Final Report

Greenhouse Gas (GHG) Inventory Program:

An Integrated Evaluation of Energy and Resource Usage

James Madison University
Harrisonburg, VA

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Greenhouse Gas (GHG) Inventory Program

Prepared for:
James Madison University (JMU)

Peter Capponi
Sr. Vice President

September 2009

O'BRIEN & GERE

5895 Shiloh Road
Suite 113
Alpharetta, GA 30005

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Acknowledgements

We acknowledge the following individuals for their participation in the development of the JMU greenhouse gas inventory program:

Peter Capponi, O'Brien & Gere

Mike Davis, James Madison University

Dennis Hart, James Madison University

Christie-Joy Hartman, James Madison University

Grant Matthews, O'Brien & Gere

Towana Moore, James Madison University

Carl Puffenbarger, James Madison University

Daniel Ramsay, O'Brien & Gere

Ronnie Rhodes, James Madison University

Aniket Sawant, O'Brien & Gere

Parikhit Sinha, O'Brien & Gere

Sarah Strode, O'Brien & Gere

Sarah Slagle-Garrett, O'Brien & Gere

John Ventura, James Madison University

Mark Wenclawiak, O'Brien & Gere

Gary Yoder, O'Brien & Gere

Executive Summary

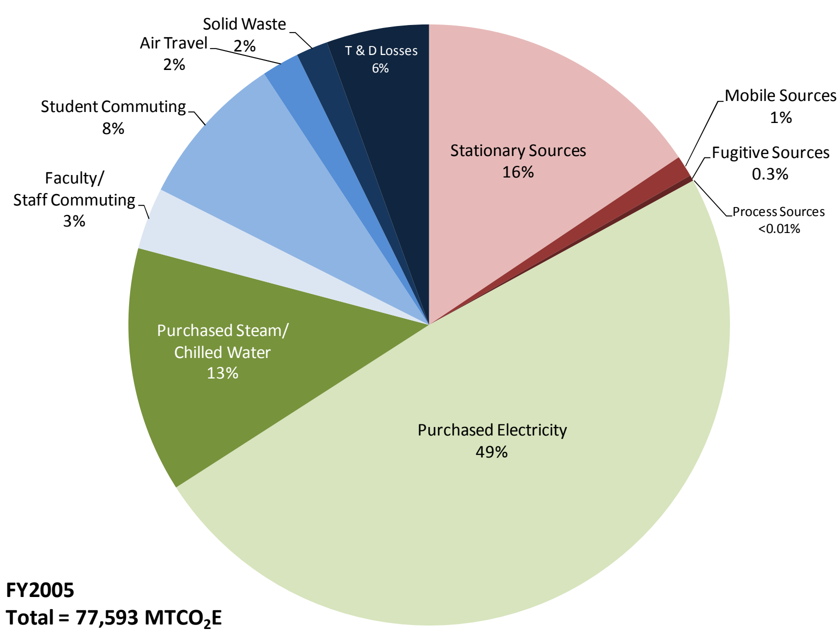
As a signatory to the American College and University Presidents' Climate Commitment (ACUPCC), James Madison University (JMU) has established a baseline greenhouse gas (GHG) inventory to benchmark its progress towards achieving a carbon neutral campus. JMU, in collaboration with O'Brien & Gere, has developed a baseline GHG inventory for fiscal year 2004-05 (FY 2005), and for subsequent years through FY 2008.

The baseline inventory is an integrated measure of JMU's institution-wide energy and resource usage. Development of the baseline is an initial required step under the ACUPCC program. It will be followed by development of a Climate Action Plan, a long-term roadmap for achieving carbon neutrality by a target date.

The primary purpose of the baseline inventory is to establish a benchmark against which future progress towards carbon neutrality can be measured, and to help establish priorities with regards to the primary emission sources responsible for the bulk of JMU's emissions.

Total gross GHG emissions for the FY 2005 baseline year were 77,593 metric tons of carbon dioxide equivalent ($MTCO_2E$), with emissions from four sources collectively accounting for approximately 89% of total emissions:

- Purchased electricity,
- Stationary combustion,
- Purchased steam and chilled water, and
- Student and faculty/staff commuting.

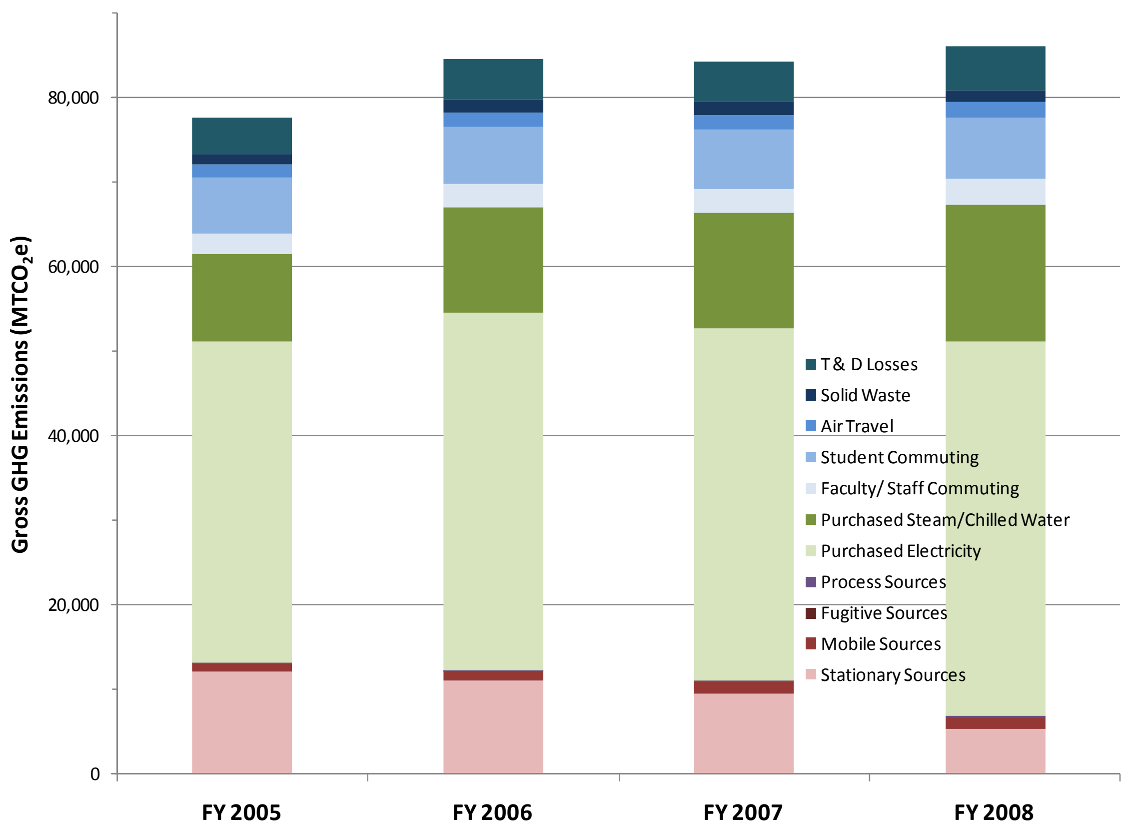


As JMU develops its long-term plan for achieving carbon neutrality, these sources will have to be prioritized in order to achieve meaningful overall GHG emissions reductions. JMU has already implemented a number of mitigation measures, including:

- use of B5 biodiesel (5% biofuel)
- purchasing steam from a municipal waste incinerator,
- aggressive recycling of solid waste, and
- free transit bus access for JMU commuters.

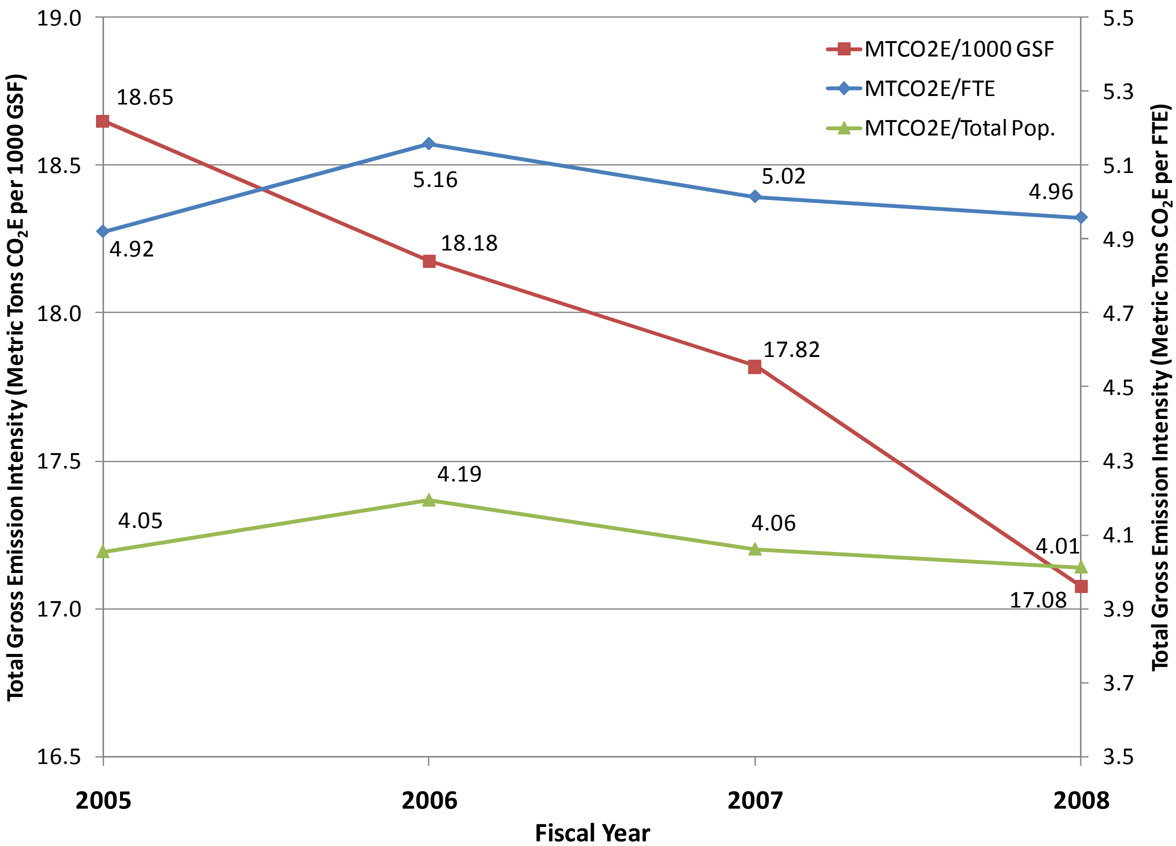
Additionally, the woodlands at the Edith J. Carrier Arboretum and the Madison College Farm provide 136 metric tons of CO_2 sequestration annually from 111 wooded acres.

In years subsequent to the baseline year, total GHG emissions increased primarily as a result of increased emissions from purchased electricity, and purchased steam and chilled water. In FY 2008, total gross emissions were 85,971 $MTCO_2E$, an 11% increase over the baseline year.



On a normalized basis, JMU's institutional GHG emissions have been consistently lower than that of peer doctorate-granting institutions. For example, in the baseline year (FY 2005), JMU's gross GHG emissions ($MTCO_2E$) per 1000 gross square feet (GSF) of building space and per full-time equivalent student (FTE) were 18.65 and 4.92, respectively. These emission intensities are lower than the average values for United States doctorate-granting institutions of higher education (20.59 and 8.33, respectively).

The period FY 2005 to FY 2008 was one of rapid institutional growth, with JMU's gross square footage (GSF) of campus building space increasing by 21%, while total GHG emissions increased by 11%. This translates into an 8% decrease in total GHG emission intensity per GSF, indicating efficiency improvements in JMU's building space management. However, emission intensity normalized by full-time equivalent students (FTE) or total population showed little change over this period. This suggests that FTE and population are fairly reliable predictors of JMU's total GHG emissions, even in times of rapid growth.



An emissions inventory of United States Environmental Protection Agency (USEPA) criteria and hazardous air pollutants was also developed using the data collected for the GHG inventory. This emissions inventory is provided in Appendix E.

1. Introduction

James Madison University (JMU), in collaboration with O'Brien & Gere, has developed a greenhouse gas (GHG) inventory in support of its participation in the American College and University Presidents' Climate Commitment (ACUPCC, 2007). The inventory is an integrated measure of JMU's institution-wide energy and resource usage. JMU's decision to join ACUPCC is indicative of its long-term commitment to climate action.

As an ACUPCC signatory, JMU is committed to set guidelines that include completion of a GHG inventory within one year of signing the commitment. The inventory will be followed by development of a Climate Action Plan, a long-term roadmap for achieving carbon neutrality by a target date.

This report describes the methodology and results of JMU's GHG inventory, including a comparative evaluation of emission sources, and a discussion of trends in emissions and emission intensity relative to the baseline year. *The primary purpose of the report is to establish a benchmark against which future progress towards carbon neutrality can be measured, and to help establish priorities with regards to the primary emission sources responsible for the bulk of JMU's emissions.*

At the request of JMU, an emissions inventory of United States Environmental Protection Agency (USEPA) criteria and hazardous air pollutants was also developed using the data collected for the GHG inventory (see Appendix E).

2. Methods

2.1. GHG Accounting Protocol

JMU's GHG emission inventory has been developed following the international consensus GHG accounting protocols developed by the World Resources Institute and World Business Council for Sustainable Development (WRI/WBCSD, 2004) in conjunction with the Clean Air – Cool Planet (CA-CP, 2008) Campus Carbon Calculator (V. 6). Both programs are based on the Intergovernmental Panel on Climate Change (IPCC) guidelines for national-level inventories, and represent state-of-the-art scientific methods for calculating GHG emissions. Emissions were considered from the six categories of greenhouse gases included in the Kyoto Protocol:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous Oxide (N_2O)
- Sulfur Hexafluoride (SF_6)
- Hydrofluorocarbons (HFC)
- Perfluorocarbons (PFC)

2.2. Inventory Boundaries and Definitions

Establishment of inventory boundaries and definitions is the first step in developing a GHG inventory program. The two key inventory boundaries are:

- Organizational boundary – extent of the reporting organization defined on the basis of operational control, which includes all sources which JMU manages on a day-to-day basis.
- Operational boundary – the scopes of emission sources (direct and indirect) that will be included in the inventory
    - Scope 1: Direct emissions (within the organizational boundary) including stationary, mobile, process, and fugitive emissions.
    - Scope 2: Indirect emissions (outside the organizational boundary) from purchased electricity, steam, and chilled water
    - Scope 3: Other indirect emissions (outside the organizational boundary) from landfilled solid waste, employee and student commuting, business air travel, and transmission and distribution (T&D) losses from purchased electricity .

In addition to the inventory boundaries, inventory development requires establishment of several key definitions:

- Baseline year – Fiscal year 2004-2005 (FY 2005); the earliest year for which comprehensive emissions data is available.

- Reporting frequency – at least every other year on a fiscal year basis, where the fiscal year extends from July 1 to June 30.

- *De minimis* threshold – 5% (Climate Registry, 2007); emission sources that collectively contribute less than 5% of total GHG emissions can be classified as *de minimis* and approximated using upper bound emission estimates in lieu of compiling detailed data.

- Emission intensity metrics – gross square footage, full-time equivalent students, total population, heating degree days, cooling degree days

These boundaries and definitions were established at a project kick-off meeting on January 15, 2009.

2.3. GHG Activity Description

A critical step in GHG inventory development is the identification of all activities that lead to GHG emissions from the organization. To identify these activities at JMU, a qualitative GHG activity description questionnaire covering Scope 1, 2, and 3 sources was distributed to JMU staff. A completed questionnaire is included in Appendix A. The questionnaire yielded the following results:

- Scope 1 GHG emission sources
  - Stationary Sources: boilers, furnaces, generators, water heaters, and kilns burning natural gas, propane, diesel, #2 and #4 fuel oil
  - Mobile Sources: JMU fleet vehicles and equipment such as backhoes, mowers, and skid steer loaders burning diesel, B5 biodiesel (5% biofuel), gasoline, and ethanol
  - Fugitive Sources: refrigeration and air conditioning units using HFC-134a, HCFC-22, R-402, R-404a, R-401a, R-500, R-402b, and R-410a

- Scope 2 GHG emission sources
  - Purchased electricity, steam, and chilled water

- Scope 3 GHG emission sources
  - Employee and student commuting
  - Business air travel
  - Solid waste landfilled

2.4. GHG Data Collection

A quantitative GHG data collection scorecard was developed based on the emission sources identified in the questionnaire. The scorecard was distributed to JMU staff and filled out for fiscal years from the baseline year (FY 2005) to FY 2008. Appendix B presents the completed scorecard, and Appendix C contains the raw data used to fill out each section of the scorecard.

2.5. GHG Accounting Methods

2.5.1. Scope 1 Methods

GHG emissions were calculated using the CA-CP Campus Carbon Calculator (v6.2). This section describes the calculations performed in the calculator. Specific emission factors and global warming potentials are documented within the CA-CP tool (CA-CP, 2008).

The following abbreviations are used in the equations below:

- CF = conversion factor,
- EF = emission factor,
- GWP = global warming potential, and
- CO_2E = carbon dioxide equivalent

Stationary Combustion

$$CO_2\ Emissions = Usage \times HeatValue \times CarbonContent \times CF_{Carbon}$$

$$CH_4\ Emissions = Usage \times HeatValue \times EF_{CH_4}$$

$$N_2O\ Emissions = Usage \times HeatValue \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

Mobile Source Combustion – Based on Fuel Usage

$$CO_2\ Emissions = Usage \times HeatValue \times CarbonContent \times CF_{Carbon}$$

$$CH_4\ Emissions = Usage \times HeatValue \times EF_{CH_4}$$

$$N_2O\ Emissions = Usage \times HeatValue \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

Fugitive Emissions

$$\mathrm{CO_2E}\ Emissions = Leakage \times GWP$$

Refrigerant leakage was estimated based on refills of air conditioning and refrigeration units. If leakage data was not available for a refrigerant type, a default leakage rate of 15% was applied to the total refrigerant charge to estimate leakage (California Climate Action Registry, 2007). Only HFC refrigerants were included in the inventory, consistent with the WRI/WBCSD (2004) GHG accounting protocols.

2.5.2. Scope 2 Methods

Electricity Emissions

$$CO_2\ Emissions = Usage \times EF_{CO_2}$$

$$CH_4\ Emissions = Usage \times EF_{CH_4}$$

$$N_2O\ Emissions = Usage \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

GHG emission factors for electricity are based on USEPA eGRID sub-regions (USEPA, 2009). JMU is located in the SERC Virginia/Carolina eGRID sub-region.

Steam Emissions

$$CO_2\ Emissions = Usage \times EF_{CO_2}$$

$$CH_4\ Emissions = Usage \times EF_{CH_4}$$

$$N_2O\ Emissions = Usage \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

JMU uses steam from the City of Harrisonburg's Resource Recovery Facility (RRF). The RRF is a waste-to-energy facility that generates steam by incinerating municipal waste. Based on typical U.S. municipal solid waste incinerated in combined heat and power plants, approximately 56% of this waste is biogenic (Energy Information Administration, 2007). Since emissions from biomass are considered carbon neutral, the emission factor for municipal solid waste is reduced by 56% to determine the emissions from purchased steam. USEPA's proposed mandatory GHG reporting rule (USEPA, 2009a) provides emission factors for combustion of municipal solid waste for CO_2, CH_4, and N_2O of 90.7, 0.03, and 0.004 kilograms per million British thermal units (MMBtu), respectively.

Chilled Water Emissions

$$CO_2\ Emissions = Usage \times EF_{CO_2}$$

$$CH_4\ Emissions = Usage \times EF_{CH_4}$$

$$N_2O\ Emissions = Usage \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

Chilled water data was converted from ton-hours (a unit of energy consumption commonly used for cooling applications) to MMBtu using a conversion factor of 0.012 (USEPA, 2009b). JMU purchases chilled water from the RRF. Greenhouse gas emissions from purchased chilled water are calculated using the emission factor and biogenic fraction for municipal solid waste described under the Steam Emissions section.

2.5.3. Scope 3 Methods

Transmission and Distribution Losses from Scope 2 Sources

$$CO_2\_emissions = CO_2electric \times {TD_{electric}}/{(1-TD_{electric})} + CO_2steam \times {TD_{steam}}/{(1-TD_{steam})} + CO_2chilled\_water \times {TD_{cw}}/{(1-TD_{cw})}$$

$$CH_4\_emissions = CH_4electric \times {TD_{electric}}/{(1-TD_{electric})} + CH_4steam \times {TD_{steam}}/{(1-TD_{steam})} + CH_4chilled\_water \times {TD_{cw}}/{(1-TD_{cw})}$$

$$N_2O\_emissions = N_2Oelectric \times {TD_{electric}}/{(1-TD_{electric})} + N_2Osteam \times {TD_{steam}}/{(1-TD_{steam})} + N_2Ochilled\_water \times {TD_{cw}}/{(1-TD_{cw})}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

CA-CP considers transmission and distribution losses ((TD in the equations below) from purchased electricity, steam, and chilled water to be Scope 3 sources.

Landfilled Solid Waste

$$CH_4\ Emissions = MassLandfilled \times EF_{CH_4}$$

$$CO_2E\ Emissions = CH_4\_emissions \times GWP_{CH4}$$

The majority of municipal solid waste (MSW) in the United States has historically been sent to landfills, although the fraction has been reduced over the years (USEPA, 2008). However, JMU has reduced the fraction of its solid waste sent to landfills by implementing a recycling program and diverting waste to the RRF. The primary GHG emitted by landfills is methane.

Incinerated Waste

$$CO_2E\ Emissions = MassIncinerated \times EF$$

JMU sends a portion of its MSW to the RRF for incineration. This disposal method reduces the GHG emissions associated with waste disposal compared with landfilling. CA-CP accounts for this savings by providing a negative emission factor for mass burn facilities.

Recycled Solid Waste

$$\mathrm{CO_2E}\ \ Emissions = \sum_{Material} RecycledMass \times EF$$

JMU's recycling program reduces the amount of solid waste sent to landfills. The GHG emissions avoided by recycling are calculated using emission factors from USEPA (2002).

Student and Employee Commuting

$$CO_2\ Emissions = Mileage \times EF_{CO_2}$$

$$CH_4\ Emissions = Mileage \times EF_{CH_4}$$

$$N_2O\ Emissions = Mileage \times EF_{N_2O}$$

$$\mathrm{CO_2E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

JMU conducted a commuting survey (JMU, 2008) to obtain estimates of the frequency and length of student and employee commutes: Relevant excerpts from the survey report are included in Appendix C and described below:

- *Percentage breakdown of faculty, staff, and students*: Figure 11 from JMU (2008) was used to identify the percentages of faculty, staff and students using different modes of transportation. Carpools of 2, 3 and 4 people were all considered under the general "Carpool" category.

- *Miles per trip:* Table 11 of JMU (2008) lists the number of survey respondents for each mode of transport, by one-way distance from campus, represented by mileage bins. The average value of a mileage bin, weighted and normalized by the number of respondents, was used to estimate a miles/trip value for the JMU campus.

- *Trips per week:* Figure 7 of JMU (2008) was used to estimate the number of trips/week using a weighted average.

- *Weeks per year:* The JMU academic calendar was used to estimate the number of weeks students would make trips to the JMU campus. It was assumed that faculty and staff did not commute to campus 4 weeks out of the calendar year.

The inputs above, along with the number of students, faculty, and staff, were used to determine the miles traveled by commuters. GHG emissions were then calculated by multiplying the mileage by emission factors for CO_2, N_2O, and CH_4, and summing these emissions weighted by their global warming potentials.

In addition to data from the JMU commuting survey, fuel usage data was utilized for the Harrisonburg bus system which provides transportation for many JMU commuters, including free transportation for riders with a JMU Access Card (JAC). It is estimated that 95% of the Harrisonburg bus ridership is associated with JMU (JMU, 2008). Consequently, 95% of the transit bus fuel usage is attributed to JMU in the commuting estimate. Since commuting emissions are calculated based on mileage, the fuel usage data was converted to mileage based on CACP (2008) default miles per gallon for a transit bus. The Harrisonburg bus system uses a minimum of 5% biodiesel fuel blend (B5). Since CACP assumes diesel fuel as part of its calculations, the fuel usage data was multiplied by the maximum diesel fuel fraction (95%, or 0.95) to estimate GHG emissions. The remaining biogenic content of the fuel was considered carbon neutral.

Business Air Travel

$$CO_2\ Emissions = Mileage \times EF_{CO_2}$$

$$CH_4\ Emissions = Mileage \times EF_{CH_4}$$

$$N_2O\ Emissions = Mileage \times EF_{N_2O}$$

$$\text{CO}_2\text{E}\ Emissions = CO_2\_emissions + (CH_4\_emissions \times GWP_{CH4}) + (N_2O\_emissions \times GWP_{N_2O})$$

Business air travel data was only available for FY 2006. For other reporting years, FY 2006 data was scaled by changes in faculty and staff population to estimate business air travel mileage. UATP/American Airlines was the air travel contractor for JMU until approximately October, 2005. During the contract period, UATP sent monthly paper statements to JMU containing itineraries for which payment was due. These statements were available for June-October 2005, and accounted for travel scheduled from June through November 2005.

To minimize errors and time spent in data entry, the paper statements were scanned electronically into JPG files and read using Optical Character Recognition (OCR) software. The itineraries were then loaded into a mapping program (Swartz, 2009) to obtain mileage for each individual itinerary. The average monthly mileage was multiplied by 12 to estimate the annual mileage traveled for FY 2006.

It should be noted that the air travel emission factor accounts for both direct GHG emissions from combustion of jet fuel and radiative forcing effects of air travel from contrails (i.e., cloud formation by jet exhaust in the upper troposphere).

Carbon Sequestration from Forest Management

$$Carbon\_Sequestration = Forested\_Acreage \times \%Canopy\_Cover \times Sequestration\_Rate$$

$$CO_2\_Sequestration = Carbon\_Sequestration \times (Molecular\_Wt_{CO_2} / Molecular\_Wt_{Carbon})$$

JMU has two properties with significant forested acreage: the Edith J. Carrier Arboretum, and the Madison College Farm. The Arboretum property contains 125 acres, 87 of which is predominately oak-hickory forest that is around 110 years old. Some portions of the Arboretum forest have been thinned for ground plantings. The Farm property contains approximately 30 acres, 24 of which is forested with 48-year-old planted pines that have never been thinned. Total forested acreage is approximately 111 acres.

For the purposes of the sequestration calculation, it was assumed that the percent canopy cover in each of these forested areas was 100%. The sequestration rate (0.335 tons C/acre) is given by Rowntree (Rowntree, 1991) and accounts for tree age (represented by diameter), since the rate that a forest sequesters carbon is dependent on the age of the trees within the forest. For the sequestration calculation, it was assumed that the tree diameter distribution of the forests on these JMU properties could be approximated by the average tree diameter distribution given by Rowntree. Both of these assumptions were considered adequate because of the small scale of the carbon sequestration provided by the forests in relation to JMU's total GHG emissions.

3. Results and Discussion

3.1. Baseline year (FY 2005) carbon footprint

Total gross GHG emissions for the baseline year FY 2005 for JMU were 77,593 metric tons of carbon dioxide equivalent ($MTCO_2E$). The primary emission sources were purchased electricity, stationary source combustion, purchased steam & chilled water, and commuting (faculty/staff and student). Together, these four source types accounted for 89% of total emissions, as shown in **Figure 1**. As JMU develops its long-term plan for achieving carbon neutrality, these sources will have to be prioritized in order to achieve meaningful overall GHG emissions reductions.

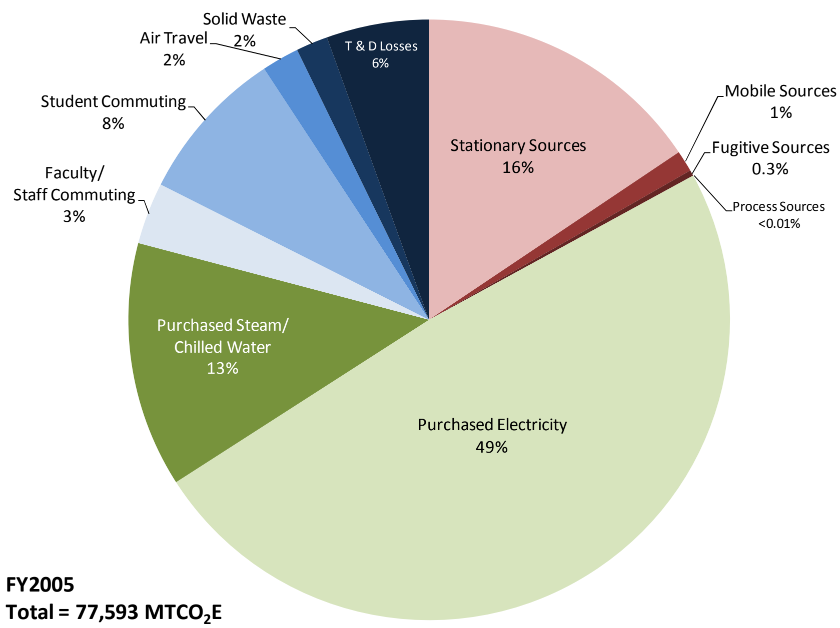


Figure 1: JMU gross GHG emissions by source for FY 2005 (baseline year).

3.2. Historical trends in GHG emissions

JMU's total GHG emissions for FY 2008 were 11% higher than the FY 2005 baseline. The majority of this increase occurred from FY 2005 to FY 2006, during which time emissions rose 9%. For reference, the total population of JMU increased by 12% and 5% over the periods FY 2005 to FY 2008 and FY 2006 to FY 2008, respectively. **Table 1** lists emissions and emissions intensity by scope and source type for FY 2005 through FY 2008.

Table 1: GHG Emissions and Emissions Intensity by scope and source, FY 2005 to FY 2008.

Scope	*Source*	*FY 2005*	*FY 2006*	*FY 2007*	*FY 2008*
Scope 1 Emissions ($MTCO_2E$)	Stationary Sources	12089	11012	9594	5420
	Mobile Sources	890	1236	1342	1322
	Fugitive Sources	238	7	129	220
	Process Sources	1	1	1	1
	Total Gross Emissions	*13218*	*12255*	*11066*	*6962*
Scope 2 Emissions ($MTCO_2E$)	Purchased Electricity	37924	42195	41573	44235
	Purchased Steam/ Chilled Water	10240	12568	13651	16141
	Total Gross Emissions	*48164*	*54763*	*55224*	*60376*
Scope 3 Emissions ($MTCO_2E$)	Faculty/ Staff Commuting	2584	2730	2840	2992
	Student Commuting	6458	6761	7009	7265
	Air Travel	1553	1641	1707	1797
	Solid Waste	1325	1483	1489	1355
	Scope 2 T & D Losses	4290	4835	4830	5224
	Total Gross Emissions	*16211*	*17449*	*17875*	*18633*
Scope 1 – 3 Gross Emissions ($MTCO_2E$)	***Total Gross Emissions***	***77593***	***84468***	***84165***	***85971***
	Gross Square Footage (GSF)	4160587	4646759	4723393	5034696
	Full-time Equivalent Students (FTE)	15771	16373	16782	17339
	Total Gross Emission Intensity per 1000 GSF	18.65	18.18	17.82	17.08
	Total Gross Emission Intensity per FTE	4.92	5.16	5.02	4.96
Scope 1 – 3 Net Emissions ($MTCO_2E$)	Purchased Offsets	0	0	0	0
	Carbon Sequestration	-136	-136	-136	-136
	Total Net Emissions	***77457***	***84332***	***84029***	***85834***
	Total Net Emission Intensity per 1000 GSF	18.62	18.15	17.79	17.05
	Total Net Emission Intensity per FTE	4.91	5.15	5.01	4.95

On a normalized basis, JMU's institutional GHG emissions have been consistently lower than that of peer doctorate-granting institutions. For example, in the baseline year (FY 2005), JMU's gross GHG emissions ($MTCO_2E$) per 1000 gross square feet (GSF) of building space and per full-time equivalent student (FTE) were 18.65 and 4.92, respectively. These emission intensities are lower than the average values for United States doctorate-granting institutions of higher education (20.59 and 8.33, respectively; AASHE, 2009).

Figure 2 below shows that the increase in emissions from FY 2005 through FY 2008 is driven largely by the increase in purchased electricity, steam and chilled water. In contrast, emissions due to stationary combustion decreased by over 50% during this time period, due to declining natural gas usage. Emissions from other sources, such as mobile sources and commuting, show large increases on a percentage basis; however, the impact of these increases on overall emissions is small.

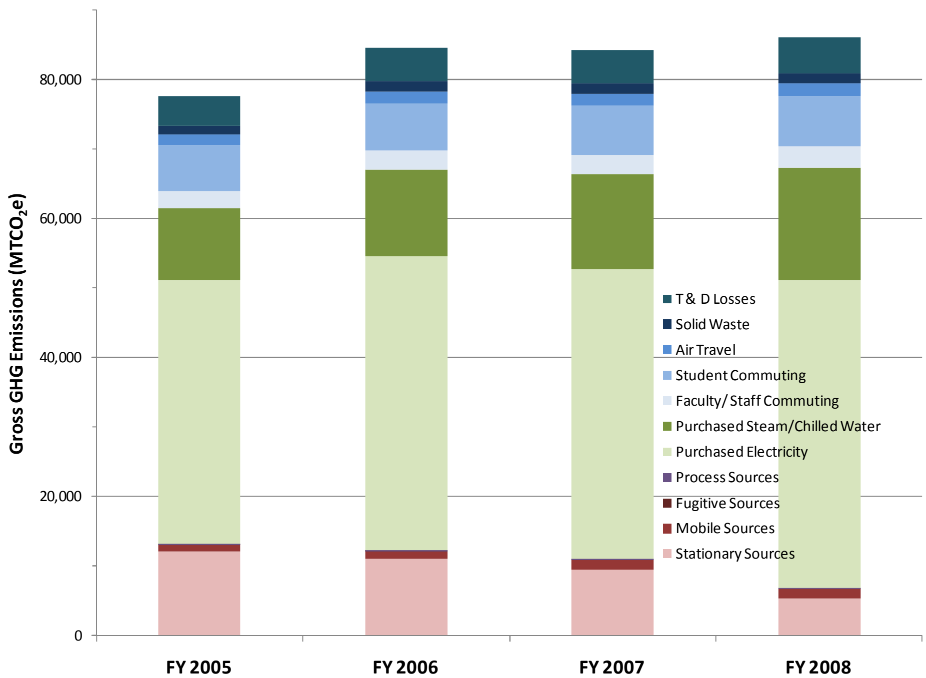


Figure 2: JMU GHG emissions by source for FY 2005 to FY 2008.

3.2.1. Weather impacts

The number of heating degree days (HDD) and cooling degree days (CDD) for a given geographic location can provide an indication of the impacts of weather on energy demand. **Figure 3** shows HDD and CDD over the period FY 2005 to FY 2008 for the Harrisonburg area. These values were fairly constant over the four-year time period, with the exception of CDD for 2006. Consequently, annual variations in temperature were not considered to exert a strong influence on GHG emissions.

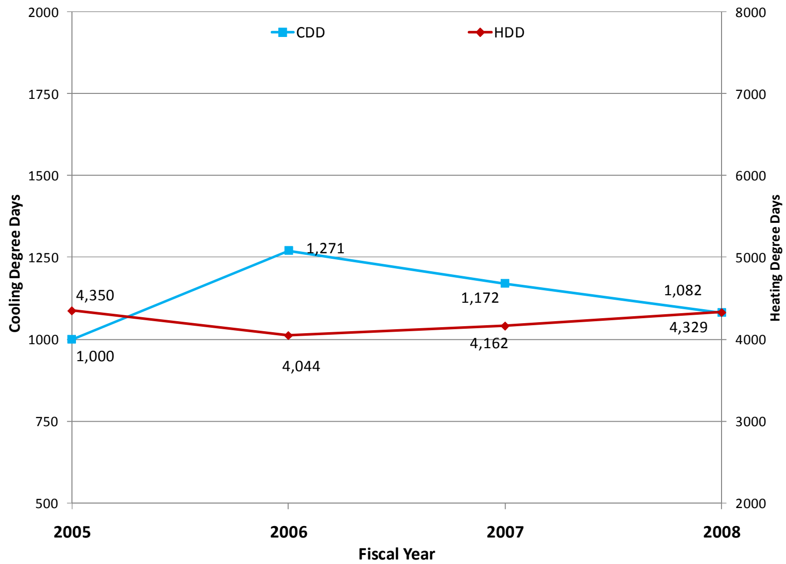


Figure 3: Cooling Degree Days (CDD) and Heating Degree Days (HDD) for Harrisonburg, VA.

3.3. Historical trends in GHG emission intensity

GHG emission intensity (i.e., GHG emissions normalized by an institutional metric such as FTE enrollment or GSF building space) is a useful performance indicator and facilitates internal and external benchmarking. As seen in Figure 4, JMU's gross emission intensity on a square footage basis ($MTCO_2E$/1000 GSF) steadily declined by 8.4% from FY 2005 through FY 2008. However, JMU's gross emission intensity on an FTE and total population basis has remained fairly constant over FY 2005-FY 2008.

The period FY 2005 to FY 2008 was one of rapid institutional growth, with JMU's gross square footage (GSF) of campus building space increasing by 21%, while total GHG emissions increased by 11%. Since emission intensity per FTE and per total population remained steady over this period, this suggests that FTE and population are fairly reliable predictors of JMU's total GHG emissions, even in times of rapid growth. However, should JMU's student enrollment increase over time, emissions per unit population will have to decline in order for JMU to successfully meet its long-term commitment to carbon neutrality.

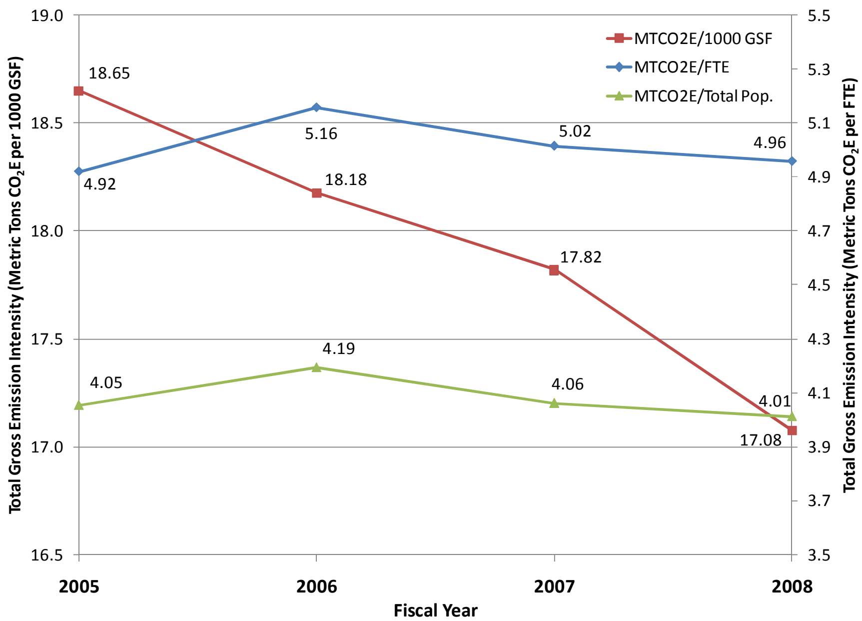


Figure 4: GHG gross emission intensity on GSF and FTE basis, FY 2005-2008.

3.4. Uncertainty

Uncertainty in GHG emission estimates is minimized for Scope 1 and 2 sources through the use of metered utility and chemical data. However, emission estimates for Scope 2 purchased steam assume a national average biogenic content of municipal solid waste (56%; Energy Information Administration, 2007).

Uncertainty is higher for Scope 3 sources, which rely on a commuting survey for commuting emission estimates and a limited (six-month) data set for business air travel emission estimates.

3.5. Mitigation

JMU has conducted a variety of emission reduction activities in past years. One of the drivers of greenhouse gas mitigation is Virginia's Executive Orders 48, 54 and 82, which mandate a reduction in non-renewable energy usage and the development of policies regarding energy use, water use, waste reduction and travel that will reduce the environmental impacts and costs of those activities. JMU's past mitigation activities are summarized below.

3.5.1. Purchased Steam and Chilled Water

Purchasing steam and chilled water from a waste-to-energy facility reduces JMU's carbon footprint in two ways. The facility diverts solid waste from the landfill, thereby reducing methane emissions. Generating steam from waste incineration also decreases the need to use fossil fuels to produce steam and chilled water. In addition, the biogenic fraction (approximately 56%) of municipal solid waste is carbon neutral and lowers the footprint of steam production.

3.5.2. Demand-Side Management

JMU accomplished several facility upgrades that increase energy efficiency over the period FY 2006 to FY 2008. These include an energy audit, lighting retrofits, heating, ventilation, and air conditioning (HVAC) and chiller upgrades, and replacement of boilers, water heaters, and steam traps.

3.5.3. Alternative Fuels

JMU has a wind turbine, a hydrogen fueling station, and a demonstration of photovoltaic technology. While these projects currently demonstrate alternative energy technologies, they do not have a measurable impact on reducing JMU's energy usage.

In addition, both JMU's vehicle fleet and the Harrisonburg bus system, which serves many JMU students, use B5 (5% biofuel) biodiesel fuel.

3.5.4. Recycling

JMU's recycling program has reduced GHG emissions by approximately three thousand $MTCO_2E$ per year, by reducing the amount of landfilled solid waste available to produce methane. USEPA (2002) provides emission factors to quantify the greenhouse gas emissions avoided by recycling rather than landfilling solid waste. These calculations are shown for FY 2005 to FY 2008 in **Table 2**.

Table 2: GHG emissions avoided at JMU through recycling, FY 2005 to FY 2008.

Type	*Emission Factor*	FY 2005	FY 2006	FY 2007	FY 2008
	$MTCO_2E$ / U.S. ton	$MTCO_2E$	$MTCO_2E$	$MTCO_2E$	$MTCO_2E$
Waste Burned at R.R.F.	*-0.12*	-130	-116	-119	-88
Mixed Paper Recycling	*-3.54*	-517	-517	-566	-460
White Paper Recycling	*-2.85*	-94	-94	-111	-131
Newspaper Recycling	*-2.79*	-78	-78	-86	-75
Cardboard Recycling	*-3.11*	-538	-538	-575	-715
Plastic Recycling	*-1.49*	-60	-60	-97	-101
Mixed Metals Recycling	*-5.25*	-189	-189	-221	-168
Steel Can Recycling	*-1.79*	-23	-23	-36	-20
Tire Recycling	*-1.82*	-4	-4	-4	-5
Wood Recycling	*-2.46*	-1,048	-1,048	-1,387	-1,082
Other Comingled Recycling	*-2.91*	-847	-52	-58	-64
Total		-3,528	-2,719	-3,260	-2,909

3.5.5. Commuting

JMU encourages students to use the Harrisonburg bus system, which is free to anyone with a JAC card. Based on default emission factors for automobiles and transit buses (CACP, 2008), using the bus rather than personal vehicles reduces the GHG emissions associated with commuting to campus by approximately 36% per passenger mile.

3.5.6. Carbon Sequestration

The forests at the Edith J. Carrier Arboretum and the Madison College Farm are together estimated to provide a total of 136 metric tons of carbon dioxide sequestration annually, from 111 wooded acres. By maintaining these acres, JMU is preventing development that would likely result in reduction of woodlands and loss of sequestration.

3.5.7. Education and Awareness

JMU's university divisions collaborate to immerse students in a living laboratory. The campus has a wind turbine, photovoltaics, a green roof, a planetarium, Arboretum, Science on a Sphere (a spherical movie system that simulates Earth systems), and a farm internship program. Elliptical exercise machines have been outfitted to produce electricity, and online-readings of energy consumption are produced for multiple buildings.

3.5.8. Initial Recommendations

As a next step to establishing a baseline GHG inventory, JMU will develop a Climate Action Plan which will establish formal recommendations for achieving carbon neutrality by a target date. Initial recommendations based on the results of the GHG inventory are presented below.

- Purchased electricity is JMU's largest emission source, responsible for approximately half of institutional emissions. JMU may install building-level sub-metering to identify buildings with the highest electricity usage in support of the Climate Action Plan process.

- Emission intensity per student has remained relatively flat (~5 $MTCO_2E$ per FTE) over the period FY 2005-2008. JMU may institute a challenge to incoming students to reduce their emission intensity by a target percentage (e.g., 15%) in 4 years (by graduation).

- JMU has already implemented a number of mitigation measures, including use of B5 biodiesel (5% biofuel), purchasing steam from a municipal waste incinerator, aggressive recycling of solid waste, and free transit bus access for JMU commuters. Wherever possible, JMU may scale up these measures (e.g., using B20 instead of B5; increasing the recycling capture rate; increasing transit bus ridership).

In addition, JMU may consider short-term tangible actions proposed by ACUPCC that JMU has not yet adopted.

- JMU may evaluate the technical and economic feasibility of purchasing RECs to offset GHG emissions from electricity usage, with the potential target of purchasing or producing at least 15% of JMU's electricity consumption from renewable sources.

- JMU may establish a policy that all new campus construction will be built to U.S. Green Building Council's LEED Silver standard or equivalent, at a minimum.

- JMU may establish a policy of offsetting all GHG emissions generated by air travel paid for by JMU.

- JMU may establish a policy or a committee that supports climate and sustainability shareholder proposals at companies where JMU's institution's endowment is invested.

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