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An Energy Use and Emissions Inventory

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Abstract

Maintaining a 400-acre campus which supports the education of 3000 students requires energy. Data were gathered from across campus as part of a faculty research project and in conjunction with an undergraduate course. The project was initiated in order to develop an energy usage and emissions inventory for the University while at the same offering students exposure to the process. Inventory inputs included stationary consumption (burning of natural gas to supply heat), electricity purchased, campus vehicle usage (gasoline consumption), commuter vehicle usage (faculty and staff only), and transportation and distribution (T&D) expenses. Whereas the student population has increased by only 8% since 2000, the dollar amount budgeted for energy expenses on campus has risen by 50% over the same time period.

Emissions from the various energy inputs were analyzed. In 2007, electricity purchased from the local utility company accounted for 74% of the campus energy usage. Since the university does not have direct control over which fuel is being used to provide this needed electricity and since Congress is currently debating "Cap and Trade" legislation, it behooves the university to take a serious look at its energy conservation practices.

Recommendations to the university administration include the following: (1) line-item the energy cost to students as a part of their bills, (2) increase the rate of replacing older equipment with high-efficiency units, (3) develop a plan for becoming carbon-neutral by a specified date in the future, and (4) sponsor a project which integrates environmental, business, engineering, and technical writing majors to produce a "Green Guide" for the campus.

Introduction

Energy costs and atmospheric concentrations of carbon dioxide (CO_2) continue to increase. Interestingly, the two are fundamentally connected as the primary by-product of our energy use is CO_2, a greenhouse gas[1]. The increases in greenhouse gas concentrations in the atmosphere are responsible for the increase in global mean temperature of 1°C over the past century. Global climate models (or GCMs) have projected that the Earth's mean annual temperature will increase by at least 1 °C and perhaps up to 5 °C over this century[2]. Given that the global mean temperature of the Earth is 13°C, even a modest increase of 1-2 °C is a 7 – 15% temperature increase that would have profound effects on humankind, living organisms, and the physical environment.

In a time of uncertainty and change with respect to the economy, government, and environmental issues we chose to conduct this analysis of our campus stewardship practices. Our goals included: to be an example to our student body, to be a witness to the community (and prospective students), to be wise stewards of our natural and financial resources, and to prepare for the future[3].

Therefore, we set out to acquire data pertaining to our University's use of energy and emission of greenhouse gases. We also purposed to involve a number of students in the process as part of two courses. This comprehensive study will establish a baseline dataset that may be used in the future to compare efforts to increase efficiency and/or decrease energy use.

Methods

Phase 1 was divided into a two-step process. First, we collected the data from campus sources. We included this as part of the Ecosystem Science course (taught by Author 1). Second, we used these data to establish a baseline from the available/accessible data. Our goal for this phase of the work is to document all the necessary input. We had hoped to gather a decades' (1999 – 2009) worth of data as it related to all the emissions sources. We accomplished this in many categories (Table 1 & 2). However, we were unable to for other areas where the records were simply not kept (fertilizer use on athletic fields), lost in conversion to digital storage (paper use on campus), or difficult to impossible to infer from the available data at this time (waste management). This phase of the study revealed where data holes existed as well as what records were readily available.

We began making initial contacts around campus in June 2009. By the end of August 2009 we had compiled a majority of the data and identified the sources for the remainder. The the Ecosystem Science course required pairs of students to make additional contacts to acquire the remaining data. Students chose to join groups assigned to collect data related to "wastewater", "paper", and "faculty/staff commuting". Each group then followed the procedure:

1. Contact a campus or community representative regarding data access
2. Collect the raw data and make any necessary conversions (i.e. sheets to lbs of paper)
3. Input the data into a spreadsheet
4. Identify any shortcomings or inherent data assumptions
5. Participate in class discussions regarding the findings

These steps allowed the students the opportunity to develop their communication skills and data management in a "real world" setting. This challenged these science students to engage in the social aspects of "doing science" that are critical to success in the field, but less commonly incorporated into course material.

In order to catalog, manage, and project our campus data we chose to use the *Campus Carbon Calculator*[4]. This spreadsheet is offered as a resource from the non-profit group Clean Air-Cool Planet (CACP). The spreadsheet itself was developed by the University of New Hampshire in an effort to catalog their campus' energy use and emissions sources. They have made it available to other universities and colleges through CACP. As of 2008 more than 1000 campuses have used the *Calculator*.

Results

In order to fulfill the objectives of this study we had the goal of acquiring institutional energy use and emissions data from the campus between 1990 and 2009. The institutional data included the budget and the university population made up of students, faculty and staff, and the university's physical size (Table 1). Each of these three general categories is well recorded and was readily accessed via a number of University Offices.

Table 1. Institutional data collected from various offices of our University. Data included are budget, population, and physical size and the period of available data. The minimum and maximum values for each category over the respective time period are also provided.

Institutional data	Years	Minimum - Maximum	Data source
Budget (millions of $)			VP of Operations
Operating	1991 - 2008	22.5 – 69.1	
Research	na		
Energy	1991 - 2008	0.86 – 2.33	
Population			
Full-time students	1990 - 2009	1,818 – 2,825	Registrar
Part-time students	1990 - 2009	65 -189	
Summer students	1990 - 2009	222 - 570	
Faculty	1990 - 2008	72 - 211	Human Resources
Staff	1990 - 2008	99 - 362	
Physical size (ft^2)			VP of Operations
Building space	1991 - 2008	724,286 – 1,377,322	

During the years 1990 – 2005 there was consistent growth in each segment of the institution with respect to the budget, population, and physical size. During the three year period following (2006 – 2009) there was a 3.8 and 12.3 % decline in the student and faculty populations, respectively. Each decrease has since rebounded slightly. In that same period the budget (total and energy) and physical space increased slightly, or were held constant.

As of August 2009 our campus had 1.3 million $feet^2$ of space to cool and/or heat using electricity and natural gas. These two sources of energy represent the major sources of Scope 1 and Scope 2 emissions (Figure 1). Together these energy sources account for most of the $2.3 million energy budget (Table 1) and 90 % of the total CO_2 emissions (Figure 1 & 2). The generation of energy is an inefficient process as much is lost by way of heat. These losses are exacerbated when the energy is produced offsite and then transmitted. This is the case of electricity such that the efficiency is much less due to increases in losses. This may be seen when comparing actual energy used (MM Btu from gas and kWh from electricity, Table 2) and the energy actually produced (Figure 3 & 4). The Campus Carbon Calculator uses a conversion factor to convert kWh to MM Btu so that the values may be more easily compared (Figure 1). This reveals that the majority of energy use is due to electricity demand by a 4:1 margin over natural gas demand. From this we know that the campus electricity demand accounts for the majority of eCO_2 emissions.

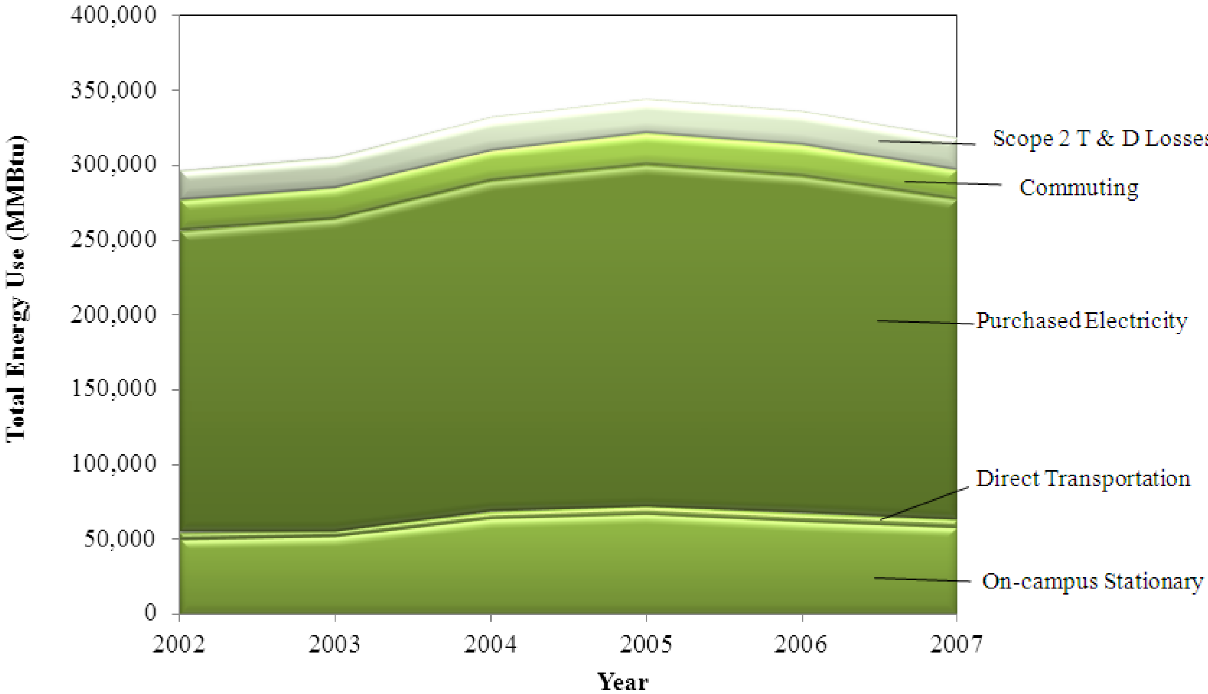

Figure 1. Total energy use (MM Btu) between 2002 and 2007 from the five major sources; transmission and distrubition losses, faculty and staff commuting, purchased electricity, direct transportation, and on-campus stationary (natural gas).

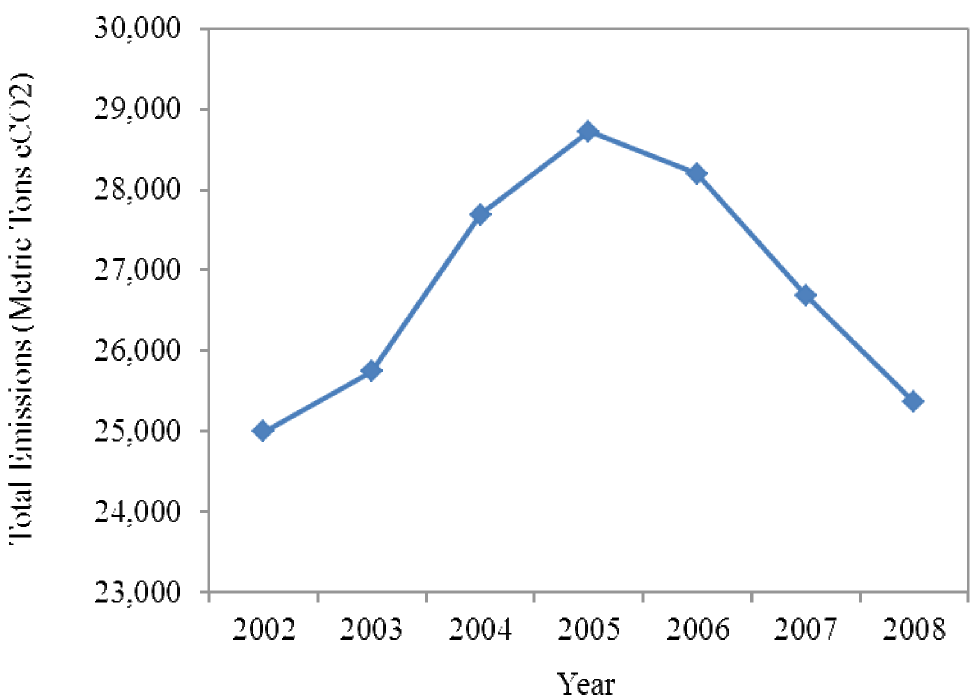

Figure 2. Total emissions (metric tons of eCO_2) for the campus from all sources during 2002 - 2008.

Table 2. Emissions and Offsets data collected from various offices of Our University. Emissions data included are categorized based on the origin of the energy used and distinguished as Scope 1 (e.g. natural gas), Scope 2 (e.g. electricity), or Scope 3 (e.g. solid waste). The minimum and maximum values are provided for each category during the period of record.

Emissions Sources	**Years**	**Minimum - Maximum**	**Data source**
Scope 1			
On-campus stationary			
Natural gas (MM Btu)	2000 - 2008	50,317 – 67,099	VP of Operations & Facilities Management
Direct Transportation			
Gasoline fleet (gallons)	2002 - 2008	39,868 – 45,855	Physical Plant
Fertilizer (lbs)	2002 - 2009	20,000	Physical Plant
Scope 2			
Purchased electricity (kWh)	2000 - 2009	18,351,141 - 29,845,007	VP of Operations & Facilities Management
Scope 3			
Faculty/Staff commuting (miles)	1990 - 2008	1,177,316 – 4,089,622	Human Resources (estimated from zip codes)
Student commuting	na		
Business travel	nd		
Solid waste (tons)*	FY 2009	584	Physical Plant
Wastewater (millions of gallons)	1991 -2008	31.32 – 48.44	Physical Plant
Paper (lbs)	2005 - 2009	62,115 – 76,979	Print Services Computer Services
Offsets	n/a	*May be purchased by the metric ton CO_2*	

As electricity and natural gas consumption account for 90% of campus emission (Figure 1), we wanted to better understand what factors dictated energy demand on our campus. Both electricity and gas are used for a variety of purposes around campus the majority is allocated for heating and cooling the campus buildings. This can be observed in the correlation between mean monthly temperature and electicity and gas demand (Figures 3 & 4). Electricity varies in direct relation with temperature, which reflects that the majority of electric demand is due to air conditioning during warm periods. In contrast, natural gas varies inversely with temperature as its primary use is for heating during cool periods. Both electricity and gas are required for other purposes and these values can be seen as the“off-season” demand. These baseline values indicate the amounts used for lighting and machine operations for electricity and the heating of water by way of natural gas.

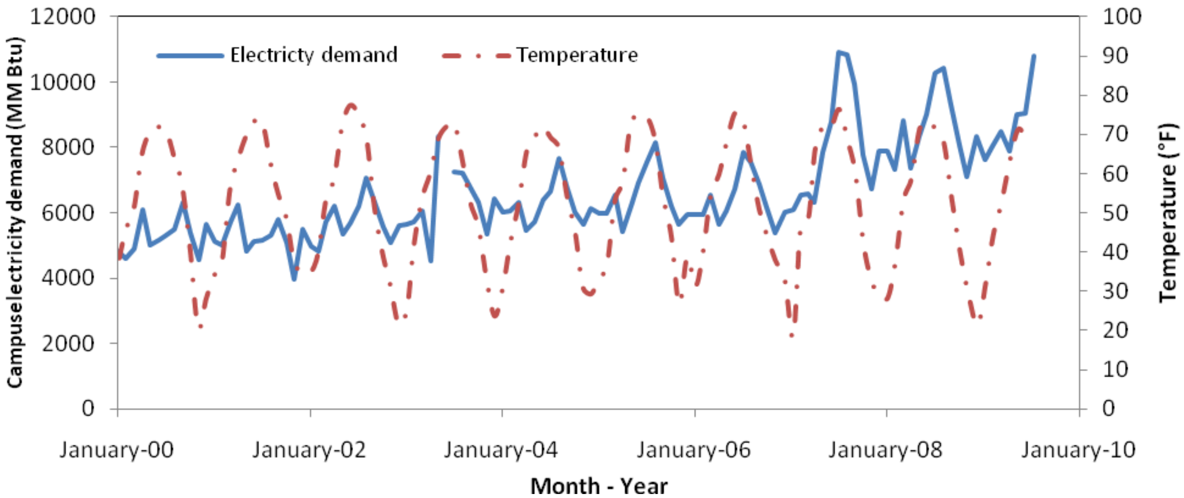

Figure 3. Campus electricity demand (converted kWh to MM Btu) and mean monthly temperature between January 2000 and August 2009.

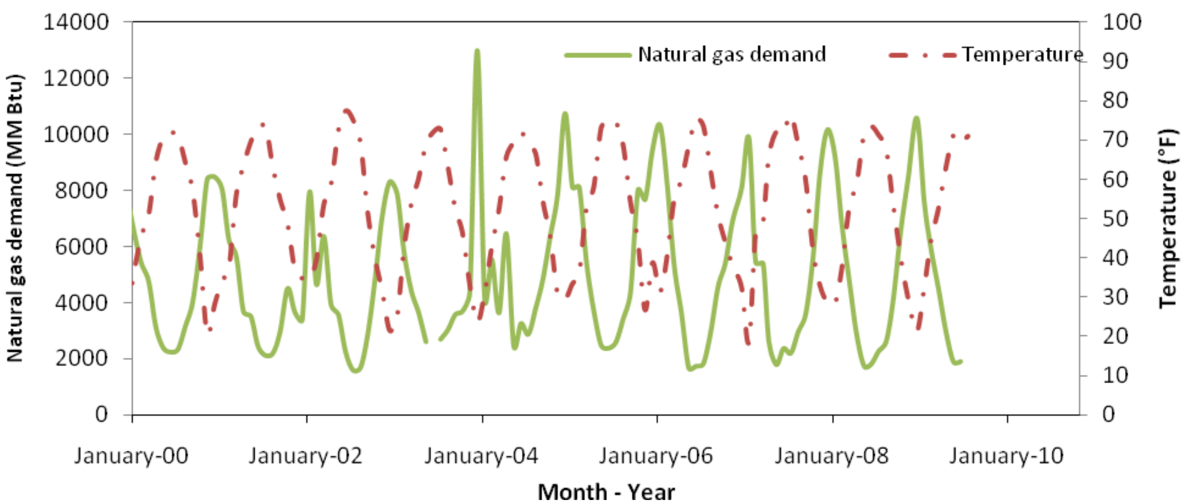

Figure 4. Campus natural gas demand (MM Btu) and mean monthly temperature between January 2000 and August 2009.

Natural gas use has (with one exception in 2004) had peak demand between 8,000 – 10,000 MM Btu since 2000. The slight increase (Figure 4) during this period is largely reflective of adding 350,000+ ft^2 of building space. That is to say that despite increasing our physical size by approximately 33% since 2000 our natural gas use has only increased by 20 – 25%. This is likely driven by a combination of factors: increased heating efficiency (new buildings and renovations), decreased demand due to energy policy and/or variability in external temperatures.

In addition to quantifying emissions from energy sources the Ecosystem Science class collected and analyzed less commonly addressed emissions sources. Most notable among these are the energy and emissions from vehicle use. This includes both the campus vehicle fleet (directly accounted) as well as estimates of faculty and staff commuting. These two together made up for the majority of the remaining 10% of the energy use and emissions. The university fleet has used on average 40 – 45,000 gallons of gas each year since 2004. We estimated round trip travel (in miles) based on faculty and staff zip codes. The data revealed that the vast majority (80%) of faculty and staff live within 20 miles (40 mile roundtrip) of the campus. In order to estimate total mileage and fuel usage we made a simplifying assumption that employees drive alone to work 274 days (75%) each year in a vehicle with 22 mpg fuel economy (the current national average). Given this we estimated a per capita drive of 25.4 miles per day, or 6885 miles per year. For a fac/staff of 594 individuals this translates to 14,940 miles driven each day, or 4,089,622 miles each year. As a group this is as if we drive to the moon and back eight times each year!

Students in the Ecosystem Science course were surprised at how electricity and natural gas emissions greatly overshadowed the emissions from wastewater, waste production, paper use and fertilizer use. . Based on the data none of these contributed significantly to campus emissions. This project revealed to students the most pressing conservation issue related to emissions (eCO_2) was energy use. Over the course of the semester Author 1 noted an important change in the focus of discussions. Early on students had believed that waste production/recycling would be greatly important. However, they now understood electricity use to be the most pressing issue. By the end of the semester it had become clear to them that small changes in large emissions categories would be more significant than large changes in small emissions categories.

Notably absent from our accounting is air travel by study abroad students, student commuting and university business travel. Each of these would be considered Scope 3 emissions. These data are difficult to collect. However, they can account for a significant amount of energy use, emissions and cost expenditures. Air travel in particular accounts for significantly greater amounts of CO_2 emissions relative to other modes of travel over the same distance. Future work is needed to quantify these variables.

While overall electricity use has continued to rise (Figure 3), this is not without just cause. During this time our University has added approximately 330,000 ft^2 of physical space (one athletic and one academic building most notably). Considering the increase in the physical size and changes in student population we noted several important trends. First, since 2004 our total energy use ft^{-2} has been trending down from a peak of 21,800 Btu ft^{-2} in 2004 to 18,400 Btu ft^{-2} in 2008 (Figure 5c). This is a 15.5% decrease in energy use per square foot, or a 15.5% increase in efficiency. Second, energy use per student peaked at 9.9 MM Btu in 2005 and has been declining to around 8.9 MM Btu in 2008 (Figure 5d). This represents a 10.1% decrease in energy use per student. Both examples reveal an overall increase in our University's energy efficiency. As emissions are paired with energy use there are identical trends in emissions in these same categories (Figure 5 a & b). This largely reflects the drafting and implementation of a formal "Energy Policy" by the VP of Operations.

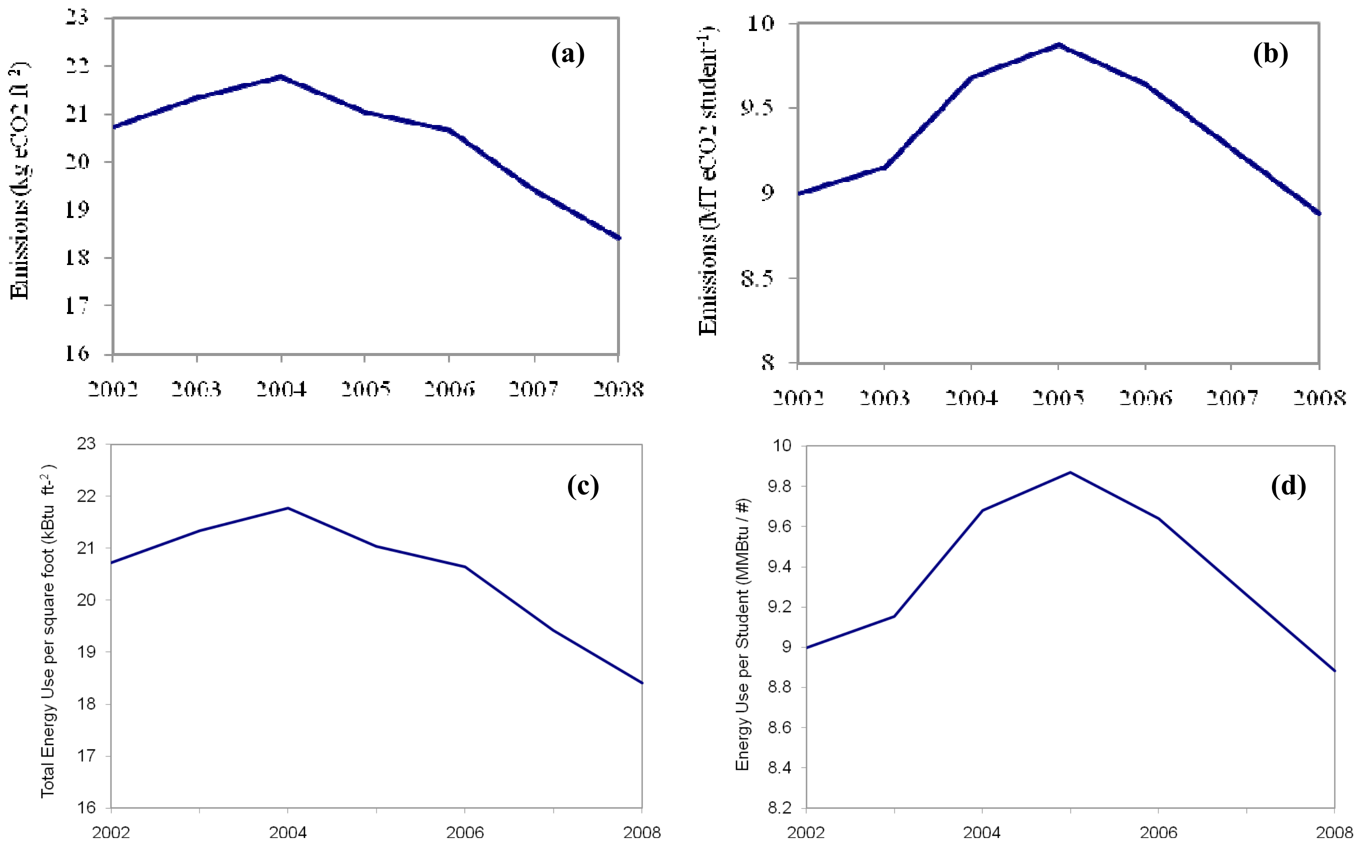

Figure 5. The data presented show annual emissions (eCO_2) (a) per square foot of building space (kBtu ft^{-2}), (b) per student and total energy use (c) per square foot (kBtu ft^{-2}), and (d) per student (MMBtu $student^{-1}$) between 2002 and 2008.

Using this study we would like to suggest developing our "Energy Policy" further by setting targets for energy use and emissions. These should be based on reasonable projections of energy use and emissions production. Our primary reasoning for this suggestion arises from the fact that the campus energy budget has increased by 50%, at a cost of $770k, between 2000 and 2009. In that same time we have increased the student population by 8% and physical size (square feet) by 38%. While the data do reveal encouraging trends in increased efficiency (Figure 5) there appears to be a mismatch in these growth rates. In the future, detailed analyses may reveal where we may most easily make up the disparity. It seems wise to begin by considering electricity and gas use as these comprise the vast majority of campus energy use.

Conclusions

We have compiled a vast data set (with significant assistance) that may serve as a solid baseline. This may be particularly useful in evaluating efforts for increased efficiency and/or energy use reductions so as to decrease costs and emissions. Furthermore, it is important to continue refining the current dataset. This may be achieved primarily through increasing the level of detail at which we can visualize campus energy demand. One suggestion we have proposed to the administration is to include an “energy” budget line next to Room and Board on student bills and offering students the option to purchase renewable energy offsets. Both options might serve to enlighten our campus community to the amount of energy used and the need for conservation.

While a primary objective of this study was to generate a baseline from which to compare future changes, it may also be used to make projections. The *Calculator* has the capacity to generate a number of scenarios based on changes in student population, physical size, and budget. It is highly customizable and may also be used to develop plans for increased efficiency, or meeting budget targets. In this respect this study may be expected to be ongoing.

Including the Ecosystem Science students in the data collection was an excellent, practical experience that honed their scientific reasoning and communication skills. It may also prove useful to other fields of study (engineering or business) or serve as the foundation on which to ask new questions. In the future Author 1 plans to expand this project by increasing the level of interactivity within the class by utilizing a blog. This would allow all students in class to share their step-by-step process with the class allowing for group discussion, editing, and critiquing. Last this would create a platform of data and protocols which later classes, faculty and administrators could utilize.

We hope that this study may be of assistance in generating ideas and strategies to reduce our energy costs based on different scenarios. Some of this work has already taken shape as a “Living in Green-ville” manual produced by Technical and Professional Communication majors, and as a project for our Thermodynamics course (taught by Author 2) for engineering majors[5]. This work may serve to distinguish our University as one which emphasizes the wise stewardship of both financial and natural resources. Furthermore, we expect that the work is an important part to substantiate our commitment to Creation care on our campus and in the lives of our students, faculty, and staff.

References

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5. R. Chasnov and M. Gathany, “Cutting Away from the Grid,” Proceedings of the ASEE Annual Conference 2011.