Boulder County

Greenhouse Gas Mitigation Analysis

Executive Summary

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Based on the Final Report

Developed for Boulder County

By

Econergy International

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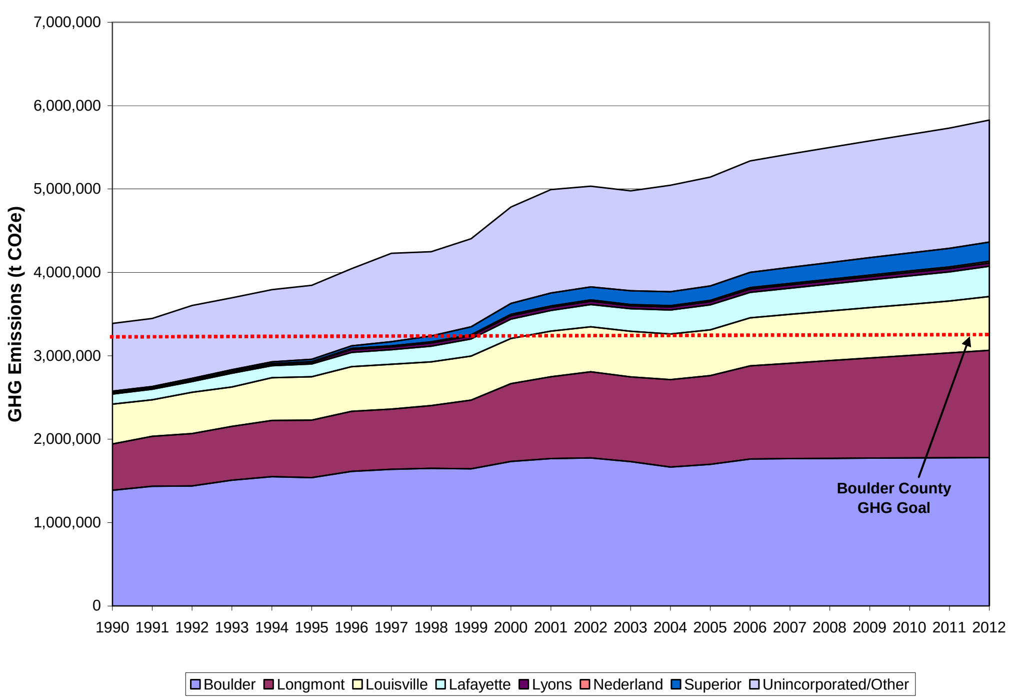
Boulder County's Greenhouse Gas Inventory

In 2005, Boulder County Commissioners adopted a resolution creating a Sustainable Energy Path for Boulder County. The resolution required the county to develop a plan for achieving an initial emissions reduction target, consistent with the Kyoto Protocol, of reducing annual greenhouse gas (GHG) emissions 7% below 1990 levels by 2012. In December 2006, Boulder County developed a comprehensive, countywide inventory of GHG inventory to identify the sources of these emissions. Figures 1 presents the results of the Boulder County inventory. Figures 2 and 3 provide a breakdown of 2005 emissions by sector and by municipality. Projecting out from emission levels beginning in 1990, in 2012 the "business as usual" (BAU) trajectory is about 5,851,000 metric tons of carbon dioxide equivalent[1] (mtCO2e). This exceeds the Kyoto goal by about 85%.

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. 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 Kyoto goal is a high bar.

Figure 1. Business-As-Usual GHG Emissions Projections by Municipality



[1] Greenhouse gas emissions are presented in metric tons of carbon dioxide "equivalent" to account for the difference in the global warming potential of the different gases.

Figure 2. Countywide Emissions by Economic Sector, 2005

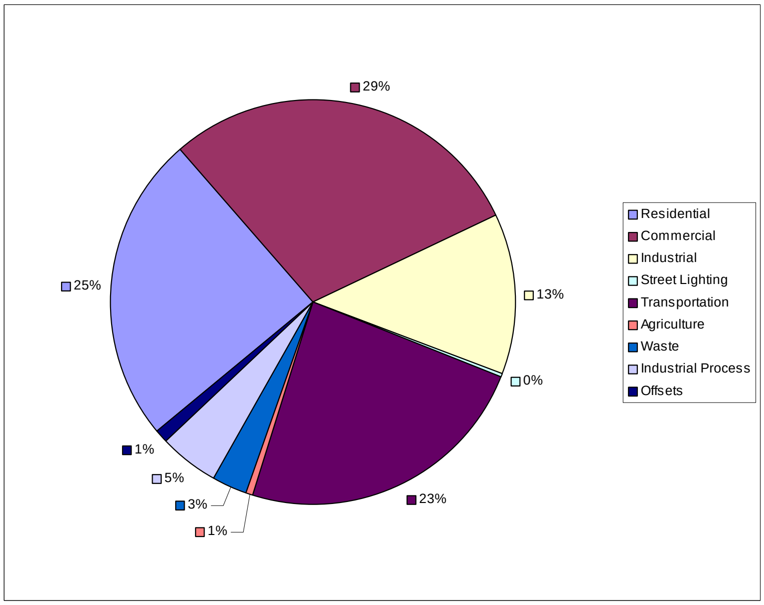
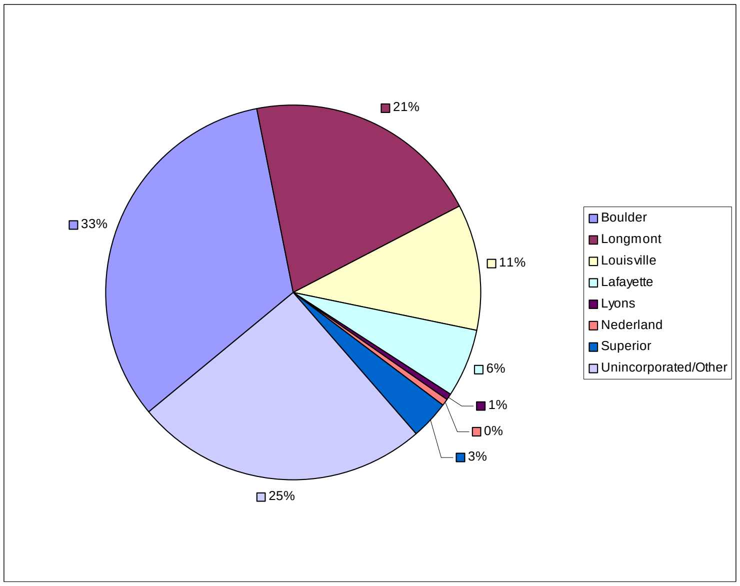


Figure 3. Countywide Emissions by Municipality, 2005



Emissions Mitigation Strategies

To determine what it would take to achieve the County Commissioners' goal of reducing GHG emissions 7 percent below 1990 levels by the year 2012, Boulder County hired Econergy International to conduct an analysis of possible emission reduction measures. The study assessed the emissions reduction potential of these measures at various implementation rates across the county. A broad range of emissions mitigation strategies were analyzed focusing on the key economic sectors identified in the inventory. Demand-side measures (DSM) were first investigated to gauge the opportunities presented by energy efficiency technologies to reduce energy demand. Supply-side measures were then evaluated to determine the impact of investments in new renewable energy supplies.

The report found that achieving realistic adoption of these strategies would produce only about 30 percent of the overall GHG emissions reductions countywide that are needed to reach the Kyoto target in 2012. This level of emissions mitigation will require investments by building owners and vehicle owners of about $850 million through 2012. While this is a substantial investment, these investments are also estimated to deliver $128 million/yr in energy cost savings and energy sales revenue by 2012. The overall Benefit/Cost ratio of this mix of measures is 2.7. This means that, over the equipment lifetime, each $1 of investment in DSM and RE will produce $2.70 in energy cost savings and energy sales revenue (constant 2006 $$).

The following is a summary of the energy efficiency and renewable energy strategies identified and the analysis of the emission reduction and cost/benefit impacts of their implementation.

I. Emissions Reductions from Commercial Buildings

This section evaluates opportunities to reduce GHG emissions through reductions in the commercial building sector's electricity and natural gas consumption. The Commercial sector (which includes private, public, and institutional buildings) uses electricity and natural gas for 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.

The commercial sector provides the largest contribution to Boulder County's GHG emissions. In 1990, the commercial sector accounted for 899,500 tCO_2e or 27 percent of the County's GHG inventory. By 2005, commercial emissions had risen to 1,591,300 tCO_2e and made up 31 percent of the County's GHG inventory. If the Business-As-Usual (BAU) trend continues, 2012 forecasts show that the commercial sector emissions will increase to 1,945,850 tCO_2e. Figure 4 demonstrates the dominance of electricity as an energy source in the commercial sector. Figure 5 shows a breakdown of commercial sector energy use in 2005 by municipality.

Figure 4: 2005 Commercial GHG Emissions by Source

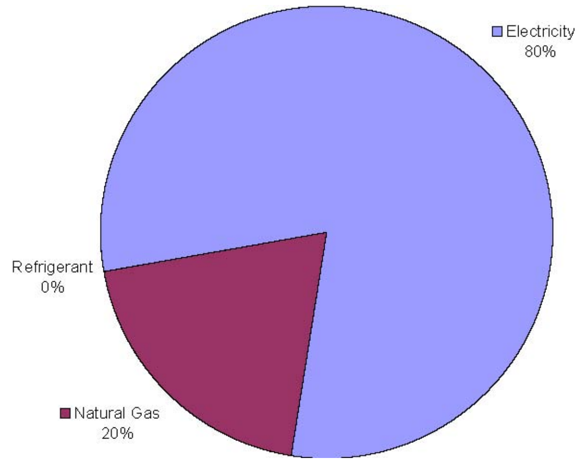
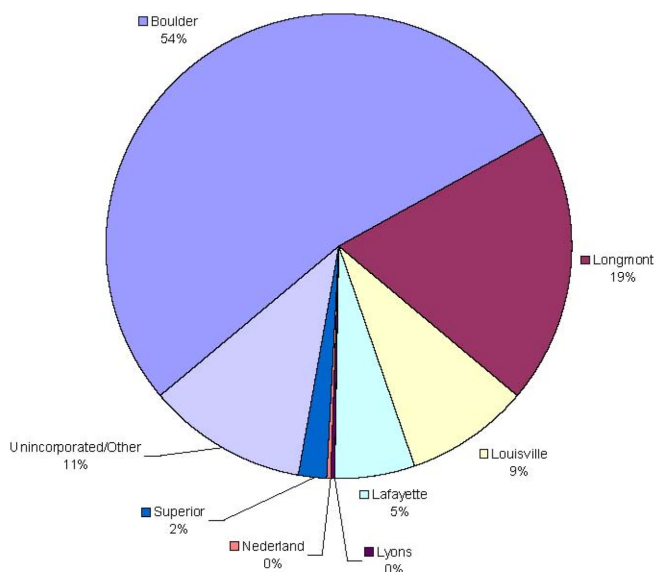


Figure 5: 2005 Commercial GHG Emissions by Municipality



A detailed analysis was performed on commercial building, which created the basis for estimating the potential for GHG reduction opportunities in this sector. The methodology used to quantify these reductions was to estimate the electricity and natural gas consumption and the associated utility costs in new and existing commercial buildings. Commercial buildings were divided between two vintages: pre- and post-1980. Second, three energy efficiency scenarios (called "bundles") were constructed and the energy savings and cost savings potential of each was established.

The Department of Energy's DOE-2.2 building energy simulation software 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.

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. It is important to note that the new construction portion of the 2012 BAU commercial inventory is only about 226,500 tCO_2e, or about 12 percent, assuming the difference between 2006 and forecasted 2012 emissions is attributable to new construction. Thus existing buildings are expected to account for 88 percent of energy use.

Table 1, below, lists the measures included in each energy efficiency bundle applied to both the pre- and post-1980 commercial buildings. 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 implementation or 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 1. Description of Energy	**OFFICE**	**RETAIL**	**RESTAURANT**

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

All things considered, Bundle 2 was judged to be the most-aggressive package that offers economic performance that can realistically appeal to the market by 2012. The marginal abatement cost of Bundle 2 is (-65)\$/mtCO_2, indicating it is an excellent investment. To achieve the reductions presented here will require investment by building owners of approximately \$90 million through 2012. Impacts for solar Photovoltaic (PV) are accounted for separately in the Renewable Energy discussion.

Table 2 presents the results of an in-depth analysis of GHG emissions mitigation opportunities from DSM in commercial buildings. Energy savings estimates were used to assess 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

Table 2. Commercial Building Mitigation Opportunities	**Annual reductions achieved in 2012 (tCO_2e)**	**Fraction of Commercial Goal Achieved (%)**	**Simple Payback (yrs)**
Commercial retrofit – Bundle 1	49,648	4%	3.9
Commercial retrofit – Bundle 2	148,320	13%	5.6
Commercial retrofit – Bundle 3	170,549	15%	12.8
Commercial new construction	56,915	5%	na

It is important to note that according to this analysis, implementing the measures identified in Bundles 2 would only achieve 15% of the emissions reductions needed from the commercial sector to reach a the Kyoto target.

II. Emissions Reductions from Residential Buildings

This section evaluates opportunities to decrease 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.

As indicated in Figure 2, above, the residential sector provides the second-largest contribution to Boulder County's GHG emissions. In 1990, the residential sector accounted for 877,850 tCO_2e or 26 percent of the County's GHG inventory. By 2005, residential emissions had risen to 1,305,000 tons carbon dioxide equivalent (tCO_2e) and continued to represent 26 percent of the County's GHG inventory. If the Business-As-Usual (BAU) trend continues, 2012 forecasts show that the residential sector emissions will increase to 1,493,200 tCO_2e. Like the commercial sector, Figure 6 demonstrates the dominance of electricity as an energy source in the residential sector. Figure 7 shows a breakdown of residential sector energy use in 2005 by municipality.

Figure 6: 2005 Residential GHG Emissions by Source

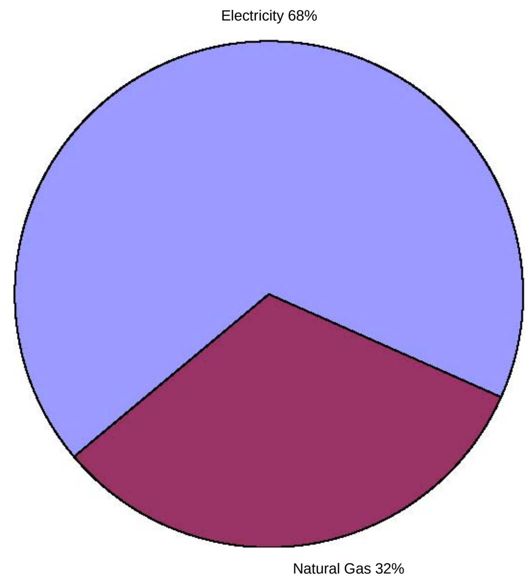
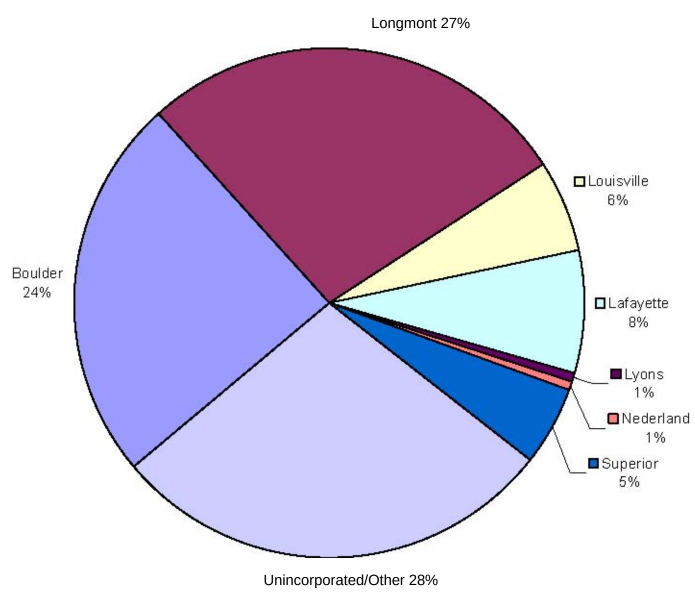


Figure 7: 2005 Residential GHG Emissions by Municipality



A detailed analysis was performed on 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.

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.

The U.S. Department of Energy's "DOE-2.2" building energy simulation software 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.

Table 3 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. Description of Single-Family Energy Savings Bundles	**SINGLE-FAMILY**	**MULTI-FAMILY**
Bundle 1	❑ Lighting efficiency upgrades – 75% of home lighting with CFLs oProgrammable Thermostats – Temperature Setback ❑ Energy Star refrigerator ❑ Energy Star washer	❑ Lighting efficiency upgrades – 75% of home lighting with CFLs oProgrammable Thermostats Energy Star refrigerator ❑ Energy Star washer
Bundle 2	❑ Lighting efficiency upgrades - – 75% of lighting with CFLs ❑ Programmable T-stats ❑ Energy Star refrigerator ❑ Energy Star washer ❑ Energy Star dishwasher ❑ Insulate ducts ❑ Replace windows with Energy Star insulated windows ❑ Condensing Furnace η – 93% ❑ Packaged AC EER – 10.5	❑ Lighting efficiency upgrades - – 75% of lighting with CFLs ❑ Programmable T-stats ❑ Energy Star refrigerator ❑ Energy Star washer ❑ Energy Star dishwasher ❑ Insulate ducts ❑ Replace windows with Energy Star insulated windows ❑ Condensing Furnace η – 93% ❑ Packaged AC EER – 10.5
Bundle 3	❑ Lighting efficiency upgrades - – 75% of lighting with CFLs ❑ Programmable T-stats ❑ Energy Star refrigerator ❑ Energy Star washer ❑ Energy Star dishwasher ❑ Insulate ducts ❑ Replace windows with Energy Star insulated windows ❑ Condensing Furnace η – 93% ❑ Packaged AC EER – 10.5 ❑ Evaporative cooling ❑ Solar Domestic Hot Water	❑ Lighting efficiency upgrades - – 75% of lighting with CFLs ❑ Programmable T-stats ❑ Energy Star refrigerator ❑ Energy Star washer ❑ Energy Star dishwasher ❑ Insulate ducts ❑ Replace windows with Energy Star insulated windows ❑ Condensing Furnace η – 93% ❑ Packaged AC EER – 10.5 ❑ Evaporative cooling ❑ 0.5 kW PV System per unit

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 of the residential Bundle 2 is (+8)$/mtCO2, indicating it is a worthwhile investment. To achieve the reductions presented here will require investment by building owners of approximately $330 million through 2012.

An in-depth analysis was performed of emissions mitigation opportunities from DSM in residential buildings. Table 4 presents the residential results. According to this analysis, implementing the measures identified in Bundle 2 would only achieve 33% of the emissions reductions needed from the commercial sector to reach the Kyoto target.

Table 4. Residential Building Mitigation Opportunities	Annual reductions achieved in 2012 (tCO_2e)	Fraction of Residential Goal Achieved (%)	Simple Payback (yrs)
Residential retrofit – Bundle 1	118,823	18%	5.2
Residential retrofit – Bundle 2	220,430	33%	12.5
Residential retrofit – Bundle 3	266,997	39%	17.7
Residential new construction	35,116	5%	Na

It is important to note that the new residential buildings subsector is not expected to offer a substantial opportunity to achieve reductions in 2012 GHG emissions. This is based on the estimate that new residential buildings, constructed during the 2007 through 2012 period, will only add approximately 140,000 tCO2e of GHG emissions 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 35,000 tCO2e in 2012, assuming a market penetration rate of 100% for the new residential building subsector is achieved in that year. This represents only about 5% of the 677,000 tCO2e emissions reductions that the residential buildings sector must produce if it is to achieve its nominal goal in 2012 BAU emissions reductions.

III. Emissions Reductions from Transportation

This section presents an evaluation of opportunities to reduce GHG emissions through strategies in the Transportation sector. Transportation sector emissions are produced through the consumption of gasoline, diesel, , and jet fuel. Gasoline and diesel are used in vehicles while airplanes use jet fuel.

As indicated in Figure 2, above, vehicle transportation is the third-largest sector contributing to Boulder County's GHG emissions. In 1990, the transportation sector accounted for 670,300 tCO_2e or 20 percent of the County's GHG inventory. By 2005, transportation emissions had risen to 1,232,300 tCO_2e and made up 24 percent of the County's GHG inventory. If the Business-As-Usual (BAU) trend continues, 2012 forecasts show that the transportation sector emissions will increase to 1,375,000 tCO_2e and comprise roughly 23 percent of the BAU inventory.

Since actual fuel usage data are not available, fuel consumption was estimated on the basis of Vehicle Miles Traveled (VMT) data. The forecast assumes the current fuel economy rate (miles traveled per gallon of fuel) for all vehicles, with a slight trend toward a higher percentage of miles traveled by more efficient, lighter-weight vehicles relative to heavier vehicles in future years. The number of VMT in the county is assumed to increase at the same rate that it has since 1990: an average increase of about 1.4%

annually. Figure 8 demonstrates the dominance of gasoline over diesel fuel as an energy source in the transportation sector. Figure 9 shows a breakdown of transportation sector energy use in 2005 by municipality.

Figure 8: 2005 Transportation GHG Emissions by Source

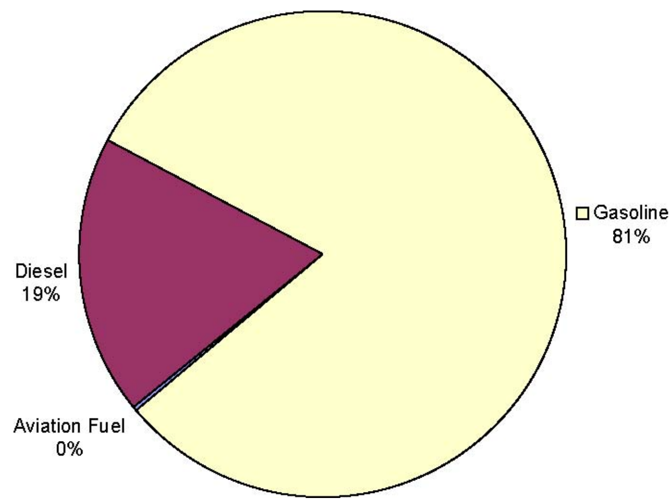
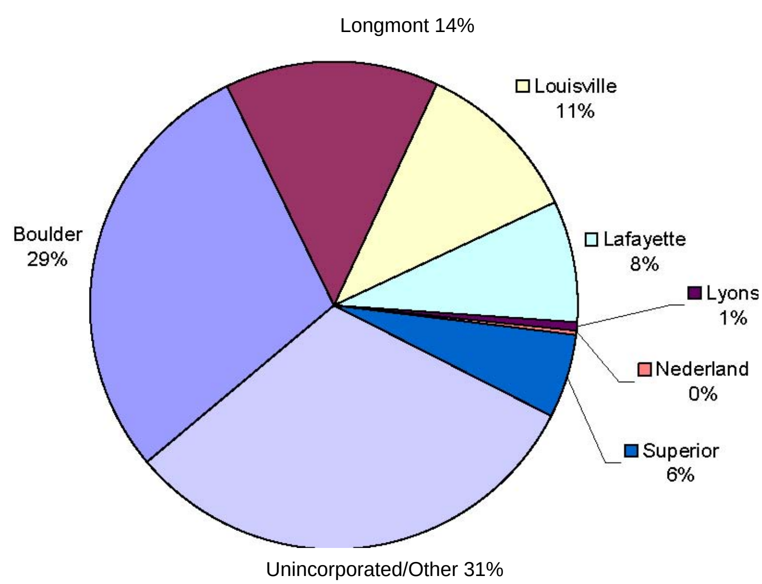


Figure 9: 2005 Transportation GHG Emissions by Municipality



The significant increase in vehicle travel and growing impact it has on the inventory emphasizes the role this sector can play in obtaining reductions in GHG emissions. Fortunately, there are significant opportunities for individual choices, private and public investments, and public policies that can significantly reduce transportation emissions in the coming years. Emissions mitigation opportunities in the transportation sector were analyzed in-depth.

These strategies boil down to reducing vehicle miles traveled through the use of alternative transportation options; increasing the vehicle fuel efficiency, increasing the use of biofuels such as biodiesel and ethanol, and adding plug-in electric vehicles to the mix. While all three approaches offer 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.

There are a number of efforts underway to provide and enhance alternative transportation use such as Fastracks, implementation of the City of Boulder Transportation Master Plan. Improving the overall fuel economy of passenger vehicles, including light-duty vehicles and heavier-duty vans and SUVs, by 5% would reduce the county's GHG emissions by about 58,000 $mtCO_2e$ in 2012, or about 8% of the emissions reduction goal for the transportation sector.

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 can be potent GHG management tools. This analysis assesses the impact of using a biodiesel/petrodiesel blend with 20 percent biodiesel (B20) to meet 10 percent of all diesel fuel needs. Ethanol is an alternative fuel replacing gasoline. Essentially all ethanol that is currently available in the US market is made from corn and is only slightly less GHG-intensive. Emerging technologies, however, promise to produce fuel-grade "cellulosic" ethanol at lower cost than traditional production methods, while deriving required process energy totally from renewable sources. Thus, ethanol is on the verge of becoming a fuel that is 100% renewable energy. This analysis assesses the impact of using a gasoline/ethanol blend with 85 percent ethanol (E85) supplying 10 percent or all gasoline use.

Plug-in hybrid electric vehicle (PHEV) technology uses standard hybrid engines, drive-trains, batteries, and regenerative braking systems, and augments them with extra battery capacity. At night, the on-board battery charger is plugged into a standard electrical outlet and the extra-capacity PHEV battery pack is fully charged. Since PHEVs are not yet available from vehicle manufacturers, this analysis uses the performance and cost of a retrofit kit that allows for all-electric operations for the first 30 to 40 miles of travel, while using the hybrid technology for longer trips. As a result, even using grid supplied electricity dramatic reductions in emissions of VOC, CO, and CO_2 are achieved. Greater reductions will be realized as more renewable energy supplies are added to the grid. The following table summarizes the air emissions impacts achievable by substituting a PHEV supplied by coal-fired electricity for a vehicle using 100 percent gasoline.

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

A combination of the measures discussed above is grouped below as a reasonable package for the Transportation sector. If the transportation sector were to achieve its 2012 reduction objective, it would have to reduce 2012 GHG emissions by 751,600 $mtCO_2e$. The package yields a 5.5% reduction in VMT, a 10% increase in vehicle fuel efficiency (VFE), a 10% market penetration for E85 fuel, a 20% market penetration for B20, and an 8.8% market penetration for PHEVs. Realizing these objectives will achieve 63% of the nominal 2012 reduction goal set for the sector. The results of implementing such a plan are summarized in Table 5.

Table 5. Transportation Strategy Description	**Annual reductions achieved in 2012 ($mtCO_2e$)**	**Percent of Goal Achieved**
Reduce VMT by 5.5%	80,853	10.8%
Improve overall vehicle fuel economy by 10%	109,948	14.6%
10% E85 market penetration	88,575	11.8%
20% B20 biodiesel market penetration	9,602	1.3%
9% PHEV market penetration	40,325	5.4%
Total Reduction	329,303	43.90%
Reduction Required to Meet Goal	751,644	
Unachieved Reduction	422,341	

The marginal abatement costs of key transportation emissions reduction strategies range from (-101) $/mtCO2 for standard hybrid electric vehicles to (+20)$/mtCO2 for B20 biodiesel to (+49)$/mtCO2 for plug-in hybrid electric vehicles (PHEVs). To achieve the reductions presented here will require investment by vehicle owners of approximately $81 million through 2012.

IV. Emissions Reductions from Renewable Energy

This section outlines the opportunities to reduce GHG emissions through reductions in the GHG intensity of grid-supplied electricity through the use of hydroelectric capacity, the purchase of renewable energy credits (RECs) and other "carbon offsets" that fund clean-energy project investments, and the installation of photovoltaic (PV) and solar water heaters on commercial and residential buildings.

The Cities of Boulder and Longmont own small hydroelectric plants. There is the potential to increase the capacity of these plants. If by 2012, 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 8,500 mtCO2/year in GHG emissions. The total cost of these systems would be about $3.5 million and they would produce annual electricity sales revenues of about $500,000 by 2012.

Wind energy conversion technology is mature and reliable. If by 2012, about 10 megawatts (MW) of wind capacity were installed approximately 23,300 MWh/year of additional carbon-neutral electricity could be produced. This would offset about 20,000 mtCO2/year in GHG emissions. The total cost of these systems would be about $15 million and they would produce annual electricity sales revenues of about $1,165,000 by 2012.

The success in Boulder County of retail RECs and carbon offsets credit 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 RECs 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 renewable energy (RE) measures presented offer lower-cost energy over the systems' lifetimes and, therefore, a financial return-on-investment.

This analysis assumes that the increasing popularity of RECs can be leveraged in Boulder County such that by 2012, RECs 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 these purchases is estimated at about $400,000 - $2 million.

Potential PV impacts can be significant. If by the end of 2012, 5 percent 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 21 mtCO2/year. The overall result would be GHG emissions reductions of about 15,800 (760 bldgs) mtCO2/year in 2012. The total cost of these systems would be about $37.2 million (net of Xcel rebates and tax credits) and they would produce annual energy cost savings of about $1,485,800 by 2012.

If by the end of 2012, 5 percent of residential buildings were to each install PV systems averaging 2 kW in nameplate rating, each system would produce about 2,400 kWh/year and would offset the emission of about 2 mtCO2/year. The overall result would be GHG emissions reductions of about 11,900 (5,700 bldgs) mtCO2/year in 2012. The total cost of these systems would be about $27.9 million (net of Xcel rebates and tax credits) and they would produce annual energy cost savings of about $1,114,300 by 2012.

Flat-plate 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 $1.50/therm, such a system would save about $218/yr and recover the $2,196 system cost (net of 30% federal tax credit) in 10 years.
If by the end of 2012, 70 percent of all residential dwelling units in Boulder County were to employ flat-plate solar systems as their exclusive source of DHW, the total GHG emissions reductions would be about 61,500 mtCO2/year. The total cost of these systems would be about $175.6 million and they would produce annual energy cost savings of about $17.5 million by 2012.

Results from analysis of renewable energy measures are presented below in Table 6.

Table 6. Renewable Energy Strategy Description	**Annual reductions achieved in 2012 ($mtCO_2e$)**	**% of Total Goal Achieved by Measure**
Additional city-owned hydroelectric capacity	8,500	0.3%
Publicly owned wind energy facilities	20,000	0.6%
Bulk purchasing RECs, CERs, VERs, CFIs	100,000	3.2%
PV installed on commercial and public buildings	15,800	0.5%
PV on residential buildings	11,900	0.4%
Solar Direct Hot Water (DHW)	61,500	2.2%
Total Reduction	**217,700**	**7.20%**

In summary, if all of the renewable energy strategies outlined above were to be implemented, total cost of these strategies would be about $354.2 million and they would produce annual energy sales revenues and energy cost savings of about $44.8 million by 2012. Total GHG mitigation of about 650 million mtCO2/year would be achieved in 2012.

V. Summary of Results

Aggregated results indicate that cost-effective energy efficiency and renewable energy measures for the residential, commercial, and transportation sectors along with investments in renewable energy will reduce countywide GHG emissions by 30% in 2012, relative to Business As Usual. These measures are estimated to deliver $128 million/yr in energy cost savings and energy sales revenues in 2012, at a total implementation cost of $850 million. Over the 25-year lifetime of the energy efficiency and renewable energy measures, the Benefit:Cost ratio is about 2.7. The following table summarizes the GHG impacts of the demand-side measures examined by this study.

Table 7. Summary of Demand Strategies	**Required Reduction in 2012 (mtCO2e)**	**Expected GHG Reduction in 2012 (mtCO2e)**	**Reduction Goal Shortfall (mtCO2e)**
Residential Buildings	676,800	255,550	421,250
Commercial Buildings	1,108,900	205,200	903,700
Transportation	751,600	329,303	422,341
Industrial Energy	113,300	11,300	102,000
Industrial Process	17,100	2,000	15,100
Agriculture	1,750	200	1,550
Solid Waste	67,700	7,000	60,700
Street Lighting	10,700	2,000	8,700
Total	**2,747,600**	**814,565**	**1,935,341**

Clearly, 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 supply-side strategies were evaluated including PV, wind energy, carbon offsets or RECs, and solar hot water. The following table summarizes the emissions reductions the analysis estimates are achievable with this mix of RE supply-side measures.

Table 8. Summary of Renewable Energy Strategies	**Reduction Shortfall after DSM (mtCO2e)**	**Expected RE GHG Reduction (mtCO2e)**	**Remaining Reduction Shortfall after RE (mtCO2e)**
	1,935,341		
Expansion of hydro capacity		8,500	
PV on commercial & public bldgs		15,800	
PV on residential buildings		11,900	
Wind		20,000	
Bulk purchase RECs and/or Offsets		100,000	
Solar DHW		61,500	
Total reduction		**217,700**	**1,717,641**

CONCLUSIONS

These results make it apparent that the demand-side management (DSM) and renewable energy measures evaluated are inadequate to the task of achieving the county's Kyoto goal. According to this analysis, the suite of DSM and RE measures will get the county only about 30 percent of the way to the goal line. Creative and aggressive strategies need to be developed to boost emissions reductions, especially via energy efficiency in the Commercial and Residential Buildings sectors.

The marginal abatement costs for the key emissions reduction strategies are summarized in the following table.

Table 9. Marginal Abatement Costs (MAC)	
Reduction Measure	**MAC ($/mtCO2)**
Commercial Buildings Bundle 2	-65
Residential Buildings Bundle 2	+8
E85	0
B20	+20
Standard Hybrid Electric Vehicle	-101
Plug-in Hybrid Electric Vehicle	+49
Solar PV	+100
Solar DHW	-39
RECs at $13/MWh	+20
Carbon Offsets at $10/mtCO2e	+10

Commercial buildings must achieve emissions reductions in 2012 of about 57% and residential buildings reductions of about 45 percent in order for these sectors to hit their targets. This analysis assumes reductions of only about 11 percent and 17 percent, 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 percent for DSM packages that achieve about 30 percent energy savings on average. Such results are quite aggressive and optimistic by historical standards, as gauged by utility company DSM program results.

It is important to bear in mind that the vast majority of the Commercial Buildings sector emissions that would be produced in 2012 under BAU (about 88 percent) emanate from the building stock existing as of 2006, as opposed to new construction that will be added during the 2007 – 2012 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).

Similar conclusions can be drawn for the Residential Buildings sector. The vast majority of the residential buildings emissions that would be produced in 2012 under BAU (about 91 percent) emanate from the building stock existing as of 2006, as opposed to new construction added during the 2007 – 2012 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.

The results for the Transportation sector highlight the crucial role that increasing fuel efficiency, reducing vehicle miles traveled, and using alternative fuels such as E85 can play in acquiring substantial GHG emissions reductions. The promotion of E85, particularly as the cellulosic ethanol sources become available, aiming to proliferate the retail availability of E85 are important objectives.