GREENHOUSE GAS EMISSIONS INVENTORY FOR THE UNIVERSITY OF WYOMING, 1990 - 2007

by

Linse N. Anderson
and
Alyssa Wechsler

For

The Campus Sustainability Committee

Laramie, Wyoming
September 15, 2008

Table of Contents

List of Figures

List of Tables

Introduction

Climate Change

Industrialized societies and many developing nations are dependent upon the burning of fossil fuels, which releases greenhouse gases (GHGs) into the atmosphere. The six main GHGs, covered under the Kyoto Protocol include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), hydroflourocarbons (HFCs), perfluorocarbons (PFCs), and sulphur hexafluoride (SF_6). These GHGs trap solar radiation in the atmosphere, keeping the planet at a hospitable global average temperature of approximately 15°C (Allali et al. 2007). Human activities have greatly increased the concentration of GHGs in the atmosphere.

Atmospheric concentrations of CO_2, the primary anthropogenic GHG, have risen from pre-industrial levels of approximately 280 parts per million (ppm) to 380 ppm today. From ice core data, scientists have determined that the concentration of CO_2 over the past 650,000 years has fluctuated between 180 ppm and 300 ppm (Allali et al. 2007). Today's level of 380 ppm far exceeds the historic range of variability. The Fourth Assessment Report by the Intergovernmental Panel on Climate Change (IPCC), released in 2007, states that there "is *very high confidence* that the global average net effect of human activities since 1750 has been one of warming" (Allali et al. 2007). A stabilization of CO_2 concentration in the atmosphere at 500 ppm would result in an approximately 2°C average global temperature increase. In order to stabilize at 500 ppm, mitigation actions must be taken quickly to decrease anthropogenic GHG emissions into the atmosphere.

Greenhouse Gas Emissions Inventories

A first step in reducing GHG emissions from any one source is to calculate the baseline amount of greenhouse gases being released. This is done by conducting a GHG emissions inventory. An emissions inventory accounts for the amounts and sources of GHG emissions attributable to an entity, be it a business, government, or other institution. There are a variety of emissions inventory calculators in use by governments, businesses, and others around the globe.

The emissions inventory calculator used by the University of Wyoming is the Campus Carbon Calculator (CCC) by Clean Air-Cool Planet (CA-CP). CA-CP is a non-profit 501(c) 3 organization focused on "finding and promoting solutions to global warming" (CA-CP 2008). Based in Portsmouth, New Hampshire, CA-CP partners with campuses, businesses, communities and science centers to develop and implement policies aimed at reducing anthropogenic GHG emissions. CA-CP's CCC was developed from a University of New Hampshire project entitled *Greenhouse Gas Emissions Inventory: 1990 – 2003.* According to the CA-CP, the CCC is based on the UNH project and workbooks by the IPCC on conducting national inventories. It is a Microsoft Excel-based spreadsheet tool customized to account for the main emission sources on

college and university campuses, including on-campus energy production, purchased electricity, transportation, waste, agriculture, and refrigerants (CA-CP 2008). According to the CA-CP website, over 150 college and university campuses in the United States are using the CCC. A list of several institutions that have completed an emissions inventory, using the CCC or a different calculator, is provided in Appendix A.

Presidents Climate Commitment

The American College and University Presidents Climate Commitment (PCC) was organized and is supported by the Association for the Advancement of Sustainability in Higher Education (AASHE), ecoAmerica and Second Nature. Colleges and universities that sign the PCC pledge to develop a climate action plan that details how carbon neutrality at their campus will be achieved. To date, there are over 558 signatories. A step in the process is to conduct an emissions inventory for the institution. According to the PCC, an inventory must be completed within one year of the start date of the commitment. Signatories prior to September 15, 2007, were designated Charter Signatories, with a start date of September 15, 2007. President Tom Buchanan of the University of Wyoming signed the PCC on August 6th, 2007, triggering the creation of this emissions inventory, due by September 15, 2008.

Greenhouse Gas Emissions Inventory

Methodology

The GHG emissions inventory for the University of Wyoming (UW) was conducted utilizing the CA-CP CCC. UW students, Linse Anderson and Alyssa Wechsler collected data for the inventory and completed this report, with oversight from UW's Campus Sustainability Committee. Work began in January 2008 and continued through August 2008. For the sake of data gathering, the University was divided into two units -- the main campus and satellite locations. Table 1 includes the locations in each of these categories.

Table 1. Inventory sites for the University of Wyoming.

Main Campus
Laramie main campus
Veterinary Sciences and State Veterinary Laboratory
Plant Sciences Insect and Soil Facility
Jacoby Golf Course
Satellite Locations
Agriculture Experiment Stations
Laramie Animal Sciences Live Stock Center, Paradise, Beef Unit, and Agronomy Farm
SAREC facilities in Lingle
Sheridan and Powell Plant Sciences Facilities
Balloon Launch Facilities
Natural Resources Research Institute (NRRI) Hanger and Laboratory
Red Buttes Research Center
Jelm Mountain Observatory
H_2S Laboratory
Casper Facilities
Casper College Satellite Campus
Family Practice Center
Jackson Research Center
President's Cabin
UW Recreation Camp
Cheyenne Family Practice Center

From the CCC inventory calculator a list of data requirements was generated (Table 2). From that list, potential contacts were identified based on where information was stored in the University system. For instance, the Physical Plant was contacted for data on purchased electricity, while Real Estate Operations was contacted for data on the physical size of the University. The potential sources of information were contacted via phone and e-mail and follow-up was conducted as necessary until the required data were gathered. As the data were collected, two separate MS Excel-based inventories were created, one for the main campus and one for the satellite areas, utilizing the CCC MS Excel database. The two databases were then combined to create one, overall inventory for the University.

Boundaries

According to the PCC, institutions are to calculate and report emissions in periods of one year, either calendar, fiscal, or academic. This inventory calculates and reports data according to the fiscal year. To the extent possible, institutions are to calculate emissions for years prior to signing the PCC, as far back as 1990. This allows the institution to calculate an emissions

trajectory. Under the PCC, each institution may decide for itself how far back to calculate emissions. For the UW inventory, data were gathered as far back as reliable information was available, which ranged from data for 1990 through 2007 to data for only 2007 (Table 2).

Table 2. Input field and dates.

Input	**Dates**
Institutional data	
Budget	1990 - 2007
Population	1990 - 2007
Physical Size	1990 - 2007
Purchased electricity	1992 - 2007
Purchased steam/chilled water	N/A
On-campus cogeneration plant	N/A
Stationary sources of emissions on campus	1995 - 2007
University fleet	2000 - 2007
Air travel	1998 - 2007
Commuting	2007
Agriculture	1994 - 2007
Solid waste	2002 - 2007
Refrigeration and other chemicals	N/A
Off-sets	N/A

Operational boundaries were followed in accordance with the GHG Protocol standards. Namely, GHG emissions were calculated and reported for the six greenhouse gases covered by the Kyoto Protocol, including CO_2, CH_4, N_2O, HFCs, PFCs, and SF_6. As stated in the PCC Implementation Guide (Dautremont-Smith 2007), the main focus is on CO_2, as "emissions of PFCs or SF_6 are unlikely to originate on campus, and emissions of CH_4, N_2O, and HFCs are likely to represent only a small percentage of an institution's total emissions" (Dautremont-Smith 2007).

In the inventory, emissions of each of the six greenhouse gases were calculated separately. The gases were then aggregated into the common unit of carbon dioxide equivalent (CO_2-e) based on the global warming potential (GWP) of each gas. According to Forster et al. (2007), the GWP index is "based on the time-integrated global mean RF of a pulse emission of 1 kg of some compound (*i*) relative to that of 1 kg of the reference gas CO_2." In other words, the GWP index accounts for the radiative forcing (RF) of a given substance being emitted in relation to the RF of CO_2. The RF of a gas depends on how it interacts with long-wave radiation and how long-lived it is; these factors determine the degree to which the gas traps the sun's energy. For instance, the GWP of CH_4 is 25, while the GWP of N_2O is 298 (Forster et al., 2007). One molecule of CH_4 warms the planet to a similar extent as 25 molecules of CO_2, not accounting for the time horizon. This means that emitting 1 kg of CH_4 is equivalent to emitting 25 kg of CO_2. Emissions are reported in this inventory in metric tons carbon dioxide equivalent (MTCDE), the product of the weight of the gas being emitted in metric tons and the GWP of the gas. This unit

facilitates comparison between different greenhouse gases relative to their effect on the climate system.

The GWP-weighted emissions of 1 kg of N_2O and 298 kg of CO_2 are equal in terms of CO_2-e emissions. They differ, however, in terms of the climate response over time (Smith and Wigley 2000). This is due to the fact that some species, such as CH_4, are short-lived, while other species are long-lived in the climate system. For example, the lifetime of CH_4 is 12 years, the lifetime of N_2O is 114 years, and the lifetime of SF_6 is 3,200 years (Forster et al. 2007). As in the Kyoto Protocol, the CCC uses 100-year time horizon GWPs. For the purpose of consistency, and because many GHG programs do so, the CCC utilizes the GWPs published in the IPCC Third Assessment Report (Houghton et al. 2001).

Scopes

The PCC identifies three scopes of emissions. Scope 1 emissions are direct GHG emissions from sources either owned or controlled by the institution. These sources include on-campus stationary fossil fuel combustion, fossil fuel combustion by institution-owned or controlled vehicles, and fugitive emissions. Fugitive emissions are either intentional or unintentional GHG emissions, including HFCs from refrigeration and air conditioning equipment and CH_4 from institution-owned farm animals.

Under PCC Scope 1 in this inventory, UW's Physical Plant provided data for on-campus consumption of coal, natural gas, and propane. The Physical Plant also provided data on the amount of #2 diesel used at the Central Energy Plant (CEP). UW's Fleet Services provided information for the amount of gasoline and diesel consumed by institution-owned or controlled vehicles on the main campus. Satellite locations provided information on the amount of gasoline and diesel consumed by institution-owned or controlled vehicles located at the satellite location and not reported in the Fleet Services figures.

Fugitive emissions from institution-owned farm animals include animals under the control of both the Department of Veterinary Sciences and the Department of Animal Science. Data for these animals spanned 1994 through 2007, with the majority of the animals being housed at the Animal Science Livestock Center. Data on the application of fertilizer were only available for the year 2007. Satellite locations and the main campus reported how many pounds of fertilizer were used in 2007 and the percent nitrogen of the fertilizer used. For each application, the percent nitrogen was multiplied by the weight of the amount applied to yield the weight of nitrogen applied. The sum of the amount of nitrogen applied at all locations was entered into the inventory as an application of 100% nitrogen since the input field does not allow multiple entries of amounts and percentages.

Hydrofluorocarbons (HFCs) from air conditioning equipment and refrigerants were not included in this inventory due to difficulty accessing such data. While future inventories may include this information, its exclusion from this inventory follows the *de minimis* rule of the PCC. According to the Implementation Guide (Dautremont-Smith 2007), "participants may designate small emissions sources that are difficult to track as *de minimis* and exclude them from the inventory, provided that the emissions sources collectively comprise less than 5% of the

institution's total GHG emissions." The UW has replaced all R11 and R12 refrigerant machines and primarily uses R134a (also known as HFC-134a) refrigerant machines. Based on completed inventories of colleges and universities of similar size as UW, and considering the amount of refrigerants used at the University, a rough estimation puts the emissions of HFCs at UW well below the 5% threshold of total emissions and thereby eligible for *de minimis* exclusion.

Scope 2 refers to indirect emissions that are generated in the production of electricity which is consumed by the university. UW's Physical Plant provided information on the number of kWh of electricity purchased by the University for 1992 to 2007.

Scope 3 refers to all other indirect emissions that occur as a consequence of activities of the university from sources that are not owned or controlled by the university. PCC signatories must report on Scope 1 and 2 emissions, as well as some Scope 3 emissions, including commuting and air travel that is paid for by or through the university. Under the commitment, commuting is defined as "travel to and from campus on a day to day basis by students, faculty, and staff" (Dautremont-Smith 2007). This does not include travel to and from campus before or after terms or during breaks. Optional Scope 3 emissions that may be reported include, among others, waste disposal and emissions embodied in purchased goods.

For Scope 3 emissions, a transportation survey conducted in 2007 by Stantec Consulting was utilized to determine the amount of gasoline and diesel used by students, faculty, and staff commuting to campus in that year. The survey was not related to the GHG emissions inventory, but its occurrence in the year prior to this inventory facilitated the gathering of this information. When the GHG inventory is updated in subsequent years, it is recommended that a survey be conducted that is designed specifically to gather data for the inventory. This would facilitate the gathering of necessary data and potentially improve the accuracy of commuting data.

Air travel data were obtained from two sources. The Department of Atmospheric Science provided data on UW research and charter flights. Data on commercial flights were difficult to gather due to the accounting system being used by the Accounts Payable office. Currently all travel, including air, rental car, bus, hotel, etc., is coded under the same number. The electronic records cannot be sorted according to which ones were for flights. Therefore, the paper files were accessed and a sample was taken for the years 2002 – 2007. From this sample, an estimate of commercial airline travel, including distance flown, was generated. This estimate approximates commercial air travel, but it is the weakest data in the inventory. It is recommended that new accounting systems be investigated that would facilitate more accurate and timely collection of air travel information for future inventories. If commercial air travel were coded separately, with a column for distance flown, then records in an MS Excel database could be used to compute commercial air miles more accurately.

Solid waste, an optional Scope 3 emissions source, was included in this inventory. The Physical Plant provided these data for 2002 - 2007. The data do not include dead animals or single large items, such as refrigerators.

According to the above methods and sources, data are presented in Appendix B. The information is displayed in the format of the CCC MS Excel spreadsheets. The emissions factors and formulas used in the CCC inventory to calculate emissions are provided in Appendix C.

UW Inventory

The American College and University Presidents Climate Commitment recommends that colleges and universities utilize the CCC to conduct their emissions inventory, although this recommendation is not a requirement since some signatories have already completed emissions inventories utilizing different calculators (Appendix A). Additionally, some institutions are enrolled in programs such as the Chicago Climate Exchange or the California Climate Action Registry, that require emissions be calculated in a specific manner. In light of this, signatories are allowed to use any emissions inventory calculator that is "consistent with the standards of the Greenhouse Gas Protocol" (Dautremont-Smith 2007). As the CCC is in accordance with the GHG Protocol, and it is designed specifically for colleges and universities, those institutions without an inventory already in place are encouraged to utilize the CCC. It is the most common inventory tool for colleges and universities, facilitating comparability and consistency. For these reasons, the CCC v5.0 is the calculator used for the UW GHG emissions inventory.

The main input fields and data sources are listed in Table 3. Some of the categories are entered solely for reporting and comparison purposes. For instance, the budget data includes input fields for the operating budget, research budget, and energy budget. This information does not impact the emissions calculations, but is used to generate reports and graphs comparing the budget data to emissions. Likewise, population and physical size are not themselves used in the calculator to determine emissions. Rather, the information is used to generate reports such as per capita emissions.

Table 3. Input fields and data sources for the Campus Carbon Calculator.

Input	**University of Wyoming Source**
Institutional data	
Budget	
Operating	Budget Office
Research	Office of Research
Energy	Physical Plant
Population	Office of Institutional Analysis
Physical Size	Real Estate Operations
Purchased electricity	Physical Plant
Purchased steam/chilled water	N/A
On-campus cogeneration plant	N/A
Stationary sources of emissions on campus	Physical Plant
University fleet	Fleet Services
Air travel	Accounts Payable

Commuting	Stantec Consulting survey
Agriculture	Various
Solid waste	Physical Plant
Refrigeration and other chemicals	N/A
Off-sets	N/A

Findings

Over the past ten years, the University of Wyoming has emitted an average of 114,452 MTCDE annually. The average annual increase in greenhouse gas emissions was 2.4% and occurred in YEAR. In 2007, UW's GHG emissions of 134,392 MTCDE were from the following sources: purchased electricity (~44%), on-campus stationary (~41%), transportation (~13%), agriculture (~1%) and solid waste (~1%; Figure 1). Of the emissions attributable to transportation, 88% were from air travel; fleet services comprised approximately 7% and commuting approximately 5%. Of the emissions attributable to on-campus stationary sources, approximately 89% was from coal and 11% was from natural gas.

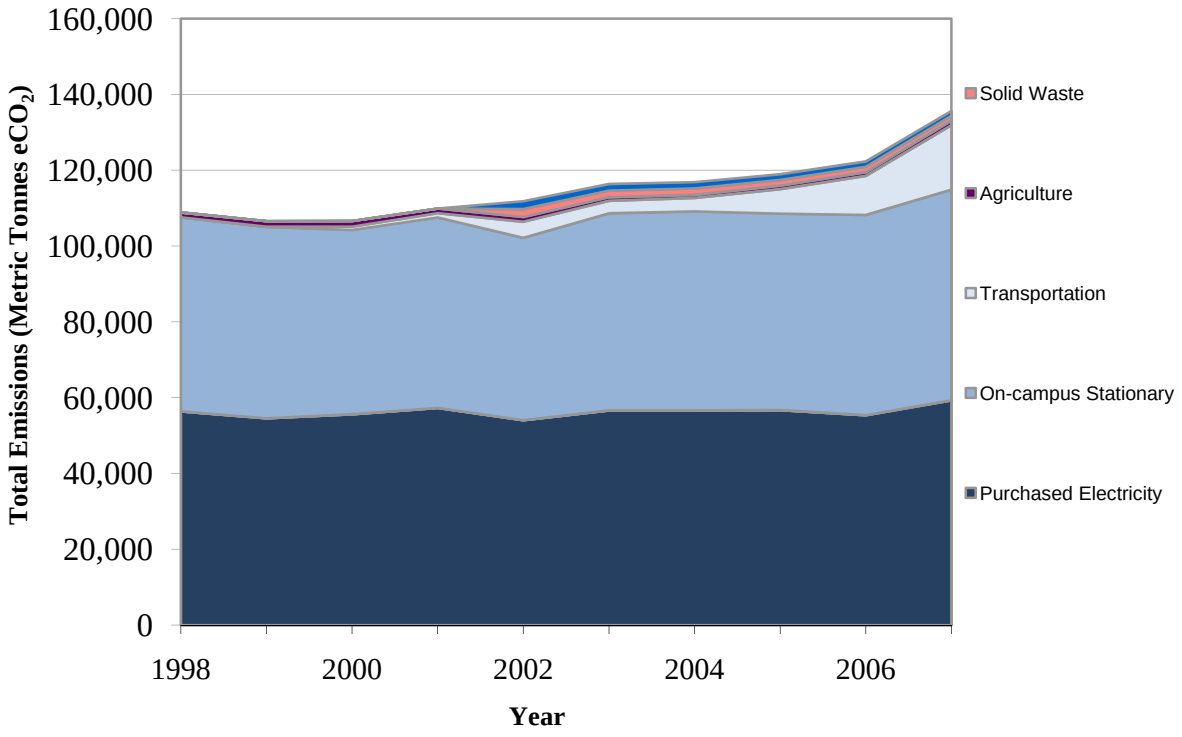

Figure 1. University of Wyoming greenhouse gas emissions by source, 1998 – 2007, reported as metric tons carbon dioxide equivalent.

Figure 2 displays the 2007 emissions by source, with the on-campus stationary and transportation sources separated into their component parts. Coal is used by the university to produce steam, which is used to heat many of the university's buildings and provide hot water. Natural gas is used for heating buildings not serviced by steam as well as for cooking and in

laboratories. Propane is used in various laboratories at UW, but since emissions from propane use in 2007 amounted to less than one-tenth of one percent, propane does not appear under on-campus stationary sources in Figure 2. Distillate oil #2 is used at the CEP to run the backup generator. In 2007, emissions from combustion of distillate oil amounted to approximately 0.02%; it is not represented in Figure 2. It is evident that the top three sources of anthropogenic GHG emissions for UW in fiscal year 2007 were purchased electricity (44%), on-campus coal (36%), and air travel (11%; Figure 5). Natural gas comprised 5%; solid waste, fleet services, and agriculture each comprised approximately 1%; and commuting contributes approximately 0.5%.

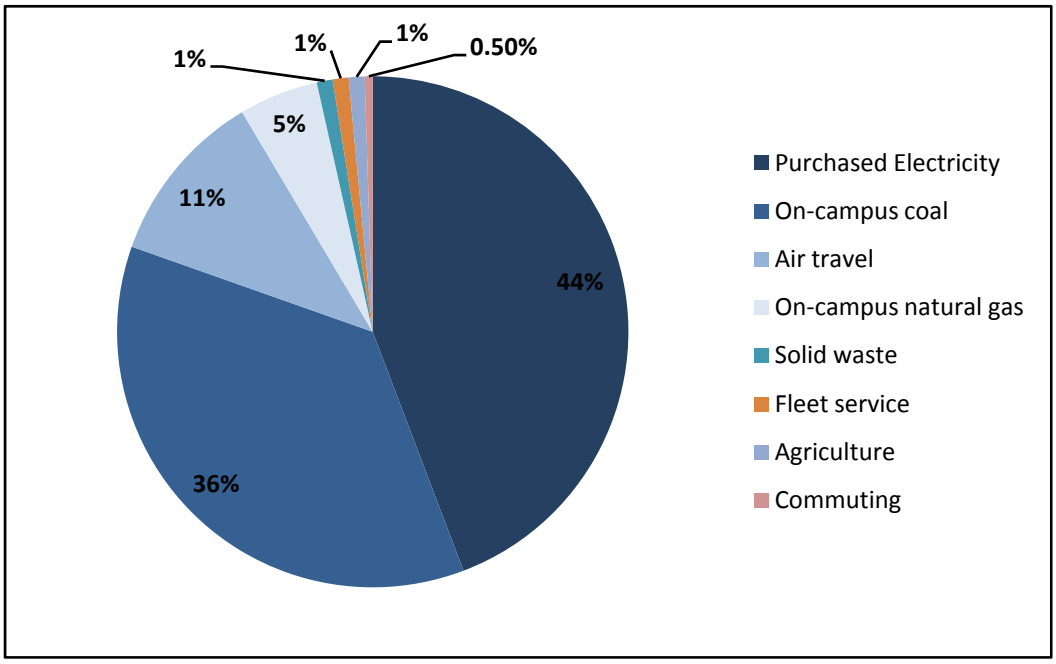

Figure 2. Fiscal year 2007 contribution to total greenhouse gas emissions for each source.

The distribution of emissions among these sources is consistent with other colleges and universities that have completed an emissions inventory. Duke University's emissions inventory in 2003 found the top three sources of emissions were purchased electricity (55%), on-campus steam production (25%), and transportation (22%; Hummel and Barkley 2004). Oregon State University's 2007 emissions inventory found that the top three sources of emissions were from purchased electricity (61%), on-campus natural gas consumption (20%), and air travel (10%; Smith and Trelstad 2008). The University of California, Santa Barbara reported the top three sources of emissions as purchased electricity (63%), on-campus natural gas consumption (35%), and air travel (10%; Ahmed et al. 2006).

Emissions Trends

The per capita emissions for the past ten years for the University of Wyoming community, including students, faculty, and staff, is displayed in Figure 3.

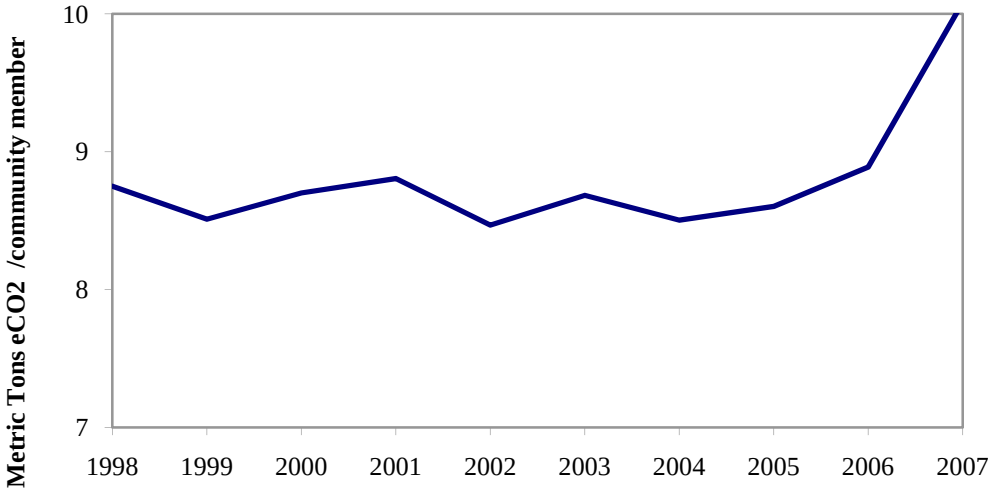

Figure 3. Per capita metric tons of carbon dioxide equivalent greenhouse gas emissions for the UW community, including students, faculty, and staff.

Over the time period, 1998 – 2007, the average emissions per UW community member was 8.8 MTCDE, with a range of 8.5 to 10 MTCDE. Annual per capita GHG emissions increased from 8.75 MTCDE in 1998 to 10 MTCDE in 2007. In comparison, greenhouse gas emissions at Oregon State University were 6.6 MTCDE per community member in 2007 (Smith and Trelstad 2008). At Duke University approximately 9 MTCDE were emitted per community member in 2003 (Hummel and Barkley 2004). The University of California, Santa Barbara reported approximately 2 MTCDE emissions per student from 1990 – 2004 (Ahmed et al. 2006).

The amount of emissions in 1998 and 2007 by source, with the percentage change indicated in the right-hand column, is presented in Table 4.

Table 4. Emissions in 1998 and 2007 by source, reported as metric tons carbon dioxide equivalent.

Source	1998 MTCDE	2007 MTCDE	% Change
Purchased electricity	56,405	59,335	5
On-campus stationary	51,193	55,571	9
Transportation[a]	890	17,020	1,812
Agriculture	1,292	1,185	-8
Solid waste[b]	2,090	1,282	-39
a) Transportation data includes research and charter flight data for 1998 - 2007, commercial air travel data for 2002 - 2007, fleet services data for 2000 - 2007, and commuting data for 2007. Starting value is for 2000. b) Solid waste data is for 2002 - 2007.			

The largest single source of GHG emissions was from purchased electricity. In 1992, the University of Wyoming purchased 53,445,897 kWh of electricity. In 2007, UW purchased 63,907,087 kWh. In 1992, the emissions per full-time student for purchased electricity were 5.7 MTCDE. In 2007, 6.85 MTCDE were emitted on a per full-time student basis for purchased electricity at UW. The net increase in emissions per full-time student for purchased electricity over that 16 year time period was 20%, in part reflective of increased usage of computing and internet on campus (Table 5).

Table 5. Purchased electricity, associated emissions reported as metric tons carbon dioxide equivalent, full-time students, and per capita emissions for 1992 – 2007.

	1992	**1993**	**1994**	**1995**
Electricity Use kWh	53,445,897	54,434,929	54,690,220	56,167,979
Emissions (MTCDE)	49,622	50,540	50,778	52,150
Change from previous yr.		1.85%	0.47%	2.70%
Full-time Students	8,698	8,584	8,551	8,564
MTCDE / Student	5.70	5.89	5.94	6.09
	1996	**1997**	**1998**	**1999**
Electricity Use kWh	60,338,399	60,852,407	60,751,336	58,793,723
Emissions (MTCDE)	56,022	56,499	56,405	54,587
Change from previous yr.	7.42%	0.85%	-0.17%	-3.22%
Full-time Students	8,412	8,354	8,139	8,230
MTCDE / Student	6.66	6.76	6.93	6.63
	2000	**2001**	**2002**	**2003**
Electricity Use kWh	59,962,790	61,759,056	58,243,383	61,039,439
Emissions (MTCDE)	55,673	57,341	54,076	56,672
Change from previous yr.	1.99%	3%	-5.69%	4.80%
Full-time Students	8,111	8,147	8,435	8,580
MTCDE / Student	6.86	7.04	6.41	6.61
	2004	**2005**	**2006**	**2007**
Electricity Use kWh	61,058,937	61,145,894	59,673,478	63,907,087
Emissions (MTCDE)	56,691	56,771	55,404	59,335
Change from previous yr.	0.03%	0.14%	-2.41%	7.10%
Full-time Students	8,610	8,744	8,620	8,659
MTCDE / Student	6.58	6.49	6.43	6.85

The second largest source of emissions was on-campus stationary. The four types of on-campus stationary sources are coal, natural gas, propane, and distillate oil. Coal data were obtained for 1995 - 2007, natural gas data were obtained for 1992 - 2007, propane data for 2007,

and distillate oil for 2002 - 2007. On a ten year average, coal accounts for 89% of the on-campus stationary emissions, natural gas accounts for 11%, propane amounted to less 0.1% in 2007, and distillate oil accounts for 0.04%. Since all on-campus stationary sources of emissions are aggregated in the CCC inventory, calculations were done in a separate MS Excel database to determine the approximate contribution of each source to the total MTCDE emissions. Overall, on-campus stationary sources account for 41% of total MTCDE emissions in 2007, with 36% attributable to coal and 5% attributable to natural gas.

Emissions attributable to the transportation sector increased more than any other source between 1998 and 2007 (Table 4), although air travel data are the least certain. The data inputs and years for which data were available within the transportation sector are presented in Table 6. The air travel data for 1998 to 2007 includes the Department of Atmospheric Science research plane, a Raytheon King Air 200T, and the UW transportation plane, a Raytheon King Air B200. The data for 2002 through 2007 also includes an estimate of commercial air travel paid for by or through the university.

The University Fleet Services data were available for 2000 through 2007. As previously mentioned, commuting data were taken from a transportation survey unrelated to this inventory and the data were only available for 2007.

Table 6. Transportation data, including fuel consumed by fleet services, air travel in miles, and fuel consumption from commuting.

	University Fleet[a]		Air Travel[b]	Commuting[a]	
Year	**Gasoline**	**Diesel**	**Miles**	**Gasoline**	**Diesel**
1998			16,100	N/A	N/A
1999			66,240	N/A	N/A
2000	81,930	12,987	36,000	N/A	N/A
2001	101,363	16,520	78,433	N/A	N/A
2002	99,005	19,805	4,076,220	N/A	N/A
2003	97,870	29,686	2,739,240	N/A	N/A
2004	103,370	36,341	2,919,214	N/A	N/A
2005	104,362	41,560	6,595,705	N/A	N/A
2006	96,069	34,851	11,722,533	N/A	N/A
2007	94,888	35,091	19,351,563	77,738	8,920

a) Gasoline and diesel reported as U.S. gallons
b) Air travel data includes the UW research and charter planes for 1998 - 2007 and an estimate of commercial air travel for 2002 - 2007.

Emissions by Type of Gas

Of the six greenhouse gases calculated in this inventory, CO_2 is emitted in the largest amounts by far. For fiscal year 2007, the contribution of the six types of greenhouse gases is presented in Table 7.

Table 7. Emissions by gas for fiscal year 2007, reported as metric tons carbon dioxide equivalent

Gas	MTCDE
Carbon dioxide (CO_2)	131,129
Methane (CH_4)	2,455
Nitrous oxide (N_2O)	808
PFC	0
HFC	0
Sulfur hexafluoride (SF_6)	0

It is clear that CO_2 is the main component of the University's GHG emissions, accounting for more than 97% of the total MTCDE emissions. Although CH_4 and N_2O have higher global warming potentials than CO_2, the amount of these gases being released is relatively small, resulting in overall contributions to the University's GHG emissions of approximately 2.0% and 0.6%, respectively.

Recommendations

Signatories to the American College and University President Climate Commitment agree to the overall goal of their institution becoming climate neutral. A first step in the process is to conduct a GHG emissions inventory. The University of Wyoming emissions inventory has been conducted, as described in this paper. According to the PCC, the University has two years from the signing of the Commitment to develop a plan to become climate neutral. Therefore, a Climate Action Plan that lays out the steps to be taken to achieve neutrality must be completed by September 15, 2009. A target date must be specified in the plan to achieve climate neutrality as soon as possible; interim targets and goals must be identified; climate neutrality and sustainability should be incorporated into the curriculum; research should aid in developing mechanisms to achieve climate neutrality; and a system for tracking progress should be developed.

According to the PCC (Dautremont-Smith 2007), UW's GHG inventory must be updated every other year. While this inventory involved collecting data for 1990 to 2007, subsequent inventories will collect data for two-year periods. As the process of data collection becomes streamlined, additional time and resources may be available to improve upon the inventory. The following recommendations suggest how the inventory may be expanded and/or improved in the future.

- To improve the accuracy of the inventory, customization to conditions at UW should continue to be investigated. It is recommended that the heat content value of coal specific to UW's Central Energy Plant be utilized.

- Commercial air travel data should be coded separately by Accounts Payable. A column should be included in the MS Excel database indicating the distance traveled for each record. This would expedite computation of air travel data and improve accuracy.

- A commuter survey, designed to gather data required for the GHG inventory, should be conducted annually. The GHG Protocol tool CO_2 Emissions from Employee Commuting v. 2.0 (WRI 2006) contains an MS Excel-based survey. This employee survey could be modified for students, faculty, and staff at UW and sent electronically to the UW community.

- Satellite locations may be expanded to include all property owned or leased by the University. For example, national public radio tower sites were not included in this inventory.

- A source of GHG emissions not included in this inventory is emissions embodied in the extraction, production, and transportation of purchased goods. It is recommended that inclusion of these optional Scope 3 emissions be investigated in the future.

- Offsets should be investigated for potential inclusion in future inventories. The PCC allows offsets for renewable energy credits, composting, and forest preservation. According to Dautremont-Smith (2007), colleges and universities that own tracts of forestland may include carbon sequestration by these forested areas in their inventory. Institutions are directed to follow the GHG Protocol Land Use, Land-Use Change, and Forestry Guidance for GHG Project Accounting (Daviet et al. 2006). It is recommended that the potential of including carbon sequestered by land owned by UW, including grasslands, be investigated because grasslands can act as carbon sinks (Hu et al. 2001).

References

Ahmed F, Brown J, Felix D, Haurin T, Seto B. 2006. Changing the campus climate: strategies to reduce greenhouse gas emissions at The University of California, Santa Barbara [Internet]. [cited 2008 Jun 1]. Available from http://www2.bren.ucsb.edu/~ccn/ Finalreport.pdf.

Allali A, Bojariu R, Diaz S, Elgizouli I, Griggs D, Hawkins D, Hohmeyer O, Jallow BP, Kajfez-Bogata L, Leary N, Lee H, Wratt D, editors . 2007. Climate change 2007: synthesis report. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. 52p.

Barker, T., I. Bashmakov, L. Bernstein, J.E. Bogner, P.R. Bosch, R. Dave, O.R. Davidson, B.S. Fisher, S. Gupta, K. Halsnaes, G.J. Heij, S. Kahn Ribeiro, S. Kobayashi, M. D. Levine, D.L. Martino, O. Masera, B. Metz, L.A. Meyer, G.J. Nabuurs, A. Najam, N. Nakicenovic, H.H. Rogner, J. Roy, J. Sathaye, R. Schock, P. Shukla, R.E.H. Sims, P. Smith, D.A. Tirpak, D. Urge-Vorsatz, D. Zhou, 2007: Technical Summary. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. P. 27, 28.

Clean Air-Cool Planet. 2008. Campuses for climate action program. [cited in 2008 March 5]. Available from http://www.cleanair-coolplanet.org.

Dautremont-Smith J. 2007 Sept. Implementation guide: information and resources for participating institutions. American college and university presidents climate commitment. Portsmouth, NH. 33p.

Daviet F, Greenhalgh S, Weninger E. 2006. The land use, land-use change, and forestry guidance for greenhouse gas project accounting. World Resource Institute, Washington, D.C.

Forster P, Ramaswamy V, Artaxo P, Berntsen T, Betts R, Fahey DW, Haywood J, Lean J, Lowe DC, Myhre G, Nganga J, Prinn R, Raga G, Shulz M, Van Dorland R. 2007. Changes in atmospheric constituents and in radiative forcing. In: Climate change 2007: the physical science basis. Contribution of working group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon S, Qin D, Manning M, Chen Z, Marquis M, Averyt KB, Tignor M, Miller HL, editors]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. p129-234.

Houghton JT, Ding Y, Griggs DJ, Noguer M, van der Linden PJ, Xiaosu D, editors. 2001. Contribution of working group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Cambridge University Press, UK. 944p.

Hu S, Chapin III FS, Firestone MK, Field CB, Chiariello NR. 2001 Jan. Nitrogen limitation of microbial decomposition in a grassland under elevated CO_2. Nature 409(11):188-191.

Hummel S, Barkley M. 2004. Greenhouse gas inventory 1990 – 2003. Duke University [Internet]. [cited 2008 Jun 1]. Available from http://www.duke.edu/sustainability/documents/Duke%20University%20Greenhouse%20Gas%20Report.pdf.

Sims, R.E.H., R.N. Schock, A. Adegbululgbe, J. Fenhann, I. Konstantinaviciute, W. Moomaw, H.B. Nimir, B. Schlamadinger, J. Torres-Martinez, C. Turner, Y. Uchiyama, S.J.V. Vuori, N. Wamukonya, X. Zhang, 2007: Energy supply. In *Climate Change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [B. Metz, O.R. Davidson, P.R. Bosch, R. Dave, L.A. Meyer (eds)], Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA. P. 253

Smith SJ and Wigley TML. 2000. Global warming potentials: 2. Accuracy. Climate Change, 44, 459–469.

Smith G and Trelstad B. 2008. Oregon State University fiscal year 2007 greenhouse gas inventory [Internet]. [cited 2008 Jun 1]. Available from http://oregonstate.edu/sustainability/docs/fy07ghgreport.pdf.

World Resource Institute. 2006. CO_2 emissions from employee commuting, version 2.0 [Internet]. [downloaded 2008 Apr 1]. Available from www.ghgprotocol.org.

Appendix A: Completed College and University GHG Emissions Inventories

Source: American Association for the Advancement of Sustainability in Higher Education

Calculator: Clean Air-Cool Planet Campus Carbon Calculator

California State Polytechnic University, Pomona, *Greenhouse Gas Emissions Inventory Report 1995 - 2005*
Carleton College, *Greenhouse Gas Emissions at Carleton College: A Complete Inventory for 2004 – 2005 with Extrapolations Back to 1990*
Colby College, *Greenhouse Gas Emissions Audit for Colby College*
College of Charleston, *Greenhouse Gas Audit 1003 - 2001*
Connecticut College, *Greenhouse Gas Emissions Inventory 1990 - 2002*
Duke University, *Greenhouse Gas Inventory 1990 - 2003*
The Evergreen State College, *Carbon Neutrality by 2020: The Evergreen State College's Comprehensive Greenhouse Gas Inventory*
Middlebury College, *A Summary of Energy Consumption and Greenhouse Gas Emissions at Middlebury College*
Pomona College, *Climate Neutral Pomona College: 2006 – 2007 Annual Report to The President's Advisory Committee on Sustainability*
Smith College, *Greenhouse Gas Emissions at Smith College: A Comprehensive Inventory from 1990 – 2004 and Suggestions for Future Emissions Reductions*
University of Connecticut, *GHG Emissions Inventory*
University of California, Santa Barbara, *Changing the Campus Climate: Strategies to Reduce Greenhouse Gas Emissions at The University of California, Santa Barbara*
University of New Hampshire, *1990 – 2000 Greenhouse Gas Emissions Inventory, 1990 – 2003 Greenhouse Gas Emissions Inventory, 2004 – 2005 Update Greenhouse Gas Emissions Inventory*
University of Pennsylvania, *University of Pennsylvania Carbon Footprint 2007*
Utah State University, *Greenhouse Gas Emissions Inventory 2006 – 2007*
Wellesley College, *Audit of Wellesley College's Greenhouse Gas Emissions*

Calculator: California Climate Action Registry

University of California, Berkeley, *Emissions Inventory*
California State University System, *Emissions from California Operations*

Calculator: Torrie Smith Associates Greenhouse Gas Strategy Software

Tulane University, *Greenhouse Gas Inventory*

Calculator: Individually-derived and other methodologies

Colorado State University, *GHG Baseline FY06 Data*
Harvard University, *Greenhouse Gas Inventory*
Lewis & Clark College, *2002 – 2003 Greenhouse Gas Inventory*
Massachusetts Institute of Technology, *A Methodology for Assessing MIT's Energy Use and Greenhouse Gas Emissions*
Oberlin College, *Oberlin College: Climate Neutral by 2020*

Pennsylvania State University, *A Greenhouse Gas Emissions Inventory and Projection for the University Park Campus of the Pennsylvania State University*
Rice University, *The Impact of CO2*
Tufts University, *Tufts University's Green House Gas Emissions Inventory for 1990 and 1998*
Unity College, *Emissions Inventory*
University of Central Florida, *Greenhouse Gas Report*
University of Colorado, Boulder, *Carbon Emissions Inventory*
Yale University, *Inventory and Analysis of Yale University's Greenhouse Gas Emissions*

Appendix B. GHG Emissions Inventory Data Sheets.

Fiscal Year	Budget		
	Operating Budget	Research Dollars	Energy Budget
1990	$208,973,119.60	$33,022,071.60	
1991	$217,516,856.84	$32,661,922.80	
1992	$221,826,669.61	$36,819,266.41	
1993	$226,048,398.16	$37,141,138.11	
1994	$222,061,833.91	$37,592,041.92	
1995	$238,043,475.34	$39,193,534.46	
1996	$241,125,554.86	$41,691,894.15	
1997	$251,121,159.84	$44,005,861.50	
1998	$243,262,153.52	$44,917,073.08	
1999	$255,011,589.19	$45,355,906.91	
2000	$246,901,889.87	$45,515,521.17	
2001	$258,261,695.02	$49,189,616.92	$4,126,859
2002	$259,603,997.22	$50,818,310.09	$3,920,389
2003	$280,791,523.00	$54,005,147.00	$5,490,658
2004	$280,524,727.43	$60,224,918.00	$5,918,324
2005	$302,707,265.99	$63,369,136.61	$6,878,942
2006	$299,264,785.09	$67,237,328.37	$8,648,020
2007	$331,344,309.67		$8,111,443

Fiscal Year	Population				
	Full Time Students	Part-Time Students	Summer School Students	Faculty	Staff
	#	#	#	#	#
1990	8797	4723	3474	612	1920
1991	8682	4921	3877	613	1920
1992	8698	4761	3761	635	1920
1993	8584	4474	3466	600	1920
1994	8551	4076	3241	591	2073
1995	8564	3953	3106	635	2073
1996	8412	3477	2700	626	2035
1997	8354	3524	2622	620	2035
1998	8139	3336	2579	615	2024
1999	8230	3315	2536	612	2024
2000	8111	3223	2488	606	1926
2001	8147	3628	2831	596	1926
2002	8435	4037	3098	604	1907
2003	8580	4208	3171	612	1907
2004	8610	4384	3204	624	2122
2005	8744	4287	3369	643	2122
2006	8620	4306	3106	651	2182
2007	8659	3606	3080		2865

Fiscal Year	Physical Size	
	Total Building Space	Total Research Building Space
	Square feet	Square feet
1990	6,366,700	1,147,299
1991	6,366,700	1,147,299
1992	6,366,700	1,147,299
1993	6,511,900	1,148,091
1994	6,544,146	1,149,529
1995	6,653,146	1,149,529
1996	6,718,146	1,171,187
1997	6,718,146	1,171,187
1998	6,718,652	1,171,693
1999	6,718,652	1,171,693
2000	6,718,652	1,171,693
2001	6,796,102	1,172,597
2002	6,799,145	1,172,597
2003	6,802,745	1,172,597
2004	6,813,324	1,172,597
2005	6,925,267	1,224,617
2006	6,913,471	1,224,617
2007	7,068,817	1,218,098

Fiscal Year	Electric produced off-campus
	WECC Rockies
	kWh
1990	
1991	
1992	5,3445,897
1993	5,4434,929
1994	5,4690,220
1995	5,6167,979
1996	6,0338,399
1997	6,0852,407
1998	6,0751,336
1999	5,8793,723
2000	5,9962,790
2001	6,1759,056
2002	5,8243,383
2003	6,1039,439
2004	6,1058,937
2005	6,1145,894
2006	5,9673,478
2007	6,3907,087

kWh – kilowatt hours
WECC – Western Energy Coordination Council

Fiscal Year	Natural Gas	Propane	Coal	Distillate Oil (#1 – 4)
	MMBtu	Gallons	Short Ton	Gallons
1990				
1991				
1992				
1993				
1994				
1995			20,233	
1996			19,443	
1997	58,807		22,717	
1998	104,822		22,995	
1999	98,058		22,892	
2000	96,486		21,963	
2001	103,020		22,787	
2002	102,155		21,864	2,293
2003	104,706		23,958	2,674
2004	115,315		24,097	3,242
2005	108,453		24,059	3,204
2006	113,063		16,040	2,021
2007	107,146	6,841	13,783	1,020

MMBtu – million British thermal units (million Btu)
Short ton – 2000 pounds

Fiscal Year	University Fleet				
	Gasoline Fleet	Diesel Fleet	Natural Gas Fleet	Electric Fleet	Other Fleet
	Gallons	Gallons	MMBtu	kWh	MMBtu
1990			0	0	0
1991			0	0	0
1992			0	0	0
1993			0	0	0
1994			0	0	0
1995			0	0	0
1996			0	0	0
1997			0	0	0
1998			0	0	0
1999			0	0	0
2000	81,930	12,987	0	0	0
2001	101,363	16,520	0	0	0
2002	99,005	19,805	0	0	0
2003	97,870	29,686	0	0	0
2004	103,370	36,341	0	0	0
2005	104,362	41,560	0	0	0
2006	96,069	34,851	0	0	0
2007	94,888	35,091	0	0	0

Fiscal Year	Air Travel		Commuters			
	Faculty / Staff Business	Student Programs	Faculty / Staff Gasoline	Students Gasoline	Faculty / Staff Diesel	Students Diesel
	Miles	Miles	Gallons	Gallons	Gallons	Gallons
1990			-	-	-	-
1991			-	-	-	-
1992			-	-	-	-
1993			-	-	-	-
1994			-	-	-	-
1995			-	-	-	-
1996			-	-	-	-
1997			-	-	-	-
1998	16,100		-	-	-	-
1999	66,240		-	-	-	-
2000	36,000		-	-	-	-
2001	78,433		-	-	-	-
2002	4,076,220		-	-	-	-
2003	2,739,240		-	-	-	-
2004	2,919,214		-	-	-	-
2005	6,595,705		-	-	-	-
2006	11,722,533		-	-	-	-
2007	19,351,563		44,007	33,731	542	8,378

Fiscal Year	Fertilizer Application			
	Synthetic	% Nitrogen	Organic	% Nitrogen
	Pounds	%	Pounds	%
1990				
1991				
1992				
1993				
1994				
1995				
1996				
1997				
1998				
1999				
2000				
2001				
2002				
2003				
2004				
2005				
2006				
2007	30,746	100%	0	0%

Fiscal Year	Animal Agriculture							
	Dairy Cows	Beef Cows	Swine	Goats	Sheep	Horses	Poultry	Other
	#	#	#	#	#	#	#	#
1990								
1991								
1992								
1993								
1994	152	1,168	346	0	1,559	11	0	0
1995	156	926	159	0	1,524	11	0	0
1996	163	858	199	0	1,855	11	0	0
1997	146	788	116	1	1,422	7	0	
1998	0	909	99	1	1,189	6	0	
1999	0	1,016	207	1	1,184	6	0	
2000	0	1,023	268	1	1,142	6	0	
2001	0	853	180	1	976	5	0	
2002	0	880	238	1	850	4	0	
2003	0	652	97	1	851	4	0	
2004	0	537	143	1	788	4	0	
2005	0	629	159	1	681	4	0	
2006	0	646	128	0	964	4	0	
2007	0	705	137	0	1,103	4	0	

Fiscal Year	Includes all solid waste produced by campus except waste composted, recycled or burned on campus for power				
	Incinerated Waste (waste to energy plant) not used for school power		Landfilled Waste with no CH_4 Recovery	Landfilled Waste with CH_4 Recovery and Flaring	Landfilled Waste with CH_4 Recovery and Electric Generation
	Mass Burn Incinerator	Refuse Derived Fuel (RDF) Incinerator			
	Short Tons	Short Tons	Short Tons	Short Tons	Short Tons
1990	0	0		0	0
1991	0	0		0	0
1992	0	0		0	0
1993	0	0		0	0
1994	0	0		0	0
1995	0	0		0	0
1996	0	0		0	0
1997	0	0		0	0
1998	0	0		0	0
1999	0	0		0	0
2000	0	0		0	0
2001	0	0		0	0
2002	0	0	2,111	0	0
2003	0	0	1,766	0	0
2004	0	0	1,696	0	0
2005	0	0	1,528	0	0
2006	0	0	1,433	0	0
2007	0	0	1,295	0	0

Appendix C. Formulas and emissions factors used to calculate emissions.

CA-CP Campus Carbon Calculator

	Emissions calculation
Purchased electricity	
CO_2	923.35 g CO_2/kWh x kWh consumed x 0.000001 = metric tons CO_2-e emissions
CH_4	0.000007 g CH_4/kWh x kWh consumed x 0.000001 x 23 = metric tons CO_2-e emissions
N_2O	0.0000167 g N_2O/kWh x kWh consumed x 0.000001 x 296 = metric tons CO_2-e emissions
On-campus stationary	
Natural gas	
CO_2	52.79 kg CO_2/MMBtu x MMBtu consumed x 0.001 = metric tons CO_2-e emissions
CH_4	0.00528 kg CH_4/MMBtu x MMBtu consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.00011 kg N_2O/MMBtu x MMBtu consumed x 0.001 x 296 = metric tons CO_2-e emissions
Coal	
CO_2[a]	1,914 kg CO_2/short ton x short tons consumed x 0.001 = metric tons CO_2-e emissions
CH_4[b]	0.21391 kg CH_4/short ton x short tons consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O[c]	0.02995 kg N_2O/short ton x short tons consumed x 0.001 x 296 = metric tons CO_2-e emissions
a) Emissions factor ranges from 1,983 kg CO_2/short ton (1995) to 1,914 CO_2/short ton (2007) b) Emissions factor ranges from 0.22028 kg CH_4/short ton (1995) to 0.21391 kg CH_4/short ton (2007) c) Emissions factor ranges from 0.03084 kg N_2O/short ton (1995) to 0.02995 kg N_2O/short ton (2007)	
Propane	
CO_2	0.09 MMBtu/gallon x gallons consumed x 62.75 kg CO_2/MMBtu x 0.001 = metric tons CO_2-e emissions
CH_4	0.09 MMBtu/gallon x gallons consumed x 0.01055 kg CH_4/MMBtu x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.09 MMBtu/gallon x gallons consumed x 0.000633 kg N_2O/MMBtu x 0.001 x 296 = metric tons CO_2-e emissions

Fleet services	
Gasoline[a]	
CO_2	8.72 kg CO_2/gallon x gallons consumed x 0.001 = metric tons CO_2-e emissions
CH_4	0.001742 kg CH_4/gallon x gallons consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.000559 kg N_2O/gallon x gallons consumed x 0.001 x 296 = metric tons CO_2-e emissions
Diesel	
CO_2	9.99 kg CO_2/gallon x gallons consumed x 0.001 = metric tons CO_2-e emissions
CH_4	0.000567 kg CH_4/gallon x gallons consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.000257 kg N_2O/gallon x gallons consumed x 0.001 x 296 = metric tons CO_2-e emissions
a) Gasoline emissions factor = (car kg GHG/gallon) x (% cars) + (truck kg GHG/gallon) x (1 - % cars)	
Air travel	
CO_2[a]	0.774 kg CO_2/mile x miles x 0.001 = metric tons CO_2-e emissions
CH_4	0.000008 kg CH_4/mile x miles x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.000009 kg N_2O/mile x miles x 0.001 x 296 = metric tons CO_2-e emissions
a) CO_2 emissions factor ranges from 0.809 kg CO_2/mile (1998) to 0.774 kg CO_2/mile (2007)	
Commuting	
Gasoline[a]	
CO_2	8.72 kg CO_2/gallon x gallons consumed x 0.001 = metric tons CO_2-e emissions
CH_4	0.001742 kg CH_4/gallon x gallons consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.000559 kg N_2O/gallon x gallons consumed x 0.001 x 296 = metric tons CO_2-e emissions
Diesel	
CO_2	9.99 kg CO_2/gallon x gallons consumed x 0.001 = metric tons CO_2-e emissions
CH_4	0.000567 kg CH_4/gallon x gallons consumed x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.000257 kg N_2O/gallon x gallons consumed x 0.001 x 296 = metric tons CO_2-e emissions
a) Gasoline emissions factor = (car kg GHG/gallon) x (% cars) + (truck kg GHG/gallon) x (1 - % cars)	

Animal agriculture	
Dairy cows	
CH_4	153.98 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.97 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Beef cows	
CH_4	46.17 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.22 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Swine	
CH_4	15.32 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.02 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Goats	
CH_4	5.5 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.05 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Sheep	
CH_4	8.29 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.01 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Horses	
CH_4	23.66 kg CH_4/head x head x 0.001 x 23 = metric tons CO_2-e emissions
N_2O	0.10 kg N_2O/head x head x 0.001 x 296 = metric tons CO_2-e emissions
Landfilled waste	0.99 metric ton CO_2-e emissions/short ton x short tons = metric tons CO_2-e emissions