Bucknell University
Greenhouse Gas Emissions Inventory
FY 1990 – 2004

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Introduction

As climate change becomes a global concern, many states, towns, companies, and even colleges and universities are completing greenhouse gas emissions inventories to determine their contribution to the increased amount of greenhouse gases in the atmosphere. Since the industrial revolution, carbon dioxide concentration levels along with other greenhouse gases have increased in the atmosphere. This increase has led to a faster rate of global climate change than in previous centuries. Greenhouse gases are produced from a number of different sources. This inventory looked at Bucknell University's contribution to global greenhouse gas emissions by studying the emissions of different sources on campus. These include transportation, on-campus stationary sources, purchased energy, refrigerants, and solid waste. Bucknell does have some offsets from the purchase of wind power. Two small solar arrays (2.4 kwh and 3.2 kwh) are in the process of being built during fiscal year 2006-2007 which will help offset total emissions slightly.

This inventory is designed to provide Bucknell with a general idea of the amount of greenhouse gases the university produces each year (going back to 1990, a target date set by the Kyoto Protocol). The results can then be used to compare data with other universities and as a building block for ideas to decrease the amount of greenhouse gas emissions produced each year.

Methods

The inventory is a MS-Excel based software program designed by the University of New Hampshire and Clean Air – Cool Planet for use at universities and colleges around the United States. The version that was used is the most current version (v5.0) which is continually updated with new parameters by Clean Air – Cool Planet. The inventory follows parameters set by the Intergovernmental Panel on Climate Change for national level inventories and includes all the calculations needed to obtain total emissions. As set by the Kyoto Protocol, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) are the gases that are of greatest interest in this inventory (CA-CP nd). All gases are measured according to their global warming potential (the ratio of global warming from one unit mass of a greenhouse gas compared to one unit mass of CO_2 over a particular time period (Eby 2004)). The results are presented in Metric Tons of CO_2 equivalents ($MTeCO_2$) and broken into total emissions by each gas within each category. Most of the data collection process required email communication with different offices on campus (Facilities, Finance, and Registrar). The data received was entered into the spreadsheet and calculations of greenhouse gas emissions were automatically made. Once all the data was collected, an analysis of the results was completed with recommendations for reducing the amount of $MTeCO_2$ produced by researching projects other universities have completed to reduce the amount of $MTeCO_2$ produced.

Various offices on Bucknell University's campus helped with the collection of the data. Facilities supplied information on energy use, the campus fleet, recycling, refrigerants, and solid waste. Information on the number of students and faculty and staff were collected from the Registrar and Human Resources offices, respectively. Finance provided information on the university's operating budget, useful for comparing with other colleges and universities and with previous years. A survey was sent out to students and faculty/staff requesting information on commuting habits for the school year September 1, 2005 to May 15, 2006. Results were averaged before entered into the emissions calculator.

General Information on Climate Change

Climate change, defined by the United Nations Framework on Climate Change, is "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods." It is caused by a variation in the amount of radiation that is absorbed by the atmosphere and reradiated to earth. Solar radiation from the sun enters the atmosphere and is absorbed by earth. About 31% is immediately reflected back to space by Earth's surface, clouds, and atmosphere. The solar radiation that is absorbed warms the earth and is reflected into the atmosphere which then absorbs the infrared radiation and reflects it back to space. Earth balances the incoming energy by radiating (on average) the same amount of energy to space; the exact amount depends on the temperature on earth and the amount the surface absorbs (Houghton 2004, Houghton and Ding 2001).

"Any factor that alters the radiation received from the Sun or lost to space, or that alters the redistribution of energy within the atmosphere and between the atmosphere, land, and ocean can affect climate." Greenhouse gases are considered one of these factors. The reaction is referred to as the greenhouse effect. Since some greenhouse gases occur naturally there are two types of greenhouse effects: natural greenhouse effect and enhanced greenhouse effect (due to humans). Within the natural greenhouse effect, gases absorb and emit radiation in all directions including back down to earth and trap heat in the atmosphere. The enhanced greenhouse effect is used to explain the fact that increased concentrations of greenhose gases in the atmosphere allow for increased absorption and emissions of infrared radiation leading to less energy being emitted into space. In order to compensate, since equal amounts of energy entering and leaving the atmosphere are required to keep the temperature constant, the temperature of the Earth increases (Watson 2001, Houghton and Ding 2001).

Information on Greenhouse Gases

Greenhouse gases can occur naturally or are man-made. Water vapor, carbon dioxide, methane, and nitrous oxide comprise the natural gases while gases used for aerosols, are man-made. Those greenhouse gases that occur naturally are also produced by humans in large quantities. There are a couple gases that effect greenhouse gas emissions indirectly, including carbon monoxide and nitrogen oxides (NO and NO_2) (Houghton 2004, NEIC 2004).

Carbon dioxide is the largest greenhouse gas produced by humans accounting for 82% of all human-made greenhouse gas emissions. There are many sources: the burning of fossils fuels for electricity, vehicles, and heat for homes and businesses; flaring of natural gas and oil; the production of cements; deforestation by burning and clear cutting; plowing and disking by farmers; solid waste; and the burning of wood and wood products. The main source is fossil fuel burning which emits about 1.6 gigatons of carbon dioxide into the atmosphere. Transportation accounts for over 30% of fossil fuel related carbon dioxide emissions with two-thirds of these emissions coming from motor vehicles. Photosynthesis normally regulates carbon dioxide within the carbon cycle absorbing about 6.1 billion metric tons of anthropogenic carbon dioxide leaving 3.2 billion metric tons to be added to the atmosphere. In addition to photosynthesis, about half the carbon is taken up by the oceans. But with an increase in carbon dioxide in the ocean, oceanic circulation and composition change, which affects the ability of oceans to take up carbon dioxide (Dauncey and Mazza 2001, Drake 2000, NEIC 2004, Reay 2006).

Methane is more potent than carbon dioxide trapping about 21 times more heat per molecule even though it only accounts for about 9% of total emissions. It is produced by the breakdown of organic matter under anaerobic conditions. Sources include: landfills; the breakdown of animal waste in an anaerobic environment; the digestion of cows; escaping natural gas; coal mines and the production and transportation of coal; oil wells; sewage treatment plants; and biomass burning due to incomplete combustion. Methane is removed in the troposphere through a chemical reaction with hydroxide radicals, producing carbon dioxide (Dauncey and Mazza 2001, Drake 2000, NEIC 2004).

Nitrous oxide only accounts for 5% of total emissions but it traps 270 times more heat per molecule than carbon dioxide. It has many sources, including natural ones (soils and oceans), and other sources including: nitrogen based chemical fertilizers, transportation, nitric acid production, poor manure management, agricultural and industrial activities, combustion of solid waste and fossil fuels, and catalytic converters used in transportation. The main sink is the stratosphere where it is broken up by high energy, short-wave sunlight in a reaction with light and excited oxygen atoms, but nitrous oxides cannot enter the stratosphere because it is blocked by the troposphere.(Dauncey and Mazza 2001, Drake 2000, NEIC 2004).

Halocarbons are the only man-made greenhouse gas. Hydroflourocarbons and perflourocarbons are the most heat absorbent out of all the gases studied. Along with sulfurhexaflouride, they account for 2% of all greenhouse gas emissions. There are two sources for these gases: as by-products of industrial processes and by leakage. Lifetimes of hydrocarbons can range from 14 to 260 years, depending upon the exact one. A reaction with hydroxide molecules removes it from the atmosphere, but that leads to a competition between the hydroflourocarbons and methane for hydroxide molecules. Concentrations of hydroflourocarbons are rising because it replaced chloroflourocarbons when production was banned by the Montreal Protocol (NEIC 2004, Reay 2006).

Evidence for Global Warming

Since the industrial revolution (1850), some greenhouse gas levels have increased by 25%. As a result, since the late nineteenth century, average global temperatures have risen 0.6 +/- 0.2^0 Celsius with half of the rise occurring since 1970. Within the United States this temperature rise has varied: parts of Alaska, the coastal Northeast, the upper Midwest, and the southwest have an increase in temperature of 2^0 Celsius while the rest of the nation has a much lower rise. The magnitude of warming in the northern hemisphere that has occurred over the twentieth century is the largest of any century in the past 1,000 years. From 1995 to 2004, nine of those years were the warmest years on record and 1998 was the warmest year since 1861 which is when reliable records began being kept. Over the last four decades, global average surface temperature has increased at a rate of 0.15 +/- 0.05^0 Celsius per decade (Houghton and Ding 2001, National Assessment Synthesis Team 2000, NEIC 2004, Pittock 2005).

Precipitation has increased by 5 to 10% due mainly to an increase in frequency and intensity of heavy rainfall which continues to increase in most places. Rain is starting to replace snow in some areas as temperatures rise. During the twentieth century, precipitation has increased by 0.5 to 1% per decade over most mid-high latitudes in the northern hemisphere. In the second half of the twentieth century the mid-high latitudes in the northern hemisphere have seen an increase of 2 to 4% in heavy precipitation frequency. Other lines of evidence include a reduction by two weeks in the annual duration of lake and river ice cover in mid-high latitudes of the northern hemisphere during the twentieth century. Northern hemisphere sea ice extent has decreased by 10 to 15% in the spring and summer since the 1950s and has decreased by 40% in the late summer and early fall in recent decades. During the twentieth century, in non-polar regions, there has been a widespread retreat in mountain glaciers and since 1960, a 10% decrease in snow cover extent. There is evidence for permafrost melting in Alaska (National Assessment Synthesis Team 2000, Pittock 2005, Watson 2001.).

Another line of evidence is the rise in sea level. During the twentieth century sea levels rose 10 to 20 centimeters due to the melting of glaciers, long-term adjustments from the removal of major ice sheets (glacial rebound) and thermal expansion of the water. From 1950 to 2000, the rate of average global sea level rise was 1.8 to 1.9 +/- 0.2 millimeters per year. When observing the global average sea level rise from 6,000 years ago to the present, an increase in the rate of sea level rise can be seen. From 6,000 years ago to the present the rate of rise was 0.5 millimeters per year. From 3,000 years ago to the present the rate of change was 0.1 to 0.2 millimeters per year. During the twentieth century the rate increased to 1 to 2 millimeters per year. There is a large difference in comparing the overall rate for the past 6,000 years and the last century (Houghton 2000, Houghton and Ding 2001, Pittock 2005).

Expected Climate Change

The Intergovernmental Panel on Climate Change (IPCC) scenarios project global greenhouse gas emissions will grow by 39 to 89% by 2025 and 63 to 235% by 2050. With the increase greenhouse gas concentrations within the atmosphere, the climate will continue to change in order to allow for the equilibrium of energy entering and leaving the atmosphere. Currently the second of two warming trends that have occurred during the 20^{th} century is taking place. The first was from 1910 to 1945 and the second one has been ongoing since 1976. By 2100 carbon dioxide concentrations are projected to reach 540 to 970 parts per million. Methane which is currently at 1,760 parts per billion is projected to change -190 to + 1,970 parts per billion over the same period. Nitrous oxide with current concentrations at 316 parts per billion is projected to change +38 to +144 parts per billion by 2100 (Baumert et al. 2005, Watson 2001.).

Global surface temperature is projected to be 1.4 to 5.8^0 Celsius warmer by 2100 compared to the baseline year 1990. There is a wide range of uncertainty due to the choice of scenarios and the uncertainty for given scenarios because of the incomplete understanding of sources and sinks of greenhouse gases, clouds, oceans, and polar ice sheets. The rate of warming that is projected to occur is at much faster rate than the average rate of warming at the end of the last glaciation. The projected rise, 5 to 6^0 Celsius, is very close to the normal temperature rise from the middle of an ice age to the warm period between ice ages (Houghton 2000, Pittock 2005).

An increase in greenhouse gases changes the temperature and leads to an increase in precipitation and a more intense hydrological cycle because of the increase in evaporation. Depending upon the scenario, global average precipitation (rain and snowfall) and evaporation is projected to increase 1 to 9% by 2100. The change will vary depending upon the region. In mid to high latitudes the annual precipitation is predicted to increase by 10%. With the increase in temperature, precipitation will fall as rain instead of snow affecting some river ecosystems that depend upon late spring snowmelt to sustain water levels. Many places will experience more frequent droughts and floods. By 2100 the IPCC expects sea level to rise 9 to 88 centimeters due to the thermal expansion of oceans and the melting of glaciers and ice caps. Sea level rise will not be consistent though because some regions are being uplifted due to plate movement (Drake 2000, Houghton 2000, National Assessment Synthesis Team 2000, Pittock 2005).

Effects on United States, Pennsylvania, locally

The Intergovernmental Panel on Climate Change lists many potential impacts for North America due to global warming in its report, *Synthesis of Climate Change 2001*. Potential impacts for cities are listed as fewer periods of extreme winter cold, an increase in the frequency of extreme heat, rising sea levels and the risk of storm surges, and changes in the timing, frequency, and severity of flooding associated with storms and precipitation extremes. The United States will gain in the early stages of global warming due to longer growing seasons, and the opportunity to grow more heat tolerant plants. This may be eventually negated by water supply problems and the spread of tropical pests and diseases. The warmer weather may also lead to increased heat stress in the summer. Climate change is hard on ecosystems; new ecosystems out compete the old because they can not adapt fast enough. Ecosystems are currently bearing other stresses and therefore will most likely be more vulnerable to climatic stress (National Assessment Synthesis Team 2000, Pittock 2005, Watson 2001).

The mid-Atlantic in particular will suffer from the impact of increased flooding and sea level rise. The temperature and rainfall change that is expected with global warming will take a toll on deciduous forests and migratory bird habitats. Warming will lead to a change in the mixture of trees within forests. Maple, beech, and birch forests will decrease and oak, hickory, and southern pine forests and mixed oak and pine forests will increase. If this change occurs faster than ecosystems can adapt it could lead to the fostering of invasive species and reduction of diversity. Bird populations could decrease with the abundance of young trees. For humans, increased temperature will lead to an increase in the risks for heat-related ailments and higher rainfalls and floods could increase the risk of water born diseases (Environmental Defense et al. 1999).

On a smaller scale, the northeast United States has one of the lowest rates of projected future warming compared to other regions in the United States. Climate change will decrease the number of some types of weather while it will increase others. Winter minimum temperatures will change the most. The projected increase is from 2 to 5^0 Celsius by 2100. As a result, winter snowfalls and periods of extreme cold will decrease. Rainfall over frozen ground or rapid snow melting events could possibly increase, leading to increased flooding. Other impacts include rising sea levels, increased ground level ozone pollution, and the impact of precipitation and evaporation changes on relatively non-flexible water supply systems (National Assessment Synthesis Team 2000).

Impacts in Pennsylvania are large. It is predicted that by 2100 temperatures in Pennsylvania will increase by approximately 4^0 Fahrenheit with a range of 2 to 9^0 Fahrenheit. Precipitation is expected to increase in all seasons: by about 10% in the spring, about 20% in the winter and summer and about 50% in the fall. The frequency of extremely hot days in the summer is expected to increase as well due to the increase in global average temperature. Ozone is also expected to increase exacerbating respiratory illnesses, reducing crop yields, and impairing ecosystem health. The range of disease baring insects could spread, bringing diseases like malaria and dengue fever to the state. Rivers are also affected by climate change. With an earlier spring snowmelt due to higher temperatures, river levels will be higher in the winter and spring and lower in the summer and fall. An increase in precipitation in the winter or summer could offset the losses, but at the same time could lead to increased flooding risks. Warmer climates could also be detrimental to crop yields pushing production patterns northward. A lack of soil moisture will result if precipitation decreases and irrigation techniques will have to be implemented leading to a decrease in water supplies for natural ecosystems and human uses. Crop yields are projected to change either very little or by as much as 39%. Unlike other areas of the United States, forested areas could change very little or decline by 15 to 20% in extent. The biggest change would be the composition of the forest and the dominating trees. (EPA 1997).

Sources of Greenhouse Gas Emissions at Bucknell University

Bucknell University has multiple sources for greenhouse gases. They include the following: energy (purchased electricity, on-campus stationary sources, and transportation), solid waste, refrigerants, and agriculture.

Purchased Electricity: Bucknell purchases about 5% of its electricity indirectly from PJM Interconnection and Community Energy through Citizen's Electric. Before the co-generation plant went online in 1997, Bucknell purchased the majority of its electricity needs. PJM Interconnection produces electricity using mainly coal and nuclear with less than 2% of the power coming from renewable resources. Starting in 2002, Bucknell has purchased 1,000,000 kWh of wind energy per year from Community Energy through Citizen's Electric. This is almost half of the total purchased electricity (Kassab 2006).

On-campus stationary sources: Prior to the year 1998, Bucknell used the coal plant on campus to produce steam and a small amount of electricity. In 1997, the co-generation plant was phased in producing 90-95% of the university's electricity needs and 100% of its steam using natural gas and #2 distillate oil (Figure 1). By switching from a coal fired plant to a co-generation plant efficiency increased from 60% to 75-80%. A gas boiler was used during the period of time between the coal plant and co-generation plant. There are also many miscellaneous boilers and furnaces on campus that produce steam using natural gas, propane, and #2 distillate oil (Kassab 2006).

Figure 1. The co-generation plant on Bucknell's campus. Produces the majority of electricity used at Bucknell. *C. Kassab*

University Fleet: The University owns approximately 144 vehicles (cars, mini buses, and on-campus vehicles) that use diesel and gasoline (Figure 2). There is one hybrid car within the fleet, a Toyota Prius (Kassab 2006).

Figure 2. Pictures of the University fleet including the vans and mini-buses. *C. Kassab*

Community Commuters: This category includes all faculty, staff, and students who drive to campus. The data is not included in the inventory because the inventory ends at fiscal year 2004 and the data collected for this category is for fiscal year 2005. It will play a part in future inventories to track commuting habits.

Solid Waste: Bucknell University transports solid waste generated on campus to the Lycoming County Landfill, which is the landfill for Columbia, Lycoming, Montour, Northumberland, Snyder, and Union counties. The landfill captures the landfill gas, produced by the decomposition of the garbage (comprised of 50% methane and 50% carbon dioxide), and flares 75% of it and uses the other 25% to produce electricity in its co-generation plant to sell back to the grid. This prevents landfill gas from reaching the atmosphere (LCRMS 2006).

Refrigerants: Refrigerants and other chemicals used for cooling purposes by Bucknell University include HFC-134a, HCFC-22, and CFC-12. Due to regulations set in the Montreal Protocol CFC-12 was phased out of use at the beginning of the 1990's and HFC-134a was phased in. Cooling purposes on campus include Dining Services refrigerators and freezers, air conditioning systems for buildings (chillers), and cold storage for laboratory needs (Kassab 2006).

Agriculture: Agriculture on Bucknell's campus consists of synthetic and organic fertilizer applied to the grounds. Synthetic fertilizers were used until 2003, after which organic fertilizer was used. Fertilizer releases nitrous oxide after being placed on the ground and the amount released depends upon the nitrogen content for each fertilizer. Fertilizer was not calculated into this inventory because the available data was very inconsistent and may have an impact on the results.

Results/Conclusions

During the fiscal year (FY) 2004, Bucknell University produced total emissions of 37,756 Metric Tons of carbon dioxide equivalents ($MTeCO_2$). Net emissions (after the offsets were added in) amounted to 37,090 $MTeCO_2$ (Figure 3). The offsets produced by the university that year equal 666 $MTeCO_2$. Prior 1997, total greenhouse gas emissions were greater than 60,000 MTeCO2. The difference from FY 1996 to FY 1997 is due to the phase in of the co-generation plant to replace the coal power plant as well as reducing the amount of electricity purchased. Greenhouse gas emissions have been fairly stable for the past eight years even though in the last three, one million kWh of wind power have been purchased to reduce total emissions by approximately 650 $MTeCO_2$.

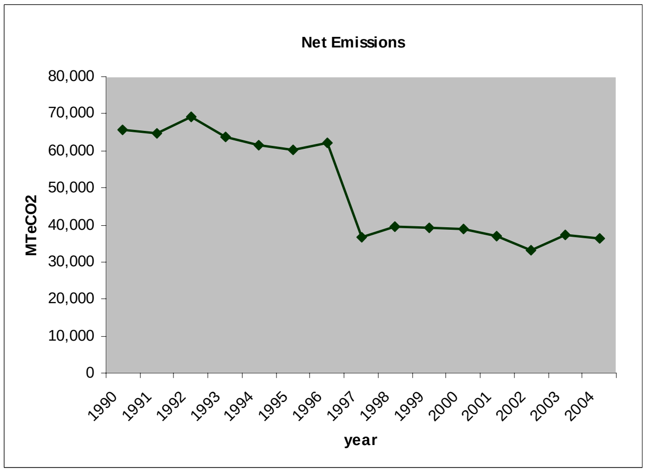

Figure 3. Graph of the net emissions, (total emissions plus offsets) in Metric Tons of carbon dioxide equivalents, produced by Bucknell University for fiscal years 1990 to 2004.

Purchased electricity: Purchased electricity accounted for about 3% of all emissions in FY 2004. This is a significant decrease from 23% of total emissions in FY 1990. Prior to 1998, the majority of electricity used on campus was purchased, with a significant drop in the amount purchased between FY 1998 and FY 1999. This is reflected in the amount of metric tons of carbon dioxide equivalents ($MTeCO_2$) produced by purchased electricity. In FY 1990, Bucknell purchased 24,549,000 kWh electricity which produced 14,913 $MTeCO_2$, and in FY 2004 purchased 1,542,194 kWh of electricity producing about 1,027 $MTeCO_2$ (Figure 4). The electricity is purchased from Citizen's Electric and is a grid-tied system meaning that Bucknell buys and sells on the grid. Citizen's Electric buys the majority of its electricity from PJM Interconnection, which is comprised of many companies within Pennsylvania, Maryland, and New Jersey. Most of the electricity is produced using coal followed by nuclear power. The fuel mix was determined by using information provided by PJM Interconnection for the years since 2000 so the 2000 data was extended back to 1990. This may lead to a difference in the amount of $MTeCO_2$ produced depending upon the actual breakdown of fuel sources. The breakdown of greenhouse gases emitted from FY 1990 to FY 2004 is as follows: in FY 1990 purchased electricity produced 60 kg of N_2O, 118 kg of CH_4, and 14,892,184 kg CO_2 and in FY 2004 it produced 4 kg N_2O, 8 kg CH_4, and 1,025,595 kg CO_2. In addition to purchasing electricity from sources that produce greenhouse gases, Bucknell has purchased 1,000,000 kWh of wind energy since 2002. The total number of kWh included this number so it was subtracted out before the data was entered into the calculator. The wind energy is purchased from Community Energy, which has set up wind farms in Pennsylvania, who provides the electricity to PJM Interconnection grid and Bucknell pays them for the contracted amount of power. Wind energy acts as an offset to the amount of greenhouse gases produced, essentially lowering our impact on the environment because it is a renewable resource that does not produce emissions as it produces electricity.

The amount of electricity purchased increased until it dropped significantly with the addition of the co-generation plant on campus. This is most likely due to an increase in the use of electricity since the only buildings built on campus were Rooke Chemistry and the Biology Building in 1990-1991 and the renovation of several buildings including Olin Science, the Botany Building, Animal Behavior Lab, and Taylor Hall. Since the addition of the co-generation plant purchased electricity for the most part has been decreasing except for an increase between

FY 2002 and FY 2003. This jump could be due to construction on campus, although it decreased the following year so this might not be the only explanation to the one year increase. Bucknell also sells electricity back to the grid if there is a surplus. At this time Clean Air-Cool Planet has not devised a way to account for the offsets produced from selling electricity back to the grid. If this were added into the offsets, it would have a small affect on the total greenhouse gases produced per year.

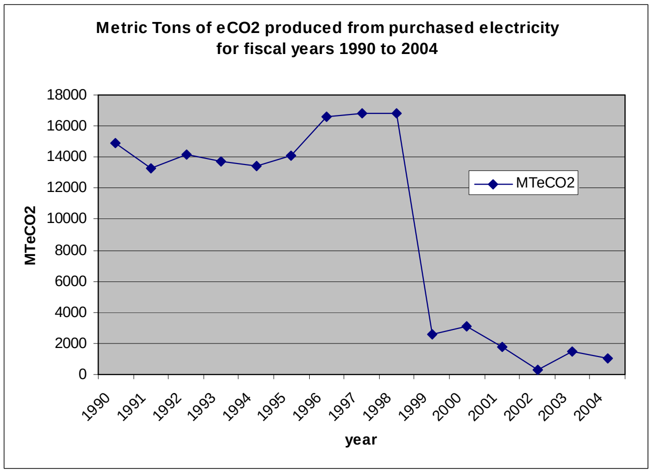

Figure 4. Graph of emissions (in Metric Tons of Carbon dioxide equivalent) produced from electricity purchased by Bucknell University for fiscal years 1990 to 2004.

On-campus stationary sources: On campus stationary sources include both the miscellaneous boilers and furnaces and the co-generation plant. In FY 1990, the main on-campus stationary source was the coal power plant accounting for about 56% of total emissions. In FY 1997 to FY 1998, the coal power plant was replaced with a co-generation plant which accounted for about 84% of all emissions in FY 2004. Other stationary sources (miscellaneous boilers and furnaces) account for about 2% of total emissions in FY 2004. All electricity produced on campus is used by the campus and the extra is sold back to the local utility company to be used by people in the Lewisburg community. The increase in purchased electricity between FY 1996 and FY 1999 is a result of the need to purchase more electricity during the construction of the co-generation plant. The sharp decline that follows is the result of the addition of the co-generation plant and a decrease in the need to purchase electricity.

The miscellaneous boilers and furnaces are powered by the exhaust gases of the co-generation plant and natural gas and #2 distillate oil. Steam is produced and passed through the steam turbine driven electric generator before it is passed through campus producing more electricity. The coal power plant provided some electricity to the campus prior to the installation of the co-generation plant. The miscellaneous boilers and furnaces also produced steam during this time but there is no fuel data until FY 1998. In FY 1990 the amount of coal used by the plant was 18,256.7 short tons and the amount increased each year until it dropped in FY 1997 to 6,625 short tons as the co-generation plant was phased in. This amounted to about 37,110 $MTeCO_2$ in FY 1990 and 13,083 $MTeCO_2$ in FY 1997. The large drop in emissions in FY 1997 reflects the coal power plant being phased out as the co-generation plant was being built (Figure 5). At this time the coal power plant was still producing a small amount of electricity and the co-generation was being phased in. The sharp rise that follows is the result of the switch to the co-generation plant.

Results can also be broken down into individual greenhouse gases produced by the co-generation plant and on-campus stationary sources. Total N_2O emissions were 571 kg in FY 1990 and 74 kg in FY 2004. Out of this, non co-generation sources accounted for all emissions in FY 1990 (the coal power plant) and 11 kg of total sources in FY 2004 (the miscellaneous boilers and furnaces). When the co-generation plant was phased in during FY 1997, N_2O emissions were 6 kg and increased to 63 kg in FY 2004. There is no steady increase in emissions, it jumps around, but there is a large increase in FY 2000 for an unknown reason. Total CH_4 emissions in FY 1990 were 4,079 kg and in FY 2004 3,298 kg, also breaking down into non co-generation and co-generation sources. In FY 1990 non co-generation sources produced all of the CH_4 emissions and in FY 2004 produced 143 kg with the decrease occurring in the time span between FY 1997 and FY 1999 when the coal power plant was placed offline and the only non co-generation sources were the miscellaneous boilers and furnaces. The co-generation plant produced 290 kg of CH_4 in FY 1997 when it was phased in and increased the first three years to 3,154 kg by FY 2004.

Carbon dioxide is the greenhouse gas that is produced in the largest amounts at Bucknell. Total amounts of CO_2 produced in FY 1990 were 36,846,959 kg and decreased slightly to 32,202,205 kg in FY 2004. Non co-generation sources produced all of the CO_2 emissions in FY 1990 and 608,822 kg in FY 2004. Again, the drop occurred during FY 1997 to FY 1999 when the coal power plant was placed offline and the co-generation plant was phased in. The co-generation plant accounted for 2,903,579 kg CO_2 in FY 1997 when it was phased in and increased the first three years as the co-generation plant produced more of the electricity on campus and eventually reached 31,593,383 kg CO_2 in FY 2004. In terms of $MTeCO_2$, total emissions were 37,110 $MTeCO_2$ in FY 1990 and 32,300 $MTeCO_2$ in FY 2004 (Figure 5). The addition of the co-generation plant influenced the amount of total emissions, but in order to see the difference, total emissions has to be broken into non co-generation emissions and co-generation emissions. In FY 1990 non co-generation emissions totaled 37,110 $MTeCO_2$ and in FY 2004 totaled 615 $MTeCO_2$ due to the removal of the coal power plant and the fact that the miscellaneous boilers and furnaces do not produce nearly as much energy as the co-generation plant does. The co-generation plant produced 2,912 $MTeCO_2$ in FY 1997 when it was first being phased in. This amount increased for the first three years and then held steady at 31,685 $MTeCO_2$ in FY 2004.

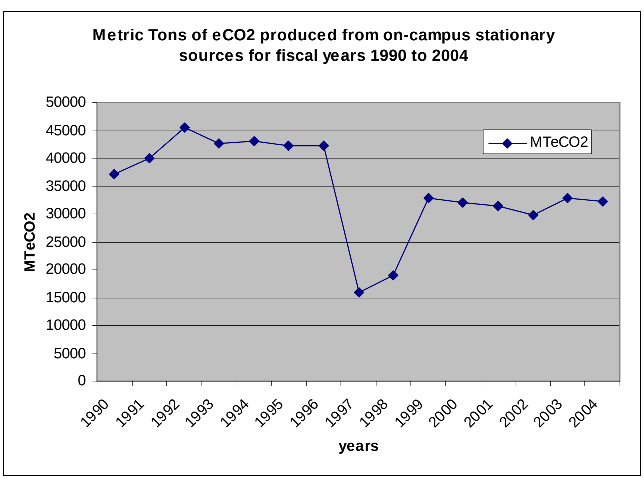

Figure 5. Graph of emissions (in Metric Tons of Carbon dioxide equivalents) produced from on-campus stationary sources at Bucknell University for fiscal years 1990 to 2004.

Transportation: Transportation comes from two sources, the university fleet which consists of 144 vehicles (one of which is a hybrid) and commuters. Commuters were not included in the overall emissions because the survey sent by email was only calculated for the academic year September 1, 2005 to May 15, 2006. Questions in the survey were used to calculate the percentage of people who drove to campus, the distance of the commute and whether or not one carpooled. The survey was sent to every student and faculty and staff who receives campus emails. Response to the survey was better for faculty and staff than students. Out of 986 faculty and staff, there were only 214 responses and out of approximately 2,700 students (excluding the graduating class since the survey was sent out over the summer); there were only 149 responses of which only 87 could be used. The data was extrapolated to cover all students and faculty and staff.

Over 50% of the faculty and staff surveyed live within 5 miles of campus, but most people drive even those living within 3 miles of campus (Figure 6a). Only those that live less than one mile from campus walk or bike more than drive to campus (Figure 6b). Most faculty and staff drive alone to campus versus carpool. Those that do carpool seem to live within 15 miles of campus with the majority living between six to ten miles from campus (Figure 7). With the results that were gathered from this survey it was calculated that 85% of faculty and 88% of staff drive; 84% of faculty and 86% of staff drive alone; and 16% of faculty and 4% of staff carpool. In order to figure out total gas used during these trips, it was assumed that each faculty and staff member made two trips per day, to and from campus. To calculate the number of days per year that faculty commuted, the mean number of days driven to campus was multiplied by 43 weeks (an estimated number). The result was that each faculty member drives about 185 days per year. To calculate the number of days per year that staff commuted, the mean number of days driven to campus was multiplied by 48 weeks (an estimated number). The result was that each staff member drives about 208 days per year. Each trip was about 8 miles for faculty and 12 miles for staff, calculated by taking the mean distance from one's home to campus of those that drive more than ride bike or walk. Total distance traveled during FY 2005-2006 for both faculty and staff was 3,357,281 miles consuming about 151,913 gallons of gasoline (using a fuel efficiency of 22.1 gallons per mile). Faculty and staff produced 91 kg N_20, 265 kg CH_4, and 1,324,230 kg CO_2 in FY 2005, totaling 1,357 $MTeCO_2$ in FY 2005.

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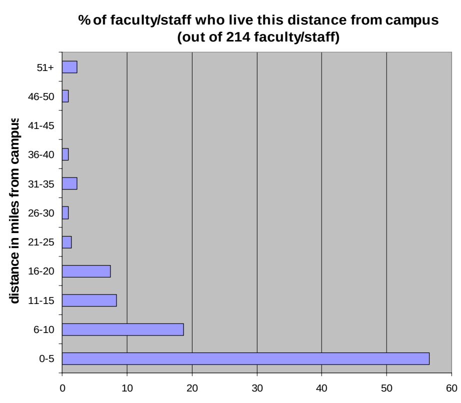

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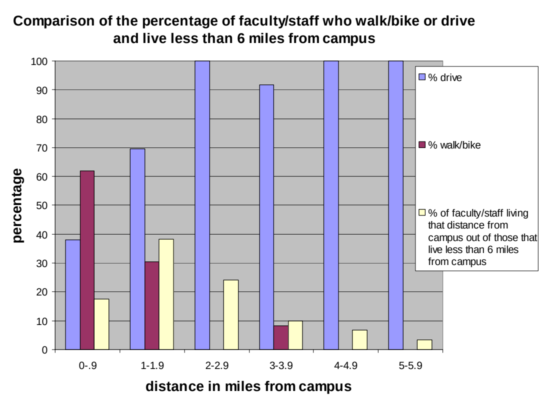

Figure 6. A. The breakdown in distance faculty and staff live from campus. B. Looking at faculty and staff living within 6 miles of campus and the breakdown of how they commute to campus.

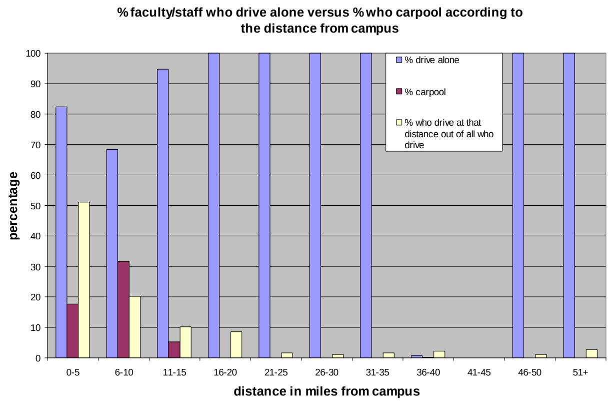

Figure 7. The breakdown of how faculty and staff commute at each distance.

Some students use their car to get around campus (visual analysis) even though the campus has been designed to reduce this by placing parking lots on the outskirts of campus. Response to the student survey was very low so this data may be skewed. Out of those that did drive around campus, the total distance driven per week was less than 5 miles (Figure 8). From the survey it was calculated that about 69% of students commute in some way to campus, whether is be from the Lewisburg community, downtown, Bucknell West, or just from one end of campus to the other. About 35% of students ride alone, while about 65% carpool. It was assumed that the number of trips per day were two, to and from campus, and the number of days per year that were commuted were 93, by calculating the mean number of days people drove around campus by 31 weeks. The average commute is about 3.2 miles which is higher than expected due to a few people that have 20+ mile commutes. The total distance driven over 31 weeks was 1,026,525 miles and the total fuel consumption was 46,449 gallons (using a fuel efficiency of 22.1 gallons per mile). Student commuting produced 28 kg N_2O, 81 kg CH_4, and 404,898 kg CO_2 in FY 2005, totaling 415 $MTeCO_2$ in FY 2005. Again these numbers (faculty, staff, and student commuting) were not inputted into the total emissions because the survey ends at FY 2004, but will be used by future surveys. The decision was made to not extrapolate them back to FY 1990 because commuting habits change.

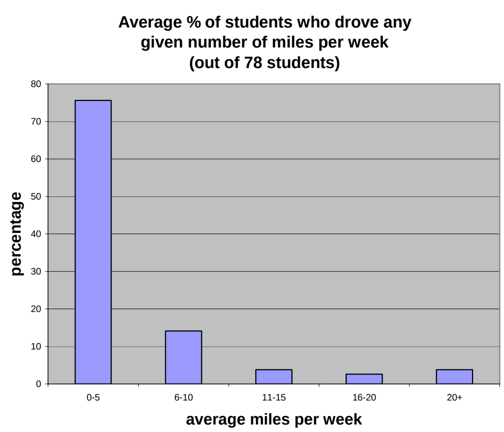

Figure 8. The breakdown of the percentage of students who drove on average a given number of miles per week

In FY 1995 (the earliest year for data), transportation (the university fleet) accounted for about 1% of the total emissions and in FY 2004, transportation accounted for about 2% of total emissions. Data was split into two sections, the diesel fleet and gasoline fleet. In FY 1995 the gasoline fleet produced 36 kg N_2O which decreased to 33 kg in FY 2004. The diesel fleet produced 2 kg N_2O in FY 1995 which increased to 4 kg in FY 2004. Methane produced by the gasoline fleet decreased between FY 1995 and FY 2004 from 104 kg to 94 kg and increased for the diesel fleet from 4 kg to 8 kg from FY 1995 to FY 2004. As always, CO_2 is the largest greenhouse gas produced. It decreased for the gasoline fleet from FY 1995 to FY 2004 from 518,425 kg to 478,957 kg. The diesel fleet saw an increase in CO_2 from FY 1995 to FY 2004 from 72,904 kg to 139,793 kg. The total $MTeCO_2$ for both fleets only increased slightly from FY 1995 to FY 2004 from 605 $MTeCO_2$ to 632 $MTeCO_2$ (Figure 9). This is due to the small decrease in emissions from the gasoline fleet and the larger increase in emissions from the diesel fleet. The decrease in emissions from the gasoline fleet is either due to an increase in fuel efficiency, a decrease in the number of gasoline powered vehicles, or a decrease in the use of gasoline powered vehicles. The diesel fleet shows an increase from FY 1995 to FY 2004 either due to an increase in the number of diesel powered vehicles in the fleet or an increase in the use of them. The use of personal or rented cars relating to Bucknell business was not calculated. Athletic team travel was also not included. This can be added at an additional date and would have an impact on total transportation emissions.

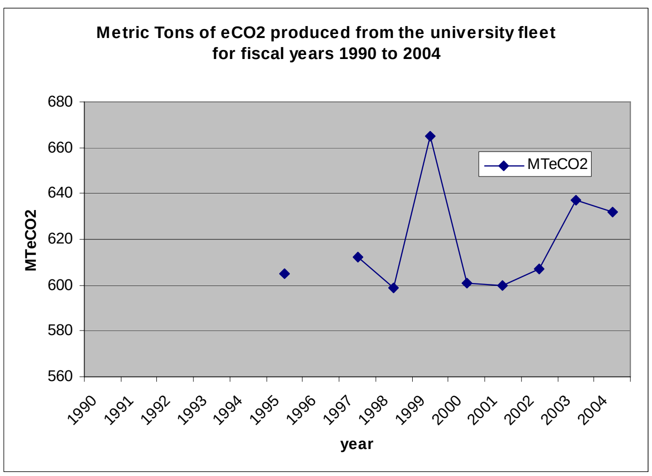

Figure 9. Graph of emissions (in Metric Tons of carbon dioxide equivalents) produced by Bucknell University's vehicle fleet for fiscal years 1990 to 2004.

Solid Waste: Solid waste produced by the university accounts for 0% of total emissions, by this calculator, because the landfill gas (CO_2 and CH_4) is captured and 25% of it is turned into electricity at the co-generation plant and the other 80% of it is flared. This reduces the amount of greenhouse gases Bucknell is emitting into the atmosphere and essentially acts as an offset. This number cannot be exact because some gas does escape the landfill through leaks, but that quantity cannot be determined in order to calculate the amount of greenhouse gases that are emitted into the atmosphere. The university does recycle which lowers the amount of waste that is transported to the landfill. At this point in time recycling is not included in the inventory. The earliest year that there is data for is FY 1994 in which total waste was 1,399.26 tons (which was inputted into the calculator as a 20/80 ratio, 20% co-generation plant, 80% flared). It increased every year to FY 2004 when 1,533.38 tons of waste was transported to the landfill. Even though it is not used in this inventory, data was available for FY 2005 and it showed a decrease in the amount of material that was taken to the landfill, maybe due to an increase in recycling. Landfill gas is calculated as CH_4 even though it includes equal parts of CH_4 and CO_2. In FY 1994 -6,692 kg of CH_4 were produced and that amount increased to -7,334 kg in FY 2004. This equates to -154 $MTeCO_2$ in FY 1994 and -169 $MTeCO_2$ in FY 2004 (Figure 10). Solid waste is not a problem because the landfill gas is captured which equates to negative emissions for the university, but the amount of waste that is thrown away should be reduced for other environmental reasons.

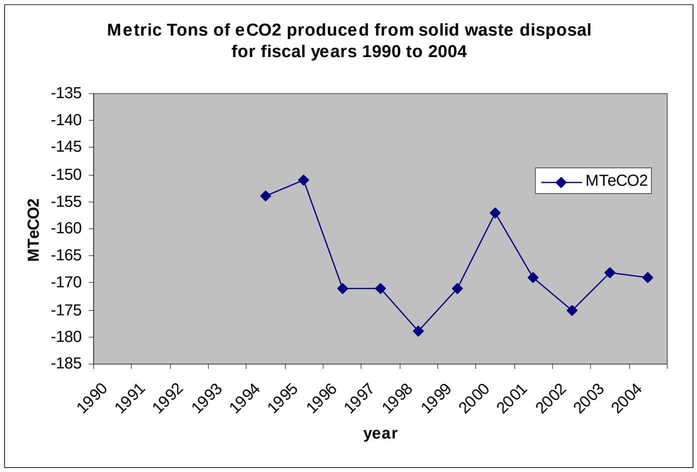

Figure 10. Graph of emissions (in Metric Tons of Carbon dioxide equivalents) produced by solid waste generated on Bucknell University's campus for fiscal years 1990 to 2004.

Refrigerants and other Chemicals: Refrigerants accounted for 21% of the total emissions in FY 1990 and for 9% of total emissions in FY 2004. The pound of each refrigerant used by the university was estimated by the Associate Director of Utilities so this percentage could be greater or less than what was used for the inventory. In FY 1990, the refrigerants used at Bucknell produced 13,530 $MTeCO_2$ and decreased to 3,300 $MTeCO_2$ by FY 1995 where it has been at since (Figure 11). The decrease is due to the change in the refrigerants used by the university. Because of the estimation the graph shows a straight line decrease. In FY 1990, Bucknell used CFC-12 (dichlorodifluoromethane) and HCFC-22 (chlorodifluoromethane). Since CFC-12 was discontinued in 1995 due to concerns about damage to the ozone, Bucknell phased it out from FY 1990 to FY 1995 and phased in HFC-134a (tetrafluoroethane).

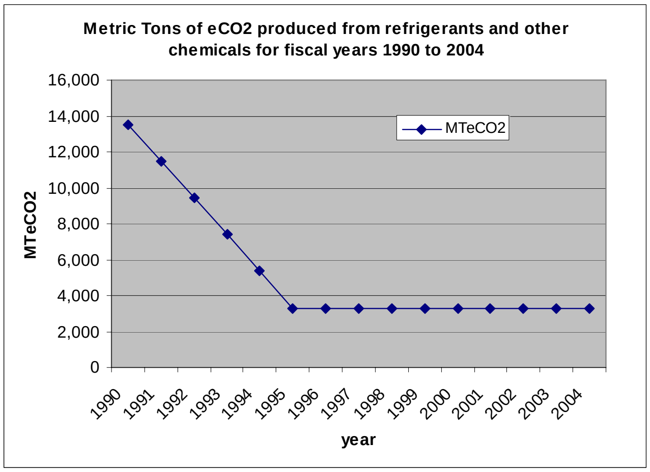

Figure 11. Graph of emissions (in Metric Tons of Carbon dioxide equivalents) produced by refrigerants and other chemicals on Bucknell University's campus for fiscal years 1990 to 2004.

Agriculture: Bucknell does not own any farm animals that produce methane gas from bodily functions. The university does place fertilizer on the grounds, but that information was not included because it is very sporadic, only being purchased when needed and not every year, and the percentage nitrogen is not available. If this information was added into the inventory fertilizers should account for a very small percentage of total greenhouse gas emissions.

Comparison with other schools

In order to compare emissions with other colleges and universities, demographic information was needed that was obtained from the Registrar and Finance offices. From FY 1990 to FY 2004 the operating budget of the university almost doubled from $69,850,924.80 to $125,896,785.00, increasing yearly. Looking at this in terms of the amount of greenhouse gases produced per operating dollar, in FY 1990, 938 grams of carbon dioxide equivalents (geCO_2) per operating dollar were produced and decreased each year to 295 geCO_2 per operating dollar in FY 2004 (Figure 12a). The largest drop was in FY 1996-97 coinciding with the large drop in total emissions. The energy budget increased from 2.8 million dollars to 3.8 million dollars over the course of FY 1990 to FY 2004. There was not a consistent increase during this time period. Kilograms of eCO_2 per energy dollar are high in FY 1990 (12.81kg) and decrease to 8.78 kgeCO_2 per energy dollar by FY 2004 with no consistent decrease (Figure 12b). The largest drop is seen in FY 1996-97 from 12.29 kgeCO_2 to 5.24 kgeCO_2 coinciding with the large decrease in emissions during that time period. This also coincides with Bucknell purchasing more energy and the increase following FY 1997 is due to the co-generation plant being online. Building space on campus has increased almost every year except for a few years where there was no increase in building space (FY 1992-93, FY 1994-96, FY 2001-02, FY 2003-04). The increase in building space is mainly due to additional buildings being built. In FY 1990, total building space was 1,977,015 square feet which increased to 2,511,955 sq. ft in FY 2004. The kilograms of eCO_2 produced per total building space decreased overall from 33.2 kgeCO_2 in FY 1990 to 14.8 kgeCO_2 in FY 2004 (Figure 12c). There was also a large drop in kgeCO_2 from FY 1996-97 coinciding with the large decrease in total emissions. The two large drops in kgeCO_2 per square foot building space (FY 1994 and FY 2003) are due to software error that cannot be fixed. The only reason the amount of emissions per building space decreased even though total building space was increasing was due to the decrease in total emissions.

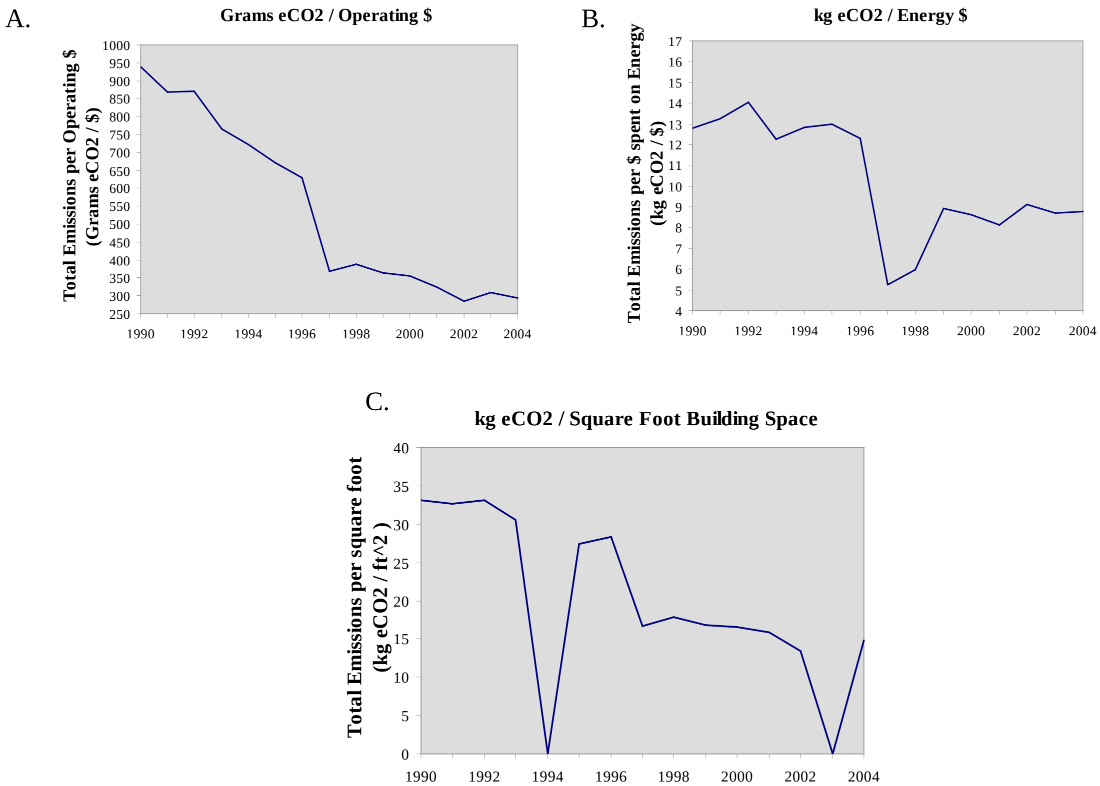

Figure 12. A. Comparison of the amount of carbon dioxide equivalents produced per operating dollar. B. Comparison of the amount of carbon dioxide equivalents produced per energy dollar. C. Comparison of the amount of carbon dioxide equivalents produced per square foot of building space.

The best way to compare Bucknell with other schools is to look at emissions per community member or student. Overall, the total number of full-time students only increased by 200 from FY 1990 (3,482 students) to FY 2004 (3,695 students). The number of part-time students increased from FY 1990-95 and then decreased to FY 2004 with one increase in the number of students in FY 2002. In FY 1990 the number of part-time students was 151 and in FY 2004 was 96 part-time students. The number of summer school students was also included in this inventory. Overall the number of students increased from FY 1990 (364 students) to FY 2004 (294 students) but it was not a steady increase with years of lower numbers of students than others. In FY 1990 18.43 $MTeCO_2$ were produced per student (Figure 12a). This number decreased greatly between FY 1996 and FY 1997 (from 17 $MTeCO_2$ to 10 $MTeCO_2$) again coinciding with the large decrease in total emissions. The overall decrease continued to FY 2004 where 9.91 $MTeCO_2$ per student was emitted. Community data cannot be compared prior to FY 1995 because there is no data on the number of faculty and staff for those years. The number of faculty has increased from 244 in FY 1994 to 300 in FY 2004 and the number of staff has increased from 682 in FY 1995 to 749 in FY 2004. Because of the lack of data the $MTeCO_2$ for FY 1990 is the same as the students. So, looking at FY 1995 the amount of emissions produced by the Bucknell community is 13.28 $MTeCO_2$ (Figure 12b). This number decreased to 7.74 $MTeCO_2$ in FY 2004.

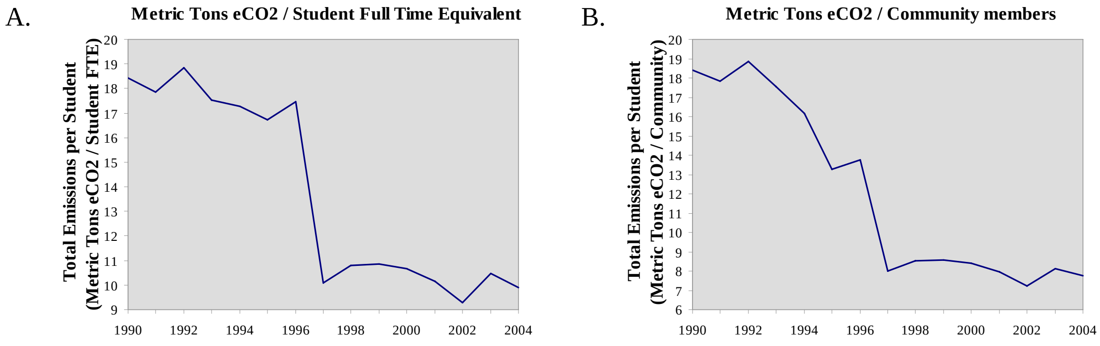

Figure 13. A. Comparison of the amount of carbon dioxide equivalents produced per full time student. B. Comparison of the amount of carbon dioxide equivalents produced per community member.

Using data obtained from Carleton College's greenhouse gas inventory completed in 2005, Bucknell ranks at about the middle in terms of the amount of emissions per student (Figure 14). A graph showing emissions per student from the most recent year of inventory includes colleges like Middlebury College, Harvard University, Oberlin College and Tufts University, all schools that are on the leading edge of environmentally friendly campuses. Out of just these four schools, Bucknell has lower emissions per student than Middlebury, Harvard and Oberlin.

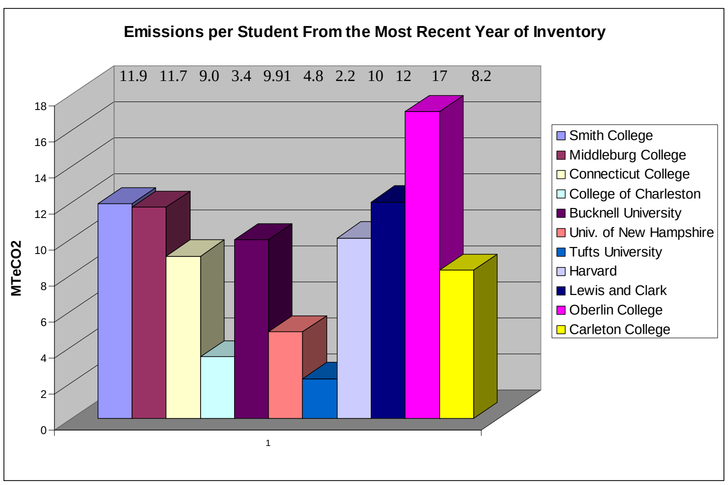

Figure 14. Comparison of the amount of emissions produced at each college or university per student.
Lord with the addition of Bucknell's data

Recommendations

Purchased Electricity: Bucknell University should look into purchasing more renewable energy, whether it is wind or solar power or another renewable source. Even though purchased electricity does not account for a large percentage of total emissions, it still produces greenhouse gases. Bucknell currently purchases about one million kWh of wind power a year, but for some schools like Bates College, all of their purchased electricity is renewable. The same at Colgate University where most electricity is hydroelectric and some electricity is nuclear. Many schools have added a couple extra dollars to their student activities fee to pay for more renewable energy:

at Clark University an additional $3, at Connecticut College an additional $25, at Smith College an additional $20 and at University of North Carolina at Chapel Hill an unknown amount was added. The move to add the student activity fee came from students most of the time. Bucknell currently pays 1.5 cents per kWh for wind power, and assuming that we could still pay this rate, in order to purchase an additional 1 million kWh an additional $5 could be added to the student activity fee. This is much less than what some colleges are adding on. (Bates College 2007, CA-CP 2004(b,d,g), Colgate University 2003, Hawley 2007, Kassab 2006, University of North Carolina 2006).

On-campus Stationary Sources: The majority of emissions on campus are due to the co-generation plant but it is the most efficient technology that is available at this time. Some schools have only started constructing co-generation plants, while Bucknell's has been in existence since FY 1998. Bucknell also has/will have two solar panels built during FY 2006, one being completed in August 2006 (2.4 kWh) and the other to be completed during spring semester 2007 (3.2 kWh). The one that has been completed provides solar electricity to the Environmental Center, providing 10-12% of the electricity consumed by the center. The other one will be used to power some functions in a mod at Bucknell West. To help offset the emissions being produced by the co-generation plant more renewable energy sources should be looked at on campus, including adding onto the two existing solar panels to power more of campus. Currently Bucknell has completed some initiatives to reduced energy consumption. All lighting is retrofitted with the current energy efficient technology, but there is still a ways to go before all buildings are retrofitted. In addition, Bucknell also uses compact fluorescent lighting for regular lights and LCD lighting for the exit signs. The larger buildings have energy management/monitoring systems to help reduce consumption and identify problem areas (Kassab 2006).

Many other universities have done a variety of initiatives to reduce the energy consumed or to reduce greenhouse gases produced by on-campus sources. Bates College is currently looking at the possibility of producing their own biofuel from dining service's oil and they also heat 12 residential houses with B5 (petroleum heating oil with 5% biofuel from soy or canola oil). Colgate University has a willow biomass facility to offset the need for mass oil-burning and a wood boiler which produces 60% of the steam for the campus heat and hot water. Many schools also have large solar arrays including: Connecticut with a 10 kW solar array, Harvard with a 36 kW solar array, Oberlin with a 36 kW solar array, University of Colorado with a 7.5 kW solar system and small solar panels spread over their campus, and the University of Vermont has 5 kW solar panels. The best option to reducing emissions is to switch from coal power to co-generation plants, which Bucknell completed in FY 1996-FY 1998. There are many schools that are still looking to make this change. It is not a feasible option for Bucknell, but many schools are looking at installing wind turbines, including Massachusetts Institute of Technology, University at Buffalo, and the University of Vermont who currently has a 10 kW wind turbine (Bates College 2007, CA-CP 2004(e,j), Colgate University 2003, Connecticut College 2006, MIT 2007, Oberlin College 2006State University of NY at Buffalo nd.).

Since the co-generation plant already has the lowest production of greenhouse gas emissions, the next solution is to work on conservation. Bucknell does replace light fixtures with energy saving alternatives, but more could be done, which also requires help from the community to reduce personal consumption of electricity. Some schools like Bates, Connecticut College, Duke, and Tufts have participated in light bulb exchange programs where compact fluorescent bulbs are distributed to the student body and at Tufts actually distributed to the community as well. Motion detectors have also become very popular to install to reduce the amount of time lights are on in some buildings. There are many unnecessary lights left on around campus when students and professors neglect to turn off the lights when they leave classrooms and lights are left on by students in their rooms as well. Motion detector lights would not be very practical in personal rooms and maybe classrooms, but could be used in hallways. There has been some testing of the practicality of motion detector lights in classrooms. Putting vending machines on timers has also become a popular idea at many schools. The timers, called vending misers, will turn the machine off if no one is around for 15 minutes. It will turn on again as soon as someone walks by, which does not affect the internal thermostat or the compressor. The other large user of electricity is computers. Many students tend to leave their computers on indefinitely, which uses much more energy than needs to be used, especially when one is not in the room or is asleep. Computers in the labs are also large consumers of electricity. The computers in the basement of the geology building do not ever completely go to sleep and are restarted about every 10 minutes if they are not in use. It is unknown how the computers in other labs are. Many schools are trying to obtain control of computers to reduce the amount of time they are on and are participating in contest aimed at reducing the time computers are on. Colgate has computer sleep protocols and Harvard has a computer energy reduction program. Mt. Holyoke is trying to obtain power management of 75% of the students' computers and Mt. Holyoke and Smith are participating in Energy Star's Million Monitor drive, a campaign to address monitor power management nationwide (CA-CP 2004(a,c,e,f,g,h), Connecticut College 2006, Duke University 2007, EPA nd., Tufts University nd.).

Since Bucknell University is using the latest technology to produce its electricity (besides using renewable energy), the only way to decrease emissions is to decrease the consumption of electricity. The largest use of electricity on campus is due to the unnecessary consumption of electricity to power devices and lights. Increasing community awareness of how much electricity is used by different devices, might offer a way to decrease consumption. In order to accomplish this, Bucknell should look into participating in many of the different campaigns that focus are reducing the consumption of energy such as the Million Monitor Drive and Change a Light, Change the World program.

Transportation: Transportation is a hard issue to make any changes to because of the size of Bucknell campus. For larger campuses that have buses, many have chosen to power them by compressed natural gas (CNG) or by biodiesel. If the university must maintain a fleet of vehicles for campus use, alternative fueled vehicles should be looked at for purchase. Carnegie Mellon has natural gas vehicles and is requiring that all new vehicles be powered by alternative fuel. The University of Southern Maine is looking to convert all vehicles to biodiesel at some point. Many schools also have either bought hybrids for use by the mail delivery and public safety or electric (GEM or RAV4) vehicles for use around campus. Some schools have even gotten rid of most of their vehicles and rely on borrowing cars through a ZipCar program or a car sharing program. Other options for student, faculty, and staff transportation need to be addressed. For many it is a life choice to drive one-half mile to school or work. Other, mainly larger, schools have found ways for carpools/vanpools and bicycle programs to decrease the amount of driving, but trying to implement these programs would not be feasible on Bucknell's campus because it is a smaller and compact campus (Carnegie Mellon University nd., CA-CP 2004(i)).

Solid Waste: Even though the greenhouse gases produced from the decomposition of solid waste are captured, flared and used for energy, reducing the amount of waste produced at the university should be addressed. Most schools recycle, including Bucknell, but there should be a greater emphasis placed on it to increase recycling. UNC provides each dorm room with a recycling tote that contains materials listing what can be recycled at the school. Bucknell will be implementing a similar tote in the spring 2007 semester. Composting has also become a big way to reduce waste. Many schools, including Bates, Bowdoin, Colby, Cornell, MIT, Middlebury, Mt. Holyoke, and UNC are now composting either pre- or post-consumer waste or both to reduce the amount of waste sent to landfills. This is something that Bucknell should look into. In addition, many schools are also using biodegradable place settings for events. Bates uses reusable ware at its outdoor events and at Middlebury all outdoor dining events use biodegradable or reusable ware. Oberlin uses biodegradable cups, cutlery and to-go containers. Coffee and tea drinkers on campus also contribute to the large amount of waste by using at least one paper cup a day. To reduce the amount of waste that is produced, reusable mugs should be handed out to at least all first-year students if not the whole student body and incentives should be offered to encourage their use. This has been successful at many other colleges and universities including Bowdoin, Colgate, Middlebury, and Oberlin. Since there is very little greenhouse gases being produced from our solid waste, the obvious thing is to not worry about this sector, but Bucknell should work to reduce its solid waste for other environmental reasons (Bates College 2007, Bowdoin College nd., CA-CP 2004(f), Colby College 2006, Colgate University 2003, Cornell University 2006, MIT 2007, Middlebury College nd., Oberlin College 2006).

Overall conclusions

Bucknell University is doing very well in reducing greenhouse gas emissions through on-campus initiatives. By switching to a co-generation plant, emissions were reduced to about 44% below 1990 levels. This does not mean that emissions should not be further reduced. The amount of greenhouse gas emissions produced by the university is in line with other universities. Most of the greenhouse gases produced is the result of on-campus stationary sources, mainly the co-generation plant which is providing the university with electricity and steam. Because electricity and steam are a vital part of our everyday lives this source cannot be eliminated, but it can be greatly decreased if lights and electronic devices were turned off when not in use. If computers can not be turned off, an energy saving sleep mode should be activated. Motion detector lights would help to reduce the amount of electricity consumed by the large amount of unnecessary lights left on in unoccupied buildings. Also, the university should look into placing energy saving light bulbs in all sockets, including residential buildings. Some universities have gone as far as supplying residents with compact fluorescent light bulbs for personal use. Bucknell should look at creating a strategic plan of initiatives to reduce greenhouse gas emissions through the implementation of previous recommendations and new ones.

Public education is the biggest obstacle. If people understood the impact they have on the environment from leaving electronic devices and lights on, or driving less than a mile to get to work or school, their habits might change and ultimately reduce the amount of greenhouse gases they personally produce, in turn reducing the amount the university produces.

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