340 | 1,185,947 | 1,194,187 | 1,297,720 | *1,091,975* |
| **Total** | **3,393,402** | **3,852,027** | **4,788,317** | **5,021,236** | **4,920,924** | ***4,977,172*** |

*Note – italics indicates forecast*

Note that there are several explanations for the surprising size of the Unincorporated/Other slice of the pie. The unexpected result that Unincorporated/Other is the second-largest source of emissions in the County has to do with the "Other" and not with the "Unincorporated". "Other" includes all incorporated municipalities in Boulder County that are not explicitly disaggregated in the GHG inventory. These include but are not limited to Erie, Gunbarrel, Niwot, and Ward, and comprise 10% of the Unincorporated/Other total.

In addition, note that Cemex is a large contributor to the Unincorporated/Other total as "cement manufacture" (industrial process emissions) is 12% of the Unincorporated/Other total. Furthermore, Cemex natural gas use is estimated to contribute roughly 5% of the Unincorporated/Other total. Next note that "Other" includes county-wide agriculture-related emissions. Lastly note that transportation emissions for Unincorporated/Other are more than double those of Longmont.

If Cemex and "Other" were removed, the Unincorporated/Other total would drop behind Longmont in the County's Inventory. The following table compares the 2011 emissions components of Unincorporated/Other versus Longmont to help illustrate why the former has totals that are larger than the latter.

**Table 2-3: Historical and Forecast GHG Emissions by Municipality (tCO2e)**

| Source | Longmont | Unincorporated/Other |
|---|---|---|
| Electricity | 679,200 | 378,174 |
| Natural Gas | 209,313 | 170,477 |
| Stationary Diesel | 270 | 153 |
| Mobile Gasoline | 135,110 | 421,321 |
| Mobile Diesel | 30,480 | 95,047 |
| Landfill Gas | 38,085 | 20,402 |
| Cement Manufacture | - | 159,879 |
| Enteric Fermentation | - | 13,723 |
| Manure Management | - | 415 |
| Soil Management | - | 27,562 |
| Aviation Fuel | 916 | - |
| **Grand Total** | **1,093,374** | **1,287,151** |

**Figure 2-13: GHG Emissions by Municipality, 2011**

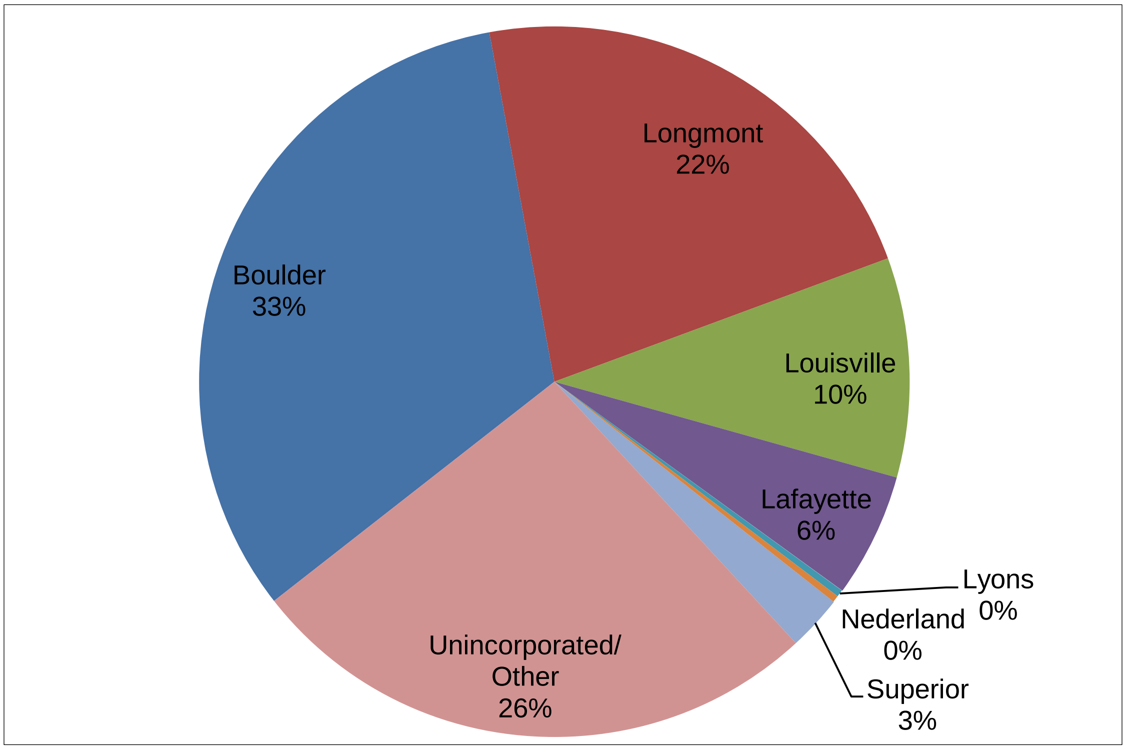



**Figure 2-14: Historical and Forecast Municipality Trends, 1990-2020**

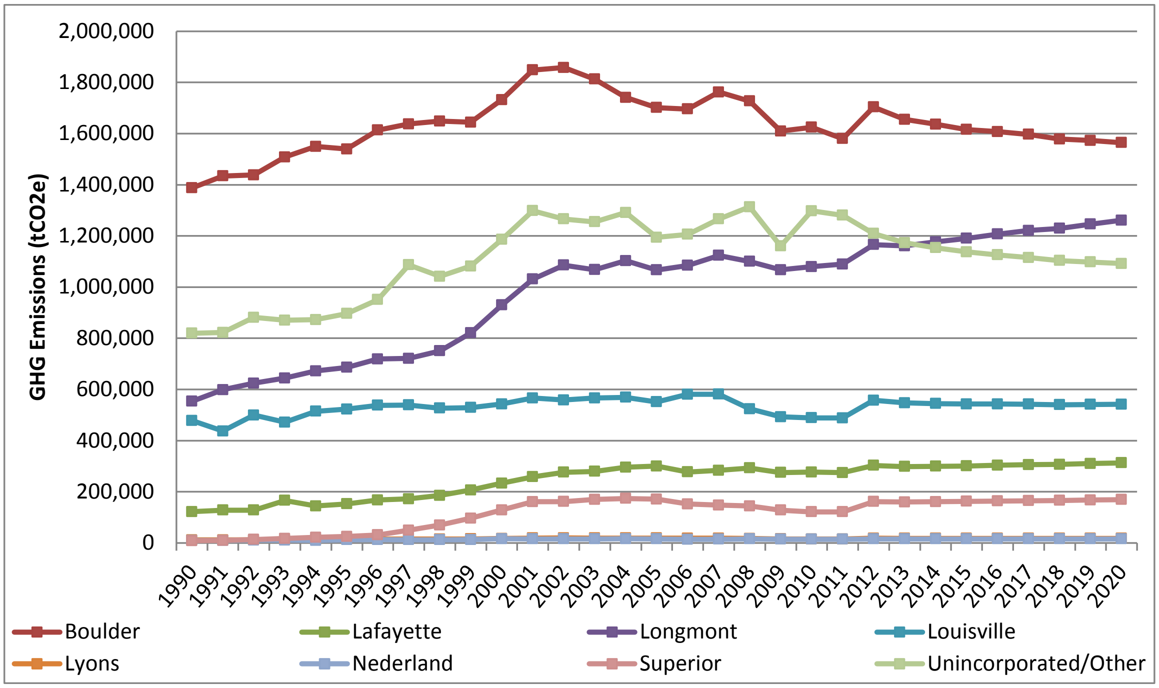


**Figure 2-15: GHG Emissions by Sector for Boulder, 2011**

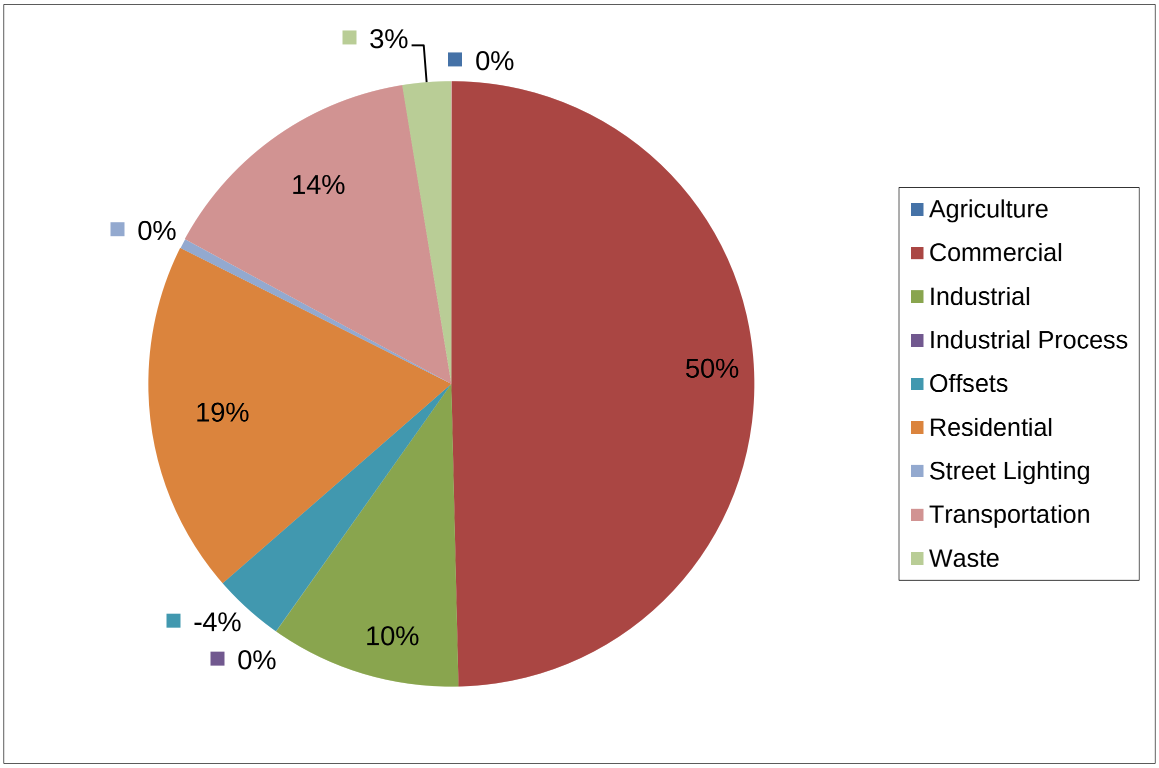



**Figure 2-16: GHG Emissions by Sector for Lafayette, 2011**

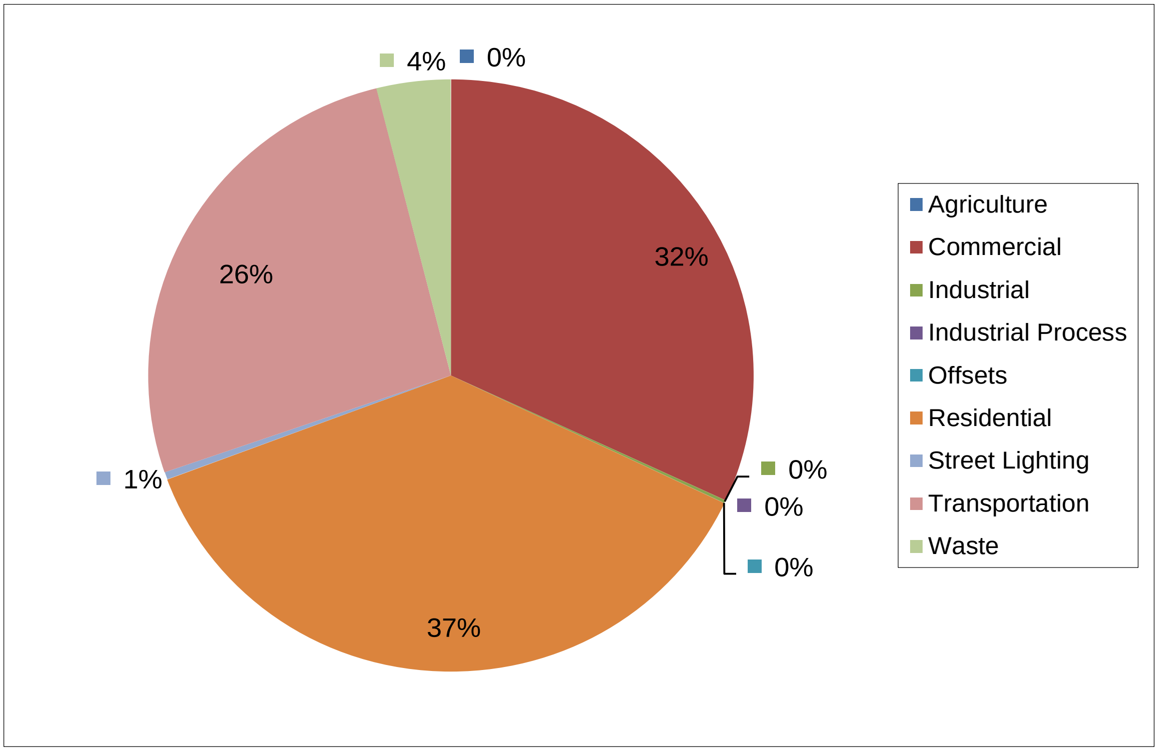


**Figure 2-17: GHG Emissions by Sector for Louisville, 2011**

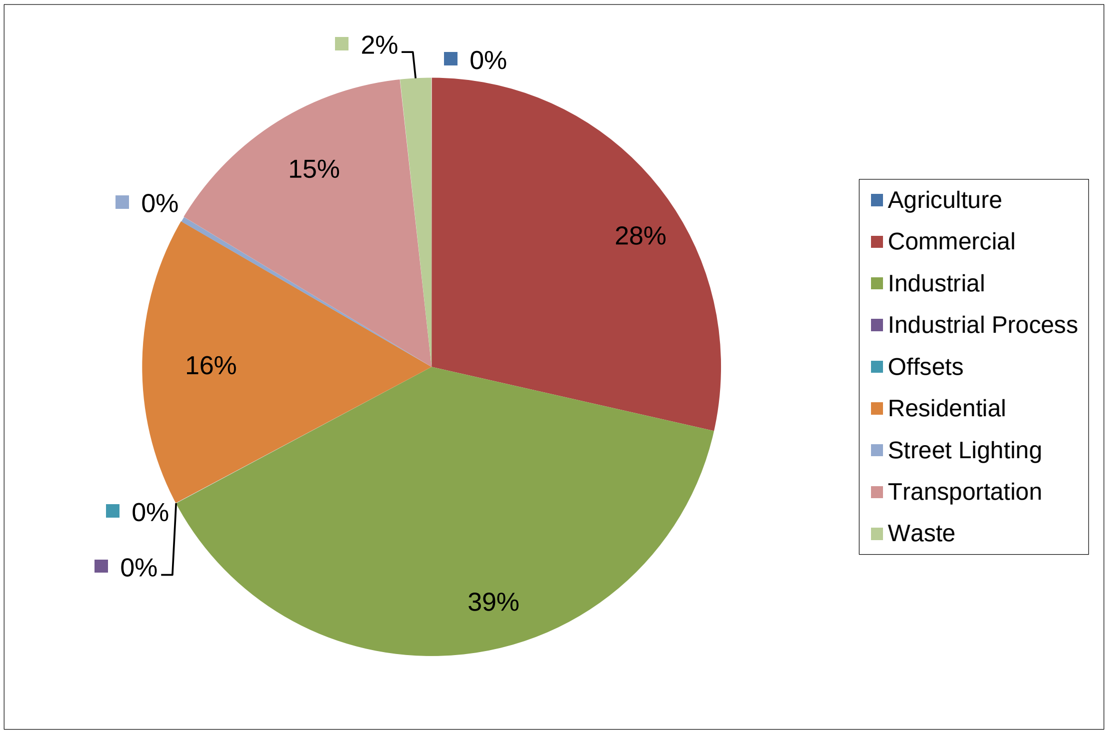



**Figure 2-18: GHG Emissions by Sector for Longmont, 2011**

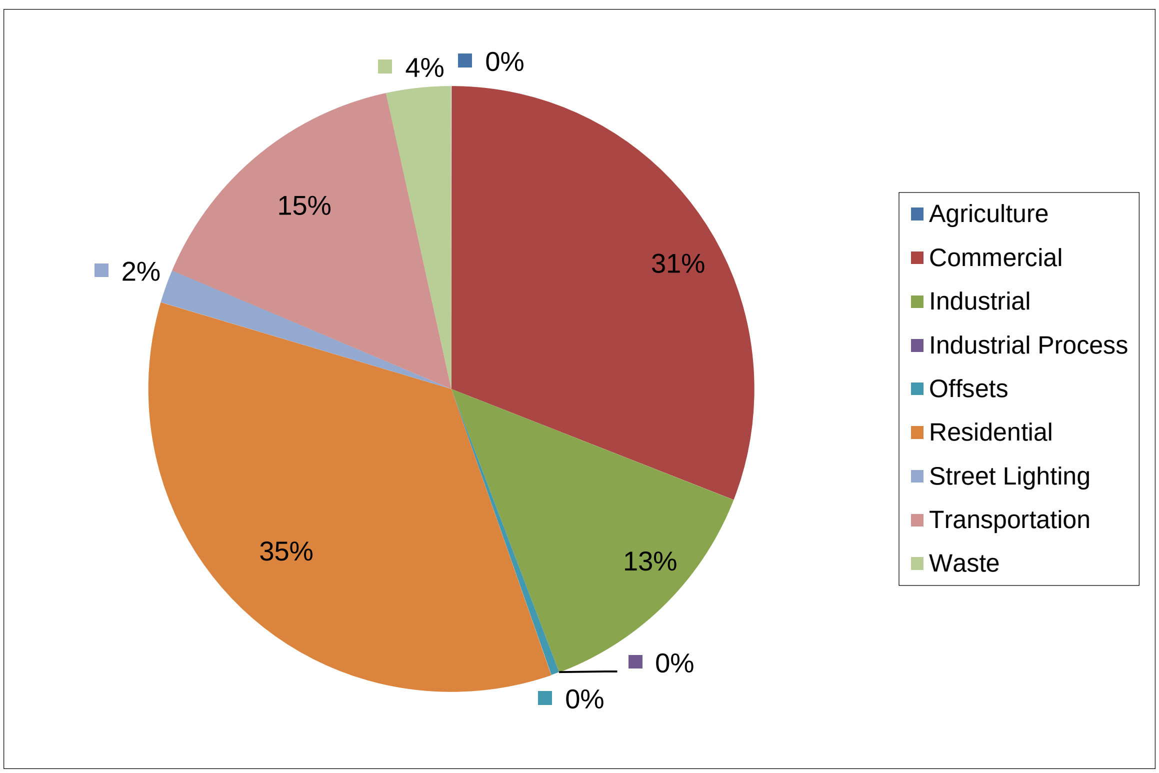


**Figure 2-19: GHG Emissions by Sector for Lyons, 2011**

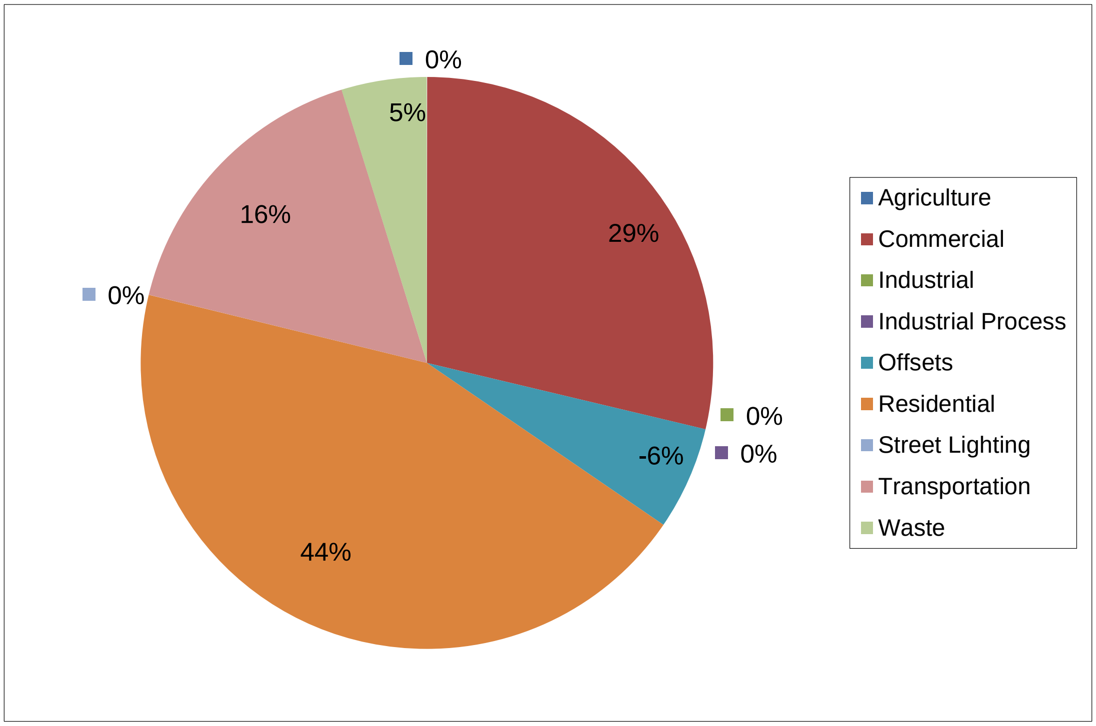



**Figure 2-20: GHG Emissions by Sector for Nederland, 2011**

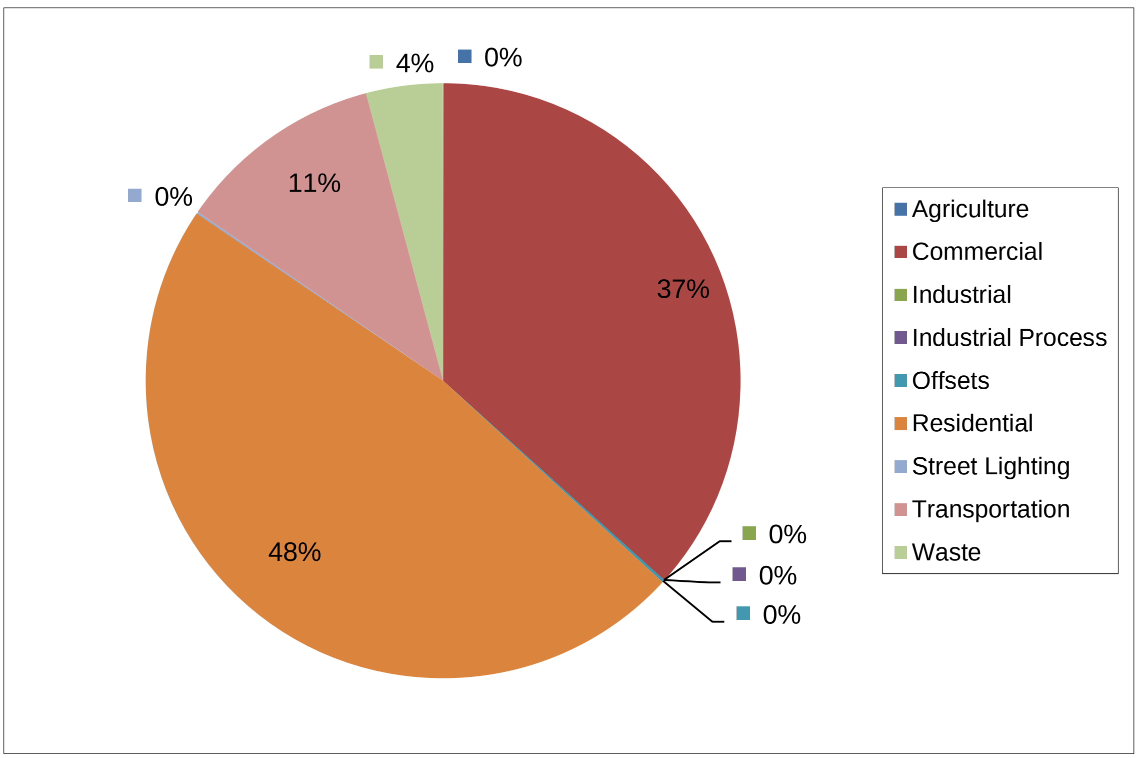


**Figure 2-21: GHG Emissions by Sector for Superior, 2011**

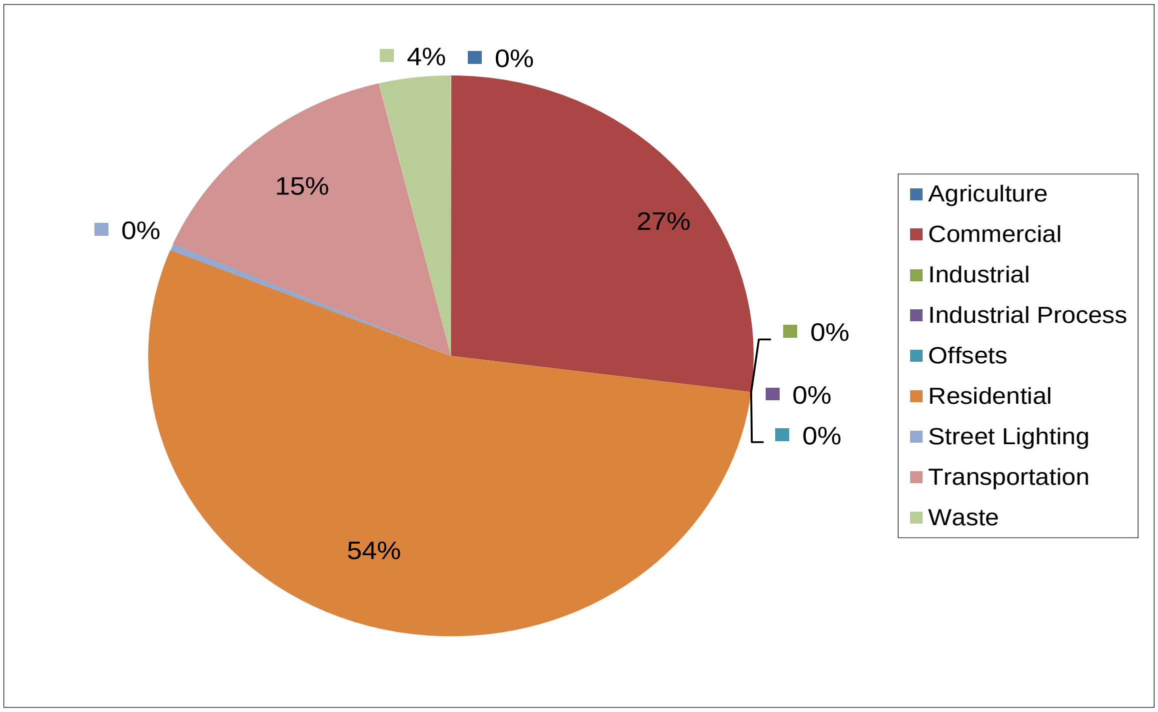
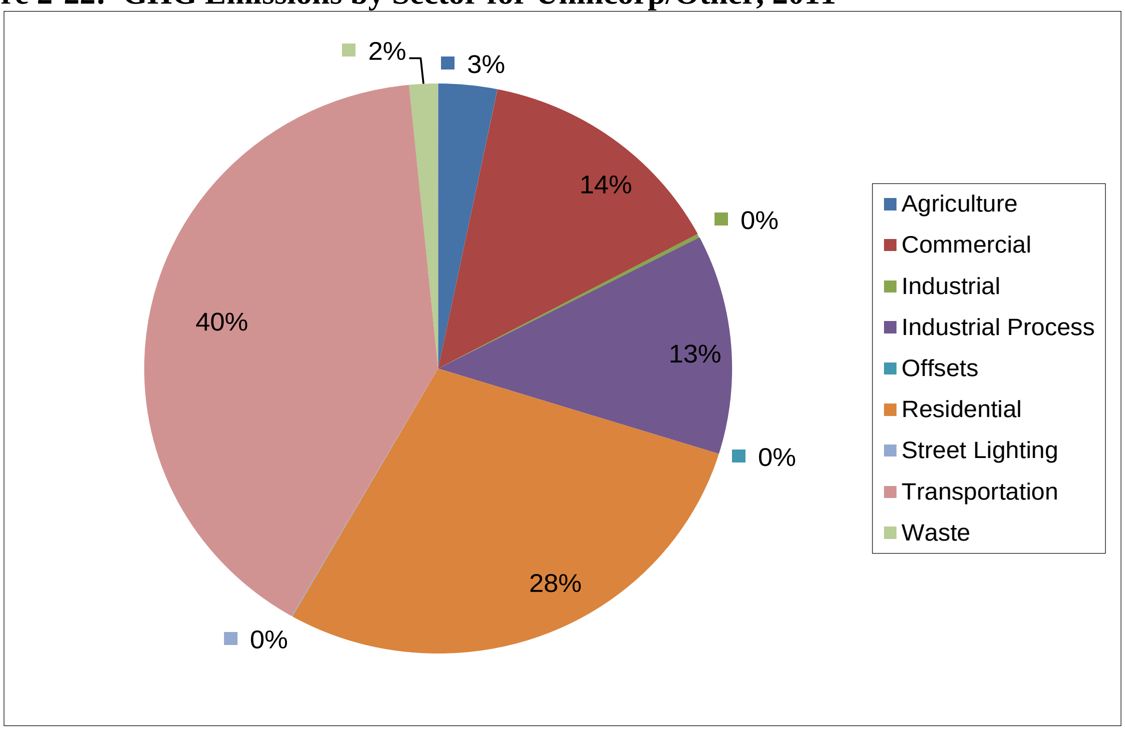



**Figure 2-22: GHG Emissions by Sector for Unincorp/Other, 2011**




NOTE: The majority (71%) of the Commercial GHG emissions emanating from Unincorporated/Other come from electricity consumed in commercial buildings located in incorporated municipalities not explicitly broken out in the GHG inventory (Erie, Niwot, Gunbarrel, Ward, and others).

# 3. RESIDENTIAL BUILDINGS SECTOR

## 3.1 OVERVIEW

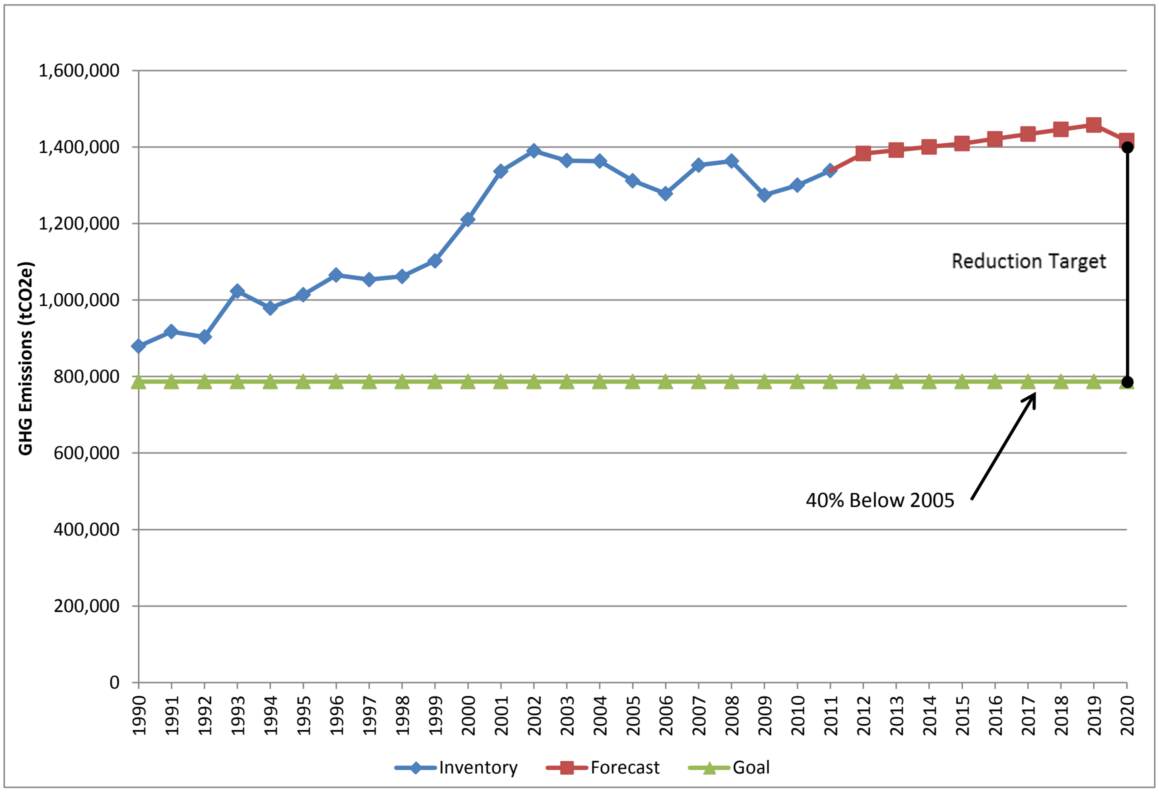
This section evaluates opportunities for the County to reduce GHG emissions through reductions in the residential sector's electricity and natural gas consumption. Residential sector electricity and natural gas are consumed by home heating, ventilation, and air-conditioning (HVAC) systems; lighting systems; and miscellaneous electrical equipment. The analysis separates the reduction opportunities into two distinct categories: existing homes and new construction. These categories are further disaggregated into single-family and multi-family building types.

The residential sector provides the second-largest contribution to Boulder County's GHG emissions. In 1990, the residential sector accounted for 879,336 $tCO_2e$ or 26 percent of the County's GHG inventory. By 2005, residential emissions had risen to 1,311,814 $tCO_2e$ and continued to represent 26 percent of the County's GHG inventory. By 2011, residential emissions had risen to 1,338,281 $tCO_2e$, representing 28 percent of the County's GHG inventory. If the Business-As-Usual (BAU) trend continues, 2020 forecast show that the residential sector emissions will increase to 1,488,114 $tCO_2e$ and 30% of emissions.

The residential sector inventory shows an increase from 1990 through 2020 of 69%. The Commissioners' goal is to reduce county-wide GHG emissions in 2020 to a level that is 40% below 2005 emissions. Thus, if the residential sector is to achieve its share of this goal, 693,058 $tCO_2e$ of GHG reductions will need to be realized, a 47% reduction in the 2020 BAU emissions.

It is important to note that the new construction portion of the 2020 BAU residential inventory is only 247,664 $tCO_2e$, or about 17%, assuming the difference between 2011 and forecasted 2020 emissions is attributable to new homes. Given that the target reduction level for the entire residential sector is over two times larger than the forecasted emissions produced by new homes, it is clear that the majority of reductions must be acquired from homes existing today.

**Figure 3-1: Residential Sector Outlook**




## 3.2 INVENTORY SUMMARY

The residential sector generates emissions indirectly through the consumption of electricity and directly through the consumption of natural gas. Electricity and natural gas are used for the building's heating, ventilation, and air-conditioning (HVAC) systems; lighting systems; and various electrical equipment.

Figure 3-2 illustrates the residential emissions profile by municipality for the 1990 through 2020 period. Table 3-1 outlines the sources of 2011 emissions and percentage of emissions by municipality. Figure 3-3 and Figure 3-4 illustrate the 2011 residential source and municipality breakdowns, respectively.

**Figure 3-2: Residential Emissions Profile by Municipality, 1990-2020**

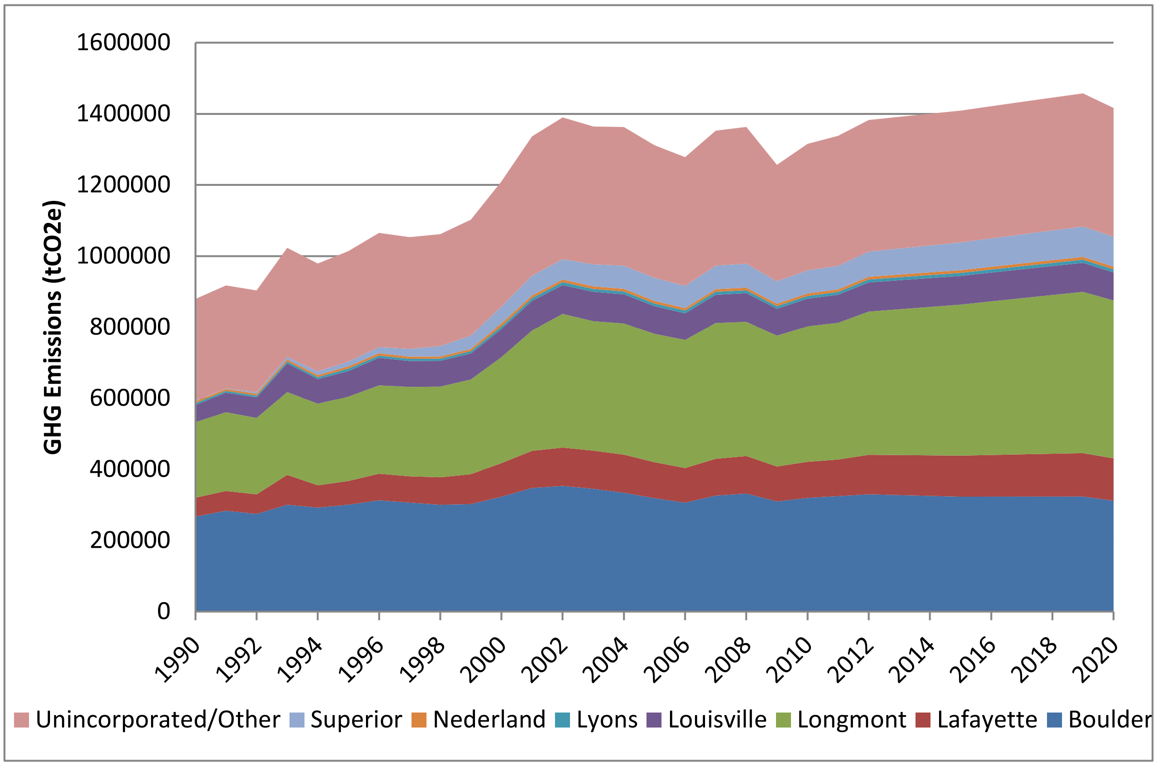



**Table 3-1: 2011 Residential GHG Emissions by Municipality ($tCO_2e$)**

| Municipality | Electricity | Natural Gas | Residential Total |
|---|---|---|---|
| Boulder | 208,696.18 | 116,239.41 | 324,935.59 |
| Lafayette | 68,090.66 | 34,823.43 | 102,914.10 |
| Longmont | 258,779.47 | 125,703.14 | 384,482.61 |
| Louisville | 50,896.38 | 28,117.48 | 79,013.86 |
| Lyons | 5,256.98 | 2,566.41 | 7,823.39 |
| Nederland | 4,540.77 | 2,663.40 | 7,204.17 |
| Superior | 42,038.39 | 24,105.59 | 66,143.98 |
| Unincorporated/Other | 255,684.83 | 110,078.06 | 365,762.88 |
| County | 893,983.67 | 444,296.92 | 1,338,280.59 |
| **Percentage by Column** | | | |
| Boulder | 23% | 26% | 24% |
| Lafayette | 8% | 8% | 8% |
| Longmont | 29% | 28% | 29% |
| Louisville | 6% | 6% | 6% |
| Lyons | 1% | 1% | 1% |
| Nederland | 1% | 1% | 1% |
| Superior | 5% | 5% | 5% |
| Unincorporated/Other | 29% | 25% | 27% |

**Figure 3-3: 2011 Residential GHG Emissions by Source**

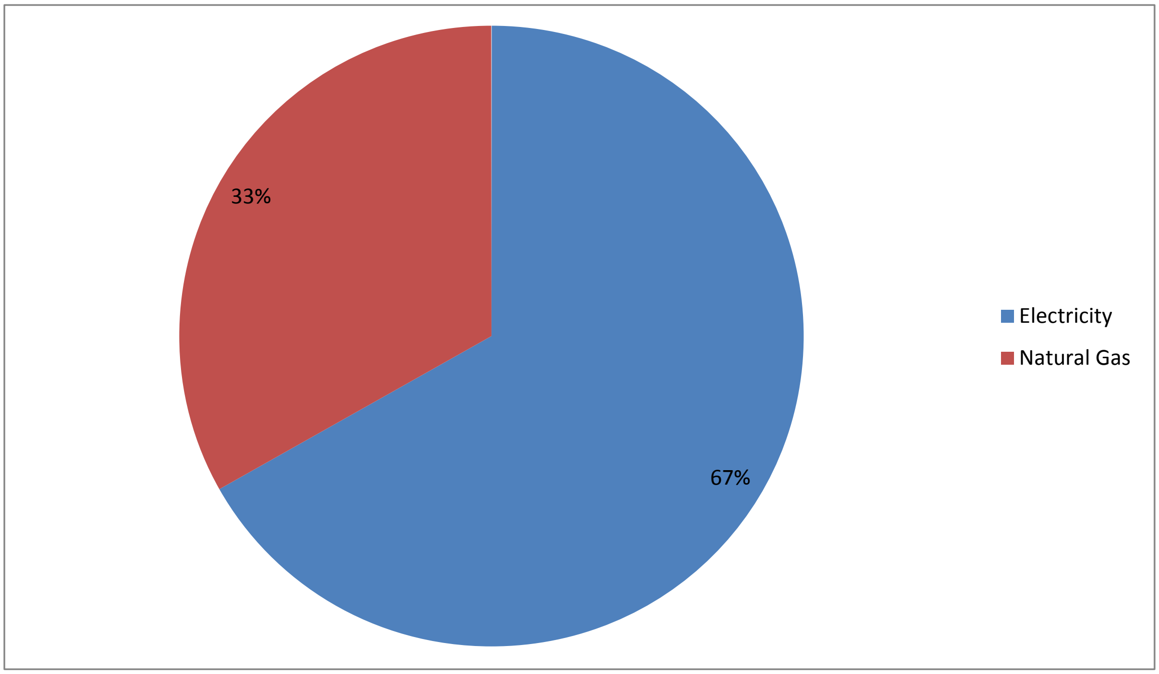
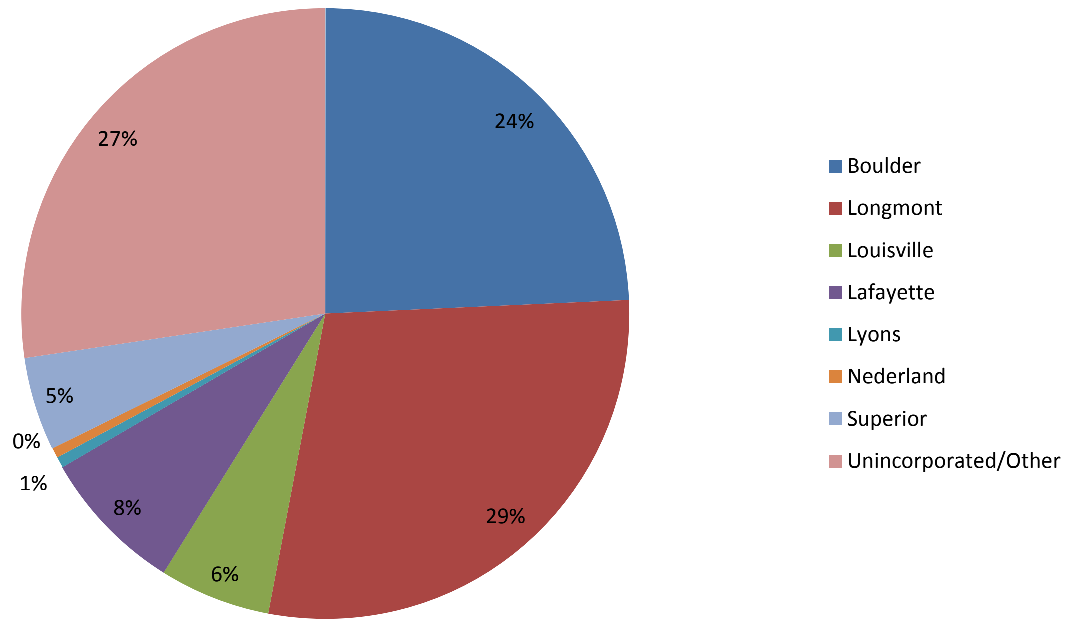



**Figure 3-4: 2011 Residential GHG Emissions by Municipality**



## 3.3 EXISTING RESIDENTIAL BUILDINGS

The first-cut nominal GHG goal is for each sector to obtain its share of the GHG reductions needed to achieve the County's objective of total 2020 GHG emissions that are 40% below 2005 levels. For the residential sector, this means a total reduction of about 693,058 tCO2e relative to the projected 2020 BAU GHG emissions. The following analysis explores strategies aimed at achieving this goal.

A detailed analysis was performed on the existing residential homes, which created the basis for estimating the potential for GHG reduction opportunities. The methodology used to quantify these reductions was to first estimate the electricity and natural gas consumption and the associated utility costs in existing residential buildings. Residential homes were divided between two vintages: pre-1980 and post-1980. For each vintage, three energy efficiency scenarios were constructed and the energy savings and cost savings potential of each was established. This analysis followed a "bottom up" approach, wherein energy efficiency opportunities were considered for several building types and extrapolated to determine the GHG reduction potential in the sector. The residential sector was also divided into single-family and multi-family building types. The sub-classifications based on two vintages and two building types were chosen to strike a balance between maintaining a manageable analysis work scope and producing meaningful results. Table 3-2 shows the building square-footages for both vintages and sector sub-classifications.

**Table 3-2: Residential Building Area (SQFT)**

| | PRE-1980 | | POST-1980 | | TOTAL |
|---|---|---|---|---|---|
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Boulder | 34,910,008 | 8,593,145 | 20,243,758 | 1,842,159 | 65,589,071 |
| Longmont | 21,765,492 | 3,865,211 | 39,265,476 | 3,980,913 | 68,877,093 |
| Louisville | 3,387,517 | 125,973 | 11,968,033 | 709,852 | 16,191,374 |
| Lafayette | 4,081,842 | 317,394 | 15,289,364 | 499,047 | 20,187,647 |
| Lyons | 528,465 | 23,560 | 1,091,166 | 2,545 | 1,645,736 |
| Nederland | 558,455 | 35,505 | 565,375 | 7,326 | 1,166,661 |
| Superior | 126,141 | - | 10,132,929 | 1,293,833 | 11,552,903 |
| Unincorporated/Other | 28,583,764 | 741,327 | 32,842,307 | 15,193 | 62,182,591 |
| **Boulder County** | 93,941,684 | 13,702,115 | 131,398,409 | 8,350,867 | 247,393,075 |

Hourly building energy simulation software (eQuest) was used to construct prototypical energy usage models for each of the residential building types. Specifically, the simulation software was used to establish base case electricity and natural gas usage intensities and also to quantify the energy savings resulting from installation of energy efficiency measures (EEMs). Three bundles of EEMs were defined for each building type and vintage. The potential energy savings and cost savings were established for each bundle by modifying the base case energy models to reflect the implementation of each energy efficiency bundle. Energy cost savings were estimated using the three different electricity rates charged by Xcel, Longmont Power & Communications, and Poudre Valley REA. Market penetration rates were assumed for each bundle and applied to estimate the energy savings that can be expected for the existing residential stock. The expected energy savings were next converted into reductions in GHG emissions. Costs to implement each bundle were estimated and the resulting economic performance of each bundle was calculated. The subsequent sections provide details of this analysis.

### 3.3.1. Prototypes of Existing Buildings

Residential building prototypes were developed using eQuest building energy simulation software. The prototype building parameters were based on data from previous studies by the Southwest Energy Efficiency Project and WSP as well as data from USDOE's Energy Information Administration. Table 3-3 provides a summary of the parameters used to construct each prototype.

**Table 3-3: Residential Building Prototype Details**

| MODEL INPUT | PRE-1980 SINGLE-FAMILY | PRE-1980 MULTI-FAMILY | POST-1980 SINGLE-FAMILY | POST-1980 MULTI-FAMILY |
|---|---|---|---|---|
| Weather | Boulder, CO | | | |
| Residential Utility rates | Electricity<br>(1) Xcel - \$0.13 per kWh<br>(2) Longmont Power & Communications – \$0.12 per kWh<br>(3) Poudre Valley - \$0.12 per kWh<br>Natural Gas<br>(1) Xcel - \$0.90 per therm | | | |
| Gross square feet of conditioned space | 2,000 $ft^2$ | 1,500 $ft^2$ per unit | 2,000 $ft^2$ | 1,500 $ft^2$ per unit |
| Exterior wall insulation | R-10 | R-8 | R-13 | R-13 |
| Roof insulation | R-19 | R-15 | R-25 | R-25 |
| Windows | U-value – 0.93 | U-value – 0.93 | U-value – 0.76 | U-value – 0.76 |
| Peak lighting power intensity | 1.0 $W/ft^2$ | 1.1 $W/ft^2$ | 0.85 $W/ft^2$ | 1.0 $W/ft^2$ |
| Appliances | Standard Efficiency<br>Electric Dryer<br>Gas Stove | Standard Efficiency<br>Electric Dryer<br>Electric Stove | Standard Efficiency<br>Electric Dryer<br>Gas Stove | Electric - 0.3 $W/ft^2$<br>Electric Dryer<br>Electric Stove |
| Programmable Thermostat | No | No | No | No |
| TEMPERATURE SETPOINTS | COOL – 76°<br>HEAT-70° | COOL – 76°<br>HEAT-70° | COOL – 76°<br>HEAT-70° | COOL – 76°<br>HEAT-70° |
| HVAC system | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace |
| Cooling efficiency | EER – 8.0 | EER – 8.0 | EER – 9.0 | EER – 9.0 |
| Heat rejection | Air-cooled | Air-cooled | Air-cooled | Air-cooled |
| Heating efficiency | 73% | 70% | 78% | 75% |
| Domestic hot water | Gas | Electricity | Gas | Electricity |
| Occupancy; lighting; equipment schedules | ASHRAE standards | ASHRAE standards | ASHRAE standards | ASHRAE standards |
| Operating schedule | 24/7 | 24/7 | 24/7 | 24/7 |

### 3.3.2. Energy Efficiency Bundles

Table 3-4 lists the measures included in each energy efficiency bundle applied to both the pre- and post-1980 vintages. For each building sub-classification, Bundle 1 only included a lighting upgrade. This approach was chosen for Bundle 1 due to its quick payback and high potential for market penetration. Bundle 2 is a collection of aggressive yet technically mature energy efficiency upgrades. This bundle aims for aggressive energy savings while maintaining an attractive market penetration level. Bundle 3 builds off of Bundles 1 and 2 but aims for extremely aggressive energy savings. Most notably, Bundle 3 achieves significantly greater energy savings, compared to Bundle 2, through the use of evaporative cooling technologies.

**Table 3-4: Description of Single-Family Energy Savings Bundles**

| | SINGLE-FAMILY | MULTI-FAMILY |
|---|---|---|
| Bundle 1 | o Lighting efficiency upgrades – 75% of home lighting with CFLs<br>o Programmable Thermostats – Temperature Setback<br>o Energy Star refrigerator<br>o Energy Star washer | o Lighting efficiency upgrades – 75% of home lighting with CFLs<br>o Programmable Thermostats<br>o Energy Star refrigerator<br>o Energy Star washer |
| Bundle 2 | o Lighting efficiency upgrades - – 75% of lighting with CFLs<br>o Programmable T-stats<br>o Energy Star refrigerator<br>o Energy Star washer<br>o Energy Star dishwasher<br>o Insulate ducts<br>o Replace windows with Energy Star insulated windows<br>o Condensing Furnace η – 93%<br>o Packaged AC EER – 10.5 | o Lighting efficiency upgrades - – 75% of lighting with CFLs<br>o Programmable T-stats<br>o Energy Star refrigerator<br>o Energy Star washer<br>o Energy Star dishwasher<br>o Insulate ducts<br>o Replace windows with Energy Star insulated windows<br>o Condensing Furnace η – 93%<br>o Packaged AC EER – 10.5 |
| Bundle 3 | o Lighting efficiency upgrades - – 75% of lighting with CFLs<br>o Programmable T-stats<br>o Energy Star refrigerator<br>o Energy Star washer<br>o Energy Star dishwasher<br>o Insulate ducts<br>o Replace windows with Energy Star insulated windows<br>o Condensing Furnace η – 93%<br>o Evaporative cooling<br>o Solar Domestic Hot Water<br>o 1 kW PV System | o Lighting efficiency upgrades - – 75% of lighting with CFLs<br>o Programmable T-stats<br>o Energy Star refrigerator<br>o Energy Star washer<br>o Energy Star dishwasher<br>o Insulate ducts<br>o Replace windows with Energy Star insulated windows<br>o Condensing Furnace η – 93%<br>o Evaporative cooling<br>o 0.5 kW PV System per unit |

### 3.3.3. Energy Consumption

The four prototype base case energy models were modified to reflect the energy efficiency measures identified for each of the three energy efficiency bundles. The modeling modifications established the potential energy savings resulting from implementing the energy efficiency bundles. The energy intensities for each bundle were used to calculate energy savings relative to the base case. The building energy usage intensities for the base case and three bundles, along with the savings impacts on both electric and gas use are shown in Table 3-5.

### 3.3.4. Energy Cost

The four prototype base case energy models were next used to establish the cost savings resulting from the three bundles. Three[3] residential electric rates were used (Xcel, Longmont Power & Communications, and Poudre Valley REA) to determine the costs and resulting cost savings for each bundle. Table 3-6 through Table 3-8 provide a summary of these energy costs.

3 Note that Poudre Valley Rural Electric Association only provides residential electric service.

## Table 3-5: Energy Use Summary

| | BASE CASE | | | |
|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Energy Usage Index (kBtu/SF yr) | 49.7 | 59.5 | 42.2 | 46.4 |
| Electric Usage Intensity (kWh/SF yr) | 5.8 | 8.4 | 5.5 | 8.2 |
| Gas Usage Intensity (therms/SF yr) | 0.3 | 0.3 | 0.2 | 0.2 |

| | BUNDLE 1 | | | |
|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Energy Usage Index (kBtu/SF yr) | 46.8 | 57.3 | 39.3 | 44.1 |
| Electric Intensity (kWh/SF yr) | 4.1 | 7.1 | 4.0 | 6.9 |
| Electric Savings Over Base | 29% | 15% | 28% | 15% |
| Gas Intensity (therms/SF yr) | 0.3 | 0.3 | 0.3 | 0.2 |
| Gas Savings Over Base | -10% | -7% | -11% | -11% |

| | BUNDLE 2 | | | |
|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Energy Usage Index (kBtu/SF yr) | 33.9 | 38.8 | 31.1 | 32.9 |
| Electric Intensity (kWh/SF yr) | 3.1 | 5.3 | 3.1 | 5.4 |
| Electric Savings Over Base | 46% | 36% | 44% | 34% |
| Gas Intensity (therms/SF yr) | 0.2 | 0.2 | 0.2 | 0.1 |
| Gas Savings Over Base | 31% | 48% | 23% | 46% |

| | BUNDLE 3 | | | |
|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Energy Usage Index (kBtu/SF yr) | 22.8 | 32.8 | 19.8 | 26.5 |
| Electric Intensity (kWh/SF yr) | 2.1 | 4.9 | 2.0 | 4.8 |
| Electric Savings Over Base | 63% | 41% | 63% | 41% |
| Gas Intensity (therms/SF yr) | 0.2 | 0.2 | 0.1 | 0.1 |
| Gas Savings Over Base | 48% | 48% | 45% | 46% |

**Table 3-6: Energy Cost Summary ($/SQFT-yr) – Xcel**

| Base Case | | | | |
|---|---|---|---|---|
| | **Pre-1980** | | **Post-1980** | |
| ($/SF yr) | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.75 | $1.08 | $0.71 | $1.06 |
| Gas Cost Intensity | $0.21 | $0.22 | $0.17 | |
| | **Bundle 1** | | | |
| | **Pre-1980** | | **Post-1980** | |
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.53 | $0.91 | $0.51 | $0.89 |
| Electric Cost Savings | $0.22 | $0.17 | $0.20 | $0.16 |
| Gas Cost Intensity | $0.24 | $0.24 | $0.19 | $0.15 |
| Gas Cost Savings | -$0.02 | -$0.02 | -$0.02 | -$0.01 |
| | **Bundle 2** | | | |
| | **Pre-1980** | | **Post-1980** | |
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.41 | $0.69 | $0.40 | $0.69 |
| Electric Cost Savings | $0.35 | $0.39 | $0.31 | $0.36 |
| Gas Cost Intensity | $0.15 | $0.11 | $0.13 | $0.07 |
| Gas Cost Savings | $0.07 | $0.11 | $0.04 | $0.06 |
| | **Bundle 3** | | | |
| | **Pre-1980** | | **Post-1980** | |
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.28 | $0.64 | $0.26 | $0.62 |
| Electric Cost Savings | $0.48 | $0.44 | $0.45 | $0.43 |
| Gas Cost Intensity | $0.11 | $0.11 | $0.09 | $0.07 |
| Gas Cost Savings | $0.10 | $0.11 | $0.07 | $0.06 |

## Table 3-7: Energy Cost Summary ($/SQFT-yr) - Longmont Power & Communications

| Base Case | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| ($/SF yr) | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.71 | $1.02 | $0.68 | $1.00 |
| Gas Cost Intensity | $0.21 | $0.22 | $0.17 | $0.13 |

| Bundle 1 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.50 | $0.87 | $0.48 | $0.85 |
| Electric Cost Savings | $0.21 | $0.16 | $0.19 | $0.15 |
| Gas Cost Intensity | $0.24 | $0.24 | $0.19 | $0.15 |
| Gas Cost Savings | -$0.02 | -$0.02 | -$0.02 | -$0.01 |

| Bundle 2 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.38 | $0.66 | $0.38 | $0.66 |
| Electric Cost Savings | $0.33 | $0.37 | $0.30 | $0.34 |
| Gas Cost Intensity | $0.15 | $0.11 | $0.13 | $0.07 |
| Gas Cost Savings | $0.07 | $0.11 | $0.04 | $0.06 |

| Bundle 3 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.26 | $0.60 | $0.25 | $0.59 |
| Electric Cost Savings | $0.45 | $0.42 | $0.42 | $0.41 |
| Gas Cost Intensity | $0.11 | $0.11 | $0.09 | $0.07 |
| Gas Cost Savings | $0.10 | $0.11 | $0.07 | $0.06 |

## Table 3-8: Energy Cost Summary ($/SQFT-yr) Poudre Valley REA

| Base Case | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| ($/SF yr) | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.69 | $0.99 | $0.65 | $0.97 |
| Gas Cost Intensity | $0.21 | $0.22 | $0.17 | $0.13 |

| Bundle 1 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.49 | $0.84 | $0.47 | $0.82 |
| Electric Cost Savings | $0.20 | $0.15 | $0.19 | $0.15 |
| Gas Cost Intensity | $0.24 | $0.24 | $0.19 | $0.15 |
| Gas Cost Savings | -$0.02 | -$0.02 | -$0.02 | -$0.01 |

| Bundle 2 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.37 | $0.63 | $0.37 | $0.64 |
| Electric Cost Savings | $0.32 | $0.35 | $0.29 | $0.33 |
| Gas Cost Intensity | $0.15 | $0.11 | $0.13 | $0.07 |
| Gas Cost Savings | $0.07 | $0.11 | $0.04 | $0.06 |

| Bundle 3 | Pre-1980 | | Post-1980 | |
|---|---|---|---|---|
| | **Single Family** | **Multi Family** | **Single Family** | **Multi Family** |
| Electric Cost Intensity | $0.25 | $0.58 | $0.24 | $0.57 |
| Electric Cost Savings | $0.44 | $0.41 | $0.41 | $0.40 |
| Gas Cost Intensity | $0.11 | $0.11 | $0.09 | $0.07 |
| Gas Cost Savings | $0.10 | $0.11 | $0.07 | $0.06 |

### 3.3.5. Implementation Costs

The costs associated with implementing each bundle were estimated on a $/sqft-of-floor area basis for each bundle and building type. These costs are listed in Table 3-9. The implementation costs were first estimated on a $/measure basis for each measure in a bundle and then aggregated to establish the figures shown in Table 3-9. The individual-measure cost estimates were based on data from previous studies by the Southwest Energy Efficiency Project, local vendor quotations, and WSP's energy project experience. *It is important to note that the costs presented here are based on assumption that 100% of the stock of a given piece of equipment is replaced over the nominal 20-year lifetime of that type of equipment. Thus, over the 2013 – 2020 period, 8/20 or 40% of the equipment stock would be replaced in the absence of the County's GHG programs. Therefore, this analysis assumes that, in aggregate, the implementation costs for the EEM bundles, involving replacement of existing equipment, comprise an incremental equipment replacement cost for 40% of replacements and the full replacement cost for 60% of replacements. Incremental cost is the difference between standard-efficiency and high-efficiency equipment.*

**Table 3-9: Implementation Cost ($/ft$^2$)**

| | PRE-1980 | | POST-1980 | |
|---|---|---|---|---|
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Bundle 1 | $0.63 | $0.80 | $0.63 | $0.80 |
| Bundle 2 | $4.79 | $6.33 | $3.38 | $4.45 |
| Bundle 3 | $9.75 | $9.59 | $7.69 | $7.72 |

### 3.3.6. Economic Performance

The energy cost savings and implementation costs shown in the previous two sections were used to establish the simple paybacks listed in Table 3-10.

**Table 3-10: Simple Payback – Xcel**

| | PRE-1980 | | POST-1980 | |
|---|---|---|---|---|
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Bundle 1 | 3.1 | 5.3 | 3.4 | 5.4 |
| Bundle 2 | 11.6 | 12.8 | 9.6 | 10.5 |
| Bundle 3 | 16.8 | 17.4 | 14.7 | 15.6 |

**Table 3-11: Simple Payback - Longmont Power & Communications**

| | PRE-1980 | | POST-1980 | |
|---|---|---|---|---|
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Bundle 1 | 3.3 | 5.6 | 3.6 | 5.7 |
| Bundle 2 | 12.1 | 13.3 | 10.1 | 11.0 |
| Bundle 3 | 17.6 | 18.2 | 15.4 | 16.4 |

**Table 3-12: Simple Payback – Poudre Valley REA**

| | PRE-1980 | | POST-1980 | |
|---|---|---|---|---|
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY |
| Bundle 1 | 3.5 | 5.8 | 3.7 | 5.9 |
| Bundle 2 | 12.5 | 13.7 | 10.4 | 11.3 |
| Bundle 3 | 18.1 | 18.7 | 15.8 | 16.9 |

### 3.3.7. Market Penetration Rates

The historical experience of US electric utility demand-side management (DSM) programs has shown that it is extremely difficult to shift energy usage patterns within a stock of buildings. Table 3-13 presents a few examples of actual DSM program market penetration rates. These are used as guidance in developing the market penetration assumptions listed in Table 3-14.

**Table 3-13: Historical US Electric Utility DSM Program Market Penetration Rates**

| DSM PROGRAM | UTILITY | MARKET PENETRATION RATE ACHIEVED |
|---|---|---|
| Small Business Services Program | National Grid | 33% |
| Small Business Energy Advantage | Northeast Utilities | 35% |
| Downstream Express Efficiency | Pacific Gas & Electric | 5% |

**Table 3-14: Market Penetration Rate**

| | |
|---|---|
| BUNDLE 1 | 40% |
| BUNDLE 2 | 35% |
| BUNDLE 3 | 30% |

### 3.3.8. Greenhouse Gas Reductions

The energy savings presented in Table 3-5 were used to estimate reductions in GHG emissions for each bundle of measures. The methodology for this calculation was to multiply the respective percentage energy savings and market penetration rate by the total energy consumption of each building type. This was done individually for both electricity and natural gas. The total electricity and natural gas consumption for each building type were established by multiplying the total floor area of each building type by the respective base case electric and natural gas usage intensity provided in Table 3-5. GHG emissions reductions for each building type and energy efficiency bundle were next established by converting the energy savings into GHG emissions reductions.

Table 3-15 provides the GHG reduction summary. It is instructive to note that the total county-wide GHG reductions associated with Bundles 1 through 3 are only 17%, 32%, and 38%, respectively, of the residential sector goal of 693,058 $tCO_2e$ of reductions by 2020.

**Table 3-15: GHG Emissions Reduction ($tCO_{2e}$)**

| BOULDER COUNTY | | | | | |
|---|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 47,445 | 5,199 | 61,478 | 3,109 | 117,231 |
| Bundle 2 | 89,311 | 15,844 | 105,738 | 8,109 | 219,002 |
| Bundle 3 | 107,226 | 14,932 | 135,171 | 8,084 | 265,413 |
| CITY OF BOLDER | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 17,631 | 3,261 | 9,471 | 686 | 31,049 |
| Bundle 2 | 33,189 | 9,936 | 16,290 | 1,789 | 61,205 |
| Bundle 3 | 39,847 | 9,364 | 20,825 | 1,783 | 71,819 |
| LONGMONT | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 10,993 | 1,467 | 18,371 | 1,482 | 32,312 |
| Bundle 2 | 20,693 | 4,469 | 31,598 | 3,865 | 60,625 |
| Bundle 3 | 24,843 | 4,212 | 40,393 | 3,854 | 73,302 |
| LOUISVILLE | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 1,711 | 48 | 5,600 | 264 | 7,622 |
| Bundle 2 | 3,221 | 146 | 9,631 | 689 | 13,686 |
| Bundle 3 | 3,867 | 137 | 12,312 | 687 | 17,003 |

| LAFAYETTE | | | | | |
|---|---|---|---|---|---|
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 2,062 | 120 | 7,153 | 186 | 9,521 |
| Bundle 2 | 3,881 | 367 | 12,304 | 485 | 17,036 |
| Bundle 3 | 4,659 | 346 | 15,728 | 483 | 21,216 |
| LYONS | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 267 | 9 | 511 | 1 | 787 |
| Bundle 2 | 502 | 27 | 878 | 2 | 1,410 |
| Bundle 3 | 603 | 26 | 1,122 | 2 | 1,754 |
| NEDERLAND | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 282 | 13 | 265 | 3 | 563 |
| Bundle 2 | 531 | 41 | 455 | 7 | 1,034 |
| Bundle 3 | 637 | 39 | 582 | 7 | 1,265 |
| SUPERIOR | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 64 | 0 | 4,741 | 482 | 5,286 |
| Bundle 2 | 120 | 0 | 8,154 | 1,256 | 9,530 |
| Bundle 3 | 144 | 0 | 10,424 | 1,252 | 11,820 |
| UNINCORPORATED/OTHER | | | | | |
| | PRE-1980 | | POST-1980 | | TOTAL REDUCTION |
| | SINGLE-FAMILY | MULTI-FAMILY | SINGLE-FAMILY | MULTI-FAMILY | |
| Bundle 1 | 12,632 | 246 | 13,445 | 5 | 26,328 |
| Bundle 2 | 26,759 | 844 | 26,024 | 15 | 53,641 |
| Bundle 3 | 32,626 | 808 | 33,785 | 15 | 67,234 |

## 3.4 NEW RESIDENTIAL BUILDINGS

Analysis of new residential homes was performed to evaluate the GHG reductions opportunities that varying building energy efficiency levels and market penetration rates will have on forecasted 2020 emissions. It is important to note that the new residential buildings subsector is not expected to offer a substantial opportunity to achieve reductions in 2020 GHG emissions. This is based on the estimate that new residential buildings, constructed during the 2013 through 2020 period, will only add approximately 125,000 tCO2e/yr of GHG emissions in 2020 under the BAU scenario. Programs aimed at reducing the energy consumption of new homes, such as aggressive energy codes and/or requiring green building certification, will reduce energy usage by these new additions by perhaps 40% compared to standard BAU construction. Therefore, new residential buildings can be expected to reduce GHG emissions by only about 49,900 tCO2e in 2020. This represents only about 7% of the 704,354 tCO2e emissions reductions that the residential buildings sector must produce if it is to achieve its nominal goal in 2020 BAU emissions reductions.

Nevertheless, it is important for Boulder County municipalities to develop and implement more aggressive energy performance building codes by which the residential buildings market will be transformed over time. Such a code upgrade will eventually create a residential building stock that contributes substantially less to global climate change.

**Table 3-16: Cumulative New Residential GHG Reductions ($tCO_2e$)**

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Boulder | - | - | - | 84 | 152 | 204 | 239 | 239 |
| Longmont | 4,435 | 8,824 | 13,167 | 17,569 | 21,926 | 26,236 | 30,502 | 30,502 |
| Louisville | - | - | - | 153 | 301 | 442 | 578 | 578 |
| Lafayette | 884 | 1,756 | 2,615 | 3,618 | 4,608 | 5,586 | 6,552 | 6,552 |
| Lyons | 74 | 146 | 217 | 308 | 397 | 485 | 572 | 572 |
| Nederland | 14 | 28 | 42 | 74 | 107 | 139 | 170 | 170 |
| Superior | 1,435 | 2,864 | 4,285 | 5,387 | 6,483 | 7,571 | 8,652 | 8,652 |
| Unincorp/Other | 123 | 235 | 337 | 930 | 1,512 | 2,085 | 2,647 | 2,647 |
| **County** | **6,964** | **13,852** | **20,663** | **28,124** | **35,486** | **42,749** | **49,913** | **49,913** |

## 3.5 RESIDENTIAL BUILDINGS SUMMARY

The residential sector BAU inventory shows an increase from 1990 through 2020 of 70%. For the residential sector to meet the emissions goal, 693,058 $tCO_2e$ of GHG reductions need to be realized in 2020. The previous sections highlight the potential of implementing aggressive GHG reductions measures throughout the county for both existing and new homes. Table 3-17 shows the impact each of the EEM bundles of measures can have in relation to the reduction goal.

**Table 3-17: Residential Summary**

| | 2020 REDUCTION ($TCO_2E$) | FRACTION OF RESIDENTIAL GOAL ACHIEVED (%) | SIMPLE PAYBACK (YRS) |
|---|---|---|---|
| Residential retrofit – Bundle 1 | 117,231 | 17% | 3.6 |
| Residential retrofit – Bundle 2 | 219,002 | 31% | 10.8 |
| Residential retrofit – Bundle 3 | 265,413 | 38% | 16.0 |
| Residential new construction | 49,913 | 7% | na |

Boulder County's strategy, and that of each municipality, should be to capture the maximum amount of utility DSM incentives possible, and to take advantage to the maximum extent possible of government incentives, in order to buy down the simple payback of a Bundle 2-like package of EEMs to a level that private capital will be willing to accept. Individual homeowners may accept simple paybacks of up to 10 years, perhaps longer in a few cases. However, the owners of rental units require shorter paybacks, more on the order of 3 years.

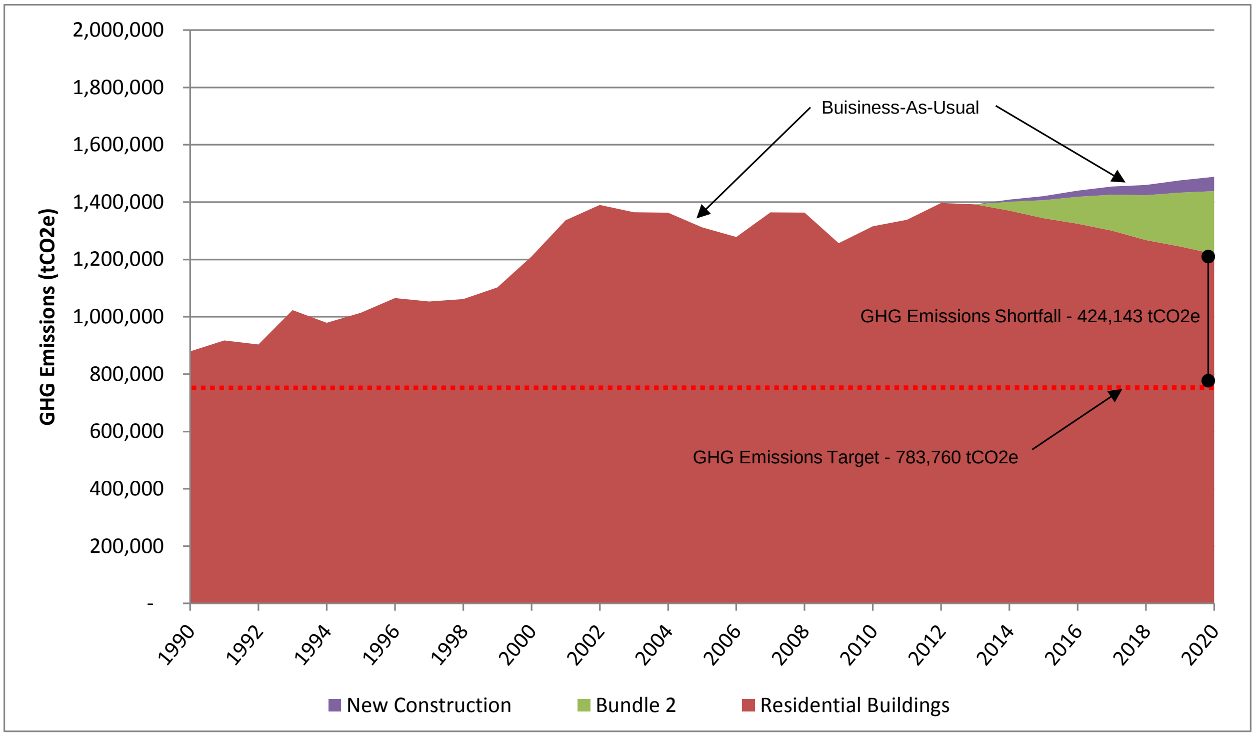
DSM incentives include electricity efficiency programs like those offered by Xcel and Longmont Power & Communications. Xcel also offers natural gas DSM programs.

Government incentives include tax credits and tax deductions for residential building energy efficiency. Tax incentives for renewable energy are accounted for in the Renewable Energy chapter.

All things considered, Bundle 2 was judged to be the most-aggressive package that offers economic performance that can realistically appeal to the market. The marginal abatement cost (MAC) for Bundle 2 is (-11) $/mtCO2. Bundle 2 results are reflected in all subsequent sections of this report. Impacts for solar DHW and PV are accounted for separately in the Renewable Energy chapter. Figure 3-5 illustrates these results.

Based on the assumed 35% market penetration rate and the estimated implementation costs for Bundle 2, it is estimated that $351 million of investment will be required to achieve the county-wide GHG impacts presented in this report for the Residential sector. Energy cost savings delivered by these investments would amount to about $33 million/yr in 2020.

**Figure 3-5: Residential Outlook**




### 3.5.1. Context Provided by Impact Evaluations

Useful data points providing context for assumptions about energy savings rates are provided by recent impact evaluations of the ClimateSmart and EnergySmart programs. The Residential EnergySmart evaluation found that from program launch in January 2011 to May 2012, 4% of Boulder County households received services under this specific program. If this rate of service were to continue through 2020, about 27% of county-wide housing stock existing as of 2012 would be treated by the program by 2020.

Of the 5,072 households served by EnergySmart through May 2012, 4,747 completed energy upgrades costing a total of $6.1 million; average upgrade cost was $1,285. Average energy cost savings and average GHG emissions reductions were, respectively, $250/yr and 0.66 mtCO2e/yr per treated household. Average simple payback was thus 5.1 years and the average MAC was (-210). Note that this payback and MAC are dramatically more attractive than the 10.8 years and (-11) estimated for Bundle 2. This is not surprising given that Bundle 2 aimed to achieve 30% energy savings in each treated residence while EnergySmart has apparently achieved actual savings of less than 10%. The MAC of the next 10% of savings delivered by Bundle 2 is higher than the first 10%; the MAC of the last 10% of Bundle 2 savings is higher still. Thus, the Residential EnergySmart impact evaluation and the Bundle 2 estimated performance are not inconsistent.

The Residential ClimateSmart evaluation found that about 0.2% of Boulder County households received services under this specific program. If this rate of service were to continue through 2020, about 2% of county-wide housing stock existing as of 2012 would be treated by the program.

Of the 219 households served by ClimateSmart before program suspension, completed energy upgrades achieved average GHG emissions reductions of about 1.6 mtCO2e/yr per treated household. This represents apparent average energy savings of about 24%. This level of savings suggests that the Property Assessed Clean Energy (PACE) type of program is more effective at incentivizing residential energy retrofits than the services-oriented type of program that BuildSmart represents.

Another key observation that is apparent from these program impact evaluations is that WSP's assumed savings rates and market penetrations are optimistic but achievable. The average savings assumption of 30% per household appears realistically achievable since actual ClimateSmart savings appear to be about 24%. The assumed market penetration rate of 35% appears to be achievable, since actual EnergySmart penetration is on track to hit 27% by 2020. The trick will be to design a suite of programs that together can achieve both 30% average energy savings and 35% market penetration.

# 4. COMMERCIAL BUILDINGS SECTOR

## 4.1 OVERVIEW

This section evaluates opportunities for the County to reduce GHG emissions through reductions in the commercial building sector's electricity and natural gas consumption. Commercial sector electricity and natural gas are consumed by building heating, ventilation, and air-conditioning (HVAC) systems; lighting systems; and miscellaneous electrical equipment. The analysis separates the reduction opportunities into two distinct categories: existing commercial buildings and new commercial buildings.

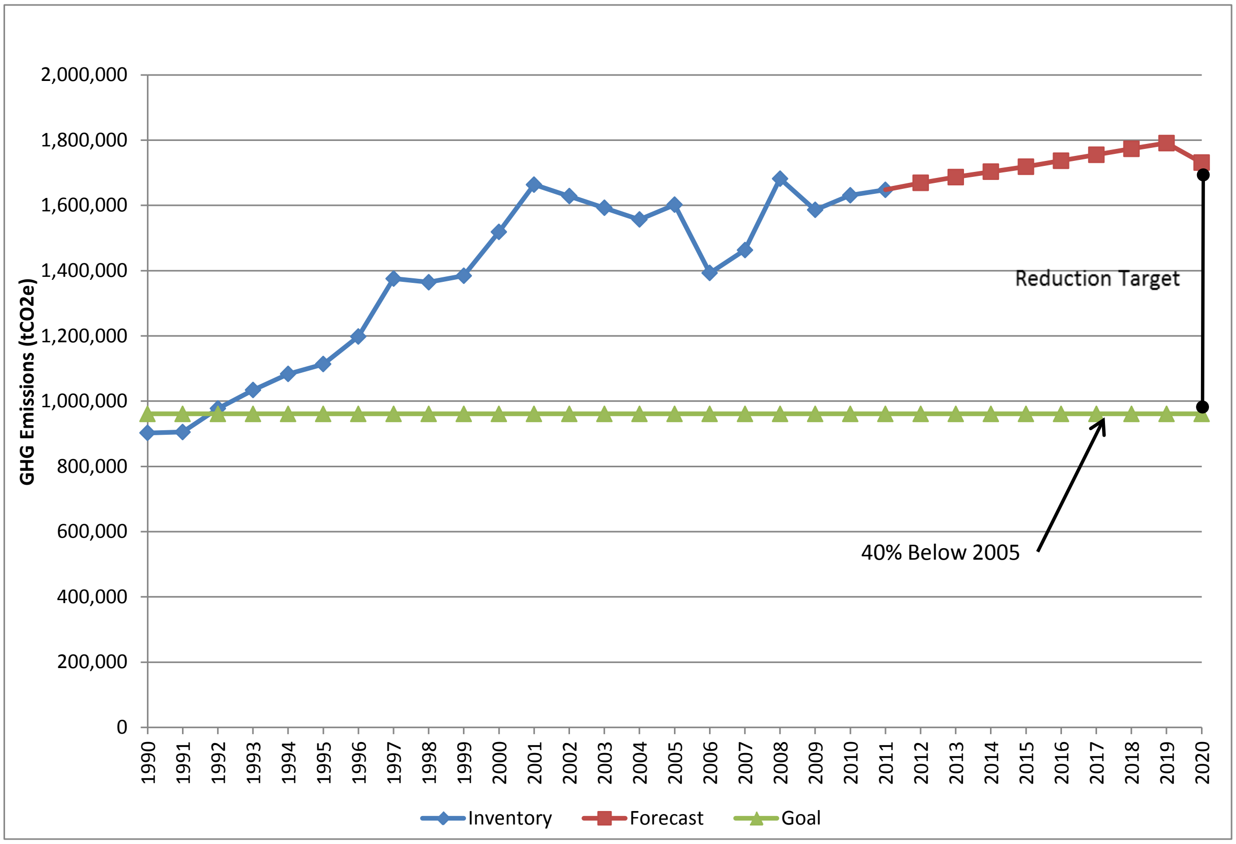
Opportunities to apply renewable energy technologies to commercial buildings are not included in this section of the report. Rather, they are treated in Chapter 6, Renewable Energy.

The commercial sector provides the largest contribution to Boulder County's GHG emissions. In 1990, the commercial sector accounted for 902,600 $tCO_2e$ or 27 percent of the County's GHG inventory. By 2005, commercial emissions had risen to 1,602,000 $tCO_2e$ and made up 32 percent of the County's GHG inventory. If the Business-As-Usual (BAU) trend continues, 2020 forecasts show that the commercial sector emissions will increase to 1,836,300 $tCO_2e$.

The commercial sector inventory shows an increase from 1990 through 2020 of over 103%. The Commissioners' goal is to reduce county-wide GHG emissions in 2020 to a level that is 40% below 2005 emissions. To achieve its share of this goal, the commercial buildings sector must realize 865,328 $tCO_2e$ of GHG reductions by 2020, a 47% reduction in the 2020 BAU emissions.

It is important to note that the new construction portion of the 2020 BAU commercial inventory is only about 122,000 $tCO_2e$, or about 7%, assuming the difference between 2012 and forecasted 2020 emissions is attributable to new construction. Given that the target reduction level for the entire commercial sector is seven times larger than the forecasted emissions produced by new commercial buildings, it is clear that significant reductions must be acquired from existing commercial buildings.

**Figure 4-1: Commercial Sector Outlook**




## 4.2 INVENTORY SUMMARY

Commercial building sector emissions are produced indirectly through the consumption of electricity and directly through the consumption of natural gas. Electricity and natural gas are used for the building's heating, ventilation, and air-conditioning (HVAC) systems; lighting systems; and various electrical equipment. Refrigerant leakage from cooling equipment represents a third and relatively insignificant source of GHG emissions.

Figure 4-2 illustrates the commercial emissions profile by municipality for the 1990 through 2020 period. Table 4-1 outlines the sources of emissions and percentage of emissions by municipality. Figure 4-3 displays 2011 emissions by source, and Figure 4-4 shows emissions by municipality for 2011.

**Figure 4-2: Commercial Emissions Profile by Municipality, 1990-2020**

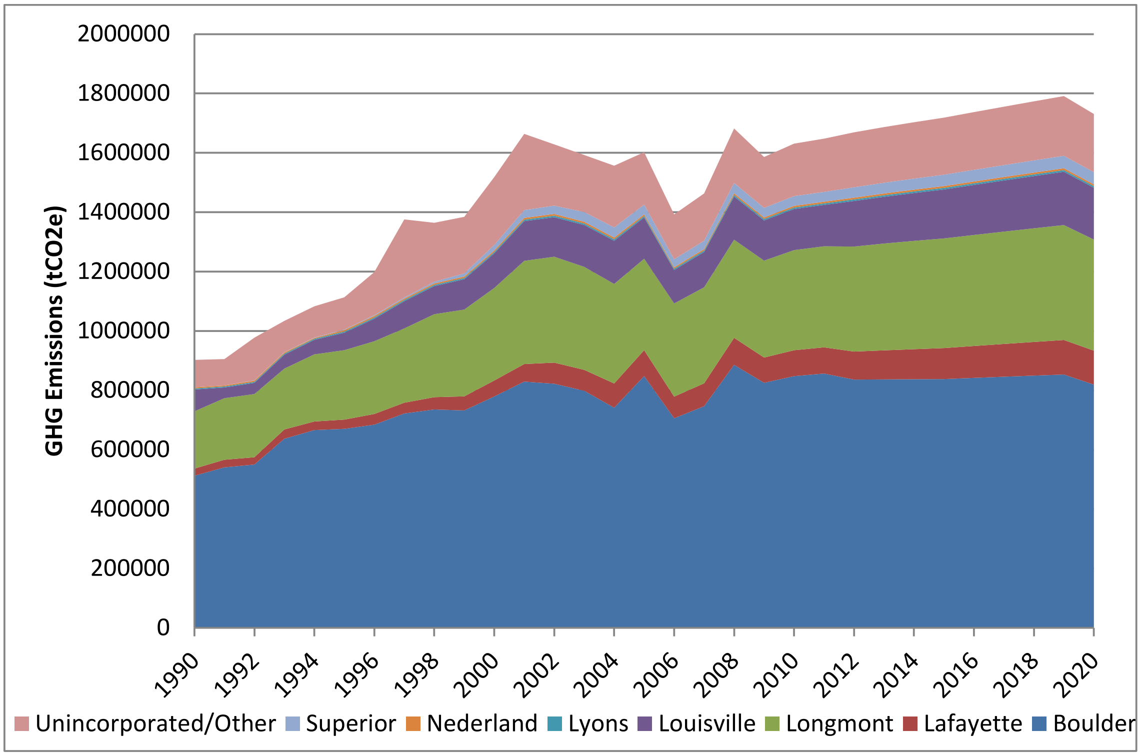



**Table 4-1: 2011 Commercial GHG Emissions by Municipality ($tCO_2e$)**

| Municipality | Electricity | Natural Gas | Refrigerants | Commercial Total |
|---|---|---|---|---|
| Boulder | 676,108 | 178,355 | 2,116 | 856,579 |
| Lafayette | 68,314 | 19,677 | 295 | 88,286 |
| Longmont | 286,378 | 52,718 | 1,195 | 340,292 |
| Louisville | 124,066 | 14,936 | 446 | 139,448 |
| Lyons | 3,966 | 1,098 | 13 | 5,077 |
| Nederland | 4,106 | 1,423 | 13 | 5,543 |
| Superior | 29,736 | 3,287 | 73 | 33,096 |
| Unincorporated/Other | 119,487 | 59,867 | 48 | 179,402 |
| County | 1,312,161 | 331,361 | 4,200 | 1,647,722 |
| Percentage by Column | | | | |
| Boulder | 52% | 54% | 50% | 52% |
| Lafayette | 5% | 6% | 7% | 5% |
| Longmont | 22% | 16% | 28% | 21% |
| Louisville | 9% | 5% | 11% | 8% |
| Lyons | 0% | 0% | 0% | 0% |
| Nederland | 0% | 0% | 0% | 0% |
| Superior | 2% | 1% | 2% | 2% |
| Unincorporated/Other | 9% | 18% | 1% | 11% |

**Figure 4-3: 2011 Commercial GHG Emissions by Source**

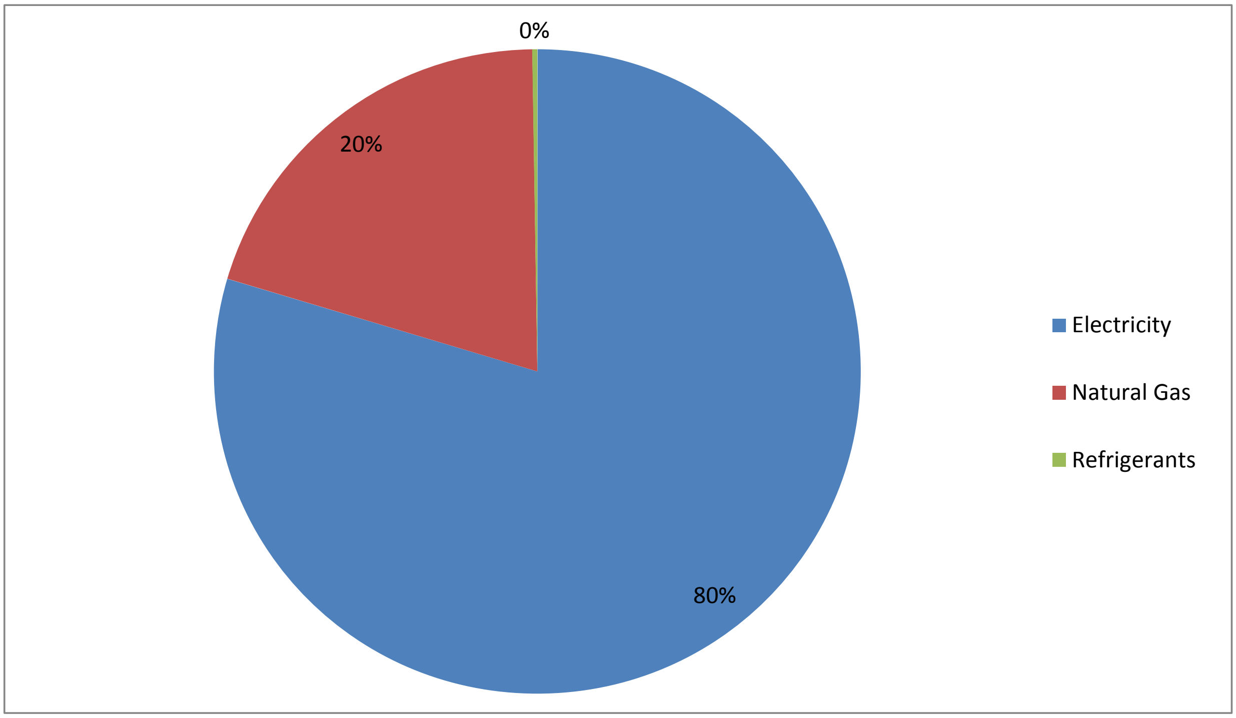
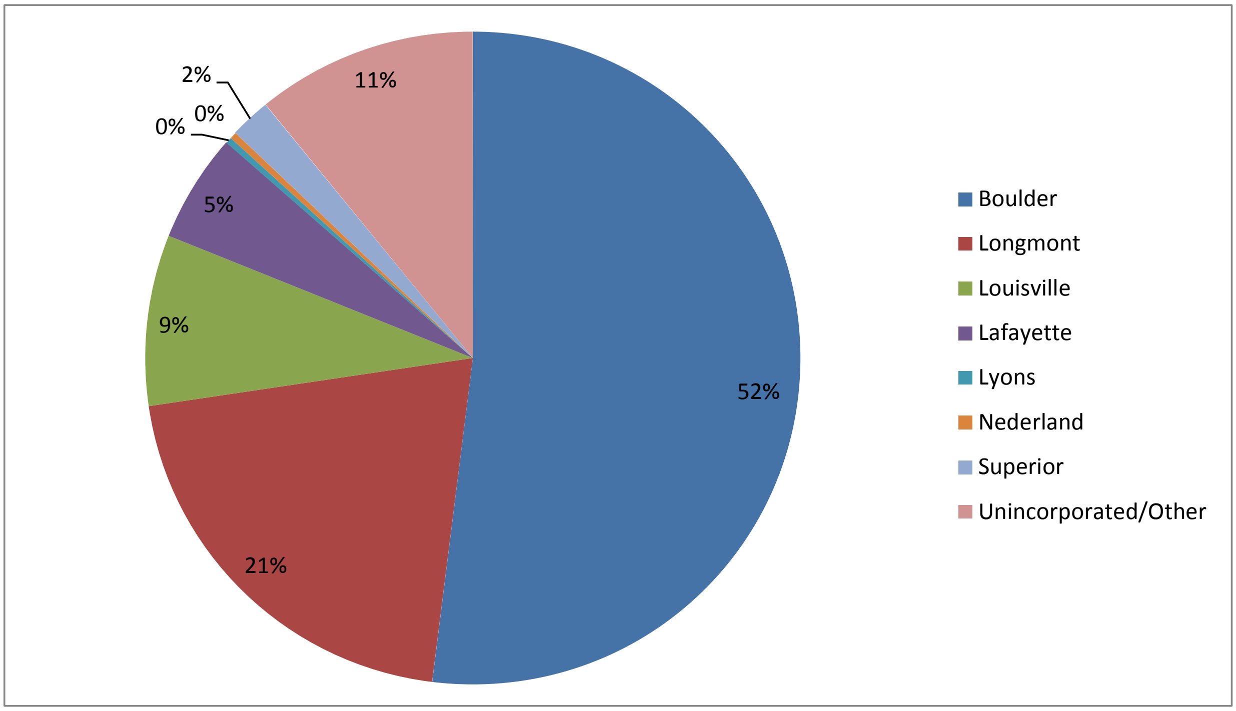



**Figure 4-4: 2011 Commercial GHG Emissions by Municipality**



## 4.3 EXISTING COMMERCIAL BUILDINGS

The first-cut nominal GHG goal is for each sector to obtain its share of the GHG reductions needed to achieve the County's objective of total 2020 GHG emissions that are 40% below 2005 levels. For the existing commercial sector, this means a total reduction of about 865,328 tCO2e relative to the projected 2020 BAU GHG emissions. The following analysis explores demand-side strategies aimed at achieving this goal.

A detailed analysis was performed on existing commercial buildings, which created the basis for estimating potential GHG reduction opportunities. The methodology used to quantify these reductions was to first estimate the electricity and natural gas consumption and the associated utility costs in existing commercial buildings. Commercial buildings were divided between two vintages: pre- and post-1980. Second, three energy efficiency scenarios were constructed and the energy savings and cost savings potential of each was established. This analysis followed a "bottom up" approach, wherein energy efficiency opportunities were considered for several building types and extrapolated to determine the GHG reduction potential in the sector.

Due to wide-ranging variations in energy use patterns within commercial building types, the sector was also divided into three sub-classifications: office, retail, and restaurant. These sub-classifications were chosen to strike a balance between maintaining a manageable analysis work scope and producing meaningful results. In reality, the commercial building sector includes many other sub-classifications such as hospitals, hotels, and schools, each with wide-ranging energy use intensities. It is estimated that these other sub-classifications do not represent a dominant portion of the commercial buildings stock. Moreover, the analysis recognizes that many of the savings opportunities demonstrated in the three analyzed sub-classifications can also be achieved in these other building types.

Building energy simulation software (eQuest) was used to construct prototypical energy usage models for each of the three building types treated by this analysis. Specifically, the simulation software was used to establish base case electricity and natural gas usage intensities and also to quantify the energy savings resulting from installation of energy efficiency measures (EEMs). Three bundles of EEMs were defined for each building type and vintage. The potential energy savings and cost savings were established for each bundle by modifying the base case energy models to reflect the implementation of each energy efficiency bundle. Market penetration rates were estimated for each bundle and applied to estimate the energy savings that can be expected for the existing building stock. The expected energy savings were next converted into reductions in GHG emissions. Costs to implement each bundle were estimated and the resulting economic performance of each bundle was calculated.

### 4.3.1. Prototypes of Existing Buildings

Commercial building prototypes were developed using eQuest building energy simulation software. The prototype building parameters were based on data from previous studies by the Southwest Energy Efficiency Project and WSP. Table 4-2 and Table 4-3 provide a summary of the parameters used to construct each prototype.

## Table 4-2: Pre-1980 Building Prototype Details

| MODEL INPUT | OFFICE | RETAIL | RESTAURANT |
|---|---|---|---|
| Weather | Boulder, CO | Boulder, CO | Boulder, CO |
| Commercial Utility rates | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel |
| Number of floors above grade | 2 | 1 | 1 |
| Gross square feet of conditioned space | 18,000 $ft^2$ | 25,000 $ft^2$ | 5,000 $ft^2$ |
| Exterior wall insulation | R-4 | R-4 | R-4 |
| Roof insulation | R-10 | R-10 | R-10 |
| Floor to floor height | 13 ft | 15 ft | 15 ft |
| Floor to ceiling height | 10 ft | 15 ft | 15 ft |
| Windows | Metal frame; double pane;<br>U-value – 0.70 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 | Metal frame; double pane;<br>U-value – 0.70 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 | Metal frame; double pane;<br>U-value – 0.70 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 |
| Window to wall ratio | 30% | 19% | 39% |
| Peak occupancy | 195 $ft^2$/person | 177 $ft^2$/person | 42 $ft^2$/person dining; 125 $ft^2$/person kitchen |
| Peak lighting power intensity | 1.80 W/$ft^2$ | 2.5 W/$ft^2$ | 2.5 W/$ft^2$ |
| Peak equipment power intensity | 1.0 W/$ft^2$ | 0.25 W/$ft^2$ | Kitchen – 3.2 W/$ft^2$ & 200 (kBtu/hr)/$ft^2$<br>Dining – 0.20 W/$ft^2$ |
| Daylighting control | No | No | No |
| Night cycle fans | Yes | Yes | Yes |
| Temperature setpoints | Occupied: cool – 76°; heat-70°<br>Unoccupied: cool – 81°; heat-65° | Occupied: cool – 74°; heat-71°<br>Unoccupied: cool – 79°; heat-66° | Occupied: cool – 76°; heat-70°<br>Unoccupied: cool – 81°; heat-65° |
| HVAC system | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace |
| Supply temperature | Cool – 55°<br>Heat – 95° | Cool – 55°<br>Heat – 95° | Cool – 55°<br>Heat – 95° |
| Zones | Perimeter and core for each floor | 2 zones | 2 zones: dining & kitchen |
| Return air path | Plenum | Direct | Direct |
| Supply fan | Standard efficiency | Standard efficiency | Standard efficiency |
| Fan schedules | Start two hours before open; Stop one hour after close | Start two hour before open; Stop one hour after close | Start three hours before open; Stop one hour after close |
| Minimum outdoor air ventilation | 20 cfm/person (ASHRAE std) | 20 cfm/person (ASHRAE std) | 17.5 cfm/person dining (ASHRAE std); 100% kitchen |
| Space cooling | EER – 8.0 | EER – 8.0 | EER – 8.0 |
| Heat rejection | Air-cooled | Air-cooled | Air-cooled |
| Economizer | Dry-bulb<br>High limit – 60° | Dry-bulb<br>High limit – 60° | Dry-bulb<br>High limit – 60° |
| Space heating | Efficiency - 70% | Efficiency – 70% | Efficiency – 70% |
| Exhaust heat recovery | No | No | No |
| Occupancy; lighting; equipment schedules | ASHRAE standards | ASHRAE standards | ASHRAE standards |
| Operating schedule | Weekday: 8 am – 5 pm<br>Weekend: closed<br>Standard US holidays: closed | Weekday: 9 am – 8 pm<br>Saturday: 9 am – 8 pm<br>Sunday: 10 am – 6 pm<br>Standard US holidays: closed | Weekday: 5 am – 10 pm<br>Saturday: 6 am – 11 pm<br>Weekend: 7 am – 10 pm<br>Standard US holidays: closed |

## Table 4-3: Post-1980 Building Prototype Details

| MODEL INPUT | OFFICE | RETAIL | RESTAURANT |
|---|---|---|---|
| Weather | Boulder, CO | Boulder, CO | Boulder, CO |
| Utility rates | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel | Electricity<br>(1) Xcel; (2) Longmont Power & Communications<br>Natural Gas - Xcel |
| Number of floors above grade | 2 | 1 | 1 |
| Gross square feet of conditioned space | 18,000 $ft^2$ | 25,000 $ft^2$ | 5,000 $ft^2$ |
| Exterior wall insulation | R-10 | R-7 | R-7 |
| Roof insulation | R-15 | R-15 | R-15 |
| Floor to floor height | 13 ft | 15 ft | 15 ft |
| Floor to ceiling height | 10 ft | 15 ft | 15 ft |
| Windows | Metal frame; double pane;<br>U-value – 0.49 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 | Metal frame; double pane;<br>U-value – 0.49 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 | Metal frame; double pane;<br>U-value – 0.49 Btu/hr-$ft^2$-F<br>SHGC – 0.76; VT – 0.81 |
| Window to wall ratio | 30% | 19% | 39% |
| Peak occupancy | 195 $ft^2$/person | 177 $ft^2$/person | 42 $ft^2$/person dining; 125 $ft^2$/person kitchen |
| Peak lighting power intensity | 1.60 W/$ft^2$ | 2.1 W/$ft^2$ | 2.1 W/$ft^2$ |
| Peak equipment power intensity | 1.0 W/$ft^2$ | 0.25 W/$ft^2$ | Kitchen – 3.2 W/$ft^2$ & 200 (kBtu/hr)/$ft^2$<br>Dining – 0.20 W/$ft^2$ |
| Daylighting control | No | No | No |
| Night cycle fans | Yes | Yes | Yes |
| Temperature setpoints | Occupied: cool – 76°; heat-70°<br>Unoccupied: cool – 81°; heat-65° | Occupied: cool – 74°; heat-71°<br>Unoccupied: cool – 79°; heat-66° | Occupied: cool – 76°; heat-70°<br>Unoccupied: cool – 81°; heat-65° |
| HVAC system | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace | Packaged single zone systems – DX coils with gas furnace |
| Supply temperature | Cool – 55°<br>Heat – 95° | Cool – 55°<br>Heat – 95° | Cool – 55°<br>Heat – 95° |
| Zones | Perimeter and core for each floor | 2 zones | 2 zones: dining & kitchen |
| Return air path | Plenum | Direct | Direct |
| Supply fan | Standard efficiency | Standard efficiency | Standard efficiency |
| Fan schedules | Start two hours before open;<br>Stop one hour after close | Start two hour before open;<br>Stop one hour after close | Start three hours before open;<br>Stop one hour after close |
| Minimum outdoor air ventilation | 20 cfm/person (ASHRAE std) | 20 cfm/person (ASHRAE std) | 17.5 cfm/person dining (ASHRAE std); 100% kitchen |
| Space cooling | EER – 9.0 | EER – 9.0 | EER – 9.0 |
| Heat rejection | Air-cooled | Air-cooled | Air-cooled |
| Economizer | Dry-bulb<br>High limit – 60° | Dry-bulb<br>High limit – 60° | Dry-bulb<br>High limit – 60° |
| Space heating | Efficiency - 80% | Efficiency – 75% | Efficiency – 75% |
| Exhaust heat recovery | No | No | No |
| Occupancy; lighting; equipment schedules | ASHRAE standards | ASHRAE standards | ASHRAE standards |
| Operating schedule | Weekday: 8 am – 5 pm<br>Weekend: closed<br>Standard US holidays: closed | Weekday: 9 am – 8 pm<br>Saturday: 9 am – 8 pm<br>Sunday: 10 am – 6 pm<br>Standard US holidays: closed | Weekday: 5 am – 10 pm<br>Saturday: 6 am – 11 pm<br>Weekend: 7 am – 10 pm<br>Standard US holidays: closed |

### 4.3.2. Energy Efficiency Bundles

Table 4-4 lists the measures included in each energy efficiency bundle applied to both the pre- and post-1980 vintages. For each building sub-classification, Bundle 1 only included a lighting upgrade. The approach was chosen for Bundle 1 due to its quick payback and high potential for market penetration. Bundle 2 is a collection of aggressive yet technically mature energy efficiency upgrades. This bundle aims for aggressive energy savings while maintaining an attractive market penetration level. Bundle 3 builds off of Bundles 1 and 2 but aims for very aggressive energy savings. Most notably, Bundle 3 achieves significantly greater energy savings, compared to Bundle 2, through the use of evaporative cooling technologies.

**Table 4-4: Description of Energy Savings Bundles**

| | OFFICE | RETAIL | RESTAURANT |
|---|---|---|---|
| Bundle 1 | • Lighting efficiency upgrades | • Lighting efficiency upgrades | • Lighting efficiency upgrades |
| Bundle 2 | • Lighting efficiency upgrades<br>• DX cooling EER – 11.5<br>• Furnace η – 85%<br>• Occupancy sensors<br>• Programmable T-stats<br>• Increase use of OA economizer<br>• Demand control ventilation | • Lighting efficiency upgrades<br>• DX cooling EER – 11.5<br>• Furnace η – 85%<br>• Occupancy sensors<br>• Programmable T-stats<br>• Increase use of OA economizer | • Lighting efficiency upgrades<br>• DX cooling EER – 11.5<br>• Furnace η – 85%<br>• Programmable T-stats<br>• Increase use of OA economizer<br>• Replace electric booster heater on warewasher with gas-fired booster<br>• Refrigeration condenser heat recovery<br>• Demand control Ventilation |
| Bundle 3 | • Lighting efficiency upgrades<br>• Indirect-direct evaporative cooling<br>• Condensing Furnace η – 93%<br>• Low-E Film and tint on windows<br>• Efficient office equipment<br>• Office equipment controls<br>• Occupancy sensors<br>• Programmable T-stats<br>• Increase use of OA economizer<br>• Demand control ventilation | • Lighting efficiency upgrades<br>• Indirect-direct evaporative cooling<br>• Condensing Furnace η – 93%<br>• Low-E Film and tint on windows<br>• Efficient office equipment<br>• Occupancy sensors<br>• Programmable T-stats<br>• Increase use of OA economizer | • Lighting efficiency upgrades<br>• Indirect-direct evaporative cooling in dining area/ direct in kitchen<br>• Condensing Furnace η – 93%<br>• Low-E Film and tint on windows<br>• Programmable T-stats<br>• Increase use of OA economizer<br>• Demand control ventilation<br>• Replace electric booster heater on warewasher with gas-fired booster<br>• Refrigeration condenser heat recovery<br>• Refrigeration efficiency upgrades |

### 4.3.3. Energy Consumption

The six prototype base case energy models were modified to reflect the energy efficiency measures identified for each of the three energy efficiency bundles. The modeling modifications established the potential energy savings resulting from implementing the proposed bundles. The energy intensities for each bundle were used to calculate energy savings relative to the base case. The building energy usage intensities for the base case and three bundles, along with the savings impacts on both electric and gas use are shown in Table 4-5.

**Table 4-5: Energy Use Summary**

| | | | | | | |
|---|---|---|---|---|---|---|
| **BASE CASE** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Energy Usage Index (kBtu/SF yr) | 100.8 | 78.0 | 439.4 | 88.5 | 64.4 | 383.8 |
| Electric Usage Intensity (kWh/SF yr) | 15.4 | 15.3 | 34.8 | 14.4 | 14.7 | 31.5 |
| Gas Usage Intensity (therms/SF yr) | 0.5 | 0.3 | 3.2 | 0.4 | 0.1 | 2.8 |
| | | | | | | |
| **BUNDLE 1** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Energy Usage Index (kBtu/SF yr) | 96.4 | 75.4 | 434.4 | 85.2 | 61.2 | 380.2 |
| Electric Intensity (kWh/SF yr) | 13.2 | 13.6 | 27.7 | 12.9 | 13.1 | 26.7 |
| Electric Savings Over Base | 14% | 11% | 21% | 11% | 11% | 15% |
| Gas Intensity (therms/SF yr) | 0.5 | 0.3 | 3.4 | 0.4 | 0.2 | 2.9 |
| Gas Savings Over Base | -6% | -12% | -6% | -5% | -18% | -5% |
| | | | | | | |
| **BUNDLE 2** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Energy Usage Index (kBtu/SF yr) | 64.8 | 65.7 | 327.9 | 54.3 | 48.2 | 299.5 |
| Electric Intensity (kWh/SF yr) | 11.4 | 11.4 | 21.1 | 11.4 | 10.9 | 20.8 |
| Electric Savings Over Base | 26% | 25% | 39% | 21% | 26% | 34% |
| Gas Intensity (therms/SF yr) | 0.3 | 0.3 | 2.6 | 0.2 | 0.1 | 2.3 |
| Gas Savings Over Base | 46% | -4% | 20% | 60% | 22% | 17% |
| **BUNDLE 3** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Energy Usage Index (kBtu/SF yr) | 55.0 | 60.1 | 314.1 | 46.7 | 43.9 | 287.0 |
| Electric Intensity (kWh/SF yr) | 9.0 | 10.2 | 19.6 | 9.0 | 9.6 | 19.3 |
| Electric Savings Over Base | 41% | 33% | 44% | 38% | 35% | 39% |
| Gas Intensity (therms/SF yr) | 0.2 | 0.3 | 2.5 | 0.2 | 0.1 | 2.2 |
| Gas Savings Over Base | 50% | 2% | 23% | 59% | 21% | 20% |

### 4.3.4. Energy Cost

The six prototype energy models were next used to establish the cost savings resulting from implementation of the three bundles. Two[4] commercial electric rates were used (Xcel, and Longmont Power & Communications) to determine the costs and resulting cost savings for each bundle.

The following tables provide a summary of these energy costs.

4 Note that Poudre Valley Rural Electric Association only provides residential electric service.

**Table 4-6: Energy Cost Summary ($/SQFT-yr) - Xcel**

| BASE CASE | | | | | | |
|---|---|---|---|---|---|---|
| | PRE-1980 | | | POST-1980 | | |
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Electric Cost Intensity | $1.15 | $1.27 | $2.61 | $1.08 | $1.10 | $2.36 |
| Gas Cost Intensity | $0.33 | $0.15 | $2.15 | $0.26 | $0.09 | $1.85 |
| | | | | | | |
| BUNDLE 1 | | | | | | |
| | PRE-1980 | | | POST-1980 | | |
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Electric Cost Intensity | $0.99 | $1.02 | $2.07 | $0.97 | $0.98 | $2.00 |
| Electric Cost Savings | $0.17 | $0.25 | $0.54 | $0.12 | $0.13 | $0.36 |
| Gas Cost Intensity | $0.35 | $0.19 | $2.28 | $0.28 | $0.11 | $1.94 |
| Gas Cost Savings | -$0.02 | -$0.04 | -$0.13 | -$0.01 | -$0.02 | -$0.09 |
| | | | | | | |
| BUNDLE 2 | | | | | | |
| | PRE-1980 | | | POST-1980 | | |
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Electric Cost Intensity | $0.85 | $0.85 | $1.58 | $0.85 | $0.82 | $1.56 |
| Electric Cost Savings | $0.30 | $0.42 | $1.03 | $0.23 | $0.29 | $0.80 |
| Gas Cost Intensity | $0.18 | $0.18 | $1.71 | $0.96 | $0.07 | $1.53 |
| Gas Cost Savings | $0.15 | -$0.03 | $0.43 | $0.16 | $0.02 | $0.32 |
| | | | | | | |
| BUNDLE 3 | | | | | | |
| | PRE-1980 | | | POST-1980 | | |
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Electric Cost Intensity | $0.68 | $0.76 | $1.47 | $0.68 | $0.72 | $1.45 |
| Electric Cost Savings | $0.48 | $0.51 | $1.14 | $0.41 | $0.39 | $0.91 |
| Gas Cost Intensity | $0.16 | $0.17 | $1.66 | $0.11 | $0.07 | $1.48 |
| Gas Cost Savings | $0.16 | -$0.02 | $0.49 | $0.16 | $0.02 | $0.37 |

**Table 4-7: Energy Cost Summary ($/SQFT-yr) - Longmont Power & Communications**

| | | | | | | |
|---|---|---|---|---|---|---|
| **BASE CASE** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Electric Cost Intensity | $0.86 | $0.95 | $1.95 | $0.81 | $0.82 | $1.76 |
| Gas Cost Intensity | $0.33 | $0.15 | $2.15 | $0.26 | $0.09 | $1.85 |
| | | | | | | |
| **BUNDLE 1** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Electric Cost Intensity | $0.74 | $0.76 | $1.55 | $0.72 | $0.73 | $1.49 |
| Electric Cost Savings | $0.12 | $0.19 | $0.40 | $0.09 | $0.09 | $0.27 |
| Gas Cost Intensity | $0.35 | $0.19 | $2.28 | $0.28 | $0.11 | $1.94 |
| Gas Cost Savings | -$0.02 | -$0.04 | -$0.13 | -$0.01 | -$0.02 | -$0.09 |
| | | | | | | |
| **BUNDLE 2** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Electric Cost Intensity | $0.64 | $0.64 | $1.18 | $0.64 | $0.61 | $1.16 |
| Electric Cost Savings | $0.22 | $0.31 | $0.77 | $0.17 | $0.22 | $0.60 |
| Gas Cost Intensity | $0.18 | $0.18 | $1.71 | $0.10 | $0.07 | $1.53 |
| Gas Cost Savings | $0.15 | -$0.03 | $0.43 | $0.16 | $0.02 | $0.32 |
| | | | | | | |
| **BUNDLE 3** | | | | | | |
| | **PRE-1980** | | | **POST-1980** | | |
| | **OFFICE** | **RETAIL** | **RESTAURANT** | **OFFICE** | **RETAIL** | **RESTAURANT** |
| Electric Cost Intensity | $0.50 | $0.57 | $1.10 | $0.50 | $0.54 | $1.08 |
| Electric Cost Savings | $0.36 | $0.38 | $0.85 | $0.30 | $0.29 | $0.68 |
| Gas Cost Intensity | $0.16 | $0.17 | $1.66 | $0.11 | $0.07 | $1.48 |
| Gas Cost Savings | $0.16 | -$0.02 | $0.49 | $0.16 | $0.02 | $0.37 |

### 4.3.5. Implementation Costs

The costs associated with implementing each bundle were estimated on a dollar-per-square foot-of-floor-area basis for each bundle and building type. These costs are listed in Table 4-8. The individual measure cost estimates were based on data from previous studies by the Southwest Energy Efficiency Project, local vendor quotations, and WSP's energy project experience. *It is important to note that the costs presented here are based on assumption that 100% of the stock of a given piece of equipment is replaced over the nominal 20-year lifetime of that type of equipment. Thus, over the 2013 – 2020 period, 8/20 or 40% of the equipment stock would be replaced in the absence of the County's GHG programs. Therefore, this analysis assumes that, in aggregate, the implementation costs for the EEM bundles, involving replacement of existing equipment, comprise an incremental equipment replacement cost for 40% of replacements and the full replacement cost for 60% of replacements. Incremental cost is the difference between standard-efficiency and high-efficiency equipment.*

**Table 4-8: Implementation Cost ($/ft$^2$)**

| | PRE-1980 | | | POST-1980 | | |
|---|---|---|---|---|---|---|
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Bundle 1 | $ 0.45 | $ 0.48 | $ 0.52 | $ 0.41 | $ 0.45 | $ 0.48 |
| Bundle 2 | $ 2.75 | $ 1.66 | $ 4.62 | $ 2.50 | $ 1.52 | $ 4.20 |
| Bundle 3 | $ 8.21 | $ 5.24 | $ 12.26 | $ 7.40 | $ 4.76 | $ 11.19 |

### 4.3.6. Economic Performance

The energy cost savings and implementation costs shown in the previous two sections were used to establish the simple paybacks listed in Table 4-9 and Table 4-10.

**Table 4-9: Simple Payback - Xcel**

| | PRE-1980 | | | POST-1980 | | |
|---|---|---|---|---|---|---|
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Bundle 1 | 2.1 | 1.6 | 0.8 | 2.8 | 2.8 | 1.1 |
| Bundle 2 | 5.2 | 3.0 | 2.6 | 5.7 | 3.7 | 3.1 |
| Bundle 3 | 10.5 | 7.7 | 6.3 | 10.9 | 8.8 | 7.3 |

**Table 4-10: Simple Payback - Longmont Power & Communications**

| | PRE-1980 | | | POST-1980 | | |
|---|---|---|---|---|---|---|
| | OFFICE | RETAIL | RESTAURANT | OFFICE | RETAIL | RESTAURANT |
| Bundle 1 | 2.1 | 1.8 | 0.8 | 2.8 | 2.8 | 1.1 |
| Bundle 2 | 5.2 | 3.4 | 2.6 | 5.7 | 3.7 | 3.1 |
| Bundle 3 | 10.5 | 8.6 | 6.3 | 10.9 | 8.8 | 7.3 |

### 4.3.7. Market Penetration Rates

The historical experience of US electric utility demand-side management (DSM) programs has shown that it is extremely difficult to shift energy usage patterns within a stock of buildings. Table 4-11 presents a few examples of actual DSM program market penetration rates. These are used as guidance is developing the market penetration estimates listed in Table 4-12.

**Table 4-11: Historical US Electric Utility DSM Program Market Penetration Rates**

| DSM PROGRAM | UTILITY | MARKET PENETRATION |
|---|---|---|
| Small Business Services | National Grid | 33% |
| Small Business Energy | Northeast Utilities | 35% |
| Downstream Express | Pacific Gas & Electric | 5% |

**Table 4-12: Market Penetration Rate**

| | |
|---|---|
| BUNDLE 1 | 40% |
| BUNDLE 2 | 35% |
| BUNDLE 3 | 30% |

### 4.3.8. Greenhouse Gas Reductions

The estimated energy savings were used to estimate reductions in GHG emissions for each bundle of measures. The methodology for this calculation was to multiply the respective percent energy savings and market penetration rate by the total energy consumption of each building type. This was done individually for both electricity and natural gas. The total electricity and natural gas consumption for each building type were established by multiplying the total floor area of each building type by the respective base case electric and natural gas usage intensity. GHG emissions reductions for each building type and energy efficiency bundle were next established by converting the energy savings into GHG emissions reductions.

Table 4-13 provides the GHG reduction summary. It is instructive to note that the total county-wide GHG reductions associated with Bundles 1-3 are only 13%, 24%, and 26% of the commercial sector goal of 865,328 t$CO_2$e of reductions in BAU emissions in 2020.

**Table 4-13: GHG Emissions Reduction ($tCO_{2e}$)**

| | Pre-1980 | | | Post-1980 | | | Total Reduction |
|---|---|---|---|---|---|---|---|
| **Bundle 1** | Office | Retail | Restaurant | Office | Retail | Restaurant | |
| Boulder | 5,065 | 5,242 | 1,199 | 6,575 | 5,591 | 263 | 23,933 |
| Longmont | 735 | 2,842 | 560 | 2,531 | 5,308 | 390 | 12,367 |
| Louisville | 105 | 173 | 119 | 1,518 | 2,291 | 200 | 4,406 |
| Lafayette | 75 | 272 | 77 | 528 | 1,445 | 133 | 2,529 |
| Lyons | 8 | 78 | 75 | 8 | 27 | 6 | 202 |
| Nederland | 22 | 33 | 85 | 5 | 95 | 41 | 280 |
| Superior | 0 | 1 | 0 | 140 | 237 | 0 | 378 |
| Unincorporated/Other | 216 | 1,499 | 236 | 279 | 1,709 | 68 | 4,006 |
| **County** | 6,224 | 10,139 | 2,350 | 11,583 | 16,704 | 1,101 | 48,101 |
| **Bundle 2** | | | | | | | |
| | Pre-1980 | | | Post-1980 | | | Total Reduction |
| | Office | Retail | Restaurant | Office | Retail | Restaurant | |
| Boulder | 15,571 | 13,111 | 4,427 | 24,730 | 14,759 | 1,093 | 73,690 |
| Longmont | 2,260 | 7,110 | 2,069 | 9,522 | 14,012 | 1,623 | 36,594 |
| Louisville | 323 | 433 | 440 | 5,708 | 6,049 | 831 | 13,784 |
| Lafayette | 230 | 679 | 283 | 1,987 | 3,815 | 554 | 7,547 |
| Lyons | 23 | 195 | 276 | 29 | 73 | 27 | 622 |
| Nederland | 67 | 81 | 313 | 19 | 250 | 173 | 903 |
| Superior | 0 | 2 | 0 | 526 | 627 | 0 | 1,155 |
| Unincorporated/Other | 663 | 3,749 | 871 | 1,048 | 4,512 | 281 | 11,124 |
| **County** | 19,136 | 25,361 | 8,678 | 43,567 | 44,096 | 4,582 | 145,419 |
| **Bundle 3** | | | | | | | |
| | Pre-1980 | | | Post-1980 | | | Total Reduction |
| | Office | Retail | Restaurant | Office | Retail | Restaurant | |
| Boulder | 18,591 | 15,331 | 4,237 | 29,737 | 16,499 | 1,073 | 85,468 |
| Longmont | 2,698 | 8,314 | 1,980 | 11,449 | 15,664 | 1,592 | 41,697 |
| Louisville | 386 | 506 | 421 | 6,864 | 6,762 | 815 | 15,755 |
| Lafayette | 274 | 794 | 270 | 2,389 | 4,265 | 544 | 8,536 |
| Lyons | 28 | 228 | 264 | 34 | 81 | 26 | 662 |
| Nederland | 80 | 95 | 300 | 23 | 280 | 169 | 946 |
| Superior | 0 | 3 | 0 | 632 | 701 | 0 | 1,335 |
| Unincorporated/Other | 791 | 4,384 | 833 | 1,260 | 5,044 | 276 | 12,588 |
| **County** | 22,848 | 29,656 | 8,305 | 52,389 | 49,294 | 4,496 | 166,988 |

## 4.4 NEW COMMERCIAL BUILDINGS

Analysis of new commercial building construction was performed to evaluate the GHG reductions opportunities that varying building energy efficiency levels and market penetration rates will have on forecasted 2020 emissions. It is important to note that the new commercial buildings subsector is not expected to offer a substantial opportunity to achieve reductions in 2020 GHG emissions. This is based on the estimate that new commercial buildings, constructed during the 2013 through 2020 period, will only add approximately 122,000 tCO2e of GHG emissions under the BAU scenario. Programs aimed at reducing the energy consumption of new commercial buildings, such as aggressive energy codes and/or requiring green building certification, will reduce energy usage by these new additions by perhaps 50% compared to standard BAU construction. Therefore, new commercial buildings can be expected to reduce GHG emissions by only about 61,000 tCO2e in 2020. This represents only about 7% of the 865,328 tCO2e emissions reductions that the commercial buildings sector must produce if it is to achieve its nominal goal in 2020 BAU emissions reductions.

Nevertheless, it is important for Boulder County municipalities to develop and implement more aggressive energy performance building codes by which the commercial buildings market will be transformed over time. Such a code upgrade will eventually create a commercial building stock that contributes substantially less to global climate change.

**Table 4-14: Cumulative New Commercial GHG Reductions ($tCO_2e$)**

| | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 |
|---|---|---|---|---|---|---|---|---|
| Boulder | 353 | 645 | 874 | 2,884 | 4,832 | 6,717 | 8,541 | 8,541 |
| Longmont | 3,070 | 5,596 | 7,844 | 10,122 | 12,352 | 14,562 | 16,730 | 16,730 |
| Louisville | 1,913 | 3,805 | 5,673 | 7,530 | 9,365 | 11,177 | 12,968 | 12,968 |
| Lafayette | 1,681 | 3,348 | 5,002 | 6,507 | 7,998 | 9,475 | 10,938 | 10,938 |
| Lyons | 47 | 93 | 138 | 197 | 255 | 313 | 369 | 369 |
| Nederland | 24 | 47 | 70 | 99 | 128 | 156 | 184 | 184 |
| Superior | 548 | 1,092 | 1,631 | 2,098 | 2,560 | 3,018 | 3,471 | 3,471 |
| Unincorp/Other | 1,205 | 2,394 | 3,571 | 4,693 | 5,804 | 6,917 | 8,016 | 8,016 |
| County | 8,842 | 17,019 | 24,803 | 34,129 | 43,292 | 52,335 | 61,216 | 61,216 |

## 4.5 COMMERCIAL BUILDINGS SUMMARY

The commercial sector inventory shows an increase from 1990 through 2020 of over 100%. For the commercial sector to meet the emissions goal, 865,328 $tCO_2e$ of GHG reductions need to be realized in 2020. The previous sections highlight the potential of implementing aggressive GHG reductions measures throughout the county for both existing and new commercial buildings. Table 4-15 shows the impact each of the EEM bundles of measures can have in relation to the 865,328 $tCO_2e$ reduction goal.

**Table 4-15: Commercial Summary**

| | 2012 REDUCTION ($TCO_2E$) | FRACTION OF COMMERCIAL GOAL ACHIEVED (%) | SIMPLE PAYBACK (YRS) |
|---|---|---|---|
| Commercial retrofit – Bundle 1 | 48,101 | 5% | 2.7 |
| Commercial retrofit – Bundle 2 | 145,419 | 17% | 4.8 |
| Commercial retrofit – Bundle 3 | 166,988 | 19% | 10.5 |
| Commercial new construction | 56,915 | 6% | na |

Boulder County's strategy, and that of each municipality, should be to capture the maximum amount of utility DSM incentives possible, and to take advantage to the maximum extent possible of government incentives, in order to buy down the simple payback of a Bundle 2-like package of EEMs to a level that private capital will be willing to accept. Individual building owners typically will accept simple paybacks of up to 3 years. A project that can attract the involvement of an ESCO must have its simple payback bought down to about 5 or 6 years.

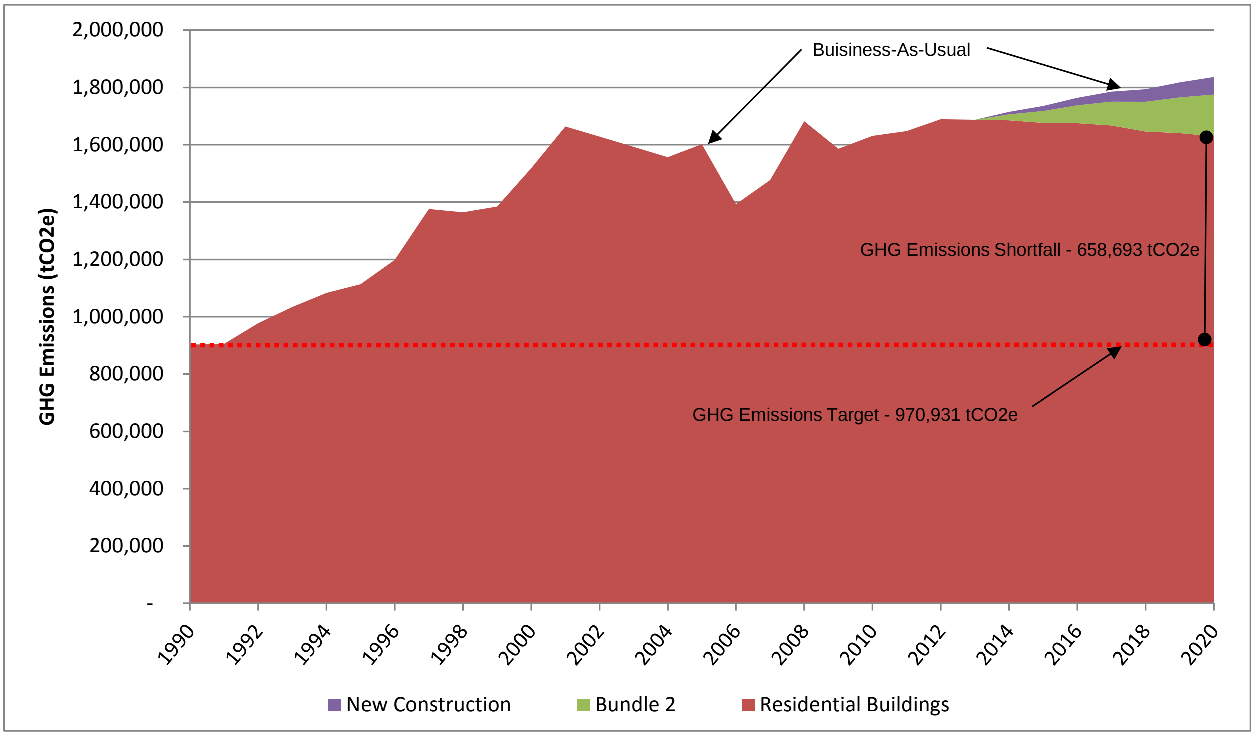
DSM incentives include electricity efficiency programs like those offered by Xcel and Longmont Power & Communications. Hopefully in the near future, utilities will also offer natural gas DSM programs.

Government incentives include business tax credits and tax deductions for commercial building energy efficiency. Tax incentives for renewable energy are accounted for in the Renewable Energy chapter.

All things considered, Bundle 2 was judged to be the most-aggressive package that offers economic performance that can realistically appeal to the market. The marginal abatement cost (MAC) for Bundle 2 is (-91)$/mtCO2. Bundle 2 results are reflected in all subsequent sections of this report. Impacts for PV are accounted for separately in the Renewable Energy chapter. Bundle 2 results are reflected in subsequent sections of this report. Figure 4-5 illustrates results.

Based on the assumed 35% market penetration rate and the estimated implementation costs for Bundle 2, it is estimated that $102 million of investment will be required to achieve the county-wide GHG impacts presented in this report for the Commercial sector. Energy cost savings delivered by these investments would amount to about $22 million/yr in 2012.

**Figure 4-5: Commercial Outlook**




## 4.5.1. Context Provided by Impact Evaluations

Useful data points providing context for discussion about energy savings rates are provided by impact evaluations of the ClimateSmart and EnergySmart programs. The Commercial EnergySmart evaluation found that from program launch in January 2011 to May 2012, 6.4% of Boulder County commercial properties implemented energy upgrades under this specific program. If this rate of service were to continue through 2020, about 36% of county-wide commercial building stock existing as of 2012 would be treated by the program. Of the 743 properties served by Commercial EnergySmart to-date, completed energy upgrades cost a total of $6.5 million; average upgrade cost was $8,748. Average energy cost savings were estimated to be $893/yr per treated commercial site, implying an average payback period of 9.8 years. GHG emissions mitigation was about 4.4% per treated site on average.

Of the 30 properties served by Commercial ClimateSmart through October 2010, 29 completed energy upgrades costing a total of $1.74 million; average upgrade cost was $59,900. Average energy savings of about 0.3% were achieved. If this rate of participation were to continue through 2020, about 2.2% of county-wide commercial building stock existing as of 2012 would be treated by the program, resulting in GHG emissions reductions of about 0.3% in 2020.

Another key observation that is apparent from these program impact evaluations is that WSP's assumed savings rates and market penetrations are quite optimistic. The assumed market penetration rate of 35% appears realistically achievable (since actual EnergySmart market penetration projected out to 2020 appears to be about 36%). However, WSP's energy savings and GHG mitigation assumptions (30% per treated site) appear to be quite aggressive, given that this program appears to have achieved a mitigation rate of only about 4%.

These levels of savings suggest that the Property Assessed Clean Energy (PACE) type of program is less effective at incentivizing commercial energy retrofits than the services-oriented type of program that BuildSmart represents. This is the diametrically opposite conclusion reached for the Residential sector and may reflect the split incentive dynamic, that is more prevalent across the commercial buildings stock, in which tenants pay the energy costs and thus would reap any benefit from energy performance upgrades the implementation cost of which would be borne by the building owner.

# 5. TRANSPORTATION SECTOR

## 5.1 OVERVIEW

This section presents the updated Transportation sector GHG inventory and a preliminary evaluation of opportunities for the County to reduce GHG emissions through mitigation strategies in this sector. These strategies boil down to reducing vehicle miles traveled, increasing vehicle fuel efficiency, increasing the use of biofuels, and adding plug-in electric vehicles to the mix.

Vehicle transportation is the third-largest sector contributing to Boulder County's GHG emissions. In 1990, the transportation sector accounted for 672,000 $tCO_2e$ or 20 percent of the County's GHG inventory. By 2005, transportation emissions had risen to 1,236,200 $tCO_2e$ and made up 25 percent of the County's GHG inventory. Historical data show that transportation emissions peaked and flattened in 2005 and 2006 and then established a decidedly downward trend through 2011, the last year of historical data analyzed. More stringent federal vehicle fuel economy standards took effect in calendar year 2010 (when 2011 model year vehicles became available), which likely contributed to the downward trajectory of the sector trend line.

If this Business-As-Usual (BAU) trend continues, 2020 forecasts show that the transportation sector emissions will decrease to 729,400 $tCO_2e$ and comprise roughly 15% of the economy-wide BAU inventory.

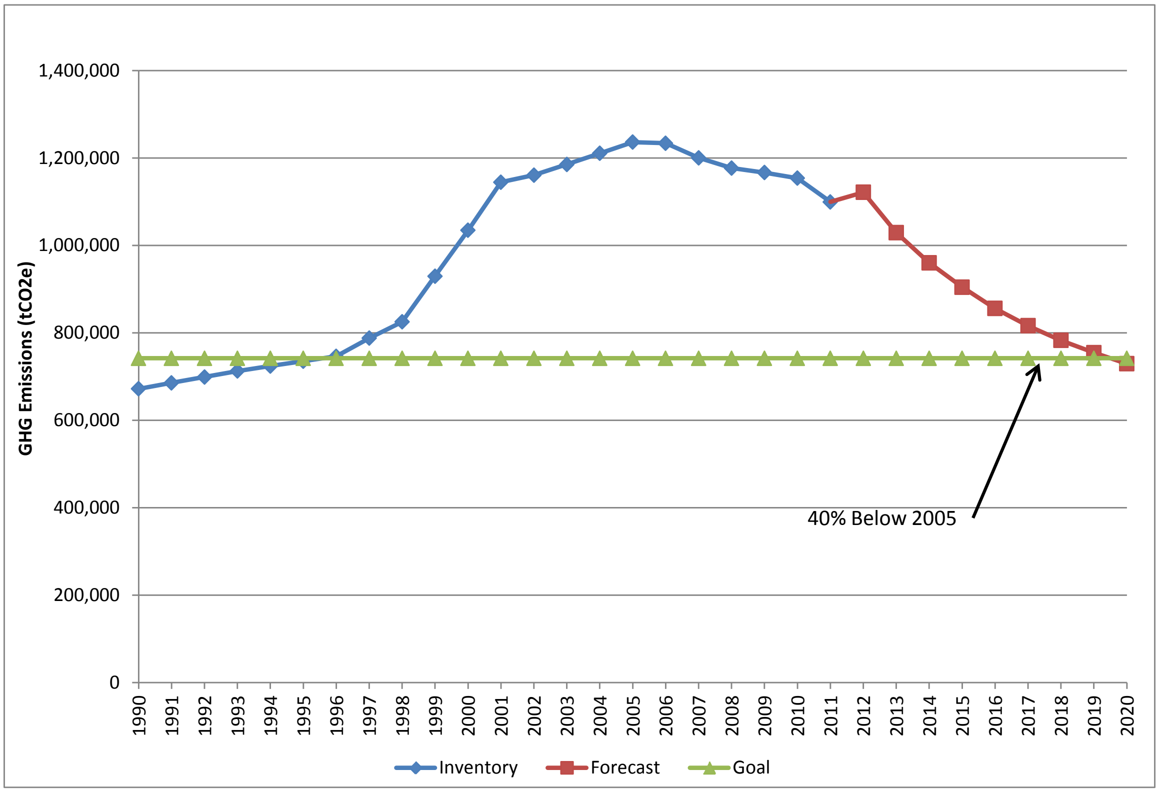
The County's goal is to be 40% below 2005 emissions, which establishes the nominal Transportation sector target at a level of 738,601 $tCO_2e$. Thus the 2020 emissions level is projected to be 9,224 $tCO_2e$ below the target.

There are significant opportunities for individual choices, private and public investments, and public policies that can reduce transportation emissions even further in the coming years.

There are three fundamental strategies for reducing vehicle GHG emissions. First, reduce VMT; second, improve fuel economy of the public and private fleets; and third, use less GHG-intensive fuels. While all three approaches offer the County several options for reducing GHG emissions, they furthermore provide several significant synergies. While reducing VMT curtails GHG emissions, it also helps alleviate other growing problems, such as traffic congestion, and offsets the need for new road infrastructure. While improving fuel economy[5] and switching to alternative fuels reduce GHG emissions, they also decrease local air and water pollution and decrease dependency on foreign oil.

5 Every gallon of gasoline and diesel fuel releases 19.6 and 21.5 pounds of carbon dioxide, respectively. These emission rates are constant, regardless of vehicle pollution control equipment, as they are a function of the carbon content in the fuel. Thus all vehicles contribute the same amount of $CO_2$ per gallon of fuel, highlighting the significance of fuel economy.

**Figure 5-1: Transportation Sector Outlook**




## 5.2 INVENTORY SUMMARY

Transportation sector emissions are produced through the consumption of gasoline, diesel, excise gas, and jet fuel. Gasoline and diesel are used in vehicles while excise gas and jet fuel are used by airplanes.

Figure 5-2 illustrates the transportation emissions profile by municipality for the 1990 through 2020 period. Table 5-1 outlines the sources of emissions and percentage of emissions by municipality. Figure 5-3 and Figure 5-4 illustrate the transportation source and municipality breakdowns, respectively.

**Figure 5-2: Transportation Emissions Profile by Municipality, 1990-2020**

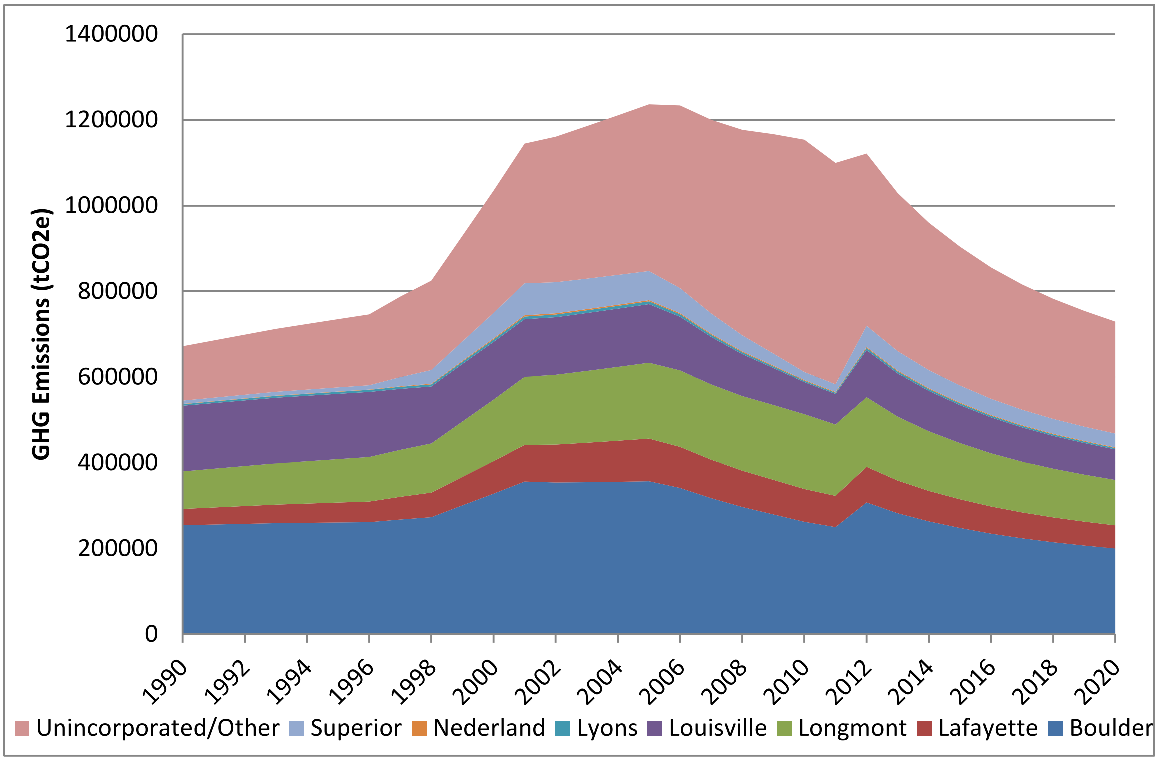



**Table 5-1: 2011 Transportation GHG Emissions by Municipality ($tCO_2e$)**

| Municipality | Gasoline | Diesel | Aviation Fuel | Transportation Total |
|---|---|---|---|---|
| Boulder | 203,478 | 45,903 | 691 | 250,072 |
| Lafayette | 59,427 | 13,406 | - | 72,833 |
| Longmont | 135,110 | 30,480 | 916 | 166,506 |
| Louisville | 58,143 | 13,117 | - | 71,260 |
| Lyons | 2,358 | 532 | - | 2,890 |
| Nederland | 1,388 | 313 | - | 1,701 |
| Superior | 14,620 | 3,298 | - | 17,918 |
| Unincorporated/Other | 421,321 | 95,047 | - | 516,368 |
| County | 895,845 | 202,095 | 1,608 | 1,099,548 |
| **Percentage by Column** | | | | |
| Boulder | 23% | 23% | 43% | 23% |
| Lafayette | 7% | 7% | 0% | 7% |
| Longmont | 15% | 15% | 57% | 15% |
| Louisville | 6% | 6% | 0% | 6% |
| Lyons | 0% | 0% | 0% | 0% |
| Nederland | 0% | 0% | 0% | 0% |
| Superior | 2% | 2% | 0% | 2% |
| Unincorporated/Other | 47% | 47% | 0% | 47% |

**Figure 5-3: 2011 Transportation GHG Emissions by Source**

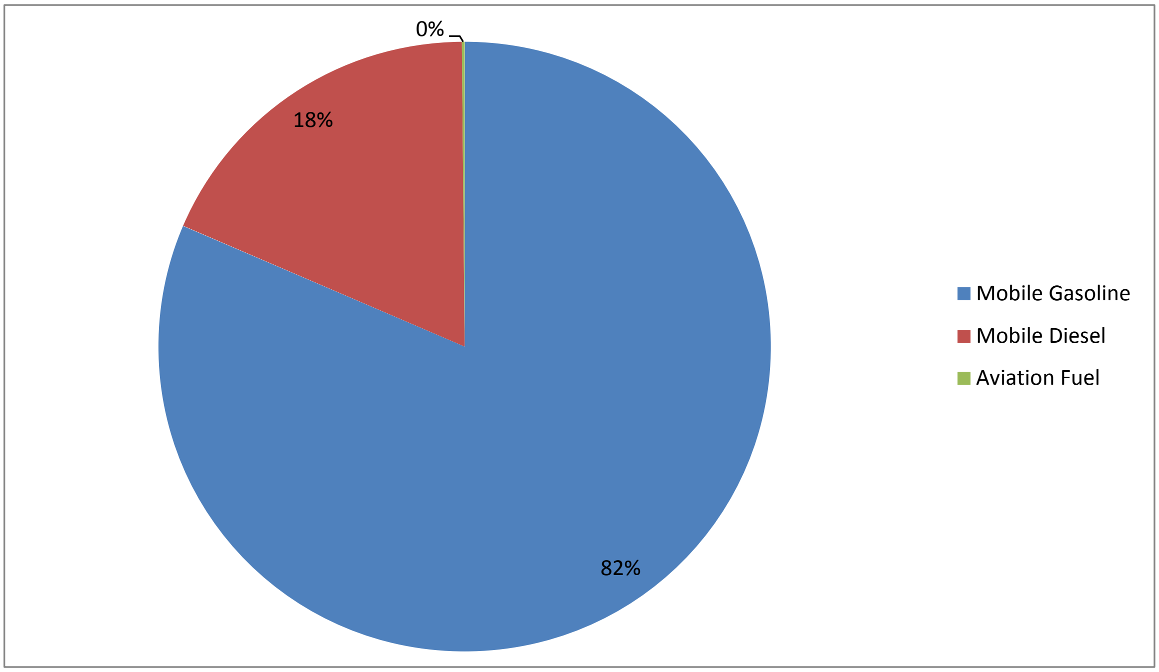
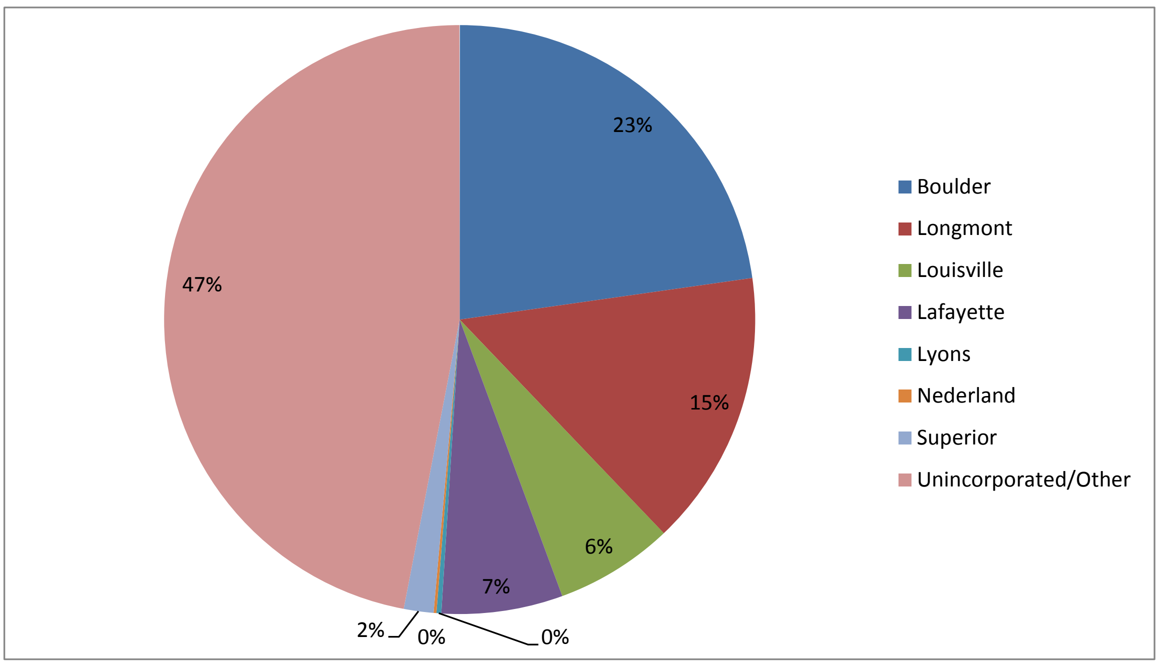



**Figure 5-4: 2011 Transportation GHG Emissions by Municipality**

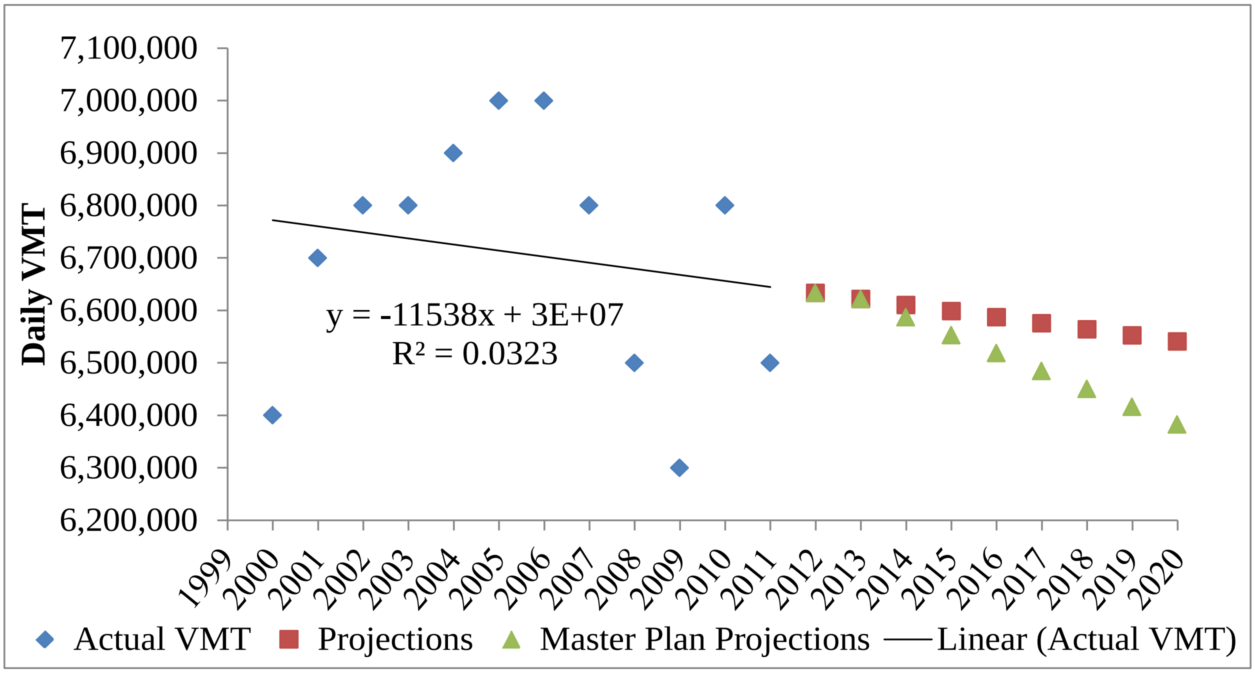



## 5.3 VEHICLE MILES TRAVELED

Based on information provided by the Boulder County Transportation Department, WSP estimates that full implementation of the TMP could reduce county-wide VMT by about 0.5%

per year, versus 0.2% per year without the TMP (see Figure 5-5). This 0.03% per year VMT difference translates into an additional 2.7% reduction in 2020 which, in turn, represents a GHG emissions reduction of about 19,000 mtCO2e in 2020 compared to BAU.

**Figure 5-5: Projected Impact of TMP on VMT**

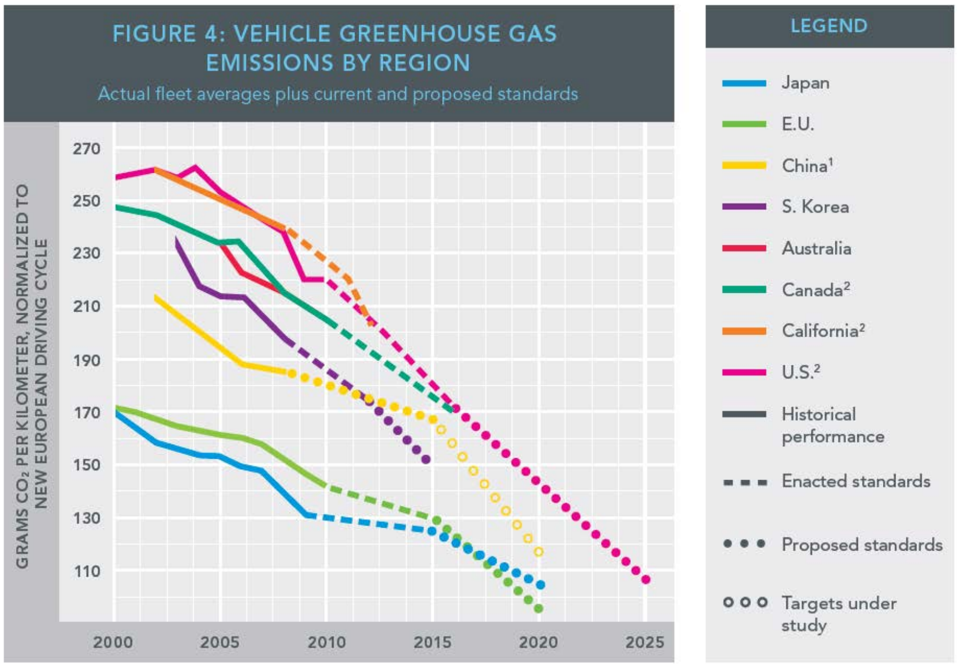



## 5.4 VEHICLE FUEL ECONOMY

Historical national trends toward declining vehicle average fuel economy have been arrested and reversed with new federal Corporate Average Fuel Economy (CAFÉ) standards. Improving the average vehicle fuel economy (VFE) in the county has already proven to be very effective in reducing GHG emissions.

Transportation sector emissions have been updated in the IMS, based on new assumptions for the rate of improvement in vehicle fleet average fuel economy. These assumptions reflect the anticipated effect of the new CAFE standards that have recently been implemented by the federal government. The graph below, provided by Climate Works Foundation, shows the recent historical and future projection of vehicle fleet average fuel efficiency for several countries, including USA. WSP's updated assumptions for average fuel economy are quite similar to the US curve shown in Figure 5-6.

**Figure 5-6: Projected Vehicle Fleet Average Fuel Efficiency**




*Passenger vehicle fuel economy standards have substantially reduced $CO_2$ emissions.*

[1] China's target reflects a gasoline fleet scenario. If other fuel types are included, the target will be lower.

[2] U.S. and Canadian light-duty vehicles include light commercial vehicles.

Source: Climate Works Foundation, 2012

## 5.5 ALTERNATIVE FUELS

Increasing the use of alternative fuels could play a substantial role in reducing the county's GHG emissions. Specifically, replacing petrodiesel consumption with biodiesel use and replacing gasoline with ethanol can be potent GHG management tools. Hybrid-electric vehicles, plug-in hybrid-electric vehicles, and compressed natural gas vehicles also hold significant potential for cost-effectively reducing GHG emissions from the Transportation sector.

### 5.5.1. Ethanol

Ethanol is an alternative fuel with the potential to be a form of renewable energy that is 100% renewable. Essentially all ethanol that is currently available in the US market is made from a renewable feedstock, usually corn. However, the process of converting the feedstock into fuel-grade ethanol requires energy that is typically provided by fossil fuels. Emerging technologies promise to produce fuel-grade ethanol at lower cost than traditional production methods, while deriving required process energy totally from renewable energy sources. Thus, ethanol is on the verge of becoming a fuel that is 100% renewable energy.

Even in the absence of 100% renewable ethanol, conventional ethanol represents a powerful GHG emissions mitigation tool. Since no ethanol is currently being produced inside Boulder

County, all GHG emissions associated with the ethanol production cycle emanate from outside the Boulder County inventory boundary. Thus, from a GHG inventory perspective, ethanol emissions within the county are strictly tailpipe emissions. For tailpipe emissions, it is assumed that the combustion of ethanol fuel is carbon-neutral since the carbon that is released was recently taken from the atmosphere to grow the crops used to make the ethanol. Therefore, from the Boulder County inventory perspective, ethanol is considered to have zero GHG emissions, and the GHG impact of displacing a gallon of gasoline with pure ethanol can be assumed to be an emissions reduction of about 19.6 pounds of CO2. This is the basis upon which the preliminary analysis results presented herein were developed.

In the 1990s, the US auto manufacturing industry started producing a certain number of "flexible fuel" vehicles (FFVs). FFVs roll off the assembly line with the capability of burning a gasoline/ethanol mixture containing up to 85% ethanol (E85 fuel). It is estimated that approximately 13,000 FFVs currently are registered to owners residing in Boulder County. However, it is likely that many of these motorists don't know they have an FFV. That, combined with limited E85 retail availability within Boulder County as of this writing, means that very little E85 is currently being used by these FFVs. Raising public awareness of availability of E85-capable vehicles, coupled with encouraging local fuel stations to offer E85, are strategies that are evaluated in this preliminary analysis as GHG management tools for the Transportation sector. Based on recent historical gasoline and E85 retail prices, the analysis assumes that gasoline costs $3.70/gallon (average of all three grades) and E85 costs $2.75/gallon.

*Source low-carbon ethanol for the county retail market*

While it is true that traditional corn starch ethanol is not a sustainable motor fuel, it is also true that corn ethanol is a necessary bridge to the future in which truly sustainable ethanol will be produced via next-generation technologies using non-food biomass feedstocks. Furthermore, it is also true that not all of today's corn ethanol is created equal. Using existing technology, it is possible today to manufacture ethanol from corn that achieves parity with the sustainability of Brazilian sugarcane ethanol, which is widely viewed as currently the planet's most sustainable biofuel. Taking a product supply-chain perspective of ethanol, and all other prospective transportation sector solutions, will be the appropriate perspective once truly sustainable ethanol is being produced by next-generation technologies. In the interim, the County should consider embracing the greenest corn ethanol available and use it aggressively toward the GHG goal. Despite resistance to ethanol by some citizens, due to concerns about the life-cycle emissions of the ethanol product supply chain, WSP recommends that ethanol fuel strategies remain a tool in the County's emissions mitigation toolbox until such time as is achieved sufficient scientific understanding of the very complicated indirect land-use change element of the ethanol life cycle and, if that scientific understanding advises against conventional biofuels, even as a temporary bridge to truly sustainable biofuels, then the County can take another approach.

WSP has shown in work for other clients that conventional corn-based ethanol can closely approach sugarcane ethanol's GHG performance if is made in certain specific ways. For example, on-site CHP, fueled by biogas produced from the plant's wastewater, can generate the electricity required by plant operations thereby displacing more carbon-intensive grid-supplied electricity. Furthermore, the thermal energy produced by a CHP plant can be used to provide some of the thermal energy required by ethanol production. Application of currently proven

CHP and biogas technology can thus enable ‘green ethanol’, a conventional corn ethanol manufactured in ways that enable it to closely approach the carbon efficiency of sugarcane ethanol.

WSP has performed work in support of refinements of the federal Renewable Fuels Standard that would create a sliding-scale incentive structure that rewards ethanol producers that implement aggressive actions to increase the “greenness” of their ethanol product. The greener the ethanol, the greater the subsidy. Under this scheme, much of the corn ethanol produced today would earn zero subsidy. This incentivizes ethanol producers to move rapidly away from traditional corn ethanol – first to greener corn ethanol and, as next-generation technology becomes available, to extreme-green ethanol. Boulder County could create a partnership with a local ethanol plant to source low-carbon corn ethanol for the county’s retail fuel markets. Such a partnership might be very attractive to a local ethanol producer since excess production capacity currently characterizes the US ethanol industry and a ‘new’ local market for ethanol (E15, see next bullet) might be viewed very favorably.

*Promote E15 fuel*

Since early 2012, USEPA has allowed the retail sale of E15 fuel (15% ethanol, 85% gasoline blend) for all gasoline automobiles and trucks of 2001 model year or newer, not just vehicles manufactured to burn E85 fuel. Nationally, these vintages of vehicles represent about 67% of the total vehicle fleet. Several independent studies have shown that gasoline vehicles newer than 1985 can actually burn up to E30 without any negative effects.

If Boulder County were to promote the retail availability of ‘green’ corn ethanol (see item above), and combine that initiative with one that promotes the retail sale of E15, conventional green ethanol has the potential to be a potent mid-term tool in the GHG mitigation toolbox for the Transportation sector, delivering significant GHG mitigation while also providing a critical bridge to the future when truly sustainable ‘deep-green’ ulta-low-carbon ethanol becomes commercially available via next-generation production technologies and non-food feedstocks. If in 2020 30% of county-wide VMT were driven by vehicles running on E15, GHG mitigation of about 20,000 mtCO2e/yr could be realized.

**Table 5-2: Strategies to Increase Use of Ethanol**

| **Private Strategies** |
|---|
| • Educate the public about the benefits of E85 and E15 and how an individual motorists can themselves blend E15 at an E85 retail outlet |
| • Develop incentive program such as free parking or discounts for alternative fuel vehicles |
| • Address potential barriers such as inconvenient fueling, lack of infrastructure, and lack of available information. |
| • Promote the use of ethanol in the county-based vehicles fleets of Qwest, Comcast, Xcel, UPS, Federal Express, etc. |
| • Promote the construction of a next-generation ethanol plant in the county |
| **Public Strategies** |
| • Expand purchase of alternative fuel vehicles. The County has already begun using ethanol in county-owned vehicles. |

### 5.5.2. Biodiesel

Since no commercial biodiesel is currently being produced inside Boulder County, all GHG emissions associated with the biodiesel production cycle emanate from outside the Boulder County inventory boundary. Thus, from a GHG inventory perspective, biodiesel emissions within the county are strictly tailpipe emissions. For tailpipe emissions, it is assumed that the combustion of biodiesel fuel is carbon-neutral since the carbon that is released was recently taken from the atmosphere to grow the crops used to make the biodiesel. Therefore, from the Boulder County inventory perspective, biodiesel is considered to have zero GHG emissions, and the GHG impact of displacing a gallon of petrodiesel with pure biodiesel can be assumed to be an emissions reduction of about 22 pounds of CO2. This is the basis upon which the preliminary analysis results presented herein were developed.

In this study, biodiesel fuel is assumed to be B20, (20 percent biodiesel and 80 percent petrodiesel), a common mixture of the fuel. Also, biodiesel is known to slightly decrease the VFE, and a 1.5% degradation of miles-per-gallon was taken into account.

Converting 20% of existing diesel vehicles in the county to B20 would save about 9,600 mt$CO_2$e. These results suggest that converting vehicles to biodiesel will not have a substantial impact on overall GHG emissions reduction. However, the use of biodiesel fuel should still play a part in the County's overall GHG reduction plan.

There are a number of benefits of converting to biodiesel in addition to reduced GHG emissions. Some of these include:

- Lower particulate emissions
- The fuel does not require special storage
- No engine modifications necessary
- The fuel is non-toxic to plants, animals, and humans
- Biodegradable fuel
- It has the potential to be a renewable source of energy

Some drawbacks to biodiesel include:

- Engine filters need to be replaced more frequently than with petroleum diesel. The City of Boulder has been replacing filters in fleet vehicles about twice as often (approximately every 15,000 miles) at a cost of about $100 each.
- Biodiesel does not function very well in cold weather. There are problems with using B100 in colder months, but using B20 in cold months provides quality performance.

Table 5-3 lists several strategies for the city to increase the use of biodiesel in the public and private fleets.

**Table 5-3: Strategies to Increase Use of Biodiesel**

| Private Strategies |
|---|
| • Provide incentives for the purchase of biodiesel to reduce the incremental cost relative to petrodiesel. |
| • Develop an incentive program such as free parking or discounts for alternative fuel vehicles |
| • Address potential barriers such as inconvenient fueling, lack of infrastructure, and lack of available information. |
| • Promote the use of biodiesel in the county-based vehicles fleets of Qwest, Comcast, Xcel, UPS, Federal Express, etc. |
| **Public Strategies** |
| • Promote the use of biodiesel in the county-based RTD bus fleet.<br>• Promote the use of biodiesel in the school district bus fleets.<br>• Continue purchase of alternative fuel vehicles for County fleet. |

## 5.5.3. Plug-in Hybrid Electric Vehicles

PHEV technology uses standard hybrid engines, drivetrains, batteries, and regenerative braking systems and augments them with extra battery capacity. At night, the on-board battery charger is plugged into a standard 120-volt electrical outlet and the extra-capacity PHEV battery pack is fully charged.

PHEV allows for all-electric operations for the first 30 to 40 miles of travel, while using the hybrid technology for longer trips. Thus, during a 40-mile trip, PHEV vehicles can achieve something like 100 miles per gallon of gasoline. As a result, dramatic reductions in emissions of VOC, CO, and CO2 are achieved.

Like E85, E15, and biodiesel, a PHEV offers numerous environmental, economic, and social benefits. Among its environmental benefits is the significant reduction of most air emissions. However, due to its consumption of grid-supplied electricity, a PHEV in Boulder County will cause an increase in certain emissions produced by an electricity generating plant. The following table summarizes the air emissions impacts achievable by substituting a PHEV for a vehicle burning G100 for the worst case in which 100% of PHEV battery-charging electricity is supplied by a coal-fired electricity generating plant.

| Air Emissions Species | Net Emissions Impact |
|---|---|
| VOC | 78% reduction |
| CO | 89% reduction |
| PM10 | 59% increase |
| NOx | 52% increase |
| CO2 | 30% reduction |

*Source:* *WSP extrapolated data from Argonne National Laboratory*

For purposes of developing preliminary estimates of GHG emissions reductions from the use of PHEVs, this analysis envisioned a program whereby the County aggressively promotes the purchase of PHEVs by Boulder businesses and citizens. The analysis assumed that this program could realistically achieve 10,000 PHEVs in Boulder County in 2020, a total penetration of the vehicle market of about 5% in 2020. As a result, GHG emissions would be reduced by about 12,000 mtCO2e/year in 2020.

This preliminary analysis focused on achieving by 2020 a 5% market penetration by PHEVs of the county's entire fleet of privately owned and publicly owned vehicles. This would be accomplished through the purchase of approximately 10,000 PHEVs/year during the 2014 – 2020 period at an annual incremental cost of $60 million, or about $6,000/vehicle, assuming the continued benefit of federal and state tax credits.

It is estimated that each of these PHEVs would on average save 240 gallons of gasoline annually, but would consume about 1,540 kWh/year to charge the batteries. At an assumed average gasoline cost of $4.00/gallon and an assumed average electricity cost of $0.12/kWh, net energy cost savings would be about $773/yr.

## 5.6 RESULTS FOR THE TRANSPORTATION SECTOR

### 5.6.1. Greenhouse Gas Emissions Reductions

A combination of the measures discussed above is grouped below as a reasonable package for the Transportation sector. Recall that the updated projection for this sector suggests is on track to over-achieve its 2020 reduction objective by 9,224 mt$CO_2$e. The suggested package yields a 3.5% reduction in VMT, a 10% market penetration for E85 fuel, a 30% market penetration for E15, a 20% market penetration for B20, and a 5% market penetration for PHEVs. The results of implementing such a plan are summarized in

Table 5-4.

**Table 5-4: Transportation Sector 2020 GHG Emissions Reductions**

| Strategy Description | GHG Emissions Reduction (mt$CO_2$e) |
|---|---|
| 10% E85 & 30% E15 market penetrations | 19,000 |
| 20% B20 biodiesel market penetration | 9,600 |
| 5% PHEV market penetration | 12,400 |
| Transportation Master Plan | 19,400 |
| | |
| Total Reduction | 60,600 |
| **Reduction Required to Meet Goal** | **-9,200** |
| **Over-achieved Reduction** | **69,200** |

### 5.6.2. Biofuels from Biomass Gasification

It is important for the County to craft its Transportation sector GHG strategy so as to capture the several co-benefits that are available from increased use of biofuels. These co-benefits include increased local economic development and increased local employment. The best way to capture these collateral economic benefits would be to create a local biofuels industry. One means of achieving this could be an advanced-technology biomass gasification system that would convert municipal solid waste (MSW), energy crops, and/or agricultural waste into ethanol. Alternatively, these feedstocks could be converted into diesel via the Fischer-Tropsch catalysis process (F-T diesel) or alcohol fuels via a catalytic synthesis process. All thermal and electrical energy required for the operation of the plant would be derived from the agricultural and MSW feedstocks. Constructed in an appropriate location within Boulder County, the plant would buy the necessary agricultural feedstocks from local farmers and would receive MSW from the surrounding municipalities. Chapter 6 presents further details on MSW-to-liquid fuels.

The resulting ethanol would be blended with gasoline to produce E85 fuel and the E85 would be distributed to a network of fuel stations in Boulder County. Any F-T diesel produced could be used unblended to displace petrodiesel. The local economy would thereby receive the benefits of new economic activity, new job creation, and insulation from future gasoline and petrodiesel price shocks.

The volume of MSW generated within Boulder County is thought to be enough to produce about 23 million gallons of ethanol annually, which would displace about 17 million gallons of gasoline annually. As a point of comparison, it is estimated that the BAU vehicle fuel consumption in the county will be about 75 million gallons/year of petroleum-based fuels in 2020. MSW gasification-to-liquid fuels plant could conceivably supply about 23% of all the vehicle fuel required county-wide. Of course, a substantially larger portion of the total market demand could potentially be supplied if MSW were supplemented with agricultural residues produced within the county to increase ethanol and F-T diesel output.

### 5.6.3. Cost Implications

Preliminary estimates of economic costs and benefits of implementing proposed emissions reduction strategies for this sector are presented in this section. Note that it is here assumed that MSW-to-fuels is not part of the mix of actions.

To achieve the substantial emissions reductions in this sector presented here, it will be necessary to overcome the economic and other barriers in the marketplace. The estimated magnitude of the economic costs is \$60 million through 2020, not including any costs for VMT reduction via the TMP. However, the proposed measures have several economic and synergistic benefits that will offset much of the costs. For example, it is estimated that fuel cost savings of about \$8 million/year will be realized in 2020. The MACs of key transportation emissions reduction strategies range from (0)\$/mtCO2 for E15 and E85 to (+20)\$/mtCO2 for B20 to (+66)\$/mtCO2 for plug-in hybrid electric vehicles (with tax credits).

### 5.6.4. Summary

The results for the Transportation sector highlight the substantial role that E85 and E15 can play in acquiring substantial GHG emissions reductions. The Commissioners must consider whether it is acceptable policy to initiate programmatic activities that will aggressively promote public awareness of conventional ethanol fuel benefits with the aim of encouraging motorists to embrace it as a bridge to the future genuinely sustainable next-generation ethanol and, in the absence of blending pumps, to themselves blend E85 with gasoline at retail outlets to achieve an E15 blend.

As the details of program funding mechanisms are developed and fleshed out, it is imperative that opportunities be exploited that may present themselves in the form of federal programs and policies as well as State of Colorado programs and policies. For example, both federal and state tax incentives currently exist to encourage individuals and businesses to purchase plug-in hybrid-electric vehicles. It is essential that Boulder County's GHG program seek maximum usage of these state and federal tax incentives, and all other available programs, in order to leverage the limited funding resources available from the County. Every effort should be made to leverage biofuels programs already offered by the Colorado Energy Office (CEO). CEO supports the Governor's Biofuels Coalition (GBC), which represents Colorado organizations, businesses, government agencies, environmental groups and others that are involved in the production, distribution, promotion and usage of biodiesel and ethanol. These entities are working together to overcome market barriers and to raise awareness for existing flex-fuel and diesel vehicle drivers of these alternative fuel options. The use of biofuels continues to grow in Colorado. Nearly 100 stations are currently open and selling E85 (ethanol and gasoline/hydrocarbon mixture) and/or biodiesel, 75% of which received support from the GBC. In 2007, the stations reporting to the GBC sold 2.614 million gallons of biofuels. From January 1 to June 30, 2008, 3.74 million gallons were reported to have been sold in Colorado. More recent sales data are not provided on the website.

# 6. RENEWABLE ENERGY SUPPLY MEASURES

## 6.1 Overview

This chapter provides a preliminary outline of opportunities for the County to reduce GHG emissions through reductions in the GHG intensity of grid-supplied electricity, through direct offsets of GHG emissions by way of clean-energy project investments, and through installation of PV or solar water heaters on commercial and residential buildings.

Renewable fuels consumed by the Transportation sector are addressed in Chapter 5 and therefore biofuels are omitted from the discussion in this Chapter.

While the preliminary analysis took account of GHG impacts associated with WindSource subscriptions by Boulder County businesses and individual citizens, none of the other green tag retail programs have been accounted for, due to lack of data.

**Potential Renewable Energy Measures**

- New capacity at hydro plants owned by cities of Boulder, Longmont, and Lyons
- County government investment in wind energy projects
- Creation of a pool whereby Boulder County businesses and citizens purchase carbon offsets and/or green tags in bulk
- PV installations on commercial and publicly owned buildings
- Solar water heating installations on commercial and residential buildings
- Construction of a municipal solid waste gasification plant to generate electricity and/or liquid fuels

## 6.2 MSW Gasification

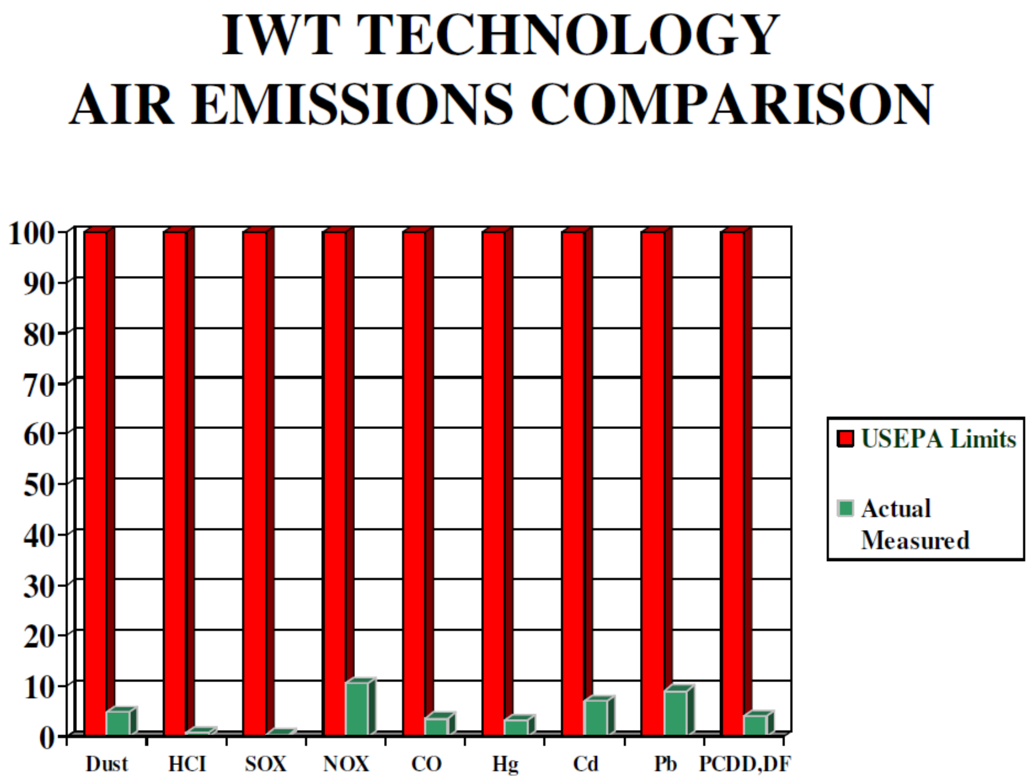
Approximately 234,000 metric tons of municipal solid waste (MSW) are generated annually within Boulder County. By 2020, this volume is projected to increase to about 267,000 annual tons of MSW in 2020. Soon-to-be-commercialized gasification technology can convert this volume of MSW into synthesis gas (syngas) which can in turn be burned in conventional equipment to generate about 60 MW and 447,000 MWh/yr of mostly carbon-neutral electricity. This represents about 60 MW of electric power capacity that would reduce GHG emissions by about 215,000 mtCO2/yr (about 65% of the MSW, by weight, is carbon-neutral). The cost of such a plant would be about $210 million. It would produce electricity sales revenues of about $51 million/year.

Alternatively, the MSW could be converted into alcohol and diesel fuels via gasification. The 267,000 tons of MSW would produce approximately 23 million gallons/year of alcohol fuels, which would produce GHG emissions reductions of about 146,000 mtCO2/yr. The cost of such a plant would be about $100 million. It would produce fuel sales revenues of about $50 million/year.

In addition to the direct emissions reductions provided by MSW gasification, via electricity generation or liquid fuels production, an additional 164,900 mtCO2/yr of GHG mitigation would be realized from the avoidance of landfill gas emissions. Thus, total GHG mitigation from MSW gasification would be in the range of 300,000 – 380,000 mtCO2/year in 2020 (MSW-to-fuels versus MSW-to-electricity). To keep this analysis conservative, it is assumed that 270,000 mtCO2e of mitigation is achieved with this technology.

MSW gasification is currently being commercialized in USA, Canada, Europe, and Japan. Because gasification enables nearly all of the toxics in the syngas to be removed before the syngas is burned, the toxic emissions from an MSW gasification-to-energy plant are extremely low. Figure 6-1 presents air emissions data for such a facility in Germany.

**Figure 6-1: MSW Gasification-to-Energy Air Emissions**




If MSW gasification is too avant-garde, a less-aggressive approach to waste-to-energy is to continue to treat dry MSW (paper, wood, plastics) as is currently being done, but to divert wet MSW to anaerobic digesters that would convert the waste into biogas. Biogas production is a well-established and cost-effective technology. While this practice would channel the wet organics component of MSW away from composting, it would yield a net increase in GHG mitigation, compared to composting, while still providing an organic fertilizer as a by-product of energy production. Furthermore, since wet MSW is already being collected/sorted for a significant fraction of the county-wide MSW stream, biogas production represents a low-risk and very cost-effective alternative to BAU practices of waste management.

## 6.3 New City-Owned Hydroelectric Capacity

The cities of Boulder, Lyons, and Longmont own small hydroelectric plants. If there is the potential to increase the capacity of these plants, doing so could be attractive. If by 2020, another 2.3 MW of hydro capacity were installed, approximately 10,000 MWh/year of additional carbon-neutral electricity could be produced. This would offset about 7,400 mtCO2/year in GHG emissions in 2020. The total cost of these systems would be about $5 million and they would produce annual electricity sales revenues of about $700,000 in 2020.

## 6.4 Wind Energy

Wind energy conversion technology is mature and reliable. If by 2020, about 10 MW of wind capacity were installed using financing provided by Boulder County and/or municipalities within the county, approximately 23,300 MWh/year of additional carbon-neutral electricity could be produced. This would offset about 17,000 mtCO2/year in GHG emissions in 2020. The total cost of these systems would be about $15 million and they would produce annual electricity sales revenues of about $1,630,000 in 2020.

## 6.5 Bulk Purchase of Green Tags or Carbon Offsets

Purchase of green tags is perhaps the easiest way that Boulder County citizens can participate in the generation of renewable energy. The unregulated, voluntary green tags markets are growing rapidly nationwide and this trend is expected to continue. The success in Boulder County of retail green tags programs such as those offered by Renewable Choice Energy, Colorado Clean and Green, and Xcel can be expanded. A caveat to bear in mind, however, is that green tags represent a pure cost to consumers in that they increase the cost of electricity. There is no financial return on this investment to the green tags buyer. All the other RE measures presented in this chapter offer lower-cost energy over the systems' lifetimes and, therefore, a financial return-on-investment.

Green tags (also known as RECs) offer an emissions marginal abatement cost (MAC) of about $13/mtCO2, but the market value of RECs varies widely depending on the location of the project and the technology employed.

An alternative to green tags or RECs is carbon offsets. One Certified Emissions Reduction (CER), the currency of the Clean Development Mechanism (CDM) market under the Kyoto treaty, equating to one metric ton of abated CO2, is currently worth about $5 or even less. One Verified Emissions Reduction (VER), corresponding to one metric ton of abated CO2 that has been verified under the Verified Carbon Standard, currently has a similar value. Thus, Carbon Offsets offer a MAC of about $5/mtCO2. RECs should be used only to offset emissions associated with grid electricity consumption. Carbon offsets should be used only to offset emissions associated with fossil fuel combustion or Scope 3 emissions such as travel by commercial airline.

This analysis assumes that the increasing popularity of green tags can be leveraged in Boulder County such that by 2020, green tags and/or carbon offsets purchased by county citizens and businesses are associated with GHG emissions reductions of 100,000 mtCO2/year. The annual cost of this volume of green tags or offsets is estimated at about $500,000 – 1 million.

## 6.6 Photovoltaics

If by the end of 2020, 5% of commercial buildings were to each install PV systems averaging 20 kW in nameplate rating, each system would produce about 24,000 kWh/year and would offset the emission of about 18 mtCO2/year. The overall result would be GHG emissions reductions of about 13,500 mtCO2/year in 2020 (assuming 760 buildings). The total cost of these systems would be about $53 million (net of tax credits; Xcel rebates are assumed to have disappeared) and they would produce annual energy cost savings of about $2.46 million in 2020.

If by the end of 2020, 20% of residential buildings were to each install PV systems averaging 1 kW in nameplate rating, each system would produce about 1,200 kWh/year and would reduce emissions by about 0.9 mtCO2/year. The overall result would be GHG emissions reductions of about 20,200 mtCO2/year in 2020 (assuming 22,800 buildings). The total cost of these systems would be about $74 million (net of Xcel rebates and tax credits) and they would produce annual energy cost savings of about $2.8 million in 2020.

## 6.7 Solar Water Heating

Flat-plate and compound parabolic collector solar thermal technology is mature and reliable as a means for making residential domestic hot water (DHW), and low-temperature hot water for commercial and industrial purposes. A typical residential application of solar DHW will displace about 150 therms/year of natural gas, thereby reducing GHG emissions by about 0.77 mtCO2/year. At a natural gas cost of $1.25/therm, such a system would save about $182/yr and recover the $2,196 system cost (net of 30% federal tax credit) in 12 years.

If by the end of 2020, 35% of all residential dwelling units in Boulder County were to employ solar DHW systems as their exclusive source of DHW, the total GHG emissions reductions would be about 30,700 mtCO2/year. The total cost of these systems would be about $88 million and they would produce annual energy cost savings of about $7 million in 2020.

## 6.8 Summary of Renewable Energy Impacts

In summary, if all of the renewable energy strategies outlined above were to be implemented, total cost of these strategies would be about $441 million and they would produce annual energy sales revenues and energy cost savings of about $66 million in 2020. Total GHG mitigation of about 460 million mtCO2/year would be achieved in 2020. This represents about 32% of the mitigation shortfall remaining after implementation of the energy efficiency and transportation measures described in previous chapters. Thus, even with the full suite of mitigation measures analyzed, it appears likely that Boulder County will fall short of its goal by approximately 935,630 mtCO2e/year in 2020.

Table 6-1 summarizes the GHG impacts that are expected from the RE measures examined here.

## Table 6-1: GHG Impacts from RE Measures

| Strategy Description | GHG Emissions Reduction (mt$CO_2$e) | % of Gap-to-Plan after DSM & Transportation Measures |
|---|---|---|
| MSW-to-electricity | 270,000 | 20% |
| Expansion of hydro capacity | 7,430 | 0.5% |
| PV on commercial & public bldgs | 13,500 | 1% |
| PV on residential buildings | 20,200 | 1.5% |
| Wind | 17,000 | 1.2% |
| Bulk purchase CERs, VERs, RECs | 100,000 | 7.3% |
| Solar DHW | 30,740 | 2.2% |
| **Total reduction** | **458,870** | **34%** |

# 7. GHG ANALYSIS SUMMARY AND CONCLUSIONS

## 7.1 EMISSIONS REDUCTIONS PROVIDED BY DEMAND-SIDE MEASURES

Reducing each sector's demand for energy is recommended as the most cost-effective and advantageous strategy for realizing the Commissioners' GHG objective. The primary justification for pursuing demand-side management (DSM) measures before supply-side opportunities is the greater synergistic benefits such as increased sales tax revenue and job creation. However, as seen below, demand-side strategies by themselves will not achieve the GHG goal. Therefore, supply-side strategies and/or emissions offsets will be needed to fill the GHG reduction shortfall.

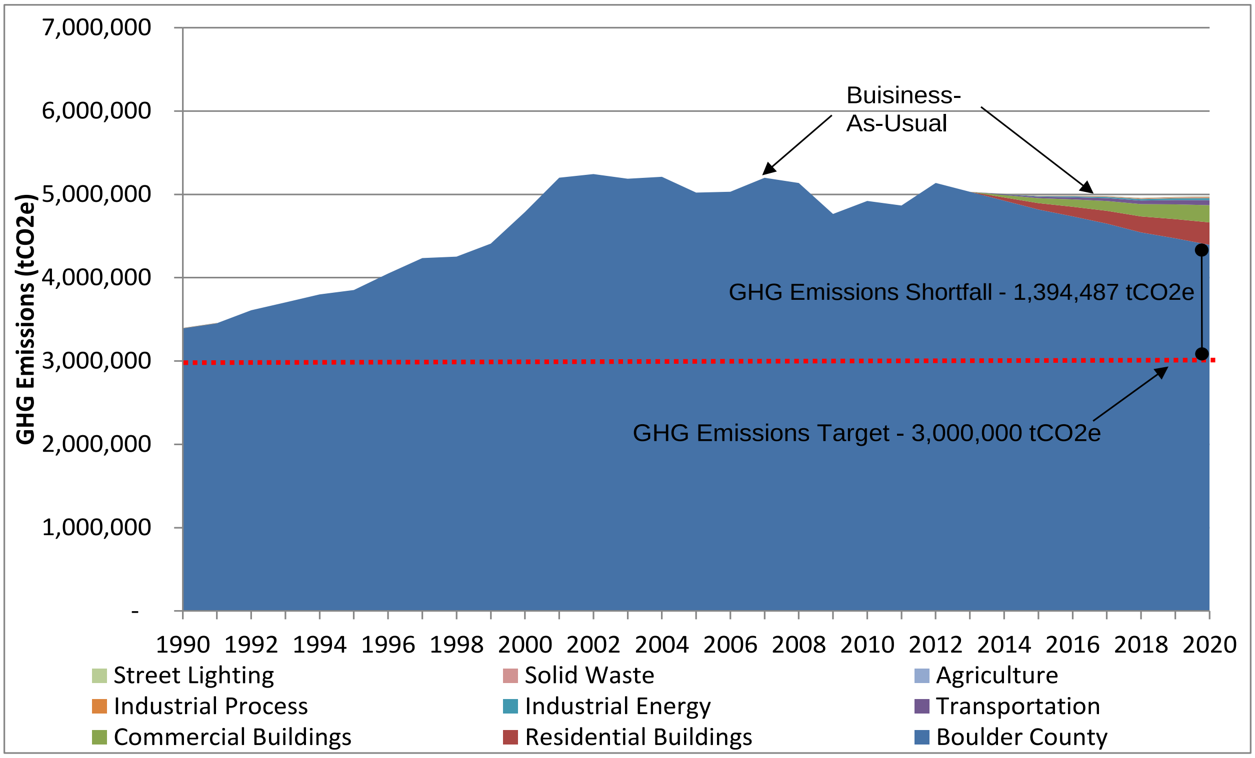
Each of the sectors evaluated in the preceding sections will play a key part in realizing the Commission's GHG objective. The goal is to reduce 2020 GHG emissions by about 2 million mt$CO_2$e, a 40% reduction compared to projected 2020 BAU emissions. Table 7-1 provides a breakdown of the individual sector goals that together will move the county toward the 3 million mt$CO_2$e level of emissions comprising the 2020 target. Table 7-1 also shows the DSM GHG reductions this analysis assumes are achievable for each sector. This assessment suggests that the assumed demand-side measures will deliver about 30% of the reductions that are needed to meet the goal.

**Table 7-1: 2020 Demand-Side Reduction Summary**

| | Required Reduction in 2020 | Expected GHG Reduction in 2020 | Reduction Goal Shortfall |
|---|---|---|---|
| | (mtCO2e) | (mtCO2e) | (mtCO2e) |
| Residential Buildings | 693,058 | 268,900 | 424,158 |
| Commercial Buildings | 865,328 | 206,635 | 658,693 |
| Transportation | 0 | 60,600 | -60,600 |
| Industrial Energy | 243,607 | 24,766 | 218,841 |
| Industrial Process | 67,588 | 8,092 | 59,496 |
| Agriculture | 16,790 | 1,961 | 14,829 |
| Solid Waste | 64,547 | 6,792 | 57,755 |
| Street Lighting | 26,253 | 4,939 | 21,314 |
| **Total** | **1,977,200** | **582,700** | **1,394,500** |

Figure 7-1 illustrates the impact the demand-side reductions will have on achieving the Commission's GHG goal. The figure shows the business-as-usual emissions trajectory as well as the impact demand-side reductions can have in deflecting the BAU trajectory downward toward the target. Based on the assumptions of this analysis, demand-side reduction opportunities will fall approximately 1,394,500 mt$CO_2$e short of the goal in 2020. Thus, if the County is to realize its goal, the GHG gap will have to be filled with supply-side strategies and offset projects, primarily renewable energy.

**Figure 7-1: GHG Inventory with Demand-Side Reductions**




## 7.2 EMISSIONS REDUCTIONS PROVIDED BY SUPPLY-SIDE MEASURES

As shown above, demand-side strategies by themselves will not achieve the GHG goal. Therefore, supply-side strategies and/or emissions offsets will be needed to fill the GHG reduction shortfall. Several renewable energy (RE) supply-side strategies were evaluated in Chapter 6. These consist of MSW-to-energy, PV, wind energy, RECs, and solar hot water. The following table summarizes the emissions reductions the analysis estimates are achievable with this mix of renewable energy supply-side measures.

**Table 7-2: 2012 Supply-Side Reduction Summary**

| | Reduction Shortfall after DSM ($mtCO_2e$) | Expected RE GHG Reduction ($mtCO_2e$) | Remaining Reduction Shortfall after RE ($mtCO_2e$) |
|---|---|---|---|
| | 1,394,500 | | |
| MSW-to-electricity | | 270,000 | |
| Expansion of hydro capacity | | 7,430 | |
| PV on commercial & public bldgs | | 13,500 | |
| PV on residential buildings | | 20,200 | |
| Wind | | 17,000 | |
| Bulk purchase CERs, VERs, RECs | | 100,000 | |
| Solar DHW | | 30,740 | |
| **Total reduction** | | **458,870** | **935,630** |

The combination of the demand-side and supply-side measures outlined above provides GHG emissions reductions that still fall short of the 2020 target by about 935,630 tCO2e. The following graphs show the deflection of the BAU emissions trend line over time in response to the mitigation impacts quantified by the 2006 analysis and by this updated analysis.

**Figure 7-2: Projected Mitigation Impacts, 2005**

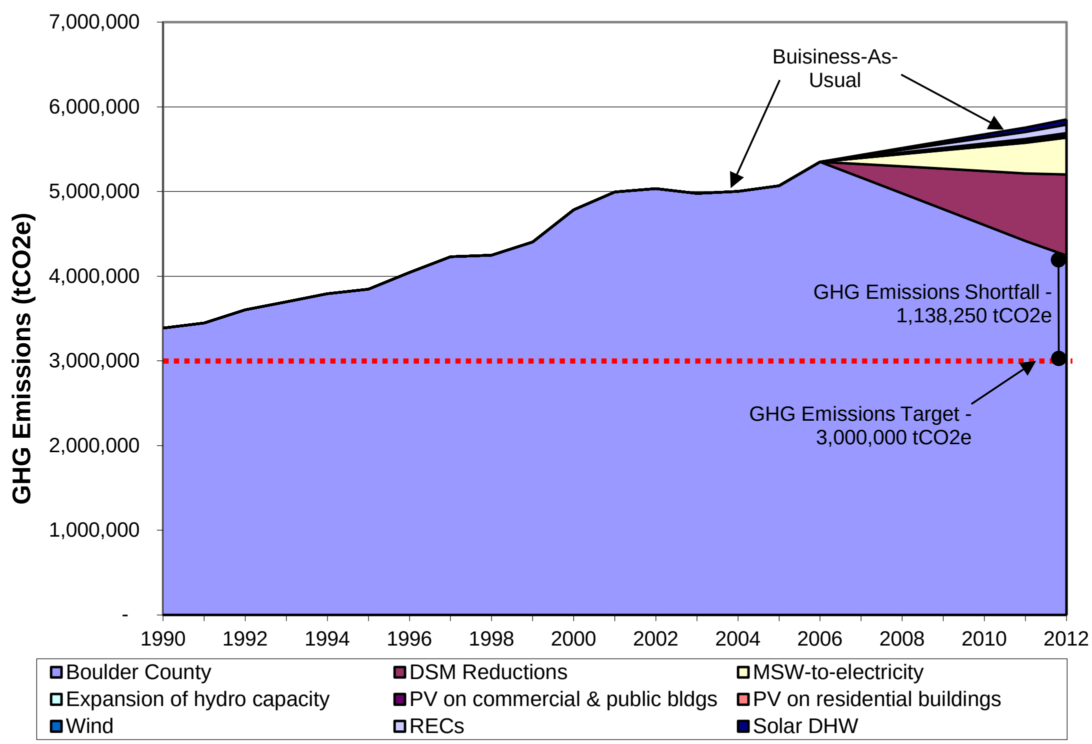
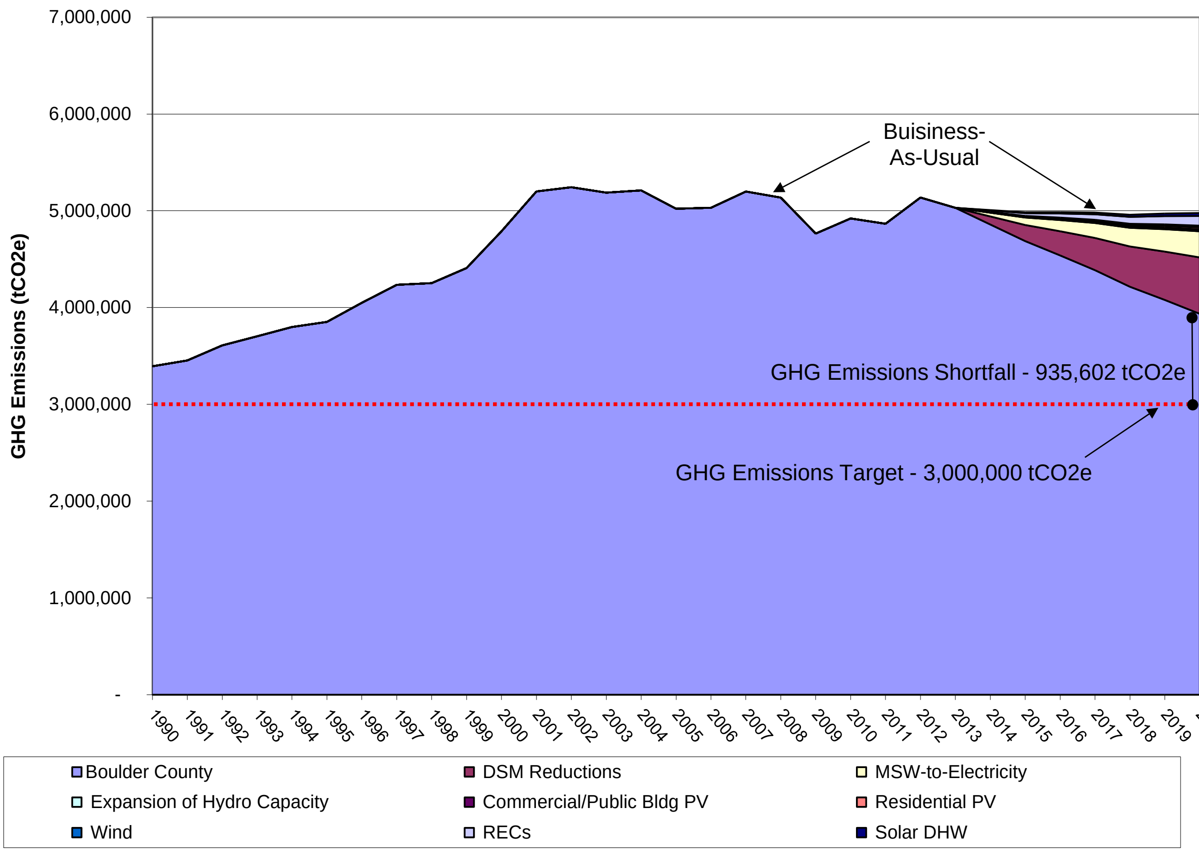


**Figure 7-3: Projected Mitigation Impacts, 2011**




## 7.3 CONCLUSIONS

These results make it apparent that the DSM and RE measures outlined in previous chapters are inadequate to the task of achieving the county's goal. According to this analysis, the suite of DSM and RE measures will get the county only about 53% of the way to the goal line. Creative and aggressive strategies need to be developed to boost emissions reductions, especially via DSM in the Commercial Buildings and Residential Buildings sectors.

The MACs for the key emissions reduction strategies are summarized in the following table.

**Table 7-3: Marginal Abatement Costs**

| Reduction Measure | MAC ($/mtCO2) |
|---|---|
| Commercial Buildings Bundle 2 | -91 |
| Residential Buildings Bundle 2 | -5 |
| Plug-in Hybrid Electric Vehicle | +66 |
| Solar PV Residential | +195 |
| Solar PV Commercial | +132 |
| Solar DHW | +85 |
| MSW-to-Electricity | -124 |
| RECs at $13/MWh | +20 (varies depending on project location) |
| Carbon Offsets at $10/mtCO2 | +10 |

These measures in aggregate are expected to yield about 54% of the required reductions in 2020 and are estimated to deliver about $129 million/yr in energy cost savings and energy sales revenues in 2020, at a total implementation cost of about $1.1 billion. The overall Benefit:Cost ratio of this mix of measures is 2.16. This means that, over the equipment lifetime, energy cost savings and energy sales revenue will total 2.16 times the total required capital investment.

Commercial buildings must achieve BAU emissions reductions in 2020 of about 48% and residential buildings BAU reductions of about 47% in order for these sectors to hit their targets. This analysis assumes reductions of only about 38% and 24%, respectively, for these sectors, reflecting the anticipated difficulty of achieving deep market penetrations for building DSM. The results presented here represent market penetrations of 35% for DSM packages that achieve about 30% energy savings on average. Such results are quite aggressive and optimistic by historical DSM program standards and in comparison to the apparent impacts actually achieved to-date by SEP programs.

Based on historical DSM program performance experienced by electric and natural gas utilities in the US over the past 20 years, it is believed that even a 35% market penetration is a high bar. Achieving this will require either substantial increases in the cost of conventional electricity and natural gas or substantial financial incentives for building owners, or both. Xcel currently offers financial incentives for commercial building DSM that should be aggressively pursued. However, Xcel incentives are expected to be insufficient to realize the Commission's GHG goal for the county's commercial buildings.

It is important to bear in mind that the vast majority (about 93%) of the Commercial Buildings sector emissions that would be produced in 2020 under BAU emanate from the building stock existing as of 2011, as opposed to new construction that will be added during the 2012 – 2020 period. Further, it is important to note that the vast majority of existing commercial buildings are small buildings that are too small to attract the interest of the energy services performance contracting industry (ESCOs). WSP has recommended that a project performance guarantee facility be established to mitigate ESCO contractual risk to a level that would attract the active engagement of the ESCO industry in order to bring substantial private capital to bear on Boulder County's existing small commercial buildings subsector.

Similar conclusions can be drawn for the Residential Buildings sector. The vast majority (about 94%) of the residential buildings emissions that would be produced in 2020 under BAU emanate from the building stock existing as of 2011, as opposed to new construction added during the 2012 – 2020 period. Thus, the key challenge for county and municipal leaders will be figuring out how to effect rapid and dramatic change in behaviors of building owners. While home owners may be willing to accept longer paybacks of investments than commercial building owners, the owners of residential rental properties will behave more like the latter.

The results for the Transportation sector highlight the crucial role that vehicle fuel economy and low-carbon vehicle fuels play in acquiring substantial GHG emissions reductions. The Commissioners must consider whether it is acceptable policy to initiate programmatic activities that will aggressively promote public awareness of E15 benefits with the aim of encouraging motorists to themselves blend E85 with gasoline at retail outlets to achieve an E15 blend.

Whether or not the Commission chooses to pursue E15, the promotion of E85 usage and initiation of policies and programs aiming to increase the retail availability of E85 are important objectives. Every effort should be made to leverage E85 programs already offered by the Colorado Biofuels Coalition.

The analysis also spotlights the substantial potential for the county's MSW resource to be exploited for important GHG emissions reductions. Since this potential represents as much as 25% of the total prospective reductions that are enumerated in this report, MSW gasification warrants serious investigation and consideration.

Finally, the purchase of Carbon Offsets should be seriously considered as one of the more cost-effective mitigation strategies. Offsets can be purchased through several sources including online "carbon calculators" and offset brokers. Attention must be paid to offset quality, however. Generally, the higher the offset quality, the higher the price. If the County finds value in fostering support for clean economic development in emerging economies, it could promote the purchase of Verified Emissions Reductions (VERs) or Certified Emissions Reductions (CERs). Alternatively, if the County wishes to foster development of US-based emissions mitigation projects, it could promote the purchase of VERs generated by US projects. The Colorado Carbon Fund is another potential channel through which Colorado-based offsets could be purchased. However, the caveat to bear in mind with respect to carbon offsets and RECs is that these are strictly costs incurred by the buyer; they offer no return on investment. In contrast, even though PV has a very high MAC it nevertheless eventually recovers the investment via avoided grid electricity costs.

# 8. SEP BASELINE ESTIMATED WITH REGRESSION ANALYSIS

## 8.1 PURPOSE

As part of WSP's 2012 – 2013 work scope, this task investigated whether it is possible to discern – in historical data for electricity and natural gas consumption at the county-wide commercial sector and residential sector levels – SEP programmatic impacts on energy usage, and thus GHG emissions. The inherent low-resolution of sector-level data necessarily leads, at best, to a rough estimate of SEP impacts on the commercial buildings and residential buildings sectors. The approach described below has potential to provide a relatively easy and low-cost estimate of SEP impacts. More accurate impact evaluation must involve evaluation of individual premise-level data across samples of building types, using well-known programmatic impact-evaluation techniques. In the future, with availability of a sufficient body of post-SEP data, it may be possible to discern approximate SEP impacts using sector-level data, via the data normalization methodology described below.

## 8.2 METHODS

Total energy usage for the commercial and residential sectors was normalized against the independent variables of population, GDP, and weather using linear regression analysis. Historical population data were readily available for Boulder county. Historical Boulder county GDP data was not available but was approximated using historical personal income as a surrogate. Historical weather was represented by readily available heating degree day (HDD) and cooling degree day (CDD) data.

Historical energy usage data was broken down into natural gas and electricity usage for each sector. The dependent variables of energy usage per capita, energy usage per GDP, and energy usage per HDD or CDD were then plotted against long-term average values of the independent variables to determine the best-fit $R^2$ correlation for each combination of dependent versus independent variables.

The HDD or CDD data corresponding to the base temperature yielding the best-fit regression was used to establish long-term average weather. For residential buildings the base temperatures were 59F for HDD and 64F for CDD. For commercial buildings these temperatures were 43F and 58F respectively. Conceptually these values represent building heating and cooling balance-point temperatures and imply that the average residential building requires space heating at ambient temperatures below 59F and the average commercial building requires space heating at ambient temperatures below 43F.

To test the effects of changing population, GDP, and weather over time (the independent variables), regression algorithms were developed relating the dependent variables of natural gas and electricity usage to each of the independent variables over time and then driving the algorithms with long-term average values for the independent variables. Energy usage normalized over long-term average weather allows comparison of what the actual energy usage was compared to what the predicted usage would be based on the variation in either population or GDP if long-term average weather had prevailed over the entire analysis period of 2002 -

2011. In similar fashion, regression algorithms were developed that enabled prediction of energy usage if population were held constant over time and if GDP were constant over time.

The algorithms that resulted in the normalized curves most closely fitting the actual energy usage curves were then driven with long-term average values for the independent variables to establish normalized baselines for natural gas and electricity usage in the pre-SEP period. In the future, with a sufficient body of post-SEP data, this same methodology can be applied to establish normalized post-SEP values for natural gas and electricity usage. The difference between pre-SEP and post-SEP will represent an estimate of the actual SEP impact.

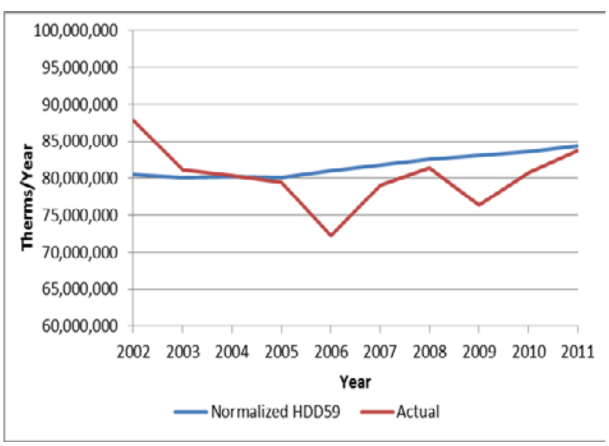
## 8.3 RESULTS

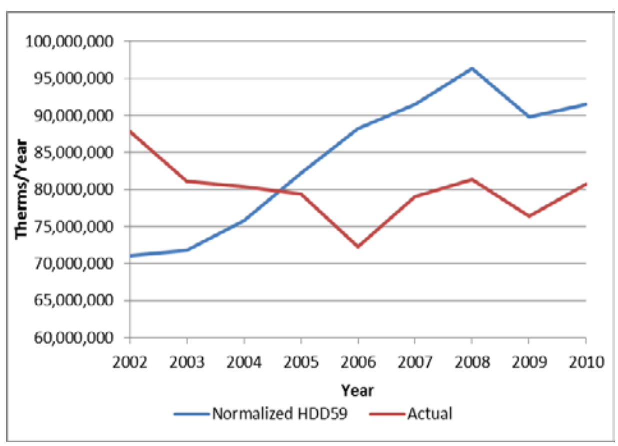
**County-Wide Natural Gas:**

Residential natural gas usage was normalized for population, weather, and GDP. Graph A shows residential natural gas usage, normalized to long-term weather with variable population. Comparison of actual energy usage to the normalized data reveals that after 2005, the actual energy dropped below normalized levels and remained below normal levels through 2011. This suggests that actual energy use was below what is predicted based on population trends. Actual energy use continually increased from 2006 through 2011, with the exception of 2009, where usage dropped by 6%. This could be a result of either Boulder County's Sustainable Energy Plan (SEP), the recession, or most likely both. WSP did not have access to sufficiently granular energy usage data to be able to discern the relative contribution, if any, made by the SEP versus the recession.

Graph B shows residential gas usage, normalized to the long-term weather with variable GDP. These curves suggest that actual energy use was below what is predicted based on GDP trends.

*Residential NG Usage*



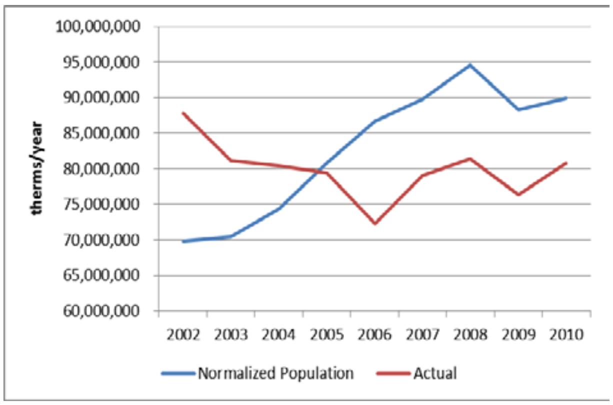




Graph A: HDD held constant; normalized variation due to population    Graph B: HDD held constant; normalized variation due to GDP

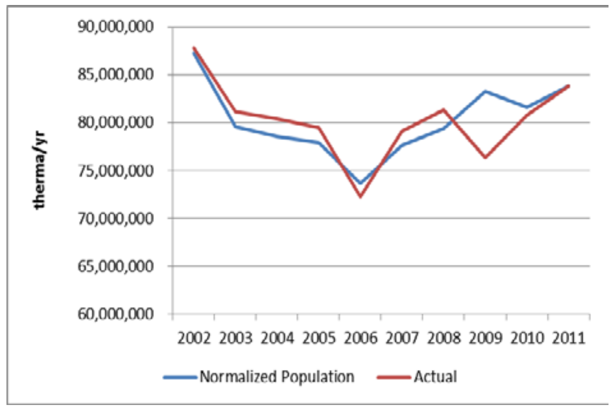
Graph C shows residential gas usage, with long-term average population held constant and variable GDP. These curves suggest that after 2005 actual energy use was substantially lower than what is predicted based on GDP trends.

Graph D shows residential gas usage, with long-term average population held constant and variable HDD. These curves show good agreement, highlighting that weather is the more important independent variable than either population or GDP in driving residential natural gas usage. The dramatic divergence of the curves in 2009 could be a result of either Boulder County's Sustainable Energy Plan (SEP), the recession, or most likely both. WSP did not have access to sufficiently granular energy usage data to be able to discern the relative contribution, if any, made by the SEP versus the recession.

*Residential NG Usage*




Graph C: Population held constant; normalized variation due to GDP

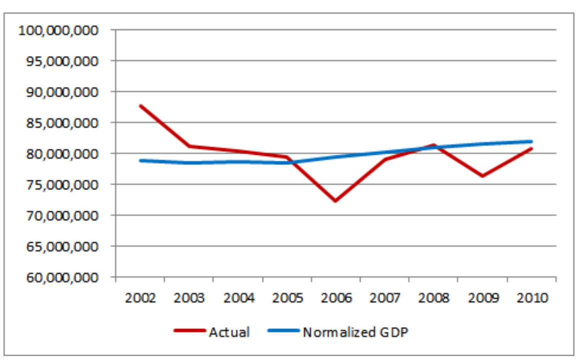



Graph D: Population held constant; normalized variation due to HDD

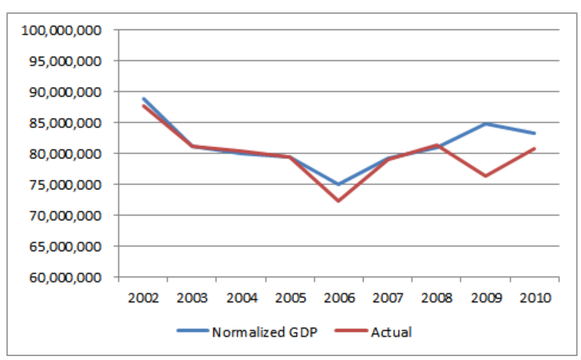
Graph E shows residential gas usage, with long-term average GDP held constant and variable population.

Graph F shows residential gas usage, with long-term average GDP held constant and variable weather. These curves show good agreement, again highlighting that weather is the more important independent variable than either population or GDP in driving residential natural gas usage. The dramatic divergence of the curves in 2009 again suggests the impact of either Boulder County's Sustainable Energy Plan (SEP), the recession, or most likely both. WSP did not have access to sufficiently granular energy usage data to be able to discern the relative contribution, if any, made by the SEP versus the recession.

*Residential NG Usage*



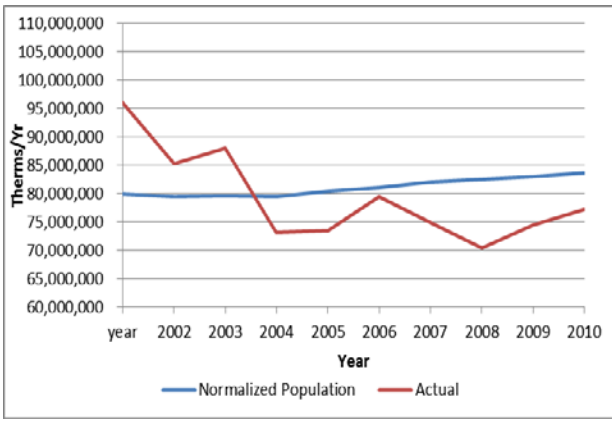

Graph E: GDP held constant; normalized variation due to population



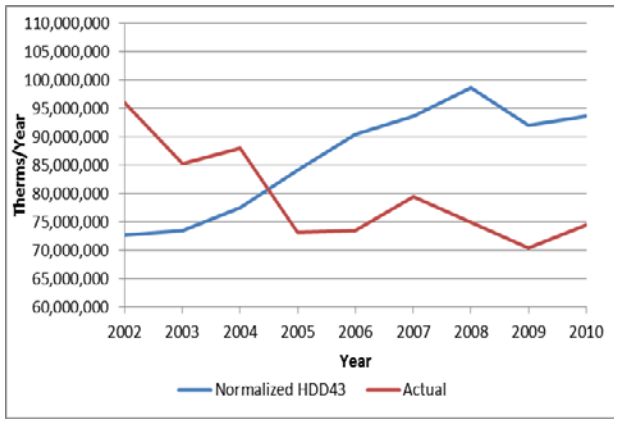

Graph F: GDP held constant; normalized variation due to HDD

Commercial natural gas usage was analyzed in the same manner as the residential data. Graph G shows natural gas usage in commercial buildings with HDD held constant over time while population varies. Graph H shows gas usage as predicted if long-term average weather had prevailed over time while GDP varied. Graph I depicts variable weather while GDP is held constant. Note the clear similarities between these commercial building graphs and their corresponding residential building graphs. Like Graph F, Graph I shows relatively good agreement between predicted gas usage and actual usage, again highlighting that weather is the more important independent variable than either population or GDP in driving commercial natural gas usage. The dramatic divergence of the Graph I curves in 2009 again suggests the impact of either Boulder County's SEP, the recession, or most likely both. WSP did not have access to sufficiently granular energy usage data to be able to discern the relative contribution, if any, made by the SEP versus the recession.

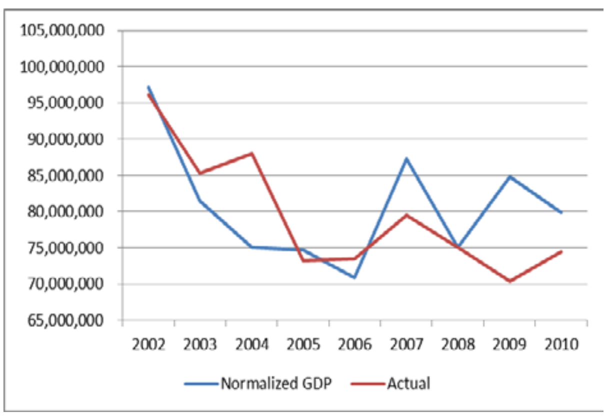
*Commercial NG Usage*




Graph G: HDD held constant; normalized variation due to population




Graph H: HDD held constant; normalized variation due to GDP



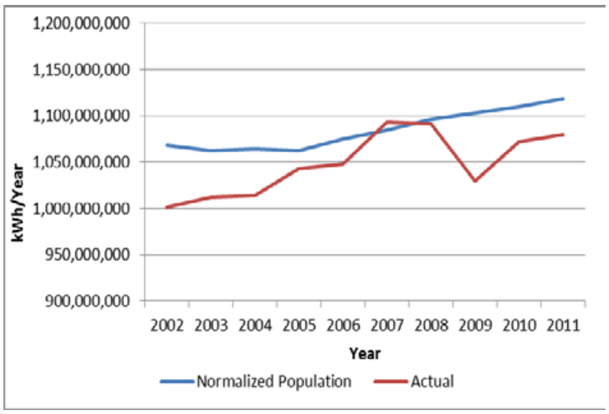

Graph I: GDP held constant; normalized variation due to HDD

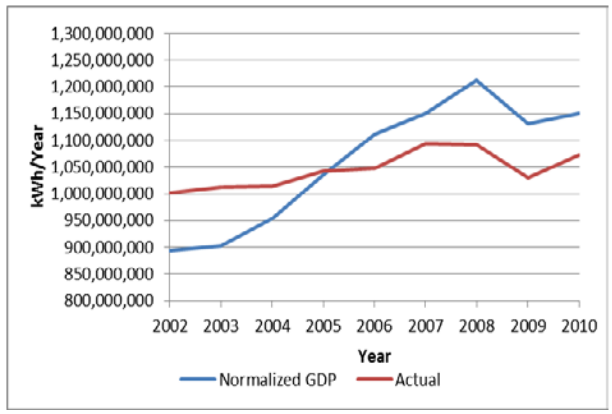
**County-Wide Electricity:**

Residential building electricity usage was analyzed using the same methods as described above. Graph J shows predicted electricity usage if long-term average weather prevailed over the analysis period while population varies. These curves suggest that actual energy use was below what is predicted based on population trends.

Graph K shows residential building electricity usage, normalized to the long-term weather and variable GDP. These curves suggest that after 2005 actual energy use was below what is predicted based on GDP trends.

*Residential Electricity Usage*

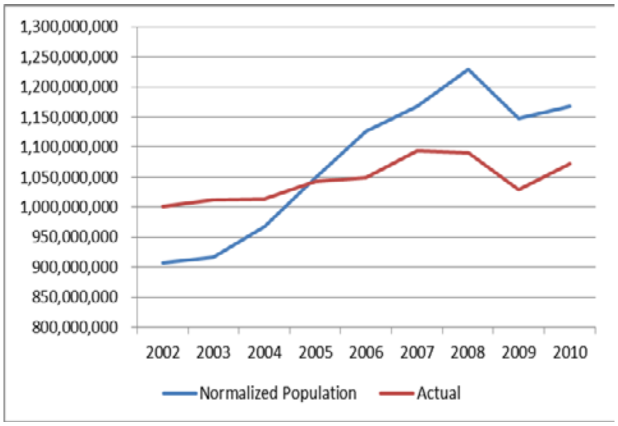


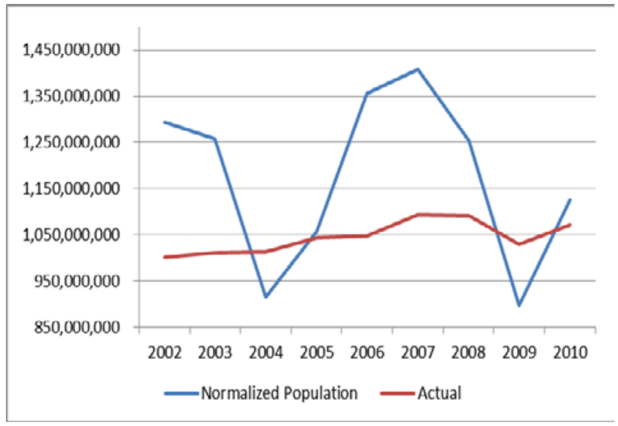




Graph J: CDD held constant; normalized variation due to population Graph K: CDD held constant; normalized variation due to GDP

Graph L shows residential electricity usage, with long-term average population held constant and variable GDP. These curves suggest that after 2005 actual energy use was substantially lower than what is predicted based on GDP trends.

Graph M shows residential electricity usage, with long-term average population held constant and variable CDD. Unlike the residential natural gas cases outlined above, that weather is the more important independent variable than either population or GDP in driving residential natural gas usage, these curves do not show good agreement, indicating that for electricity usage, weather is not the most important independent variable driving residential electricity usage. Rather, the curves featuring variable GDP seem to most closely predict actual electricity usage. As with the natural gas curves, the dramatic divergence of the electricity curves in 2009 could be a result of either Boulder County's SEP, the recession, or most likely both.



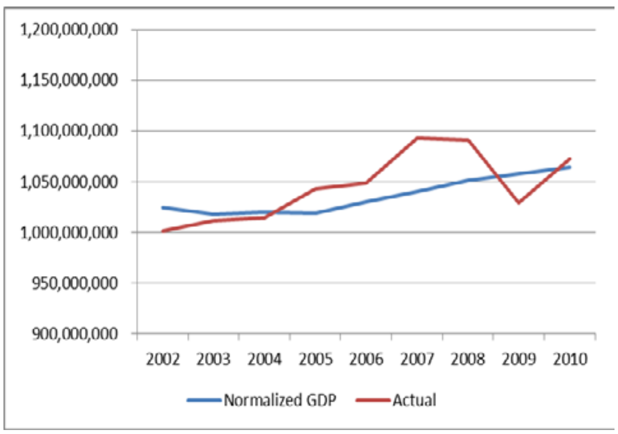



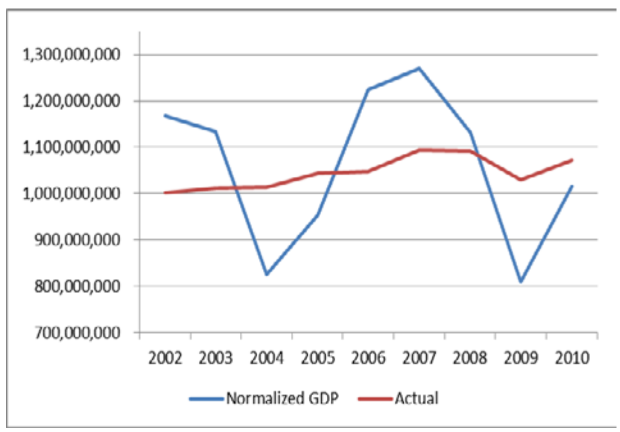

Graph L: Population held constant; normalized variation due to GDP

Graph M: Population held constant; normalized variation due to CDD

Graph N shows residential electricity usage, with long-term average GDP held constant and variable population.

Graph O shows residential electricity usage, with long-term average GDP held constant and variable weather. Unlike the residential natural gas cases outlined above, these curves do not show good agreement, indicating that for electricity usage, weather is not the most important independent variable driving residential electricity usage. Rather, the curves featuring variable GDP seem to most closely predict actual electricity usage.



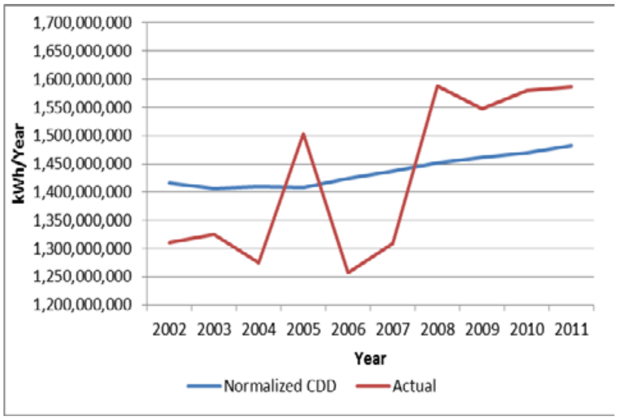




Graph N: GDP held constant; normalized variation due to population

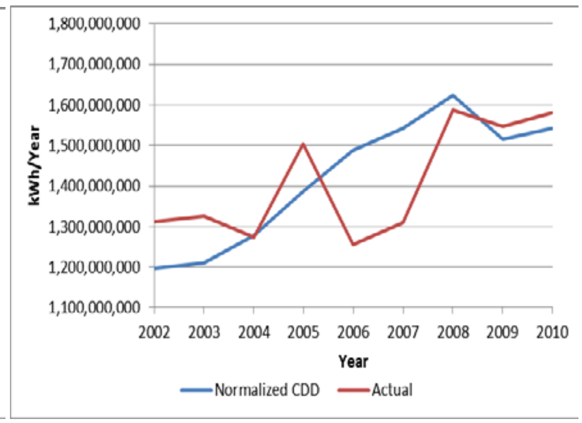
Graph O: GDP held constant; normalized variation due to CDD

Commercial building electricity usage was also analyzed in the same manner as the residential electricity data. Graph P shows electricity usage in commercial buildings with CDD held constant over time while population varies. Graph Q shows electricity usage as predicted if long-term average weather had prevailed over time while GDP varied. Graph R depicts variable weather while GDP is held constant. Note the rough similarities between these commercial building graphs and their corresponding residential buildings graphs. Like Graph K, Graph Q shows fairly good agreement between predicted electricity usage and actual usage, again highlighting that among the independent variables analyzed here, GDP appears to be the most important independent variable in driving commercial electricity usage.

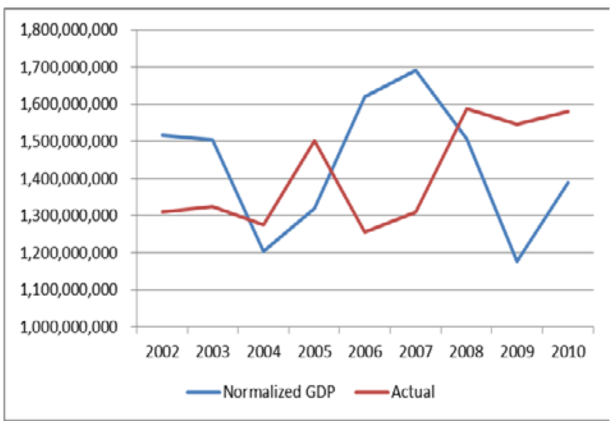
*Commercial Electricity Usage*




Graph P: CDD held constant; normalized variation due to population




Graph Q: CDD held constant; normalized variation due to GDP




Graph R: GDP held constant; normalized variation due to CDD

## 8.4 SUMMARY

The purpose of normalizing energy use data to population, GDP, and weather was to establish reasonable baselines for natural gas and electricity usage in the buildings sectors prior to SEP implementation. This was accomplished by selectively removing the influence of these independent variables on the dependent variables (natural gas and electricity usage) and discerning the relative strength of each independent variable in driving the dependent variables. In addition, our purpose was to hopefully be able to draw some conclusions from the analysis about the impact of Boulder County's SEP. Unfortunately, many factors affect energy usage, including energy costs and the recession, making it difficult to make any definitive conclusions that the SEP has had an effect on energy usage within Boulder county.

It is our understanding that the SEP was implemented in 2008, and in many of the graphs, we observed a drop in energy usage between 2008 and 2009. However, this time period also corresponds to the Great Recession, so it is not possible to distinguish whether the drop we see is due to the recession, the SEP, or a combination of both.

In general, natural gas usage leveled out throughout the 2000s, while electricity usage continued to increase. One possible explanation for this natural gas trend is that natural gas prices increased in the mid-2000s which could have caused a drop or leveling off in natural gas usage. A plausible explanation for the observed increasing trend in electricity usage is the cultural phenomenon of dramatic expansion in use of electronic devices.

This analysis indicates that, among the independent variables of weather, population, and GDP, weather most influences natural gas usage in both residential and commercial buildings while GDP most influences electricity usage in both building sectors.

Best-fit algorithms from the normalization exercise were driven with long-term average values for the independent variables to establish normalized baselines for natural gas and electricity usage in the pre-SEP period. In the future, with a sufficient body of data from the post-SEP implementation period, this same methodology can be applied to establish normalized post-SEP values for natural gas and electricity usage. The difference between pre-SEP and post-SEP will represent an estimate of the actual SEP impact.

Normalized pre-SEP baseline values for natural gas and electricity usage for the Residential and Commercial buildings sectors are summarized in Table 8-1, expressed as annual average per-capita values. For comparison, actual historical annual average per-capital values are also presented.

**Table 8-1: Annual Average Per-Capita Natural Gas & Electricity Usage**

| | Residential Buildings Sector | Commercial Buildings Sector |
|---|---|---|
| **Natural Gas Usage, therms/person-yr** | 291.68 Baseline | 294.23 Baseline |
| | 277.56 Actual | 276.36 Actual |
| **Electricity Usage, kWh/person-yr** | 3684.41 Baseline | 4938.05 Baseline |
| | 3632.16 Actual | 4902.53 Actual |

# 9. SEP GAP ANALYSIS

## 9.1 PURPOSE

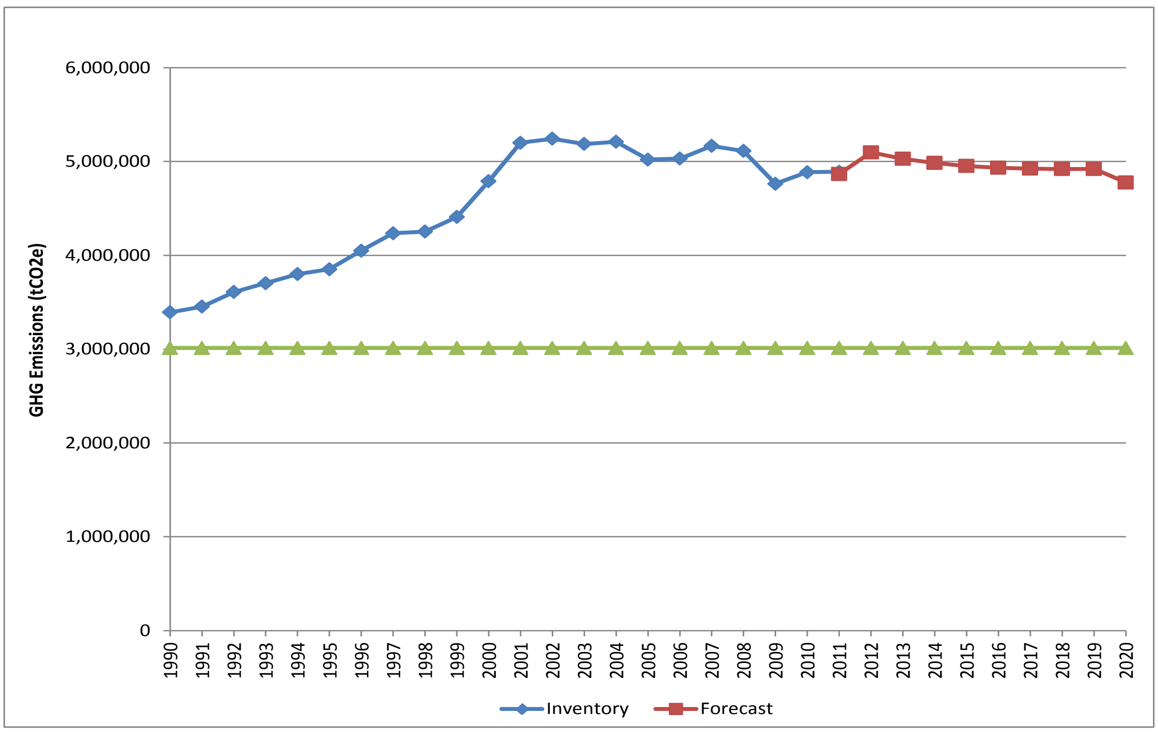
As part of WSP's 2012 – 2013 work scope, new initiatives were identified that could be pursued within the SEP context in order to increase programmatic impacts and thereby reduce the projected gap-to-plan.

## 9.2 PROJECTED GHG EMISSIONS GAP-TO-PLAN

WSP's 2012 update of the inventory of GHG emissions emanating from within the county economy produced an updated future Business as Usual emissions trajectory. This BAU trajectory incorporates anticipated future changes including: 1) reductions in the regional electricity grid carbon intensity; 2) improvements in average fuel efficiency of the vehicle fleet; 3) on-going impacts of the SEP and Xcel's DSM programs. Each of these emissions drivers are now part of the future BAU.

This recast BAU emissions trajectory is depicted in the following graph. In 2020 it estimates that economy-wide GHG emissions will be about 4,977,200 mtCO2e/yr. Compared to the goal of 3 million this leaves a gap of about 2 million mtCO2e/yr in 2020.

**Figure 9-1: Emissions Trajectory, 1990 - 2020**



## 9.3 GAP-CLOSING STRATEGIES FOR THE TRANSPORTATION SECTOR

WSP's 2012 – 2013 work scope included looking specifically at opportunities to reduce emissions from the Transportation sector. The updated IMS estimates that in 2020 county-wide BAU Transportation sector emissions will be about 729,400 tCO2e. This represents an impressive reduction compared to the historical peak of 1,003,800 tCO2e in 2006. Furthermore, this sector's nominal 2020 target is 738,600 (40% below 2005 sector emissions), meaning the updated BAU trajectory projects that this sector will *over-achieve* its nominal target by 9,200 tCO2e/yr in 2020 without Boulder County taking any additional actions.

As detailed in the following section of this chapter, WSP analyzed several specific emissions mitigation actions that offer potential to further deflect downward the already-established declining BAU trajectory for the Transportation sector. Clearly it is technically and economically feasible to reduce emissions well below the target level. To the extent that this outcome can be realized, it will reduce pressure on other sectors which are projected to face much more formidable gaps-to-target. Below are summarized several key Transportation sector strategies that together have real potential to achieve substantial reductions beyond BAU.

### 9.3.1. Transportation Sector Summary

Table 9-1 summarizes the potential impact of the specific Transportation sector mitigation actions discussed above that appear to offer attractive technical and financial performance. NOTE: This summary does not account for interactions among the various actions. For example, while fuel efficient tires will benefit the performance of electric vehicles, the emissions mitigation attributable to the tires will be lower for an EV than for a gasoline-fueled vehicle. Likewise, the mitigation attributable to the tires will be lower for a vehicle running on E15 than for a vehicle running on pure gasoline. Thus, this summary represents relative magnitudes of mitigation achievable with the specific actions.

**Table 9-1: Potential Mitigation in Transportation Sector**

| | tCO2e/yr in 2020 | Mitigated tCO2e/yr in 2020 |
|---|---|---|
| Projected Transportation sector BAU Emissions | 729,400 | |
| Nominal Transportation sector target | 738,600 | |
| **Required emissions reduction** | **(9,200)** | |
| Feebate | | 33,000 |
| Battery leasing | | 12,400 |
| Green E15 fuel | | 19,000 |
| Fuel efficient tires | | 10,000 |
| Hybrid-electric vehicles | | 21,400 |
| Compressed natural gas vehicles | | 13,200 |
| TMP | | 19,400 |
| | **Total mitigation** | **128,400** |
| **Remaining gap-to-plan after mitigation actions** | **(137,600)** | |

The strategic planning implication of this analysis is that the Transportation sector offers the opportunity to over-achieve its GHG target by about 138,000 mtCO2e/yr, relative to the sector's nominal 2020 target, and thereby reduce in like amount the nominal 2020 targets of the Commercial and Residential Buildings sectors.

## 9.4 CANDIDATE INITIATIVES TO CLOSE GAP

While the gap between projected emissions in 2020 and the 2020 goal, remaining after implementation of all mitigation actions discussed previously, is only a rough estimate, it strongly suggests that the County and its partners must design and implement new mitigation initiatives that will further deflect the trajectory downward over time. The primary targets for additional mitigation actions are the same today as they were in 2006 when WSP developed the first economy-wide GHG inventory for Boulder County. The Commercial Buildings sector remains the largest emissions source followed by the Residential Buildings sector and then the Transportation sector. These relative rankings are projected to continue until approximately 2020 when anticipated improvements in vehicle fleet average fuel efficiency push the Transportation sector GHG emissions below those of the Industrial sector. Thus, it is critical that new and effective mitigation initiatives be crafted to strongly impact the buildings and transportation sectors in particular.

Toward this end, WSP describes below several initiatives that have potential to capture substantial emissions mitigation if designed well and implemented properly. Some of these represent new initiatives while others are existing SEP initiatives but warrant redoubled effort to capture their mitigation potential. Some of these can be pursued by Boulder County independent of local governments, the State of Colorado, and federal government while others will require collaboration with these other players. Therefore, the menu of gap-closing initiatives is parsed into three 'buckets' – 1) those actions over which Boulder County has direct control; 2) those actions over which Boulder County can exert influence; and 3) those actions requiring legislation at the state level.

### 9.4.1. Actions Over Which Boulder County Exercises Direct Control

The emissions mitigation actions described here can be unilaterally implemented by Boulder County government.

#### i) PACE – Commercial & Residential Solar and Energy Efficiency

During the 2013 legislative session, the Colorado Senate passed SB 212 to create a commercial property-assessed clean energy (CPACE) program that would give Colorado commercial property owners access to loans for energy efficiency and renewable energy projects.

Through the CPACE program, businesses would be able to finance energy projects upfront and save on their electricity costs, as they pay back the loans via special assessments on their property tax.

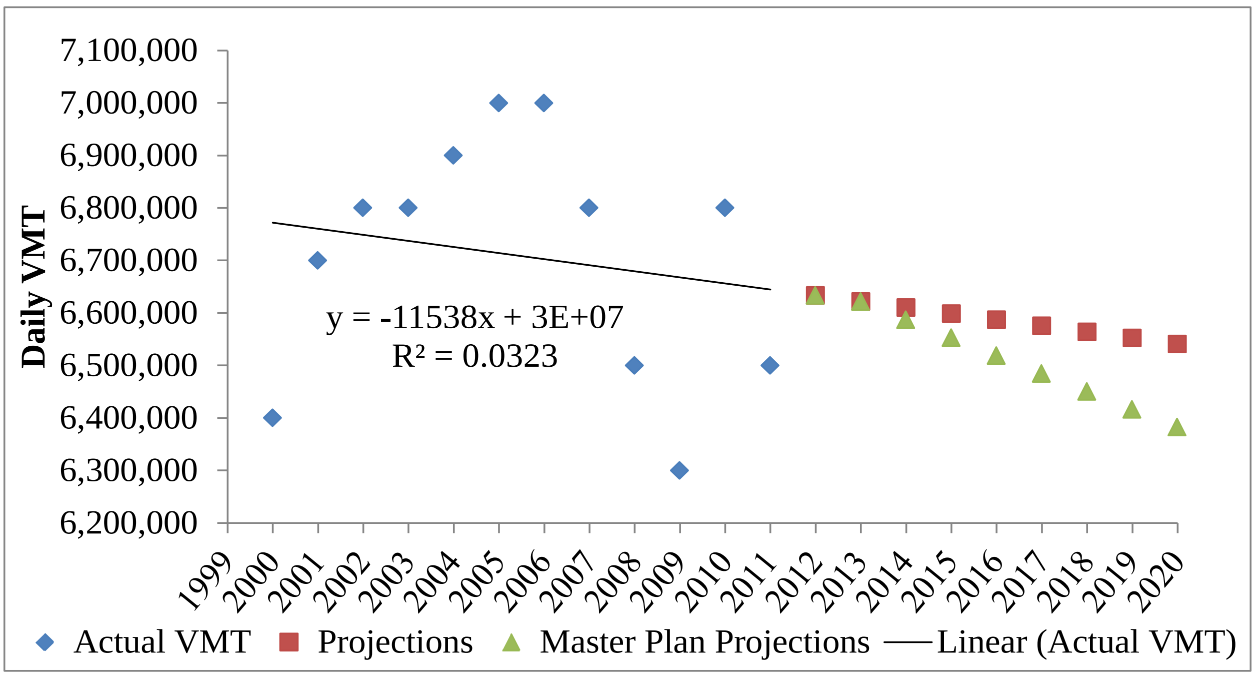
If the Colorado House passes the companion bill and the governor signs it, the CPACE program would follow this process:

- Commercial property owners will voluntarily opt into a PACE district, which is a specially designated economic improvement district.
- The business will specify the cost of the energy project it wants, such as HVAC, refrigeration, solar hot water, etc.
- The district will issue a bond to fund the project.
- The resulting bond sale proceeds would fund approved energy projects.
- The business' incremental property tax assessment would be less than the energy cost savings delivered by the project.

### ii) Transportation Master Plan Impact on VMT

Based on information provided by the Boulder County Transportation Department, WSP estimates that full implementation of the TMP could reduce county-wide VMT by about 0.5% per year, versus 0.2% per year without the TMP (see graph below). This 0.03% per year VMT difference translates into an additional 2.7% reduction in 2020 which, in turn, represents a GHG emissions reduction of about 19,000 mtCO2e in 2020 compared to BAU.

**Figure 9-2: Projected Impact of TMP on VMT**




### iii)ESCO Guarantee Fund to Backstop Small Commercial Buildings Sector

ESCOs are traditionally unwilling to enter the market segment represented by smaller businesses, given (i) the high failure rate of small businesses, which exposes the performance contracting scheme at an unacceptable degree of risk; and (ii) the high transaction costs of engaging with small companies relative to the potential savings (and thus earnings) achievable from them.

A Guarantee Fund supporting performance contracting could address both barriers:

- It could be designed as a mechanism covering either the credit risk taken by ESCOs that obtain loans to finance the project development costs, or the performance risk from the expected savings of ESCOs' customers.
- It could be offered within a program framework that bundles together several end-users in need of similar EE measures.

The effect of the Guarantee Fund would be that of opening to the ESCO industry an entirely new market that offers among the highest potential for energy savings and emissions reductions for the county. If effective, it could support a real market transformation in a critical market segment.

### iv)RECO/CECO in Unincorporated Boulder County

A Commercial Energy Conservation Ordinance (CECO) program would require energy efficiency measures to be undertaken by commercial building owners. The CECO can be implemented at the point of sale of a building or when a new lease is put in place. By having a regulatory mandate as a means to aggressively push forth these energy reduction measures, the likelihood of coming closer to the County's GHG goals is increased. Combined with a strong Commercial PACE program and an ESCO guarantee fund, the CECO would have the financial support needed to facilitate substantial retrofits.

A Residential Energy Conservation Ordinance (RECO) program would similarly require energy efficiency measures to be undertaken by residential building owners. The RECO can be implemented at the point of sale of a residential unit or through the renewal/application of rental license. Combined with a strong Residential PACE program, the RECO would have the financial support needed to facilitate substantial retrofits.

RECO could be implemented in Unincorporated Boulder County. If RECO drove energy savings to the level estimated in Chapter 3: Residential Buildings to be delivered by a hypothetical package of energy efficiency measures represented as Bundle 2, WSP estimates that 56,290 mtCO2e/yr of emissions mitigation would be realized in 2020.

Likewise, CECO could be implemented in Unincorporated Boulder County. If CECO drove energy savings to the level estimated in Chapter 4:Commercial Buildings to be delivered by a hypothetical package of energy efficiency measures represented as Bundle 2, WSP estimates that 19,400 mtCO2e/yr of emissions mitigation would be realized in 2020.

### v) County Operations Internal Carbon Tax

Relatively low energy prices benefit operating costs for County government operations but they diminish the economic incentive for operations managers to invest in energy efficiency and renewable energy actions. While Boulder County commissioners have no control over an economy-wide carbon tax, they could act unilaterally to impose an 'internal carbon tax' on County government operations. An internal carbon tax, if designed and implemented properly, would provide an economic incentive for managers to take actions to shrink the County operations carbon footprint.

WSP is currently assisting Microsoft Corporation to structure an 'internal' carbon tax. This tax is strictly an internal accounting tool used in Microsoft's corporate GHG mitigation strategy. An operating unit that exceeds its carbon emissions allocation has an additional operating 'cost' tallied on its profit-and-loss statement that reduces the internally-recognized net profit and thereby incentivizes the management to take emissions mitigation actions to avoid this carbon 'tax'.

This same concept could be applied to the County's operations, as a mechanism to internalize the externalities of fossil fuel usage, increase the apparent cost of that energy, and thus incentivize actions that aren't economically attractive otherwise.

Using the assumptions of the Colorado Model developed by the Carbon Tax Center (http://www.carbontax.org/issues/energy-demand-how-sensitive-to-price/), WSP estimates that an internal tax on carbon emissions, applied to Boulder County operations, would drive mitigation of about 3,130 mtCO2e/yr in 2020. Total internal carbon tax burden in 2020 would be about $716,000 and the MAC would be (+229) $/mtCO2e. It is useful to bear in mind that the internal carbon tax 'burden' should be viewed as a local economic development tool (see discussion below in context of an actual carbon tax).

#### vi) Low energy-intensity asphalt

To the extent that Boulder County has the authority to require road-paving contractors to use low energy-intensity asphalt, GHG mitigation of as much as 18% can be realized in the process energy required for asphalt paving operations. Additives are now available that can enable savings of this magnitude by means of temperature reduction during both the manufacturing and paving processes, so less energy is needed, and costs are reduced for both asphalt manufacturers and road pavers.

#### vii) Low solar-absorptivity pavement topping

Nano-engineered pavement toppings are now available that dramatically reduce the solar absorptivity of paved surfaces. Widespread treatment of roads and parking lots has the potential to significantly reduce the urban heat island effect and thereby reduce the associated electricity consumed by neighboring buildings for summertime air conditioning. The limited durability data available so far strongly suggest that these toppings can actually reduce paved surface maintenance costs.

### 9.4.2. Actions over Which Boulder County Exercises Influence

The emissions mitigation actions described here cannot be unilaterally implemented by Boulder County government, but represent actions that commissioners could encourage municipalities to act on.

#### i) RECO/CECO in Municipalities

If RECO could be implemented in any of the Boulder County municipalities it would be a powerful tool for driving emissions mitigation in the local housing stock. Similarly, if CECO could be implemented it would be a powerful driver of mitigation in the local commercial buildings sector.

### ii) Longmont Power EE Rebates

Longmont has the good fortune of owning its own municipal utility. This presents important opportunities that are not available to the other communities within Boulder County. Longmont officials should vigorously explore the many ways in which Longmont Power & Communications can cost-effectively promote DSM and RE to benefit its citizen-owners. A potentially powerful tool at LP&C's disposal is its state-of-the-art fiber optic network. Combining this asset with a smart grid would unlock substantial potential to tap aggressive DSM and thereby significantly reduce GHG emissions associated with Longmont buildings.

### iii) City of Boulder Municipalization

Since the primary challenge Boulder County faces in terms of its updated BAU emissions trajectory is the projected continuing growth of emissions from electricity usage, the Commissioners should consider supporting the City of Boulder in the event that City Council decides to pursue municipalization. WSP has not analyzed the veracity of the City's claims that municipalization will enable dramatic and rapid de-carbonization of the city's economy-wide carbon footprint. However, even if these claims turn out to be only half-correct, Boulder would realize a 25% reduction in its footprint in short order. This in turn would automatically translate into an approximate 8% reduction in the county's economy-wide footprint; an approximate 400,000 mtCO2e/yr 'freebie' in 2020.

### iv) Combined Heat & Power

If about 26% of county industrial facilities installed natural-gas fired reciprocating engine CHP by 2020 and if another 15% installed natural-gas fired microturbine CHP by 2020, GHG mitigation of about 62,000 tCO2e/yr could be realized in 2020. This level of mitigation represents 100% of projected gap-to-plan for the sector in 2020.

### v) Green leases

Existing commercial buildings are the single largest source of GHG emissions in the Boulder county economy. Thus they offer substantial opportunities to save energy and reduce carbon emissions. However, the "split incentive" associated with the investments required to improve operating efficiency is a result of standard leasing practices that share operating and capital expense responsibilities between landlord and tenant. This split greatly reduces the landlord's ability to recover capital invested in energy efficiency. Unfortunately the result is inaction, even in the face of rising energy prices and other pressures to improve the performance of buildings. Without addressing the split incentive, landlords will continue to be discouraged from upgrading their buildings and tenants will continue to be largely saddled with the operating costs of inefficient buildings.

Much work has been done in recent years, by WSP and many others, on the creation and implementation of 'green leases' that directly attack the split-incentive challenge. Implementation of a green lease program has the potential to unlock the very substantial energy savings, and thereby the critical GHG mitigation potential, that could be enabled by harnessing the ESCO-delivery model and a complementary and reinvigorated Commercial PACE program.

### 9.4.3. Actions Requiring State or Federal Legislation

The emissions mitigation actions described here cannot be implemented by Boulder County government, but require legislation at the state or federal government levels.

#### i) Economy-Wide Carbon Tax

Conventional energy costs in Boulder County are relatively low compared to most regions of USA. While these low energy prices benefit operating costs for businesses and living costs for citizens, they do not reflect the true cost of fossil fuel consumption in terms of the real impacts imposed on the environment and on society. Paid prices do not incorporate these ‘externalities’. Avoiding having to pay for externalities naturally diminishes the economic incentive to invest in energy efficiency and renewable energy actions within individual business operations and individual households. A tax on carbon could internalize most or all externalities, thereby providing an economic incentive to take actions to shrink business and household carbon footprints.

Furthermore, a carbon tax can be a powerful channel for financing the energy efficiency, renewable energy, and fuel-switching actions that are necessary to aggressively mitigate carbon emissions. It is in fact an economic development tool since the tax proceeds, if channeled into mitigation projects, will create substantial numbers of new jobs and with them substantial new economic activity and new sales and property tax revenues.

Using the assumptions of the Colorado Model developed by the Carbon Tax Center (http://www.carbontax.org/issues/energy-demand-how-sensitive-to-price/), WSP estimates that a tax on carbon emissions, applied across the entire Boulder County economy, would drive mitigation of about 1,113,500 mtCO2e/yr in 2020. Total carbon tax burden in 2020 would be $254.7 million and the MAC would be (+229) $/mtCO2e.

The carbon tax ‘burden’, viewed more appropriately as a revenue stream with which energy efficiency, renewable energy, and fuel-switching actions within the county economy can be financed, is actually a powerful economic development tool.

#### ii) Vehicle Feebate

Under a feebate program, purchasers of new light vehicles are charged a fee or assigned a rebate depending on the vehicles’ relative greenhouse gas (GHG) emissions level. Vehicles with a GHG emissions level lower than a certain benchmark earn a rebate, while vehicles with a GHG emissions level higher than the benchmark incur a fee. Receipts from the fees provide resources for the rebates, so that the program is self-financing.

If a feebate program were implemented, such that by the end of 2020, 100% of the county’s private vehicle fleet comprised vehicles treated by the program, it is estimated that 2020 carbon emissions reductions could be about 33,000 mtCO2e/yr.

### iii) Increase Colorado RPS

If the State were to increase the Renewable Portfolio Standard, the County would reap significant GHG reduction benefits. Increasing the RPS to 35% by 2020 (current target is 30% by 2020) would result in emissions reductions of 274,208 mt$CO_2$e/yr in 2020. A 40% RPS would reduce emissions by a further 73,873 metric tons $CO_2$e, for a total reduction of 348,081 mt$CO_2$e/yr in 2020.

### iv) Extend Tax Credit for Hybrid-Electric Vehicles

As a specific real-world point of comparison, the Honda Civic hybrid-electric vehicle (conventional hybrid, not plug-in hybrid) achieves GHG emissions reductions of about 29%, compared to the standard gasoline Civic. If purchased in 2013, a Honda Civic HEV would have a simple payback of about 7 years due to the fact that federal tax credits for HEVs have already expired. The Colorado tax credits for HEVs will expire at the end of 2013 after which simple payback would increase to about 8 years. If in 2020, 10% of the county-wide vehicle fleet were HEVs, about 21,000 mtCO2e/yr of emissions mitigation would be achieved.

### v) Promote E15 Fuel

Since early 2012, USEPA has allowed the retail sale of E15 fuel (15% ethanol, 85% gasoline blend) for all gasoline automobiles and trucks of 2001 model year or newer, not just vehicles manufactured to burn E85 fuel. Nationally, these vintages of vehicles represent about 67% of the total vehicle fleet. Several independent studies have shown that gasoline vehicles newer than 1985 can actually burn up to E30 without any negative effects.

If Boulder County were to promote the retail availability of ‘green’ corn ethanol (see discussion in 5.5.1), and combine that initiative with one that promotes the retail sale of E15, conventional green ethanol has the potential to be a potent mid-term tool in the GHG mitigation toolbox for the Transportation sector, delivering significant GHG mitigation while also providing a critical bridge to the future when truly sustainable ‘deep-green’ ulta-low-carbon ethanol becomes commercially available via next-generation production technologies and non-food feedstocks. If in 2020 30% of county-wide VMT were driven by vehicles running on E15, GHG mitigation of about 19,000 mtCO2e/yr could be realized.

### vi) Promote CNG Passenger Vehicles and Fueling Stations

Compressed natural gas is an attractive alternative vehicle fuel due to its lower cost and lower GHG emissions relative to gasoline and diesel. WSP compared the performance of a Honda Civic CNG vehicle to that of a standard gasoline Civic. The $8,700 difference in retail price can be recovered fairly quickly by taking advantage of federal and Colorado tax credits that are available through 2020. A CNG version of this vehicle could achieve about a 4-year simple payback.

Honda Civic CNG vehicles deliver GHG emissions reductions of about 18%, on a per-mile-driven basis, compared to a standard gasoline Civic. If in 2020 10% of county-wide vehicles were running on CNG, GHG mitigation of about 13,000 mtCO2e/yr could be realized.

Note that the biggest barrier to adoption of this technology by the motoring public is the lack of fueling infrastructure. Thus, a key strategy for enabling market penetration of CNG vehicles is incentivizing the construction of a robust fueling infrastructure.

### vii) CNG Trucks

Compressed natural gas is an attractive alternative truck fuel too. Using DOE-VICE, a model developed by NREL specifically to estimate the life-cycle cost of owning and operating CNG trucks and buses, WSP compared the performance of a generic CNG trash-hauling truck fleet to that of a standard truck fleet running on diesel. The $30,295 difference in truck purchase price can be recovered by taking advantage of federal tax credits on fleet CNG fuel and the lower fuel cost-per-mile offered by CNG versus diesel. A CNG version of a 15-truck fleet purchased in 2013 could achieve a 3-year simple payback and realize NPV of about $293,000 per truck over its assumed 8-year lifetime.

CNG trash trucks deliver GHG emissions reductions of about 22%, on a per-mile-driven basis, compared to a diesel truck. Since WSP didn't have data on the specific VMT for the county-wide trash truck fleet, we were not able to estimate the economy-wide impact of CNG conversion. However, this GHG mitigation action is quite attractive because the mitigation potential for this sub-sector is substantial and, with a simple payback of 3 years, the private trash-hauling businesses that operate in Boulder county may find conversion to CNG to be an attractive investment.

### viii) Tax Credit for Fuel Efficient Tires

Vehicle tires specifically designed to maximize fuel efficiency can reduce fuel usage by as much as 7%, according to General Motors. If 20% of vehicles in Boulder county were equipped with such tires in 2020, the Transportation sector GHG emissions in that year could be reduced by 10,000 tCO2e/yr

### ix) PHEV/EV Battery-Leasing Program

This temporary program would aim to alleviate concerns about the current high cost of batteries for plug-in hybrid electric vehicles (PHEVs) and electric vehicles (EVs), and thereby facilitate market transformation toward widespread adoption of these types of vehicles. The batteries would be owned and managed by an ESCO or equipment leasing company, or possibly the local electric utility, and leased to PHEV/EV owners. When a battery reaches the end of its life, the program would recycle the battery properly and lease another battery to the car owner.

If a PHEV/EV battery leasing program were aggressively implemented, such that by the end of 2020, 5% of the county's private vehicle fleet were PHEVs or EVs, it is estimated that 2020 carbon emissions reductions could be about 12,000 mtCO2e. Even greater impacts can be achieved if Vehicle-to-Grid (V2G) technology were significantly deployed and exploited via a Smart Grid.

Note that the cost of batteries is expected to drop substantially over time and the cost of gasoline is expected to rise. For these reasons, the battery-leasing concept is a temporary programmatic action to create a bridge to the future in which consumers are not put off by PHEVs or EVs solely due to the cost of the battery packs. Note also that this analysis indicates this measure has a MAC of +339, compared to +38 for an HEV and +66 for a PHEV. However, this approach to PHEV ownership involves an up-front incremental capital cost of $4,000/vehicle (compared to the cost of a conventional vehicle). In contrast, the up-front incremental cost of a PHEV is $6,000. Thus, for consumers that want a PHEV but are constrained by the net up-front cost, a battery-leasing program appears to have significant advantage because 1) it would put these consumers in a PHEV, 2) even after their battery lease payment they would realize net energy cost savings compared to a conventional vehicle, and 3) they would emit about 16% fewer GHG emissions than if they were driving an HEV.

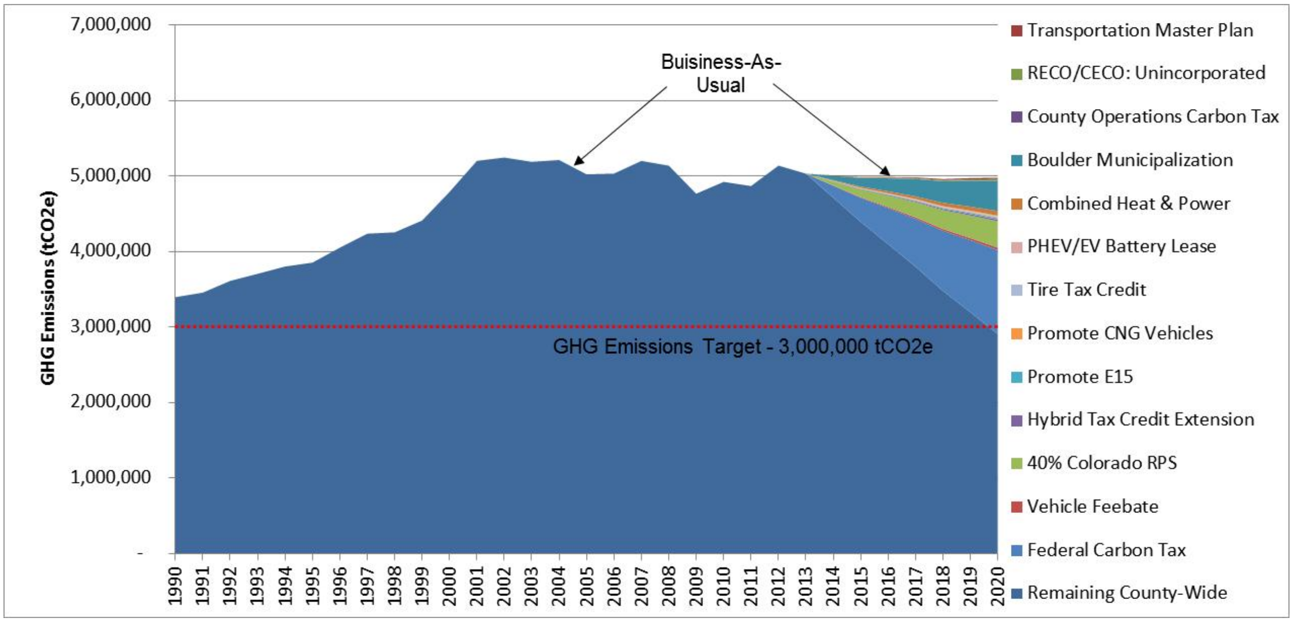
### 9.4.4. Summary of Gap-Closing Strategies

**Table 9-2: Potential Mitigation To Close the Gap**

| Bucket | Project | GHG Savings in 2020 (tCO2e) | |
|---|---|---|---|
| Control | Transportation Master Plan | 19,000 | |
| | RECO/CECO: Unincorporated | 19,400 | |
| | County Operations Internal $CO_2$ Tax | 3,130 | 41,530 |
| Influence | Boulder Municipalization | 400,000 | |
| | Combined Heat & Power | 62,000 | 462,000 |
| State/ Federal | Colorado $CO_2$ Tax | 1,113,500 | |
| | Vehicle Feebate | 33,000 | |
| | 40% Colorado RPS | 348,081 | |
| | Hybrid Electric Tax Credit Extension | 21,000 | |
| | Promote E15 | 19,000 | |
| | Promote CNG Vehicles | 13,000 | |
| | Hi-Efficiency Tire Tax Credit | 10,000 | |
| | PHEV/EV Battery Lease | 12,000 | |
| | | | 1,569,581 |
| **Total** | | | **2,073,111** |

These mitigation actions, if fully realized, would completely close the gap that the updated BAU trajectory projects in 2020. The wedge diagram below depicts the potential of each mitigation action. Note that interactions among these measures have not been quantified since this is beyond the WSP scope of work.

**Figure 9-3: Closing the Gap**




MACs for some of the above measures are summarized in Table 9-3.

**Table 9-3: MAC for Gap-to-Goal Projects**

| Reduction Measure | MAC ($/mtCO$_2$e) |
|---|---|
| Unincorporated Boulder County CECO | -91 |
| Unincorporated Boulder County RECO | -5 |
| Hybrid Electric Vehicle | +38 |
| Compressed Natural Gas Vehicle | -196 |
| CNG Trash Truck | -73 |
| Battery-Leasing Program | +339 |
| Carbon Tax | +229 |

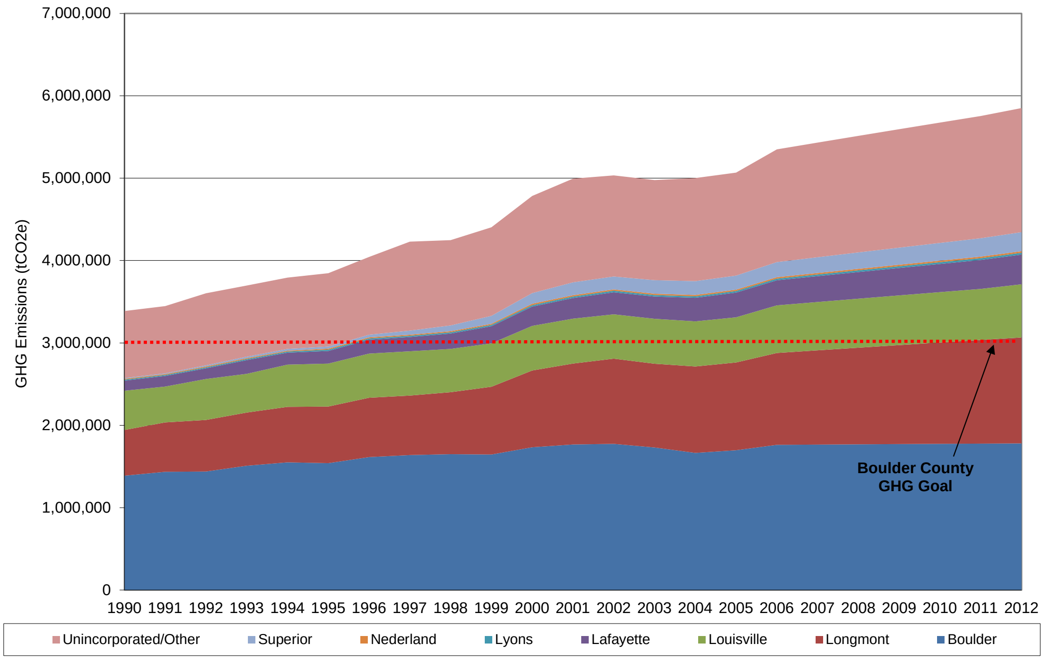
# 10. APPENDIX

## COMPARISON OF 2005 VERSUS 2011 INVENTORIES

*County-Wide Inventory*

Comparison of the county-wide GHG inventory developed by WSP in 2006 (based on historical data through 2005 and projected out to 2012) with the 2012 update (based on historical data through 2011 and projected out to 2020) clearly shows the desired trending. Figure 2-1 and Figure 10-2 illustrate the 2005 and 2011 Inventory profiles. They show that in 2006 the trajectory out to 2012 was decidedly an upward trend with projected GHG emissions of 5.85 million tCO2e/yr in 2012. Encouragingly, the 2011 trajectory out to 2020 flattens and actually starts to deflect downward with projected GHG emissions of 5.1 million tCO2e/yr in 2012, dropping to 4.95 million tCO2e/yr in 2020. SEP impacts are no doubt contributing to this trend, but currently it is macroeconomic forces that are likely the overwhelming drivers of this trajectory. While the desired trend of the historical upward-trending trajectory being flattened and then deflected downward over time is evident, the 2011 projection still leaves an estimated 2.1 million tCO2e/yr gap-to-goal in 2012 and a 1.98 million tCO2e/yr gap-to-goal in 2020. The current outlook is a substantial improvement over the 2.7 million tCO2e/yr gap-to-goal in 2012 predicted back in 2005, but clearly much additional progress is required.

## Figure 10-1: Boulder County GHG Inventory Profile, 1990 – 2012




## Figure 10-2: Boulder County GHG Inventory Profile, 1990 – 2020

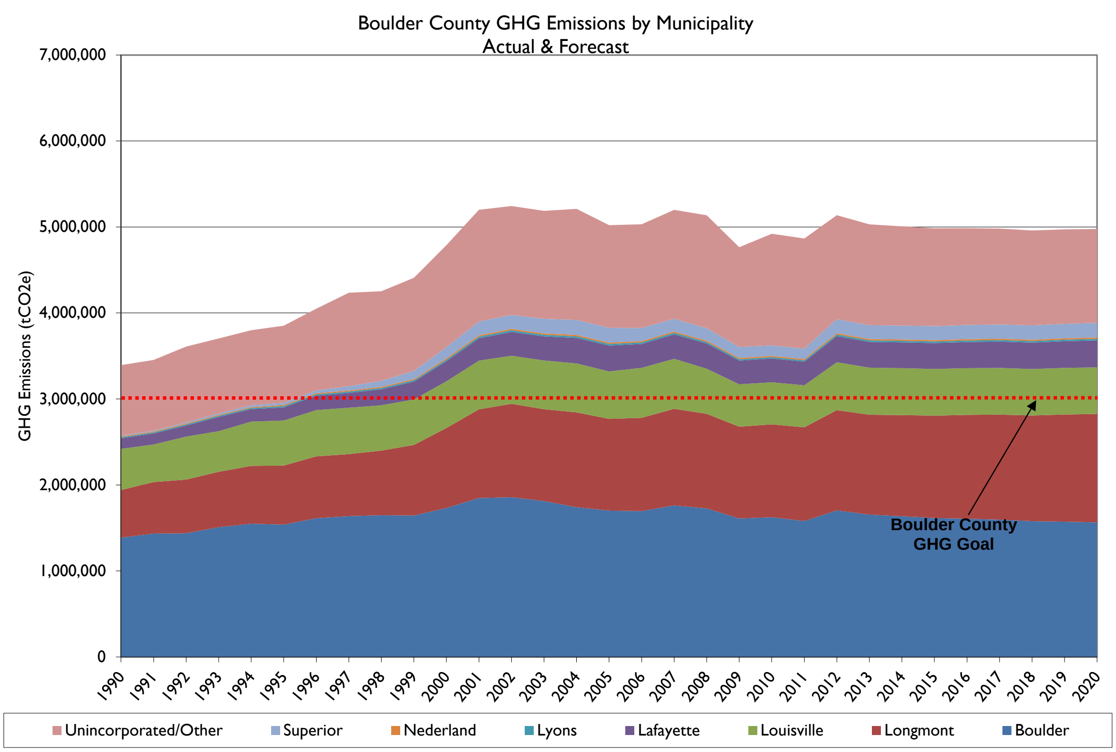


**Figure 10-3: GHG Emissions by Municipality, 2005**

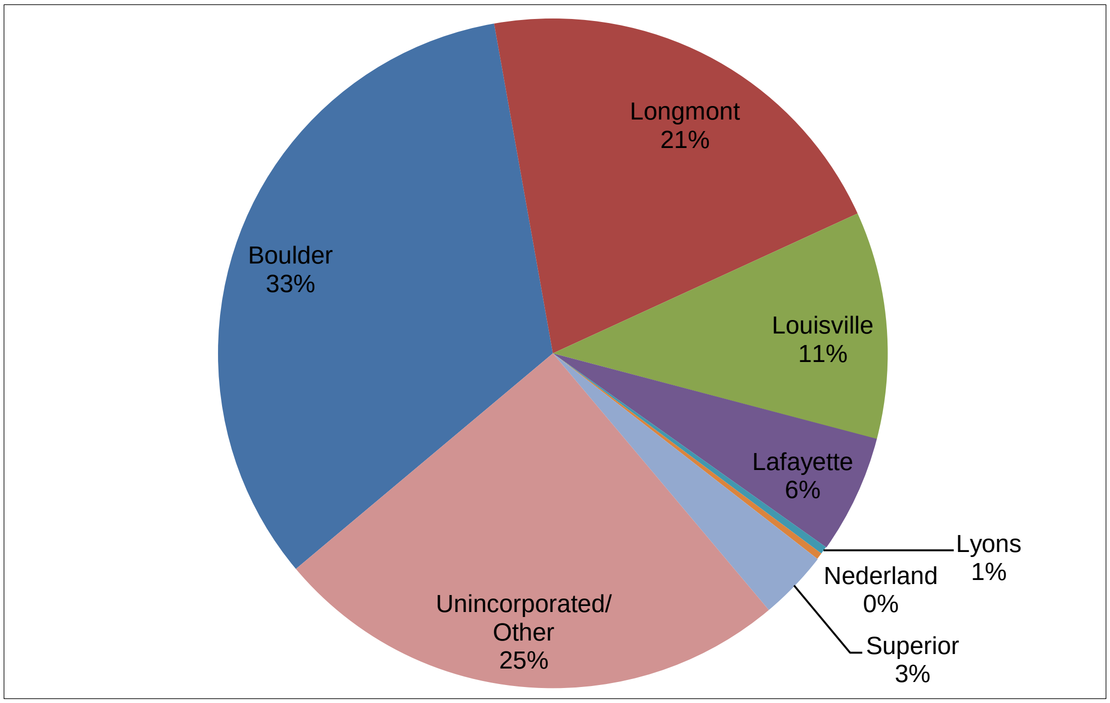



**Figure 10-4: GHG Emissions by Municipality, 2011**

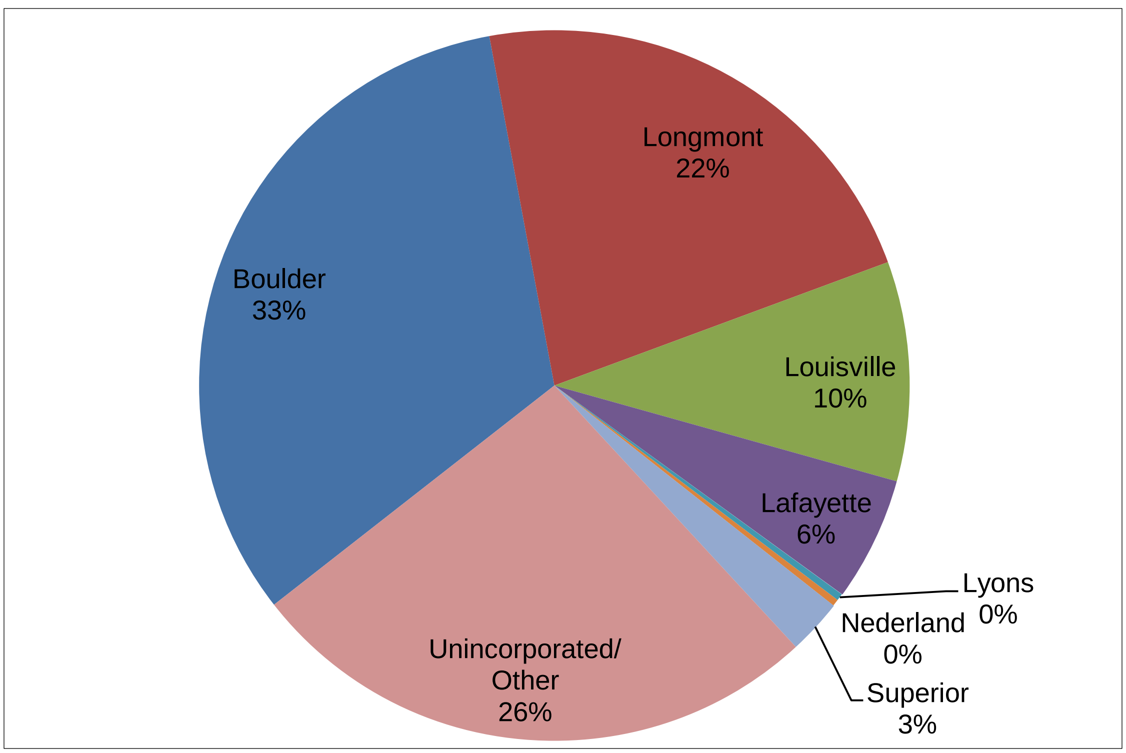


**Figure 10-5: Historical and Forecast Municipality Trends, 1990-2012**

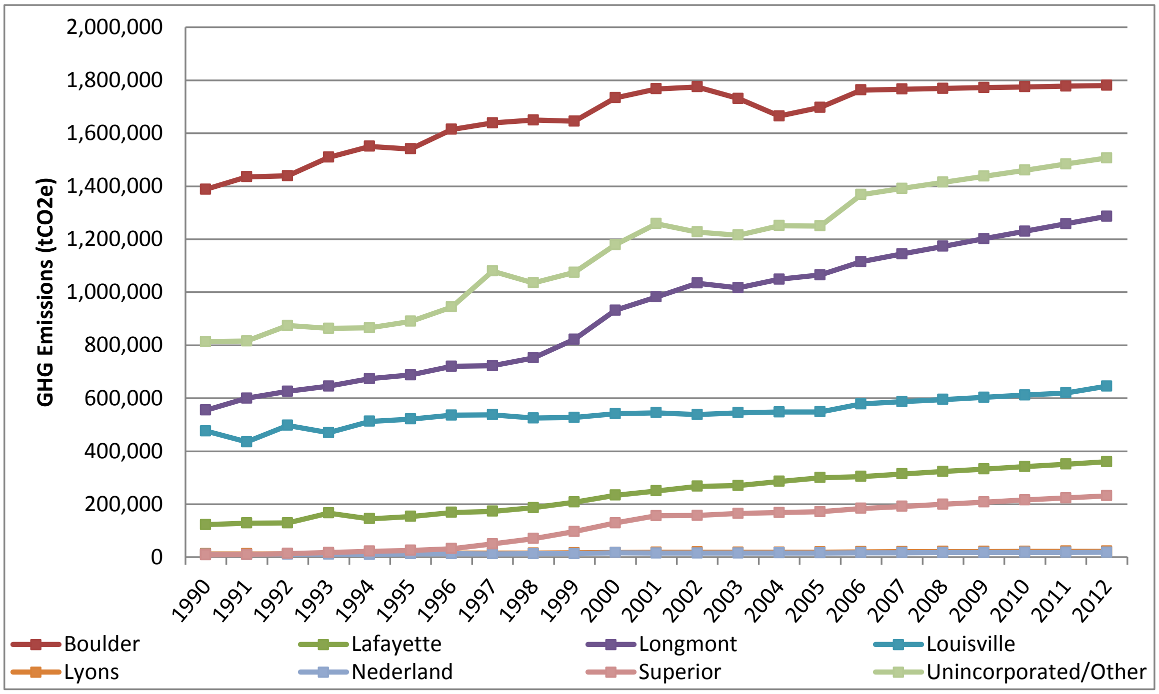



**Figure 10-6: Historical and Forecast Municipality Trends, 1990-2020**

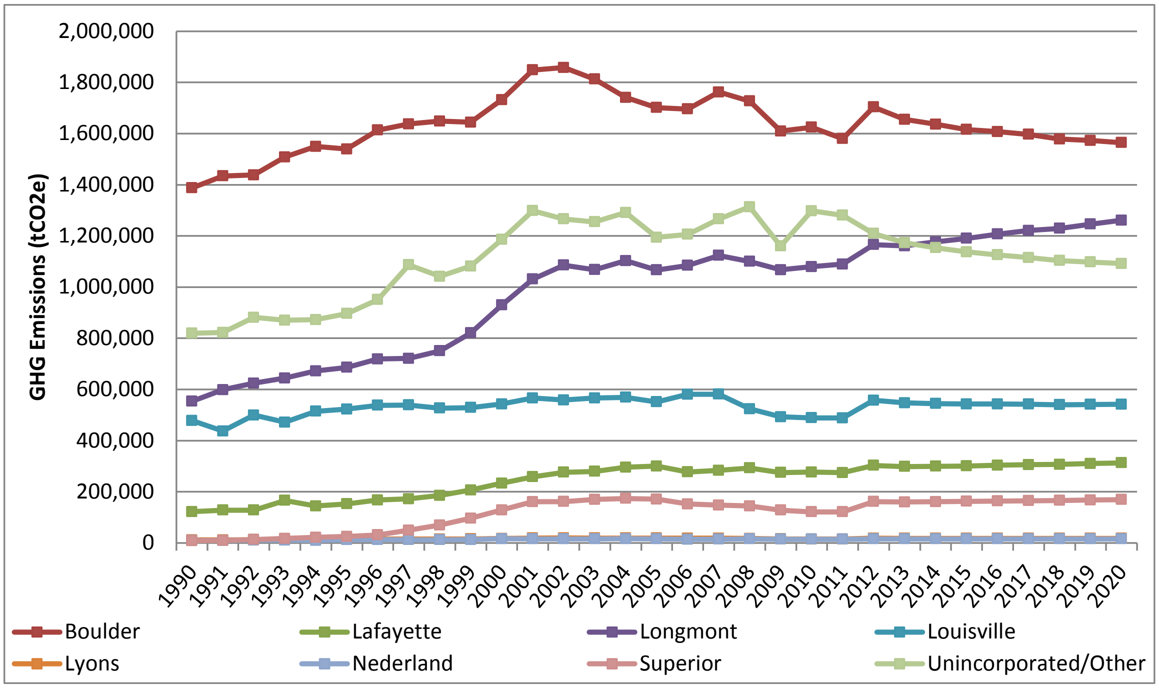


**Figure 10-7: GHG Emissions by Sector for Boulder, 2005**

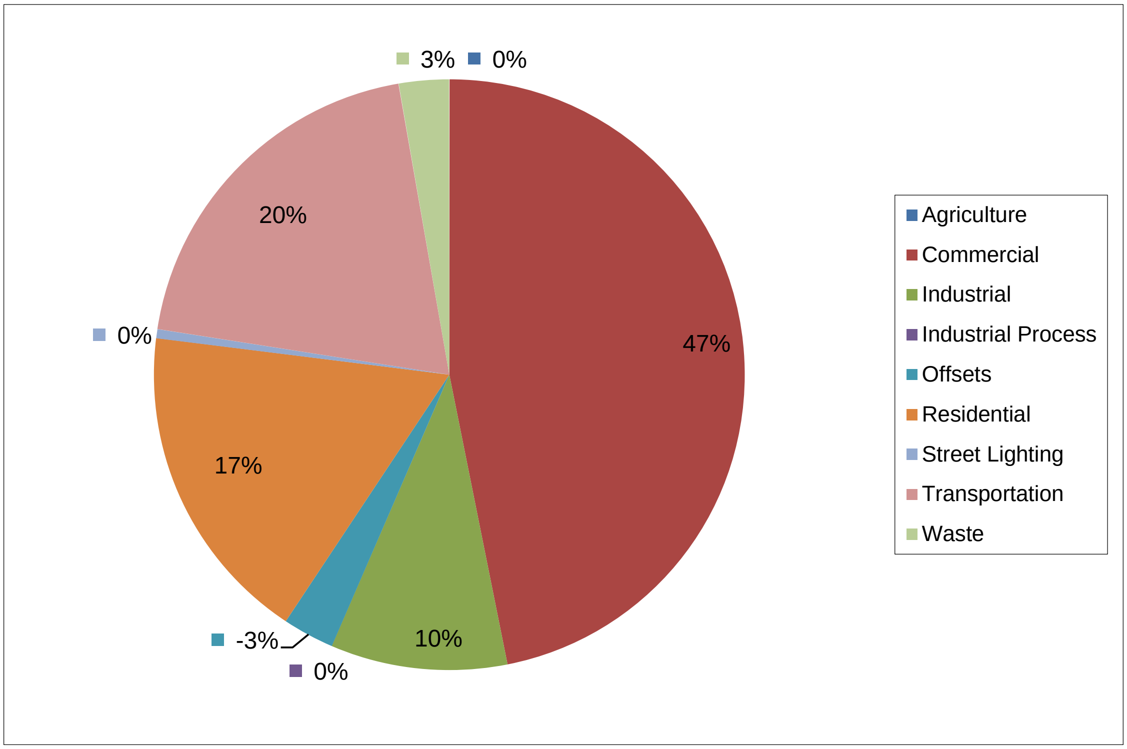



**Figure 10-8: GHG Emissions by Sector for Boulder, 2011**

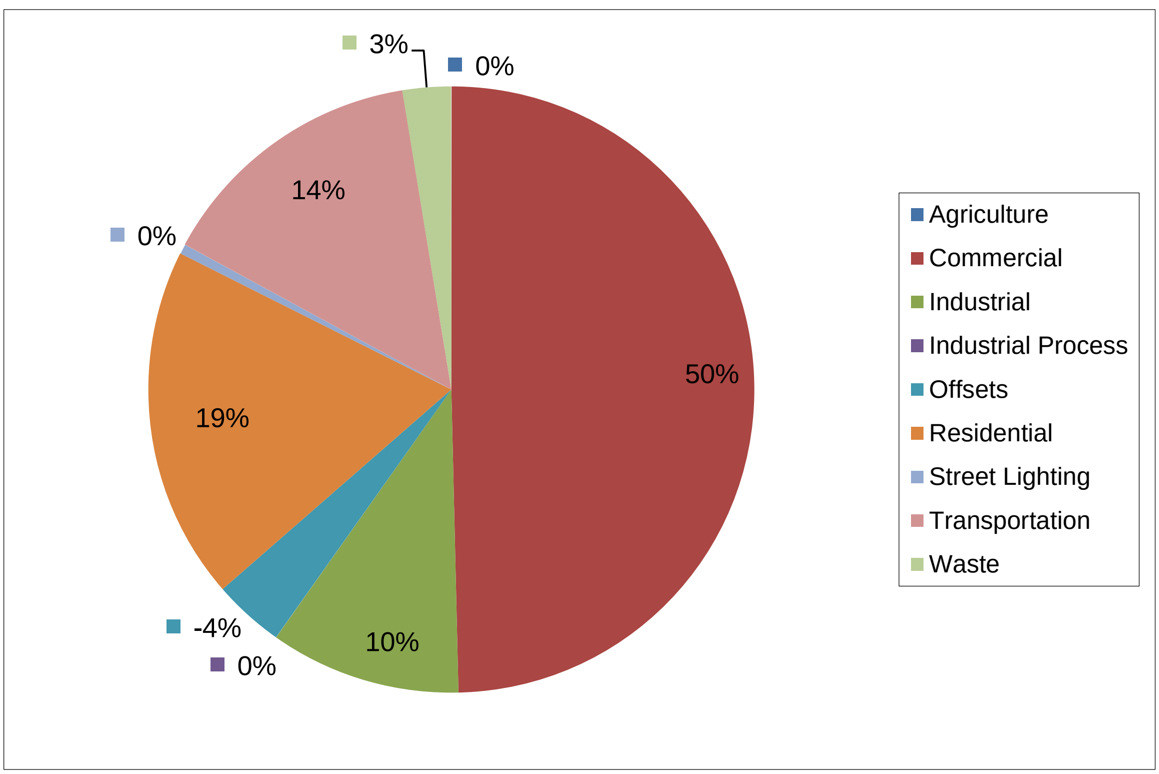


**Figure 10-9: GHG Emissions by Sector for Lafayette, 2005**

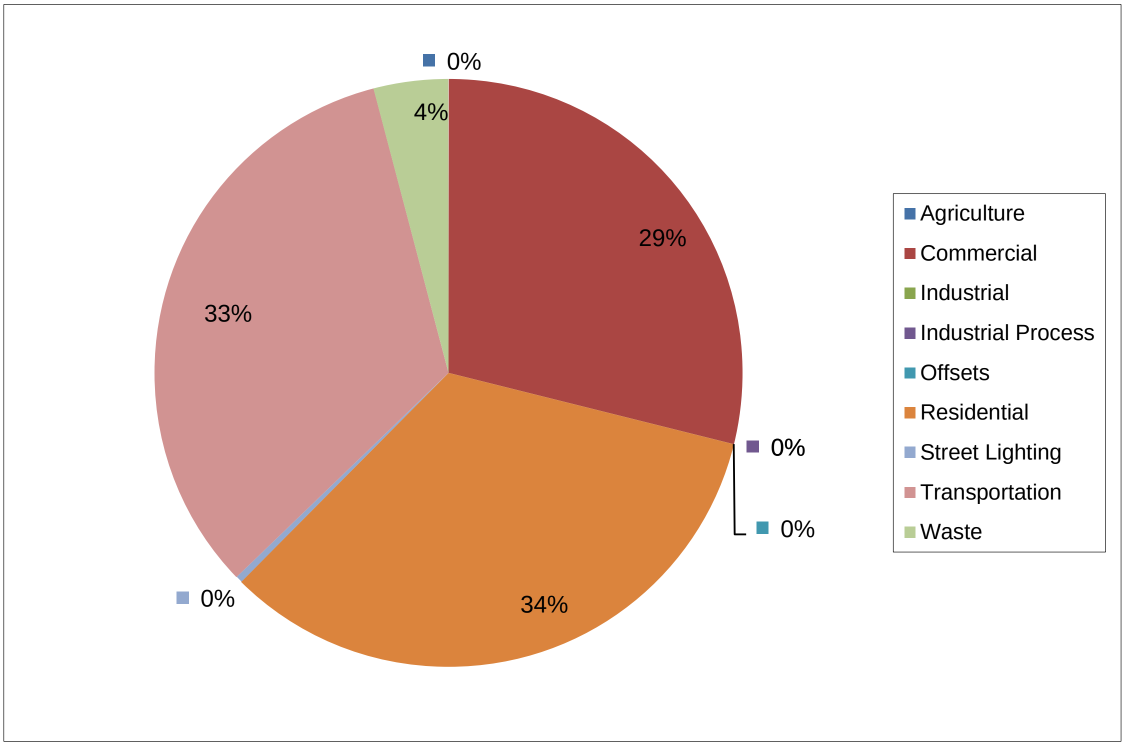



**Figure 10-10: GHG Emissions by Sector for Lafayette, 2011**

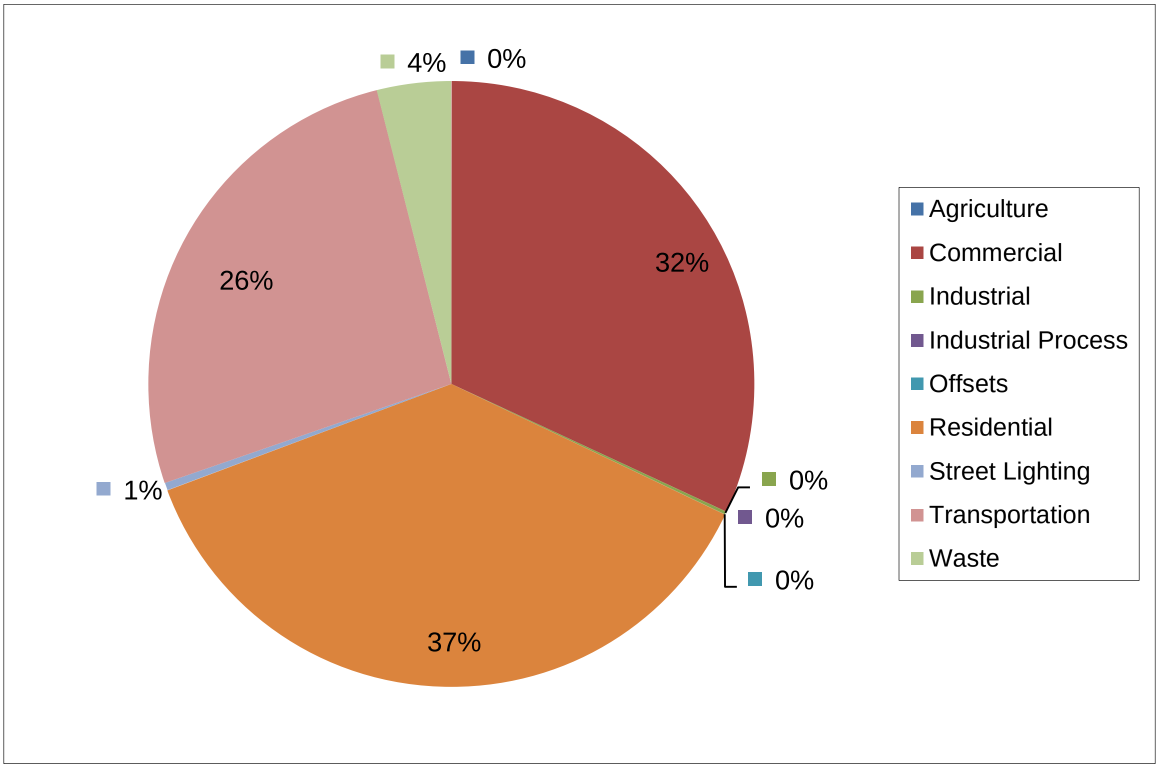


**Figure 10-11: GHG Emissions by Sector for Louisville, 2005**

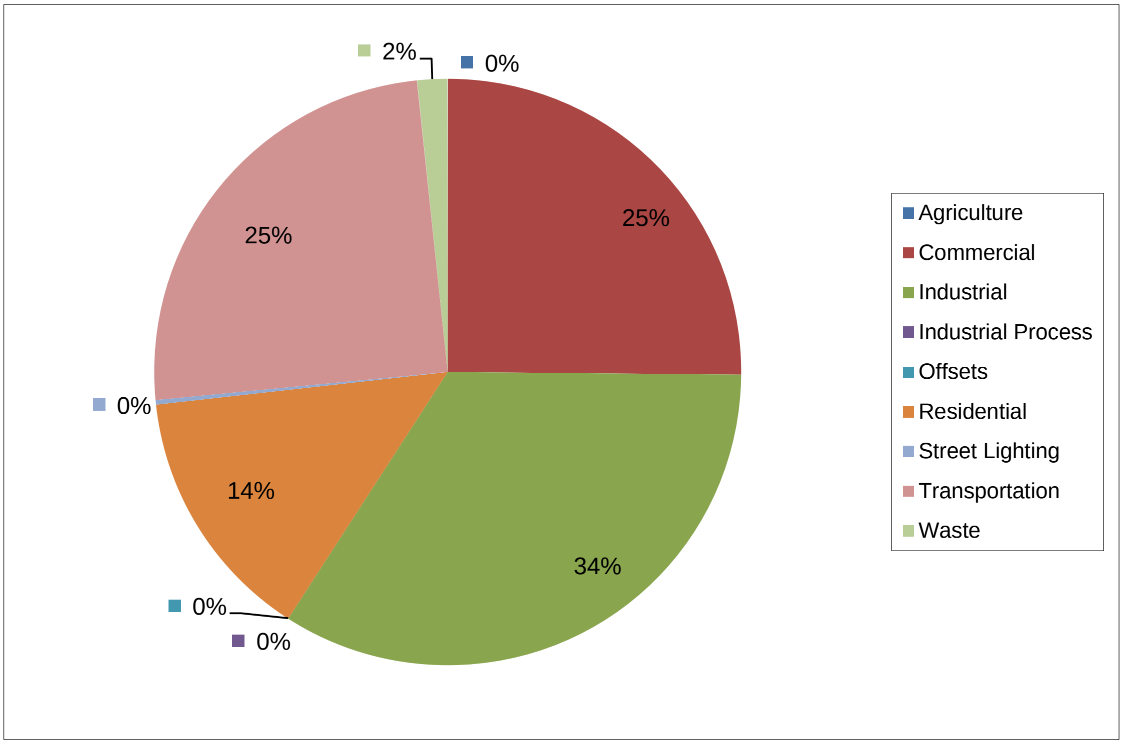



**Figure 10-12: GHG Emissions by Sector for Louisville, 2011**

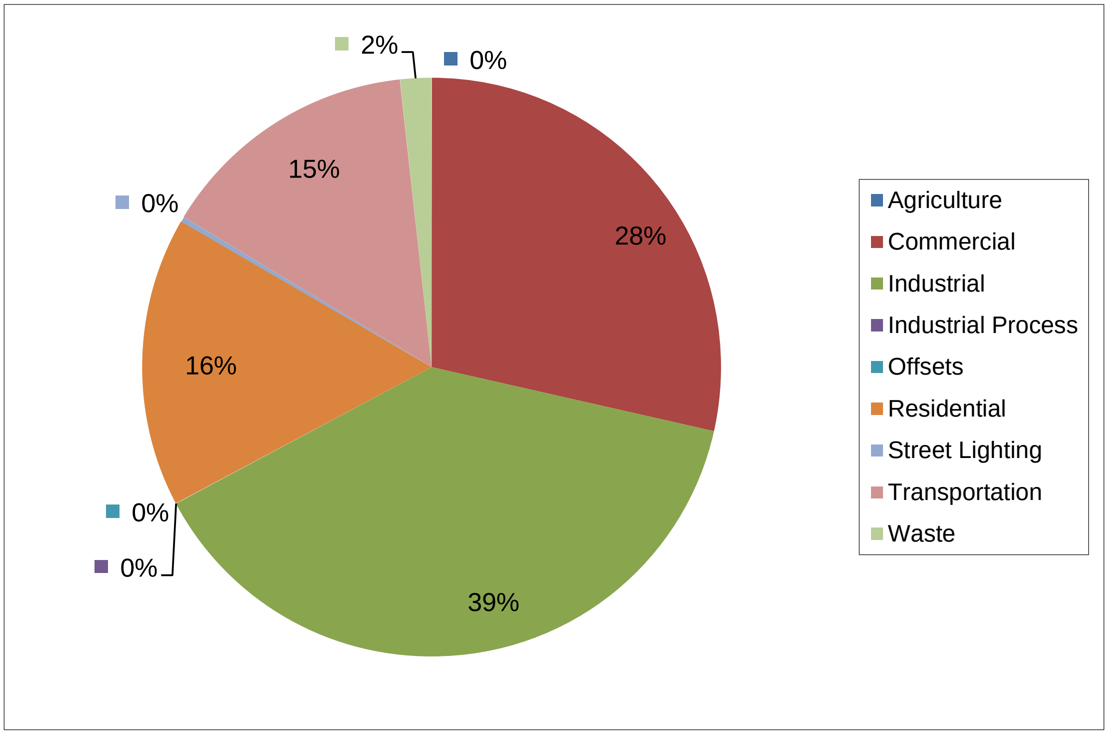


**Figure 10-13: GHG Emissions by Sector for Longmont, 2005**

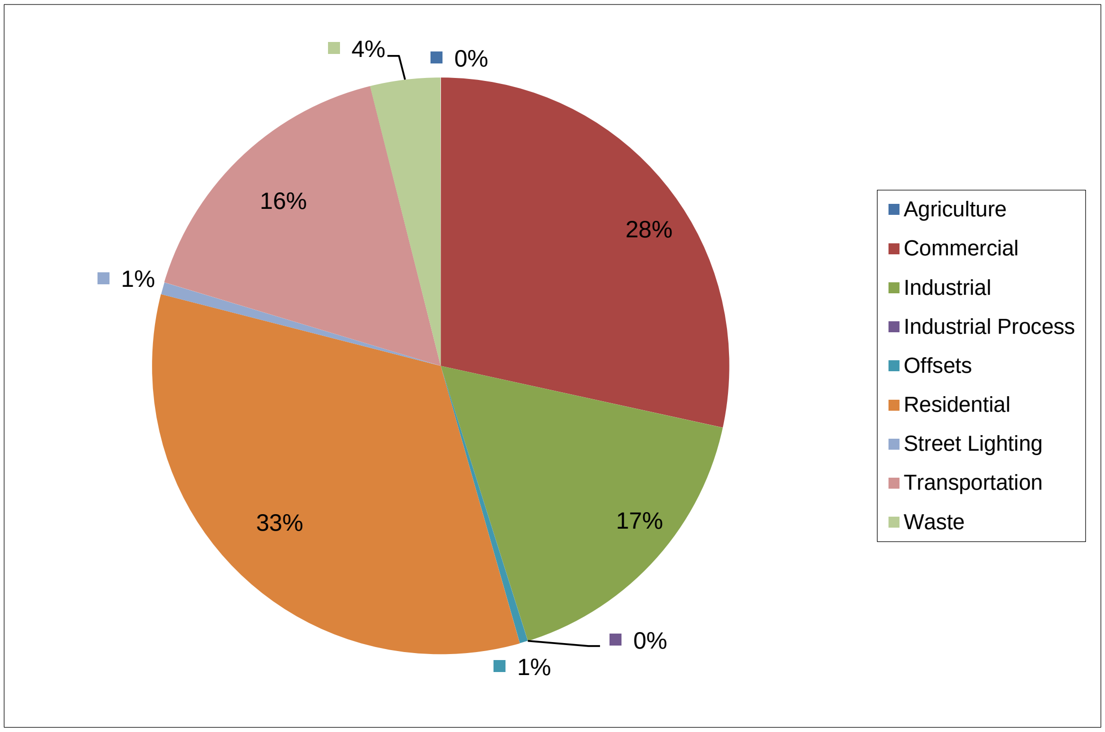



**Figure 10-14: GHG Emissions by Sector for Longmont, 2011**

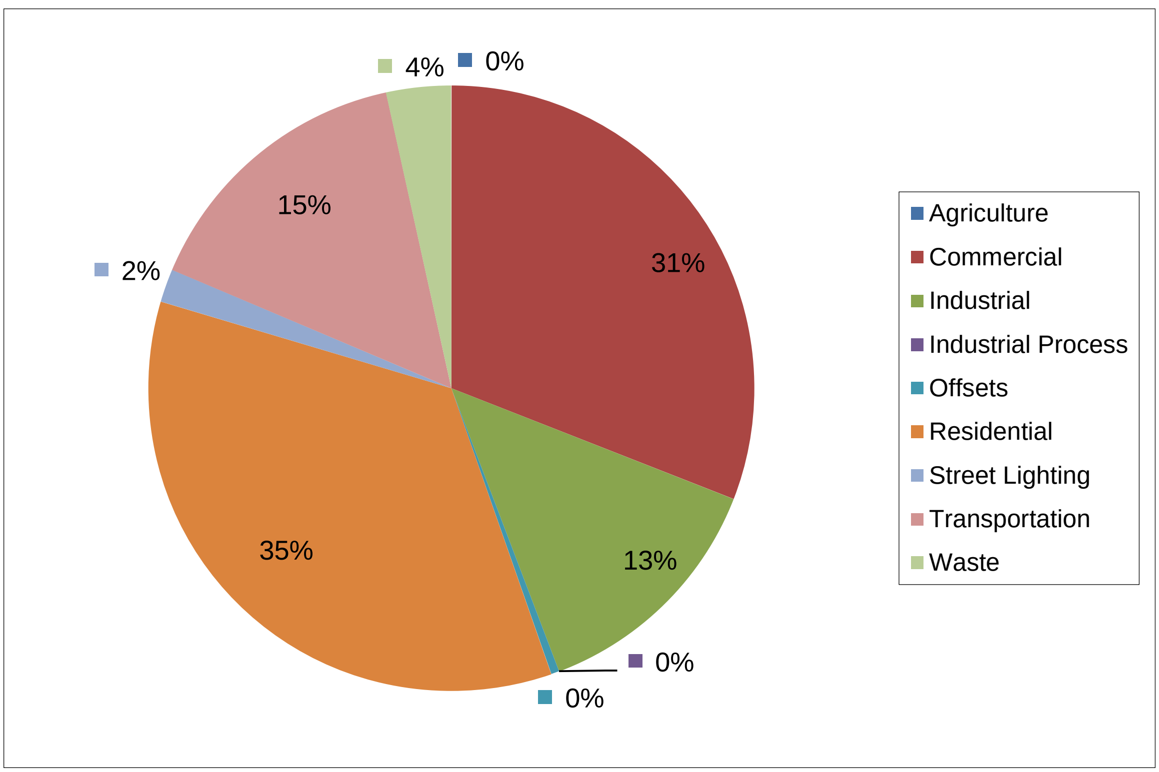


**Figure 10-15: GHG Emissions by Sector for Lyons, 2005**

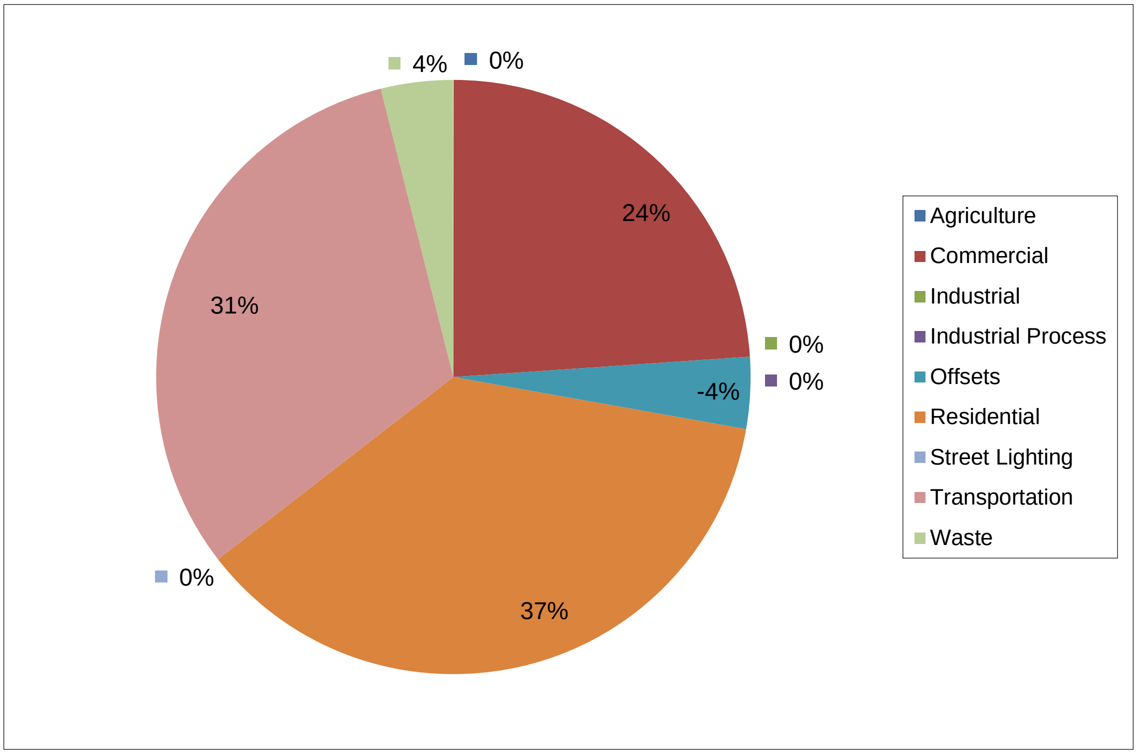



**Figure 10-16: GHG Emissions by Sector for Lyons, 2011**

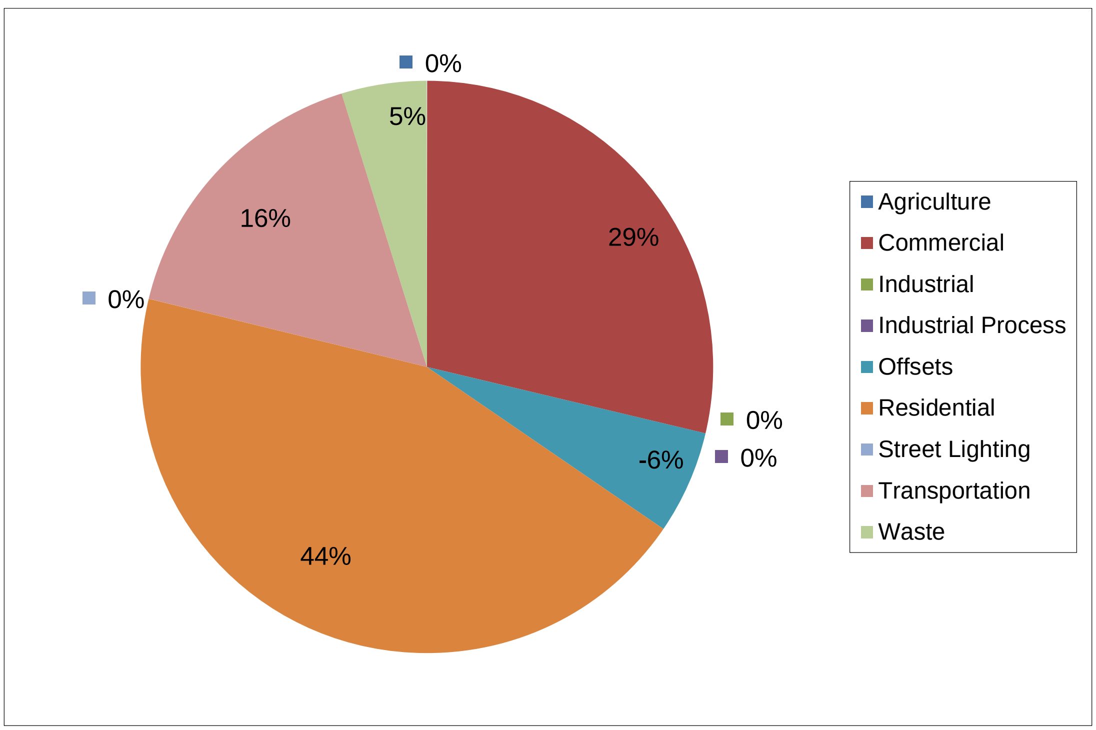


**Figure 10-17: GHG Emissions by Sector for Nederland, 2005**

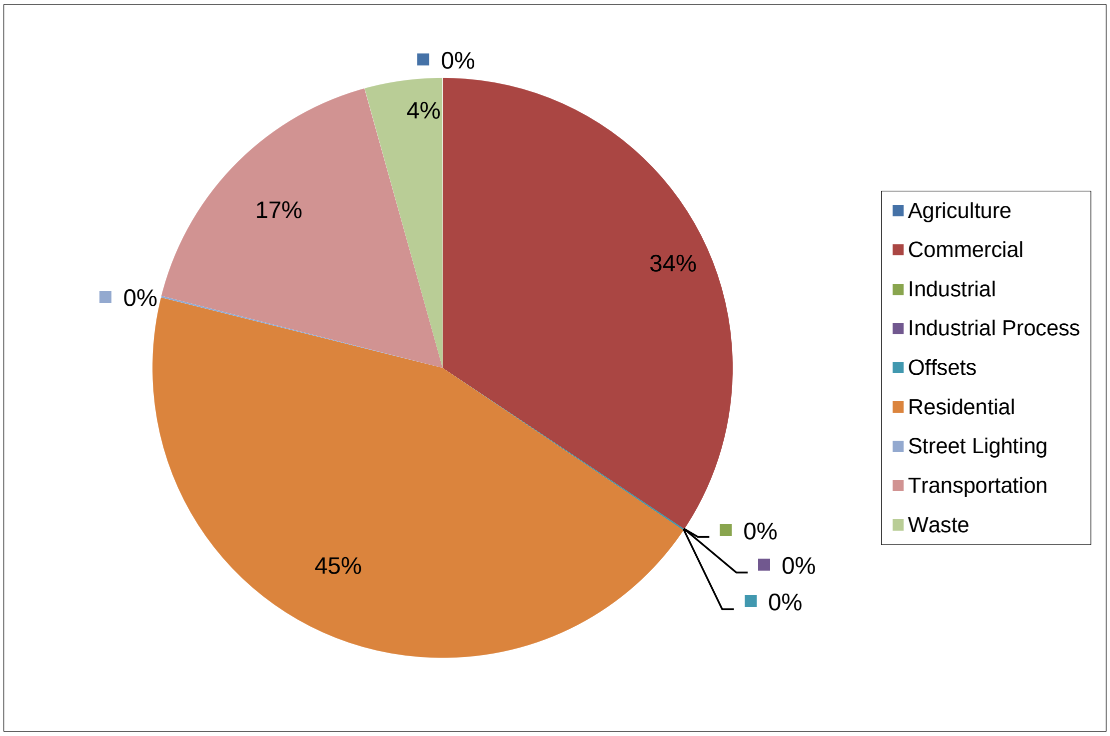



**Figure 10-18: GHG Emissions by Sector for Nederland, 2011**

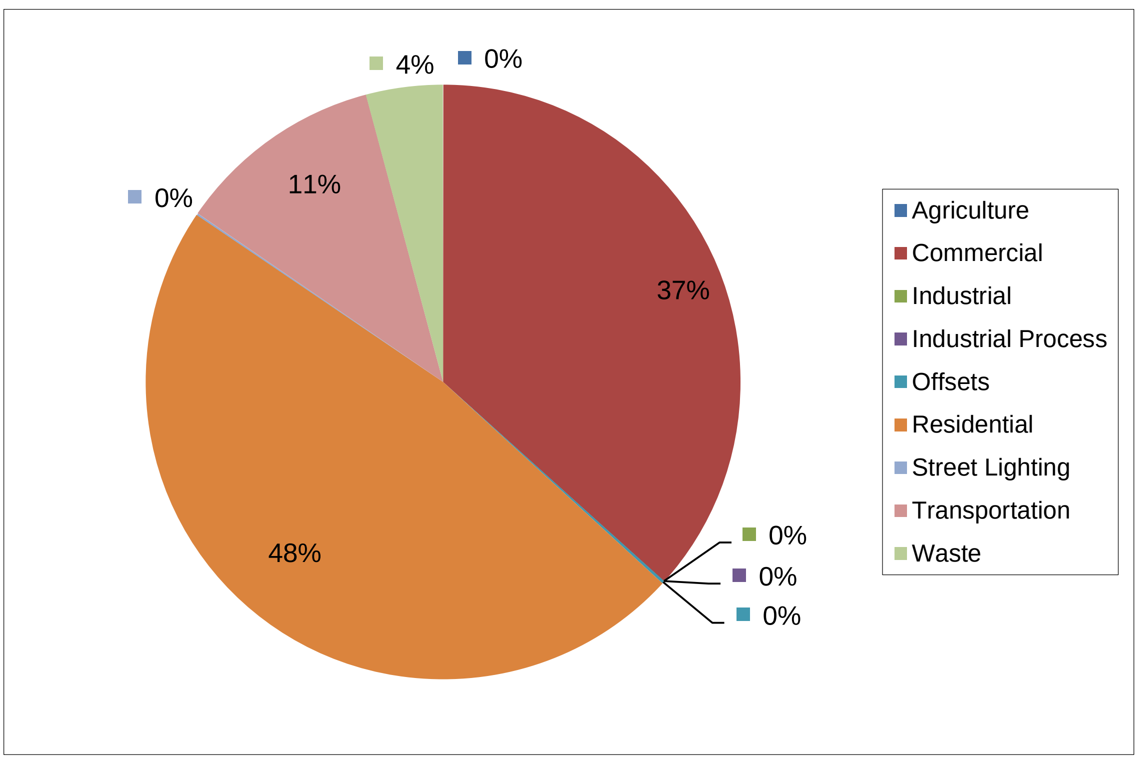


**Figure 10-19: GHG Emissions by Sector for Superior, 2005**

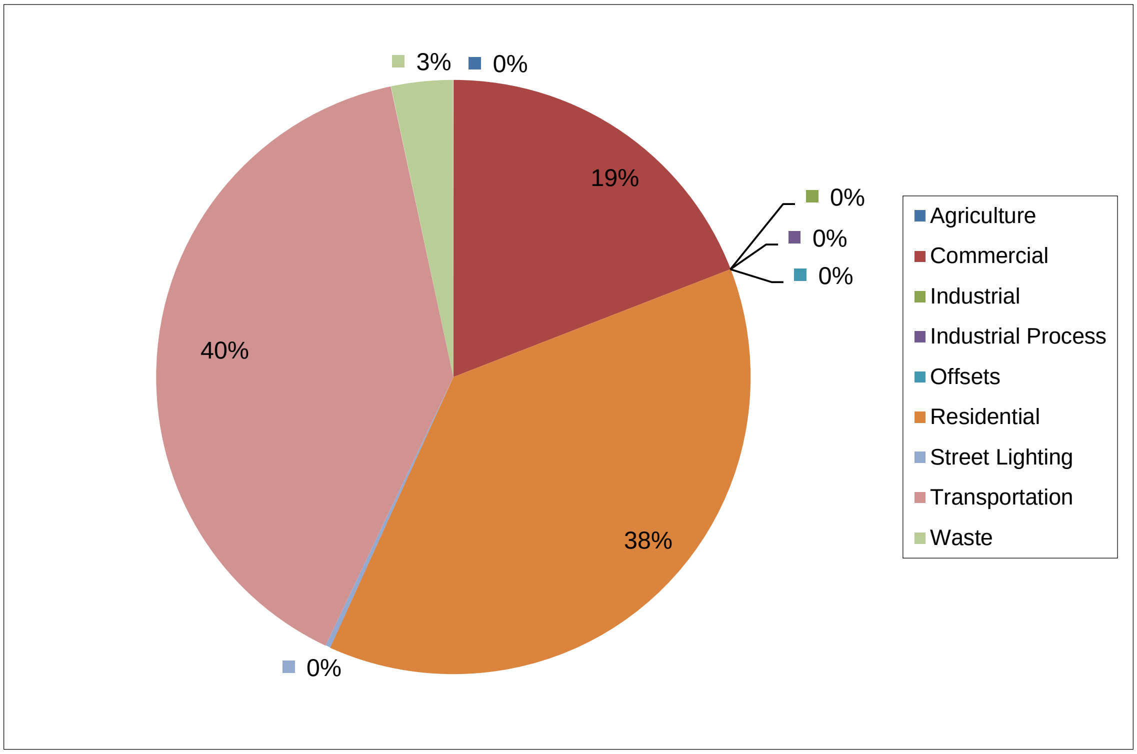



**Figure 10-20: GHG Emissions by Sector for Superior, 2011**

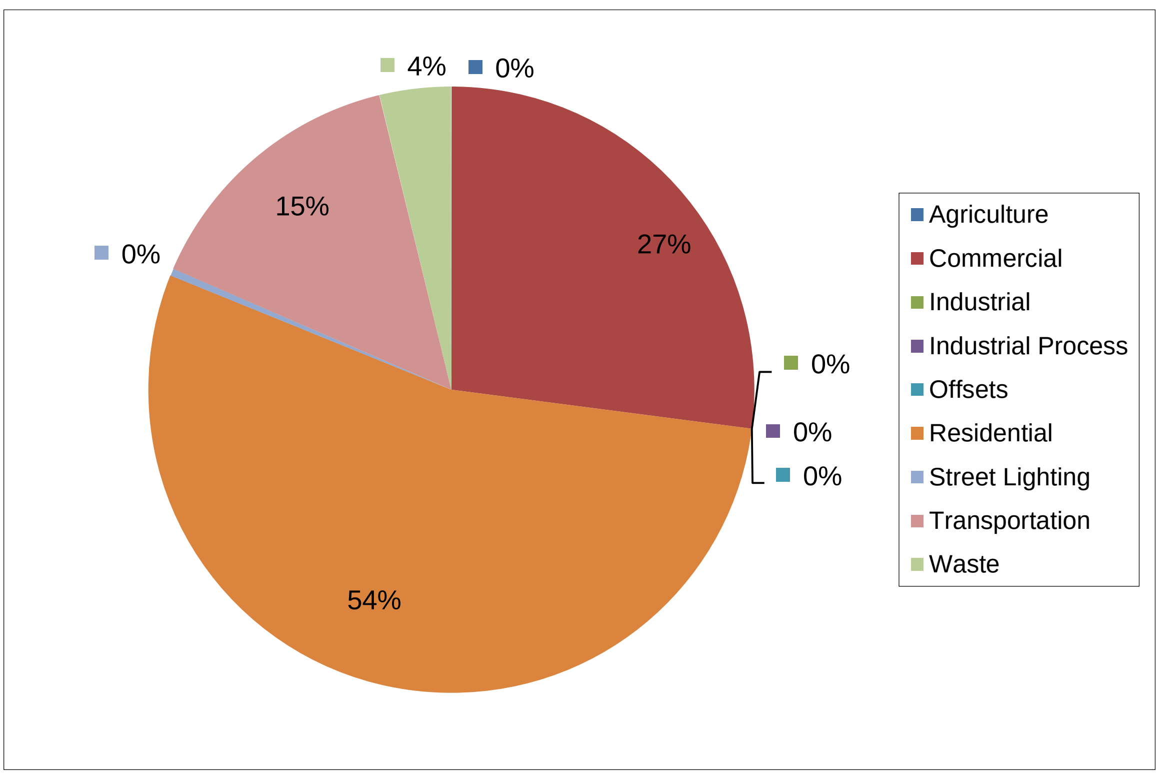


**Figure 10-21: GHG Emissions by Sector for Unincorp/Other, 2005**

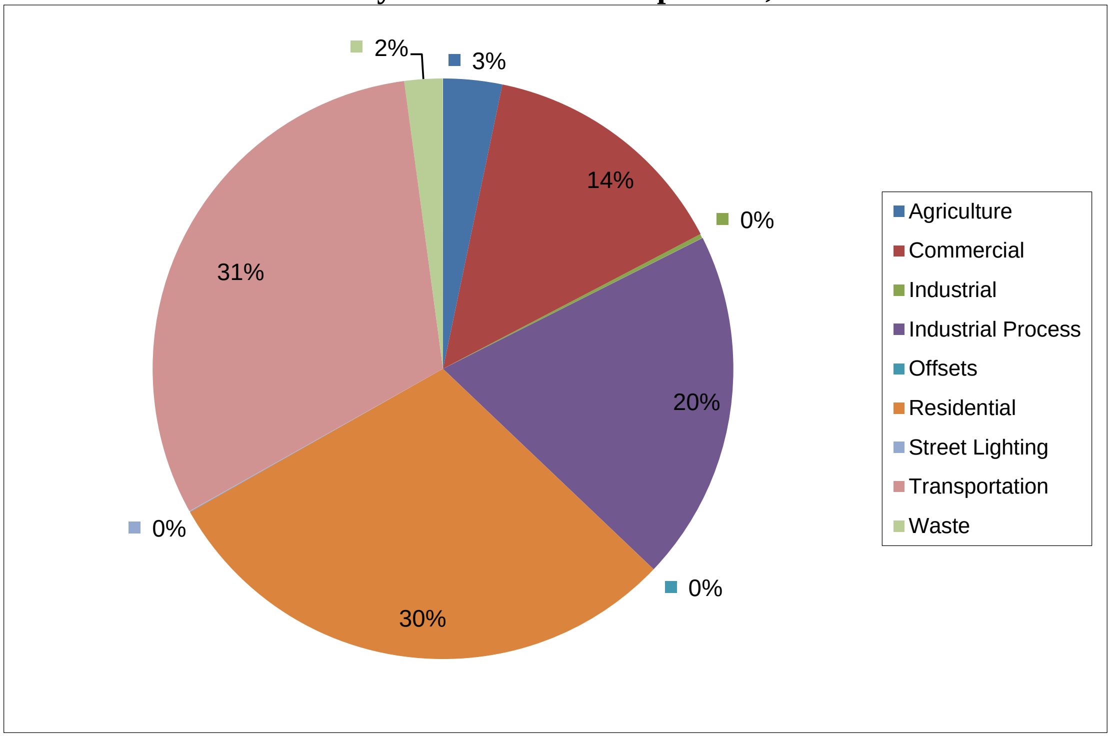
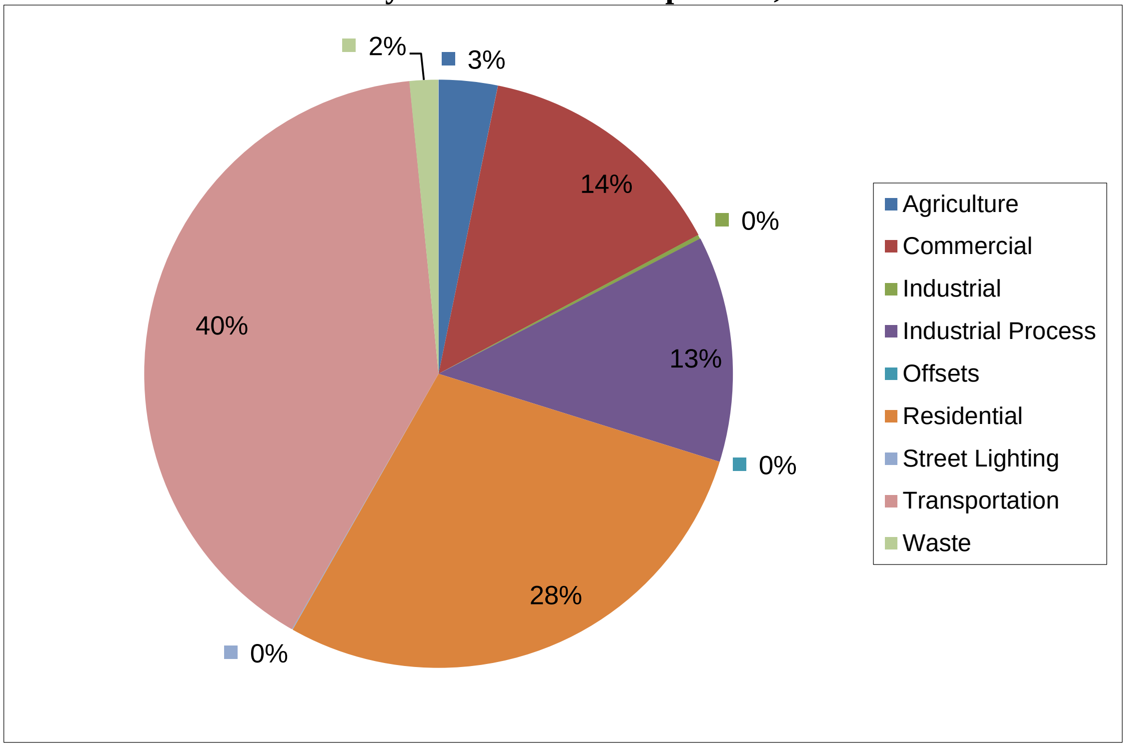



**Figure 10-22: GHG Emissions by Sector for Unincorp/Other, 2011**




*NOTE: The majority (71%) of the Commercial GHG emissions emanating from Unincorporated/Other come from electricity consumed in commercial buildings located in incorporated municipalities not explicitly broken out in the GHG inventory (Erie, Niwot, Gunbarrel, Ward, and others).*

Figure 10-23 presents the Inventory disaggregated by sector for 2005 and Figure 10-24 for 2011. The figures show that the Commercial Buildings sector is the largest source of GHG emissions. This reinforces the need to focus in detail on the existing Commercial Buildings sector for emissions mitigation. Contributing 29% of the 2005 Inventory and 33% of the 2011 Inventory, the Commercial sector provides a large opportunity for the county to achieve GHG reductions.

**Figure 10-23: Breakdown of Boulder County Inventory by Sector – 2005**

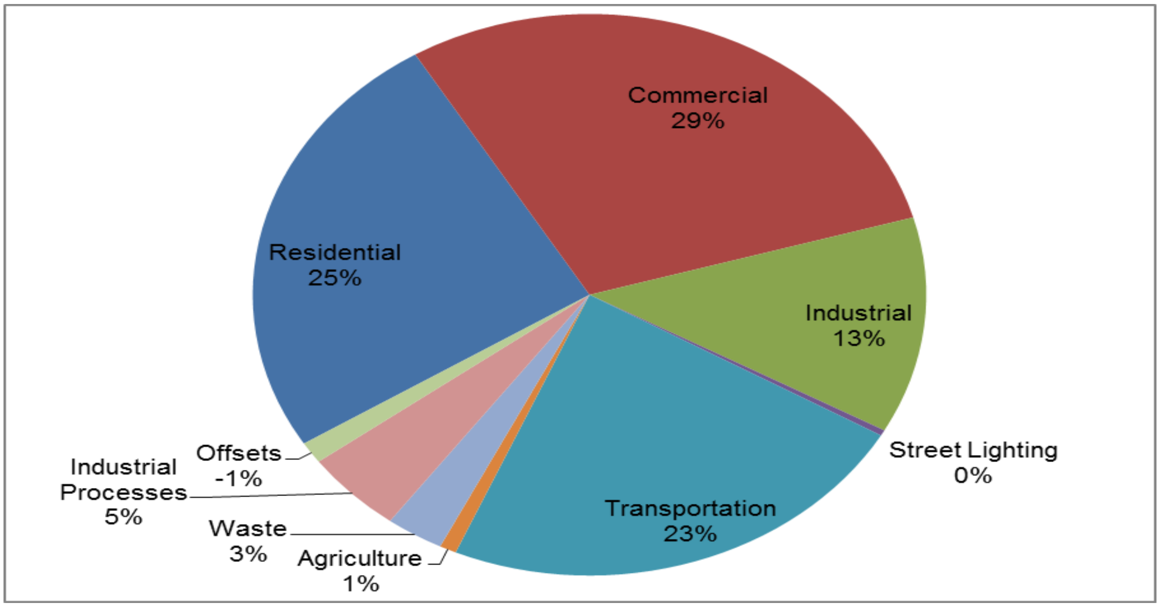
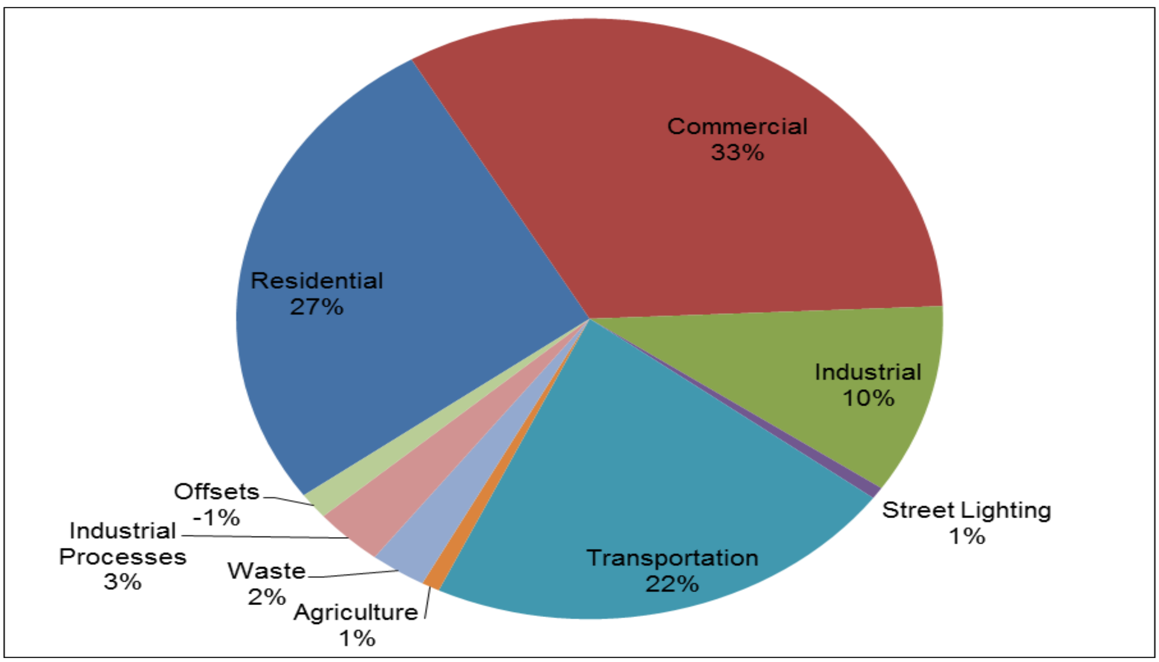



**Figure 10-24: Breakdown of Boulder County Inventory by Sector – 2011**



The following figures present the inventory breakdown by emissions source, based on 2005 data and based on 2011 data. They show that Electricity is the foremost source of GHG emissions with Vehicle Fuel a distant second. It is instructive to recall that emissions resulting from electricity consumption are classified as an indirect emissions source. These indirect emissions result from consumption of electricity within the county's boundary. However, the actual direct emissions occur mostly outside of this boundary, at the individual fossil-fueled power plants that generate the electricity.

These figures draw attention to the importance of addressing electricity consumption and of accurately quantifying the GHG intensity of electricity supply. Furthermore, the figure highlights, to a lesser extent, the need to deal with emissions resulting from Vehicle Fuel and Natural Gas consumption. Finally, the figures underscore the relatively insignificant role landfill gas, voluntary RECs, municipal renewable energy, enteric fermentation, manure management, soil management, refrigerants, aviation fuel, and amendment 37 RECs, collectively have on the Inventory.

**Figure 10-25: Breakdown of Boulder County Inventory by Energy Source – 2005**

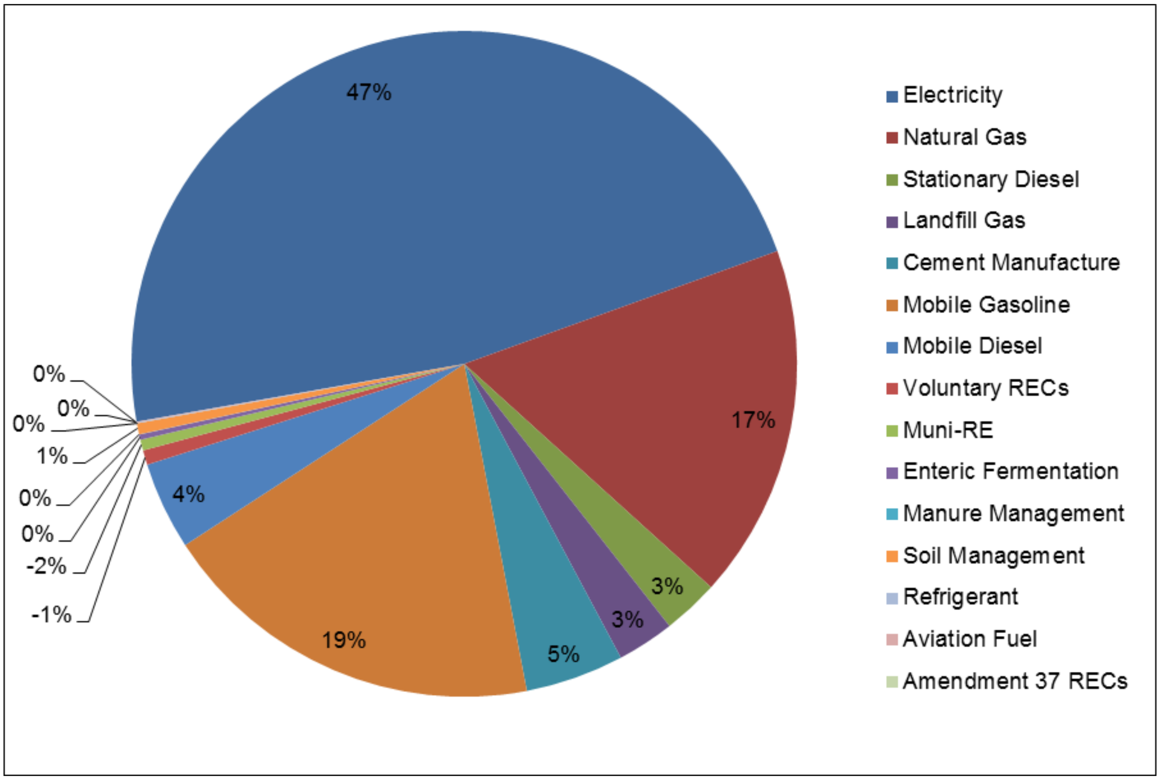
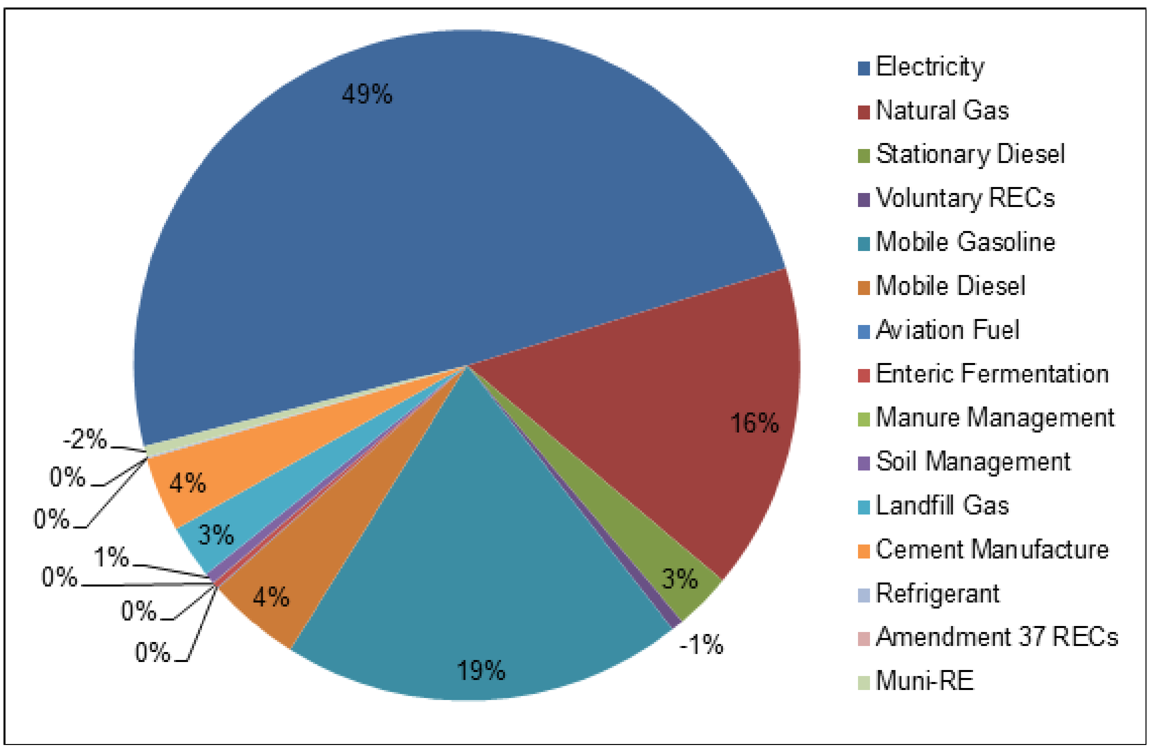



**Figure 10-26: Breakdown of Boulder County Inventory by Energy Source – 2011**



*Residential Sector Inventory*

The Residential Buildings sector produced 25% of the county's GHG emissions in 2005 and 27% in 2011. The following figures illustrate the Residential Inventory profile and indicate that emissions increased from 879 thousand to 1.31 million metric tons of carbon dioxide-equivalent, an increase of 49%, during the 1990 – 2005 period and from 879 thousand to 1.34 million metric tons of carbon dioxide equivalent during the 1990 – 2011 period. Moreover, the figures illustrate that, in 2006, emissions were projected to reach nearly 1.5 million metric tons in 2012 unless action were taken to counteract the BAU trend. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only 1.40 million metric tons and Residential sector emissions in 2020 are now expected to be only 1.49 million metric tons.

**Figure 10-27: Residential GHG Inventory Profile, 1990 – 2012**

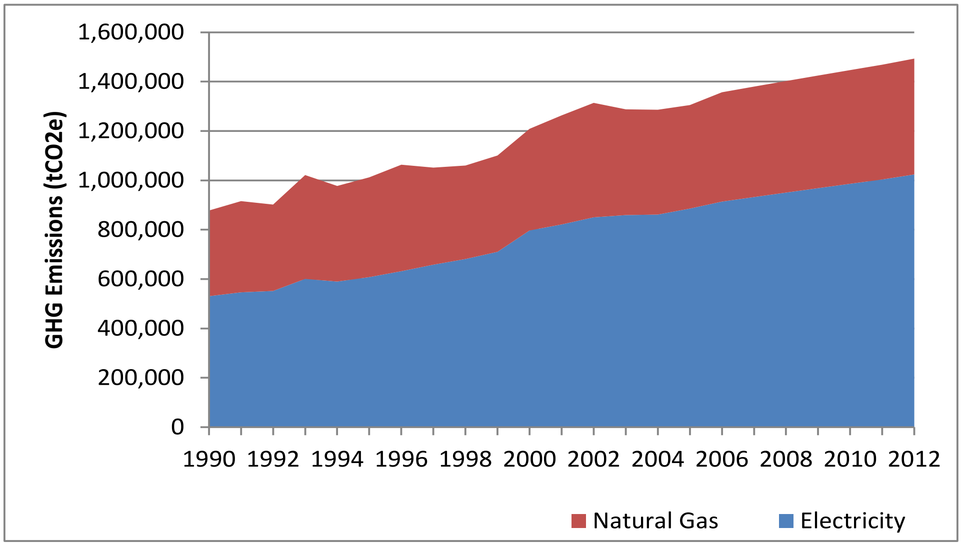
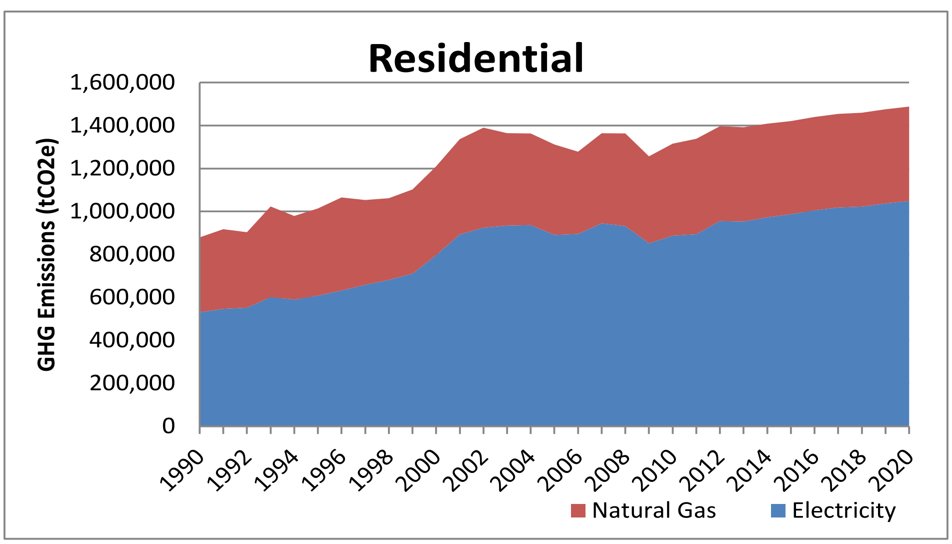



**Figure 10-28: Residential GHG Inventory Profile, 1990 – 2020**



The following figures illustrate the breakdown of the Residential Inventory by emissions source for 2005 and 2011. The figures highlight the primary role electricity has on the sector's inventory.

**Figure 10-29: Breakdown of Residential Emissions by Source - 2005**

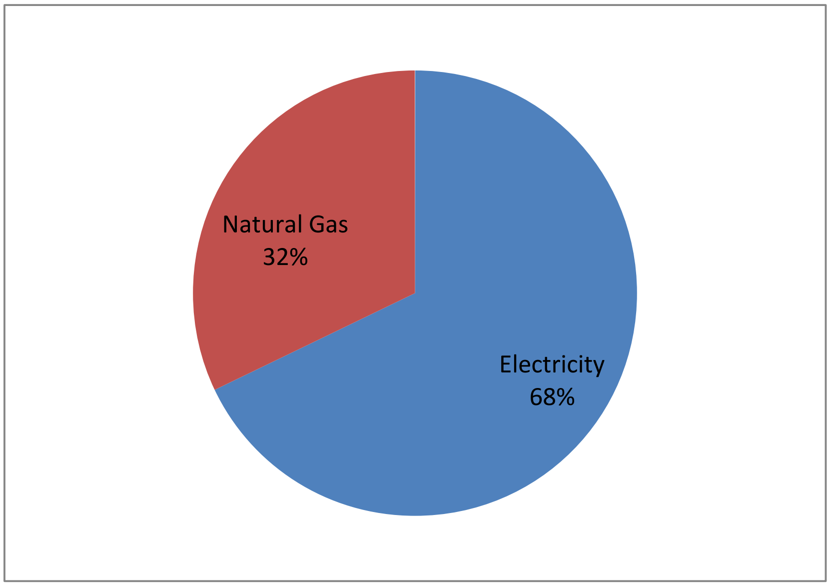
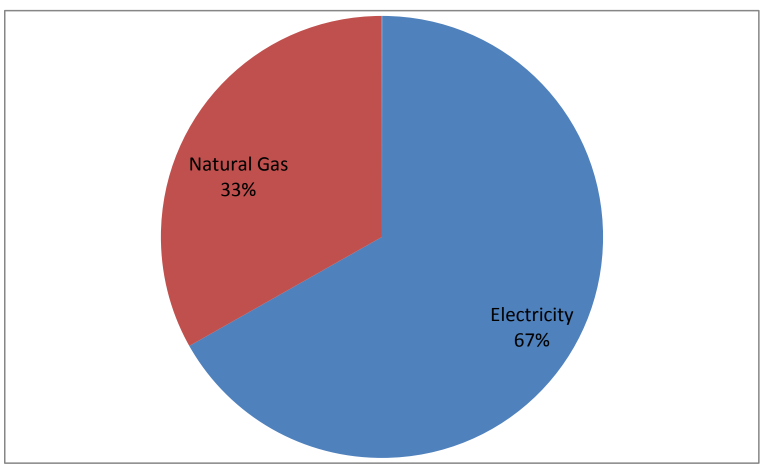



**Figure 10-30: Breakdown of Residential Emissions by Source - 2011**



*Commercial Sector Inventory*

The Commercial Buildings sector produced 32% of the county's GHG emissions in 2005 and 34% of the county's GHG emissions in 2011. Figure 10-31 and Figure 10-32 illustrate the Commercial Buildings Inventory profile and indicate that emissions increased from 903 thousand to 1.60 million metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and from 903 thousand to 1.65 million metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to reach nearly 2 million metric tons in 2012 unless action was taken to counteract the BAU trend. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only 1.69 million metric tons and Commercial sector emissions in 2020 are now expected to be only 1.84 million metric tons.

**Figure 10-31: Commercial GHG Inventory Profile, 1990 – 2012**

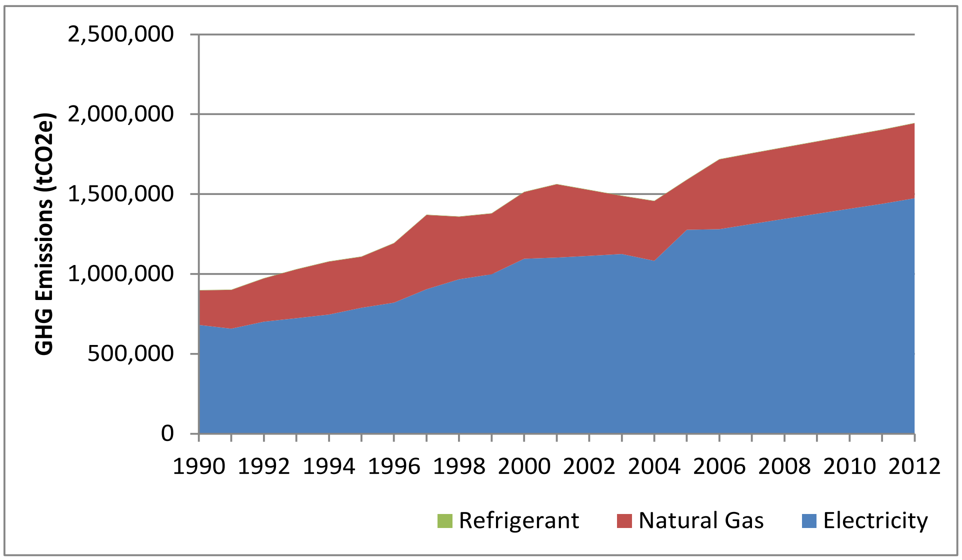



**Figure 10-32: Commercial GHG Inventory Profile, 1990 – 2020**

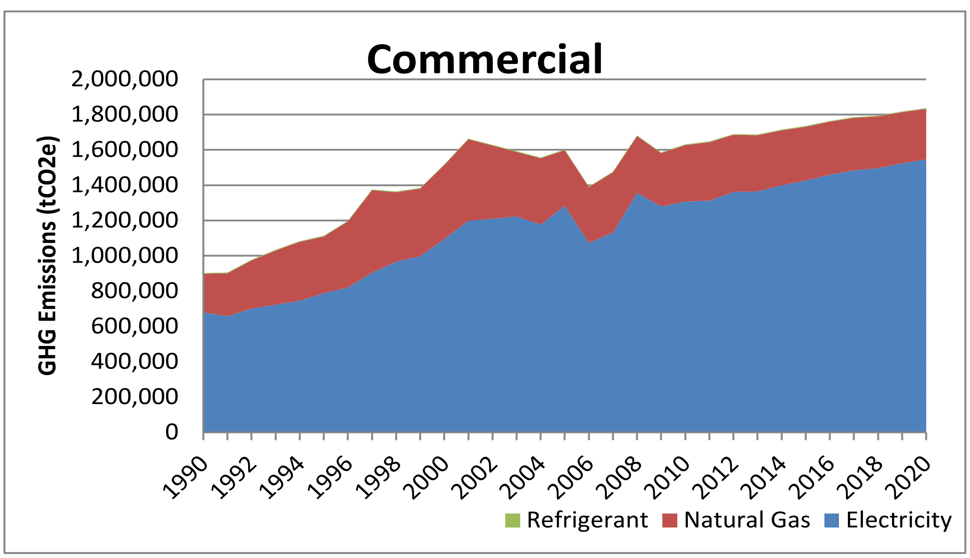


**Figure 10-33: Breakdown of Commercial Emissions by Source - 2005**

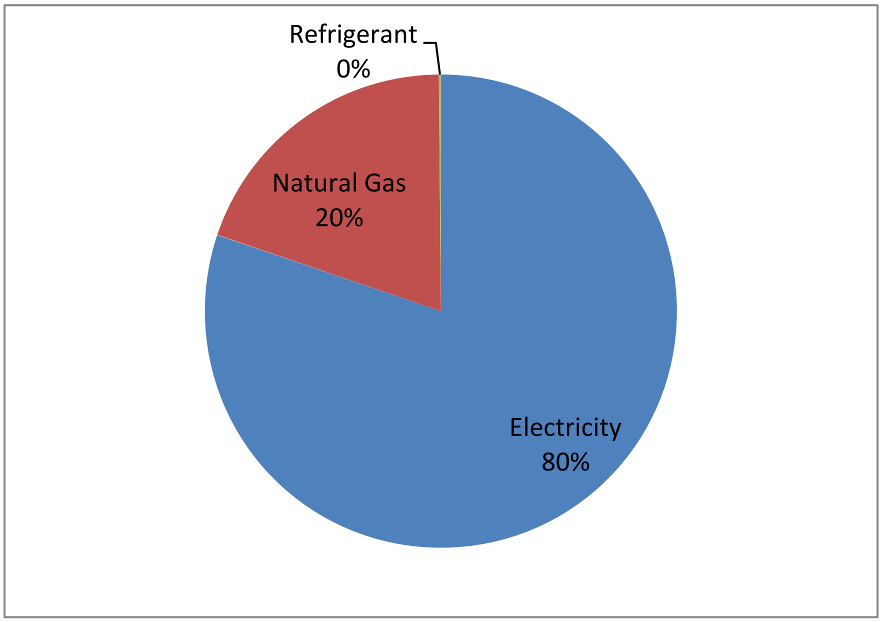
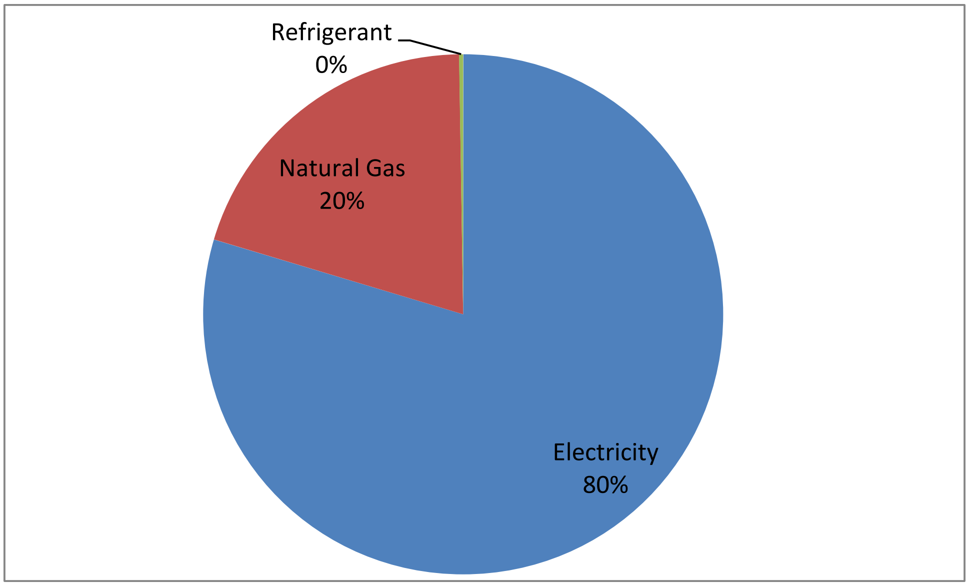



**Figure 10-34: Breakdown of Commercial Emissions by Source - 2011**




*Transportation Sector Inventory*

Vehicle fuel usage accounted for 25% of the County's overall GHG emissions in 2005 and 23% in 2011. Unlike all other sectors, the Transportation sector has posted a downward-trending emissions profile in recent years. The total emissions from vehicle fuel combustion from 1990 to 2005, and projections through 2012, are shown in Figure 10-35. The historical period 1990 – 2011 and projection out to 2020 are illustrated in Figure 10-36. These figures illustrate that, in 2006, emissions were projected to reach nearly 1.4 million metric tons in 2012 unless action was taken to counteract the BAU trend. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only about 1.1 million metric tons and Transportation sector emissions in 2020 are now expected to be only about 0.7 million metric tons.

**Figure 10-35: Transportation GHG Inventory, 1990-2012**

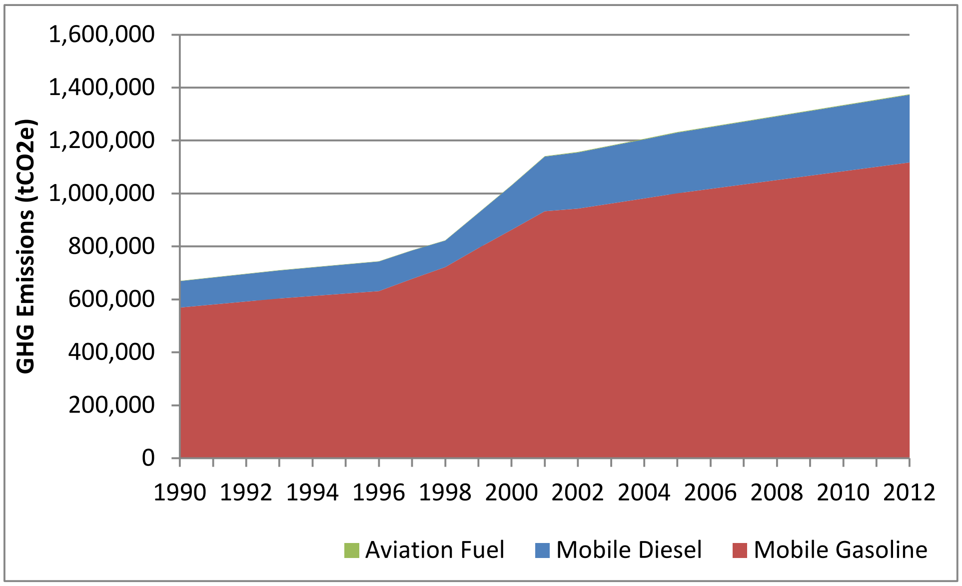
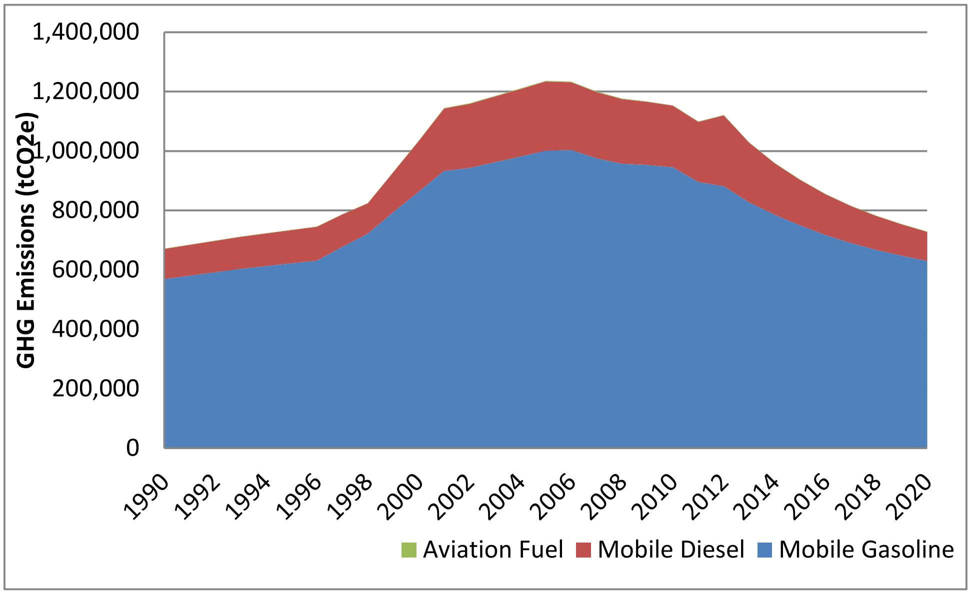
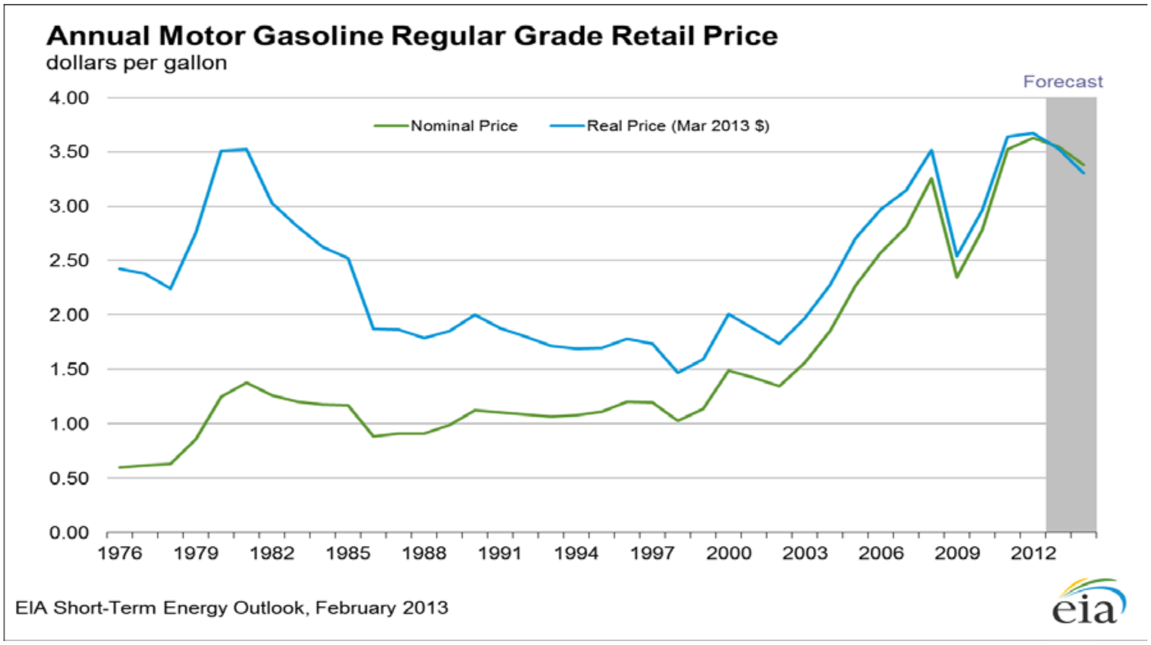



**Figure 10-36: Transportation GHG Inventory, 1990-2020**




Since actual fuel usage data are not available, fuel consumption was estimated on the basis of Vehicle Miles Traveled (VMT) average vehicle fuel economy data, which are readily available from the Colorado Department of Transportation and Denver Regional Council of Governments. The forecasted fuel economy rates (miles traveled per gallon of fuel) reflect the effect of federal standards, resulting in a trend toward a higher percentage of VMT by more efficient, lighter-weight vehicles relative to heavier vehicles in future years. The VMT in the county peaked in 2005 and has trended downward since then. This is evidence of possible TMP effects but may be more likely to reflect the dramatic increase in vehicle fuel prices. For example, Figure 10-37 shows that during the 2002 – 2005 period, regular gasoline prices increased 55%. Prices increased a further 30% from 2005 to 2009.

**Figure 10-37:**




Demand-elasticity models for VMT versus fuel price typically predict that VMT will fall 1% for each 5% increase in fuel price. This implies that VMT should have dropped 11% during 2002 – 2005 and should have dropped another 6% during 2005 – 2009. However, actual VMT data indicate total VMT *increased* more than 4% from 2002 to 2005 and remained flat from 2006 to 2009. Countervailing trends during this period were likely more influential than fuel price – from 2002 to 2005, county population remained flat and grew by nearly 4% from 2005 to 2009; GDP grew 16% from 2002 to 2005 and grew another 9% from 2006 to 2009. Taken together, these population and GDP trends may have outweighed the dampening effect of price increases.

**Figure 10-38: Breakdown of Transportation Emissions by Source - 2005**

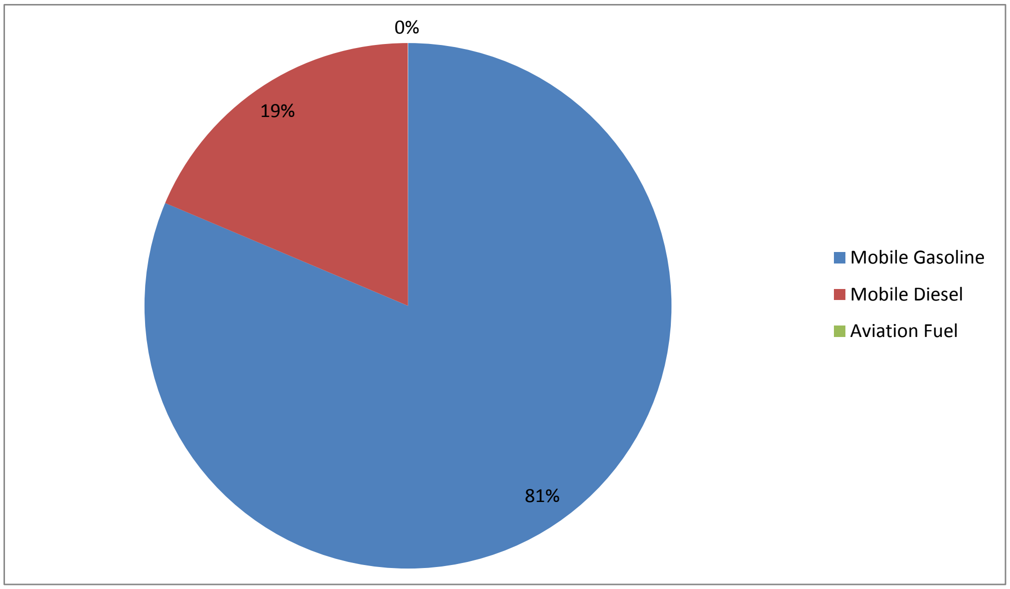
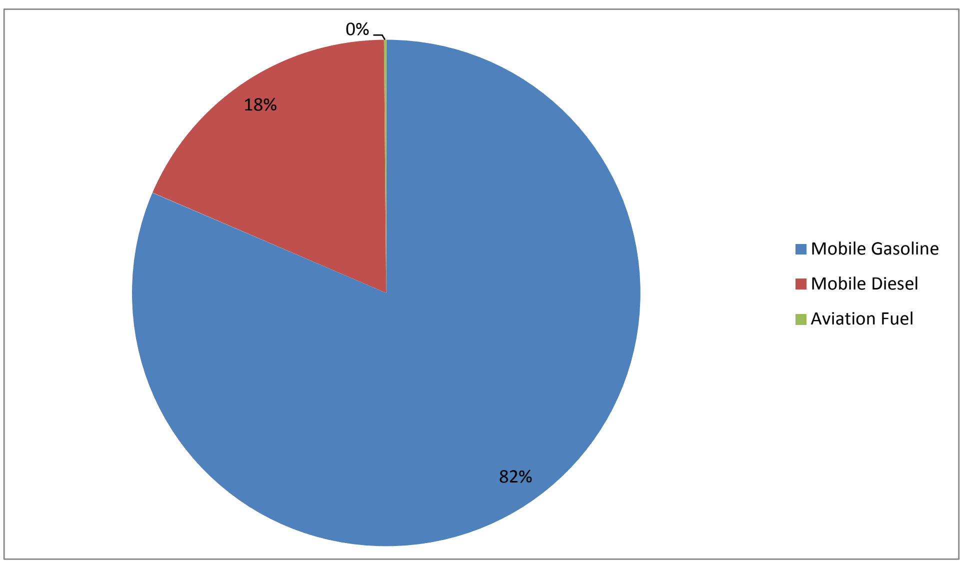



**Figure 10-39: Breakdown of Transportation Emissions by Source - 2011**




*Industrial Sector Inventory*

The Industrial sector produced 11% of the county's GHG emissions in 2005 and 11% of the county's GHG emissions in 2011. Figure 10-40 and Figure 10-41 illustrate the Industrial Inventory profile and indicate that emissions decreased from 551 thousand to 547 thousand metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and from 551 thousand to 513 thousand metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to reach nearly 624 thousand metric tons in 2012 unless action was taken to counteract the BAU trend. The updated trend line using 2011 data projects that 2012 emissions are expected to be 814 thousand metric tons, but Industrial sector emissions in 2020 are now expected to be only 575 thousand metric tons.

**Figure 10-40: Industrial GHG Inventory Profile, 1990 – 2012**

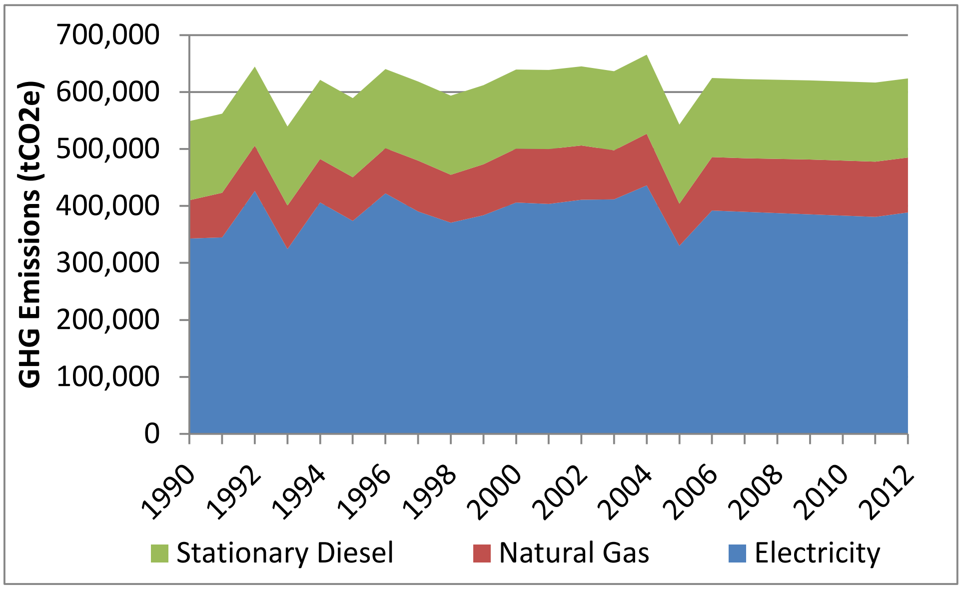



**Figure 10-41: Industrial GHG Inventory Profile, 1990 – 2020**

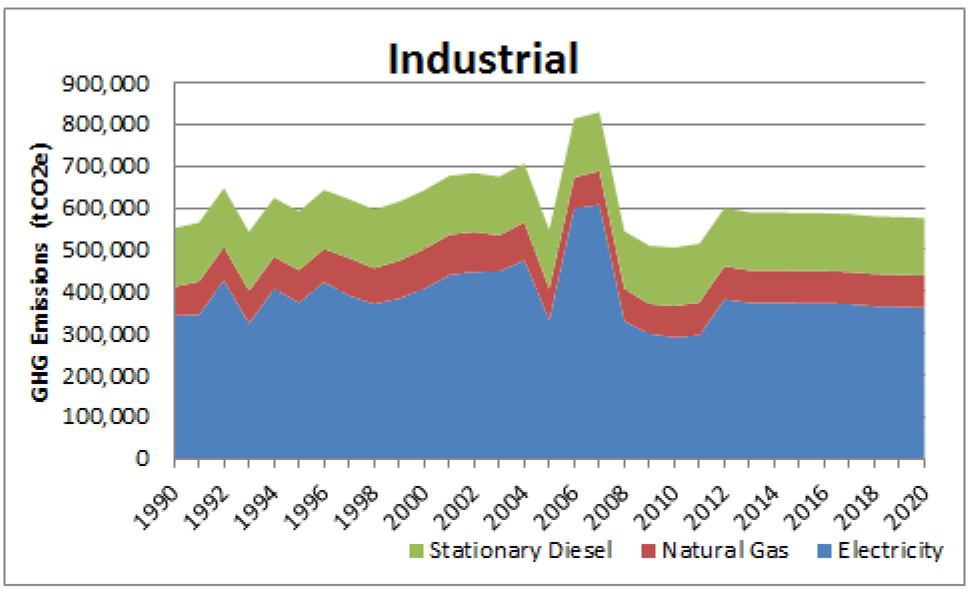


**Figure 10-42: Breakdown of Industrial Emissions by Source – 2005**

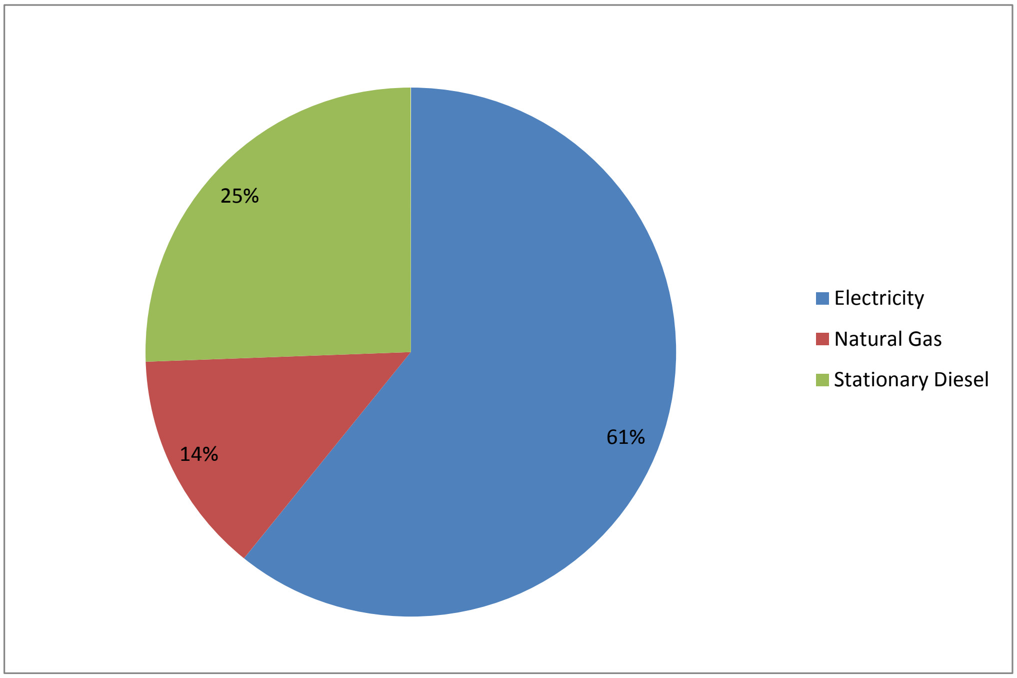
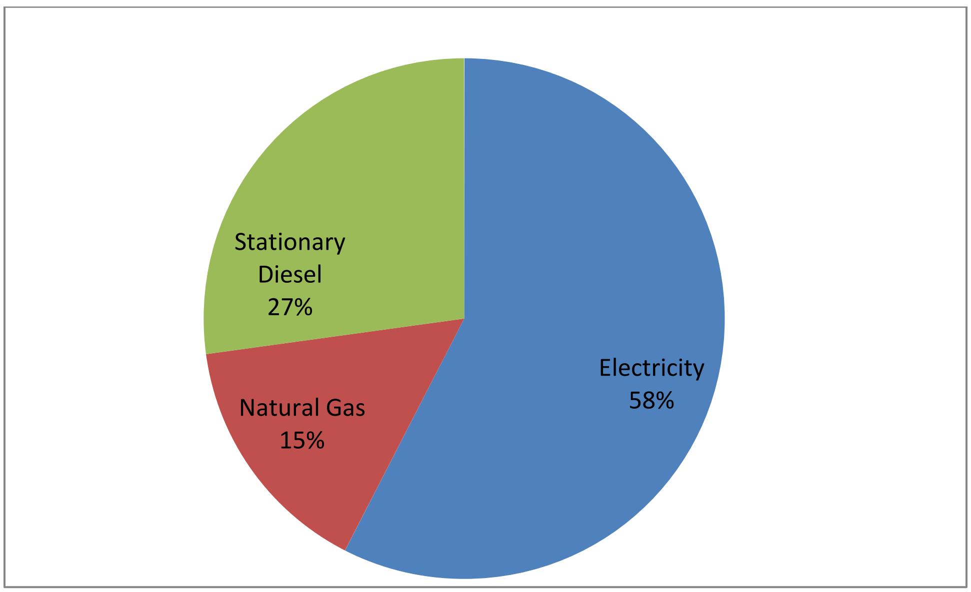



**Figure 10-43: Breakdown of Industrial Emissions by Source – 2011**




*Industrial Processes Sector Inventory*

The Industrial Processes sector produced 4% of the county's GHG emissions in 2005 and 3% of the county's GHG emissions in 2011. Figure 10-44 and Figure 10-45 illustrate the Industrial Processes Inventory profile and indicate that emissions remained stable at 244 thousand metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and decreased from 244 thousand to 160 thousand metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to remain steady at about 244 thousand metric tons in 2012 unless action was taken to counteract the BAU trend. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only 180 thousand metric tons and Industrial Processes sector emissions in 2020 are now expected to be only 180 thousand metric tons.

**Figure 10-44: Industrial Processes GHG Inventory Profile, 1990 – 2012**

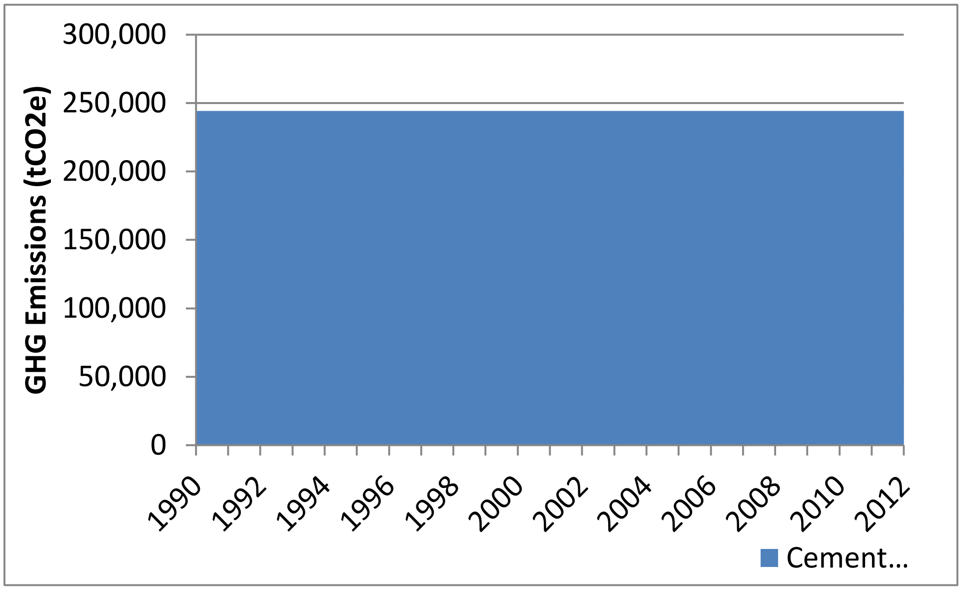
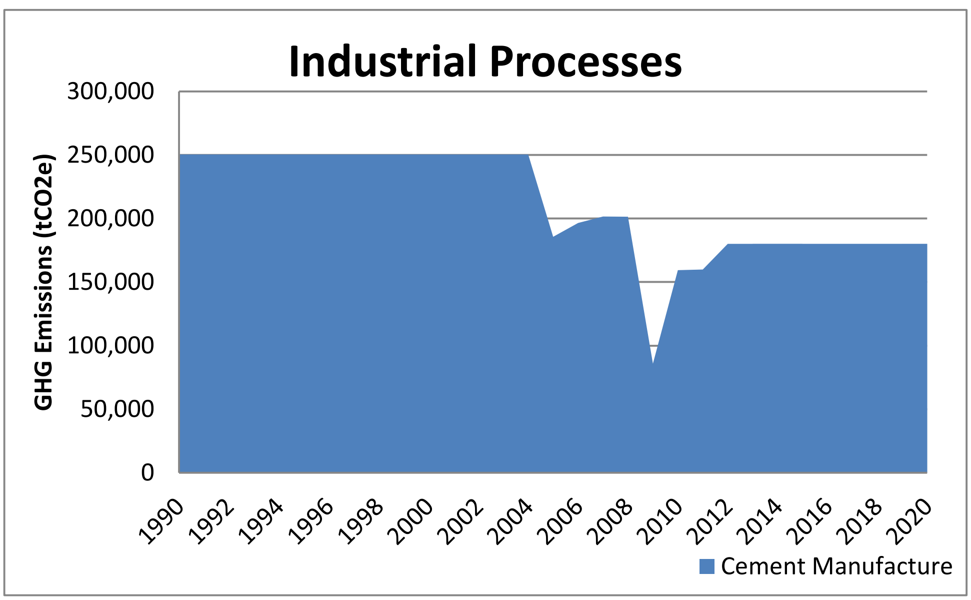



**Figure 10-45: Industrial Processes GHG Inventory Profile, 1990 – 2020**



*Street Lighting Sector Inventory*

The Street Lighting sector produced 0.4% of the county's GHG emissions in 2005 and 0.7% of the county's GHG emissions in 2011. Figure 10-46 and Figure 10-47 illustrate the Street Lighting Inventory profile and indicate that emissions increased from 12 thousand to 20 thousand metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and from 12 thousand to 32 thousand metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to reach 22 thousand metric tons in 2012 unless action was taken to counteract the BAU trend. The updated trend line using 2011 data projects that 2012 emissions are expected to be 26 thousand metric tons and Street Lighting sector emissions in 2020 are now expected to be 38 thousand metric tons.

**Figure 10-46: Street Lighting GHG Inventory Profile, 1990 – 2012**

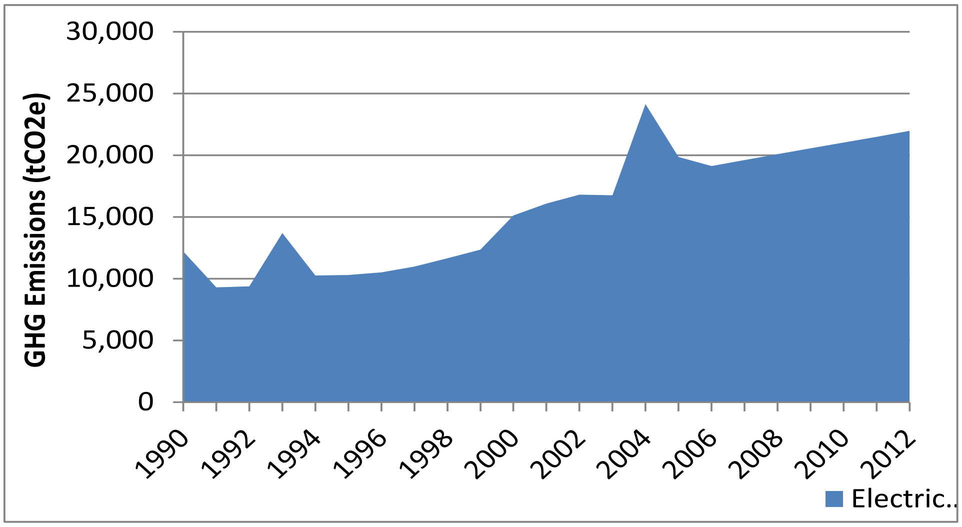
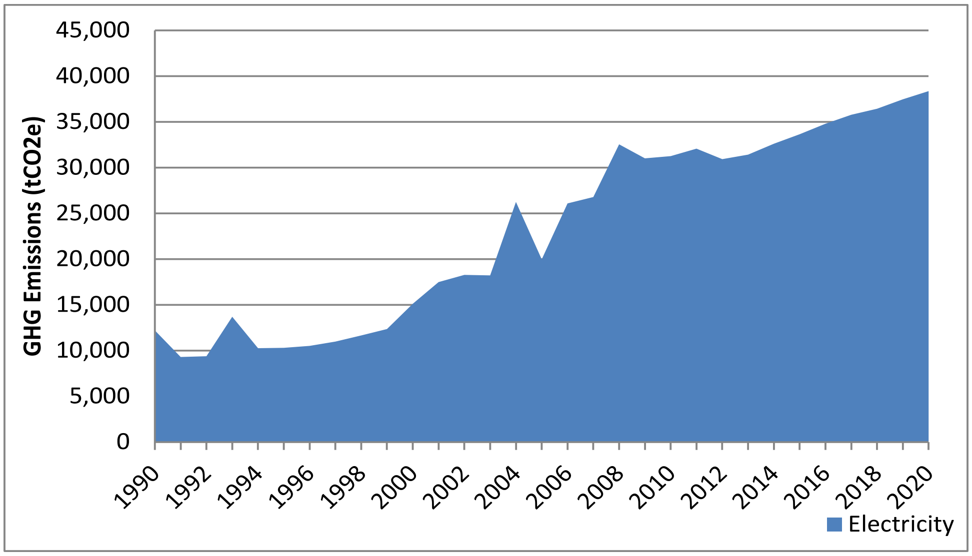



**Figure 10-47: Street Lighting GHG Inventory Profile, 1990 – 2020**



*Agriculture Sector Inventory*

The Agriculture sector produced 1% of the county's GHG emissions in 2005 and 1% of the county's GHG emissions in 2011. Figure 10-48 and Figure 10-49 illustrate the Agriculture Inventory profile and indicate that emissions decreased from 44 thousand to 43 thousand metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and from 903 thousand to 42 thousand metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to decrease to 41 thousand metric tons in 2012. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only 43 thousand metric tons and Agriculture sector emissions in 2020 are now expected to be only 43 thousand metric tons.

**Figure 10-48: Agriculture GHG Inventory Profile, 1990 – 2012**

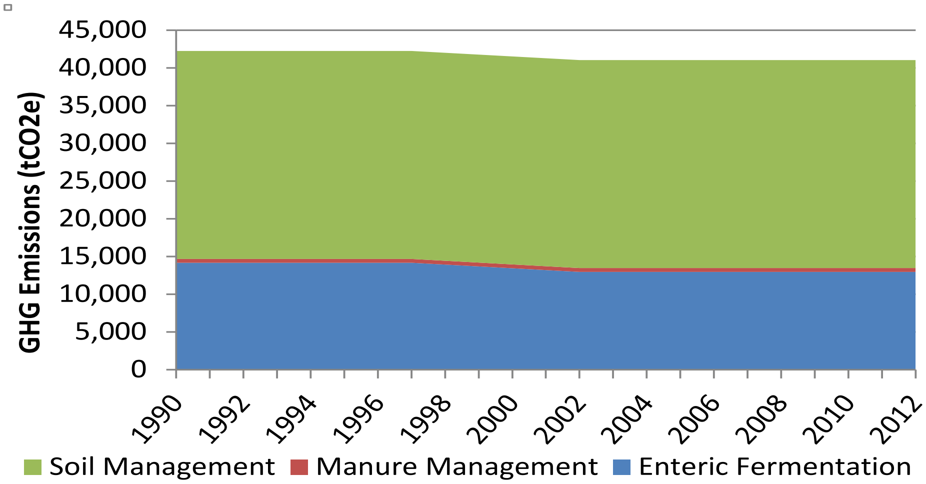



**Figure 10-49: Agriculture GHG Inventory Profile, 1990 – 2020**

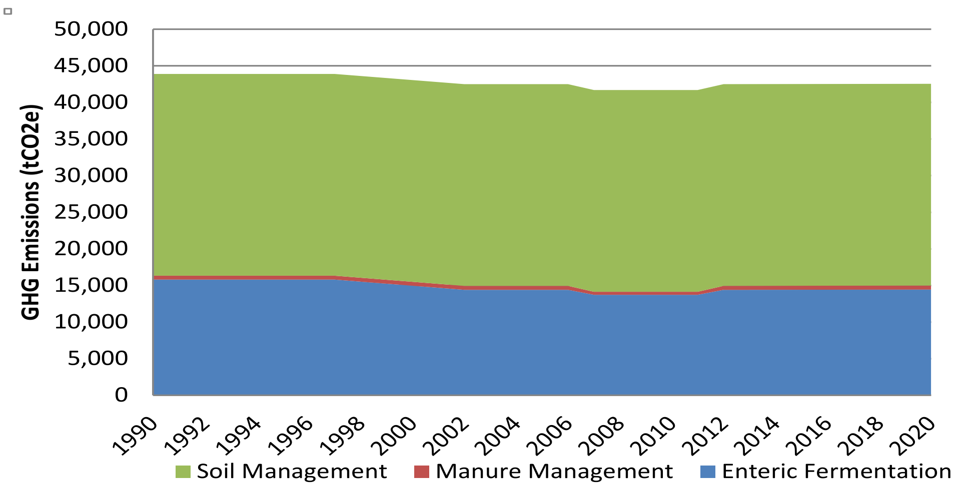


**Figure 10-50: Breakdown of Agriculture Emissions by Source – 2005**

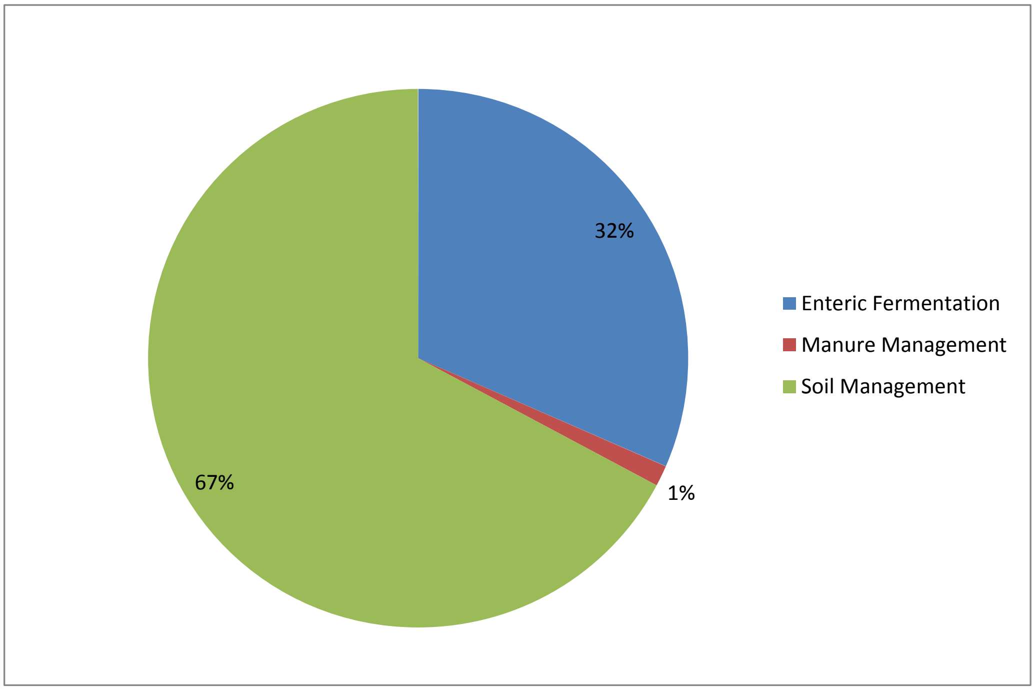
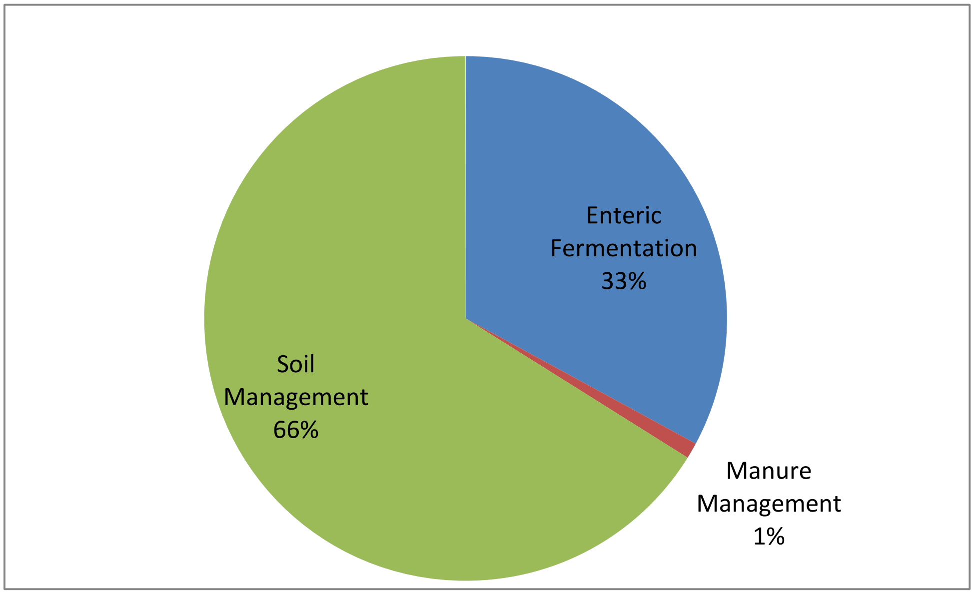



**Figure 10-51: Breakdown of Agriculture Emissions by Source – 2011**




*Waste Sector Inventory*

The Waste sector produced 3% of the county's GHG emissions in 2005 and 3% of the county's GHG emissions in 2011. Figure 10-52 and Figure 10-53 illustrate the Waste Inventory profile and indicate that emissions increased from 94 thousand to about 145 thousand metric tons of carbon dioxide-equivalent during the 1990 through 2005 period and from 94 thousand to 129 thousand metric tons during the 1990 – 2011 period. These figures illustrate that, in 2006, emissions were projected to reach nearly 165 thousand metric tons in 2012 unless action was taken to counteract the BAU trend. However, the updated trend line using 2011 data projects that 2012 emissions are expected to be only 136 thousand metric tons and Waste sector emissions in 2020 are now expected to be only 145 thousand metric tons.

**Figure 10-52: Waste GHG Inventory Profile, 1990 – 2012**

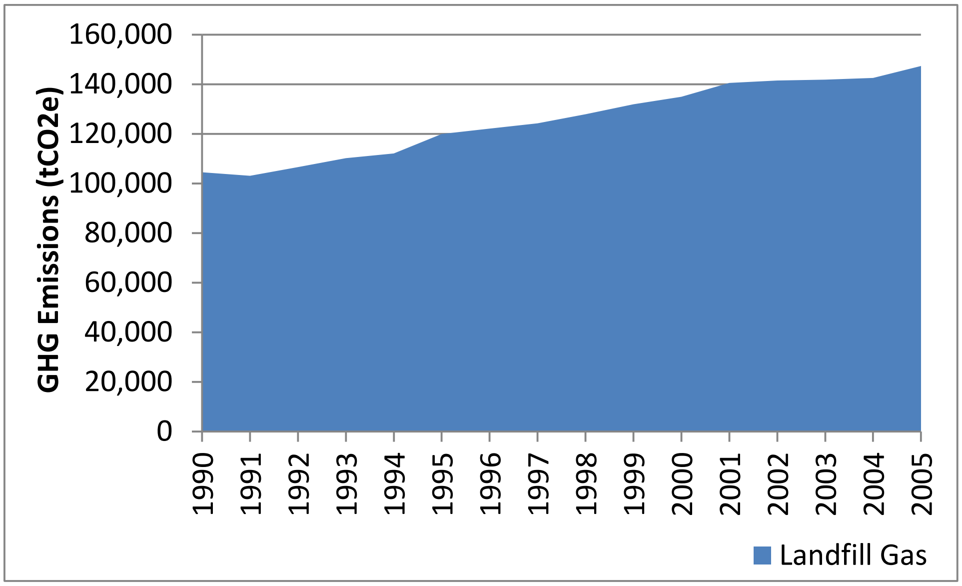
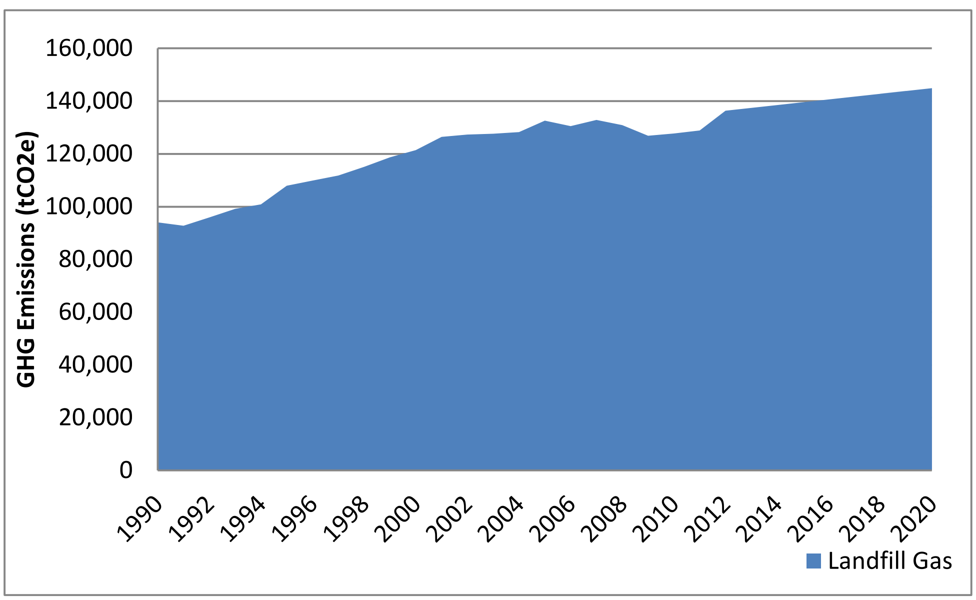



**Figure 10-53: Waste GHG Inventory Profile, 1990 – 2020**



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