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Carbon Neutrality at Colby College

Jamie K. O'Connell
Colby College

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Jamie K. O'Connell
Environmental Studies Program
Colby College
Waterville, ME

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Thomas H. Tietenberg, Mentor | F. Russell Cole, Reader | Philip J. Nyhus, Reader

INTRODUCTION

What is Carbon Neutrality?

Carbon neutral is a term used to describe any organization, entity, or process that has a net greenhouse gas (GHG) emissions level of zero (Dautremont-Smith *et al.* 2007a). Since carbon neutrality only requires a net greenhouse gas emissions level of zero, organizations do not need to eliminate all carbon pollution to become carbon neutral. *Net emissions* differ from *gross emissions* in that gross emissions are the sum of all emissions released by the individual or entity, whereas net emissions are equivalent to the gross emissions minus any carbon offsets. A *carbon offset* is any activity that reduces carbon emissions so as to exactly compensate for a carbon emitting activity elsewhere (Dautremont-Smith *et al.* 2007a). If net emissions were greater than zero, the entity would be considered a net emitter of carbon. If they were less than zero, then the entity would be a net reducer of carbon. If the net emissions level was zero, then the entity would be carbon neutral.

While a zero carbon economy may be possible in the future, present technology, infrastructure, and the availability of alternatives to carbon emitting devises make it impossible to continue the status quo without carbon pollution. For example, it would be impossible for many individuals, businesses, and other organizations to stop using fossil fuel-consuming transportation and continue with their basic operations. However, these same entities could achieve carbon neutrality without needing to wait for alternatives to fossil-fuel powered transportation to become widely available. These organizations could reduce or eliminate emissions where possible and offset carbon emissions where reduction or elimination of emissions is not an option. Organizations may also choose to offset emissions when it costs less to purchase offsets than to reduce emissions.

Where is Carbon Neutrality Occurring?

There is often much debate over whether carbon neutrality is attainable and the time frame over which it can be accomplished. While carbon neutrality at the national level has not been widely discussed, it is becoming an increasingly practical goal for many institutions. A prime example is the American College and University Presidents Climate Commitment (ACUPCC), an agreement with signatures from 542 colleges and universities as of May 7, 2008 (ACUPCC 2007-2008)[1]. By signing the document, a college president agrees to complete the following actions (Dautremont-Smith *et al.* 2007a):

- form an institutional body to monitor and guide the process of achieving neutrality
- conduct an annual emissions inventory including as many years prior to signing the Commitment as possible
- formulate a carbon neutrality action plan with a target date and interim goals
- explain how items in the action plan will be financed
- make sustainability an important part of the school's academic experience by adding it to the curriculum
- make the action plan and progress in achieving neutrality available to the public.

In December of 2007, College of the Atlantic (COA) became the first commitment signatory to achieve carbon neutrality (COA accessed 2008). Middlebury College and

[1] http://www.presidentsclimatecommitment.org/

Oberlin College have made publicly available their plans to achieve carbon neutrality by 2016 and 2020, respectively (Isham *et al.* 2003, Middlebury College 2007, RMI 2002). Citing preliminary results from this thesis, Colby announced it will also join the Commitment in May of 2008 (Adams, pers. comm).

Colleges and universities play a unique role in society as centers of research and progressive thought. These institutions have the responsibility of educating and preparing the next generation of leaders in every aspect of society. Reflecting this special role, places of higher education are granted such privileges as tax-free status and the ability to receive both private and public funds (Dautremont-Smith *et al.* 2007b). Collectively, colleges and universities comprise a $317 industry that spends billions on energy consumption and fossil fuel products (Dautremont-Smith *et al.* 2007b). The United Nations International Panel on Climate Change (IPCC) has shown that emissions must be reduced by 50 to 85 percent below 2000 levels by 2050, with peak CO_2 occurring before 2015 to hold temperature increase to within 2.0 to 2.4 degrees Celsius of the pre-industrial era (Dautremont-Smith *et al.* 2007a, IPCC 2007).

Given role of higher education in preparing students to find solutions to climate change, the potential impact on markets for clean energy and sustainable products, and the importance of taking immediate climate action, this thesis investigated the feasibility of carbon neutrality at Colby College and the timeframe over which neutrality could be reached. This study began by creating a greenhouse gas emissions inventory for Colby and establishing an emissions baseline. Options for reducing or eliminating emissions from individual sources were investigated, and future emissions were projected under different reduction scenarios. This thesis also discussed the role of offsets in achieving emissions, and outlines the offsetting options available to the College.

METHODS

Measuring Greenhouse Gas Emissions

An annual inventory of greenhouse gas emissions dating back to 1990 was created using the Campus Carbon Calculator version 5.0, an excel-based document created and distributed by the environmental nongovernmental organization Clean-Air Cool-Planet (CA-CP)[2]. The emissions were calculated on a fiscal year (FY) basis, beginning on July 1st and ending June 31st. For example, FY 2007 began on July 1, 2006 and ended June 31, 2007. The World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI) have published the "Greenhouse Gas Protocol: a corporate accounting and reporting standard[3]," which is the most widely accepted set of standards for both calculating GHG emissions and deciding which carbon sources to include in an inventory. The implementation guide for the ACUPCC requires that schools use an inventory that is "consistent with the standards of the Greenhouse Gas Protocol (GHG Protocol) of the World Business Council for Sustainable Development (WBCSD) and the World Resources Institute (WRI)" and states that the Campus Carbon Calculator meets the Protocol criteria (Dautremont-Smith *et al.* 2007a).

The Campus Carbon Calculator contains a series of spreadsheets that comprise three general modules: data input, emissions factors, and summary. There are three data input sheets: a general input sheet, one for entering data used to calculate emissions from student, faculty, and staff commuting, and a third to enter the college's electricity fuel

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[2] http://www.cleanair-coolplanet.org/toolkit/content/view/146/132/
[3] http://pdf.wri.org/ghg_protocol_2004.pdf

mix. These sheets ask the user to enter non-greenhouse gas data, such as the gallons of residual oil used during FY 2007, or the kWh of electricity purchased in FY 2007.

The calculator uses these input variables to calculate greenhouse gas emissions and offsets based on conversion factors stored in the emissions factors module (CA-CP 2006a). All emissions and conversions factors contained in the Campus Carbon Calculator came from the United States Department of Energy, the United States Environmental Protection Agency, or the United States Department of Transportation and are referenced in more detail in a reference worksheet within the calculator (CA-CP 2006a). The gross emissions, net emissions, and emissions by source are converted into metric tons of carbon dioxide equivalents (MTCDE) and can be viewed in the summary module. All emissions factors, conversion factors, and assumptions included in the calculator were used unless otherwise noted (see Appendices A-E). The majority of input data were provided by the Colby Physical Plant Department by the Environmental Programs Manager, Dale DeBlois.

While most GHGs contain carbon, inorganic GHGs such as N_2O and sulfur hexafluoride (SF_6) also contribute to climate change. Different GHGs vary in their ability to trap heat, resulting in disproportionate impacts on global warming. For example, one molecule of methane traps heat 23 times more effectively than carbon dioxide (CA-CP 2006a). To relate the effect of emitting equal amounts of different gases, carbon emissions were measured in Metric Tons of Carbon Dioxide Equivalent (MTCDE). The kilograms of each pollutant emitted were multiplied by the pollutant's global warming potential (GWP) (the warming effect the gas has in relation to carbon dioxide, with carbon dioxide having a GWP of 1), which were then converted to MTCDE. Even though carbon dioxide is the least potent GHG, it is currently released in the greatest quantities so its effect on global warming is large (CA-CP 2006a). Since greenhouse gas emissions are reported in MTCDE, the term “carbon neutrality” encompasses both organic and inorganic GHG emissions.

Defining the Scope of Emissions at Colby College

The first step in making a plan for neutrality is to quantify GHG emissions using the college inventory so that these emissions can be analyzed to find ways to eliminate, reduce, and offset emissions. Unfortunately, it is not always clear which emissions are the responsibility of the institution pursuing neutrality. For example, could Colby say it is carbon neutral if it had zero net emissions from heating and electricity use by all of the buildings on campus? Many would argue that the scope of emissions Colby is responsible for extends to the rented Colby Gardens residential building, even though the college does not own this off-campus space. Others would argue that solid waste should be included in the inventory, even though the methane emissions from the decaying material occur only after the waste as left Colby and has arrived at the landfill.

If one argues that vehicle emissions should be included, does this mean only emissions from vehicles that the college owns? What about emissions from vehicles that the college rents for transporting students to athletic competitions, or the emissions from students and employees commuting to campus each day, or student travel to campus at the beginning and end of semester breaks? Should emissions from the transportation of heating oil to Colby be included in the inventory? How about the emissions from the operation of the buildings where the fuel was processed and the emissions resulting from the extraction of the fossil fuel? Does Colby need to account for the emissions from the production of the fertilizer used to grow the fruits and vegetables served in the dinning halls, and account for the emissions from transporting the dining hall food to campus? How far down a supply chain does Colby need to go to address emissions for neutrality?

Given the complexity of determining ownership of emissions, it is important for an institution to define the extent of its emissions responsibility. To assist with this process, CA-CP categorized emissions sources based on the degree of control an institution has over these sources. Adapting from the definitions in the Greenhouse Gas Protocol, **Scope 1** emissions were defined as "all direct sources of GHG emissions from sources that are owned or controlled by your institution [.] (CA-CP 2006b)" **Scope 2** emissions encompassed emissions "associated with the generation of imported sources of energy," such as electricity (CA-CP 2006b). **Scope 3** emissions "includes all other indirect sources of GHG emissions that may result from the activities of the institution but occur from sources owned or controlled by another company, such as: business travel, outsourced activities and contracts, emissions from waste generated by the institution when the GHG emissions occur at a facility controlled by another company, e.g. methane emissions from landfilled waste, and the commuting habits of community members (CA-CP 2006b)."

After categorizing emissions into Scope 1, 2, or 3, an institution can then define its *operational boundary*, or the sources and emissions for which it is responsible. Defining operational boundaries is a somewhat arbitrary process. The ACUPCC requires that colleges include all Scope 1 and 2 emissions (Dautremont-Smith *et al.* 2007a). The Commitment also requires that colleges include Scope 3 emissions from college sponsored air travel and from student, faculty, and staff commuting with the exception of travel at the beginning and ends of breaks (Dautremont-Smith *et al.* 2007a). However, the commitment encourages schools to count as many Scope 3 emissions as possible (Dautremont-Smith *et al.* 2007a).

The operational boundary for Colby College was defined using all the Scope 1, 2, and 3 emissions included in the Campus Carbon Calculator, but went a step further to track emissions from college related activity travel (Table 1). While not required by the Campus Carbon Calculator, the inclusion of college-related activity travel is on par with the decision of Middlebury, Oberlin, and College of the Atlantic to include this source in their inventories (RMI 2002, Middlebury College 2007, COAb accessed 2008). Many other Scope 3 emissions sources may be significant contributors of greenhouse gases, but the unavailability of data or a decision that those emissions were the responsibility of other individuals or organizations excluded these sources from Colby's operational boundary.

Table 1. Greenhouse gas emissions sources by scope at Colby College. Emissions sources are categorized as Scope 1, 2, or 3 emissions. Emissions included in the Colby operational boundary or are required by the ACUPCC are notated with a Y, and those sources not included or required are denoted with an N.

	Operation	Current or potential emissions sources	Included in Operational Boundary	Required by ACUPCC
Scope 1	Heating and cooling of college-owned buildings	Residual oil, distillate oil, propane, and B10 biodiesel mix	Y	Y
	Heating and cooling of college rented buildings	Distillate oil at Colby Gardens	Y	Y
	Electricity generation on-campus	Residual oil at the cogeneration facility*	Y	Y
	College vehicle fleet	Gas and diesel PPD vehicles	Y	Y
	Landscaping	Synthetic and organic fertilizer	Y	Y
	Refrigeration or chemical use	Leakage of CFCs, PFCs, and SF_6 (none currently)	Y	Y
Scope 2	Electricity purchased for college owned or rented buildings	Fuel mix of 50% hydro, 50% biomass is zero emissions	Y	Y
Scope 3	Solid waste disposal	Landfilled without methane recovery	Y	N
	Transportation of waste to landfill	Waste to Norridgewock Landfill	Y	N
	Commuting of off-campus students, faculty, and staff to campus	Vehicle emissions	Y	Y
	Air travel financed by Colby	Athletic competitions, academic conferences, etc.	Y	Y
	Non-air travel/transport financed by Colby	Athletic competitions, academic conferences, etc.	Y	N

(Table 3 continued from previous page)

	Operation	Current or potential emissions sources	Included in Operational Boundary	Required by ACUPCC
Scope 3 (cont.)	Relocation of new faculty and administrators to campus	Car, bus, train, and air travel	N	N
	Student travel to and from campus for breaks	Car, bus, train, and air travel	N	N
	Transportation of food to campus	Food and beverages served in dining halls Pulver Pavilion, the Marchese Blue Light Pub, and vending machines	N	N
	Transportation of fuel and supplies to campus	-Heating oils and vehicle fuels -paper, office supplies, etc. -items sold in College bookstore	N	N
	Emissions from operating buildings/facilities associated with Scope 2 and 3 emissions	e.g., facilities where the purchased electricity is generated	N	N
	Emissions from the extraction and production of goods purchased by the campus	e.g., extraction of petroleum for heating fuels	N	N

*Emissions from the cogeneration of heat and electricity are not double counted. The emissions from residual oil use at the cogeneration facility are calculated once each fiscal year.

Measuring Emissions by Source

The summary module of the Campus Carbon Calculator reports gross emissions in MTCDE. It also reports the MTCDE from different sources broken into the following categories: purchased electricity, on campus stationary sources, transportation, agriculture, refrigerants and other chemicals, and solid waste. However, when describing

Colby’s historical emissions or when forecasting future emissions scenarios, it was often necessary to obtain the emissions from individual sources. For example, the Campus Carbon Calculator reported emissions from residual oil, distillate oil, and propane were reported under one category for on-campus stationary sources. To find the emissions from each of these individual fuels, the gallons of distillate oil, for example, were entered into the input spreadsheet but all other values were left blank. The summary module would then only report the emissions from the entered amount of distillate oil. This method was used for any emissions values that were combined and reported in the summary module as a single number.

Future Projections

Similarly, the Campus Carbon Calculator was used to forecast the college emissions under different scenarios. Since emissions have stayed been 18,808 MTCDE and 21,324 MTCDE between 2004 and 2007 (a switch to green electricity in 2003 caused a large drop in emissions), and the contribution of individual sources has also stayed relatively constant, 2007 was chosen as the baseline year (Figure 1). To calculate a new emissions level under different circumstances, all 2007 input values were held constant except for the input value that would be changed by the new technology. An example would be if the college adopted a technology that could reduce fossil fuel A by 20%. All input values, emissions factors, and other assumptions from 2007 would remain constant, but the gallons of fossil fuel A would be entered as 20% less. The summary module would report a new emissions figure, which could then be compared to the baseline 2007 emission level.

BACKGROUND AND HISTORICAL EMISSIONS AT COLBY COLLEGE

Greenhouse Gas and Energy Use Trends at Colby College 1990-2007

In 2007, Colby's gross GHG emissions were 20,372 MTCDE, which is 11 percent less than in 1990 (Figure 1). Emissions peaked in 2000 at 29,461 MTCDE; while the building area of the campus increased during the 1990s, the steady increase in emissions from 1990 to the peak in 2000 is also likely due to an increase in use of energy consuming devices, such as computers. The introduction of green electricity in 2003 caused Colby's emissions to drop by 34 percent between 2002 and 2004 (Figure 1). Generated by biomass and hydroelectric power, green electricity produces power more efficiently than the previous fuel mix of 70 percent coal and 30 percent hydro (CA-CP 2006a). This increased efficiency caused energy use to drop along with emissions in 2003 (Figure 1). Since 2004, emissions have stayed between 18,808 and 20,372 MTCDE despite a 73,000 sq. ft. increase in building area (Figure 1). The increase in emissions between 2006 and 2007 is likely because a greater number of staff were included in commuter emissions calculations than in previous years (Figure 1).

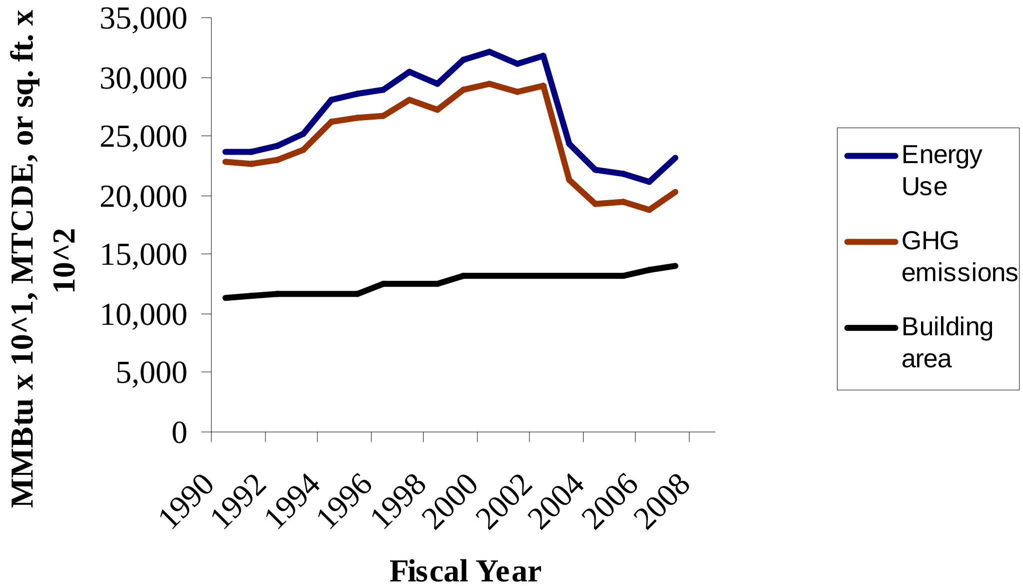

Figure 1. Gross greenhouse gas emissions, energy use, and building area at Colby College from 1990 through 2007. Carbon emissions and energy use increased steadily from 1990 until they peaked in 2000. A switch to green electricity in 2003 caused a large drop in emissions and energy use. Green electricity and other environmental initiatives have allowed Colby to expand its campus without increasing its emissions.

This consistency in emissions, despite increases in building area, demonstrate the success of Colby's environmental initiatives. These initiatives include: green electricity, improvements in building efficiency, and the addition of two buildings receiving a Leadership in Energy and Environmental Design (LEED™) certification from the non-profit U.S. Green Building Council's LEED Green Building Rating System™. The Schair-Swenson-Watson Alumni Center, which received a silver LEED certification, where platinum is the highest level of LEED certification and bronze the lowest, uses geothermal heating, a carbon-free source of heat (Table 2). The 54,000 sq. ft. Diamond Building has a bronze LEED certification, although it did not receive points for energy conservation (Table 2). Energy use in the Diamond is more typical of a building without LEED certification. With the exceptions of the Colby Gardens, a building the college is temporarily renting for additional residential space, the two new buildings added since 2005 are LEED Certified (Table 2).

Table 2. Buildings constructed or rented at Colby College since 2005 and their and LEED status. The Schair-Swenson-Watson and Diamond buildings are new buildings on campus. The Colby Gardens is a rented facility.

Building Name	Year came online	Area (sq. ft.)	LEED Certification	Greenhouse gas reducing attribute
Schair-Swenson-Watson Alumni Center	2005	28,000 (1)	Silver	Wind REC, geothermal heating, green electricity, vegetable oil for hydraulic lifts in for elevator (1)
Diamond Building	2007 (3)	54,000 (2)	Bronze	Wind REC
Colby Gardens	2006	22,000	None	Green electricity

1.(Collins 2006)
2. (Jacobs 2008)
3. (Colby College 2008b)

These improvements in energy efficiency and consumption are further shown by the reduction in energy use per square foot of building space (Figure 2). In Figure 1, both energy use and greenhouse gas emissions decreased as building area increased after the switch to green electricity in 2003. Likewise, energy use per square foot decreased after 2003 suggesting that new buildings constructed after 2003 are less energy intensive, bringing down the overall energy use/square foot of building space for the entire campus (Figure 2). For example, even though emissions increased between 2004 and 2005 by about 200 MTCDE and the building area increased with the addition of the 28,000 square foot Schair-Swenson-Watson Alumni Center, energy use per square foot decreased (Figure 2, Table 2).

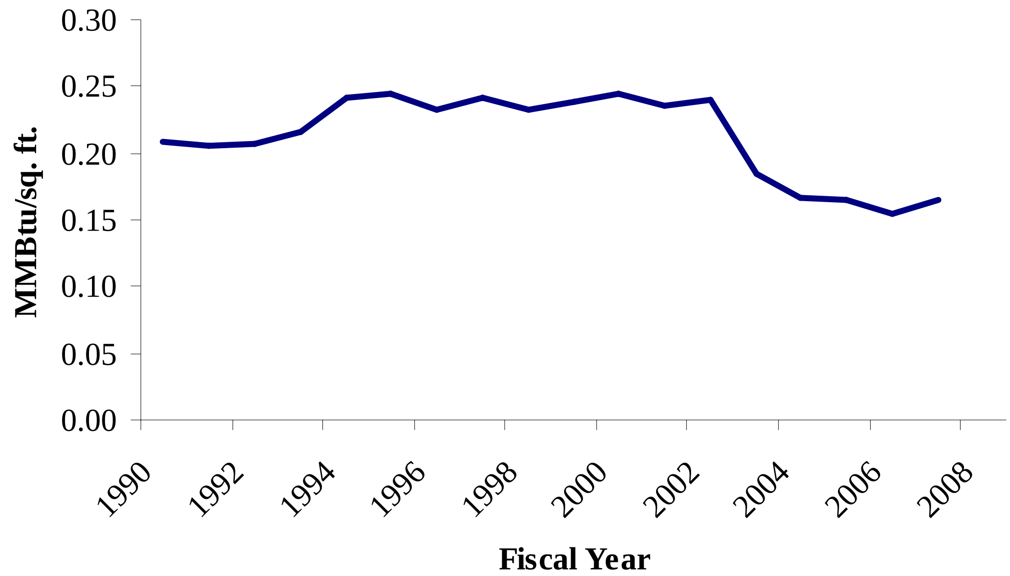

Figure 2. Energy use per square foot of building space at Colby College 1990 through 2007. Energy use per square foot peaked in 2000, and dropped steadily with the switch to green electricity in 2003 and LEED certified buildings.

Emissions by Source at Colby College 1990-2007

While annual gross emissions levels varied between years, the relative contribution of individual sources between 1990 and 2007 has stayed constant with the exception of electricity (Figure 3). In all years, residual oil contributed the most to GHG emissions, followed by electricity use until the switch to green electricity in 2003. College related transportation was the next largest contributor, followed by student, faculty, and staff commuting, landfilled waste, non-residual fuel use, PPD vehicle fleet (except in 2004 PPD vehicles contributed slightly more than non-residual oil fuels), and fertilizer application, respectively. College related travel was calculated using 2006 - 2007 data since data for previous years were unavailable.

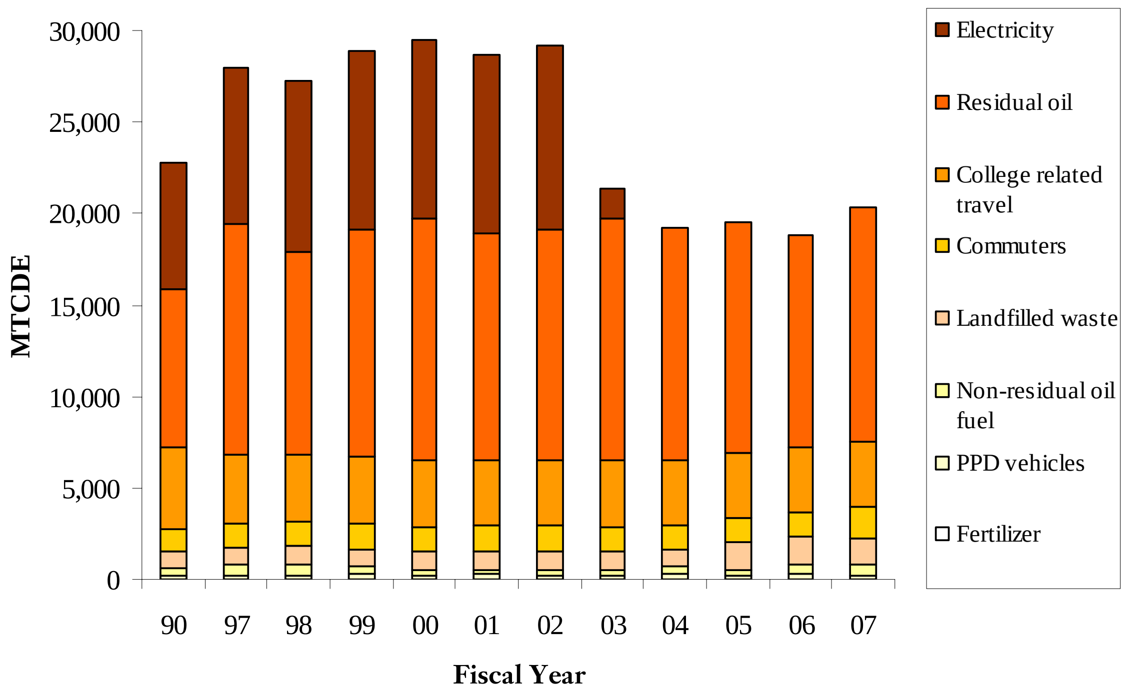

Figure 3. Greenhouse gas emissions by source at Colby College 1990 through 2007. The relative contribution of each source to gross emissions has not varied much through this time period. The one exception is green electricity, implemented in 2003, which eliminated GHG emissions from electricity.

Since gross emissions and the contribution of emissions by source experienced little variation between 2004 and 2007, 2007 was used as the baseline year for this study (Figure 3). In 2007, residual oil was the largest contributor of emissions at Colby, contributing 63 percent of gross emissions (Figure 4). The three next largest sources were college related travel, commuting by students, faculty, and staff, and landfilled waste, respectively (Figure 4).

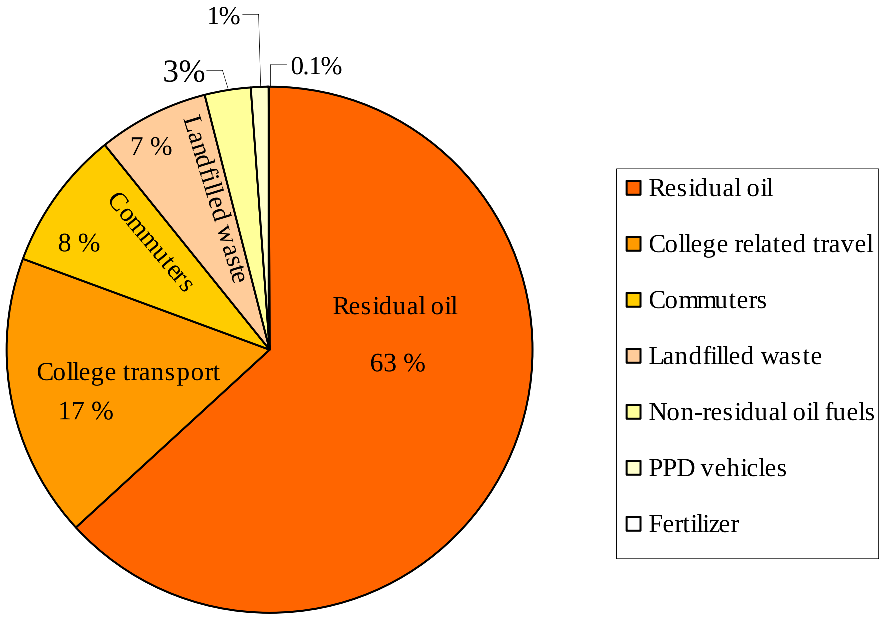

Figure 4. Percent contribution to gross greenhouse gas emissions by source at Colby College in 2007. Residual oil was the largest single source of emissions.

EMISSIONS AND REDUCTION STRATEGIES BY SCOPE

Scope 1

Residual Oil (#6)

Residual oil (#6) is a petroleum-based fossil fuel and is the largest source of GHG emissions at Colby, contributing 63% of gross emissions in 2007 (Figure 4). Residual oil is used exclusively at the college cogeneration steam plant to supply the majority of heat and hot water on campus (Murphy, pers. comm, PPD 2002). The residual oil is used to heat three Babcock Wilcox FM-9 water tube boilers, producing steam that is piped to campus buildings through an underground distribution system (PPD 2002). A turbine generator was installed in 1999 so that the steam produced for heat could also pass through the turbine and generate electricity (PPD 2002). This double production of heat and electricity from the same source of residual oil is what is frequently referred to as "co-generation." In 2007, nine percent of Colby's electricity was supplied by the cogeneration facility.

Of the three fuels used for heating at Colby – residual oil, distillate oil, and propane – residual oil has the highest energy content per gallon, but also has the highest greenhouse gas emissions per gallon and per unit energy (Table 3).

Table 3. A comparison of the energy and greenhouse gas content of residual oil, distillate oil, and propane. These fuels are used primarily for heating at Colby. A small amount of a B10 biodiesel mix also used as an alternative for distillate oil. B10 produces 10 percent fewer greenhouse gas emissions than distillate oil.
Source: (CA-CP 2006a).

	Energy per gallon (MMBtu/gal)	GHG emissions per gallon (MTCDE)	GHG emissions per unit energy (MMBtu/gal)
Residual oil	0.15	0.012	0.08
Distillate oil	0.14	0.010	0.07
Propane	0.09	0.005	0.06

BIOMASS

Biomass is an alternative fuel for residual oil. In Maine, biomass fuel in the greatest abundance is wood. In theory, the act of combusting of woodchips or other forms of biomass is carbon neutral since the carbon released during the combustion of the biomass would be offset by the carbon sequestered during the lifetime of the plant. As long as the biomass fuel was sustainably harvested, so that the net stock of forest carbon was not reduced, the combustion of biomass would be carbon neutral. The use of wood waste or harvest residues for fuel would also have zero net emissions because these wood products would have otherwise decomposed or been combusted in a waste disposal facility. If the college decides to pursue biomass as a replacement for residual oil, it will be important to investigate the available sources of wood fuel.

While not included in the inventory, the Scope 3 emissions from using biomass would be less than those from residual oil. If the biomass was waste wood, there would be no additional emissions from harvesting since the emissions from the extraction machinery would be occurring regardless of whether the waste wood was used as fuel. If Colby's demand for biomass was the reason the wood was harvested, then emission from the harvest machinery should be included in the Scope 3 emissions. However, it is likely that these emissions are less than those from the extraction of petroleum.

Scope 3 emissions from the processing of fuel would also be eliminated; unlike residual oil that must be processed from its raw petroleum form, biomass would be brought to campus unprocessed. Finally, the emissions from transporting the wood fuel to Colby would be less than residual oil. Biomass would be traveling to Colby from within Maine, possibly from a location near Colby, whereas petroleum is shipped from out of state regions, such as in the southern United States or from a foreign country. While switching from residual oil to biomass would reduce greenhouse gas emissions, other types of air pollutants may increase. It will be important for the college to consider both the positive and negative consequences of any alternative technologies it decides to pursue.

In 2006, the college hired the consulting firm Sebesta Blomberg & Associates, Inc. to conduct a feasibility study examining the "viability and cost-effectiveness of providing central steam to the College with wood chip boilers (Sebesta Blomberg & Associates 2006)." The report gave four possible options for using biomass at Colby, all of which had a simple payback of less than seven years and reduced spending on fuel costs by roughly 50 percent.

The report investigated biomass stokers and gasifiers; both types of systems can combust wood fuel, but differ in the number of combustion chambers and in their method of burning the wood fuel (Sebesta Blomberg & Associates 2006). Under any situation, it was recommended that the plant should have at least one oil boiler on standby as a back-up for the biomass boilers. Oil may also be required to service the low summer loads and peak winter loads depending on the number and sizes of the boilers installed (Table 4). For example, option 3 consists of a single biomass boiler, which would be uneconomical to run for the small summer loads (Table 4). With option 3, an oil boiler would be used during the summer months. If a biomass system was installed that could accommodate the peak loads during the winter, then the system would sacrifice efficiency during the times when peak load is not met.

Table 4. A comparison of different biomass configurations and technologies that could provide central steam at Colby College. These are the results of a feasibility study done by the consulting firm Sebesta Blomberg & Associates, Inc. for Colby College. Source: (Sebesta Blomberg & Associates 2006)

Option	Technology	% Reduction in Residual oil or GHG emissions from 2007	% Reduction in 2007 gross emissions	% Rreduction in fuel costs (oil + wood) from Sebesta Blomberg baseline	Simple payback years	# Wood chip boilers	Load size
1	Stoker	89	56	45	3.4	2	25 and 4.5 MMBtu/hr
2	Gasifier	88	56	46	3.9	2	26 MMBtu/hr
3	Stoker	76	48	55	3.6	2	26 MMBtu/hr
4	Stoker	64	40	66	6.6	1	50 MMBtu/hr

*Sebesta Blomberg & Associates, Inc. calculated fuel use and costs for the different biomass scenarios based on a projected future baseline load of residual oil. Because 2007 was used as the baseline year for this study, the percent reduction in residual oil in each scenario from the projected baseline was used to calculate the amount of oil reduced based on a 2007 baseline. The estimates of fuel costs and savings presented are those based on projections with the Sebesta Blomberg & Associates, Inc. baseline.

Sebesta Blomberg & Associates, Inc. concluded that the easiest option would be for Colby to install one or two wood chip boilers able to meet two thirds of the peak load (Options 2 and 3). These smaller units would maximize the amount of time the machines run at best efficiency. Option 2, the Gasifier unit, would reduce emissions about 12 percent more than option 3, although the cost savings for option 2 is slightly less. Option 1 is estimated to have the highest reduction greenhouse gas emissions, but less than one percent more than option 2. Option 4 had the lowest emissions reduction potential and the longest payback time, although it represented the highest savings in fuel costs.

Other Alternatives

Biomass is currently the best known alternative to residual oil for Colby, with the potential to reduce gross emissions between 40 and 56 percent. However, if after further investigation the boilers are unable to be installed at Colby, a menu of other alternatives or offsets must be pursued. Without biomass, a combination of actions would need to be taken to collectively make an impact on residual oil use; examples include solar hot water and improvements in building insulation and efficiency.

Solar Hot Water

No studies have been currently completed investigating how much oil would be saved by switching to solar hot water, although there is a Spring 2008 Science Society and Technology course with students investigating solar hot water heating at Colby. It is likely that the biggest savings in residual oil use from solar hot water would occur at the athletic center. At Middlebury College, about 20 percent of the residual oil used during the winter months was for hot water heating (Isham *et al.* 2003). Table 5 shows the gross emissions reductions that could be achieved at Colby if solar hot water heating were able to reduce oil use by different percentages.

Table 5. Reduction in 2007 gross emissions at Colby College if solar hot water were able to reduce residual oil use by different percentages.

Percent reduction in Residual Oil	Percent reduction in gross emissions
5	3
10	6
15	9
20	13

Building Weatherization and Design

Improving building energy efficiency is another way to reduce residual oil use. For example, Middlebury College estimated that updating old-single pane windows in certain campus dorms with new double-pane windows would reduce emissions by 220 tons/year (Isham *et al.* 2003). Middlebury also found that reducing the heat in their academic buildings from 70 to 68 degrees Fahrenheit would reduce their emissions by 400 to 500 MTCDE per year, or a 2 to 2.5 percent reduction in heating and cooling emissions (Isham *et al.* 2003). Residential and academic buildings at Colby are set to stay between 65 and 70 degrees (PPD 2002). For new buildings, using energy efficient materials and design techniques such as passive solar or geothermal heating can help prevent residual oil emissions from rising as the campus grows.

Colby does have a policy where old buildings undergoing renovations are updated to meet the standards set by the American Society of Heating, Refrigeration, Air-conditioning Engineers[4] (ASHRAE), an organization that provides technological research and education on heating, air-conditioning, ventilation, and refrigeration (DeBlois, pers.

[4] http://www.ashrae.org/aboutus/

comm., ASHRAE 2008). Where possible, Colby tries and meets LEED standards during renovations, although in some cases ASHRAE standards can be more rigorous than LEED (DeBlois, pers. comm). Colby has plans for a new 32,000 square foot science building which will aim for a LEED certification, which will be heated and cooled by geothermal heating and have a carbon neutral source of electricity (Murphy, pers. comm). Geothermal does not produce carbon emissions because the system pumps would be powered by a zero carbon source of electricity.

Distillate Oil (# 2)

Distillate oil (#2) oil is a petroleum-based fossil fuel used at Colby to heat many of the smaller buildings, which are not connected to central heat. These buildings include the Millet House, Lunder House, the President's House, Hill House, and the Butler building. Distillate oil is also used to heat water in these buildings (DeBlois, pers. comm). Distillate oil also used to provide heat and hot water to the Colby Gardens, an off-campus property rented by the College as additional residential space (DeBlois, pers. comm).

Distillate oil contributed 1.65% to gross emissions in FY 2007. Of the three fuels residual oil, distillate oil, and propane used for heating at Colby, distillate oil has the second highest energy and greenhouse gas emissions per gallon and per unit energy (Table 3).

BIODIESEL

One alternative to distillate oil is biodiesel. Biodiesel is compatible with distillate oil, making the switch to biodiesel a relatively straightforward transition (Murphy, pers. comm). Unlike the more common petroleum diesel, biodiesel is made from animal fat and plant oils (Radich Undated).The carbon emitted by biodiesel combustion is offset by the carbon sequestered during the life of the fuel source, such as the soybean or vegetable matter from which the diesel was derived (Radich Undated). A life cycle analysis by the National Renewable Energy Laboratory compared the petroleum consumed from the production and use of petroleum diesel and soybean-based biodiesel, assuming that biodiesel production did not significantly increase the demand for soybeans (Radich Undated). The study found that biodiesel reduced petroleum use by 95% compared to petroleum diesel (Radich Undated). While the emissions from production and transportation to the point-of-use should be considered when selecting the most climate friendly fuel, these Scope 3 emissions are not included in the Colby emissions inventory.

Biodiesel can be mixed with petroleum diesel to create different “blends.” For example, a mix of 5% biodiesel and 95% petroleum diesel is labeled as a “B5 mix.” A mix of 20 percent biodiesel and 80% petroleum diesel would be labeled as B20. Pure biodiesel is labeled as B100.

Since 2006, Colby has used a B10 mix as a substitute for some of the distillate oil demand. Biodiesel contributed 35 MTCDE, or 0.17% to gross emissions in 2007. Colby has encountered technical difficulties with biodiesel (Murphy, pers. comm). However, it is anticipated that the quality and technology of the blends will improve in the near future, with suitable technology potentially available as soon as 2010 (Murphy, pers. comm). Middlebury has replaced all of its distillate oil with a B20 blend, and the school’s carbon neutrality proposal recommends experimenting with increasingly higher blends to further reduce emissions (Middlebury College 2007).

Given the relatively small contribution of distillate oil to gross emissions, the reduction in gross emissions from any biodiesel mix rounds to between 1 and 2 percent, depending on whether the distillate oil used at Colby Gardens is included in the calculation (Table 6). Distillate oil used at the Colby Gardens is included in the 2007 baseline, but is anticipated that by 2010 Colby's unusually high enrollment will return to normal levels and the school will stop renting the Gardens facility (Terhune, pers. comm).

Table 6. Reduction in 2007 gross greenhouse gas emissions at Colby College from the substitution of different blends of biodiesel for distillate oil.

Biodiesel Mix	% reduction distillate emissions	% reduction gross emissions
including Colby Gardens		
20	20	1
50	50	1
100	100	2
excluding Colby Gardens		
20	20	1
50	50	1
100	100	1

OTHER ALTERNATIVES

In addition to switching to biodiesel, improvements in energy efficiency, building design, and water heating systems mentioned the residual oil section can also help reduce distillate oil use.

Propane

Propane is a liquefied petroleum gas used at Colby to heat the zamboni room in the Athletic Center and for cooking by Colby Dining Services (DeBlois, pers. comm, EIA 2008). Of the fuels used for heating at Colby, propane has the lowest energy and greenhouse gas emissions per gallon and per unit energy (Table 3). Since propane contributed only 0.8% to Colby's gross 2007 emissions, offsetting is most likely option to handle this source.

PPD Vehicle Fleet

In 2007, vehicle emissions from the PPD fleet contributed 1 % of Colby's gross emissions (Figure 4). The majority of the PPD fleet is fueled by gasoline, but emergency vehicles, such as snow-removal equipment, are powered by diesel fuel. Of the 225 MTCDE emitted by these vehicles, 194 MTCDE were from gasoline vehicles 31 MTCDE were from diesel vehicles.

BIODIESEL

One alternative to petroleum diesel is biodiesel. Diesel engines can be modified to run on biodiesel. As mentioned in the distillate oil section, it is common to create fuel mixes that are part biodiesel and part petroleum diesel. A pure biodiesel blend would have a net carbon emissions level of zero.

The College is currently experimenting with a B10 mix (10 percent biodiesel and 90 percent petroleum diesel) to heat buildings (see Distillate Oil (#6): Biodiesel). However, PPD does not want to experiment with using biodiesel in its diesel vehicles for safety reasons. Because emergency equipment is powered with diesel fuel, the consequences of a technology malfunction are high (Murphy, pers. comm). PPD diesel vehicles only contributed 0.2 percent to 2007 gross emissions, but once biodiesel technology has matured and its reliability has increased, it could be an acceptable alternative to petroleum diesel.

Vehicle Efficiency

There is currently no available low-carbon fuel substitute for gasoline. Colby does have a policy for purchasing new vehicles where the new vehicle must have a higher fuel efficiency than the vehicle being replaced (Murphy, pers. comm). This can help reduce PPD vehicle emissions in the long term but will not eliminate them entirely. Given the lack of carbon free alternatives to gasoline and diesel, most vehicle emissions will need to be offset to achieve carbon neutrality.

Fertilizer

Fertilizer application produces the greenhouse gas N_2O when nitrogen applied to the soil volatizes and forms N_2O. Fertilizer application contributed the least (0.01 percent) to 2007 gross emissions (Figure 4). Colby used both synthetic and organic fertilizer for landscaping purposes (DeBlois, pers. comm). The synthetic fertilizer had a nitrogen content of 23 percent and contributed 0.08 percent to gross emissions, while the organic fertilizer was 21 percent nitrogen and added 0.04 percent to gross emissions. Per pound of nitrogen applied, synthetic fertilizer produces more MTCDE per pound than organic fertilizer (0.0040 MTCDE and 0.0038 MTCDE, respectively) (CA-CP 2006a).

Scope 3 fertilizer emissions were not included in the inventory. However, the differences in Scope 3 emissions from the production and transportation of fertilizer can be large. Producing synthetic nitrogen fertilizer is an energy intensive process, where nitrogen and hydrogen gases are held to react in a tank at high pressure and temperature (Brown *et al.* 2003). The fertilizer must then be packaged and shipped to its destination for use. Compare this to organic fertilizer which is usually in the form of organic waste, such as manure or compost, which does not involve much processing or many external inputs.

ORGANIC FERTILIZER AND REDUCING NITROGEN CONTENT

One way to reduce emissions from fertilizer use is to switch from synthetic to organic fertilizer, which has fewer greenhouse gas emissions per pound of nitrogen. If all of the fertilizer Colby applied in 2007 was organic and 21% nitrogen, emissions would drop by 0.001 percent, although the reduction in Scope 3 emissions could be much greater. Colby could also experiment with fertilizers that have a lower nitrogen content, as many organic fertilizers have around a 4 percent nitrogen content, manure has about a 1 percent nitrogen content, and synthetic fertilizers have labels indicating their nitrogen content (CA-CP 2006b).

Refrigerants and Chemicals

Hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs) are greenhouse gases that are often used for refrigeration (CA-CP 2006b). These gases are alternatives to the ozone depleting chlorofluorocarbons (CFCs) that are being phased out under the Montreal Protocol and the United States Clean Air Act (CA-CP 2006b). In theory, these gases are used in a closed system and would not contribute to GHG emissions. However, it is important to include accidental leaks in the inventory since these chemicals are potent greenhouse gases. Depending on the type of HFC, the global warming potential (GWP) of these gases range from 12 to 12,000 times the GWP of carbon dioxide (CA-CP 2006a). The GWP of PFCs have a range similar to HFCs, while some inorganic chemical gases, such as sulfur hexafluoride (SF6) with a GWP of 22,000, are also strong GHGs (CA-CP

2006a). In 2007, there were no releases of GHG refrigerants at Colby (DeBlois, pers. comm).

Scope 2

Purchased Electricity

In 2007, Colby purchased 13,978,862 kWh of electricity for the Colby campus and Colby Gardens (DeBlois, pers. comm). Colby purchased its electricity from Constellation NewEnergy and had a fuel mix of 50% Maine biomass in the form of wood waste by-products and 50% Maine hydropower (MacLeay 2003). Colby switched to this green fuel mix in October of 2003 (MacLeay 2003). This fuel mix is considered carbon neutral since the carbon released from the biomass woodwaste is equivalent to that which would have been released by the decomposition of the wood (see Residual Oil (#6): Biomass).

Hydroelectricity does not produce carbon emissions from the generation of the electricity (Pacca and Horvath 2002). However, vegetation in the area flooded by the dam can release carbon as it decays. Additional carbon can no longer be sequestered because the vegetation has been replaced by water (Pacca and Horvath 2002). Some hydro electric projects have been found to have a net release of carbon; for example, hydroelectric dams in tropical rainforests are generally net emitters of carbon and methane, although these emissions may still be less than emissions from fossil fuels used to generate the same amount of electricity (Fearnside 1997).

However, the rate of decay tends to be slower in colder environments, leading to lower annual emissions levels (Pacca and Horvath 2002). While no scientific studies were found examining biomass decay from dams in Maine, it is generally assumed that the cold temperatures in this region, as opposed to the tropics, result in little or no annual emissions from biomass decay. In addition, the Carbon Calculator considers hydroelectric power to have zero carbon emissions. As such, Colby's current electricity mix of Maine-based biomass and hydroelectric are measured as having zero carbon emissions. If the electricity used in 2007 were generated using the old fuel mix of 70 percent coal and 30 percent hydroelectric, then gross emissions would have increased by 11,620 MTCDE or 57 percent.

Scope 3

College Related Transportation

College related transportation is the second largest source of emissions at Colby, contributing 17% of gross emissions in 2007 (Figure 4). This category encompasses emissions from student, faculty, and staff travel to academic or extracurricular activities associated with the College. Moving vans rented from Pro Moving services to transport items between buildings on or around campus were also included. Air travel contributed the majority of emissions, with cars, buses, trains, and moving vans adding only 0.9 percent to gross emissnios (Figure 5).

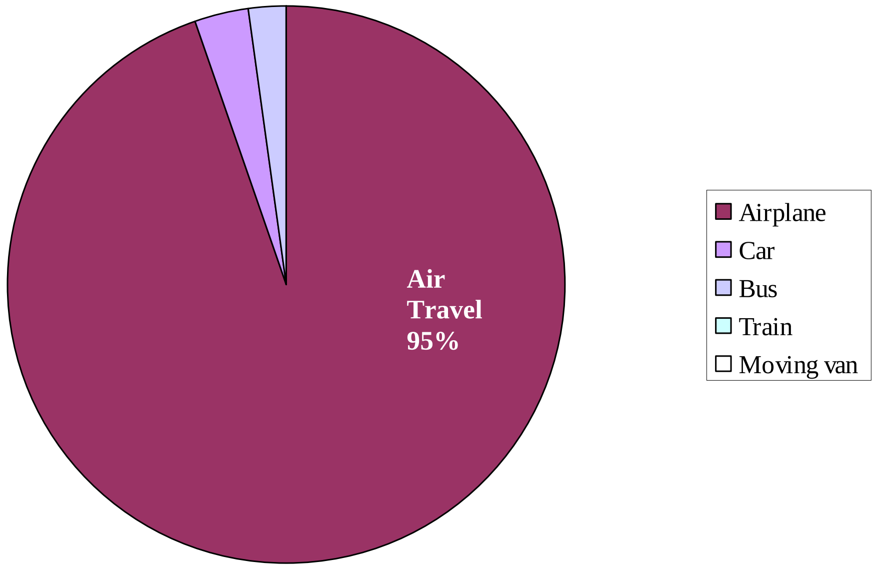

Figure 5. Composition of greenhouse gas emissions from college transportation emissions at Colby College in 2007. Air travel was responsible for the majority of emissions.

It is not surprising that air travel contributed the majority of emissions since of all the modes of transportation used for college transportation, air travel has the highest impact on climate change per passenger kilometer (Chapman 2007). This is because jet fuel combustion produces greenhouse gases in addition to carbon dioxide, which have a greater impact on global warming when released at high altitudes than when emitted at ground level (Williams *et al.* 2002). For example, NO_x emissions react photochemically with sunlight to produce ozone, a greenhouse gas. The same amount of NO_x produces more ozone when emitted high in the atmosphere than on the ground (Chapman 2007). Similarly, water vapor released directly into the stratosphere remains as a greenhouse gas, while water vapor released at ground level has the potential to be removed from the atmosphere through precipitation (Chapman 2007).

Alternate Modes of Transportation and Offsetting

Emissions from air travel at Colby could be reduced by encouraging the use of other modes of transportation, such as train, bus, or carpooling. Some events will be located too far from Colby to feasibly take a different mode of transportation and air travel will be required. For all college related transportation emissions that cannot be reduced, offsets will be needed to achieve neutrality.

Commuting

The ACUPCC requires that participants account for commuter emissions. Student, faculty, and staff commuters contributed 8 percent of gross emissions in 2007 and were the third largest source of carbon pollution at Colby (Figure 4). Since staff commuters outnumber faculty, and faculty outnumber student commuters, staff collectively produced the most emissions, followed by faculty, and then by student commuters. Emissions calculations for faculty and staff commuters used in this thesis are likely overestimates due to the demographic data used and assumptions entered into the Carbon Calculator (see Appendix A).

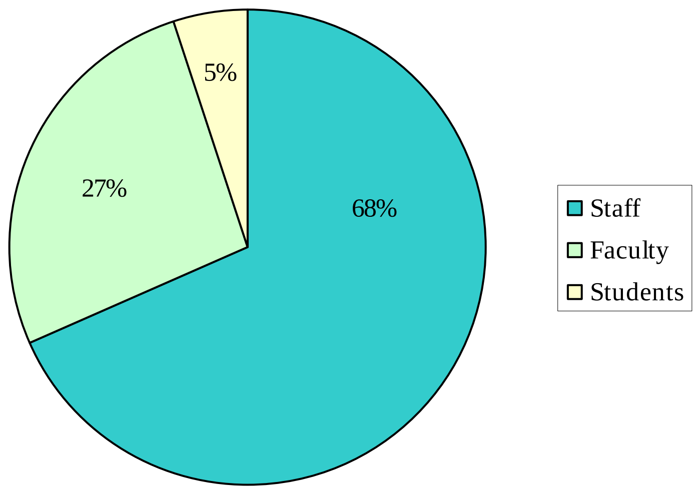

Figure 6. Relative contribution of faculty, staff, and students to commuter emissions at Colby College in 2007.

INCENTIVES

Since Colby does not own the vehicles driven by its commuters and it cannot control the commuting behaviors of its students and employees, the college cannot use its own purchasing power to change the types of cars or the amount of driving from commuters. However, the college could investigate different types of incentives that would entice commuters to carpool, reducing the number of cars driving to Colby each day, and to purchase more fuel efficient vehicles when investing in a new car. Ideas for such incentives include: preferential parking for carpoolers and monetary supplements for employees purchasing fuel efficient vehicles.

Given that student, faculty, and staff commuting is the third largest source of emissions at Colby, it may be worthwhile for the College to create a committee to brainstorm and investigate programs that would reduce commuter vehicle emissions at Colby. Also, some faculty and staff either walk or commute by bicycle. Facilitating these forms of travel with measures such as the showers for commuters at the Diamond Building could also be beneficial.

Bates College has recently started initiative where students, faculty, and staff can sign up for the car-sharing program, Zipcar (Bates College 2007). Zipcar users have access to two Toyota Hybrid Priuses which can be rented on an hourly or daily basis (Bates College 2007). The goal of the program is to reduce the number of students who bring cars to campus and provide a fuel efficient mode of vehicle transport for when students need a vehicle (Bates College 2007).

Bates has also started a bicycle co-op, where students can share bicycles as an alternative to driving around campus (Bates College 2007). Colby is also considering a similar program. While these types of programs may be effective in reducing emissions from student errands or traveling around campus, these types of trips are not included in the Colby greenhouse gas inventory. As such, the effects would not be reflected in future emissions calculations. Current calculations of commuting emissions only include student travel to and from campus on a daily basis, not trips made for personal reasons. Even though the Zipcar and bike sharing programs are more likely to reduce personal vehicle emissions rather than commuter emissions, they could still have an impact on Colby's overall carbon footprint.

OFFSETS

Most of the commuter emissions will need to be offset. The cost of purchasing offsets for commuter emissions in 2007 would likely range between $20,448 and $34,080, depending on the price of carbon (see Offsets: Cost of offsetting emissions by source Table 8). The College may want to implement a fee for parking passes to help fund the purchase of offsets. Colby does not currently charge for parking, but if the college decides to become carbon neutral, it may be beneficial to internalize the costs of carbon pollution from the vehicles by charging for parking.

IMPROVED ACCOUNTING

Along with any incentive to reduce emissions from commuting, data collection would need to be expanded so that reductions in emissions from behavior changes can be reflected in the inventory. For example, part of the reason that commuter emissions from 2007 are an overestimate is because it was assumed that 100 percent of the commuters drove to campus alone. If a new incentive program increased the number of people who carpool to the campus, there is currently no data collection mechanism that would allow the 100 percent assumption to be replaced with a more accurate number. It is also likely that the number of days commuters drove to campus was overestimated, especially among faculty and staff. For a detailed description of how commuter emissions were calculated, see Appendix C.

One way to improve data collection could be to administer a survey to commuters to ask about carpooling behavior and how often, if ever, they walk, bike, or take a different zero emissions form of transportation to the campus. When cars are registered with security, part of this registration could include answering a question on fuel economy or checking a box indicating truck, SUV, or car to allow the calculator to capture changes in emissions from a change in the commuter fleet composition.

Solid Waste

In 2007, landfilled waste was the fourth largest contributor of emissions at Colby, producing 7 percent of gross emissions (Figure 4). Colby’s solid waste is landfilled without methane recovery or electricity generation at the Norridgewock Landfill and

Transfer Station owned by Waste Management, Inc in Norridgewock, ME (DeBlois, pers. comm). Landfills release methane and carbon dioxide emissions as organic waste decomposes (EPA 2002). The carbon dioxide emissions are not included in the inventory since the carbon dioxide would have been emitted into the atmosphere as part of the natural lifecycle of the biomass (EPA 2002). The Scope 3 carbon dioxide emissions from hauling the waste to the landfill are included, but are already incorporated into one of the emissions factors used to convert the amount of landfilled waste into emissions and are not calculated separately (see Appendix C).

Unlike carbon dioxide, methane emissions, which result from the decomposition of organic matter by anaerobic bacteria are included in the inventory since methane emissions would not have been produced if not for the anoxic environment created by the landfill (EPA 2002).

Alternative Waste Disposal Methods

Different methods of waste disposal result in different levels of emissions. Table 7 shows the emissions that would result from the 1,469 short tons of solid waste Colby generated in 2007 under different waste disposal systems. An alternative to landfilling, waste can also be disposed by incineration. Waste incineration results in mostly carbon dioxide emissions and some N_20 emissions, although carbon dioxide emissions from biogenic sources would not be included in the inventory (EPA 2002).

Table 7. A comparison of the 2007 greenhouse gas emissions from solid waste at Colby College under different waste disposal systems*.

	Waste to energy plant: Mass Burn Incinerator	*Waste to energy plant*: Refuse Derived Fuel (RDF) Incinerator	*Landfilled Waste*: methane recovery and electricity generation	*Landfilled Waste*: methane recovery and flaring	***Landfilled Waste*: no methane recovery or electricity generation**
MTCDE	-162	-54	215	377	**1454**

* Only greenhouse gases were included in this analysis of options. There could be other pollutants resulting from each waste management option that may need to be included when making a final decision on waste management strategies.

Energy from incinerating solid waste can be captured and used to generate electricity in one of two waste-to-energy schemes: a mass burn incinerator and a refuse derived fuel incinerator (RDF) (EPA 2002). A mass burn incinerator produces steam and/or electricity from unprocessed solid waste, whereas a RDF burns waste that has been processed so that combusted material is more uniform and easily combusted (EPA 2002).

Waste-to-energy plants actually produce a net reduction in emissions since amount of carbon emitted from the combustion of the waste is less than the carbon that would have been emitted in generating the steam or electricity by conventional means (Table 7) (EPA 2002). Landfilled waste with methane recovery, coupled with either electric generation or flaring, had much lower emissions than landfilled waste without methane recovery due to a reduction in emissions from conventional utility-generated electricity. Landfilled waste without methane recovery, Colby’s current waste management strategy, produces the highest amount of carbon emissions (Table 7).

According to the Morning Sentinel, a local newspaper, Waste Management Inc. is planning a methane capture and electricity generation plant at the Norridgewock landfill, and construction could begin as early as April or May 2008 (Grard 2008). If this gas to electricity facility were to be completed, then Colby's solid waste emissions would drop by 85% and gross emissions would drop by 6%. Another option would be to use a different type of waste management system, such as a waste to energy mass burn or refused derived fuel system. However, before switching waste disposal sites, consideration of the emissions from transportation the waste to a potentially farther location (Norridgewock is 14 miles from Colby, according to Mapquest.com), and any non-greenhouse gas related environmental impacts associated with the new disposal system should be considered.

WASTE REDUCTION

Another way to reduce emissions from waste is to reduce waste itself, since the amount of emissions produced depend on the amount of waste landfilled. Colby already composts 100% of its food waste from the dining halls at the Hawk Ridge Composting facility in Unity, ME and composts yard waste, both of which count as offsets for the College (Colby Dining Services 2008). Colby also offers recycling in academic and residential buildings, which diverts waste from landfills. Colby dining services buys bulk foods whenever possible to reduce packaging waste, and printing paper for college printers is purchased in bulk (EAG 2004a). One particularly important program is Colby RESCUE. Unwanted items from student dorm rooms are collected and resold at the start of the following year, greatly reducing the amount of waste sent to the landfill (EAG 2004b). Ensuring that these programs are maintained and expanding them where possible would be conducive towards reducing the College solid waste emissions.

Summary of Emissions and Reduction Strategies by Source

Sources of emissions at Colby during the baseline year of 2007 are summarized in Table 8. Potential ways to reduce emissions and the impact of each action on gross emissions are also listed in the table. Actions where no reduction in gross emissions was shown meant that the impact of the action was unknown.

Table 8. Summary of greenhouse gas reduction strategies at Colby College and their impact on 2007 gross emissions.

Source	Alternative/Reduction method	% Reduction in gross emissions
Residual oil	Biomass Option 1	56
	Biomass Option 2	56
	Biomass Option 3	48
	Biomass Option 4	40
	Solar Hot Water	--
	Expansion of geothermal heating to existing buildings	--
	Building weatherization	--
	Efficient building design	--
College Related Travel	Avoiding air travel by using alternate modes of transportation	--
Commuting	Incentives for carpooling, efficient vehicle purchase, etc.	--
Landfilled waste	Waste to energy (mass burn incinerator)	8
	Waste to energy (refuse derived fuel incinerator)	7
	Landfilled waste (methane recovery and electricity generation)	6
	Landfilled waste (methane recovery and flaring)	5
	Waste Reduction	---
Distillate Oil	Biodiesel B20	1
	Biodiesel B50	1
	Biodiesel B100	1
	Expansion of geothermal	---
Distillate oil and propane	Building weatherization	---
	Efficient building design	---
PPD Vehicles	Biodiesel	0.2 (if B100)
	Improved fuel efficiency	---
Fertilizer	Switch to all organic	0.001
	Use fertilizer with lower N content	---

OFFSETS

What is an Offset?

A *carbon offset* is any activity that reduces carbon emissions to compensate for carbon released by a different activity (Dautremont-Smith *et al.* 2007a). Carbon offsetting can be used either as a complement or a substitute for on-campus reductions. While the entity that is trying to reduce emissions can perform the offsetting activity, often the offset involves a financial transaction with a different organization. Since carbon offsets are generated to neutralize a specific amount of emissions, and generally involve at least two parties, the amount of carbon reduced must be quantifiable. For a carbon offset to be credible, it must also be additional (Kollmuss and Bowell 2007). Since the effect of carbon pollution on the warming of the planet is the same regardless of where the emissions are released, offsets and emissions do not need to occur in the same location.

To illustrate the concept of carbon offsetting, consider a simple example where a person wants to offset her emissions from a plane flight that will produce one ton of carbon. If the vacationer decided to plant enough trees to offset a ton of carbon, then he needs to know how much carbon will be sequestered by the trees to know how many to plant. With trees, the vacationer may also need to know the rate at which the plants grow to know how long it would take for enough carbon to be incorporated into the tree biomass to offset the trip. The vacationer would also need to have a mechanism to track the condition of the trees so that further offsetting activity could happen if a storm or other event occurred that killed the trees, causing them to decay and re-release their carbon into the atmosphere. Given the amount of time and resources needed to manage the trees, the vacationer may decide to pay an organization to plant, manage, and monitor the trees into the future.

While quantifying the carbon by an offset is an important first step, the most important criterion for offset quality is additionality. For the emissions reduction project to count as an offset, the reduction in carbon must not have otherwise occurred without the purchase of the offset (Kollmuss and Bowell 2007). For example, if a forester was going to plant the trees anyway, giving the forester money to help plant the new trees would not be an additional reduction. Likewise, if a timber company was being paid to not harvest a stand of trees, but the company harvested the same number of trees in a different location, a phenomena called “leakage,” then that transaction would not count as an offset since no reduction in carbon occurred beyond a business-as-usual baseline (Kollmuss and Bowell 2007).

Another problem with addressing the additionality of offsets is ensuring that they are not double counted (Kollmuss and Bowell 2007). For example, if a company paid for the installation of a wind turbine at an elementary school that previously generated its electricity from coal and received credit for the emissions reduction, then if the elementary school later decided to become carbon neutral it could not count the wind emissions as a reduction since the offset purchasing company is already counting the wind power as an offset. The school would have to reduce emissions elsewhere in the amount of the wind offset to truly be carbon neutral.

Carbon offsets used to fulfill regulatory obligations, such as the Regional Greenhouse Gas Initiative (RGGI) or the Clean Development Mechanism will be overseen by a regulatory body. However, no official governing body exists to ensure the quality of voluntary carbon offsets. Despite this, offset providers often enlist a third party to verify that the organization's offsets meet the standards claimed by the provider. Since the market for carbon offsets is not yet mature, especially in the United States, any institution using offsets to help achieve neutrality must carefully investigate offset options before purchasing to ensure that offset quality criteria are met (Kollmuss and Bowell 2007). Clean-Air Cool-Planet[5], an environmental nongovernmental organization, has published a comparison and ranking of various offset providers which may be useful to any institution selecting offsets (CA-CP 2006c). Tufts University[6] also has a report on purchasing offsets for air travel emissions, which also contains useful information on offsetting in general.

Offsetting Activity in 2007

Composting and the purchase of wind power Renewable Energy Credits (RECs) collectively offset Colby's gross emissions by 176 MTCDE in 2007, resulting in a net emissions level of 20,196 MTCDE. Forested lands owned by Colby also sequester carbon, which could potentially supply future offsets needed at Colby. These three offsets are discussed in the following sections.

Composting

When managed properly, compost does not produce methane like unmanaged biogenic waste in landfills (CA-CP 2006b). Applying carbon to soils helps sequester carbon, which counts as a carbon offset for the college. Colby began composting pre- and post-consumer food waste in all three of the schools dining halls in 2002, although data were only available for inclusion in the inventory since 2005 (Upton 2007). In the spring of

[5] http://www.cleanair-coolplanet.org/ConsumersGuidetoCarbonOffsets.pdf
[6] http://www.tufts.edu/tie/tci/pdf/TCI_Carbon_Offsets_Paper_April-2-07.pdf

2007, Colby Dining Services expanded this program to include food service paper, compostable plates, and unbleached napkins from the school's catering services (Upton 2007). During 2007, Colby composted 89.87 short tons of food waste, which resulted in a net reduction of 16 MTCDE from the gross emissions value of 20,372 MTCDE (DeBlois, pers. comm). Colby also composts landscaping materials, such as twigs and leaves. This is not currently included in the inventory due to a lack of data, but could be counted as an offset if the college is able to measure composted yard materials (DeBlois, pers. comm).

Renewable Energy Credits (RECs)

Renewable Energy Credits (RECs) represent electricity generated from renewable resources. In most cases, the electricity supplied to the REC purchaser is not generated by electricity resulting from the REC purchase. However, if the amount of RECs purchased is equal to or greater than the fossil-fuel generated electricity demand of the buyer, the RECs can act as an offset since it allows electricity demand elsewhere to be met with renewable energy instead of fossil fuels as long as issues such as additionally and double-counting have been addressed.

Colby began purchasing wind RECs in 2005 from Constellation NewEnergy[7] to receive credit towards a LEED certification for the Alumni Center and later in 2007 for the Diamond Building (Table 2) (DeBlois, pers.comm). These RECs are green-e certified[8], which is a third party certification program designed by the Environmental Protection Agency and World Resources Institute. The green-e certification is only awarded to offset providers that have met certain standards to prove the authenticity, additionality, and avoidance of double counting of their offsets (Constellation

[7] http://www.newenergy.com/portal/site/cne/
[8] http://www.green-e.org/

NewEnergy 2008, Green-e Governance Board 2007). Since the RECs are purchased in addition to Colby's green electricity, which is already carbon neutral, the RECs function as an offset to the College's gross emissions. In 2007, Colby purchased 202,460 kWh of wind power RECs which offset 160 MTCDE of gross emissions (CA-CP 2006a).

Forest Preservation

The ACUPCC allows schools to use forest stands in their carbon inventories, provided that these forests meet the standards set in the Greenhouse Gas Protocol's GHG Protocol's Land Use, Land-Use Change, and Forestry Guidance (LULUCF) for GHG Project Accounting[9] (Dautremont-Smith *et al.* 2007a, Greenhalgh *et al.*). Through the process of photosynthesis, plants remove carbon dioxide from the atmosphere to build their biomass. Forested areas hold carbon in plant biomass that, if the land were cleared, would be re-released back into the atmosphere adding to carbon emissions.

Since emissions are calculated on an annual basis, the amount of carbon offset from forests at Colby in 2007 was calculated by estimating the amount carbon added to the plant biomass from forest growth in a single year, although no figure was available to indicate how much carbon was lost through plant decay (see Appendix E). Most of Colby's forests are in the earlier stages of succession, which means that their annual growth and carbon sequestration rates are high (Firmage, pers. comm.). As forests age and reach their climax stages, the annual growth, and by default carbon sequestration rates, decline.

When Colby moved from downtown Waterville to its current location around 1937, the majority of campus was not forested (Colby College 2008a, Firmage, pers. comm). As such, it is possible that much of the forested land at Colby could qualify as a

[9] http://www.ghgprotocol.org/files/lulucf-final.pdf

reforestation project. Colby owns 315 acres of forested land on-campus, as well as a 243 acre woodlot in Vasselboro, ME, and the 21 acre Colby-Marston Preserve. The total carbon held in the biomass of Colby's forests was calculated at 1,324,212 MTCDE, and the biomass added from growth in 2007 at 22,577 MTCDE.

Even though these numbers were calculated based on data and assumptions that are an approximate of forest activity at Colby, this is an exciting finding because, according to these figures, carbon sequestration from these sources would be more than sufficient to offset all of Colby's gross emissions in 2007. Given the impact of Colby's forests on net emissions, the College may want to undertake a more comprehensive study of forest behavior and composition that would allow Colby to measure forest carbon using the guidelines in the GHG Protocol's LULUCF accounting guide.

Since Colby has been allowing the forests to regenerate as part of its business-as-usual practices and the forests would continue to grow regardless of whether the school was focused on climate issues, it is not clear that forest growth represents an "additional" reduction in carbon. Since the problems associated with climate change are predicted to occur based with the current types of human activity and ecosystem status, and Colby's forests and activity are theoretically included in the planet's baseline, Colby should not substitute significant emissions reductions, such as biomass, for forest carbon sequestration.

However, it is also true that Colby's land-use practices have allowed forests to regenerate and allow additional carbon to be removed from the atmosphere. While valid arguments exist both for excluding and including forest growth in the inventory, a compromise would be for the school to continue to pursue carbon reductions as if its emissions level were not offset by forest growth, but instead of purchasing offsets from external providers, consider Colby's forests sufficient to offset the remaining emissions. This reflects the fact that Colby's forest sequestration is not additional under business-as-usual activities, but is additional in the sense that if a different group possessed the land instead of Colby, the land may have a different land use such as agriculture, development, or resource extraction.

Doing this would allow Colby to devote the thousands of dollars it would have spent purchasing offsets on campus emissions reduction initiatives instead (Tables 7 and 8). Real emissions reductions on campus in many cases also impact Scope 3 emissions not included in the inventory that would not be impacted if only offsets were pursued. Carbon sequestered in excess of Colby's current emissions could be nominally counted towards offsetting the Scope 3 emissions that, while potentially large, are unable to be quantified.

Cost of Offsetting Emissions by Source

In "A Consumer's Guide to Retail Carbon Offset Providers," published by Clean Air – Cool planet, the price per ton of carbon in the top tier listing of offset providers ranged from $12 to $20 /ton[10] (CA-CP 2006c). Using these bounds, Table 8 estimated a high and low cost of offsetting emissions by category and the cost to offset all the gross emissions from 2007.

[10] The price range listed for Tier 1 offset provider AgCert/Driving Green was listed as $8-13/ton.

Table 8. Cost to offset 2007 gross emissions by source at Colby College. Source for carbon prices: CA-CP 2006c

Source	% contribution to 2007 gross emissions	Cost ($) low estimate ($12/ton)	Cost ($) high estimate ($20/ton)
Residual oil	63	154,440	257,400
College related travel	17	42,768	71,280
Commuting	8	20,448	34,080
Landfilled waste	7	17,448	29,080
Distillate oil, propane, and B10 biodiesel	3	6,300	10,500
PPD vehicles	1	2,700	4,500
Fertilizer	0.1	300	500
Totals	100	244,464	407,440

ACHIEVING CARBON NEUTRALITY

Forecasting

While the emissions actions modeled in this section do not show all the ways emissions could be reduced at Colby, they are representative of actions for which quantitative data were available to make projections. For a more comprehensive discussion on GHG reducing possibilities, see Emissions Reduction Strategies by Scope. See Appendix F for an explanation of the calculations and assumptions used to forecast emissions.

Carbon emissions at Colby College were projected from 2008 through 2017 (Figure 7). Seven different emissions scenarios were considered (see Appendix F). Scenarios I and II were business-as-usual cases, which showed the progression of emissions if the college did not take climate action beyond any existing plans (see Appendix F). A time table of emissions for Scenario I and II is as follows:

- 2008 – the Cotter Union/Pulver Pavilion renovation is complete, resulting in 9,026 sq. ft. of new building space and an estimated 131 MTCDE of GHG emissions.
- 2009 – the 9,557 sq. ft. addition of the new Colby Bookstore in Cotter Union is complete, adding an estimated 139 MTCDE.
- 2011 – in scenario II, a methane recapture and electricity generation facility planned for the Norridgewock Landfill becomes operational (see Solid Waste: alternatives to waste disposal). Scenario I assumes that the facility is not built.
- 2012 – A renovation of Roberts Hall and the construction of a new science building on the Colby green is complete. Colby Gardens is no longer rented since Roberts has been converted to a residential space. The new science building produces zero emissions due to geothermal heating and green electricity; emissions from distillate oil use at the Colby Gardens is eliminated, dropping emissions by 198 MTCDE.
- 2013 – quality and technology issues with biodiesel have been resolved, and a biodiesel blend of B100 replaces the remaining distillate oil (Distillate oil: biodiesel). Emissions drop by 179 MTCDE.

Scenarios III, IV, and V are the same as the business-as-usual scenario II, which assumes that the Norridgewock Landfill constructs a methane gas to electricity facility. In addition, they predict the effect on emissions if solar hot water were able to reduce residual oil use by 5, 10, or 15 percent, respectively. These three scenarios also show a reduction of 31 MTCDE from switching the PPD diesel vehicles to run on B100 and from replacing synthetic fertilizer with the currently used organic fertilizer.

- 2010 – switch to all organic fertilizer reduces emissions by 2 MTCDE.
- 2013- solar hot water heating reduces emissions by 611 MTCDE (III), 1,222 MTCDE (IV), or 1,833 MTCDE (V) depending on the scenario
- 2017-B100 biodiesel reduces emissions by 31 MTCDE

Scenarios VI and VII show the impact of using biomass instead of residual oil at the cogeneration facility. Scenario VI has the same characteristics as scenarios III-V, except it models the impact of biomass instead of solar hot water. Scenario VII differs from scenario VI because it assumes Colby hauls its waste to a waste-to-energy mass burn incinerator facility instead of a landfill with methane recapture and electricity generation.

- 2011 – waste is brought to a mass burn incinerator (VII only)
- 2013 – biomass replaces the majority of residual oil at the cogeneration facility

Scenarios VI and VII resulted in the largest reductions in greenhouse gas emissions, reducing 2007 gross emissions by 64 and 66 percent, respectively (Figure 7, Table 9). The switch to biomass at the cogeneration facility in VI and VII was responsible for these large reductions in emissions, as compared to scenarios I through IV which reduced 2007 emissions between 0.5 (scenario I) and 16 percent (scenario V).

Figure 7. Future projected greenhouse gas emissions at Colby College after 2007 through 2017. Scenarios I and II represent baseline business-as-usual scenarios; Scenario I would occur if a proposed waste to electricity facility at the Norridgewock Landfill is not built. Scenario II assumes that the facility is constructed and comes on-line in 2011. Scenarios III – V show the potential impact of solar hot water on emissions. Scenario VI and VII model emissions after switching to biomass boilers at the cogeneration facility – scenario VI assumes that waste is brought to a landfill with methane gas recapture and electricity generation. Scenario VII assumes waste is brought to a mass burn incinerator with electricity generation.

Table 9. Gross greenhouse gas emissions and the cost of offsetting at Colby College in 2017. The present value (PV) of the low and high cost estimates of offsets was calculated using a discount rate of 3 percent. Source for carbon prices (CA-CP 2006c). Net emissions in 2017 were calculated using the amount of offsets generated or purchased in 2007 (176 MTCDE), and do not include forest carbon sequestration.

	I	II	III	IV	V	VI	VII
Gross 2017 emissions (MTCDE)	20,266	19,027	18,382	17,771	17,160	7,315	6,938
PV Cost ($) to offset gross 2017 emissions ($ 12/ton)	186,382.70	174,987.70	169,061.10	163,442.70	157,821.50	67,273.12	63,805.85
PV Cost ($) to offset gross 2017 emissions ($ 20/ton)	310,637.90	291,646.10	281,768.50	272,404.40	263,035.80	112,121.90	106,343.10

Since biomass reduced greenhouse gas emissions by such a large amount compared to scenarios I –V, the college would need to spend less money purchasing offsets under scenarios VI and VII (Table 9). In addition, two of the largest sources of emissions reductions, switching to biomass at the cogeneration facility and the construction of a methane gas-to-electricity plant at the Norridgewock landfill, would not be costly for Colby (see Residual oil (#6): Biomass, Table 4). The two options for converting to biomass at Colby considered in this model are predicted by the Sebesta Blomberg & Associates, Inc. report to have a payback time of between 3.4 and 3.9 years and cut fuel costs between 45 and 46 percent (see Residual oil: Biomass, Table 4).

The methane gas-to-electricity landfill facility would not add any cost to Colby since the project is being pursued by a third party, Waste Management Inc (see Solid Waste: Alternative waste disposal methods). It would be more difficult to benefit from the extra percent reduction in emissions that could be achieved by using a new waste disposal facility that incinerates in a waste-to-energy mass burn facility since the Colby would need to find and form agreements with the new facility, and the costs of switching are unknown. Non-greenhouse gas related environmental concerns may also need to be investigated if considering switching waste disposal methods.

Interestingly, even under the business-as-usual scenario I, which does not incorporate emission reductions from a gas-to-methane facility at the landfill, greenhouse gas emissions are not projected to increase, and are even estimated to be 106 MTCDE less than in 2007. Even though the additional building area in Cotter Union added to emissions, the elimination of emissions from distillate oil use by switching to biodiesel and losing the Colby Gardens more than compensated for the Cotter emissions.

Colby could, of course, achieve carbon neutrality immediately by purchasing enough offsets to neutralize its emissions. Based on the 2007 gross emissions level of 20,372 MTCDE, this would mean spending between $244,464 and $407,440 (see Offsets: Cost of offsetting emissions by source, Table 8). The ACUPCC does not a deadline for when signatories are required to achieve neutrality. The agreement does suggest that schools consider the IPCC projections, which show emissions need to peak by 2015 and drop 50 to 85 percent below 2000 levels by 2050, when selecting target dates for neutrality.

The question is not so much *can* Colby achieve carbon neutrality, but *when* should Colby achieve neutrality and by what means. Should Colby expend the money necessary to purchase offsets and announce its neutrality in 2008? If Colby decided to purchase enough offsets to negate emissions in 2008, it could still pursue emissions reducing projects, such as switching to biomass at the cogeneration facility, so that the college could reduce spending on offsets in future years. However, the college may decide that the cost of offsets needed to become carbon neutral in 2008 is prohibitive. Instead, Colby may decide to focus on reducing emissions to minimize the amount of carbon needing to be offset. Since the solutions to climate change are time-sensitive, the challenge in achieving carbon neutrality at Colby will be to determine the most cost effective, yet timely, way to achieve neutrality.

CONCLUSIONS

This thesis demonstrates that Colby College can achieve carbon neutrality at a reasonable cost and over a short timeframe. A scenario that included biomass boilers at the cogeneration facility in 2010 and a methane gas to electricity facility at the Norridgewock landfill in 2011 had the potential to reduce 2007 gross emissions by 64 percent, or 13,057 MTCDE. Emissions from vehicles are the most difficult source to reduce, and is where most of the offsets will be needed. A preliminary calculation showed that Colby's forested lands may sequester enough carbon from annual growth to offset all remaining carbon emissions. If correct, this would allow money earmarked for offset purchasing to instead be spent on initiatives to further reduce carbon pollution at Colby.

RECOMMENDATIONS

- *Switching from residual oil to biomass at the cogeneration facility should be the top priority*. Residual oil is the largest source of emissions at Colby. Switching to biomass is projected to single-handedly reduce gross carbon emissions by over 50 percent. According to the consultant's report, the installation of a biomass system is expected to have a payback period of less than four years and reduce fuel costs by about 50 percent. One caveat is that non-greenhouse gas air pollutants may increase as a result of biomass.

- *Colby should monitor the progress of the proposed methane gas to electricity facility set to begin construction in the spring of 2008 at the Norridgewock Landfill.* The existence of this facility would result in a 6 percent reduction in gross emissions at no additional cost to the college.

- *Future buildings should use carbon- free sources of energy, such as biomass or geothermal heating, and the college should continue with green electricity*. The small increases in area from the expansion of Cotter Union were projected to increase carbon emissions. However, the much larger addition of a new science building with geothermal heating and green electricity is not projected to add to emissions.

- *A plan for carbon neutrality should clearly state which emissions sources would be reduced from particular strategies.* This will help the college avoid funding projects that would reduce the same emissions. For example, if the college switched to biomass at the cogeneration facility and replaced distillate oil with B100, then solar hot water projects on campus would not result in additional greenhouse gas reductions because the biomass[11] and biodiesel would already have eliminated emissions from these sources.

[11] A small amount of residual oil may still be used for the small summer loads and to help meet the peak load in winter (see Residual Oil: Biomass).

- *Data collection and measurement techniques should be improved in the areas of solid waste, faculty and staff commuting, and college related transportation. In some cases, improved data would lead to a "reduction" in emissions since the current numbers used are overestimates.*
    - The accuracy of emissions from solid waste is dependent on using the correct weight of solid waste. Solid waste is currently determined by estimating the weight of one or two truck loads of waste, which are then used to estimate the amount of waste for the entire year. Large discrepancies in waste measurements between years could show artificial increases and reductions in emissions and would prevent the college from gauging the success of future waste reduction initiatives. These discrepancies would also prevent the college from measuring the impact on emissions from new practices, as switching breakfast to the Spa on weekends and grab-and-go lunches, which result in less composting and increased use of disposable dining ware.
    - If Colby studied the composition of its waste, it may also find that it sends fewer sources of biogenic material to landfills than assumed in the calculator due to its recycling and composting policies. That finding would allow a new, lower emissions factor to be calculated to reflect the reduced contribution of methane emissions from Colby's solid waste.
    - The ACUPCC requires that schools include emissions from commuting. Better information on student, faculty, and staff commuting behavior and the composition of the commuting fleet would likely show that fewer

emissions are produced from commuting than currently found by the calculator. It would also help monitor the success of future incentives to reduce commuter emissions.

- Collecting data on college related transportation by tracking receipts from the business office, the method used in this study, is time consuming and lacked some of the detail needed to make informed assumptions for calculations. Restructuring the travel reimbursement procedure to require this information, such as the mode of transportation and the travel origin and destination, would improve the calculation of emissions generated by these sources.

- *Scope 3 emissions not included in the emissions inventory should still factor into the college decision making process.* For example, the Colby initiative to increase the amount of local and/or organic foods served in the dining hall reduces Scope 3 emissions, even if this is currently not reflected in the inventory. Replacing residual oil with Maine-based biomass would not only reduce the Scope 1 emissions from heating the campus, it would also reduce emissions from the extraction, processing, and transportation of the oil to the Colby campus. Initiatives to reduce Scope 3 emissions could be tracked in a document that complements the annual inventory reports. See Methods: Defining the scope of emissions at Colby College, Table 3 for more examples of Scope 3 emissions.

- *Reducing emissions should be favored over purchasing offsets when possible.* Offsets that the college does purchase should be quantifiable, additional, permanent, and must not be double counted.

- *Colby should also study in more detail the carbon sequestered by the annual growth of its forested lands. Before Colby can use its forests as carbon offsets for the ACUPCC, the college must investigate whether its forests qualify based on the standards in the LULUCF Guidance document of the GHG Protocol*[12]. Preliminary estimates indicate that the carbon from the annual growth the college forests could provide all of the offsets needed for Colby to achieve neutrality. Better information on the species composition and volume of growing stock per acre in Colby's forested lands, along with more exact ages of forests, would result in more accurate calculations. ACUPCC requires that schools follow the standards set in the GHG Protocol's LULUCF Guidance document when including forest stocks in a campus greenhouse gas inventory – further research and discussion is needed to determine whether Colby's forest qualify as offsets under GHG Protocol standards.

- *Any funds saved by using Colby's forest growth to neutralize emissions instead of purchasing offsets should be earmarked for carbon reducing initiatives on campus.* Creating this pool of funds would allow Colby to undertake initiatives that would have been impracticable without this financial aid. Using the money to further carbon reduction projects may have a greater impact on emissions than

[12] http://www.ghgprotocol.org/files/lulucf-final.pdf

purchased offsets due to multiplier effects that can be generated throughout the community and region, such as by raising awareness about carbon neutrality or influencing the demand for climate friendly technologies and products.

- *Future research topics include:*
    - Conducting a study to specifically measure the carbon held in Colby's forested stock. The measurement procedures should be in accordance with the standards set by the GHG Protocol and the LULUCF Guidance document of the GHG Protocol. A campus wide discussion should occur to decide which parcels of forested land meet the additionality criteria described in the LULUCF Guidance document and to develop a management scheme to continuously track and manage the carbon.
    - Qualitatively or quantitatively measure carbon from Scope 3 emissions not included in the inventory, such as those from the production, extraction, and transportation of food, consumer products, and supplies and materials purchased by the college.
    - Investigate how climate change actions fit into sustainability as a whole. Do some actions reduce carbon emissions but produce other effects that are at odds with sustainability initiatives? Identifying practices that reduce climate change but are complementary with other environmental priorities could help the college prioritize its options.

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DEFINITION OF TERMS

Carbon neutral – a term used to describe any organization, entity, or process that has a net greenhouse gas (GHG) emissions level of zero.

Gross emissions – the sum of all greenhouse emissions, in this study measured in MTCDE

Net Emissions – gross emissions minus offsets, in this study measured in MTCDE

Offset – any activity that reduces carbon emissions to compensate for carbon released by a different activity

Global Warming Potential – The heat trapping capacity of a gas in relation to carbon dioxide

Operational boundaries – the emissions sources for which an institution is responsible

Scope 1 emissions – emissions from sources that are directly emitted by the institution

Scope 2 emissions – emissions from imported energy sources, such as electricity

Scope 3 emissions – emissions that are an indirect consequence of institutional activity, such as commuter travel. These sources are not directly controlled by the institution.

ACRONYMS

ACUPCC – American College and University Presidents Climate Commitment, http://www.presidentsclimatecommitment.org/

ASHRAE – American Society of Heating, Refrigerating and Air-conditioning Engineers, http://www.ashrae.org/

CA-CP – Clean Air-Cool Planet, http://www.cleanair-coolplanet.org/

GHG – Greenhouse Gas

GWP – Global Warming Potential

LEED – Leadership in Energy and Environmental Design, http://www.usgbc.org/leed

MMBtu – Million British thermal unit

MTCDE – Metric ton of carbon dioxide equivalent

REC – Renewable energy credit

WRI – World Resources Institute, http://www.wri.org/

WBCSD – World Business Council for Sustainable Development, http://www.wbcsd.org

APPENDIX A [13]

Scope 1 Emissions Data, Assumptions, and Calculations

All data was supplied by Dale DeBlois, the Environmental Programs Manager at the Colby Physical Plant Department, unless otherwise noted in this appendix.

Residual Oil, Distillate Oil, B10 Biodiesel, and Propane

Emissions from each fuel source were calculated by inputting the number of gallons of each fuel used each year into the Clean Air – Cool Planet Campus Carbon Calculator version 5.0. The calculator estimates emissions based on fuel-specific emissions factors. Residual oil is used to produce central steam at the campus cogeneration facility. Distillate oil is used in buildings that do not receive central steam to provide heat and hot water. Distillate oil used at the Colby Gardens, a leased facility used as a temporary dormitory, is included in this calculation. Propane is used for cooking in campus dining halls as well as to heat the room where the Zamboni ice management vehicle is stored.

The Campus Carbon Calculator version 5.0 is not designed to calculate emissions from biodiesel mixes. As recommended by Jennifer Andrews of Clean Air-Cool Planet, emissions from Colby's B10 biodiesel were calculated by taking 90 percent of the gallons of B10 used, representing the petroleum diesel component of the mix (the other 10 percent was biodiesel and, by assumption, had no emissions), and entering these gallons into the distillate oil section of the input module (Andrews, pers. comm.).

[13] This appendix was originally written by Jackleen S. Sorenson '11. It was edited and modified by the author of this thesis, Jamie O'Connell '08.

Physical Plant Department Vehicle Fleet

The vehicles owned by the Colby Physical Plant Department use both diesel and gasoline. In order to calculate the emissions factors of these fuels, the gallons of both gasoline and diesel fuels were entered into their respective locations in the input module of inventory. The calculator used fuel-specific emissions factors to estimate the emissions.

Agriculture

At Colby, the only contributor to emissions from the agriculture category was fertilizer used for landscaping. To calculate emissions from fertilizer application, the pounds of fertilizer, defined as synthetic or organic, and the nitrogen content of each were required for the Campus Carbon Calculator to calculate emissions.

This section also includes livestock, which would need to be included in the future if Colby were to obtain farm animals.

Refrigerants and Chemicals

According to Dale DeBlois in PPD, there were no leaks from refrigerants or other chemicals on campus that would add to emissions. Types of potent greenhouse gases resulting from refrigeration include hydroflourocarbons (HFCs) and Perflouronatedcarbons (PFCs).

APPENDIX B[14]

Scope 2 Emissions Data, Assumptions, and Calculations

Purchased Electricity

The purchased electricity is measured in kilowatt hours (kwh) and is currently purchased from Constellation New Energy, which began supplying Colby in 2003 (DeBlois, pers. comm). Our current fuel mix is 50% biomass and 50% hydroelectric, all of which are from within Maine (DeBlois, pers. comm). Prior to 2003, the fuel mix was 70% from coal and 30% hydroelectric (DeBlois, pers. comm). Electricity data were supplied by Dale DeBlois in PPD. The category of purchased electricity does not include electricity generated at the cogeneration facility, as this source of electricity was calculated elsewhere in the calculator.

[14] This appendix was originally written by Jackleen S. Sorenson ’11. It was edited and modified by the author of this thesis, Jamie O’Connell ’08.

APPENDIX C

Scope 3 Emissions Data, Assumptions, and Calculations

College Related Transportation

This category includes travel to college related academic, business, or extracurricular activities, as well as moving vans rented from Pro Moving services to transport items from buildings on or around campus. Student travel to and from campus for college breaks and the relocation of new staff and faculty were not included in this category or elsewhere in the inventory since the ACUPCC does not require schools to inventory these emissions (Dautremont-Smith *et al.* 2007a). Since data were only available on this category from FY 2007, input data from this year was used to calculate emissions each year from 1990 to 2007 so as not to show an artificial jump in emissions in 2007.

Aside from air travel, college related transportation was not included in the Campus Carbon Calculator, so emissions from this category were calculated independently, although many of the calculations were made using the Campus Carbon Calculator as explained later in this appendix. Middlebury, Oberlin, and College of the Atlantic include this category in their emissions inventories and neutrality plans (RMI 2002, Middlebury College 2007, COAb accessed 2008). The ACUPCC requires that air travel be included and suggests that as many Scope 3 emissions as possible be included (Dautremont-Smith *et al.* 2007a). College related travel emissions were reported under five categories: air, car, bus, train, and moving van. The following list describes the emissions calculations and data sources for each of the five college travel categories. The information used in the following calculations was derived from receipts and reimbursement forms provided by the Colby Business office.

AIR TRAVEL

Air travel emissions were calculated by entering the passenger-air miles into the input module of the Campus Carbon Calculator. The Calculator then used its preexisting emissions and conversion factors to calculate emissions.

Air mileage was calculated by dividing the total money spent on air travel in 2007 by $0.25/passenger mile, the conversion factor recommended by the ACUPCC (Huang 2000, Dautremont-Smith *et al.* 2007a). Even though the same 2007 data was used to calculate emissions from 1990 though 2007, the emissions levels differed slightly among years due to differences in the respective emissions factors stored within the calculator, such as increases in the fuel efficiency of jets between 1990 and 2007.

CAR TRAVEL

The gallons of gasoline were input into the Campus Carbon Calculator, which used emissions factors such as energy use per gallon and kg of different greenhouse gases per gallon, and the GWP factor to arrive at a gross emissions figure in MTCDE. Since the Carbon Calculator did not have an input category for college related travel, for calculation purposes, the gallons of gasoline from college related travel were entered into the campus carbon calculator along with the gasoline used by the Colby PPD gasoline vehicle fleet. Emissions resulting from PPD gasoline vehicles and college related travel are reported separately in this report. To do this, the gallons of gasoline from PPD vehicles and college related travel were entered into a blank input cell of the calculator separately. The emissions from each source were recorded before the two were combined and entered jointly.

The gallons of gasoline from college related car travel were estimated by the following process:

1) Estimate miles traveled from each source of car emissions in 2007. Different financial statistics, such as the cost of a shuttle ticket for a known distance in 2007, were used to estimate mileage. Since data for mileage estimates were unavailable prior to 2007, the 2007 mileage was used to calculate fuel use (as described below) each year from 1990 to 2007.
2) The average fuel economy (mi/gal) for each year (1990-2007), as listed in the Carbon Calculator commuter input sheet[15], was used to convert the estimated 2007 mileage into gallons. Since data were unavailable prior to 2007, the 2007 mileage figure was used for each year from 1990 through 2007, although the gallons of fuel may differ slightly from year to year due to differences in fuel economy.
3) Gallons of gasoline from each source were summed, and added to the College PPD gasoline vehicle total and entered into the emissions calculator.

The miles traveled from various car sources included in "college related travel" were estimated as described below:

Mileage reimbursements:

The money spent reimbursing students/faculty/staff as reported on mileage reimbursement forms were summed. A conversion factor of $0.40/mile, the college reimbursement rate, was used to covert the total cost into miles traveled[16].

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[15] CA-CP lists data source as USDOT, Bureau of Transportation Statistics

[16] In 2008, this reimbursement rate will increase to $0.44/mile.

Car rentals:

A regression equation calculated by Professor Russ Cole was used to translate the money Colby spent on car rental to miles traveled as shown in the equation below:

f(x) = 8.830260E-1*x +1.421813E+2

x=car rental cost
f(x)=miles traveled

($p<0.0001$, d.f.=1, 186, R squared value = 32%)

The money spent on car rental in 2006-2007 was entered into the equation in place of "x" to estimate the miles traveled.

Taxis:

Taxi mileage was calculated by converting the money spent reimbursing taxi trips by to miles using the conversion factor $2.79/mile[17] (Schaller Consulting 2006). This conversion factor was derived by calculating the mean taxi fare for a 5 mile trip with 5 minutes of wait time in 24 major United States cities. This mean of $13.95 was then divided by 5 (the distance of the trip) to arrive at the conversion factor of $2.79/mile.

The locations of the Colby taxi trips were unknown, and may not have occurred in the United States. However, it was assumed that the majority of trips were within the US, so foreign cities were not included in calculating the $2.79/mile conversion factor.

Limo/shuttle:

Reimbursement totals from limousines and shuttles were used to estimate mileage. It was assumed that the majority of these trips were transporting student groups, faculty, or guest speakers from the Colby campus from the Portland jetport. The distance from

[17] http://www.schallerconsult.com/taxi/fares1.htm average taxi fares in US cities provided by this source.

Colby to the Portland Jetport (77.84 miles) was calculated using mapquest.com. The cost of a one-way shuttle ticket from Moonlight Limousine and Transportation, Inc. from Colby to the Jetport was $115 (a two way ticket is twice this cost). These numbers were used to calculate a conversion factor of $1.48/mile, which was used to convert money spent on limo and shuttle reimbursement into miles traveled. It was assumed that many of the limousines and shuttles were commuter vehicles rather than large buses, so the fuel economy used for the other car travel categories was used to convert the limo/shuttle mileage as well.

Bus Travel

Most bus travel was the result of rented charter buses for athletics or student activities. Emissions from bus travel were calculated by converting the money spent on bus travel into miles traveled using the factor of $5.11/mile. According to Cyr Bus Lines, the fuel economy of their buses ranges from 6.5-8 miles per gallon (mpg) and all their buses use diesel fuel (Cyr Bus Lines, pers. comm.). A fuel economy of 7.25 mpg, the number halfway between 6.5 and 8, was used to convert mileage into gallons of diesel fuel. The gallons of diesel fuel were then added to the gallons diesel fuel used by the Colby PPD diesel vehicle fleet and entered into the Carbon Calculator. The Calculator then used conversion factors to produce an emission figure.[18]

[18] NOTE: emissions resulting from PPD gasoline vehicles and college related travel are reported separately in this report. The gallons of diesel from PPD vehicles and college related travel were entered into a blank input cell separately and the emissions from each source were recorded before the two were combined and entered jointly.

This conversion factor of $5.11/mile was calculated as follows:

1) The distance from Colby to (a) Massachusetts Institute of Technology in Cambridge, MA (181.49 mi) and (b) to the University of Southern Maine in Portland (81.92 mi) was calculated using mapquest.com.
2) The cost of renting a bus for a round trip from (a) Colby to Boston ($1,550) and (b) Colby to Portland ($975) were given by Cyr Bus Lines (pers. comm.) were divided in half to find the cost of traveling one-way.
3) The cost per mile of traveling from Colby to each location was the quotient of the distance traveled and the one-way travel cost.
4) The cost per mile of traveling from Colby to MIT ($4.27/mile) and USM ($5.95/mile) were averaged to arrive at the conversion factor of $5.11/mile).

TRAIN TRAVEL

Train emissions were calculated converting the money spent on train travel into passenger miles using a conversion factor of $0.19/mile, which the Carbon Calculator was able to use to convert into carbon emissions in MTCDE. The conversion factor of $0.19/mile was calculated as follows:

1) The rail distance between Portland and Boston (120 mi), and Boston and DC (450 mi) was calculated using ArcGIS by Manuel Gimond, GIS & Quantitative Analysis Specialist.
2) The one way cost as of January 2008 for the following Amtrak rail services: Acela Express ($83, Boston-DC), Downeaster ($23, Portland to Boston), and Regional ($86, Boston to Newport News, VA) were divided into the distance

to each respective location to calculate the cost per mile for each route. The mean cost per mile, $0.19/mile, was the conversion factor used.

It was unknown where in the United States or world this train travel occurred, so the calculation of the $0.19/mile conversion is only a rough estimate of mileage. Since the Campus Carbon Calculator does not have an input module for college related travel, passenger miles were entered into the “passenger miles” column of the student commuter input module, as this column was empty since Colby does not have students commuting to campus via rail.[19]

The Calculator requires that passenger miles are differentiated by light rail (electric) or commuter rail (diesel); since it was unknown whether the train travel occurred on light or commuter rail, half the passenger miles were entered into the light rail column and the other into the commuter rail column. Since data were only available for 2007, the same number of passenger miles was entered for 1990 through 2007, although the actual number of emissions may vary slightly due to differences in fuel light rail and commuter rail fuel efficiencies.

MOVING VANS

Moving van emissions were calculated by entering the gallons of gasoline and gallons of diesel to the totals used by PPD vehicles, the sum of which was entered into the gasoline and diesel input cells under the university fleet category in the Carbon

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[19] NOTE: emissions resulting from train travel and student commuting are reported separately in this report even though they were entered into the same input module. Passenger miles were entered into a blank input row separately to find the emissions from train travel and commuting individually before the two were combined.

Calculator[20]. The Carbon Calculator then used emissions and conversion factors to convert gallons of fuel use into carbon emissions in MTCDE.

Peter Cary of Pro Moving Services, the company Colby uses to move items on campus, provided the fuel economy, miles traveled, and fuel type for the different types vehicles used at Colby during 2007 (pers. comm.). The fuel economy (in miles per gallon) was used to convert the mileage into gallons of fuel used. Since data were unavailable prior 2007, the 2007 data were used to estimate emissions for each year 1990 through 2007.

Commuter Emissions

Commuter emissions were calculated by entering demographic and commuter information and assumptions into the "commuter input" module of the Campus Carbon Calculator, which had separate input areas for student, faculty, and staff commuting information. The carbon calculator then used the input data to calculate the number commuter miles driven, and used the average fuel economy for each year to calculate gasoline fuel use. It then used emissions and conversion factors provided by the Environmental Protection Agency, the Department of Energy, and Department of Transportation to calculate emissions in MTCDE.

It was assumed that all commuting was by car (personal vehicle) with no carpooling. It was also assumed that there was summer commuting by students or summer program participants. The assumptions and data sources entered into the commuter input module

[20] NOTE: emissions resulting from moving vans and college vehicles are reported separately in this report even though they were entered into the same input module. Moving van gasoline and diesel use were entered into a blank input row separately from PPD vehicle fleet fuel use to find the emissions from both categories individually before the two were combined.

to calculate total distance traveled, which was used to calculate fuel use and emissions, are described below:

STUDENT COMMUTERS

1) Number of Students: academic year students, number automatically entered into the commuter input module from the general input module
2) Student fuel efficiency: data already supplied in the Calculator from the Department of Transportation
3) Percent of Students Commuting by Personal Vehicle: entered as the percentage of students living off-campus. The number of students living off-campus, and thereby percent of students living off-campus, was available only for 2005, 2006, and 2007 (6.9, 6.6, and 6.1, respectively). The mean of these percentages, 6.5 percent, was entered from 1990 to 2004.
4) Percentage of total students (not the percentage of commuting students) that drive alone: due to a lack of data, such as a survey or observational study stating otherwise, it was assumed that all of the student commuters drove alone. The percentage of off-campus students was entered for this category.
5) Percentage of total students carpooling: assumed to be 0 percent.
6) Number of trips per day: assumed to be two trips per day—one trip to arrive at school and one trip to return home.
7) Number of days per year: 288 days/year. Assumes the following number of days/month--Sept-30, Oct-27 (4 day break), Nov-26 (4 day break), Dec-21 (3 weeks), Feb-28, Mar-21 (3 weeks, 1 wk break), Apr-30, May-31. Jan-14 days (2 weeks, assumes 1/2 the students are doing a Janplan)

8) Miles per trip: Mapquest.com was used to calculate the distance to campus for each off-campus student listed in the Colby directory that is distributed to faculty members. The mean distance of 4.18 miles was calculated from off-campus students in the 2006-2007 school year. Since off-campus addresses were not available for students previous years, 4.18 miles was used for each year 1990 through 2007.

FACULTY AND STAFF COMMUTERS

1) Number of Faculty: number automatically entered into the commuter input module from the general input module
2) Faculty fuel efficiency: data already supplied in the Campus Carbon Calculator from the Department of Transportation)
3) Percent of Faculty Commuting by Personal Vehicle: due to a lack of data, such as a survey or observational study stating otherwise, it was assumed that 100% commute by car
4) Percentage of total faculty that drive alone: due to a lack of data, such as a survey or observational study stating otherwise, it was assumed that all of the faculty commuters drove alone.
5) Percentage of total faculty carpooling: assumed to be 0%.
6) Number of trips per day: assumed to be 1.42 trips per day— assumes that faculty make 2 trips/day, but only 5 days per week.

$$\frac{14 \text{ trips}}{7 \text{ days}} = \frac{x \text{ trips}}{5 \text{ days}}$$

$$x=1.42 \text{ trips}$$

7) Number of Days per year: 320 days/year. Assumes 228 days (the number of days that students commute) + 30 days (June) + 31 days (July) + 31 days (August)
8) Miles per trip: ArcGIS was used to calculate the distance to campus for each full and part time faculty and staff member based on a central point in the town that each employee lives. A mean distance of 10 miles was calculated from 2007 data. Since data were unavailable for students previous years, 10 miles was entered for each year 1990 through 2007. Data compilation and GIS work were done by Alaina Clark ’08 and Manuel Gimond, GIS and Quantitative Analysis Specialist.

Emissions calculations for faculty and staff commuters are likely over estimates due to the demographic data and assumptions entered into the Calculator. No mechanism currently exists for capturing data regarding student, faculty, and staff commuting frequencies, carpooling tenancies, or for accounting for faculty who walk/bike/live on campus. Including these data would allow Colby to lower the percent, assumed to be 100, of faculty commuting by personal vehicle.

For example, the number of faculty used to calculate commuter emissions include both full and part-time positions, but assumes that both classes commute to Colby five days per week. It also assumes that all faculty commute to campus days a week during the summer. Likewise, all staff are assumed to commute to Colby five days a week throughout both the academic year and summer[21]. It is unlikely that all of the faculty and

[21] In 2007, all Sodexo employees, including on-call employees were included in the staff count. Since these employees were not included in previous years due to lack of data, emissions in 2007 seem artificially higher than in previous years. Prior to 2007, emissions from staff and faculty commuting ranged from 1,112 to 1,310 MTCDE. In 2007, faculty and staff commuting emitted 1,619 MTCDE, increase of over 300 MTCDE from 2006.

staff are commuting with this frequency, but no data exist to provide a realistic assessment.

Student commuting emissions data are likely more accurate since the number of students living off-campus is known. However, no studies have been conducted affirming the assumptions made about student commuting behavior. For a more detailed description of who is included in student, faculty, and staff counts, see Appendix D.

Solid Waste

The number of short ton of solid waste landfilled by Colby was entered into the “landfilled waste with no CH_4 recovery” column of the input module. The calculator used an emissions factor of 0.27 metric tons of carbon equivalent/short ton (MTCE/short ton) (0.26 MTCE/short ton of methane emissions from the waste decomposition and 0.01 MTCE/short ton from hauling the waste to the landfill). The calculator included methane emissions because the anaerobic conditions created by the landfill allow anaerobic bacteria to decompose organic waste, producing the methane emissions that would not occur from decomposition in natural environments (EPA 2002). Carbon dioxide emissions from transporting the waste to the landfill were incorporated into the emission factor, but carbon dioxide from waste decomposition in the landfill was not included because these emissions would occur regardless of whether the organic material was decomposing in the landfill or elsewhere (EPA 2002).

It is possible that the composition of Colby’s waste is different than that assumed for municipal solid waste. If Colby were able to determine the composition of its landfilled waste, an emissions factor specific to Colby could calculated and used instead of the mixed municipal solid waste (Table 10). Since Colby recycles and composts, it is possible that the college disposes of less biogenic waste, which causes methane emissions when landfilled (EPA 2002).

Table 10. Table of emissions factors used in the Campus Carbon Calculator version 5.0. Mixed MSW was the category of material used in the calculator. If Colby decided to calculate solid waste emissions based on a known composition of the college's wasted, other emissions factors listed in the table could be used to calculate emissions specific to Colby. Table from (EPA 2002).

Net GHG Emissions from Landfilling

(a)	(b) Net GHG Emissions from CH_4 Generation (MTCE/Wet Ton)				(c)	(d)	(e) (e = b + c + d) Net GHG Emissions from Landfilling (MTCE/Wet Ton)			
Material	Landfills Without LFG Recovery	Landfills With LFG Recovery and Flaring	Landfills With LFG Recovery and Electric Generation	Year 2000 National Average	Net Carbon Storage (MTCE/Wet Ton)	GHG Emissions From Transportation (MTCE/Wet Ton)	Landfills Without LFG Recovery	Landfills With LFG Recovery and Flaring	Landfills With LFG Recovery and Electric Generation	Year 2000 National Average
Aluminum Cans	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Steel Cans	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Glass	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
HDPE	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
LDPE	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
PET	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.01	0.01	0.01
Corrugated Cardboard	0.48	0.12	0.06	0.29	-0.22	0.01	0.27	-0.09	-0.15	0.08
Magazines/Third-class Mail	0.26	0.07	0.03	0.16	-0.29	0.01	-0.02	-0.21	-0.25	-0.12
Newspaper	0.23	0.06	0.03	0.14	-0.36	0.01	-0.12	-0.29	-0.32	-0.21
Office Paper	1.09	0.27	0.14	0.66	-0.04	0.01	1.05	0.24	0.10	0.62
Phonebooks	0.23	0.06	0.03	0.14	-0.36	0.01	-0.12	-0.29	-0.32	-0.21
Textbooks	1.09	0.27	0.14	0.66	-0.04	0.01	1.05	0.24	0.10	0.62
Dimensional Lumber	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Medium-density Fiberboard	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Food Discards	0.30	0.08	0.04	0.18	-0.02	0.01	0.29	0.06	0.03	0.17
Yard Trimmings	0.17	0.04	0.02	0.10	-0.21	0.01	-0.03	-0.15	-0.18	-0.09
Grass	0.19	0.05	0.02	0.12	-0.12	0.01	0.09	-0.06	-0.08	0.01
Leaves	0.15	0.04	0.02	0.09	-0.39	0.01	-0.23	-0.34	-0.36	-0.29
Branches	0.15	0.04	0.02	0.09	-0.21	0.01	-0.04	-0.16	-0.18	-0.10
Mixed Paper										
Broad Definition	0.53	0.13	0.07	0.32	-0.23	0.01	0.31	-0.08	-0.15	0.10
Residential Definition	0.49	0.12	0.06	0.29	-0.24	0.01	0.26	-0.10	-0.16	0.07
Office Paper Definition	0.58	0.15	0.07	0.35	-0.21	0.01	0.38	-0.05	-0.12	0.15
Mixed MSW	0.26	0.06	0.03	0.16	-0.10	0.01	0.17	-0.02	-0.06	0.07

Note that totals may not add due to rounding, and more digits may be displayed than are significant.

The number of short tons of solid waste in 2007 was estimated by Dale DeBlois based on the weight of one or two truck loads of waste assumed to be representative of Colby's waste hauls throughout the year. This 2007 value was used for 2006 and 2005 since the solid waste estimate from these years were less reliable, producing estimates that were nearly 50 percent less than in 2007. The more accurate 2007 value was used to prevent an artificial increase in emissions in 2007.

APPENDIX D[22]

Colby Demographics and Physical Characteristics: Emissions Data, Assumptions, and Calculations

Demographics

The college population data were supplied by the Office of the Vice President. It includes the number of students for each school year on and off campus, number of summer students living on campus, number of summer program students, and number of faculty and staff. Demographic data were used to calculate commuter emissions

Data were entered into the calculator on a fiscal year basis. This means that the number of students in fiscal year 2007 would correspond with the academic year 2006-2007. Since the number of students on campus varied between fall and spring semester, the average number of students from the two semesters was entered into the calculator..

Summer students include both on-campus Colby students plus the number of students in summer programs run by the college. The number of program students were accounted for each day of the month and converted into an average number of students per month in June, July, and August. Since the fiscal year runs from July to June the number of summer students were added up as follows:

FY 2006 = (Avg. of July ’05 + Avg. of August ’05 + Avg. June ’06) + summer Colby students

FY 2007 = (Avg. of July ’06 + Avg. of August ’06 + Avg. June ’07) + summer Colby students

[22] This appendix was originally written by Jackleen S. Sorenson ’11. It was edited and modified by the author of this thesis, Jamie O’Connell ’08.

The numbers of summer students, however, did not affect the commuter emissions as it is assumed that these students lived on campus and did not commute to the college everyday.

The staff numbers were also obtained from the Office of the Vice President, which included the number of administrative staff, support staff, and Sodexo employees The number of staff for FY 2007 was larger than years previous because Sodexo employees were included in 2007 but not in previous years due to lack of data. On-call staff were included in these numbers since it was unknown how often on-call staff commuted to campus. As a result, more employees are entered in the calculator then are likely on campus in any given day.

The faculty numbers, taken from the Office of the Vice President, include the number of professors and other related positions, both full and part time.

Building Area

The building area, measured in square feet, includes all building structures on the Colby campus and the Colby Gardens. In cases when buildings came on-line in the middle of the fiscal year, a weighted average for the year was taken and entered into the calculator. This occurred, for instance, when the Diamond Building came on-line during January of 2007. The area during FY 2007 was calculated using the following method:

$$\text{Building area FY 07} = \frac{(\text{Sq.ft. pre-diamond} * 6 \text{ months}) + (\text{sq. ft. with diamond} * 6\text{months})}{12 \text{ months}}$$

The building area data were provided by Dale DeBlois. Area was used to calculate emissions and energy use per sq. ft. of building space.

APPENDIX E

Offsets: Data, Assumptions, and Calculations

Composting

The short tons of compost data entered into the Campus Carbon Calculator were provided by Dale DeBlois, the Environmental Programs Manager at the Colby Physical Plant Department.

Forest carbon offsets

Forest carbon sequestration was calculated by first finding the total carbon sequestered in Colby's forested land by the method developed by Jeff Carroll '08, and then dividing the different stands by their approximate age to estimate annual growth in carbon (Carroll, pers. comm., Firmage, pers. comm.). The total carbon of the annual growth was converted into MTCDE to estimate the amount of carbon offset in 2007.

Calculation of forest carbon stock in total stand:

1. Categorizing forest types.

Colby's forests first needed to be categorized into one of five categories listed in Maine's Forests 1995 (Griffith and Alerich 1995): maple-beech-birch, pine, spruce/fir, hemlock, or bottomland hardwoods. Colby's forests were categorized as follows:

- *Maple-beech-birch*: 305 acres. Of the 315 acres of forested land at Colby (including the arboretum), 300 were estimated as maple-beech-birch (Firmage, pers. comm.). Of the 21 acre Colby

Marston Preserve, 10 acres were estimated as forested, five of which as maple-beech-birch (Firmage, pers. comm.).

- *Pine*: 119 acres. There are 86 acres of pine stands and 33 acres of pine mix at the Vasselboro Woodlot (DeBlois, pers. comm).
- *Spruce/fir*: 5 acres. Estimated area of spruces at the Colby Marston Preserve (Firmage, pers. comm.).
- *Hemlock*: 57.5 acres. Includes half the area of an 85 acre hemlock and hardwood stand at the Vasselboro woodlot plus 15 acres of hemlock on campus (DeBlois, pers. comm., Firmage, pers. comm.).
- *Unspecified hardwoods*: 42.5 acres. Half the area of the hemlock and hardwood stand at the Colby-Marston Preserve.

2. Calculating forest volume (cubic feet) per acre.

A. The area of each forest type in the Capitol Region of Maine in 1995[23] was divided by the volume of growing stock in 1995 to develop a conversion factor for area to volume of forests. Area and volume of forest types in 1995 were calculated by (Griffith and Alerich 1995). A sample calculation for maple-beech-birch is as follows:

Area in capitol region (1995) = 121.1 thousand acres
Volume of growing stock in capitol region (1995) = 34.6 million ft^3 (maple) + 21.9 million ft^3 (beech)+ 27.9 million ft^3 (birch) = 84.4 million ft^3

[23] Since the species composition of Colby's pine stands were unknown, the area in the Capitol Region of Maine in 1995 for white pine was used in this calculation. For Colby's spruce/fir stands, the area for balsam fir and black spruce was used. It was also unknown what species of hardwoods were at the Vasselboro woodlot, so the area of maple-beech-birch was used.

Conversion factor = $\frac{84.4 \text{ million ft}^3}{121.1 \text{ thousand acres}}$
= 0.696944674 million ft^3/thousand acres

Conversion factor = (0.696944674 million ft^3/thousand acres)/1000
= 0.000696945 million ft^3/acre

B. The growing stock volume of forests at Colby was calculated using this conversion factor. The example for maple-beech-birch is as follows:

Growing stock at Colby = 305 acres x 0.000696945 million ft^3/acre = 0.212568126 million ft^3

3. Converting to Carbon and MTCDE.

A. The growing stock volume of forests at Colby was converted to carbon by multiplying the growing stock volumes by the following conversion factors provided by (Birdsey 1996):

Growing stock to total volume = 2.14 for hardwoods or 2.193 for softwoods[24]

Conversion of tree volume to (million ft^3) to biomass (million lbs) = (varied by species, conversion factors were chosen based on similar species)

Weight of 1 ft^3 of water = 62.4

Conversion of biomass to carbon = (varied by species, conversion factors were chosen based on similar species)[25]

Example for maple-beech-birch:

Carbon = 0.212568126 million ft^3 x 2.14 x 0.6 x 62.4 (lbs/ ft^3) x 18.65
= 317.6337138 million lbs C

[24] The conversion factor for softwood pines was used for Colby's pine stands.
[25] The conversion factor for softwood pines was used for Colby's pine stands.

Carbon = 317.6337138 million lbs C x 1,000,000
= 317,633,714 lbs. C

B. The pounds of carbon were converted to MTCDE by first converting from pounds of carbon to pounds of carbon dioxide equivalent by multiplying by 3.667 (carbon dioxide is 44/12 heavier than carbon). Carbon dioxide was converted from lbs to short tons (divided by 2000) and from short tons to metric tons (multiply 0.9027). These conversion factors were found in the Campus Carbon Calculator's "Constants" emissions factor sheet (CA-CP 2006a).

Example for maple-beech-birch:
Carbon dioxide =317,633,714 lbs. C x 3.667
=1164762828 lbs. CO_2

MTCDE = (1164762828 lbs CO_2/2000)*0.9072
= 641,954.8 MTCDE

C. The MTCDE for each forest type were summed to derive the total biomass of Colby's forests. To estimate the amount of annual growth in added in 2007, the MTCDE was divided by the age of the stand (Firmage, pers. comm.). The ages used in these calculations were estimates, since the actual ages were unknown. It is known that the majority of the Colby Campus was cleared land when the college was moved to its current location circa 1937, with the exception of a stand of hemlocks (Firmage, pers. comm., Colby College 2008a). Old photographs show that the hemlock stand was already mature at the time Colby moved to the current campus (Firmage, pers. comm.). As such, the forested land on campus was estimated as 70 years old[26] and the hemlock stand was assumed to be 150 years old (Firmage, pers. comm). There was no known history of cutting at the Colby-Marston Preserve so the trees were assumed to be 200 years old (Firmage, pers. comm.). Trees at Colby's Vasselboro woodlot were assumed to be 50 years old since the stands have been uncut since between 1950 and 1970 (DeBlois, pers. comm).

RECs

The kWh of RECs Colby purchased were provided by Dale DeBlois, Environmental Programs Manager at the Colby Physical Plant Department and were entered into the Campus Carbon Calculator for record keeping. The Carbon Calculator assumes that the RECs were purchased to offset emission from campus electricity use; to determine the amount of carbon offset by the kWh purchase, it calculates the carbon emissions produced by the same number of REC kWh of electricity generated under the electric fuel mix used by the campus and subtracts this number from the gross emissions.

However, since Colby has an electric fuel mix that does not produce carbon emissions, the Calculator incorrectly calculates that the RECs do not offset any emissions. To obtain a more correct estimate, the amount of carbon offset was calculated by changing the electricity fuel mix setting from custom to the default value for the United States as a whole. The amount of carbon offset by the wind production compared to the same amount of carbon released generating the electricity under the nationwide fuel mix value could then be viewed in the summary module.

[26] Some forested areas on campus, such as patches of the arboretum, are younger than 70 years. However, this age stratification was not factored into these calculations.

The Calculator has the option of selecting a fuel mix representative of a specific state in a particular sub region. However, the nationwide fuel mix default was used because it was unknown where REC wind project sites were located and the grid that receives the electricity represented by the REC was unknown. While using the US default is the most accurate information currently available for calculating the offset, selecting different default fuel mixes does result in a different offset calculation. For example, if the Maine's subregion fuel mix were used instead of the national setting, the amount of carbon offset would be calculated as 91 MTCDE instead of the 160 MTCDE using the national default.

APPENDIX F

Assumptions and Calculations for Future Projections

Emissions after 2007 were calculated for seven different scenarios. Scenarios I and II were business-as-usual scenarios and represent emissions as if the college did not change any of its current behavior surrounding climate action. The difference between the two situations is that in case I, a proposed methane recapture and electricity facility at the Norridgewock landfill is not constructed; solid waste from the college continues to be landfilled at Norridgewock without methane recapture. According to an article printed by the Morning Sentinal on January 26, 2008, Waste Management has plans to begin construction in the spring of 2008 (Grard 2008). As such, it was assumed that the facility would become operational in 2010. In scenario II, it was assumed that the electric facility was constructed and that Colby continued to bring its waste to Norridgewock, benefiting from the resulting reduction in emissions.

Both baseline scenarios also included the replacement of distillate oil and the current B10 biodiesel mix with a biodiesel mix of B100 in 2014. Colby is already planning to replace all of its distillate oil with biodiesel as soon as the quality and technology have adequately improved, which is predicted to occur around 2010 (Murphy, pers. comm). However, it was not specified what blend of biodiesel would be pursued by the college. For simplicity, a mix of B100 was chosen for the scenario since it would eliminate all carbon emissions from distillate oil. Since this is a much higher blend than currently used at Colby, 2014 was chosen for the implementation date instead of 2010 to reflect the need for experimentation with the fuel source.

Colby also has plans for a new 32,000 square foot science building to be located on the Colby Green (Murphy, pers. comm). It has already been agreed that the building will have the same green electricity provided to the rest of campus and will be heated with a geothermal system (Murphy, pers. comm). While Scope 3 emissions from the construction of the building will be generated, these are not included in the inventory. As a result, the new building will not generate addition greenhouse gases. The college also plans in the near future to renovate the Roberts Hall building, which currently meets a variety of needs, holding a dining hall, bookstore, and academic spaces and convert the academic spaces to residential areas (Murphy, pers. comm). Once the science building is open and Roberts Hall renovations are complete, the Colby Gardens would no longer be needed for residential space, eliminating the distillate oil used at the building. The dates of construction and completion of these projects are unknown at this time, but the 2009-2010 school year was the earliest date that construction would begin (DeBlois, pers. comm). As such, 2013 was the year chosen for this model when these projects would be complete.

In the fall of FY 2008, the renovation of the Colby student union resulted in additional building area added to campus. The college is also in the process of finishing an addition to the student union to be the new location of the Colby Bookstore, which is expected to be complete in 2009. Since it is unknown how many additional greenhouse gases will be produced from these new spaces, which are heated using steam from the cogeneration facility, greenhouse gas emissions per square foot of building area calculated for 2007 was used to determine how many additional emissions would result from the new area.

The estimated emissions from the Colby Bookstore and from the renovation of the student center were added to the gross emissions level from the baseline year of 2007. The amount of emissions reduced from waste disposal, biodiesel, and the loss of the Colby Gardens were calculated based on their impact on 2007 emissions, but were subtracted from the new gross emissions levels that incorporate the effect of the increased building area. Scenarios III-VII include all of the same assumptions as in scenarios I and II with regard to emissions from future buildings and use the same method for determining emissions levels in any given year.

Scenarios III-V show the effect of switching to solar hot water, while VI and VII model the impact of the switch to biomass at the cogeneration facility. Colby is in the process of completing the final biomass feasibility study, and hopes to present a proposal to the Board of Trustees in either October 2008 or January of 2009 (Libby, pers. comm). If all measures proceed without obstacle, the construction of the biomass facility could occur during the spring or summer of 2009 and become operational in 2010 (Libby, pers. comm).

Table 11. Summary of annual carbon dioxide emissions (MTCDE) at Colby College through 2017 projected under seven (I-VII) different scenarios. Actions beyond those in a business as usual scenario (I or II) are shown in bold.

	I	II	III	IV	V	VI	VII
2007	20,372, baseline	20,372, baseline	20,372, baseline	20,372, baseline	20,372, baseline	20,372, baseline	20,372, baseline
2008	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131	Pulver Pavillion expansion + 131
2009	Colby Bookstore + 139	Colby Bookstore + 139	Colby Bookstore + 139	Colby Bookstore + 139	Colby Bookstore + 139	Colby Bookstore + 139	Colby Bookstore + 139
2010	---	---	**Switch fertilizer all organic* 21% N, -2**	**Switch fertilizer all organic* 21% N, -2**	**Switch fertilizer all organic* 21% N, -2**	**Switch fertilizer all organic* 21% N, -2** **Biomass replaces residual oil** -11,679**	**Switch fertilizer all organic* 21% N, -2** **Biomass replaces residual oil** -11,679**
2011	---	Methane recovery and electricity generation -1239	Methane recovery and electricity generation -1239	Methane recovery and electricity generation -1239	Methane recovery and electricity generation -1239	Methane recovery and electricity generation -1239	**Switch waste disposal sites to a location with a waste-to-energy Mass Burn facility, -1616**
2012	---	---	---	---	---	---	---

(Table 11 continued from previous page)

	I	II	III	IV	V	VI	VII
2013	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0	New science building and Roberts Renovation, + 0
	No Colby Gardens, -198	No Colby Gardens, -198	No Colby Gardens, -198	No Colby Gardens, -198	No Colby Gardens, -198	No Colby Gardens, -198	No Colby Gardens, -198
			Solar hot water (5%)* -611**	**Solar hot water (10%)**** -1,222**	**Solar hot water (15%)***** -1,833**		
2014	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179	Biodiesel B100 replaces remaining distillate oil, -179
2015	---	---	---	---	---	---	---
2016	---	---	---	---	---	---	---
2017	---	---	**Biodiesel (B100) replaces petroleum diesel in PPD fleet, -31**	**Biodiesel (B100) replaces petroleum diesel in PPD fleet, -31**	**Biodiesel (B100) replaces petroleum diesel in PPD fleet, -31**	**Biodiesel (B100) replaces petroleum diesel in PPD fleet, -31**	**Biodiesel (B100) replaces petroleum diesel in PPD fleet, -31**
Gross emissions (MTCDE) 2017	***20,266***	***19,027***	***18,382***	***17,771***	***17,160***	***7,315***	***6,938***

*Calculated by entering the pounds of organic and synthetic fertilizer applied in 2007 into the organic input cell of the Campus Carbon Calculator. The resulting emissions were subtracted from 2007 emissions that included both organic and synthetic fertilizer.
**The reduction 11,679 MTCDE reduction = 11,408, the reduction in gross 2007 emissions from biomass boilers option 1 or 2 (see Table 4) + 271, the emissions added by the student union renovations and from the new Colby Bookstore since these emissions result mostly from residual oil but were added after 2007
***Assumes that solar hot water would reduce 2007 residual oil use by 5 percent
**** Assumes that solar hot water would reduce 2007 residual oil use by 10 percent
***** Assumes that solar hot water would reduce 2007 residual oil use by 15 percent

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