Greenhouse Gas Emissions at Smith College: A Comprehensive Inventory from 1990-2004 and Suggestions for Future Emissions Reductions

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Abstract

Anthropogenic emissions of greenhouse gases are known to be causing an increase in atmospheric greenhouse gas concentrations well above natural levels. This drastic increase may be causing global warming that is resulting in worldwide climate change. As part of an agreement with Clean Air-Cool Planet, whose mission is to address the issue of global warming, Smith College conducted a greenhouse gas emissions inventory. In 2004, Smith College emitted 33,025 metric tonnes of carbon dioxide equivalents, an 11% increase in emissions since 1990. 59% of 2004 emissions were due to stationary sources (burning oil and natural gas to produce steam for heat and domestic hot water). Thirty-one percent of 2004 emissions were a result of electricity production, purchased from Mass Electric. The remaining 10% of 2004 emissions was due to transportation (the college fleet and daily commutes to the college), agriculture (horses in the college stables and fertilizer application) and refrigerant gases. While formulating policies to reduce emissions, Smith College has focused on the sectors that produce the most emissions: stationary sources and electricity. Some options that would reduce the college's emissions include: turn building heat down from 70ºF to 68ºF, repair or replace old heating and insulation systems, install a co-generation plant that burns natural gas, diesel and biodiesel, and implement policies that encourage energy conservation, such as turning appliances off when leaving a room for any period of time.

Introduction

In 2003, Smith College signed an agreement with Clean Air-Cool Planet to promote greenhouse gas emissions reductions at Smith College. Smith College received Clean Air-Cool Planet's eCalculator v. 4.0, and obtained funding to hire a student intern to locate the necessary energy use data and enter these data into the eCalculator. Elizabeth Thomas was hired in November 2004 as the Smith College Greenhouse Gas Emissions Inventory Intern. Since being hired to this position, she has been locating energy use data and using the eCalculator to determine Smith College's greenhouse gas emissions for each year from 1990 to 2004.

Important terms needed to understand a greenhouse gas emissions inventory:

1. **eCO_2** stands for carbon dioxide equivalents, which is a universal standard of measurement for the impacts caused by releasing greenhouse gases. eCO_2 is calculated using the global warming potential (GWP) of each greenhouse gas. The GWP of CO_2 is arbitrarily set at 1. Because methane (CH_4) traps 23 times more heat than CO_2, its GWP is 23. Therefore, if Smith College releases 1 kg of CO_2 and 1kg of CH_4, 24kg eCO_2 are released.
2. **one metric tonne** is 1000 kilograms or 2200 pounds. **One metric tonne of CO_2** is enough CO_2 to fill $509m^3$, or a cube approximately 8m on each side, with **pure** CO_2.
3. **Btu** is an abbreviation for the British thermal unit. One Btu is the amount of heat needed to raise one pound of water one degree Fahrenheit. **MMBtu** = one million Btu.

Methods

A plethora of information was needed to calculate Smith College's greenhouse gas emissions. To obtain this information, many people within the Smith community and from the City of Northampton were contacted. Institutional numbers (e.g., number of students per year, operating budget, etc.) were provided by people in several different departments throughout campus. These individuals and organizations are all named in my acknowledgements section.

Sources for greenhouse gas emissions (along with the gas emitted) included:

- electricity in kWh purchased per year (CO_2, CH_4, N_2O),
- #2 and #6 oil in gallons and natural gas in MMBtu combusted to produce steam and hot water (CO_2, CH_4, N_2O)
- diesel and gasoline in gallons used by the university fleet per year (CO_2, CH_4, N_2O),
- solid waste in tons disposed of in the Northampton landfill per year (CH_4),
- fertilizer in kilograms purchased and applied to the campus lawns per year (N_2O),
- refrigerant gases in pounds replaced in refrigerator units on campus each year (CFCs and other gases) and
- number of horses in the Smith College stables per year (CH_4).

Data on the number of faculty, staff and students who commute to Smith per week were estimated based on a survey conducted in 2002 by the Smith College Office for Institutional Research. Institutional information (number of students, faculty and staff, square foot of building space, operating and energy budget, etc.) was also obtained in the course of this inventory. Once obtained, energy use data were entered into the eCalculator spreadsheet.

There are many missing data points, especially for the earlier years of this study. Because of the vast amount of data needed for this inventory, and the amount of time it took to gather each data set, it was not possible to address all of these gaps. Furthermore, some of these data were not obtainable (e.g., 2002-2004 are the only years for which there are receipts for refrigerant gas replacement). If several years' worth of data were missing, the last year of information was extrapolated back to the previous years.

The eCalculator v. 4.0, provided to Smith College by Clean Air-Cool Planet, is a Microsoft Excel™ program that calculates greenhouse gas emissions based on the College's energy use data entered into a spreadsheet and emissions conversions factors obtained from the United States Environmental Protection Agency (Table 1). For example, the college burned 1,488,092 gallons of #6 oil in 2004. Each gallon of #6 oil released 11.7kg of CO_2. 1,488,092 gallons x 11.7kg/gallon = 17,410,676kg of CO_2 released due to the combustion of #6 oil in 2004. Output from the eCalculator included information on the energy use in MMBtu and emissions released in metric tonnes of CO_2, CH_4, N_2O and eCO_2 during each year inventoried.

Table 1: Conversion factors obtained from the EPA and provided by Clean Air-Cool Planet on the eCalculator.

Emissions source	**EPA Conversion Factors**
#2 oil	9.99kg CO_2/gallon
#6 oil	11.7kg CO_2/gallon
Natural Gas	53kg CO_2/MMBtu
Electricity (New England Grid)	0.408kg CO_2/kWh
Gasoline	8.81kg CO_2/gallon
Diesel	9.99kg CO_2/gallon

Results and Discussion

Smith College's greenhouse gas emissions have increased from 29,741 metric tonnes of CO_2 in 1990 to 33,025 metric tonnes of CO_2 in 2004, an increase of 11% (Figure 1). When emissions are enumerated by sector, it is evident that stationary sources contribute the most greenhouse gas emissions (57% in 1990 and 59% in 2004; Figure 2). Emissions due to stationary sources have also increased the most since 1990 (Figure 1). Emissions due to electricity account for 31% of total emissions. The remaining 10% of emissions is derived from transportation, agriculture, solid waste disposal and refrigerant chemicals (Figure 1).

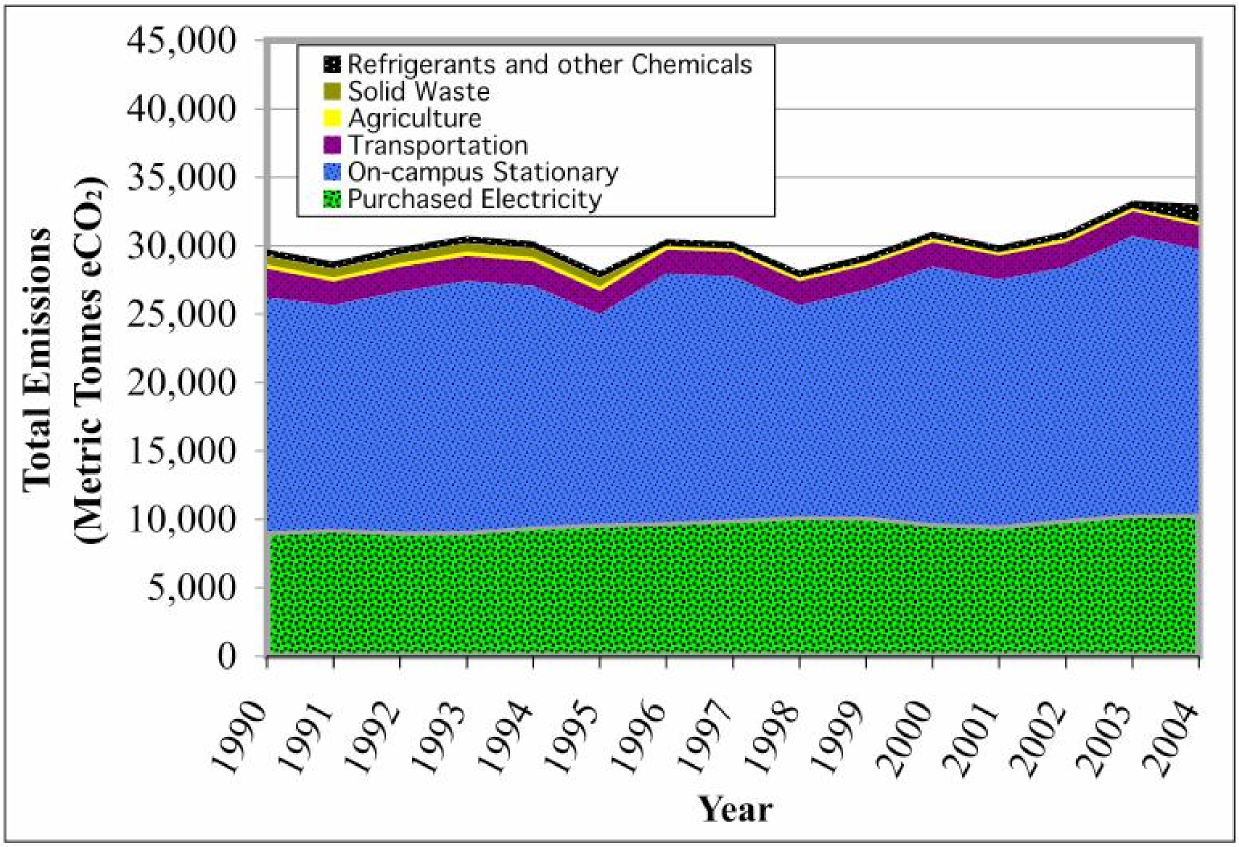

Figure 1: Emissions of carbon dioxide equivalents (eCO_2) per year at Smith College. Emissions are shown per sector. Agriculture accounts for so few emissions that this sector does not appear on the chart. After 1996, methane was recovered and flared at the Northampton Landfill, causing the disappearance of emissions due to solid waste disposal.

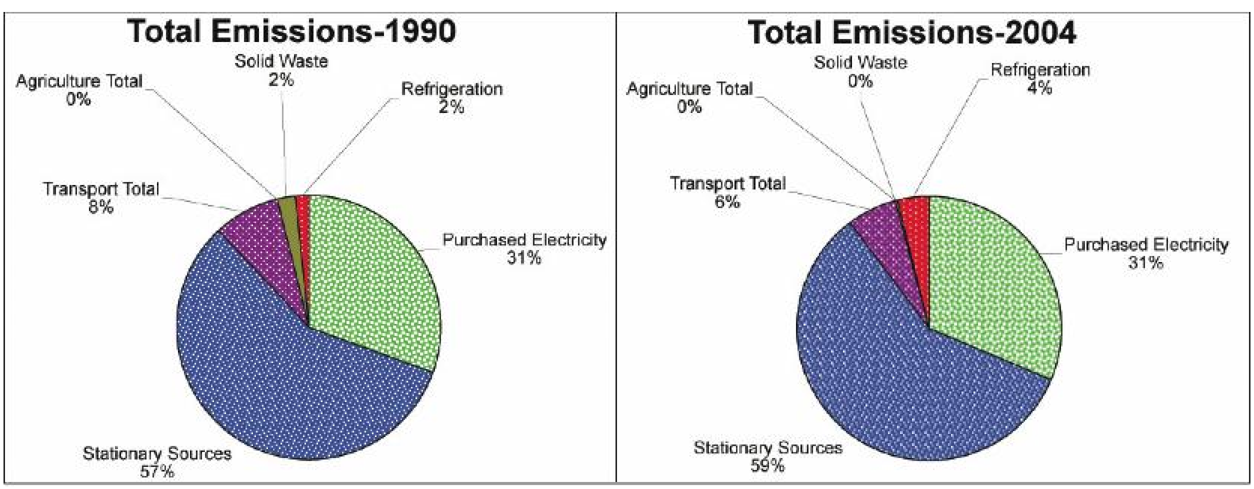

Figure 2: Emissions for 1990 and 2004 by sector. Percentage contribution by sector to total emissions is shown. Agriculture accounts for <1% of emissions. Solid waste accounts for zero emissions in 2004

because all methane is recovered and flared at the Northampton Landfill. This recovered methane will be used by the city of Northampton and Ameresco, an energy services company, to generate electricity beginning in 2005.

Causes for the increase in greenhouse gas emissions: Demand

The slight increase in emissions due to electricity (Figure 1) may be due to the increased use of technology on campus. There are many more computers used in labs, offices and in student rooms in 2004 than there were in 1990 (A. Rhodes, personal communication, 2005). The increase in emissions due to electricity use, however, is slight when compared to emissions due to stationary sources, which accounts for a much higher percentage of Smith College's emissions.

To explore why stationary source emissions have been increasing since 1990, the total number of emissions per year was divided by several different factors that may cause an increase in demand for energy on campus: number of students, total number of community members (faculty, staff and students) and total square foot of building space. Both the number of students on campus and the total number of community members has remained relatively constant since 1990, fluctuating by less than 100 people. Therefore, metric tonnes of carbon dioxide equivalents released per person at Smith College have increased 18% since 1990 (Figure 3). Despite the increase in square foot of building space on campus, caused by the construction of several large buildings in the past few years (Hillyer Hall, the Lyman Plant House and the Campus Center), the emissions per square foot of building space has also increased. Since greater numbers of people on campus and more building space to heat don't fully explain the increase in emissions, other factors that would cause a demand for more steam and hot water were explored.

Table 2: MMBtu released by combustion of fuels for steam and hot water production on campus.

Year	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004
#2 oil										270	1253	1022	949	3575	7482
#6 oil	122045	108750	136839	187553	169676	132657	185319	173536	119284	151741	201955	209262	218752	228987	223213
NG (main plant)	140978	147607	127474	66299	79590	91601	67327	77338	112630	86671	51496	26840	21258	39094	24260
NG (other)										33	62	64	62	141	130
Total	**263023**	**256357**	**264313**	**253852**	**249266**	**224258**	**252646**	**250874**	**231914**	**238715**	**254766**	**237188**	**241020**	**271797**	**255084**

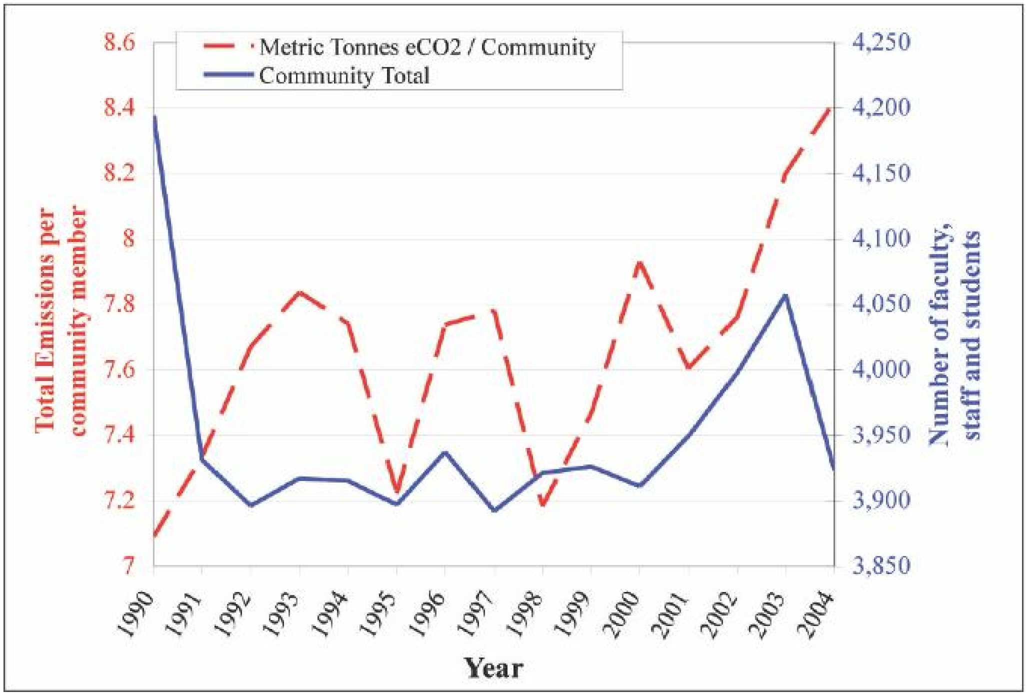

Figure 3: Emissions per person at Smith College have increased slightly since 1990.

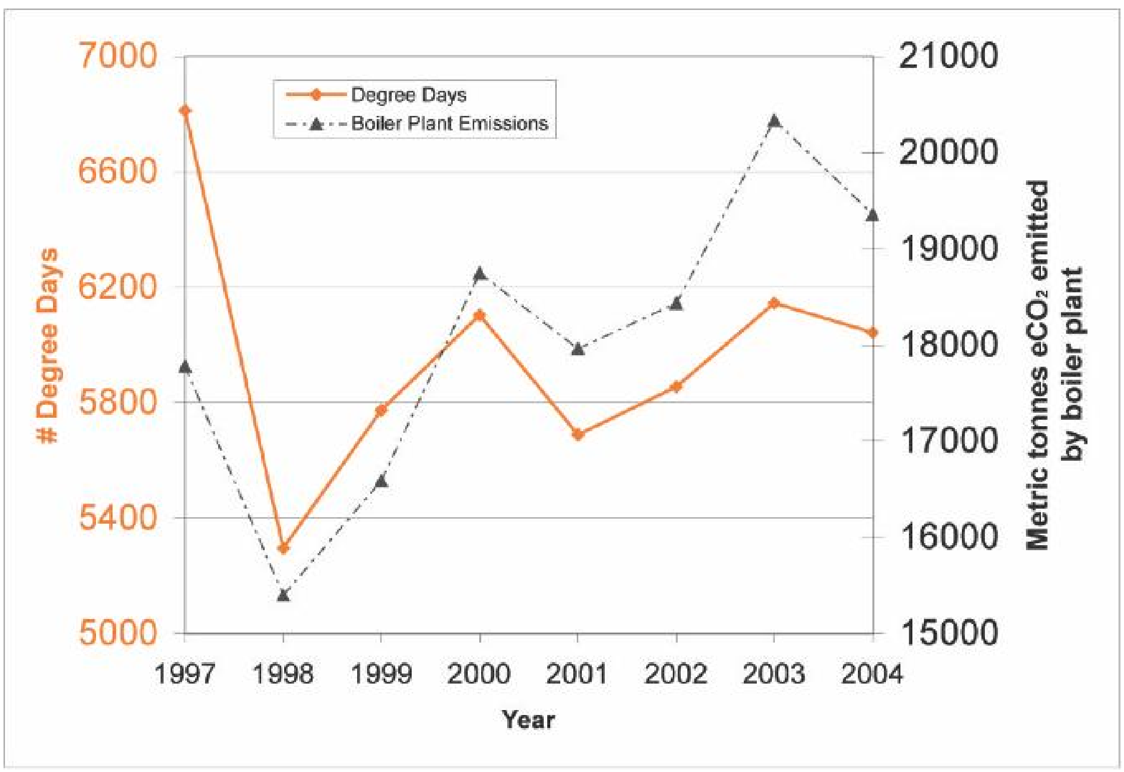

Figure 4: Emissions from Smith College's boiler plant plotted with heating degree days. Heating degree days are a measure of how cold the outside temperature is: a colder year has more heating degree days.

Here, a strong correlation is seen between the number of heating degree days and boiler plant emissions per year. Fluctuations in the number of heating degree days per year are therefore the cause for the observed fluctuations in greenhouse gas emissions.

Heating degree days are a measure of the amount of heat needed to be produced to maintain a comfortable living temperature in Smith buildings. A colder year will have more heating degree days than a warm year. Emissions from stationary sources show a strong correlation to the number of heating degree days per year (Figure 4). Heating degree days are therefore a major cause for the observed fluctuations in Smith College's annual greenhouse gas emissions.

The boilers that Smith College is currently using were installed in 1972 (Boilers #4 and #5) and 1947 (Boilers #1-#3; F. Raymond, personal communication, 2005). Because these boilers are 32-58 years old, they are not as efficient as a modern boiler. Despite projects that have replaced heating systems and windows in buildings on campus, many buildings are poorly insulated and have old, inefficient heating systems. Complaints of overheated rooms and radiators that cannot be turned off are common. Students often resort to opening their windows, releasing heat to the outdoors, and putting a greater load on the boiler plant (various, personal communication, 2005). Students also complain of windows that they can't close completely, which results in a loss of heat and puts a greater load on the boiler plant. When used as a primary heat source, steam heat has a tendency to exceed the set temperature in any building, especially in the spring and fall. Finally, steam heat is difficult to control and has a significant distribution loss as the steam is brought from the boiler plant to all parts of campus (G. Hartwell, personal communication, 2005).

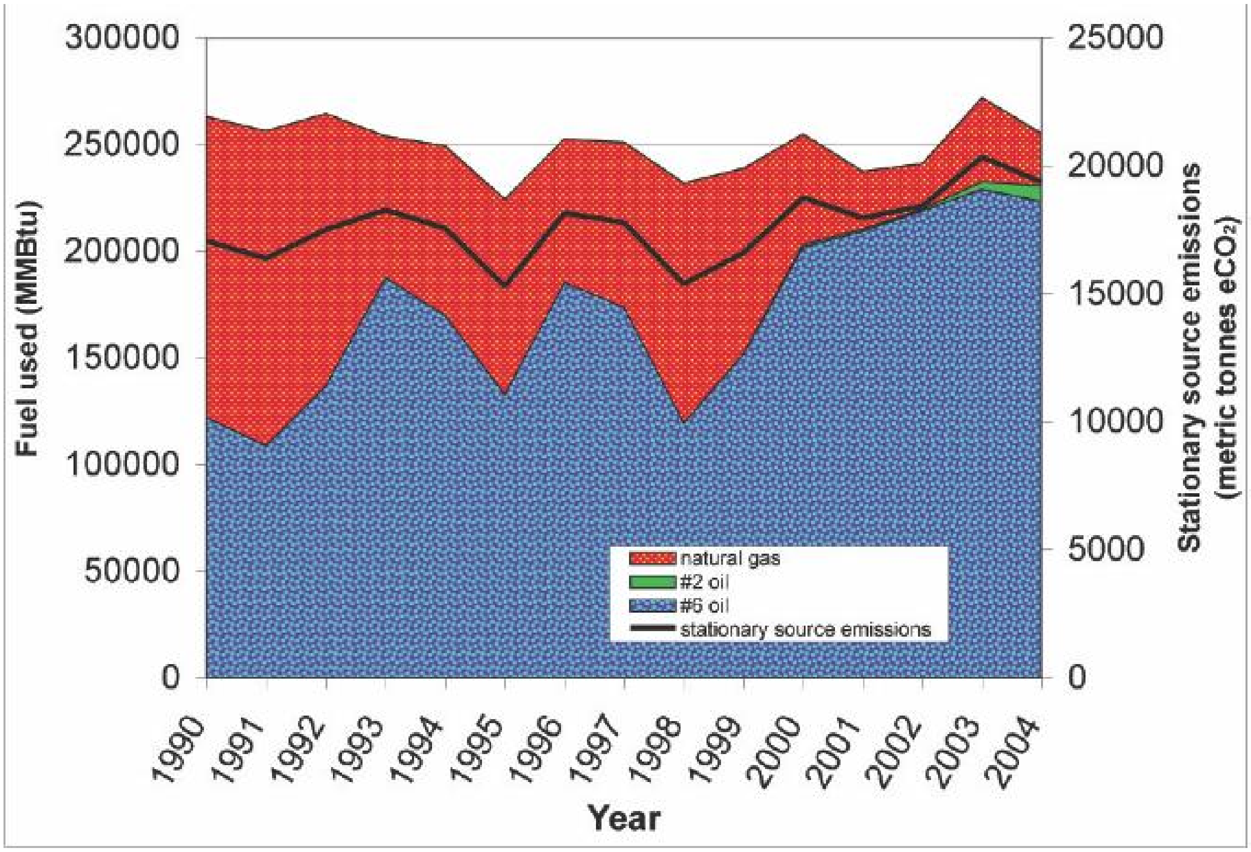

Figure 5: Stationary source emissions plotted with million Btu of fuel burned at Smith College's boiler plant per year. Stationary source emissions correlate well with gallons of #6 oil burned. Increased use of this fuel is thought to be the major cause for the observed overall fluctuations in emissions since 1990.

Causes for the increase in greenhouse gas emissions: Fuel use

Three different types of fuel are used to create steam and hot water at Smith College. In 1990, 54% of fuel used to heat was natural gas and 46% was #6 oil. In 2004, 40% of fuel used to heat was natural gas, 58% was #6 oil and 2% was #2 oil (Table 2; Figure 5). Greenhouse gas emissions are different for each of these types of fuels (Table 1). Natural gas is the cleanest, releasing 3.52×10^{-10}kg CO_2 per gallon equivalent burned. #6 oil is by far the dirtiest, releasing 11.7kg CO_2 per gallon burned. #6 oil therefore releases 100,000,000,000 (one hundred billion) times more CO_2 per Btu than natural gas. The gallons of #6 oil burned correlates well with stationary source emissions (Figure 5). Therefore, #6 oil is a major cause for the observed fluctuations and steady increase in Smith College's greenhouse gas emissions since 1990.

Suggestions for Emissions Reductions

Because on campus stationary sources produce 59% of Smith College's greenhouse gas emissions, the college is concentrating on reducing emissions within this sector. Electricity produces 31% of Smith College's emissions, and is also being considered when formulating plans for emissions reductions.

Methods of reducing stationary source emissions

A simple way to immediately reduce emissions with no cost would be to turn the heat in buildings down from 70ºF to 68ºF. This has been done in the past, during the energy crisis in the 1970s (F. Raymond, personal communication, 2005). In an effort to become carbon neutral (i.e., have zero net emissions) Middlebury College has proposed turning its heat down, estimating that this will result in a 2% decrease in total emissions per year (Hanley, et al., 2003).

Another option is to install a co-generation system in the boiler plant. A co-generation plant would burn natural gas and diesel, which both release fewer emissions than #6 oil. These fuels would power a turbine that drives electric generators. The exhaust gases from the turbine will produce steam to heat campus buildings. The same amount of fuel would therefore be used to create two types of energy, thus reducing Smith College's overall emissions. A co-generation plant can also burn biodiesel, which would drastically reduce Smith College's emissions. While this option is initially expensive, the college would not have to purchase as much electricity each year, and a new boiler would be more efficient and burn less fuel than the current boilers. It is estimated that a co-generation plant will have a 5 to 7 year payback period.

A third option to decrease emissions would be to continue to repair the old heating systems, add insulation and repair or replace windows in buildings around campus. Some repairs are probably relatively simple (e.g., replace malfunctioning valves in radiators and add weather stripping and attic insulation in buildings). Repairing existing systems in buildings would save money and reduce emissions in the short term at relatively low cost. The load on the boiler plant will decrease, and therefore the college will have to purchase less fuel. The savings from such repair projects could be used to fund larger whole system replacement projects (e.g., entire replacement of windows, insulation and building heating systems) which are more costly. Students, faculty and staff will be more comfortable in rooms where they can control the ambient temperature and Smith College will be saving money while reducing emissions.

Methods of reducing electricity emissions

Simple options that would reduce emissions immediately at no cost include: 1. programming computers to switch to sleep mode when not in use, instead of going to screen saver, 2. requesting that faculty, staff and students turn lights off when leaving a room (as well as other appliances, including TVs, radios, and transformers for computers and cell phones, which use electricity even if the computer or cell phone is not on) and 3. instituting a "cold turkey Thanksgiving" and other academic holidays, during which students turn off all appliances, including clocks and refrigerators. All of these options would not cost anything up front, except for the funding needed to create awareness within the campus community about these initiatives. Furthermore, these options will save money while reducing greenhouse gas emissions.

Installing a co-generation plant will result in a 67% decrease in the amount of electricity purchased from Mass Electric (T. Holland, personal communication, 2005).

The proposal by the student group, Clean Energy for Smith, to purchase renewable energy, is an effective option for reducing the college's emissions. This is, however, an expensive option because renewable electricity certificates are purchased from Mass Electric at a premium. Smith College could use money saved by the aforementioned emissions reductions efforts to purchase these renewable electricity certificates.

Suggestions for Future Inventories

The data required for a greenhouse gas emissions inventory were difficult to obtain because they were not located in a single database. Because Smith College is committed to reducing greenhouse gas emissions and will likely be implementing changes that will reduce the college's emissions, future emissions inventories will help to gauge whether these reductions efforts are successful. To facilitate future greenhouse gas emissions inventories the college should establish a database in which all of the necessary energy use data are entered annually. It would be helpful to have a single person administering this database to be sure that all of the data are entered correctly each year. Middlebury College, has established two positions, the Director of Environmental Affairs and the Sustainability Coordinator, that are charged with the responsibility of promoting sustainability and facilitating sustainable efforts on campus. Having such a position at Smith College would facilitate the maintenance of an emissions database to track how well the college is reducing emissions. A Sustainability Coordinator would also facilitate communication between committees, departments and student groups to help coordinate efforts to obtain and maintain a sustainable campus.

Conclusions

Smith College produced 33,025 metric tonnes eCO_2 in 2004. Given that anthropogenic greenhouse gas emissions are causing an increase in the atmospheric concentration of greenhouse gases well above the natural background levels, and that this increase may be causing the detrimental climate changes that are visible around the world, there is a compelling need to reduce emissions. Smith College was established by Sophia Smith to be a "perennial blessing to the country and the world" (Smith, S., Smith College website, 2005). Smith College therefore has a responsibility to reduce greenhouse gas emissions, as well as use these emissions reductions efforts as a powerful teaching tool for the world's future politicians, teachers, doctors, lawyers, scientists and mothers.

This greenhouse gas emissions inventory provides information to help Smith College focus emissions reduction efforts. On campus stationary sources produce 59%, while electricity produces 31% of Smith College's greenhouse gas emissions. The college should focus emissions reductions efforts on these sectors before moving to other sectors, such as transportation, commuting, fertilizer application and refrigerant gases. This study also suggests that the amount of #6 oil used for heating has a strong influence on the annual emissions. Smith College should therefore consider using alternative fuel options to reduce emissions. Finally, this inventory provides a baseline for future inventories, allowing the college to determine whether future emissions reductions efforts are effective.

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