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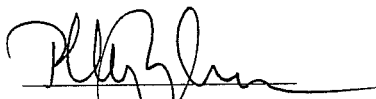
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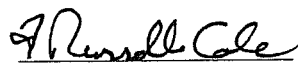
# Biomass Energy at Colby College

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May 6, 2011

A thesis submitted to the faculty of the Environmental Studies Program  
in partial fulfillment of the graduation requirements for the Degree  
of Bachelor of Arts with honors in Environmental Studies

  
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## **INTRODUCTION**

In light of growing concern regarding the effects of global climate change, Colby College signed the American College and University Presidents' Climate Commitment (ACUPCC) in 2008. Through this pledge, Colby has committed to reducing carbon emissions in its Climate Action Plan (IPCC 2007; CCAP 2010). The College seeks to be carbon neutral by 2015 (CCAP 2010). This will be accomplished through a variety of mechanisms, one of which includes the construction of a biomass facility to replace most of the oil currently used for heating (CCAP 2010).

Anthropogenic global climate change has been documented by many scientists, but was widely publicized in the late 1980's by James Hansen, director of NASA's Goddard Institute for Space Studies. Hansen testified in front of Congress in 1988, stating that the greenhouse effect has been observed in many cases and predicting a significant temperature increase in the next few centuries (Shabecoff 1988). His testimony was reinforced by the report he and his colleagues published that year (Hansen et al. 1988). Two years later, in 1990, the Intergovernmental Panel on Climate Change (IPCC) published its first report on climate change (IPCC 1990). The IPCC has published three updates since the 1990 report, the most recent of which was released in 2007 (IPCC 2007). The numerous scientists that take part in these assessments have concluded that the global warming trend is caused by greenhouse gas (GHG) emissions, which are gases in Earth's atmosphere that trap heat. These gases are emitted from many sources including deforestation, transportation and energy production.

In 2008, by far the largest contributor to GHGs emitted in the United States was fossil fuel combustion. The energy sector in the US relies heavily on fossil fuels; over 88% of total energy consumption comes from oil, coal or natural gas (EIA 2008). Given fossil fuels' non-renewable nature, they are inherently unsustainable sources of energy.

Biomass energy has emerged as an alternative to fossil fuels. It is a renewable fuel source that can be used for the production of both electricity and thermal energy. Biomass facilities in the US run on a variety of fuel sources, including corn stalks, switchgrass, plantation-grown willow branches, construction debris, urban waste wood, and forest-harvested waste wood (Perlack et al. 2005). In the context of Maine and this thesis, I use the "operative definition" of forest biomass, which refers to fuel comprised

of logging residues, previously un-merchantable stems, and other such woody material harvested directly from the forest for the purpose of energy production (Benjamin 2009).

In the state of Maine, forest resources are plentiful; nearly 90% of Maine is forested (Smith et al. 2009). Because of this fact, the logging industry is an important sector of the economy, with forest-related resources contributing \$1.98 billion to annual state income in 2008 (BEA 2008). Given the extent of forest resources available in Maine, this thesis focuses on biomass projects that utilize only forest waste wood, representing the dominant trend in the state.

Biomass is a considerable part of Maine's energy portfolio, comprising 35% of total energy produced, and in the near future is expected to provide a consistent source of renewable thermal energy (EIA 2010). There is debate in the literature over the relative advantages and disadvantages of biomass energy. In this thesis, I introduce the topic of biomass energy, outline the related policy, explore the debates within the scientific community regarding the carbon neutrality of biomass, analyze the differences between forest certification mechanisms, explain Colby College's biomass facility as a case study, discuss Colby's current plan and possible options, and then analyze the direction of Colby's biomass facility into the future, including a matrix analysis of the different sourcing options and conclusions on the best options.

## **METHODS**

I began the research for this thesis with an extensive literature review of relevant reports, journal articles and data. Part of the research was conducted in conjunction with the production of a chapter on biomass energy in the 2010 edition of the annual State of Maine's Environment Report in fulfillment of the curriculum of ES 493 – the Environmental Studies Practicum (Baron, Braverman, and Gassert 2010). I acquired these materials through searches using databases of peer-reviewed journals including Web of Science and Google Scholar. I also used government reports, accessed from the respective agency websites. For data relating to forest certification mechanisms, I used information from the organizations' websites and external analyses and summaries from peer-reviewed journals. I conducted six interviews with experts in the field plus additional interviews with Physical Plant Department staff on campus to gain knowledge on the various aspects of the research. The aim of some of these interviews was to gain information specific to the Colby biomass facility, while others focused on forestry practices and biomass use cases in the Northeast.

### **Matrix Methods**

To create a matrix of important factors on forest certification, I first established five variables on which to score the different mechanisms. The variables are: Biological, Economic, Social, Enforcement, and Widespread. The Biological category is based on the stated goal of the certification mechanism; if biological integrity is of the utmost concern the mechanism received a 1. The Economic category is based on the prioritization of economic concerns in the mechanism's standards; the mechanism received a 1 if economic success is a priority. The Social category is based on whether the mechanism prioritizes social issues in their standards; the mechanism received a 1 if social issues are a priority. The Enforcement category was based on the rigor of the verification and enforcement of the mechanism, contingent in part upon the true "third party" nature of the program; the mechanism received a 1 if it has rigorous enforcement. The Widespread category is based on international and national widespread acceptance; the mechanism received a 1 if it is broadly accepted and utilized. This category was not

applicable to all mechanisms, because the expressed goal of some mechanisms is to be regionally-specific.

In order to draw conclusions about the best methods for sourcing the Colby facility, I created a second matrix, which compares six different options for sourcing by using seven different benefits as indicator variables. The variables are: Reasonable Cost, Simple to Implement, Efficiency ME Compliant<sup>1</sup>, Sustainability, Educational Benefits, and Local Forestry Benefits. Each option was assigned a relative value of 1 if the benefit was present, or a 0 if it was not. One received a 0.5 if the benefit was minimally present, or could be present under some conditions. The total of the seven variables produced a score used to rank the different options for sourcing.

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<sup>1</sup> Efficiency ME is an organization that works to promote the adoption of energy efficient practices in Maine. To receive a grant from Efficiency ME, applicants must comply with certain standards.

## **BACKGROUND**

The term “biomass” technically refers to all living or dead organic matter in an ecosystem, but when used to describe an energy source, it means the material used to generate heat and/or electricity (Benjamin et al. 2010; Forest Guild 2010). An important distinction lies in the difference between production of heat and electricity, because when using biomass, it is considerably more efficient when used to generate heat (75-85%) than for electricity (20-25%) (Manomet 2010). It also depends on which type of biomass fuel is being used for energy generation.

In this thesis, I focus on forest biomass, which comes from waste wood from forestry operations, including tree-tops, limbs, bark, and other unmerchantable wood (Benjamin 2009). Some biomass operations use whole tree chips, meaning wood chips made from the entire tree. This is not economically feasible in Maine, given the established market for the higher value wood that comes from tree-trunks, or “stems” (Kittler 2011). Also, wood pellets are considered biomass in some accounts. Wood pellets burn more efficiently than biomass chips do: 80-90% efficiency as opposed to 75% (Manomet 2010). This is because the pellets are more uniform in size density and moisture content, but since they require manufacture they are more expensive and better suited for domestic use. Wood pellets are not feasible on a large scale such as a college campus due to higher cost (Murphy pers. comm.). For this reason this thesis does not include analysis of wood pellet use.

There are two crucial elements to investigate when discussing biomass energy and its relative benefits. The first is the type of energy it is producing (electricity, heat, or both). When a biomass facility produces both heat and electricity it is said to produce “combined heat and power”, or CHP (EPA 2011). Within this category there are thermally-led CHP operations that produce primarily heat with electricity production being proportionally smaller, and electricity-led CHP operations that scale the project to produce electricity, then use some of the heat produced as a by-product (EPA 2011).

The other important distinction when assessing the conversion to biomass energy is to note what fuel source is being replaced. The most common sources are natural gas, coal, #2 heating oil and #6 heating oil, listed in order of efficiency. There are dramatic differences in carbon emissions and efficiency among these sources. Noting the



efficiency differences is important when assessing carbon impacts of switching to biomass.

### **Policy Pertaining to Biomass, US and Maine**

In the United States, federal funding for biomass is limited and is aimed at biomass projects producing electricity and transportation fuels (Manomet 2010). There are approximately \$16 billion annually in subsidies for corn-based ethanol production, primarily through two federal programs, and approximately \$6 billion in subsidies for renewable electricity generation projects (Manomet 2010). There are no significant federal subsidies provided specifically for thermal biomass energy.

The Biomass Crop Assistance Program, or BCAP, was introduced as a pilot program in 2008 to provide federal incentives for biomass as part of the Farm Bill (FSA 2010; Sims 2011). It acted as a catalyst for the expansion of the biomass industry in recent years, and provides financial assistance to owners and operators of agricultural and non-industrial private forestland who wish to establish, produce, and deliver biomass feedstocks (FSA 2010; Tatko pers. comm.). BCAP allows participating farmers to enter into a five-year agreement with USDA to establish annual or perennial crops or a fifteen year agreement for woody biomass, and provides annual incentive payments for the production of perennial and annual crops, cost-share payments to establish perennial biomass crops, and a dollar-for-dollar matching payment of up to \$45 per ton of eligible biomass to assist with the collection, harvest, storage and transport of a BCAP crop to a biomass conversion facility (NSAC 2011).

Other important federal legislation includes the Clean Air Act of 1970, which establishes ambient air quality standards and permit systems for polluters, and features biomass-related portions including National Ambient Air Quality Standards (NAAQS) and New Source Review (NSR) permits; the Biomass Research and Development Act of 2000, which created the Biomass R & D Board to promote biofuels through federal grants and assistance, and guide federal strategic planning; and the American Recovery and Reinvestment Act: Public Building Wood-to-Energy program of 2009, which includes a \$11.4 million grant to assist in wood-to-energy installations in Maine public facilities (Baron, Braverman, and Gassert 2010).

There are some Maine-specific pieces of legislation that serve to regulate and promote biomass energy. One important state law is the Renewable Portfolio Standards of 1999 that sets the standard that at least 30% of energy generation sold in Maine be from renewable sources, and the 2006 Maine Renewable Portfolio Goal, which requires an additional 10% of new renewable energy capacity by 2017 (DSIRE 2010). These standards and goals encourage fossil fuel alternatives for the state of Maine, especially encouraging biomass energy expansion. Also, in 2008, Governor Baldacci introduced the Governor's Wood-to-Energy Initiative. This program promotes the conversion to wood biomass use in public buildings, encourages homeowners to switch from oil heat to heat from renewable energy sources, and promotes Maine-grown alternative energy industries (Wood-to-Energy Task Force 2008).

Lastly, the Regional Greenhouse Gas Initiative (RGGI) is a cap-and-trade system for CO<sub>2</sub> emissions from power plants in the ten Northeastern member states: Connecticut, Delaware, Maine, Maryland, Massachusetts, New Hampshire, New Jersey, New York, Rhode Island and Vermont (RGGI 2011). Emission permit auctioning began in September 2008, and the first three-year compliance period began on January 1, 2009. Proceeds are used to promote energy conservation and renewable energy within the member states. Maine is investing RGGI proceeds in energy efficiency programs administered by Efficiency Maine (Efficiency ME 2010). Programs implemented in 2010 were projected to save nearly \$3 for every \$1 invested; generate over \$95 million in lifetime economic benefits for the state of Maine; and avoid more than 429,901 tons of CO<sub>2</sub> pollution over the lifetime of the installed measures (MPUC 2010). According to staff of Efficiency Maine, CO<sub>2</sub> allowance proceeds from RGGI represented 35% of Efficiency Maine's total funding in 2010.

### **The State of Biomass in Maine**

In Maine, biomass comprises 35% of total energy consumption and 70% of all renewable energy consumption (EIA 2010). Maine is nearly 90% forested, and is the most forested state in the nation in terms of percent of land cover; the state's vast forest resources make it well suited for the production of biomass energy. Of this forestland, 97% is available timberland, which gives it an advantage over all other states in terms of

resources for biomass energy production (Baron, Braverman, and Gassert 2010). Furthermore, most of Maine's forestlands, including conservation land, preserve logging rights, which contributes to the high percentage of available timberland.

The forest product sector makes up an important part of Maine's economy, employing over 18,000 people (INRS 2005). Maine's well-established forest products industry better prepares the state for adoption of biomass energy because it already has the necessary infrastructure and equipment, knowledge of management practices, and a trained labor force.

### **Carbon Impacts**

There are two important questions that help to frame the debate over the value of biomass as a tool for emissions reductions. The first is whether biomass energy facilities have higher or lower carbon emissions than those using fossil fuels, and the second is whether biomass can be labeled "carbon neutral." In addressing these questions, two broad camps have emerged. The first group posits that biomass is carbon neutral. This group maintains that because biomass comes from forests, which are constantly growing, the new trees that grow will replace harvested trees, and then will sequester the same quantity of carbon that was released (EPA 2011). They note that the carbon emissions from biomass are part of the natural cycle because trees naturally die in the forest and emit CO<sub>2</sub> as they decay. The same trees used for biomass energy would have eventually died and decayed, emitting carbon. The growing forest eventually re-captures carbon equal to the quantity emitted by the decaying trees. The biomass energy cycle is similar to this in that the wood used for biomass is classified as waste wood, and would decay regardless of whether it is burned. The emissions from biomass-burning energy facilities would eventually be recaptured by the re-growth of the forest. Among the proponents of this line of reasoning emerges a subset of this group: those who label biomass energy as carbon neutral. This perspective is held by the International Energy Agency (IEA), and is supported by the International Panel on Climate Change (IPCC) and the European Union (EU), though the EU states the importance of "taking into account the need for biomass resources to be managed in a sustainable manner" (IEA 2007; IPCC 2007; European Parliament and Council of the European Union 2009; EU 2009). In fact, the

Environmental Protection Agency (EPA), which is the regulator of emissions from energy producers, has long labeled biomass as carbon neutral, and recently decided to keep this designation for another three years (EPA 2011). Further, the biomass industry has been a strong advocate of using biomass energy to achieve carbon neutrality (Huang 2010).

The other broad camp questions the carbon neutrality of biomass energy, and seeks to analyze carbon impacts in tangible ways. A growing number of studies have attempted to calculate the actual carbon emissions of forest biomass energy. Marland and Marland (1992) published one of the first carbon sequestration studies of biomass, and found carbon benefits for switching to biomass from certain fossil fuels (EU 2009); thinning of the forest facilitates growth of young saplings, allowing carbon to be sequestered at a higher rate and offsetting the emissions from combustion. They concluded that carbon released from forest harvesting for biomass energy may be completely replaced in the long-term. Marland and Schlamadinger (1996) noted that carbon offsets for biomass are greater in forests that are more heavily managed. Later studies, such as those conducted by Katers and Kaurich (2007) and others conducted more complex analyses, utilizing techniques such as the life-cycle carbon analysis. This type of research gives quantitative values to the carbon benefits of biomass. For example, Katers and Kaurich (2007) concluded that biomass emits 9 to 21 times less carbon than fossil fuel sources do, even when accounting for the lower efficiency of biomass. However, within the scientific community, there is not yet agreement that biomass is carbon neutral, or even that biomass presents a less carbon-intensive option than certain fossil fuels. For example, Timmons and Mejia (2010) note that biomass energy is at least partially reliant on diesel fuel, though it is not significant: less than 2% of the total energy of biomass chips.

According to multiple studies, the switch from fossil fuels to biomass actually creates an initial increase in carbon emissions, and can take 5 to over 100 years to reach a point where net carbon emissions decline, and is dependent upon the fossil fuel that biomass replaces (Campbell and Block 2010; Manomet 2010; McKechnie et al. 2011). Further, the efficiency rating for electricity generated from biomass is around 25%, lower than both coal (32%) and natural gas (33%) (Manomet 2010). However, carbon “neutrality”, meaning net zero carbon emissions, is more feasible for other applications,

namely heat or CHP generation, because they are 75-85% efficient. When switching to thermal or CHP biomass from a system using #6 fuel oil (as is the case at Colby), the payoff timescale is less than five years. Compared to biomass systems that replace more efficient fossil fuel sources, this is a short payoff timescale. Converting to electricity-generating biomass from coal has a carbon debt payoff of 21 years, converting to thermal biomass from gas takes 24 years, and the conversion to electricity-generating biomass from natural gas has a carbon debt payoff over 90 years (Manomet 2010). Tables 1 and 2, below, demonstrate the carbon impacts of switching from fossil fuels to biomass. Table 1 illustrates the initial increase in carbon emissions when converting to biomass from the four specified fossil fuel sources: coal, #6 fuel oil, #2 fuel oil, and natural gas. Table 2 shows the net percentage of carbon emission reductions after 40 and 90 years, differentiated by the fuel source biomass is replacing.

**Table 1.** Excess Biomass Carbon Emissions as Percent of Total Carbon Emissions, Comparison to Fossil Fuel Sources (Manomet 2010)

	Coal	#6 Oil	#2 Oil	Natural Gas
Electric	31%	--	--	66%
Thermal/CHP	--	2%-8%	9%-15%	33%-37%

**Table 2.** Percent Reduction of Cumulative Carbon Emissions from Biomass Replacement of Fossil Fuel in 2050, 2100 (Manomet 2010)

Year	#6 Oil, Thermal/CHP	Coal, Electric	Gas, Thermal	Gas, Electric
2050	25%	-3%	-13%	-110%
2100	42%	19%	12%	-63%

Besides the fuel type biomass is replacing, the other main determining factor in the carbon impacts is the source of the wood chips, particularly with regard to forest management practices. The sustainability of the wood depends on the sustainability of the forest from which it comes. One way of ensuring forest sustainability is through forest certification mechanisms, which I discuss in the Forest Certification Mechanisms section.

In Maine, the issue of carbon neutrality has received more attention following the publication in 2010 of a study carried out by the Manomet Center for Conservation Studies, examining the carbon impacts of biomass (Manomet 2010). Bob Cleaves, the president of the Biomass Power Association, a national organization based in Maine, claims that nearly all the biomass produced in Maine is waste wood from forestry operations, including tree-tops and small-diameter limbs, that would otherwise go to landfills or decay in the forest (Huang 2010). He concludes that it should not be counted as emitting extra carbon because it had already been cut. Further, he argues against the Manomet (2010) assessment that using wood from land clearing for development cannot be labeled as sustainable because it will not grow back. Cleaves points out that the biomass industry does not cause land clearing, and is in fact using by-products that have no other use.

Another realm in which the carbon impact of biomass is contentious is the current congressional discussions on the ability of the EPA to regulate carbon dioxide under the Clean Air Act. If its jurisdiction over carbon is upheld, the carbon neutrality of biomass energy must be reassessed because it could be either controlled or excluded from the regulations. Republican Senator Susan Collins of Maine stated that biomass facilities should not be subject to the same regulations as fossil fuel energy facilities, citing the fact that biomass has historically been treated as carbon-neutral (Huang 2010). The EPA more recently decided to postpone any decision to regulate emissions from biomass for three years, which Collins supported (EPA 2011; Collins press release 2011).

### **Carbon Neutrality**

The term “carbon neutral” refers to a goal in which the net sum of all emissions from a certain source is zero. This condition is achieved when carbon emissions are greatly reduced and when all of the remaining emitted carbon from the source is accounted for through sequestration. Many institutions, Colby College included, seek carbon neutrality (CCAP 2010). This is pursued by first completing carbon audits to assess the quantity of CO<sub>2</sub> emitted from all potential sources, then implementing reduction measures and finally purchasing carbon credits to offset the remainder of the calculated emissions, bringing net carbon to zero. Carbon credits can be purchased from a variety of sources and often

go towards reforestation projects or other means of carbon sequestering [See Abbott 2010 for a more detailed discussion of carbon offsets]. However, one could easily argue that the term “carbon neutral” is essentially meaningless, because carbon offsets are hard to measure and long-term implementation cannot be ensured.

In the case of biomass, it is not a given that the project itself will be carbon neutral. A better phrase might be “carbon lean”. The false assertion of “carbon neutrality” hinges upon the assumption that the trees from which the biomass chips came will be replaced by new trees that will sequester the same quantity of carbon released by burning the chips. Some biomass comes from land-clearing initiatives for development that will never re-grow trees, meaning that the emissions from these sources will not be re-sequestered. In these cases, carbon emissions would likely be higher than those from fossil fuel energy production, because per unit of energy (MMBtu), biomass emits more carbon, regardless of the energy type being produced (Table 3; Manomet 2010). Moreover, the sequestration of carbon from forest re-growth relies on the health of the forest, which may or may not be ensured, depending on the forest management practices. It is possible that the label of carbon neutrality may never be applicable to the use of biomass energy. It might be useful in describing such renewable energies as wind or solar power, which have absolutely no emissions from energy production, except those involved in their manufacture, transportation, and installation, but is likely an unattainable goal for biomass facilities. However, carbon neutrality still presents a worthwhile goal because it produces incentive to monitor and greatly reduce carbon emissions.

**Table 3.** Carbon Emissions by Source (lbs/MMBtu) (Manomet 2010)

	Electricity	Thermal	CHP
Coal	642	--	--
Natural Gas	355	138	146
Oil	--	217	232
Wood Biomass	863	288	287

## **SUSTAINABILITY OF BIOMASS ENERGY**

Biomass is comprised of woody material harvested from the forest for energy production, and includes residues produced during harvesting, fuelwood from forestlands, residues from processing mills, and woody material extracted for fire hazard reduction and forest health improvement initiatives (Perlack et al. 2005). The material for biomass energy is harvested simultaneously with wood for other markets from managed timberlands.

Biomass energy has the potential to be completely renewable if managed sustainably. If poorly managed or harvested, it can lead to diminished soil productivity, water quality, decreased biodiversity, and lower forest yields in the long term (Benjamin 2009). Maine's forestry sector has extensive experience with forest management, as the paper and timber industries have long been integral to Maine's economy and culture. Both state and national legislation promote Best Management Practices (BMPs) and other sustainable forestry practices to protect forest health and ensure sustained productivity. Best Management Practices are a series of forestry guidelines designed to minimize negative environmental impacts of logging; BMPs include erosion control measures, soil stabilization, and proper handling of hazardous material (MFS 2005). The risk of Maine's forests becoming significantly damaged due to biomass harvesting is relatively low because of Maine's longstanding history with working forests and timber management and extraction (Benjamin et al. 2009).

Forests play an important role in the natural carbon cycle. Trees absorb carbon dioxide as they grow and release it when they die and decompose. This carbon cycle is part of the global balance of carbon, and influences and is influenced by climate change. Forests are used to balance GHG emissions, as mitigation and offset techniques. However, forests have multiple purposes, including providing fiber for the forestry industry, recreational use, providing habitat, and ecosystem services. All of these uses must be considered when determining the use of a forest.

### **Responsible Forest Management**

Responsible forest management is vital to forest health. If Best Management Practices are not followed, wildlife habitats and long-term forest productivity, could be



jeopardized (Shepard 2006). The most invasive and potentially damaging aspect of the wood production process is resource extraction. Soil quality, water quality, and diversity are three main factors that, if compromised, could lead to decreased overall forest productivity (Benjamin 2009). Within the forest products extraction process, soil productivity can be diminished if erosion prevention measures are not implemented. Water quality can be threatened by excessive forest floor disturbances, lack of control of water flow, or erosion control methods that are implemented too close to the water level in streams. Habitats can be disturbed by changing the composition of the forest by tree species, number, and density; reducing the number of decomposing down logs and standing dead trees; disruption from skidders and other large machinery; and the creation of roads, which can cause problems with runoff, soil compaction and habitat fragmentation (Benjamin 2009).

One impact of increased wood harvesting that has the potential to harm forest ecology is nutrient depletion, which results from the removal of living biomass, including mineral nutrients, from the forest without proper supplementation (Ljung and Nordin 1997). This can lead to decreased forest productivity, diminishing future potential for biomass resources.

A tree consists of five distinct components: roots, stem, bark, branches, and foliage. In tree harvesting, the roots are almost never taken from the forest. These contain a significant proportion of the tree nutrients, so when they decompose, the nutrients are recycled back into the soil (Sendak et al. 2003). Conventional stem-only harvesting is generally accepted as a sustainable practice for most forest sites and is not considered to have any long-term detrimental effects on site nutrient pools because of the small portion of nutrients extracted in the stems (the stump, branches and tops are left), and the long rotation periods that allow for nutrient replenishment (Smith et al. 1986). In fact, stems contain approximately 65% of total above-ground biomass, yet only 25% of above-ground nutrients, making them relatively nutrient-poor. However, the most dominant extraction method in Maine is whole-tree harvesting, potentially a cause for concern for long-term nutrient diminution (Benjamin 2009).

## **Biomass in the Wood Industry Context**

Nearly all biomass fuel consists of “waste wood,” predominantly the branches and bark that are otherwise unmarketable wood, and “hogfuel,” residues from sawmills and paper mills. This wood is of “pulpwood quality” or lower, which comprises the lowest quality wood products and were previously only used by the paper industry. The introduction and expansion of the biomass energy sector creates a new market for loggers, adding value to their harvest and utilizing that which was previously considered waste. This new market has economic benefits, but may also introduce conflicts of interest (Benjamin et al. 2009). For example, a standing dead tree has at least three conflicting values that must be balanced by loggers. First, standing trees provide habitat and thus help to protect biodiversity. Second, if chipped and spread in skid trails the tree chips will help to reduce soil compaction and erosion from the machinery, helping to protect the overall forest health. Lastly, if chipped and sold to a bioenergy facility, a tree will generate income and provide energy. Benjamin (2009) summarizes this conflict of values, and explains that tradeoffs are necessary when deciding on the use of an individual tree. Although regulations exist to deal with these tradeoffs with regard to the general forest industry, there are no specific guidelines outlined for woody biomass use. Essentially, biomass energy promises a new and economically beneficial use for low-grade wood, but it introduces yet another option for its use, further complicating the decision-making process for forest management.

Within the forest sector there are varying levels of wood quality, from the most expensive, veneer wood, to the least expensive, biomass wood chips (Wood-to-Energy Task Force 2008). The difference in quality is substantial enough that the wood used for wood biomass energy could not be used for anything else, with the possible exception of pulp for paper mills. Because loggers want to maximize their profits, the economic incentives of the forest products market ensure that wood is used for different purposes depending on quality. In an ideal world where there are enough buyers of wood and contractors, the growth of the wood biomass energy sector would merely increase revenues for the wood industry, but the reality may not be so simple. Benjamin et al. (2009) warn that the bioindustry may be forced to compete for services and materials with existing wood-using facilities.

## **FOREST CERTIFICATION MECHANISMS**

In discussions regarding forest certification mechanisms, there are two broad camps: one claims that the differences between forest certification mechanisms are not of significant importance; the other believes that the differences are significant. Within the latter group, some argue that though different, all certification mechanisms strive to improve sustainability, and should therefore ought to be equally valued. Others in this group argue that although the mechanisms originated differently, they have since converged enough so that their differences are no longer distinct. For example, the National Organization of State Foresters announced that "while in different manners, the ATFS [American Tree Farm System], FSC [Forest Stewardship Council], and SFI [Sustainable Forestry Initiative] systems include the fundamental elements of credibility and make positive contributions to forest sustainability... No certification program can credibly claim to be 'best', and no certification program that promotes itself as the only certification option can maintain credibility" (NOSF 2008).

However, others argue that the origins of the mechanism matter; for example, some experts assert that SFI's origins in the US forest industry (AFPA) preclude it from being objectively oriented towards sustainable forest management. Another argument for the substantial differences between certification mechanisms is that each one has a different set of requirements, and different methods of confirming compliance with standards.

The consequences of the differences between certification mechanisms are difficult to discern, even for forestry experts. The guidelines and requirements for the varied schema may seem similar or equally rigorous, but may be dramatically different when put into practice in the field. This has implications for consumer awareness as well; a 2003 report notes that "consumers of forest products cannot be expected to make assessment of the credibility of certificate as the task is complex and requires expertise and information they do not usually have" (Rametsteiner and Simula 2003). It is therefore valuable to assess the different certification programs and attempt to discern the strengths and weaknesses of each.

## **Certification in Maine**

Maine has been the leading state in forest certification since the early 1990s when the Pingree Heirs land became the first million-acre ownership to get certified under the Forest Stewardship Council (North East State Foresters Association 2007). Since then, acreage of certified land has continued to increase. Today, 37% of Maine's productive forestlands, or nearly 7 million of the total 17.6 million acres are certified by one of the major certification systems: Forest Stewardship Council (FSC), Sustainable Forestry Initiative (SFI), or American Tree Farm System (ATFS). In Maine, there are differences in the extent to which each certification mechanism is present. In 2004, SFI was by far the most widespread, with over 4.8 million acres certified (MFS 2005). FSC had over 366,000 certified acres, and there were over 1.4 million acres dual certified by SFI and FSC. ATFS had 300,000 certified acres. These three certification schemes are not the same, and there are important differences to recognize between them. In the following sections, I describe four certification mechanisms and one set of guidelines and compare their strengths and weaknesses.

### **Forest Stewardship Council (FSC)**

The Forest Stewardship Council (FSC) was established in 1993 (Maser and Smith 2001). The purpose of this non-profit international organization is to create market incentives for responsible forestry management. The formation of FSC was in response to concern over global deforestation (FSC 2010). According to their website, their stated vision is that "world forests meet the social, ecological, and economic rights and needs of the present generation without compromising those of future generations." FSC seeks to affect "solutions to the pressures facing the world's forests and forest-dependent communities" through a voluntary, market-based forest products certification program. It often works in tandem with national forest management policy, because if there are policy incentives for certification, certification is more likely to be pursued, and on a larger scale (Ebeling and Yasué 2009).

The organization uses democratic processes with collaboration among participants from developed and developing nations, and large and small companies to determine responsible forestry practices that are "environmentally appropriate, socially beneficial

and economically viable” (FSC 2010). FSC awards certificates for forest management and chain-of-custody. The former refers to logging operations while the latter refers to the stages of transfer between timber extraction and sale to consumers. To receive either type of certificate, applicants must fulfill certain requirements in terms of ecological impacts, environmental sustainability and social practices, as assessed through an on-site audit completed by an FSC-accredited third-party certifier.

Since its inception in 1993, FSC has experienced two significant and unforeseen outcomes: industry competitors and regional concentration (Cashore et al. 2006). In every country in which FSC has gained traction, industry-initiated competitor forest certification schemes have emerged, aiming to provide an alternative option that is less stringent and more business-friendly for logging operations that wish to gain “eco-certification.” This market competition can create confusion among consumers who are likely unable to differentiate between the competing schemes. The second unexpected outcome has been a concentration of FSC certification in developed countries. Although FSC was initially created to address unsustainable forest management in developing countries, the majority of FSC certifications are in Europe and North America, both in percent of forests certified and in total area, despite the assertion that certification could have greater impacts in the developing nations (Ebeling and Yasué 2009). This is possibly due to greater awareness of certification programs, easier access to environmentally sensitive markets, and more stringent forest regulations, making achievement of FSC requirements more easily attainable.

In terms of sustainability, FSC has the most stringent requirements for forestry practices of any of the forest certification schemes. It is also the only scheme that is completely external to the forestry industry; it is a third-party certifier. For these two reasons FSC is the most well regarded within the forestry industry (Perschel 2011). Another indication of the acceptance of the FSC program is that it is endorsed by environmental non-profit organizations that focus on forests, including the Rainforest Alliance Network and the Forest Guild (FG). These groups seek to protect and enhance forest health, and their support for FSC may help to identify this program as an effective one.

However, FSC does not have management specifications for forests utilized for biomass extraction. In this way, FSC certification is still not tailored to biomass operations, as it does not have retention guidelines for woody material to be left on the forests floor for nutrient cycling. It contains such vague language as “the rate of harvest of forest products shall not exceed levels which can be permanently sustained” (FSC 1996). This standard is hardly explicit in its description of ways to ensure sustainability. Further, the FSC requirements state that “ecological functions and values shall be maintained intact, enhanced, or restored, including: forest regeneration and succession; genetic, species, and ecosystem diversity; and natural cycles that affect the productivity of the forest ecosystem” (FSC 1996). Nutrient depletion caused by excessive removal of woody material is one of the greatest concerns in terms of forest sustainability of biomass operations (Benjamin et al. 2009). This issue is not adequately addressed in the FSC criteria for certification.

### **Sustainable Forestry Initiative (SFI)**

The SFI program was launched in 1994 as one of the U.S. forest sector’s contributions to the vision of sustainable development established by the 1992 United Nations Conference on Environment and Development (SFI 2010). The American Forest and Paper Association (AFPA) led the initiative. Its original principles and implementation guidelines began in 1995, and it evolved into the first SFI national standard backed by third-party audits in 1998.

Today, SFI is an independent, non-profit organization responsible for maintaining, overseeing and improving a sustainable forestry certification program that is internationally recognized and is the largest single forest standard in the world. The SFI 2010-2014 Standard is based on principles and measures that promote sustainable forest management and consider all forest values (Sustainable Forestry Initiative 2010). It includes specific fiber sourcing requirements to promote responsible forest management on all forestlands in North America. SFI also certifies fiber under its own label if the fiber is certified by any standard operating in North America that endorsed by the Programme for Endorsement of Forest Certification schemes, PEFC.

According to Bob Perschel of the Forest Guild, the SFI certification program has improved in recent years, but still considered second-best to the FSC mechanism (Perschel pers. comm.). Part of Perschel's concerns lie in the beginnings of the Initiative. There is concern that SFI may be more lenient because of its industry-based origins. The fear is that AFPA wants to provide an easily attainable "green certification" to improve public appearance while avoiding the introduction of any strict regulations or limitations on industry members (Queena Sook and Carlton 2001). However, a study conducted by Lenox and Nash (2003) shows that, compared to other industry-based self-regulation certification schemes like that of the chemical industry, SFI attracts more environmentally clean firms because of its policy of sanctions for non-compliant members.

### **American Tree Farm System (ATFS)**

ATFS is a program of the American Forest Foundation's Center for Family Forests (ATFS 2011). The foundation is a non-profit conservation and education organization that strives to ensure the sustainability of America's family forests for present and future generations. The mission of ATFS is to promote the growing of renewable forest resources on private lands while protecting environmental benefits and increasing public understanding of all benefits of productive forestry (ATFS 2011). Family forest landowners own nearly two-thirds of U.S. forestlands, and 60% of all the wood harvested in the country comes from family forestlands. Further, ATFS is endorsed by the PEFC. Thus, fiber from ATFS-certified forests can be counted as certified content for SFI label use.

The ATFS forest certification standard applies to small landowners in the United States. It requires that private forest landowners develop a management plan based on environmental standards and pass an inspection by an ATFS inspecting forester. Third-party certification audits, conducted by firms accredited by the ANSI-ASQ National Accreditation Board or the Standards Council of Canada, are required for all certification programs of the ATFS. In 2009, ATFS had certified more than 25 million acres in the US of privately owned forestland managed by over 90,000 family forest landowners who are committed to excellence in forest stewardship (ATFS 2011).

Among forestry experts with whom I spoke, it seems that ATFS is regarded as the third choice among certification mechanisms. These sources include Bob Perschel of the Forest Guild, Peter Stein of the Lyme Timber Company, and Brian Kittler of the Pinchot Institute for Conservation Studies. This assessment is due to the lack of clarity of the ATFS's certification requirements (Stein pers. comm.; Kittler pers. comm.).

### **Master Logger Certification (MLC)**

While the FSC, SFI, and ATFS programs certify that wood products industries are managing their lands in a manner that will not jeopardize the availability of forest resources for future generations, the Master Logger Certification (MLC) program aims to monitor and certify wood harvesting (Northeast Master Logger 2011). From the perspective of MLC, wood harvesting companies, which range from sole proprietors to large-scale businesses with multiple employees, may have the greatest direct impact on the health of the forest ecosystem. Their operations supply raw material for wood products industries, but they also have the potential to conserve or compromise water and soil quality, wildlife habitat, biodiversity, and forest aesthetics.

Responding to the need to certify natural resource harvesting companies, the Professional Logging Contractors of Maine began developing the Master Logger Certification Program in 2000. A draft MLC document outlining the certification requirements was written and widely distributed to wood harvesters, forest products industry representatives, and policy makers during the spring and summer of 2000. Their feedback was incorporated into the document, and MLC began a pilot program. The first MLC received certification in July of 2001. In 2005, the Trust to Conserve Northeast Forestlands, an independent non-profit organization, took over the administration of the MLC program, which allows for the MLC to be classified as a third-party certification system.

MLC is split into regional groups, allowing each region to establish standards and self regulation methods. The benefits of this design are that it can be a smaller, more manageable scale and can be tailored to specific bio-regional and political needs, but it also risks weakness due to lack of oversight and accountability.



Similarly to the SFI, MLC was initiated by the industry that it is designed to regulate. It is now technically a third-party system, but many would say that the origins of the program cannot be discounted. It is also important to note that this program's aim is to certify a different aspect of the forestry process. MLC seeks to improve the health of the forest ecosystem, but does not certify forest management practices. This is seen as the weakest certification mechanism for ecosystem protection and strictness. This may be due to the design of the program, its newness, or a combination of other factors.

The New England Master Loggers Certification Program (NEMLC) is the recipient of the world's first SmartLogging certificate – an international harvest standards recognition by the Rainforest Alliance's SmartWood program, and NEMLC is audited annually to maintain this certificate (Northeast Master Logger 2011). The content of the Master Logger Certification program is based on a common vision for the rural communities and forest resources of the Northeast. These eight goals guide Master Loggers in their work: document harvest planning, protect water quality, maintain soil productivity, sustain forest ecosystems, manage forest aesthetics, ensure workplace safety, demonstrate continuous improvement, and ensure business viability. There are detailed harvest responsibilities with explicit performance standards under each goal. Field verifiers visit harvest sites to determine whether candidates for Northeast Master Logger Certification are meeting the standards that are required for certification. Their findings are submitted to an independent, national board that makes the final decision on whether a company will be certified. Maine was the first place in the world with a point-of-harvest Master Logger Certification (MLC) program, offering independent third party certification of logging companies' harvesting practices (Northeast Master Logger 2011).

### **Biomass Retention Guidelines**

Two Northeast-specific reports exist that outline specifics for biomass extraction retention guidelines. The first study was edited by Benjamin (2009). The second was produced by the Forest Guild Biomass Working Group (Forest Guild 2010). Both of these studies consider the soil productivity, water quality, biodiversity and wildlife

habitat of forests harvested for biomass energy, and propose leaving certain percentages or quantities of waste wood on each acre of harvested forest. The material left behind is called downed woody material (DWM) and a certain amount should be left in the forest to maintain habitat diversity, soil productivity, and nutrient cycling. The Forest Guild report offers specific tonnage and percentages of harvest to be left on the floor, such as 8-16 tons per acre in a Northern Hardwood forest versus 5-20 tons per acre in a Spruce-Fir forest (Forest Guild 2010). It also recommends 25-33% of all tree-tops and limbs be left in the forest to retain nutrients (see Appendix 1).

## **BIOMASS AT COLBY COLLEGE**

Colby is committed to environmentalism, as expressed in the College's list of core values. The pertinent text of the statement of values is as follows:

*“Colby is committed to nurturing environmental awareness through its academic program as well as through its activities on campus and beyond. As a local and global environmental citizen, the College adheres to the core values of respect for the environment and sustainable living. Colby seeks to lead by example and fosters morally responsible environmental stewardship. Environmentally safe practices inform and guide campus strategic planning, decision making, and daily operations. We urge community members to recognize personal and institutional responsibilities for reducing impact on the local and global environment. Finally, we recognize that achieving environmental sustainability will be an ongoing challenge that evolves as we become more aware and educated as a community”* (Colby College Catalog 2009).

Further, Colby College has committed to achieving carbon neutrality by 2015 (CCAP 2010). This commitment was inspired in part by a national Climate Commitment that Colby signed in 2008. Colby has planned, undertaken, and completed a number of projects designed to help meet this goal of carbon neutrality, the largest of which is the conversion of the campus steam plant from fuel oil to woody biomass.

### **The American College and University Presidents' Climate Commitment**

The American College and University Presidents' Climate Commitment (ACUPCC), is a commitment to which many presidents and chancellors of colleges and universities have signed. The text of the formal Commitment states that climate change is real and primarily caused by humans. It also recognizes the need to reduce global emissions of greenhouse gases by 80% by mid-century (Presidents' Climate Commitment 2007). It then outlines many benefits of reducing carbon emissions including short-, medium-, and long-term economic, health, social and environmental benefits, educational opportunities for students, and public relations benefits.

Upon signing the commitment, each college or university pledges to develop a comprehensive plan to achieve climate neutrality as soon as possible. This is further specified by the following requirements:

1. Within two months of signing this document, create institutional structures to guide the development and implementation of the plan.
2. Within one year of signing this document, complete a comprehensive inventory of all greenhouse gas emissions (including emissions from electricity, heating, commuting, and air travel) and update the inventory every other year thereafter.
3. Within two years of signing this document, develop an institutional action plan for becoming climate neutral, which will include:
  4. A target date for achieving climate neutrality as soon as possible.
  5. Interim targets for goals and actions that will lead to climate neutrality.
  6. Actions to make climate neutrality and sustainability a part of the curriculum and other educational experience for all students.
  7. Actions to expand research or other efforts necessary to achieve climate neutrality.
  8. Mechanisms for tracking progress on goals and actions.

The colleges also pledge to initiate two or more of the following tangible actions to reduce greenhouse gases while the more comprehensive plan is being developed.

1. *Establish a policy that all new campus construction will be built to at least the U.S. Green Building Council's LEED Silver standard or equivalent<sup>2</sup>.*
2. Adopt an energy-efficient appliance purchasing policy that requires purchase of ENERGY STAR certified products in all areas for which such ratings exist.
3. Establish a policy of offsetting all greenhouse gas emissions generated by air travel paid for by the institution.
4. Encourage use of and provide access to public transportation for all faculty, staff, students and visitors at the institution.
5. *Within one year of signing this document, begin purchasing or producing at least 15% of institution's electricity consumption from renewable sources.*

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<sup>2</sup> Italics indicates that Colby College has initiated this action

6. Establish a policy or a committee that supports climate and sustainability shareholder proposals at companies where the institution's endowment is invested.
7. *Participate in the Waste Minimization component of the national RecycleMania competition, and adopt three or more associated measures to reduce waste.*
8. *Make the action plan, inventory, and periodic progress reports publicly available by providing them to the Association for the Advancement of Sustainability in Higher Education (AASHE) for posting and dissemination.*

### **Colby's Commitment to Carbon Neutrality**

Colby College signed State of Maine Governor's Climate Challenge in 2005 and the American College and University Presidents' Climate Commitment in 2008 (CCAP 2010). As part of the compliance with ACUPCC, Colby developed a climate action plan. In Colby's Climate Action Plan (CCAP), the College has committed to achieving "carbon neutrality" by 2015 (CCAP 2010). In this document, "carbon neutrality" refers to achieving net zero total carbon emissions for which Colby is responsible, through efforts to minimize CO<sub>2</sub> emissions, paired with purchasing carbon offsets that support carbon sequestration. Colby plans to reduce current emissions by 41% before 2015 by building a biomass facility to be functional by January 2012; improving efficiency, conservation, and waste-minimization efforts; considering alternative energy vehicles; and promoting online meetings and better-coordinated travel (CCAP 2010). The remaining carbon emissions for which the College is responsible will be offset by the purchase of renewable energy credits and carbon offsets (see Appendix 2).

### **The Efficiency Maine Grant**

The Energy Programs Division (Efficiency Maine) part of the State of Maine Public Utilities Commission (MPUC), is in charge of a program started in 2009 to allocate one-time grants for energy efficiency and renewable energy projects. The funding for these grants in part comes from the American Recovery and Reinvestment Act of 2009, which provided Maine with economic stimulus funds for job creation, energy efficiency, renewable energy, weatherization, and workforce development (MPUC 2010). Funds also

come from revenue from quarterly Regional Greenhouse Gas Initiative (RGGI) auctions. The Commission stipulated a simple payback of less than 10 years, where simple payback is defined as the total cost of the measure divided by the energy savings per year.

For 2010, the maximum grant awarded was expected to be \$750,000. The grants were awarded based on three main criteria: cost effectiveness in reducing greenhouse gas emissions, management and resource adequacy and readiness, and economic viability. One of the many stipulations of the grant is planned completion by December 31, 2011. Colby's proposal for a biomass facility scored first among projects applying for this grant, receiving \$750,000.

### **The Colby Facility**

As reported in the 2010 Colby Climate Action Plan (CCAP), approximately 70% of the college's total carbon emissions are from heating. The CCAP introduces specific actions to reduce and mitigate these emissions, one of which involves the construction of a biomass facility. This \$11.25 million proposed facility, to be completed by January of 2012, has been approved by the Board of Trustees and construction has commenced (Terp pers. comm.).

The new biomass facility will be comprised of two ChipTec 400 boiler horsepower fire tube boilers fed by close-coupled gasification units. These boilers will be fueled by waste wood chips, or "hog fuel" (Murphy pers. comm.). The new facility will provide 90% of the campus steam demand, replacing the use of the current steam plant, which is run on #6 residual oil, during all but the coldest days of the year (CCAP 2010). The College currently consumes over one million gallons of residual fuel oil, about two to three truckloads per day (Murphy pers. comm.). After the biomass facility is on-line, the Colby Physical Plant Department (PPD) predicts that the campus will use about 22,000 tons of wood chips per year, or three to four truckloads per day in peak season. The area of forestlands needed to supply this quantity of waste wood is estimated to be between 60,000 to 100,000 acres (Stein pers. comm.). This estimate is based on known yields of and low-grade and waste wood per acre, harvested using a 60-year harvesting cycle. The higher end of the estimates would reflect more conservative harvesting practices and

more consideration given to sustainability of the harvest.

The wood source for this project has not yet been determined, although Colby's Physical Plant Department (PPD) plans to source all the wood within a 50 mile radius from campus (Libby pers. comm.). Further, they will only purchase wood residues, and will source the fuel wood from certified logging initiatives. The current steam plant includes a turbine that co-generates electricity from the steam produced in the boilers, and this turbine will continue to function with the transition to biomass energy, allowing for co-generation of heat and electricity and improvement of the facility's over-all efficiency.

Although Colby's biomass facility has an up-front cost of over \$11.25 million, the predicted payback time scale is six to nine years, depending on fuel oil and biomass chip cost fluctuations (Murphy pers. comm.). Further aiding in the financing of the project is a \$750,000 grant from the Efficiency Maine Trust. In order to qualify for this grant, the Colby biomass project must comply with certain specifications, such as sourcing all the wood from FSC, SFI, or Master Logger certified logging initiatives (Murphy pers. comm.).

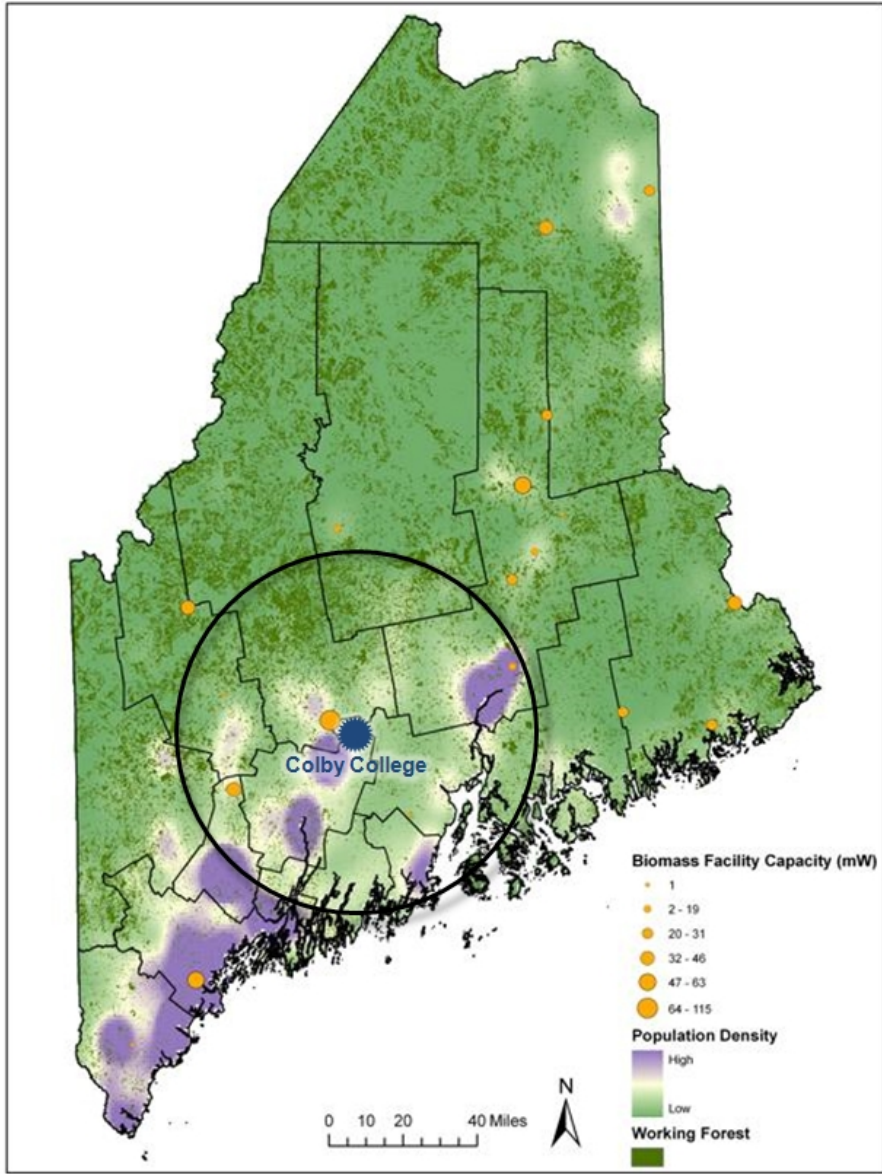
### **Sourcing the Colby Facility**

According to the text of the Efficiency Maine grant, biomass projects that receive Efficiency Maine funding, including the Colby facility, must agree to use certified sustainable wood:

*“For biomass conversions applicants must provide assurances that the fuel will come from certified sources such as Maine Tree Farm, Sustainable Forestry Initiative, Forest Stewardship Council and/or Master Logger with a harvest plan” (MPUC 2010).*

For this reason, Colby has committed to using only certified sources. However, there are differences among the certification schemes, and it is important to recognize the benefits and shortcomings among those being considered by the College. As previously described, there is debate as to whether the certification mechanisms should be seen as interchangeable, or if there are in fact dramatic differences that have implications for their ability to protect forests.

Colby has also committed to sourcing the facility from forestry operations within a 50-mile radius of the College. Figure 1 shows the 50-mile radius around Colby College, other biomass facilities in the state, population density, and lands classified as working forests. It can be assumed that only lands classified as working forests would produce biomass waste product.



**Figure 1.** Colby College, 50-Mile Sourcing Radius, and Other Biomass Facilities in Relationship to Population Centers and Working Forests in Maine (EIA 2008)



## **ANALYSIS**

Accounting for the positive and negative impacts of the adoption of biomass energy is a valuable step in an analysis of the Colby biomass project. This section seeks to synthesize the advantages and disadvantages of the biomass at Colby, and can serve as a reference for the College.

### **Differences in Forest Certification Mechanisms**

As described above, it is apparent that not all certification programs are similar or mutually exclusive because a single tract of land can hold multiple certifications. Their differences lie partly in the goals they seek to achieve, with FSC and SFI focusing on balancing sustainability and forest health with economic and social concerns, the ATFS program specifically targeting private landowners, and MLC focusing exclusively on wood harvesting, as opposed to management. Another difference is the rigor of the auditing and the various requirements with which the land management must comply.

A 2002 study conducted by the Pinchot Institute for Conservation assessed the differences between the SFI and FSC certification systems (Mater et al. 2002). The study assessed six different parcels of forest. Over the course of the study, each of the managers attempted to gain certification by both the FSC and SFI programs. The study conducted surveys on the standards, process, and outcomes of the two programs. According to these results, FSC certification was rated higher in comprehensiveness; coverage of biological/ecological and social issues; and relevance to the forest management agencies' objectives. The SFI program ranked higher in clarity of guidelines, coordination of assessment, and rigorous requirements for improvement over time and staff training.

From my interviews with experts in the field of biomass, FSC is held in the highest esteem, followed by SFI, with ATFS ranking third (Perschel pers. comm.; Kittler pers. comm.). Because the Master Logger programs do not seek to promote or ensure sustainability, this program is not easily compared to the other three. From my interviews, I conclude that Master Logger Certification, when used as the sole certification of a forest, is not sufficient for ensuring forest sustainability.

When assessing biomass retention, both the Benjamin (2009) and the Forest Guild (2010) reports are helpful guidelines and recommendations for forestry management on

sites with extraction for biomass. The former offers many considerations to be taken into account when managing a forest for biomass extraction, while the latter report offers tangible goals, numbers and percentages of DWM to leave in the forest. For the purpose of implementation, the Forest Guild report seems easiest to implement, use and enforce, because it provides concrete goals and indicators of success of failure to comply.

In order to compare the different forest certification mechanisms, I created a matrix of important factors of each mechanism. The sum of each column creates a score for each mechanism, seen in the last row of the Table 4. These scores rank the mechanisms against one another, with FSC emerging as the best, SFI second, ATFS third, and MLC last. The Forest Guild Retention Guidelines is not included in the rankings because it is not meant to replace any of the certification mechanisms, nor is it an enforced certification. It is a set of guidelines designed to specifically help with forestry operations engaging in biomass extraction, to be utilized in addition to any other requirements.

**Table 4.** Comparative Matrix of Forest Certification Mechanisms<sup>3</sup>

	FSC	SFI	ATFS	MLC	FG
Biological	1	1	1	0	1
Economic	1	1	1	1	0
Social	1	0	0	0	0
Enforcement	1	1	0	0	-
Widespread	1	0	-	-	-
<b>Total</b>	<b>5</b>	<b>3</b>	<b>2</b>	<b>1</b>	<b>1</b>

<sup>3</sup> See Matrix Methods on page 3 for explanation of scoring

## **Benefits of Biomass at Colby**

There are many benefits in the conversion from fuel oil to biomass energy. Possible benefits of the facility at Colby include the financial investment, local energy, educational opportunities, public relations implications, and environmental concerns regarding carbon emissions and ecosystem impacts.

### *Financial Gains*

Though the initial cost of building the facility is large, the Physical Plant Department expects achieve complete payback in nine years or less. As oil prices continue to rise, biomass as a renewable resource may have a more stable price. Biomass prices in 2011 are \$35-40 per ton, so Colby will spend between \$770,000 and \$880,000 per year on fuel (Murphy 2011; PPD 2011). This is in contrast to Colby's spending on fuel oil, which fluctuates considerably. In the 2008-2009 school year, the average cost of oil was \$103 per barrel; for 2009-2010, the average was \$73 per barrel; the projected average for 2010-2011 is \$89 per barrel. Using the most recent average, Colby will spend about \$2,331,000 on fuel this year. This means that in one year, Colby can save nearly \$1.5 million on heating fuel.

### *Energy Independence*

The biomass fuel used for the facility will all come from Maine, providing a local and renewable source, allowing Colby to avoid reliance on energy sources from far away. Petroleum reserves are being diminished, and international conflict and instability make prices volatile and supply inconsistent. Between June 2010 and January 2011, oil prices rose from around \$80 to \$95 per barrel (PPD 2011). Year to year fluctuations are also wide and unpredictable. Meanwhile, there is predicted to be a relatively stable supply of biomass chips from sources within 50 miles of Colby College (Murphy pers. comm.). These factors make energy independence seem a more attractive option.

### *Local Industry Support*

The Maine forestry sector has long been an important industry for the state, in terms of jobs, income, and state identity. Historically, the low-grade wood from Maine forestry

operations was used in Maine's many paper and pulp mills. Recent trends indicate that Maine is no longer competitive in the paper industry due to international competition. Biomass woodchip production can provide an alternative use for Maine's low-grade wood. By creating a substitute market for the use of low grade wood, this project may support the continual use of Maine's forests as a natural resource, and possibly prevent land conversion such as subdivisions, which has become a concern in Maine as the trend of subdivision emerges and threatens Maine's wildness (Stein 2011).

### *Education*

The biomass facility will provide an invaluable resource for Colby students and faculty on campus as a case study of renewable energy use. For example, science students may approach it from a technical viewpoint, looking at the physical mechanisms and energy conversion process, while social science students may study the impact of the facility on local communities or energy policy. The Colby biomass plant will function as a laboratory for students to engage in co-curricular research on the various aspects of the process, from discussing carbon impacts to studying the functions of the technology. The presence of the facility serves as a real-world example for students, grounding their more theoretical education in a practical application of local and renewable resource use. It can be used for classes in the Environmental Studies Program and beyond, as well as serving as a resource to illustrate Colby's Climate Commitment and as an educational tool for campus sustainability.

The facility also will provide a valuable educational resource for the surrounding community. Local elementary, middle and high schools can utilize the facility as an educational resource. Also, Colby could strengthen its connection to local colleges by extending this educational opportunity to Thomas College, Kennebec Valley Community College, and Unity College. Further, the City of Waterville has expressed interest in constructing a biomass facility to provide energy for Waterville and the surrounding communities. Colby's experience and expertise can serve as a resource for the city.

### *Public Relations*

There is constant competition among American colleges as each school tries to attain higher rankings, more applicants, lower acceptance rates, larger endowments, and better reviews. One way that Colby has attempted to distinguish itself from competitors is its green initiatives. Colby is one of only a small handful of colleges to use biomass energy as part of its energy portfolio (CCAP 2010). The biomass facility, in concert with the effort to achieve carbon neutrality by 2015, helps Colby to stand out among many similar and competitive institutions.

### *Green Leadership*

Among American colleges and universities, there is competition to keep up or outperform the other schools in terms of reductions of carbon emissions and energy consumption. From my research, I encountered five colleges with biomass facilities installed and operational, four of which are in the Northeast<sup>4</sup>. There are at least four more in the process of converting to biomass energy<sup>5</sup>. While Colby is not the first college to install a biomass facility, it is among the first few, and can serve as an example for other institutions to follow. The competition between schools encourages a “race to the top” phenomenon, in which colleges compete with others to achieve better practices or facilities. Colby’s aim to achieve carbon neutrality by 2015 is very progressive, as it will be one of the first colleges to achieve this goal, if successful. This has and will motivate other schools to aim for carbon neutrality, expanding Colby’s influence beyond the campus borders.

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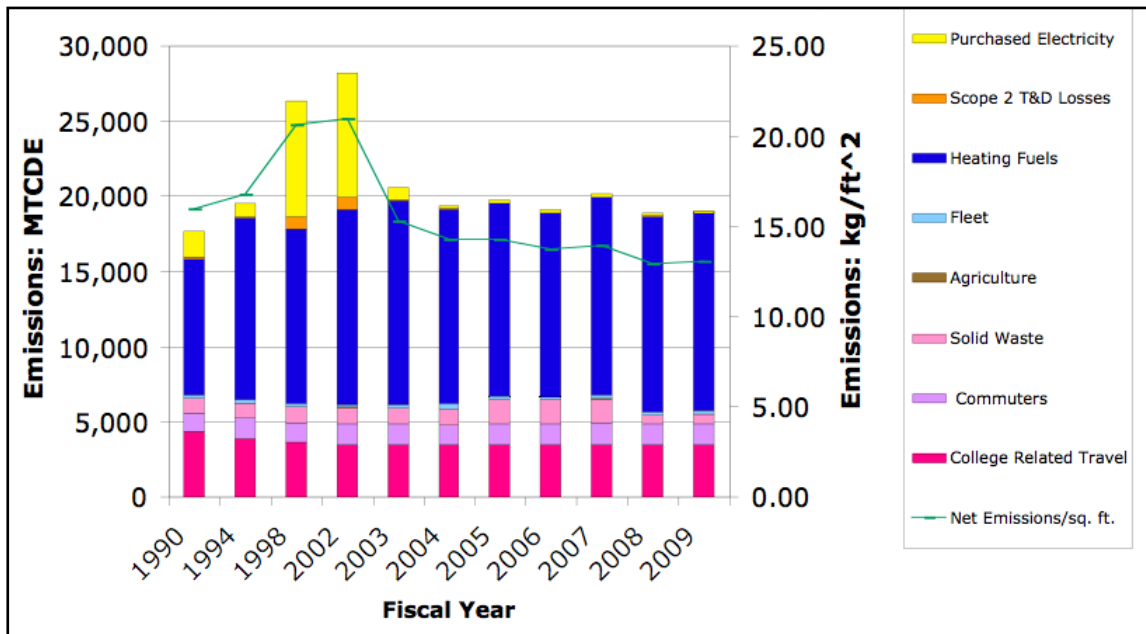
<sup>4</sup> The Northeast colleges and universities with biomass facilities include Colgate University (NY), Green Mountain College (VT), Middlebury College (VT), and Mount Wachusett Community College (MA). The University of Iowa (IA) also uses biomass energy.

<sup>5</sup> Other colleges and universities in the process of biomass conversion include Central College (IA), Evergreen State College (OR), University of Minnesota (MN), and University of Montana (MT).

### Carbon Emissions

As previously discussed, over the long-term, biomass provides a carbon emission reduction because although it emits more carbon per unit of energy produced, it comes from a renewable source; the trees that continue to grow in the forest absorb carbon from the atmosphere. The biomass project will result in a reduction of more than 9,500 tons of carbon annually, with a potential reduction of over 13,500 tons annually (PPD 2011).

Figure 1 shows Colby’s GHG emissions by source. The blue bars, emissions from heating fuel, comprise the largest portion of the GHG emissions. By reducing heating oil consumption by 90%, Colby will considerably reduce its emissions.



**Figure 2.** Colby College Greenhouse Gas Emissions by Source, 1990-2009 (CCAP 2010)

### Ecosystem

Because of the Efficiency Maine grant stipulation that requires all fuel wood to be certified, Colby’s biomass facility will encourage local forestry operations to attain certification, which hopefully also ensures better management practices and more sustainable forestry (see Sustainability of Biomass and Forest Certification Mechanisms).

## **Disadvantages of Biomass at Colby**

The construction of a biomass facility at Colby also requires serious consideration of the negative impacts it may have. Questions that have been raised include issues regarding biomass as an inappropriate alternative or short-sighted solution, considerations of human health impacts, complicated logistics, and costs.

### *Inappropriate Alternative*

The switch from fuel oil to biomass chips for filling the campus steam needs may not necessarily get to the root of the carbon emissions problem, which is energy consumption. There is the fear that the adoption for biomass energy may defer discussion of consuming less energy by reducing the demand for steam on campus. As an example, Colby may continue to heat the campus buildings to a certain temperature in the winter, requiring large amounts of energy. The adoption of biomass energy may divert the attention directed towards green initiatives away from the smaller and less glamorous energy conservation projects. Rather than setting thermostats lower or investing in energy conservation projects, the College may see the biomass facility as sufficient action to reduce carbon emissions. It also may make less financial resources available for investment in other environmental initiatives.

However, Colby specifically laid out its intent to reduce energy use in the 2010 Climate Action Plan (CCAP 2010). In the CCAP, biomass was not the only proposed solution to the problem; it also outlines other emissions and waste reduction initiatives. The concern that biomass may act as an inappropriate alternative to fossil fuels could arise as an issue, if other institutions attempt to follow Colby's model by adopting biomass energy, but do so exclusively, as opposed to coupling it with other consumption- and waste-reduction initiatives.

### *Short-Term Solution*

Biomass still emits carbon - more carbon per unit of energy produced than the fossil fuel alternatives. It does use a resource that is extremely abundant in Maine, but the supply is by no means inexhaustible. The main issue with biomass as a renewable energy source is scale. It is not appropriate for use as electricity generation alone, on a large

scale, or in regions without large forests resources. Woody biomass can provide energy to a finite number of facilities, and is thus not adequate for wholesale adoption across the entire state. An issue could arise if many other biomass facilities are constructed in Maine, increasing demand for biomass and possibly putting greater stress on the forests.

### *Human Health Impacts*

Biomass combustion generates some pollutants, the emissions of which are regulated by the EPA under the Clean Air Act and the Clean Water Act (Baron, Braverman, and Gassert 2010). Pollutants of particular concern to human health include particulate matter, heavy metals, ground-level ozone, and dioxin (van Loo and Koppejan 2007). The release of these substances may be minimized and partially or entirely contained through primary and/or secondary emissions reduction measures such as precipitators, baghouses, and scrubbers. Associated emissions include sulfur dioxide, nitrogen oxides, and particulate matter (PM) from the burning of the fuel (Baron, Braverman, and Gassert 2010). PM is a risk to human health because it gets lodged in the lungs and can be carcinogenic or cause respiratory illnesses (EPA 2007; van Loo and Koppejan 2007).

The Colby facility will feature two methods of reducing particulates emissions (Murphy pers. comm.). The first method is comprised of cyclonic dust collectors in the flue gas ducting, which direct the emitted gas into a vortex, causing the particulates to fall down into a collecting bin. The second method is an electrostatic precipitator (ESP), which induces an electrostatic charge on the particulate matter to attract and collect the particulates. Although there are these and other methods of minimizing emissions of the facility, it is important for the College to monitor the emission, as it may have health impacts.

### *Logistics*

The switch to biomass involves an increase in daily deliveries of fuel in peak season from 2 to 3 truckloads of oil to 3 to 4 truckloads of biomass (Murphy pers. comm.). This will increase the number of trucks that drive to and from the Colby facility by up to 34%. This also implies more transportation-related emissions. Depending on the distance that the fuel oil currently travels, there could be a significant increase in trucking emissions, a



carbon emissions source not currently accounted for in the carbon analysis. Further, increased truck travel could potentially cause issues with traffic, road maintenance, etc, though this is not likely, and is not predicted by the Director of the Physical Plant Department, Patricia Murphy (pers.comm.).

Another logistical consideration is the 50-mile radius restriction established by the college. The radius was chosen to limit distance of biomass fuel travel to get to Colby's facility, however the rather arbitrary limit may impose unnecessary restrictions on the sources available for use. Further elaboration as to why the College chose this limit or consideration of expanding it to 75 or 100 miles might alleviate the pressure of finding the most sustainable practices within such a small vicinity.

### *Costs*

The price of biomass woodchips may be more stable in the short-term than the highly volatile price of oil, but it will not be constant. Price fluctuations may be caused by a variety of factors. Increased demand could cause an increase in price. The adoption of biomass in Maine is a recent and steadily increasing trend, which may mean that in the next few decades, there will be increased demand for low-grade wood for biomass fuel. This would allow the market to increase price. Natural disasters could also cause price fluctuations. For example, a large forest fire could destroy a portion of the fiber stock, decreasing supply and therefore increasing price. However, often with disaster events like a forest fires or blight, forest managers engage a practice called salvage forestry (Tatko pers.comm.). This entails harvesting all salvageable low-grade wood from a recently burned area in the case of a fire, or all trees not yet infested, in the case of blight. When this happens, the market is flooded with low-grade wood, causing prices to plummet. This may have price implications in later years, however, as the stock will be diminished.

### **Sourcing Options**

Although many of the specifics for the biomass facility have already been decided, there are still decisions to be made that will influence the impact of the facility and its sustainability. This section discusses and compares various sourcing options for the biomass facility.

At the time of writing, Colby had not yet secured sources of fuel wood for the project. Even when they do, the contracts will likely be short- to medium-term agreements, allowing for a variety of scenarios in the future. One way to analyze the future impact of the biomass facility at Colby is to formulate scenarios for sourcing the project. The following scenarios are possible trajectories for sourcing the Colby biomass plant, including the reason they might be pursued, and considerations.

#### *Option 1– No Guidelines*

In this scenario, Colby puts out a bid that includes only the technical specifications for the technology used at Colby. The specifications would include annual quantity needed (22,000 short tons per year), moisture content (45%), woodchip size, and the ratio of hardwood to softwood. The specifications would have no other stipulations, such as forestry certification. The reason this scenario might be pursued would be to simplify the bidding process, or to get the lowest price. With fewer specifications, more biomass sources would qualify for and respond to the bid, allowing Colby to choose the most inexpensive option. Colby has committed to sourcing the facility from local sources, and if the closest sources are not certified, it is possible that Colby would opt for “local” wood over “certified” wood.

If this scenario were chosen, Colby would have to consider that there is no guarantee of sustainability. Certification does not guarantee sustainability, but it does require that certain guidelines for forestry practices are met, and includes a third party surveyor to assess the forestry operation. The certification schemes often require protections of habitat and soil, and limit allowable clear-cutting, all of which are important in maintaining long-term forest health. The carbon impacts of biomass energy are heavily dependent on the forestry practices of the sources. In this scenario, Colby’s uncertified wood could potentially have a greater environmental impact in terms of carbon emissions, though carbon impacts are extremely difficult to calculate with any certainty. Colby could also jeopardize its goal of “carbon neutrality” by 2015. Choosing the option is not consistent with Colby’s stated core goal of sustainable campus operations. Further, opting to utilize uncertified wood would not be compliant with the Efficiency Maine grant that Colby has received, eliminating \$750,000 from the budget. However,

considering the full budget is \$11.25 million, it is feasible that Colby would forgo this grant, as it is less than 7% of the total financial requirements, to save money on the woodchips, which will be purchased annually.

### *Option 2 – Certified Wood*

In this scenario, Colby would source the wood for the biomass facility from only certified sources, complying with the Efficiency Maine grant specifications that require all biomass projects only use wood that is certified by FSC, SFI, ATFS or MLC. This also would comply with Colby's commitment to considering sustainability. This scenario is the current short- to medium-term plan for sourcing. Under this scenario, the College does not differentiate between the certification mechanisms, treating them as interchangeable. However, there are considerable differences in the certification schemes. Only one scheme under consideration – FSC – is not industry-sponsored. The differences among the certification mechanisms may have environmental implications, both in terms of forest sustainability and carbon impacts, as described earlier. Further, none of the certification guidelines have biomass-specific regulations, indicating that they are not tailored to the distinct needs of forests utilized for biomass production. Lastly, none of the schemes have guidelines for retention, which refers to the woody material left behind on the forest floor once extraction has taken place. The only specifications for certification are value language such as “enough material to ensure nutrient cycling”.

### *Option 3 – Modified Specifications for Sustainability*

In this scenario, Colby tailors the biomass specifications for improved sustainability. The specifications might include the requirement to be FSC certified, as opposed to woodchips certified by any of the four programs allowed under the Efficiency Maine Grant, and perhaps also requires that the forestry operation utilize the Forest Guild Retention Guidelines. These guidelines, established by the Forest Guild specifically for biomass operations and developed for the northeastern forest ecosystems, give definite quantities of woody material to be left on the forest floor per acre of harvested forest (Forest Guild 2010). These were developed to ensure proper nutrient cycling and to protect against long-term nutrient depletion and habitat degradation (Forest Guild 2010).

The extraction practices are an important part of ensuring biomass sustainability, and requiring an extra certification by the Forest Guild would help in this respect.

In considering this scenario, the College must acknowledge that these specifications severely limit the possible number of sources for biomass chips. Also, because the specifications impose restrictions on the sources, it might push up prices for the product. This scenario's benefit is that it would help to ensure forest sustainability and increased carbon benefits, two of the main reasons cited for doing the biomass conversion in the first place.

#### *Option 4 – Certified and Modified with Transition Time*

A variation on the previous two scenarios is that the College's biomass specifications do not require Forest Guild Retention Guideline compliance in the short-term, but after a specified number of years the sources produce a certain percentage that complies with the retention guidelines. Then a few years later, the percentage must increase by a certain interval. For example: *“by 2015, 25% of the College's biomass supply must come from forests that are managed to comply with the Forest Guild's Northeast Forest Biomass Retention Guideline. In 2025, 55% must be in compliance, and by 2040, 100% of the College's biomass supply will follow the guidelines.”* In this scenario, Colby is not immediately ruling out many sources, but over a specified amount of time actually improving the sustainability of the source of its biomass woodchips. Further, it would both encourage local forestry operations to improve their management practices and ensure that the foresters near Colby have a guaranteed buyer for their product. If the foresters know that they can always sell their certified sustainable biomass chips to Colby at a price premium to regular biomass chips, they will have an incentive to follow the guidelines.

#### *“Option 5 – Seed to Ash”*

The “seed to ash” scenario involves Colby's purchasing and managing of a tract of forest. From personal calculations that were verified by Peter Stein of Lyme Timber Co., the total forest area needed to acquire 22,000 tons of waste wood per year for the Colby facility is upwards of 60,000 acres, probably nearer to 100,000 acres. This forest would

produce more than just waste wood, and Colby would need to sell all higher value wood except the waste or low-grade wood, which would be used for biomass. In order to do this, Colby would likely contract with a forestry firm for a certain number of years. The firm would manage the forest, and Colby would retain control and oversight for the proceedings. In this way, Colby could ensure that management was acceptable to the College's sustainability goals.

One possibility for this option is that the school could partner with an NGO like The Nature Conservancy to share mutual benefits of the land; Colby would extract biomass to run the steam facility, and the NGO could protect the land from development. Another possibility is that Colby could work with the UMaine School of Forestry— they would benefit from the educational and research opportunities, and Colby would benefit from the biomass product plus the security of knowing that the source would be reliable indefinitely.

#### *Option 6 – Middlebury-style Plantation*

In this scenario, Colby could work with local farmers or owners of farmland, contracting a mutually beneficial agreement in which the farmers would commit to growing fast-growing woody plant like willow to sell to Colby tri-annually. This example is modeled after a pilot project undertaken at Middlebury College in Vermont. Middlebury also has a biomass plant, and wanted to experiment with different methods of sourcing. In their example, they tested various species of willow in multiple fields with different soil types to find the best-suited species. The benefits of this example are that it has a three-year harvesting cycle, as opposed to 30 to 100 years needed for forestry harvesting, there is also life-cycle oversight because Colby could be much more involved in the process start to finish, providing an educational resource for students the community. Lastly, it supports local economic growth by contracting to local farmers and guaranteeing payment in three years.

#### *Matrix of Sourcing Options*

Table 5 shows the matrix that I created to compare the different options for sourcing the biomass wood for the Colby facility. This matrix compares six potential options for

sourcing by using six different benefits as indicator variables: reasonable cost, simple to implement, Efficiency ME compliant, local forestry benefits, educational benefits, and sustainability. Each option was assigned a relative value of 1 if the benefit was present, or a 0 if it was not. Some received a 0.5 if the benefit was minimally present, or could be present under some conditions. Reasonable cost was evaluated by assigning a 1 if, in that option, the cost for acquiring a biomass fuel source would not cost significantly more than the proposed method, which consists of selecting a source from a response to Colby's request for bids. Simplicity to implement was evaluated by assigning a 1 if the sourcing option would not require significant planning including land acquisition and management. Compliance with the Efficiency Maine grant was determined by whether the program was certified by a forest certification mechanism; if so, it received a 1. Local forestry benefit was evaluated based on the presence of management practices above the basic non-certified forestry operations; if present the option received a 1. This is different from Efficiency Maine compliance in that it allows for a wider range of benefits that mere presence or absence of certification, but rather allocates a 1 to options that go beyond the status quo in terms of forest management. Educational benefits were evaluated on the basis of the option incorporating forestry practices beyond basic standards in order to provide a hands-on illustration for students of the benefits of alternative methods of forestry; if this was the case, the option received a 1. Sustainability was assessed in terms of long-term nutrient retention, monitoring, and consideration given to carbon emissions of the operation; if all of these were present, the option received a 1. The total of the six variables produced a score used to rank the different options for sourcing.

The table shows the total scores on the bottom row. Option 4 received the highest score of 6, Option 3 scored a 5, Option 2 scored a 4.5, Option 6 scored a 3, Option 5 received a 2-4, and Option 1 received the lowest score of 2.

**Table 5.** Matrix of Biomass Sourcing Options for Colby College

	More Likely				Less Likely	
	Option 1	Option 2	Option 3	Option 4	Option 5	Option 6
Description	Technical specs only	Certified sources	Certified + retention guidelines	Option 2 w/ transition to Option 3	Colby owns /manages process	Woody biomass plantations
<b>Reasonable Cost</b>	1	1	0	1	0	0
<b>Simple to Implement</b>	1	1	1	1	0	0
<b>Efficiency ME Compliant</b>	0	1	1	1	1/0	0
<b>Local Forestry Benefits</b>	0	1	1	1	1	1
<b>Educational Benefits</b>	0	0	1	1	1	1
<b>Sustainability</b>	0	.5	1	1	1/0	1
<b>Total</b>	<b>2</b>	<b>4.5</b>	<b>5</b>	<b>6</b>	<b>2-4</b>	<b>3</b>

## CONCLUSIONS

To provide enough biomass for the Colby facility requirements every year, roughly 60,000 to 100,000 acres of forestland will be needed. Because of the extent of land needed for this project, Colby must seriously consider the environmental impacts of the project, particularly the sourcing of fuel.

Colby should be conservative with carbon reduction estimations in the next decade, as converting to biomass fuel incurs an initial carbon debt. It has been shown that biomass emits more carbon per unit of energy than fossil fuels do, and only after a certain number of years does the sequestration of forest re-growth counterbalance the initial emissions surplus. Colby should continue to use carbon emission calculators that are consistent with other institutions, while noting that the classification of biomass energy as “carbon neutral” may be an oversimplification.

When choosing suppliers for the biomass facility, Colby should aim to use sources that are certified by the FSC and/or SFI programs, and should consider avoiding sources that are solely certified by ATFS, which is the weakest out of the three mechanisms. Colby should also avoid sources certified solely through MLC, as this program monitors and certifies resource extraction, but does not aim for forest sustainability as its primary goal. It is important to note that none of the four certification schemes have specifics for biomass procurement. I recommend that biomass sources be certified by multiple programs when possible, and that they also ascribe to the Forest Guild Retention Guidelines. This could be achieved either immediately or as a transition over a predetermined period of time. The Forest Guild’s Retention Guidelines are not meant to ensure overall forest sustainability or to serve as replacement for forestry certification mechanisms, but to augment the management practices already in place and to suggest specific guidelines for biomass harvesting operations. Lastly, to attain biomass chips from the most sustainable sources available, Colby should consider expanding its 50-mile radius limit to allow for a broader range of options for sourcing.

The adoption of these specific recommendations regarding the sourcing of the biomass woodchips for the Colby facility will help College fulfill its expressed goal of being environmentally conscious and reducing Colby’s footprint, both in terms of



ensuring long-term sustainability of the forest resources used, as well as reducing carbon emissions in an effort to curb GHG levels that are causing global climate change.

### **Further Study**

This thesis is a preliminary analysis of sustainability impacts and sourcing options of biomass energy at Colby College. It does not cover health impacts, cost/benefit analyses, educational opportunities, or comparison to other forms of renewable energy. Future questions that would be valuable to pursue are: What are the social, economic, ecological or environmental health impacts of the facility? What are the costs and benefits of all the sourcing options for the facility? In what ways can the biomass facility serve as an educational benefit to the College? This thesis could outline concrete plans for educational integration. Lastly, What are carbon benefits of switching to other renewable energy sources, including for example, solar thermal energy?

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Kittler, Brian. Pinchot Institute – Project Director. January 10, 2011. Telephone conversation and email correspondence.

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**APPENDICES**

**Appendix 1 Forest Guild Biomass Retention Guidelines**

**A. General Guidelines for Retaining Forest Structures (Forest Guild 2010)**

Structure	Minimum Target (per acre)		Considerations
	Number	Basal area (ft <sup>2</sup> )	
Live Decaying Trees 12-18 inches DBH	4	4	Where suitable trees for retention in these size classes are not present or may not reach these targets due to species or site conditions, leave the largest trees possible that will contribute toward these targets.
Live Decaying Trees >18 inches DBH	1	1	
Snags > 10 inches DBH	5	5	Worker safety is top priority. Retain as many standing snags as possible, but if individual snags must be felled for safety reasons, leave them in the forest.

**B. DWM Ranges by Forest Type (Forest Guild 2010)**

	Northern Hardwood	Spruce-Fir	Oak-Hickory	White and Red Pine
Tons of DWM per acre*	8-16	5-20	6-18	2-50

\* Includes existing DWM and additional material left during harvesting to meet this target measured in dry tons per acre.

## Appendix 2

Colby College Emissions Trajectory (CCAP 2010)

