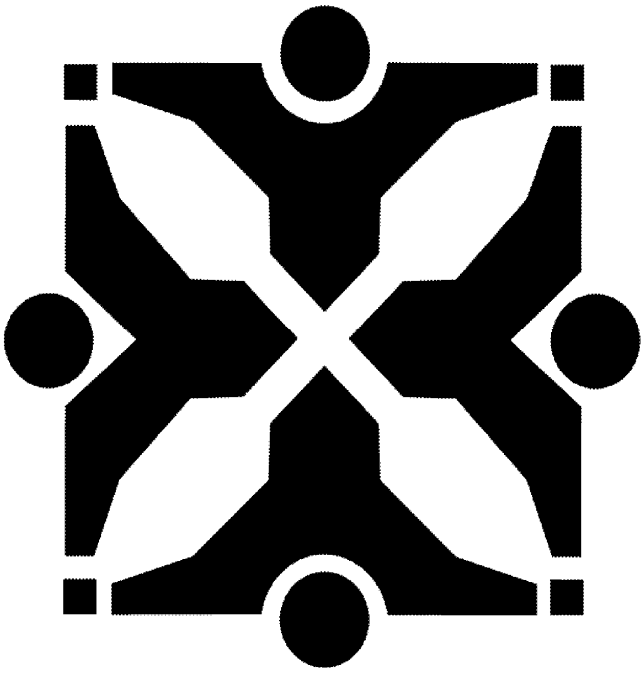
City of Columbia, Missouri Greenhouse Gas Inventory 2010 Update and Emission Reduction Recommendations

University of Missouri Pollution Prevention Program



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Executive Summary

On July 17, 2006, the City Council of Columbia, Missouri adopted the U.S. Mayors Climate Protection Agreement. By doing so, the Council agreed to strive to meet or exceed Kyoto Protocol global warming pollution reduction targets of 7% by 2012, using 2000 as the city's emission baseline.

This project assesses Columbia's response to the Mayors Climate Protection Agreement with four objectives. The first objective was to conduct a citywide greenhouse gas emission inventory for the 2010 calendar year. The second was to standardize the City of Columbia's two previous citywide emissions inventories (2000 and 2005) with their 2010 inventory. The third was to complete the city's first municipal greenhouse gas inventory. The fourth was to make greenhouse gas emission reduction recommendations to the City of Columbia based on the results of the emissions inventory. See Table 1 for standardized emissions.

Residential, commercial, and industrial sectors encompass Columbia's electricity and natural gas consumption. It was found that natural gas emissions increased steadily from 2000 to 2010. This was due to population growth. Electricity production emissions increased from 2000 to 2005 but decreased slightly from 2005 to 2010. The increase was due to population growth. The decrease in emissions was because Columbia's largest utility, Columbia Water and Light, purchased less power from carbon-intensive power plants and also purchased 5% renewable energy in 2010.

Waste emissions encompass emissions from the Columbia Sanitary Landfill and Wastewater Treatment Plant. Solid waste emissions increased from 2000 to 2005 but decreased from 2005 to 2010 despite an increase in tonnage landfilled. The increase was due to population growth and the decrease was attributed to a large decrease in paper content in Columbia's waste stream. This was determined by comparing the 1998 and 2008 Missouri Department of Natural Resources *Waste Composition Studies*, which are the best datasets available.

Wastewater emissions declined slightly from 2000 to 2005 and increased from 2005 to 2010. The decrease was due to an improvement in biological oxygen demand removal by primary treatment. The increase was due to population growth.

Transportation emissions represent the miles driven within Columbia annually. Calculating emissions in this was determined to be the most reproducible method. Emissions rose faster than population from 2005 to 2010. This was due to an increase in miles driven per person in Columbia in 2010.

Aggregate emissions increased from 2000 to 2005 and decreased slightly from 2005 to 2010. This was due to a decrease in electricity production emissions in 2010 relative to 2005. Columbia's emissions increased by 8.6% relative to 2000 levels instead of decreasing by 7%. Columbia did not meet its Mayors Climate Protection Agreement Goal.

The standardization of 2000 and 2005 inventories was completed successfully. It required recalculating transportation and wastewater emissions for 2000 and 2005.

The municipal (city government) inventory was not completed because it was impossible to collect the needed utility information for specific city departments. The city's internal information systems simply were not designed to generate utility use by department.

This project gave three recommendations to the City Council of the City of Columbia. The first recommendation was to vastly improve internal information systems. Improved information systems would enable the city to see and optimize the impact of their retrofit and efficiency programs.

In the course of the project, it was discovered that Columbia had lost track of its emissions reduction goals. The second recommendation was that Columbia recommit to serious emission reductions. Reduction goals would serve as an impetus to find ways to make more serious emission reductions.

The third recommendation was to increase Water and Light's renewable energy purchases to 35% by 2015. This was found to be the only way for Columbia to reach their 7% emissions reduction goal. If Council acted upon the recommendation, it would decrease Columbia's CO_2e emissions by over 360,000 metric tons per year. In this report's August 6th, 2012 presentation to City Council, 30% renewable energy purchases were recommended. The 35% figure is based on final calculations.

It is unclear whether Columbia will act on any of this project's recommendations in the near future. In response to the project and its findings, the Mayor stated clearly that he is happy with the path that Columbia is on; however, because the city is operated by a council-manager style government, most power is vested in the City Council.

Table 1

Year	2000	2005	2010
Subtotoal Energy Sector	**1,653,200**	**1,850,335**	**1,735,490**
Subtotal Natural gas	172,764	187,789	207,799
Subtotal Electricity	1,480,435	1,662,547	1,527,691
Residential	**567,032**	**633,421**	**641,302**
*Natural Gas	93,293	101,406	112,160
Electricity	473,739	532,015	529,142
Commercial	**678,051**	**759,964**	**748,131**
*Natural Gas	41,463	45,069	49,498
Electricity	636,587	714,894	698,633
Industrial	**408,117**	**456,950**	**346,057**
*Natural Gas	38,008	41,313	46,141
Electricity	370,109	415,637	299,916
Subtotoal Waste Sector	**30,486**	**33,623**	**33,118**
Wastewater	5,366	5,157	7,127
Solid Waste (OLD METHOD, included in aggregate)	25,120	28,466	25,991
Solid Waste (NEW METHOD, not included in aggregate)	-	-	61,160
Subtotal Transportation Sector	**487,754**	**500,968**	**589,693**
Aggregate Emissions in Metric Tons CO2e	**2,171,440**	**2,384,926**	**2,358,301**
per capita	25.7	26.0	21.7

*Data unavailable for natural gas emissions by subsector (res., comm., ind.) in 2000 and 2005. The 2010 gas usage ratio was applied to 2000 and 2005 subtotals. All natural gas subtotals are correct. These estimations do not affect sector subtotals.

Background

The City of Columbia, Missouri is located in Boone County and is inhabited by 108,500 residents based on the 2010 Census. In 2000, Columbia's population was 84,531. The city is positioned on Interstate 70 approximately midway between Kansas City and St. Louis. It is home to the University of Missouri-Columbia, which currently has over 33,000 students. Columbia is governed by a council-manager style government that vests most power in its City Council.

On July 17, 2006, the City Council of Columbia adopted the U.S. Mayors Climate Protection Agreement. By doing so, the Council agreed to strive to meet or exceed Kyoto Protocol global warming pollution reduction targets of 7% by 2012. As was done by many other U.S. cities, Columbia used 2000 as their baseline emissions level because a lack of applicable data from the previous decade. Columbia completed 2000 and 2005 emissions inventories in 2007. There was an unsuccessful attempt to complete Columbia's 2010 inventory in 2011.

The minutes from the City Council meeting on July 17th, 2006 show at the time of approval there was clear intent to cut emissions by 7% by 2012.[i] Focus on the goal may have been lost through miscommunication in city government or loss of institutional memory. Neither the Columbia's 2012 Climate Protection Agreement Report nor any other document since 2006 mentions the 7% reduction target. In a 2011 attempt to continue the project, university students were charged with producing a 2010 emissions inventory but were unsuccessful in collecting the needed data.

The methodology used for the 2012 greenhouse gas inventory was the *International Council for Local Environmental Initiatives* (ICLEI) global community-scale greenhouse gas emissions inventory protocol. It is widely used by municipalities in over seventy countries. ICLEI Clean Air and Climate Protection 2009 tool (CACP 2009) is the software used for some emissions inventory calculations. Greenhouse gas emissions are grouped into five categories: residential, commercial and industrial energy use, transport, and waste emissions. The report calculates carbon dioxide equivalent (CO_2e) emissions from electricity production and natural gas consumption, transportation, and the Columbia Sanitary Landfill and wastewater treatment plant.

Methodology

Data Management, Acquisition, and Verification

Data acquisition and normalization was the majority of this project. Data was collected electronically via email and telephone, and entered into a spreadsheets immediately following collection. Once data was entered, the project contact log (file name: 2010_Contact_Log) was updated with the date of data collection, source of the

data, the company/department that generated the data, contact information, and general notes about the data collection. All data spreadsheets and the contact log were saved automatically to Dropbox™ throughout the project. All files, including this report, have been transferred to the Sustainability Manager's computer.

Electricity production and consumption data, natural gas purchase data, vehicle miles travelled (VMT), and tonnage of waste landfilled were only accepted for use if they were based on the 2010 calendar year and from the most reliable source possible. Some data, specifically precise waste composition and emission coefficients by power plants, was not available for 2010. In these cases, the most recent data from 2007 or later was accepted.

Most acquired data was provided in units that needed to be converted. All conversions and calculations were done transparently in Excel and then verified with a calculator. Because all data, processes, and sources were documented, calculations and conversions are easily reproducible.

Data and analyses were verified by the City of Columbia and the Office of Sustainability.

Community Emissions Inventory and Inventory Standardizations

Energy:

Electricity - Energy emissions are the emissions created by the production of electricity and the consumption of natural gas. The study included emissions from residential, commercial, and industrial sectors. To calculate CO_2e emissions from electricity the energy production, energy usage by sector, and power purchase information were collected from the three utilities that provide power to the City: Columbia Water and Light, University of Missouri Columbia (UMC) Power Plant, and Boone County Electric Cooperative. See the project contact log for specific contact references.

For comparing emissions from the University of Missouri Power Plant, it was necessary to obtain power production and consumption data from the actual calendar year, not their reported data from the American College & University Presidents Climate Commitment. This will be important when conducting future City greenhouse gas inventories.

Each of the three utilities purchases power from multiple sources, including various power production facilities or power control areas (PCA). Precise emission coefficients for each power production facility and PCA were obtained from the Environmental Protection Agency's *Emissions & Generation Resource Integrated Database* (eGRID 2012). The eGRID provided emission coefficients in "tons of carbon dioxide equivalent per megawatt hour," or CO_2e/mWh, from each plant in 2009, which is the most recent available annual emissions information.

The energy Columbia consumed (in mWh) from each power provider and power supplier was multiplied by the specific emissions coefficient to calculate annual emissions in metric tons. The three utility totals were divided into residential, commercial, and industrial sectors using the usage percentages provided by each utility. The usages for each emissions sector were also summed.

It should be noted that ICLEI considers universities to be commercial, hence emissions from the UMC Power Plant are attributed entirely to the commercial sector. Government emissions are also considered commercial.

Grid loss for the United States' Eastern grid is included in calculations. Because grid loss cannot be calculated for each power production facility, the ICLEI recommended practice is to apply an average across all facilities, even those located in Columbia. See Table 2 for an illustration of 2010 electricity generation emission calculations with grid loss.[ii] Calculations have been made transparently in Excel (file name: 2010_Columbia_Electricity_Emissions).

Electricity production emissions were calculated in the same way in 2000, 2005, and 2010 inventories. It was not necessary to update 2000 and 2005 numbers.

Natural Gas - Data for natural gas sales (in therms) to residential, commercial, and industrial sectors in Columbia were collected from Ameren UE, the city's sole provider. Ameren UE provided data for a fourth sector as well: the power supply sector. This sector represents the natural gas used to create power at the UMC Power Plant and at the Columbia Energy Center, a natural gas power production facility within Columbia, Missouri. Because UMC Power Plant's electricity generation had already been accounted for in commercial sector electricity generation emissions, the natural gas that they used to create energy was subtracted from the power supply sector. Because none of Columbia's three utilities purchased energy directly from the Columbia Energy Center in 2010, emissions from natural gas used to create energy at the Columbia Energy Center were attributed to the industrial sector.

UMC Power Plant's gas usage data was taken from eGRID 2012 because Ameren UE is not allowed to provide information on specific purchases. This was determined to be the best source for information; however, because it contains information from 2009, it is not a perfect source. Therms used by UMC Power Plant were subtracted from the power supply sector. The remaining therms were attributed to the Columbia Energy Center because there are only two natural gas power plants in Columbia, Missouri.

The therms used by each sector were input to an excel calculator (file name: 2010_Columbia_gas_usage) to calculate tons CO_2e emissions for each sector from natural gas usage. See Table 3 for an illustration of natural gas usage by sector, including calculations for the power supply sector.

There was not enough information to recalculate 2000 and 2005 natural gas emissions; however, when the old and new calculation methods were compared the produced results were within .1%. The Excel calculator that was created for this project includes a calculator for future emissions inventories (file name: 2010_Columbia_gas_usage). The calculator is based on the *EPA Climate Leaders Direct Emissions from Stationary Combustion Guidance*, which is recommended by ICLEI.[iii]

Aggregate emissions by sector were calculated by summing electricity production emissions and natural gas consumption emissions for each sector. For results, see Table 1.

Table 2

2010 Columbia Electricity Emissions

Columbia Water and Light energy use and purchase

emission coefficients

Source	To	So	mWh consumed	NC	SO	CO	CH	N	CO2e (lbs/mWh)	Grid Loss %	MTCO2e emission by provider
Columbia Power Plant	#	0	69,087	##	#	#	#	#	2,892.81	5.82%	95,929
Bluegrass Wind (Associated)	#	0	17,339	0	0	0	0	0	0	5.82%	0
Ameresco Landfill gas- Jefferson City	#	0	21,708	0	0	0	0	0	0	5.82%	0
local Landfill gas generation	#	0	13,052	0	0	0	0	0	0	5.82%	0
Ameren Energy Marketing	#	0	595,085	##	#	#	#	#	2,019.96	5.82%	576,974
Board of Public Utilities (Nearman)	#	#	113,298	##	#	#	#	#	2,690.85	5.82%	146,334
Board of Municipal Utilities (Sikeston	#	#	367,679	##	#	#	#	#	2,357.92	5.82%	416,133
Boone Electric Coop	#	0	266	##	#	#	#	#	1,909.00	5.82%	244
Solar One Suppliers	#	0	10	0	0	0	0	0	0	5.82%	0
UMC Power Plant	#	0	604	##	#	#	#	#	1,217.28	5.82%	353
Total:	**#**	**#**	**1,198,128**	**##**	**#**	**#**	**#**	**#**	**total metric tons emitted:**		**1,235,966**

Emissions by Sector		
Sector	**mWh Consumed**	**MTCO2e**
Residential (37%)	443,307	457,307
Commercial (41%)	491,232	506,746
Industrial (22%)	263,588	271,913

Boone Electric Cooperative energy use in Columbia

emission coefficients

Source	To	So	mWh consumed	NC	SO	CO	CH	N	CO2e (lbs/mWh)	Grid Loss %	MTCO2e emission by provider
Associated Electric Cooperative (P.C.A.)	#	0	132,881	##	#	#	#	#	1,909	5.82%	121,754
			132,881	**73**	**#**	**#**	**#**	**#**	**total metric tons emitted:**		**121,754**

Emissions by Sector		
Sector	**mWh Consumed**	**MTCO2e**
Residential (59%)	78,400	71,835
Commercial (18%)	23,919	21,916
Industrial (23%)	30,563	28,003

University of Missouri Columbia Power Plant

emission coefficients

Source	To	So	mWh consumed	NC	SO	CO	CH	N	CO2e (lbs/mWh)	Grid Loss %	MTCO2e emission by provider
UMC Power Plant (including co gen)	#	0	144,420	##	#	#	#	#	1,217.28	5.82%	84,382
UMC Purchased Electricity	#	0	101,364	##	#	#	#	#	1,759.15	5.82%	85,589
Total	**#**	**0**	**245,784**	**##**	**#**	**#**	**#**	**#**	**total metric tons emitted:**		**169,972**

Emissions by Sector		
Sector	**mWh Consumed**	**MTCO2e**
Residential (0%)	0	0
Commercial (100%)	245,784	169,972
Industrial (0%)	0	0

Table 3

Natural Gas Usage Within the City of Columbia in 2010

*Like previous studies, this does not include large commercial customers that purchase from other suppliers

	therms
given total usage	39,720,331
adjusted total gas usage:	**38,732,221**
residential	**20,898,327**
commercial	**9,222,768**
Industrial*	**8,611,126**

655,489	therms used by "industrial sector" customers
8,943,747	therms used by "power supply sector" customers
98,811	MMBtu natural gas used to produce power at UMC
10	therms in 1 MMBtu
988,110	therms used to generate electricity at UMC
7,955,637	adjusted "power supply sector"
8,611,126	therms attributed to industrial sector (industrial sector + adjusted power supply sector

*Industrial sector includes power supply sector except for those therms that produced electricity at the UMC Power Plant. These therms are subtracted from the industrial sector so that their emissions do not count twice in the overall emissions inventory. mWh produced by gas were taken from EPA eGRID 2012.

Source: Ameren UE

Waste Emissions: Waste emissions include emissions from the Columbia Sanitary Landfill and wastewater treatment plant. Waste sector emissions were calculated by summing each year's wastewater and solid waste emissions.

Solid Waste - In 2000 and 2005 inventories, solid waste emissions were calculated for the Columbia Sanitary Landfill using the CACP 2009 software. The new ICLEI method is to take emissions numbers directly from the EPA Large Facility Greenhouse Gas Database.[iv] Columbia Sanitary Landfill did not report to the Large Facility Greenhouse Gas Database in 2000 and 2005, so solid waste emissions were calculated for this study using both methods. The old method was included in aggregate emissions so that inventories are directly comparable to one another; however, results are flagged and the results from the new method are displayed.

The active section of the landfill operation, known as "Cell 4," is a bioreactor that incorporates landfill gas recovery. The cell has been operated as a bioreactor since April 2008. Waste is moistened before it is put in Cell 4 to speed the decomposition of organic material to produce much more methane in a shorter amount of time than in a traditional anaerobic landfill. As with all landfill gas

recovery systems, a portion of the landfill gas is recovered and is either flared or used to produce power for Columbia Water and Light.

The 2010 comparison study used the old ICLEI method, for which solid waste emissions were estimated using the CACP and inputting the total tonnage of landfilled waste by category. Organic material in the landfill was recorded in four categories: paper products, food waste, plant debris, and wood/textile. Each of these categories decay at different rates and have different percentages of carbon content, which determines how much of the material can decay to methane or CO_2. The Columbia bioreactor landfill is considered a "managed landfill" in the CACP. By marking the landfill as a bioreactor, organic matter decay rates within the CACP are increased compared to a traditional anaerobic landfill.

The remaining landfill tonnage was included in a fifth category—"all other waste"—and it was assumed that it does not decay to methane or CO_2 in a time scale relevant to this project. The total tonnage landfilled was taken directly from the Columbia Sanitary Landfill's 2010 landfill tipping fee data, obtained from Columbia Public Works.

The composition of the landfilled waste was taken from the Missouri Department of Natural Resources 2008 Missouri Waste Composition Study.[v] The study contains estimated percentages of organic inputs based on 50 hours of input observation at the Columbia Sanitary landfill. This data was taken in 2007, before the landfill operated as a bioreactor. This did not affect the accuracy or the usability of the data from the 2008 Waste Composition Study because the change to a bioreactor did not affect organic material input to the landfill.

The 2010 greenhouse gas inventory used percentages calculated for the 2008 Waste Composition Study because it was the most recent and accurate data available for the Columbia Sanitary Landfill. Missouri Department of Natural Resources is uncertain whether they will have funding for another Waste Composition Study by 2015; therefore, this project also reports waste emissions with the new ICLEI method. The Columbia Sustainability Manager will decide which method to use in the 2015 study.

For comparison using the new ICLEI method, the 2010 solid waste emissions were reported in $MTCO_2e$ using data for the Columbia Sanitary Landfill contained in the EPA Large Facility Greenhouse Gas Database.[vi] Biogenic CO_2 was excluded at the recommendation of ICLEI.

Wastewater - In Columbia's 2000 and 2005 emission inventories, wastewater treatment plant (WWTP) emissions included only the CO_2 emissions resulting from the combustion of methane from the anaerobic digester. Emissions were recalculated for the 2000 and 2005 using the new ICLEI method, which is also used in the 2010 study.[vii]

The new ICLEI method calculates emissions from each stage of treatment: primary treatment, anaerobic digestion, and treatment pond/effluent release.

Primary treatment includes all processes within the WWTP leading up to anaerobic digestion. It should be noted that in wastewater treatment terminology, this stage includes "primary" and "secondary" treatments. This can cause confusion when talking with WWTP technicians and engineers. See the Excel-based calculator

for a description of each dataset that is needed to complete calculations (file name: 2010_Wastewater_emissions).

Primary WWTP treatment as defined by ICLEI is an aerobic process, so there is no methane produced by methanogenic (methane producing) bacteria, which are only active in anaerobic environments. CO_2 and N_2O are produced in primary treatment. N_2O was calculated in the Excel-based calculator. CO_2 was not counted in Columbia's emissions inventory because is biogenic CO_2.

Anaerobic digestion of solids is an anaerobic process in which methane is produced. At the Columbia WWTP, this methane is combusted to reduce emissions and create electricity for use within the facility. N_2O and uncombusted methane were counted in the emissions inventory and calculated in an excel calculator. CO_2 produced from the combustion of methane is considered biogenic CO_2, so it is not counted in the inventory. The methane content of anaerobic digester gas is not monitored, so it is estimated in the wastewater emissions calculator in accordance with the ICLEI Protocol.[viii] Columbia Public Works had the digester gas analyzed by Black and Veatch in 2007. A report summarizing the analysis is available but should not be used in future inventories. Public Works does not use it and its tables have mistakes without explanations.

Columbia's WWTP effluent (partially-treated wastewater) flows into a series of treatment lagoons. There is no mechanical "stirring" of the lagoons, so anaerobic conditions do occur. Methane and N_2O emissions were calculated for this final stage of treatment using the five-day biological oxygen demand of the partially treated effluent that enters the lagoons. The CO_2 produced is considered biogenic and is not included in the emissions inventory. Calculations are made in the Excel calculator.

The Excel calculator that is developed for this emissions inventory is also provided, with equations but without data, for future inventories (file name: 2010_Wastewater_emissions). This insures that the future greenhouse gas emissions studies will use the same methodology. See Table 4 for 2010 wastewater emission calculations.

Table 4

CO2e emissions from primary treatment

N20 emissions in MTCO2e

Formula Used: ICLEI WW.8
MTCO2e emitted annually = ((P x Find-com) x EF x mtg) x GWP

108500	**P**	Population served by WWTP
1.25	**F ind-com**	factor for significant industrial and commercial co-discharge waste as determined by EPA 40 CFR 403.6
3.2	**EF**	emissions factor for plant without nitrification/denitrification
0.000001	**mtg**	metric tons in 1 gram
310	**GWP**	Global warming potential of N2O relative to CO2
134.54	**MTCO2e emitted**	

CO2e emissions from Anaerobic digester

N2O emissions in MTCO2e

Formula Used: adapted from ICLEI WW.2.a
MTCO2e generated= ((Scf gas/year)(gas CH4 composition)(BTU/scf CH4)(MMBTU/BTU)(kg N20/MMBTU)(MT/kg))(GWP)

Data used for calculations	
48,002,000	scf combusted in 2010
0.65	the % of digester gas that is CH4
1028	BTU per SCF of Methane
0.000001	MMBTU/BTU
0.00063	kg N20/MMBTU
0.001	MT/kg
310	Global warming potential when compared with CO2
6.3	**MTCO2e emitted**

CH4 emissions from incomplete combustion of digester gas

Formula Used: adapted from ICLEI WW.1.a
MTCO2e emitted= ((Scf gas/year)(gas CH4 composition)(BTU/scf CH4)(MMBTU/BTU)(CH4 emission factor)(MT/kg))(GWP)

Data used for calculations	
48,002,000	scf combusted in 2010
0.65	the % of digester gas that is CH4
1,028.0	BTU per SCF of Methane
0.000001	MMBTU/BTU
0.0032	CH4 emission factor (kg CH4/MMBTU)
0.001	MT/kg
21.0	Global warming potential when compared with CO2
2.2	**MTCO2e emitted**

CO2e emissions from wastewater treatment ponds and effluent release

CH4 emissions from wastewater treatment ponds

Formula Used: ICLEI WW.6
MTCO2e from CH4 = (BOD5 load x (1-fp) x Bo x MCFa x DY x MTK) x GWP

20157.645	**BOD5 load**	amount of 5 day Biological oxygen demand treated per day (kg BOD5/day)
0.92	**Fp**	Fraction BOD removed in primary treatment in 2010
0.6	**Bo**	Maximum CH4 producing capacity for domestic wastewater (kg CH4/kg BOD)
0.8	**MCFa**	Methane correction factor for anaerobic systems
365.25	**DY**	conversion factor (day/year)
0.001	**MTK**	Conversion from kg to mt (mt/kg)
21	**GWP**	Global warming potential of methane relative to CO2
5,937.2	**MTCO2e emitted**	

N2O emissions from wastewater treatment ponds

Formula Used: ICLEI WW.12
MTCO2e from N2O= (N-load x EF x DY x MTK x NON) x GWP

1177.07124	**N-load**	Average total nitrogen per day (kg N/day)
0.005	**EF**	Emission factor (kg N2O-N/kg sewage-N discharged)
365.25	**DY**	conversion factor (day/year)
0.001	**MTK**	Conversion from kg to mt (mt/kg)
1.57	**NON**	Molecular weight ratio of N2O to N2
310	**GWP**	Global warming potential of N2O relative to CO2
1,047.2	**MTCO2e emitted**	

Transportation Emissions:

Transportation emissions are defined as emissions from combustion of fossil fuels, biodiesel, and ethanol by internal combustion engines within the City of Columbia. As with previous inventories, the 2010 inventory represents only automobile traffic because it represents the primary mode of travel within the City, because vehicle miles traveled (VMT) is the only available reliable information, and because this is an ICLEI recommended practice.[ix]

It is notable that improvements have been made to the pedestrian and bicycling infrastructure over the past four years. Though a large *Non-motorized Transportation Pilot Program* grant awarded by the Federal Highway Administration, Columbia now has over 350 miles of sidewalks, 28 miles of bicycle lanes, and 25 miles of shared paths. The program reported increases in bicycle traffic of up to 124% and decreases of automobile traffic of 4% in targeted areas.[x]

The U.S. Department of Transportation Office of Highway Policy Information publishes an annual statistics series that contains daily VMT traveled in many urbanized areas of the U.S.[xi] Table HM-71 from *Highway Statistics 2010* was obtained directly from the Department of Transportation, which also provided data for Columbia's 2000 and 2005 greenhouse gas inventories. In Table HM-71, Columbia's 2010 population is listed as 96,417, which is well below the actual population recorded in the 2010 Census. VMT calculations are not affected by population, so it is not necessary to adjust for this discrepancy. VMT is not adjusted for student population fluctuations. It was determined that there is no way to accurately determine the percentage of students that remain in Columbia during breaks, or to estimate what the trend might have been over the past decade.

As recommended by ICLEI, daily VMT was multiplied by 365 to calculate yearly VMT. Yearly VMT was input to the CACP 2009 "Transport Assistant," which gave emissions in $MTCO_2e$.[xii]

The Transport Assistant has an option to input custom VMT percentages. VMT percentages are the percent of the annual VMT driven by a specific vehicle class (diesel and gasoline car, diesel and gasoline trucks class 1-8, and buses). This information is not available for Columbia, so default figures, representing national averages, were used in 2010 calculations and for the 2000 and 2005 recalculations. These recalculations were made because it was found that the 2000 and 2005 emission inventories were calculated incorrectly. These inventories added roadway mileage from Missouri Department of Transportation (MODoT) to the Federal Highway Administration's VMT before inputting information to the Transport Assistant. The federal VMT is based on MODoT roadway mileage, so the addition was redundant and led to reporting transportation emissions that were too high.

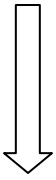
Government Inventory – The government inventory was not completed because the city's current internal information systems did not allow for collection of utility use by department.

Policy Recommendations - Once all data was collected, verified and the aggregate emissions calculated successfully, Columbia's emissions were compared with other

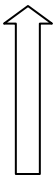
cities to identify emission reduction strategies. Emissions data and reduction strategies were collected from the Carbon Disclosure Project, Heartland Local Government Sustainability Network, and the World Bank. See Table 5 for a comparison of Columbia to other cities.

Findings

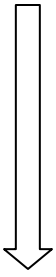
Community Inventory (see Table 1):



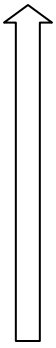
Electricity production emissions increased from 2000 to 2005 but decreased slightly from 2005 to 2010. The decrease in emissions from 2005 to 2010 was because Columbia's largest utility, Columbia Water and Light, purchased less power from carbon-intensive power plants and also purchased 5% renewable energy in 2010.



Natural gas emissions increased steadily from 2000 to 2010. It is reasonable to assume that this is due to an increase in population. Because actual natural gas usage was not included in 2000 and 2005 inventories, it was estimated from emissions. Using these estimates, natural gas usage increased approximately 10% while population increased around 20%.



Solid waste emissions increased from 2000 to 2005 but decreased from 2005 to 2010 despite an increase in the tonnage of landfilled waste. Because the 2000 and 2005 reports were calculated using the 1998 Waste Composition Study, the only variable that changed in calculations was input tonnage. Columbia's population increased from 2000 to 2005; therefore, it is reasonable to attribute higher emissions to higher population. The decrease from 2005 to 2010 was due to a large decrease in paper content in Columbia's waste stream (See 2008 Waste Composition Study).



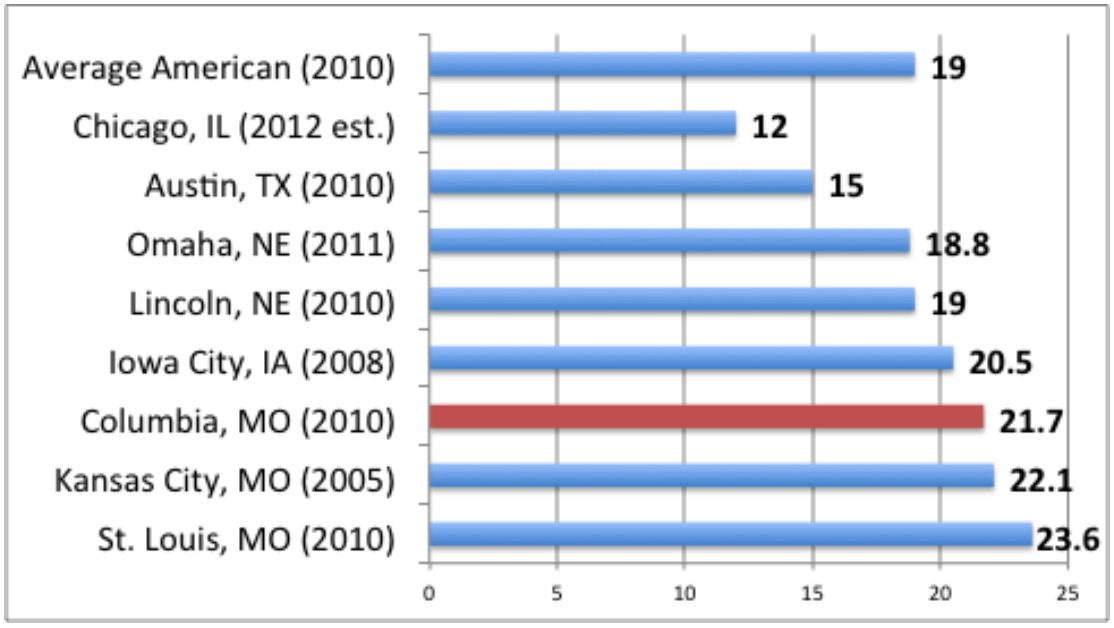
Wastewater emissions declined slightly from 2000 to 2005 and increased from 2005 to 2010. The decrease was due to an improvement in biological oxygen demand removal by primary treatment. This information was obtained directly from Columbia's Public Works Department. The increase was due to population growth. Because wastewater treatment procedures removed the exact same percentage of biological oxygen demand in 2010 as they did in 2005, the only variable that can raise emissions is the total amount (lbs.) of biological oxygen demand. It is reasonable to attribute higher biological oxygen demand to a population increase. Waste emissions represent a small percentage of emissions sources.

Transportation emissions rose from 2000 to 2005; however, transportation emissions rose faster than population from 2005 to 2010. This was due to an increase in miles driven per person in Columbia in 2010. In 2010, Columbians drove 9,311 miles per person; however, in 2005 Columbians drive 9,056 miles per person.[xiii]

Aggregate emissions increased from 2000 to 2005 and decreased slightly from 2005 to 2010. This was due to a decrease in electricity production emissions in 2010 relative to 2005. Columbia's greenhouse gas emissions increased by 8.6% relative to 2000 levels. The goal for 2012 was a 7% decrease from 2000 base levels. **Columbia did not meet its Mayors Climate Protection Agreement Goal.**

Comparisons – Columbia emits less CO_2e than Kansas City or St. Louis, Missouri per capita; however, the City's per capita emissions are greater than most towns in the region and greater than the average American per capita, as depicted in Table 5.

Table 5



Recommendations and Conclusions

This project recommended three strategies to the Columbia City Council on August 6, 2012.

1) The City of Columbia should vastly improve internal information systems for City government. Improved information systems would enable the city to see and optimize the impact of future efficiency programs on reducing greenhouse gas emissions rates.

2) The City of Columbia should recommit to a goal of measured emissions reductions, and reference the goal in future decisions and investments. Reduction goals serve as an impetus to find ways to make more serious emission reductions.

3) In the August 6th, 2012 presentation to the City Council of Columbia, this report recommended that Columbia Water and Light purchase 30% renewable energy to meet its 7% emissions reduction goal by 2015. After final calculations, this report now recommends that Water and Light purchase 35% renewable energy to replace its most carbon-intensive sources of electricity- Columbia Power Plant, Nearman, and Sikeston. 35% renewable energy purchases would decrease Columbia's CO_2e emissions by over 360,000 metric tons per year and would meet their 7% emissions reduction goal. An impact on utility rates could not be calculated for the 35% renewable energy purchase in the time allotted to this study.

[i] City Council Meeting Minutes. Columbia, Missouri. July 17th, 2006. Page 15; available from http://www.gocolumbiamo.com/Council/Minutes/2006min.php

[ii] ICLEI. *Community-Scale Greenhouse Gas Emissions Accounting and Reporting Protocol.* Available from http://www.icleiusa.org/tools/ghg-protocol/community-protocol

[iii] ICLEI.

[iv] U.S. Environmental Protection Agency, EPA Large Facility Greenhouse Gas Database. Available from http://ghgdata.epa.gov

[v] Missouri Department of Natural Resources, Solid Waste Management Program, *2008 Missouri Waste Composition Study,* March *2009* (accessed June 12th, 2012); available from http://www.dnr.mo.gov/env/swmp/rrr/wastecompositionstudies.htm

[vi] U.S. Environmental Protection Agency.

[vii] ICLEI.

[viii] ICLEI.

[ix] ICLEI.

[x] U.S. Department of Transportation, Office of Planning, Environment, & Realty, *Report to the U.S. Congress on the Outcomes of the Nonmotorized Transportation Pilot Program,* April 2010 (accessed July 19, 2012); available from http://www.fhwa.dot.gov/environment/bicycle_pedestrian/ntpp/2012_report/page01.cfm

[xi] U.S. Department of Transportation, Office of Highway Policy Information, *Highway Statistics 2010, n.d.* (accessed June 11, 2012); available from http://www.fhwa.dot.gov/policyinformation/statistics/2010

[xii] ICLEI.

[xiii] U.S. Department of Transportation, Office of Highway Policy Information.