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An Environmental Assessment of Energy Biomass for Bates College and Environmental Implementation Recommendations

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Environmental Studies

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Executive Summary

Bates is considering whether or not to build a biomass cogeneration plant to help meet its pledge to become carbon neutral by 2020. However, questions about sustainability, as well as questions raised about whether or not biomass power is actually carbon neutral need to be seriously considered. In the short and mid-term, biomass actually has a greater negative impact on climate change than fossil fuels, especially natural gas, which Bates currently uses. In fact, moving from natural gas to biomass energy production could double Bates' carbon emissions. The exception to this is the production and harvesting of short-rotation woody crops, specifically willow. This perennial crop can have positive ecological benefits in certain circumstances and shorten the length of time between the carbon debt created at combustion and re-sequestration of the carbon released to a short 3-5 years.

Fellow NESCAC schools, Middlebury and Colby, have already implemented biomass energy plants. If Bates decides to do so as well it will need to seriously consider how it sources its biomass and how quickly it can move to more environmentally friendly sources of energy.

The Biomass Question at Bates College

This assessment of the environmental issues associated with using biomass for energy at Bates College is part of a larger strategy for reducing greenhouse gas emissions. Bates signed the American College and University Presidents Climate Commitment (ACUPCC) as a pledge to reduce greenhouse gas emissions in 2007. The College did an audit of campus emissions in 2009 and, in 2010, developed the Bates College Climate Action Plan for working towards carbon neutrality by 2020.

Goals and Strategies

Strategies for achieving carbon neutrality by 2020 included in the Bates College Climate Action Plan include:

- Reducing the amount of energy used on campus
- Using energy as efficiently as possible
- Converting to renewable energies, including purchasing green electricity, and building wind, solar and biomass capabilities
- Offsetting remaining emissions with renewable energy certificates and carbon offsets
- Requiring that new construction achieves a minimum of LEED silver level certification
- Continuing to evaluate the financial feasibility of other opportunities such as geothermal heating of individual buildings

- Replacing fossil fuel powered campus boiler plant with a biomass cogeneration plant

Bates is planning significant new construction under its Campus Facilities Master Plan and would need to upgrade the physical plant infrastructure to meet increased demand. It therefore plans to convert to a biomass cogeneration system once construction starts on projects south of Campus Avenue.

Social responsibility and environmental stewardship are part of campus culture and history. Bates has a strong historical commitment to sustainability. Thus, not only converting to biomass as a renewable resource, but also ensuring the sustainability of the fuel supply will be an important aspect of this project. Converting to a biomass cogeneration plant may help Bates move towards its goal of long-term climate neutrality but the college must think carefully about what kinds of biomass to source. The college will need a reliable supply, but will also want to source in a way that will not be environmentally detrimental.

Pre-Implementation Situation

In 2009, Bates College greenhouse gas emissions totaled 18,953 metric tons of carbon dioxide equivalents (CO_2e), of which heating and cooling accounted for 39%. Currently, the Bates boiler uses natural gas to produce heat and hot water for 85% of campus needs. The College also buys renewable energy certificates that, in the 2009 data, reduced Bates' emissions footprint to a net of 10,466 metric tons of CO_2e.

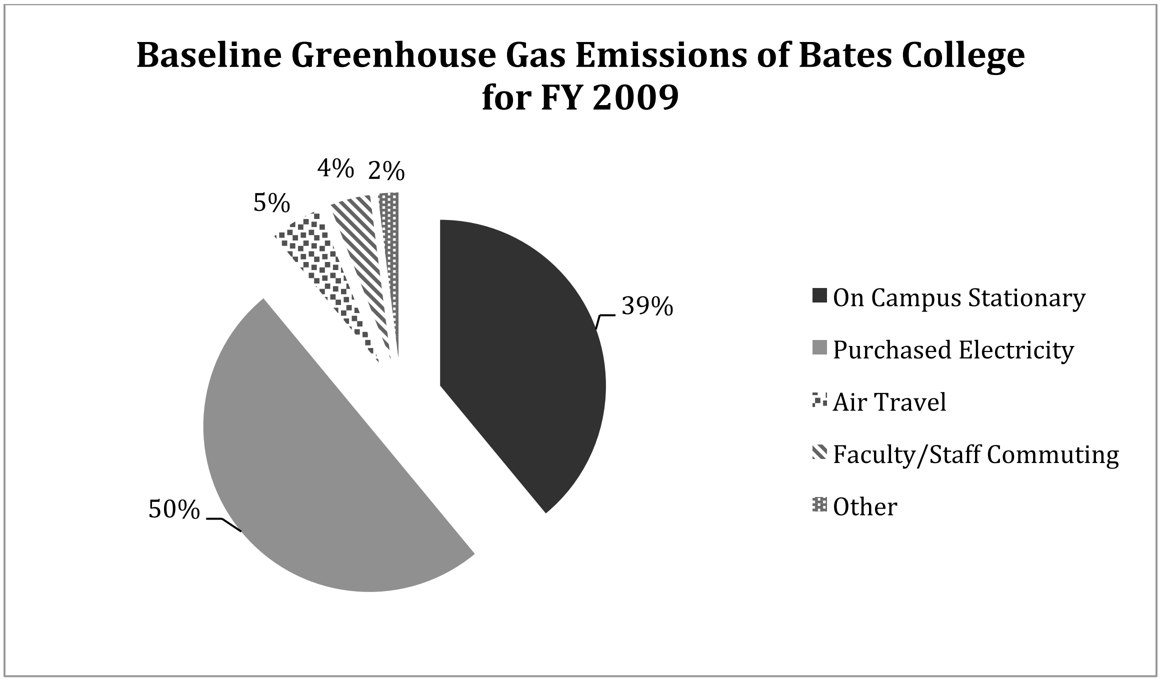

Figure 1. The percent contribution to Bates' total greenhouse gas emissions by source for the 2009 fiscal year. "On Campus Stationary" sources include heat and hot water from main steam plant and in individual buildings. Data source: Bates Climate Action Plan, 2010.

According to Bob Leavitt, the Assistant Director of Operations and Facility Services at Bates, the college currently uses 650,000 gallon #2 fuel oil equivalents, which they burn in natural gas. Assuming 8,000BTU per pound of biomass, he estimates that the amount of biomass needed to replace current annual usage for the steam plant would be 5,500 tons of biomass (D. Nein & B. Leavitt, personal communication, May 7, 2013). This amount underestimates the future need as the college embarks on further construction, and should be checked against the experiences of Middlebury and Colby.

“Implementing this [biomass cogeneration] recommendation would reduce our net GHG emissions (after RECs) more than 80% and its completion will define our date for achieving climate neutrality.”

- Bates Climate Action Plan

An Introduction to Biomass

Biomass is biological material from living or recently living organisms that can be converted into energy through combustion. It’s considered a renewable resource because its energy derives from the sun and the biomass material can regrow in a relatively short period of time. It is part of the natural terrestrial carbon cycle in which plants absorb carbon dioxide (CO_2) from the atmosphere during growth and release it into the atmosphere during decomposition. When biomass is used for energy production, combustion replaces the decaying part of the natural cycle in release carbon back into the atmosphere. Therefore, biomass is considered carbon neutral because carbon dioxide emitted during combustion is recaptured by new plant growth within the same cycle. This differs from the combustion of fossil fuels, which release excess carbon dioxide that is outside of the current terrestrial carbon cycle, and that had been stored in a carbon sink for a very long time. In other words, carbon neutrality is a question of geologic time scale.

The Five Types Of Biomass

Generally speaking, biomass is broken down into five basic categories of material:

1. **Virgin wood:** Wood and logging residues harvested during forestry activities or material from wood processing (lumber, timber, chips)
2. **Agricultural residues:** Residues from everyday agricultural processing or harvesting (for example, corn husks and stems)
3. **Food wastes:** post-consumer waste
4. **Industrial wastes and co-products:** Waste from manufacturing processes such as paper production or furniture construction
5. **Energy crops:** High yield crops grown specifically for energy production

Each category of biomass has certain environmental liabilities. Harvesting *virgin wood* energy biomass increases pressure on forest resources and jeopardizes wildlife habitats. Creating a demand for agricultural *crop residues* increases soil erosion and decreases the return of nutrients back to the soil that these residues provide. Bates generates a small amount of *food waste*, however it would not be a large enough supply for the College's fuel needs and may not be compatible with the final technology chosen. In addition, a good portion of it is currently being sent to a local pig farm in Poland, ME. Concerns about using *industrial wastes* center around the possibility of releasing heavy metals and other toxins into the atmosphere. The production and use of dedicated *annual energy crops* have the same environmental concerns as conventional monoculture agriculture, including soil erosion, nutrient depletion and water contamination. *Perennial energy crops* show more promise for environmental sustainability.

Within each of these categories some biomass sources are more environmentally friendly than others. David Tilman et al. (2009) distinguishes what he calls "beneficial biomass." These would include biomass crops that don't compete with food crops (i.e. grown on abandoned or degraded lands), that do not result in land clearing or other environmentally detrimental practices, and that offer reductions in greenhouse gas emissions over fossil fuels. Any supply that Bates chooses should be a beneficial biofuel in keeping with Bates' commitment to sustainability. Laura Paine et al. argue that waste wood from logging, paper and furniture industries and perennial energy crops are the most environmentally friendly options (1996).

Bates should focus upon sourcing biomass chips from forest logging residues (waste wood) because of their availability locally and should also consider the potential growth for local perennial woody energy crops.

Biomass Availability in Maine

The good news for Bates is that the state of Maine is identified as having one of the highest biomass producing potentials in the United States (Fig. 2) (Milbrandt, 2005).

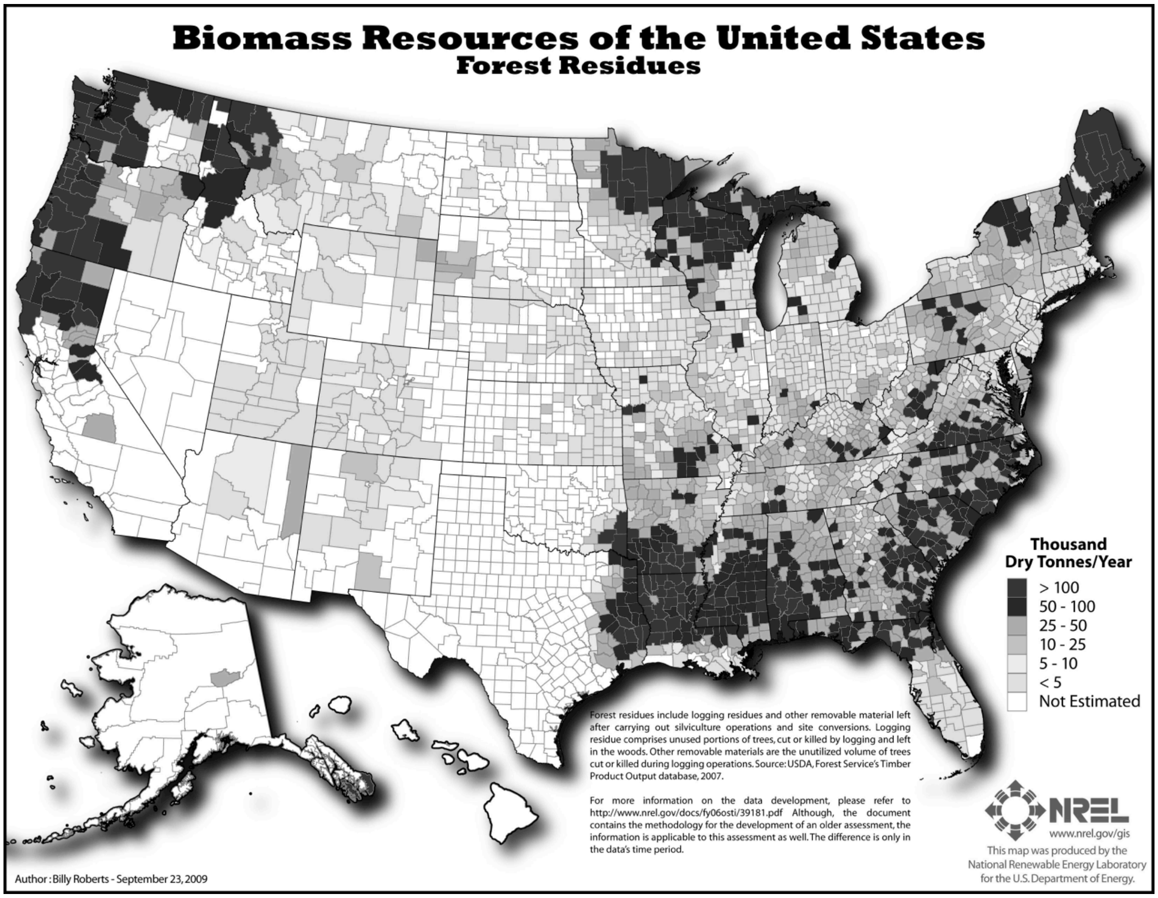

Figure 2. Amount of forest residues available by county in thousand dry tons per year. Forest residues defined here include logging residues, removable material left after silvicultural operations and site conversions. Androscoggin County is estimated to have 50-100 thousand dry tons/year of forest residues and surrounding counties have 100+. (Roberts, 2009).

According to Jon Baker of Cousineau Forest Products, who is the biomass broker for Colby and Middlebury Colleges, there is more than enough forest biomass available within a 50-mile radius of Lewiston for the College's needs. This makes it a viable option for Bates to consider.

An alternative to harvesting forest biomass is to grow woody biomass energy crops, which may be a long-term option for Bates. These are fast growing woody shrubs such as willow, poplar and eucalyptus. Willow specifically has many benefits as a woody crop for Maine: it provides a high yield; it is not a monoculture; it has a short harvest cycle of 3-4 years; it can be harvested using modified agricultural equipment; it re-sprouts after multiple harvests; it can tolerate a short growing season; and it tolerates high planting density. Poplars don't provide as high a yield and eucalyptus is generally grown in warmer climates.

Though wood chips from forest residues and short rotation willow crops are potentially viable fuel sources, there are certain concerns related to bioenergy and biomass sourcing that should at least be considered when Bates develops its biomass energy sourcing plan. The first concern is the complexity of the carbon neutrality claim. There are also concerns about increasing harvesting intensity and the impact this may have on forest ecology and productivity. These considerations may impact decisions Bates makes about its environmental policies as well as, in the shorter-term, from where and how the College sources their woodchips.

The Link Between Carbon Neutrality and Sustainability

The issue of carbon neutrality is more complex than might be initially assumed. The theory behind the carbon neutrality of biomass is two-fold:

1. Carbon dioxide that is released into the atmosphere through combustion is re-sequestered as the next generation of trees or biomass grows.
2. Biomass that is removed from the forest would have decomposed and released the same amount of CO_2 through processes of the natural carbon cycle if it had been left in the forest.

While this has been the theoretical argument supporting the push for biomass as a renewable, carbon neutral energy alternative, it's a flat, one-dimensional look at the process. It doesn't take into account: the time needed to re-sequester the carbon; the fossil fuel inputs over the biomass production system; potential forest productivity losses; or the complexities of the natural carbon cycle such as carbon sinks. Acknowledging these aspects of bioenergy can help Bates make informed decisions.

Time and Carbon Debt

The basic assumption is that in order to be carbon neutral the same amount of biomass needs to regrow to sequester the carbon that is released upon combustion. The idea of carbon neutrality needs to be thought of on a large time scale, and the short term and long-term realities of biomass energy emissions must be differentiated to see the full picture. Carbon neutrality in the long term is theoretically feasible as long as conditions stay the same (for example, forest productivity is not decreased) but in the short-term biomass is often not carbon neutral. Carbon dioxide and other greenhouse gasses are emitted instantly into the atmosphere upon combustion while the next generation of trees can take decades to grow and sequester those emissions.

The deficit between those initial emissions and net carbon neutrality is often termed the "carbon debt" by researchers. As time passes the carbon debt decreases as carbon sequestration by plant matter increases. This time can be fairly long – some models estimate up to 190+ years to reach theoretical carbon neutrality (Domke et al., 2012). The amount of time it takes to repay that carbon debt will depend upon a variety of factors including:

- Forest management techniques
- The type of biomass used
- The impact biomass removal has on ecosystem carbon fluxes and sinks
- The amount of fossil fuel inputs
- Type of conversion technology used and efficiency of conversion

Biomass vs. Fossil Fuels

In the very long run, biomass is more carbon neutral than fossil fuels because it is part of the terrestrial carbon cycle and eventually will be re-sequestered. However, in the short-term, biomass actually has a greater negative impact on climate change than fossil fuels, especially natural gas.

Biomass, including woody biomass, actually has *higher* CO_2 emissions per unit of energy produced than fossil fuels. According to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories, wood and wood wastes used for energy production release 112,000kg of greenhouse gas per TJ as compared to residual fuel oil (77,400kg GHG/TJ) and natural gas (56,100kg GHG/TJ) on a net calorific basis. This is because woody biomass stores less potential energy per unit mass than fossil fuels and therefore more biomass must be burned to create the same energy output. In the short-term, then, using biofuel not only creates carbon debt, but *increases* the amount of greenhouse gasses released into the atmosphere. Since Bates is currently using so much natural gas, which is a relatively clean burning fossil fuel, the immediate impact of moving to biomass energy will be to essentially double greenhouse gas emissions for the foreseeable future.

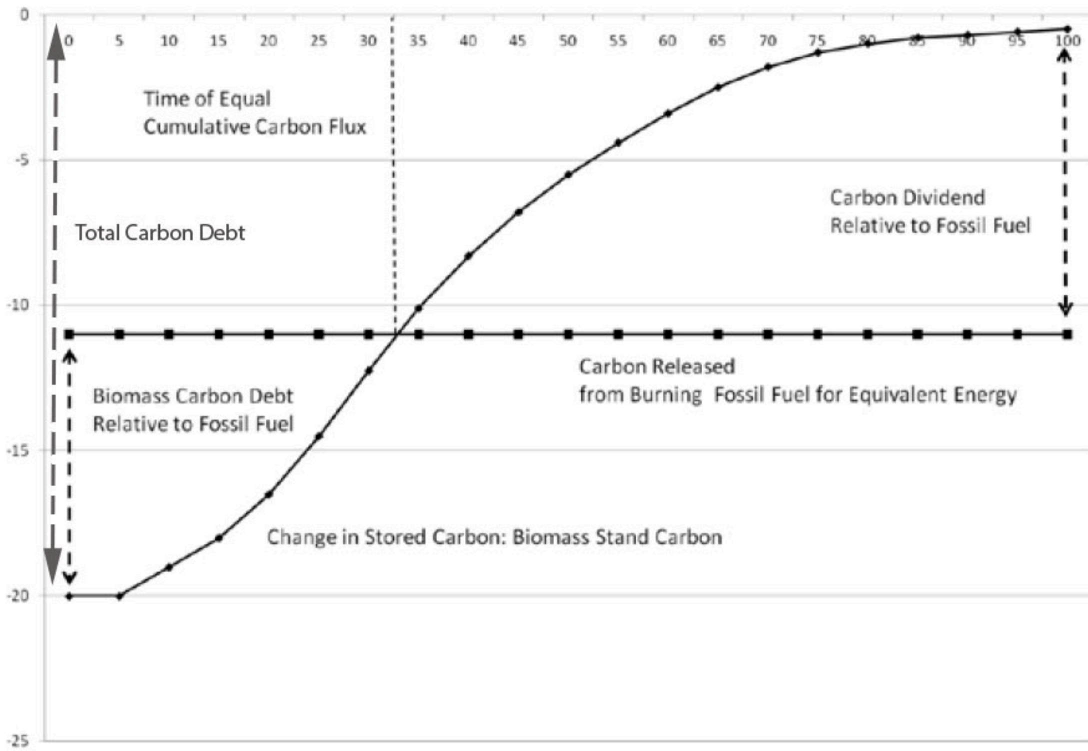

Figure 3. Representation of the carbon storage over time following a single combustion event of biomass compared to that of fossil fuel for the same amount of energy produced. The y-axis represents time (years) and the x-axis represents the amount of carbon stored (sequestered) in a forest stand (in tons). The amount of carbon released due to the combustion of fossil fuels remains constant, as they are not sequestered. The initial emissions from biomass create immediate carbon debt greater than that of fossil fuels. This carbon debt is repaid over time as carbon is sequestered and stored in forest biomass, represented by the S-curve. The intersection of the fossil fuel line with the biomass line is the point at which using either fuel source provides the same carbon debt. The top of the S-curve represents carbon neutrality. The report this figure is taken from found that it took almost 35 years to reach the point where net carbon emissions from bioenergy equaled fossil fuel emissions. Furthermore, it took 100+ years to reach net carbon neutrality (Graph adapted from Manomet Center for Conservation Sciences, 2010).

In order to reach theoretical carbon neutrality, the same amount of carbon must be sequestered as was burned. The amount of time it takes to re-sequester the same amount of emitted carbon can be long and is impacted by the rate of forest regrowth. Degradation of forest productivity decreases carbon sequestration capabilities, further lengthening time to carbon neutrality. Since reaching carbon neutrality is dependent upon equal or greater biomass regrowth, sustainable harvesting techniques are critical when forest biomass is the primary source of fuel. When harvesting forest products, it is hard to guarantee equal regrowth of plant matter in the time span required to reach carbon neutrality. The use of willow biomass eliminates this uncertainty with its short growing cycle, so it is worth exploring this option.

Furthermore, it is important to consider the entire life cycle of the fuel supply. Harvesting and transporting biomass requires fossil fuel inputs that are often not included in carbon neutrality assessments. Life cycle assessments have shown that transportation and harvesting comprise a relatively small portion of the total life cycle GHG emissions relative to the combustion phase. Nonetheless, those emissions are not sequestered in the terrestrial carbon cycle. Bates should try to minimize the amount of transport in its biomass supply chain.

The remainder of this thesis will focus upon the environmental components of sustainability, the pros and cons of biomass options that Bates might pursue, the experiences of other institutions with biomass energy plants and, finally, specific recommendations for how Bates should proceed.

The Environmental Impact of Using Forest Biomass for Energy Production

Since reaching carbon neutrality depends upon the speed and success of biomass regrowth, it's important to understand how forestry practices can impact forest productivity and the size of the forest carbon sink. Understanding the complexities of the forest ecosystem will help Bates choose the type of biomass and harvesting practices that will help them repay their carbon debt. In addition, this information can aid in promoting sound environmental stewardship.

Types of Wood Used

For cost reasons, forest biomass used for energy creation tends to be woody material that is not viable for other commercial purposes. It includes:

- **Harvest residues** such as branches, leaves, or bark not being used commercially
- **Low-value bole wood,** which is low value trunk or main stem material
- **Silvicultural forest materials**, which include non-merchantable whole trees and other woody material that is harvested to actively improve forest health

Soils and Hydrology

Soils are an integral part of the overall health of the forest ecosystem as they play several important roles in plant growth. These include: serving as a substrate for plant growth; absorbing rainfall and providing water to trees; housing microorganisms essential to decomposition and nutrient recycling; and retaining and supplying nutrients to tree roots (Janowiak and Webster, 2010). Diminishing a soil's ability to serve any of these functions can negatively impact forest productivity, and thus forest management plans should include prescriptions to ensure soil health.

The nutrients in soil that are essential for plant growth and may be impacted by harvesting are nitrogen, phosphorous, calcium, magnesium, and potassium. These are residual nutrients from: decaying organic matter; from atmospheric deposition; and soil weathering (the natural breakdown of rocks, soils and minerals). Nutrients in the soil are taken up by plants and can be a limiting factor in plant growth when not available. Nutrients and carbon are stored in plant matter, then returned to the soil when the plants die and decompose.

The scientific community has voiced concern over the impact biomass harvesting may have on soil nutrient depletion. Janowiak and Webster (2010) noted that the reason intensive whole tree harvesting (where the branches and trees are removed along with the stem) removes nutrients that impact long-term stand sustainability (vs. stem-only harvesting, where residues are left on-site) is that roots and leaves hold disproportionately high concentrations of nutrients compared to tree stem wood. Models suggest that the intensified removal of forest matter created by greater biomass demand would reduce nutrient content, and field studies have shown this to be the case in site-specific situations, especially on sites with naturally low phosphorous or base cation loads (Lamers et al., 2013). However, other field studies have found that nutrient losses are not as drastic as some models predict (Lamers et al., 2013). Overall the only conclusion that can be made based on current research is that the effects of harvesting on nutrient depletion are site specific.

Similar concerns exist about the impact increased biomass removal will have on soil carbon stores and the amount of organic matter in the soil. Modeling analyses have shown that forest harvesting generally decreases soil carbon contents relative to no-harvesting scenarios, and that increased harvesting intensity could further reduce soil carbon levels (Lamers et al., 2013; Vanhala et al., 2013). Specific field studies report certain situations in which carbon stock is reduced by harvesting. Results varied by time since harvest, composition of the stand, management practices, and site characteristics of soil. But a meta-analysis of a wide range of soil and stand types, done by Johnson and Curtis in 2001, demonstrates little significant impact of harvesting intensity on soil carbon storage *in aggregate* except in cases of intense burning, mechanical disturbance or soil tillage. Within the meta-analysis, whole tree harvesting resulted in slight decreases of soil carbon content, while the results of stem-only harvesting varied by stand species composition and specific harvesting practices. In general, in stands where whole tree harvesting is practiced, leaving some residues behind may help mitigate nutrient and carbon losses. However, the results of these studies suggest the need for stand-specific planning and management.

While removing forest residues may have an impact on nutrients in certain situations, they have less of an impact on total forest carbon storage. They decay quickly relative to trunks and thicker branches and it therefore takes less time to repay the carbon debt they create (Vanhala et al., 2013).

The implications for Bates are that specific site management plans need to be in place to ensure forest productivity is not being compromised. There are no generalized rules that will apply to all situations and the impact of nutrient depletion and soil carbon retention are stand specific. Forest residues can be removed in many situations at sustainable levels without damaging soil health or productivity and are a viable potential source of biomass fuel.

The Impact of Soil Compaction, Displacement, and Erosion on Soil Health

While research is inconsistent when it comes to the impacts of nutrient loss in forest harvesting, it is quite consistent about the negative impact of soil disturbance. Disruption of soil can lead to losses in soil carbon and can increase rates of decomposition, thus further reducing carbon stores.

Soil compaction is a concern in any harvesting operation, as it occurs when heavy machinery used for harvesting and transporting moves through the forest. Compaction negatively impacts root growth, the soil's ability to hold water and air, and seedling emergence, thereby impacting forest productivity. As infiltration capacity diminishes, the probability of erosion and runoff increases, negatively impacting local water quality. Benjamin (2010) notes that soil compaction is one of the primary sources of long-term soil degradation and provides significant detail about the complexities of the many factors that impact the susceptibility of the soil to compaction. Erosion is also increased when the mineral soil underneath the organic layer is exposed, or layers of organics on top of soil (such as leaf litter) are disturbed. The placement of roads, trails and felled logs can also add to erosion – water moves around these obstacles, increasing the chance of channels forming that encourage soil displacement.

Different sites have different rates of susceptibility to compaction based upon the type of soil, harvesting practices chosen and the type of machinery used (Benjamin, 2010). The meta-study done by Johnson & Curtis (2001) showed that soil carbon levels were altered with mechanical disturbance and soil tillage. It is not coincidental that sustainable harvesting guidelines recommend minimizing the number of skid trails, arranging residues on skid trails, and minimizing the number of trips along those trails. One concern about biomass harvesting is that is can potentially increase the number of trips for heavy machinery. Soil compaction is worst with wet soils, hence Abbas et al. (2011) recommend that harvests should be done when soils are dry or frozen.

If forest practices cause soil disturbance that leads to a loss of carbon, this would increase the repayment time needed to reach carbon neutrality.

These are all serious concerns, so much so that the state of Maine has in place laws regarding water quality and have created best management practices regarding harvest activities as they impact soil erosion. In essence, Section 413 of the Protection and Improvement of Waters Law requires that organizations involved in activities, including timber harvesting operations, that discharge or could discharge materials into waters of the State are required to obtain a discharge license. However, it also states that discharge licenses are not issued for soil material, therefore best practices must be used to prevent all soil erosion.

The Maine Forest Service has been monitoring the use and effectiveness of water quality best management protocols within the state for a number of years and as of 2012 found that sediment erosion into water bodies was prevented in 90% of the sites where best management practices were properly employed. In areas where best management practices were not being employed appropriately there was sediment at 17% of approaches and 39% of stream crossings. And 7% of approaches and crossings showed no sign of best practices application at all (Maine Forest Service, 2012).

Soil compaction directly impacts the potential for sustainable harvesting and reaching carbon neutrality. Maine monitors this obliquely through its water quality testing, which suggests that while most loggers are in compliance, not all are. Bates, therefore, should require that all suppliers follow appropriate compaction and erosion guidelines and recommendations.

Wildlife and Biodiversity Issues Associated with Harvesting Forest Biomass

Wildlife uses the forest as a habitat. Benjamin (2010) states that carefully planned harvesting can be compatible with preserving wildlife habitat for forest biodiversity. They go on to state "as with other forest resources, the potential risk to biodiversity increases with the amount and type of woody biomass removed from a site and with the frequency of such removals. Therefore, high rates of woody biomass removal can negatively affect forest biodiversity."

Fine woody matter is generally not used by wildlife as a habitat because it decays quickly. Live trees and coarse woody debris such as trunks and felled logs, however, do provide habitat for various creatures. In addition, coarse woody debris is a better carbon sink. So Maine recommendations for biomass retention include leaving this wood as well as live cavity wildlife trees and snags on the site.

In the state of Maine, the whole tree harvesting method was used on over 85% of harvested areas between 2005-2009 (Benjamin, 2009 *in* Benjamin, 2010). Careful guidelines to maintain structural diversity within the forest are, therefore, required to assure biodiversity. This is yet another reason that best practices guidelines for responsible harvesting should be required by Bates of its suppliers.

The Environmental Impact of Using Willow Crops for Energy Production

The Benefits of Willow

The intrinsic biological characteristics of willow and its management make it – in theory – a wonderful option for sustainable energy biomass for Bates. It has many potential environmental benefits and it repays its carbon debt quickly. Preliminary and ongoing research suggests that willow cropping systems are environmentally and ecologically sustainable. Economic viability remains to be determined.

Short rotation woody crops have an added benefit of growing well in areas with short growing seasons (Paine et al., 1996). A stable energy crop might end up being a reliable incremental source of income for local farmers in the Lewiston area who own degraded agricultural land. Bates could potentially create long-term contracts with these farmers, strengthening local relationships. It is interesting to note that in conjunction with SUNY College of Environmental Science and Forestry, Middlebury College is currently experimenting with growing 30 species of willow crops on 10 acres of their own college lands to determine the viability of willow for their own biomass needs. Middlebury found that the softer willow burns differently from hardwood chips and that mixing the two required recalibration for best efficiency. So using willow would not just be an issue of "throwing more biomass into the burner."

In terms of carbon neutrality, if a willow plantation displaces a natural habitat, especially a forest habitat, it will have a huge carbon debt repayment period. If it replaces conventional annual crop agriculture, or is grown on degraded agricultural lands, willow can actually improve soil carbon stocks. On top of that, because it grows back quickly – 3 years – carbon is sequestered quickly and the carbon debt is repaid in 3-5 years. This is a huge improvement over the payback length associated with forest biomass sequestration. If willow can be managed with fewer pesticides and other fossil fuel inputs, this would also mean that there would be a smaller total life cycle impact on the carbon debt repayment.

The Effects of Willow Plantations on Biodiversity and Wildlife Habitat

Short rotation willow coppices can have a positive impact on both above and below-ground biodiversity, especially when they are replacing intensive agricultural activities. Willow can increase the number of insect species on intensively farmed land, and thus contribute to its overall biodiversity (Sage, 1998). *"The diversity and density of soil microarthropods under willow immediately after planting is similar to that in agricultural fields that are tilled annually, but lower than in undisturbed fallow fields. Four years after planting, however, the density and diversity of soil microarthropods under willow are similar to levels in nearby undisturbed fallow fields"* (Volk et al., 2004:413).

Many insects seem attracted to willow. While this is good for overall biodiversity, it may also mean more potential insect pest species. Sage (1998) argues that willow crops can be managed with fewer pesticides than food crops without compromising production levels. Insects only require control when they become so numerous that their damage causes a significant loss to vegetation. For example, Sage notes that "in defoliation trials of short rotation coppice, significant reductions in biomass yield have only occurred following severe losses in leaf area" (1998:40).

On the other hand, chemical application of herbicides may be necessary as willow is very sensitive to competition during establishment, affecting overall plant biodiversity. Once the crop is established, the use of herbicides is less than in other crops (Sage, 1998). The use of herbicides may be proven unnecessary in some cases, especially with integrative crop management.

Large numbers of insects attract birds. In addition, animals that feed on insects that are present due to decreased pesticide application make use of the structure and cover this crop provides as habitat and foraging grounds.

Willow is not a monoculture. The common practice is planting mixtures of different species and hybrids across the same field. The three-year cropping rotations further create a diverse habitat by creating a variety of growth stages, making it structurally diverse. Research has shown that different bird species favor different age classes (Sage, 1998). Between 24 and 41 species of birds regularly use woody crops and the biodiversity of birds is "greater than on agricultural land and comparable to natural habitats" (Volk et al, 2004: 413). The complex vegetation structure provides a good feeding and breeding habitat for many bird species.

So, from a diversity standpoint, willow has many potential positive benefits when grown on the right types of sites.

The Impact of Willow Production on Soil Health

Because willow production is a managed process, it can be designed to maintain or improve soil health. Soil health is improved because fewer pesticides are needed for willow, as mentioned in the biodiversity section. This allows a healthier soil microorganism system, and those organisms help cycle nutrients back into the soil (U.S. Congress OTA, 1993).

With conventional agriculture, soil health is degraded through runoff, excessive tillage and low organic matter litter rates. While a willow coppice is being established, soil erosion can be comparable to or greater than runoff from annual row crops (Volk et al., 2004; Cook & Beyea, 2000). Once the willow is established, however, there is little potential for runoff because of a strong root system, organic leaf litter and the perennial nature of the crop. Without erosion, and with fewer chemicals than traditional agriculture, water quality in the nearby areas may be improved, as well.

Timothy Volk and his colleagues at SUNY ESF have been researching the optimal management practices for sustainably growing willow. Some of these include: harvesting after leaf fall; integrative pest and fertilizer management; and project placement to maintain and encourage biodiversity. Volk will be an excellent resource for Bates if they move forward in this area.

Willow has many potential benefits and could help Bates meet its goal of carbon neutrality more quickly than forest biomass would. However, this is a long-term option as there is not a sufficient supply of willow near Bates at this time.

Biomass Harvesting Guidelines – An Overview

To minimize ecological damage and maximize carbon sequestration, Bates will need to purchase biomass from sustainably harvested forests. The state of Maine has created recommendations for biomass, which are outlined below, but they are not legally mandated. Biomass sourced from Maine may or may not, therefore, meet Bates' sustainability standards. One way to ensure biomass resources are sustainably harvested is through sustainable forestry certification systems.

According to the Maine Forest Service website, the four commonly used sustainable forestry certification systems operating in Maine are the American Tree Farm System (ATFS), the Forest Stewardship Council (FSC), the Sustainable Forestry Initiative (SFI), and the Master Logger Certification program.

American Tree Farm System

The ATFS is a national organization that focuses primarily on family forests and small woodlands. It strives to give recognition to good forest practices. They have three certification options, all of which are optional. Certification requires the creation of a site-specific management plan and meets third party guidelines. It also includes occasional monitoring. The landowner is allowed flexibility to adapt the plan when needed, but adaptations must still result in a sustainable forestry practice.

The Forest Stewardship Council

The Forest Stewardship Council (FSC) has an independent international certification system that applies to forestlands of all sizes and whose performance-based guidelines are designed to promote "environmentally appropriate, socially beneficial, and economically viable forest management" (Forest Stewardship Council U.S., n.d.). FSC develops and updates the standards but relies on other third party organizations to perform the verification of compliance for certification. FSC is widely recognized by environmental and social NGO communities as the strongest of the large certification systems.

FSC has developed a set of 10 Principles and Criteria of Sustainable Forest Management, and all of them must be met in order to be certified. Within these, Principle 6 deals with minimizing the environmental impacts of forestry practices. It broadly requires that "Forest management shall conserve biological diversity and its associated values, water resources, soils, and unique and fragile ecosystems and landscapes, and, by so doing, maintain the ecological functions and the integrity of the forest" (Forest Stewardship Council U.S., 2010). FSC incorporates biomass-specific indicators into their standards – but broadly, with the idea that management practices must not impact soil productivity, nor the "natural cycles that affect the productivity of the forest ecosystem" (Forest Stewardship Council U.S., 2010).

According to Jon Baker of Cousineas Forest Products, FSC certified wood is not available within a 50 mile radius of Bates as maintaining the standards requires a large staff and significant expense. Only the very large tracts of forests previously owned by the pulp and paper industries use this certification (personal communication, May 9, 2013).

Nonetheless, because the standards are strong, it's useful to know what they are. Specific standards and requirements for FSC certification that pertain to issues related to biomass harvesting include:

- An Environmental Impact Assessment based on "credible scientific analysis" must be conducted prior to the commencement of harvesting operations. The analysis includes (but is not limited to) forest community types, water resources and hydrology, and soil resources.
- Management decisions and site prescriptions are developed using the findings of the Environmental Impact Assessment, and are implemented so that negative short- and long-term impacts are minimized or avoided, and the long-term ecological viability of the forest is maintained or enhanced.
- Average annual harvest rate of forest products will not exceed a calculated, site-specific "sustained yield harvest" level. The "sustained yield harvest" level refers to harvesting rates that do not exceed growth rates, and that "do not diminish the long term ecological integrity and productivity of the site".
- Plant species "composition, distribution, and frequency of occurrence" must be maintained at levels that would naturally occur on site.

- “Written guidelines shall be prepared and implemented to: control erosion; minimize forest damage during harvesting, road construction and all other mechanical disturbances; and protect water resources.” This standard includes indicators specifically addressing the disturbance of topsoil, compaction, erosion, soil productivity, water quality, seasonality of activities, and the frequency of whole-tree harvesting (which may only be done when “research indicates soil productivity will not be harmed”).
- Management guidelines must meet or exceed regional Water Quality BMPs so as to meet water quality regulations.
- With rare exceptions, the conversion of natural forests is prohibited (Forest Stewardship Council U.S., 2010).

Independent, FSC-accredited third-party certifiers verify that land management practices and forest sites meet the requirements of the FSC standards. Each certified entity is audited at least once a year to ensure continued compliance to FSC standards.

In addition to certifying landowners and forest managers, FSC also certifies supply and production chains through their “Chain-of-Custody” certification.

The Sustainable Forestry Initiative

The Sustainable Forestry Initiative (SFI) has a certification system that focuses on forestlands larger than 10,000 acres. It is a common certification system in the U.S., and is a requirement for membership in the AF&PA, which is the national trade association for the U.S. forest products and paper industries. Members participating in the SFI program can choose between first-party (self-assessment), second-party, and third-party verification, although only third-party verification qualifies as 'certification'. In general, the SFI certification standards are thought to be less stringent than FSC standards. Historically, the credibility of the SFI certification program has been questioned by environmental and social NGOs due to it's funding dependence on the forestry industry, it's comparatively relaxed standards and lack of consistent benchmarks regarding environmental and social issues, and the opacity of it's standard-setting committees (Stryjewski, 2007). Their standards can be found at www.sfiprogram.org.

Maine Master Logger Certification

The Master Logger Certification program was started in Maine in 2001 and was merged with the Trust to Conserve Northeast Forrest Lands in 2005, making it an independent, 3rd party certification system. It provides independent certification to logging companies who meet their standards, which are cross-referenced to standards of all the major certification systems. Unlike SFI and FSC, which certify that wood products industries are managing their land sustainably, the Master

Logger program certifies the wood harvesting companies because their actions have the greatest direct impact on forest health. Their robust and environmentally-oriented standards include nine goals that must be met to achieve certification:

- Document harvest planning
- Protect water quality
- Maintain soil productivity
- Sustain forest ecosystems
- Manage forest aesthetics
- Ensure workplace safety
- Demonstrate continuous improvement
- Ensure business viability
- Uphold certificate integrity

Within each of these goals there are harvest responsibilities and detailed performance standards that certified companies must follow in order to be certified. There seem to be several Master Logger Certified companies within a 50-mile radius of Bates. Their guidelines are the most specific of those available to Bates, are locally applicable, and amongst the strongest. They can be found in their entirety at www.masterloggercertification.com.

State of Maine Biomass "Considerations and Recommendations for Retaining Woody Biomass on Timber Harvest Sites in Maine"

The Maine biomass guidelines were developed as a collaborative effort between the Maine Forest Service, The University of Maine and The Trust to Conserve Northeast Forest Lands as interest in biomass harvesting increased in the state. Biomass chip harvest in Maine increased more than three and a half times to 3.5 million green tons between 2000 and 2007 and is projected to further increase (Benjamin, 2010).

The guidelines are meant to be used in conjunction with "all applicable regulations and water quality best management practices." The guidelines define biomass as "all organic matter" but go on to identify "energy wood" and "energy fiber," which is a sub-category of energy wood, but excludes saw timber quality wood. To be specific, the state of Maine defines woody biomass as "logging residues, previously unmerchantable stems, and other such woody material harvested directly from the forest typically for the purposes of energy production." (Benjamin, 2010:5)

The report is broken into three main sections that address concerns about soil productivity, water quality and forest biodiversity. Each section provides extensive background information and provides a set of voluntary guidelines at the end of each section. At this point, these biomass guidelines are voluntary. Given that even the required water guidelines are not fully executed it seems likely that some number of foresters will not follow these guidelines, confirming the need for Bates to use some sort of certification.

Compared to the FSC guidelines, the Maine guidelines are vague and were created as a starting point to be used with the input of an expert forester to develop site-specific/individual best management practices for that tract of forest.

The State recommendations (Benjamin, 2010) are:

Water Quality

- Disturbance of the forest floor should be minimized
- Woody biomass may be used to control water flow, to prevent soil disturbance, and/or to stabilize exposed mineral soil, especially on trails and the approaches to stream crossings
- Woody biomass used for erosion control and soil stabilization may be left in place, if it is above the normal high water mark of streams or other water bodies

Soil Productivity

- Except where scarification of the soil is important for regeneration, leave the litter layer, stumps, and roots as intact as possible. Wood decaying on the ground, especially tops and limbs, contributes nutrients that help build up the growth potential of the soil
- Leave as many tops and branches as possible on:
    - Low-fertility sites
    - Shallow-to-bedrock soils

  - Coarse sandy soils
  - Poorly drained soils
  - Steep slopes
  - Other erosion-prone sites

Forest Biodiversity

- Leave as much dead wood on site as possible
  - Leave as many snags standing as safety and access will permit
  - Leave any felled snags in place
  - Limit disturbance to existing down logs
  - If large woody material is lacking on the ground, consider leaving some newly cut logs scattered throughout the harvest area
  - Large woody material can be created over time by retaining all snags possible and leaving some large trees to die
- Leave some live wildlife trees
  - Retain live cavity trees on site. Cavity trees are live trees with holes, open seams or hollow sections that wildlife can use
  - Leave live trees with rot when cavity trees are not available
- Vary the amount of snags, down logs, and wildlife trees across the harvest area
  - Stream buffers, retention patches and other protection zones provide an opportunity to leave more large trees than may be possible in other harvest areas

    - Leaving lightly cut or un-cut patches in heavy harvest areas yields more biodiversity benefits than widely dispersed single trees
    - The larger the retained patch, the greater the benefit to sensitive understory species
- Leave as much fine woody material as possible.
    - Where possible and practical (depending on harvest method and system) retain and scatter tops and branches (fine woody material) across the harvest area
    - If trees are delimbed at roadside, haul a portion of the tops and limbs back into the woods. Leave the material along skid trails if carrying it off the trail would cause greater damage.

So, though the State of Maine has created recommendations for biomass harvest practices, they are voluntary. The best way to ensure site-specific sustainable forestry practices are being implemented is through certification systems. The most robust certification available to Bates seems to be that of Master Logger.

Colby College Experience Using Biomass Energy

Colby College is located in Waterville, Maine and is home to 1,825 students, of which 1,725 are residential. There are 171 full time faculty, 48 part-time faculty, 405 full-time staff and 115 part-time staff at the college ("GHG report for Colby College," 2012). Colby is a signatory of the American College and University President's Climate Commitment pledge to reach carbon neutrality.

Goals and Strategies

Colby College set the goal of becoming carbon neutral by 2015. The strategies they chose included:

- Reducing campus greenhouse gas emissions by 41% from 2010 levels
- Purchasing carbon offsets
- Requiring that all new buildings achieve a minimum of LEED silver standard
- Operating facilities as efficiently and sustainably as possible
- Raising environmental awareness and responsible living practices for students, faculty and staff

Since their original report was written, they have also discovered they can take the college trash stream to the Norridgewock waste management facility, which has a methane recapturing program for the use of producing electricity. They do not purchase this electricity, but this practice reduces the College's methane gas emissions. Bates may wish to pursue a similar strategy.

Pre-Implementation Situation

According to the ACUPCC website, Colby's gross emissions for the 2010/2011 academic year were:

- *Scope 1* (stationary combustion, mobile combustion, process emissions and fugitive emissions): 12,941 metric tons of CO_2e.
- *Scope 2* (purchased electricity): 0 metric tons of CO_2e.
- *Scope 3* (commuting, air travel, solid waste, auto travel and other travel): 5,030 metric tons of CO_2e.
- *Biogenic Mobile:* N/A
- *Biogenic Stationary:* N/A

Net emissions, including offsets were: 17,748 metric tons of CO_2e. Their offsets included sequestration due to land owned of 177 metric tons of CO_2e, and carbon storage due to composting of 46 metric tons of CO_2e ("GHG Report for Colby College," 2012). Their biomass plant came online in January 2012, and in 2013 the college declared they had achieved carbon neutrality. Their process towards their goal is described below.

The heating portion of Colby's environmental footprint was estimated to be 70% of the College's emissions as of 2010, when the College's Climate Action Plan was developed. Note that Colby began purchasing electricity from renewable sources in 2003, so that by the time of their report, one third of their total emissions had already been replaced and heating fuel had become a larger proportion of their remaining GHG. The campus steam plant was fueled by about 1.1 million gallons of No. 6 fuel oil each year at the time of their report. No. 6 fuel oil burns less cleanly than distillate No. 2 fuel oil or natural gas (which Bates currently uses), and so Colby had a large incentive to convert to biomass. Colby estimated that their return on investment for the plant would be in the 6-year range (P. Whitney, personal communication, May 7, 2013).

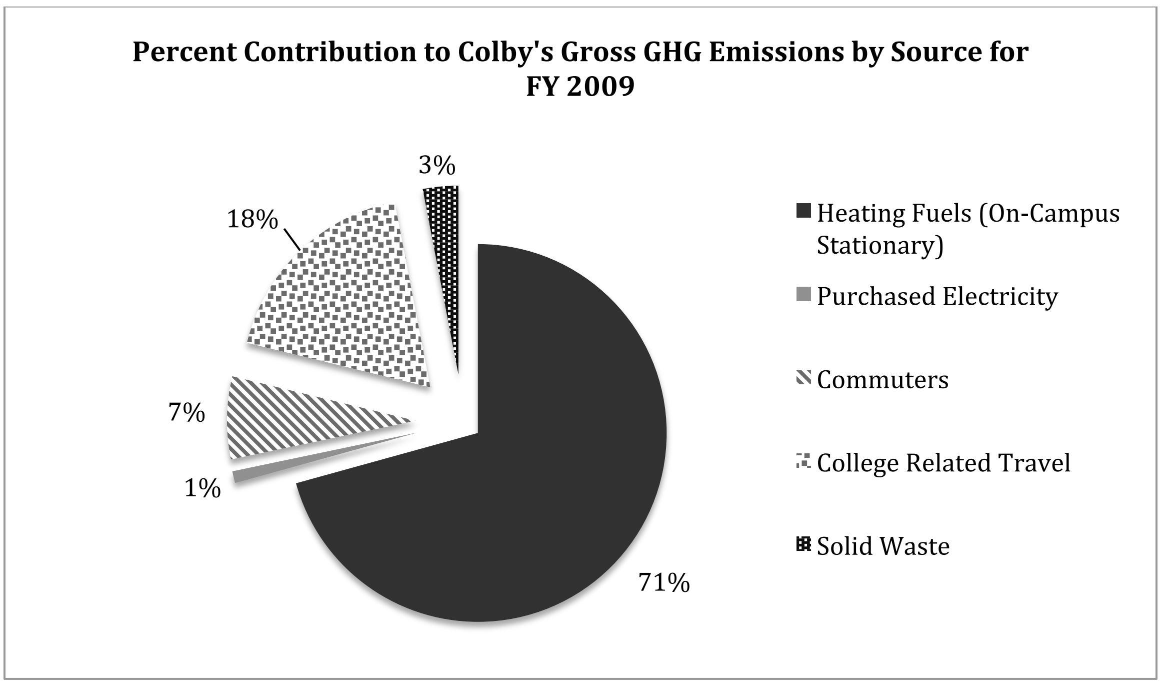

Figure 4. Breakdown of sources contributing to Colby College's greenhouse gas emissions. Data sourced from Colby College Climate Action Plan (2010).

The 12-page Colby College Climate Action Plan developed in 2010 included one small paragraph about their plans for biomass, saying that they would build a plant that would supply heat and replace the need for 1 million gallons of fuel oil, which would provide an estimated 90% of the campus steam demand.

Implementation of BioMass at Colby

On January 17, 2012, the college announced that their new biomass plant would go into operation that week. Construction of the cogeneration plant cost $11.25 million and was expected to replace 1 million gallons of heating oil with 22,000 tons of locally sourced wood annually.

Though they are early in the process, Colby's experience has been better than their projections. Due to repairs, their two small biomass boilers were offline for parts of 2012, but they used 14,000 tons of wood across about 9 months. Patricia Whitney, Colby's Director of Physical Plant, is pleased with the performance of the plant – she estimates that they used only about 60% of the wood they projected they would need, and decreased their oil use by 75% of their target (P. Whitney, personal communication, May 7, 2013). The plant also provides about 10% of the campus' electricity needs.

According to Whitney, the college has "Gone above the minimum requirements to try to have the cleanest emissions we can" (Colby College, 2012). She is referring to two incremental systems they use to reduce particulate emissions above and beyond state requirements. One is an electrostatic precipitator (ESP), the other a cyclonic dust collection system. According to Whitney, these don't impact CO_2 levels, only particulate levels (P. Whitney, personal communication, May 7, 2013).

Colby uses the same broker as Middlebury, Cousineau Forest Products, for doing so allows them to use a number of smaller, more local providers while still receiving the volume of chips they require. Cousineau also helps enforce the quality and environmental standards they have for their suppliers. All of the College's wood suppliers sign a contract that they will provide wood that was harvested under guidelines of either Sustainable Forestry Initiative or the Forest Stewardship Council, from a Maine tree farm, or from a master logger with a certified harvesting plan. Whitney reports that whenever possible they use treetops, limbs, bark and lower value hardwood (P. Whitney, personal communication, May 7, 2013).

One of the problems they've had with their system is the conveyor belt. "There is a lot of newer technology – gasification, controls, computers. They've all been working great. What we've had problems with is the oldest technology that's been around for about 90 years - the conveyors that move the wood. We've had to rebuild them…the designs weren't strong enough, so we've had to shut down to replace conveyors…" They've also had some issues with the quality of the wood they receive. Sometimes they receive sawdust-sized chips, which don't burn well, and others times they get pieces bigger than their specified 12 inch maximum. She recommends Bates create a system that is flexible enough to tolerate imperfect wood supplies. Colby has, for example, resizer technology that separates out pieces that are too large, rechips them, and sends them back to the conveyor. She praises Cousineau for helping them enforce quality control.

Colby Reaches Carbon Neutrality

On April 4th, 2013 Colby announced that it is one of four colleges in the ACUPCC group to have reached carbon neutrality, and is the largest institution to reach that goal to date.

They have reached this status with following combination:

- Switching to 100% renewable electricity
- Replacing most No. 6 fuel oil use with biomass for campus heating
- Increased energy efficiency and lowered temperatures in buildings
- LEED certification for new buildings and renovations
- Geothermal heating and cooling in two new buildings
- Waste management, composting and recycling
- Purchase of offset credits

Their wood suppliers sign contracts that ensure the sustainability of their wood products. "We don't have the staffing to go out into the field to guarantee this – we rely on the honor system and Cousineau's experience," says Whitney. To determine the effectiveness of their efforts, they use the Clean Air – Cool Planet Campus Carbon Calculator. They originally assessed their emissions using three entities – the calculator, their mechanical engineers and an independent consultant and found that the calculator was the most conservative measurement tool. This calculator tool is also recommended by the ACUPCC.

So, a fast payback and a heavy dependence upon #6 fuel oil meant that a switch to biomass energy production made a lot of sense for Colby. Their results have been better than expected, though they did experience some mechanical setbacks.

Middlebury College Experience Using Biomass Energy

Middlebury College, located in Middlebury, Vermont is home to 2,715 residential students, 238 full-time faculty and 890 full-time staff ("GHG report for Middlebury," 2013).

Gross emissions for the college as of the 2011/2012 academic year ACUPCC report were:

- *Scope 1* (stationary combustion, mobile combustion, process emissions and fugitive emissions): 14,046 metric tons of CO_2e.
- *Scope 2* (purchased electricity): 437 metric tons of CO_2e.
- *Scope 3* (commuting, air travel, solid waste, auto travel and other travel): 4,139 metric tons of CO_2e.
- *Biogenic Mobile:* 0
- *Biogenic Stationary:* 17,315 metric tons of CO_2e.

Net emissions, including offsets, were: 8,176 metric tons of CO_2e. Their offsets include purchased carbon offsets 541 metric tons of CO_2e and sequestration due to land owned by the college of 9,905 metric tons of CO_2e ("GHG Report for Middlebury," 2013).

Goals and Strategies

Initially the plans for building a biomass cogeneration plant were part of the college's 2004 goals for reducing carbon emissions on campus by 8% below 1990 levels (Middshift Implementation Working Group, 2008). In 2007, due to pressure from the college community, the college implemented a more stringent goal of reaching carbon neutrality by 2016.

Their 2008 Climate Action Implementation Plan suggested these implementation strategies:

- Heating and cooling improvements through biomass cogeneration
- Retrofit buildings to increase energy efficiency. They audited all buildings for energy efficiency and cost payback on implementation of recommended strategies over the long run
- Educating the college community about the importance of energy conservation
- Require Middlebury College specific LEED certification of new buildings and renovations
- Other parts of the implementation plan (college travel, waste minimization, energy offsets and sequestration) do not relate directly to heating and cooling

A subset of goals pertaining specifically to the energy generation portion of the project was put forth in the same Climate Action Plan. They addressed the possible environmental, economic and social benefits of the project:

- *Environmental:* Reduce greenhouse gas emissions; Decreasing wood waste going to landfills; Making the preservation of forests more economically feasible
- *Economic:* Create local jobs for logging and transportation; Develop a local supply of biomass; Infuse $500,000 into the local economy if a second biomass plant is constructed
- *Social:* Extending education about sustainable forestry and global warming

At the same time, they recognized there might be environmental and social costs, most notably that an increased competition for local low-grade wood chips might force previous buyers, including both industry and Vermont homeowners, to move to less sustainable practices.

Pre-Implementation Situation

The heating and cooling portion of Middlebury's total carbon emissions was estimated to be 89% of their total emissions.

Yearly heating and cooling of 2,564,867 gross square feet of campus building space was provided by approximately:

- 2 million gallons of #6 fuel oil
- 175,000 gallons of #2 fuel oil (80%)/bio fuel (20%) blend
- Small quantity of propane

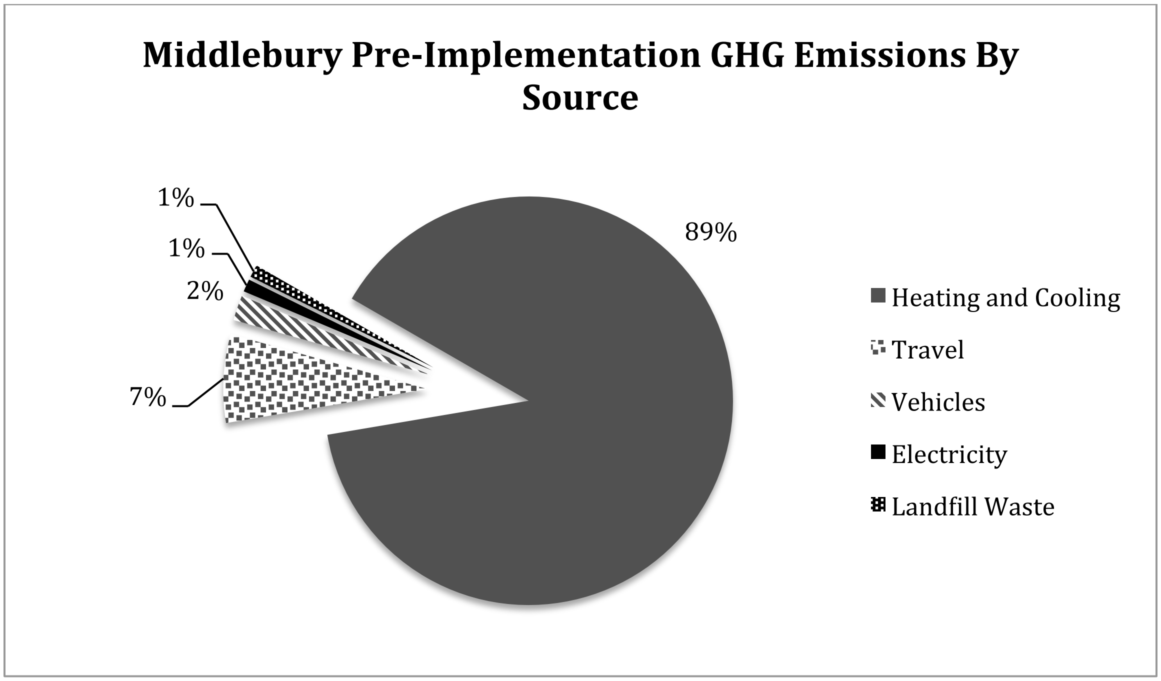

Figure 5. Breakdown of total greenhouse gas emissions by contributing source for Middlebury College as of 2008 (before biomass plant came online). Data source: Middshift Implementation Working Group, (2008)

Expectations for Project Implementation

The college hoped that building a biomass cogeneration plant would replace 1 million gallons of #6 fuel oil usage annually with approximately 20,000 tons of woodchips. They estimated that this would result in a 40% reduction in net emissions of carbon, which is equivalent to 12,500 metric tons of carbon emissions. In addition to environmental benefits, the College hoped that the project would also have local social and economic benefits, as well. The Middshift Working Group set goals to source local fuel supply for environmental and economic reasons and made the project an educational opportunity for both the college and local communities.

The College never assumed that biomass energy production would meet its peak capacity demands. In their Climate Action Implementation Plan adopted in 2008, they noted:

"The new biomass facility will be able to meet only a fraction of the campus demand at full capacity. Reaching the peak demand for steam requires the production of 90 MMBTUs of energy. The current biomass facility produces 30 MMBTUS meaning an additional 60 MMBTUs is required from any alternative at peak times. This implies that an additional burning with the capacity for producing 60 MMBTUs is necessary to meet the demand entirely through the use of biomass. The existing heating plant infrastructure is fully capable of producing the additional 60 MMBTUs by burning biodiesel and will provide the college a backup system in the event that the biomass facility is inoperable."

Implementation and Results

Middlebury College completed construction of a $12 million biomass cogeneration heating plant in 2008, which came into full operation in 2009. According to Mike Moser, the Assistant Director of Facilities Services, Central Heating and Utilities at Middlebury, the College is currently replacing somewhat more than the million gallons of #6 fuel oil they projected. Their facilities co-fire both wood chips and fuel oil, which provides backup security in the event that the wood chip supply were interrupted.

According to Moser, getting the plant going took more time than expected. "We had a hard time figuring out how to make the equipment run in the first two months. It turned out there were some control system design flaws. There was a good 6-12 month commissioning phase. My advice to Bates would be to not underestimate the amount of time it takes to get a plant running" (M. Moser, personal communication, May 1, 2013).

Middlebury uses hard wood, whole tree wood chips for its energy. Moser reports that they have never had a problem with obtaining their biomass supply. However, he notes that their "ongoing problems are all about the *sustainability* of the wood chip supply. There is no real supply of sustainably sourced wood chips. And there is a lot of discussion about the [actual] sustainability of biomass." Initially they had hoped to use a single supplier in the area who would be able to supply certified, sustainably sourced wood. However, they found the actual situation significantly more complex, with neither a single supplier nor an ability to assess the true sustainability of their sources. Moser admits, "Naively, I started calling around to woodchip suppliers thinking 'this will be a piece of cake' and that we would just start burning! That's not at all how it turned out."

He is concerned that the supply chain is complex and "tangled" and that this adds to the difficulty of ensuring that their supply is sustainable. Although the college wants to have as sustainable a supply as possible they have found that this is quite a challenge. Their first difficulty is defining what sustainable harvesting is and what it means. “Sustainable means one thing to the Environmental Studies Department and something totally different to the loggers.” He adds “Now we are taking in chips harvested under managed land efforts and we routinely get out into the woods with our suppliers to understand what their business plans are…What works for the one time may not be the same sustainable thing that's employed elsewhere [so we collect a lot of data and ask] in general, are we okay?” (M. Moser, personal communication, May 1, 2013).

In order to better understand what quality of wood they are getting, Middlebury now tracks the following things:

- Supplier
- Type of wood
- State, county and town of origin
- Mileage in delivery
- Certifications that apply

Eventually they ended up choosing Cousineau Forest Products to be their wood chip broker. They decided upon using a broker because: they weren't well versed enough to talk with local loggers to understand the sustainability of their products; it was too complicated to coordinate three daily truckloads of wood chips; they needed some storage capacity beyond the 1.5 day capacity they have on campus; Cousineau could deliver upon request.

Middlebury's Experience with Willow

Recognizing that the local supply of wood may fluctuate and, therefore, become costlier, Middlebury collaborated with SUNY College of Environmental Science and Forestry to begin researching the possibility of growing short-rotation woody willow crops locally. Research is taking place on 9 acres of their own college lands, where they planted multiple types of willow. In January of 2011 they tested their first harvest, which ended up yielding 120 tons of willow wood chips on the six acres that produced, which is slightly over one day's worth of fuel. They did several tests to incorporate willow at a 25/75 blend, a 50/50 blend and at 100% willow. They learned that their plant can burn willow, but that it takes a significant recalibration to do so, and they did not have enough wood to optimize their calibrations. Moser asks, "Do we want to modify the setup of our gasifier and combustion controls to handle willow? It's a gross change in fuel source."

So Middlebury's implementation of biomass energy production has proceeded as expected, with the exception of mechanical delays at the outset of the project. The college continues to press for environmental stewardship improvements, giving considerable thought to the definition of "sustainable," particularly in the supply chain, and experimenting with willow production on its own land.

Conclusions and Recommendations

The concept of "carbon neutral" is heavily dependent upon long time periods for the re-sequestration of carbon released prematurely from biomass during combustion.

In the very long term, biomass energy that is sustainably sourced is theoretically carbon neutral if supply chain fossil fuel inputs are excluded from the equation. In the short-term, using biomass instead of natural gas more than doubles the amount of carbon released into the air. Unless it chooses to pursue willow energy production, what Bates is faced with, then, is a decision about whether to become carbon neutral in name while increasing carbon emissions in action (at least in the foreseeable future), or to continue to pursue other, less potentially damaging options such as solar, wind, hydro, carbon credits and geothermal. Since the timing of plant replacement will coincide with new construction elsewhere on campus, Bates has some time to explore ecological and economic realities of other options in-depth before making its decision as to whether to pursue biomass energy usage. Though Bates has made a pledge to be carbon neutral by 2020, the questions about carbon neutrality are significant enough that it makes sense to carefully consider all options before moving ahead, even if the deadline is missed.

The emissions from Bates' boiler plant are a significant portion of the College's current carbon footprint, so it is possible that Bates may still choose to build a biomass plant to reach their goal of carbon neutrality by 2020 since the ACUPCC accepts biomass energy as "carbon neutral." In this event, there are certain guidelines the College should follow in order to minimize their carbon debt and environmental impact:

- From an ecological standpoint willow, if made available, is the best biomass option as long as its production does not replace forest or natural habitats. It provides significant positive ecological benefits when replacing annual row crop production or on degraded land. The carbon debt from willow fuels can be repaid in 3-5 years thus ensuring its actual carbon neutrality.

- Bates should explore whether or not strategic partnerships can be created for willow production in the Lewiston area. Timothy Volk of SUNY ESF seems to be one of the best experts on willow production for bioenergy and should be consulted if Bates decides to further explore this option.
- Forest residues represent the second best biomass energy option as long as they are sourced from forests where environmentally friendly and sustainable management plans are applied.
- The carbon impact of the supply chain should be minimized by sourcing within a 50-mile radius of Lewiston.
- Certain forestry practices put sustainability and future forest productivity levels at risk. These include whole tree harvesting and soil compaction. Bates should only source residues.
- The best way to ensure sustainability is to source only certified products. Within a 50-mile radius of Lewiston, the best available certification seems to be the Maine Master Logger certification. It requires that a sustainable management plan is in place and the site prescriptions for that plan are applied. Individualized management plans are important because sustainable harvesting practices are very stand-specific.

- The experiences of Middlebury and Colby suggest that Bates will need to use a broker to obtain its biomass supply. Both colleges have been happy with Cousineau Forest Products.
- The experiences of Middlebury and Colby also suggest that Bates will need to plan for a potentially lengthy start up process for the plant. Both colleges ran into unexpected mechanical issues.

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Glossary of Terms

Biological Diversity (biodiversity): The variety and abundance of life forms, processes, functions and structures of plants, animals and other living organisms, including the relative complexity of species (the variety of species and abundance of these species), communities, gene pools, and ecosystems at spatial scales that range from local through regional to global.

Biomass: Biological material from living or recently living organisms that can be converted into energy through combustion.

Carbon Dioxide Equivalents (CO_2e): A metric measure used to compare the emissions from various greenhouse gases based upon their global warming potential.

Carbon Neutrality: Refers to achieving net zero carbon emissions by balancing an amount of carbon released with an equivalent amount sequestered or offset to make up the difference.

Carbon Sequestration: The process by which carbon sinks such as forests remove carbon from the atmosphere

Carbon Sink (Carbon Pool): A reservoir (such as plant material, soils, etc) that accumulates and stores carbon compounds for an indefinite period

Cavity (Den) Tree: A hollow (or partially hollow) living tree used by wildlife.

Clearcut: An area with less than 30 square feet of basal area on an acceptable growing stock in trees >6 inches diameter breast height (dbh) and lacking established regeneration, as further defined by Maine's Forest Practices Act rules.

Ecosystem: A spatially explicit, relatively homogeneous unit of the earth that includes all interacting organisms and components of the abiotic environment within its boundaries.

Fine Woody Material: Woody material, living or dead, less than 4 inches diameter inside bark at the large end; including fine woody debris and portions of standing living and dead shrubs and trees.

Habitat: The environment (including food, water, cover, and climate) where an animal, plant, or population naturally or normally lives and develops.

Logging Residue: The unused portions of trees cut during logging and left in the woods or at roadside.

Silviculture: The art and science of controlling the establishment, growth, composition, health, and quality of forests and woodlands to meet the diverse needs and values of landowners and society on a sustainable basis.

Slash: The residue left on the ground after logging or accumulating as a result of storm, fire, girdling, or de-limbing.

Snag: Standing dead tree.

Stem-only Harvesting: Forestry practice in which the nutrient-low stems are removed but the nutrient-rich branches and leaves are left on-site to decompose.

Whole-tree Harvesting: Felling and removing an entire upper portion of a tree consisting of stem, top, limbs, and leaves (or needles).

Appendix A: SFI 2010-2014 Standard Excerpts

The indicators (or, "objectives"), by which SFI measures a certificate holders' conformance to SFI's standards, that pertain to issues related to biomass harvesting include:

- Objective 1. Forest Management Planning - "Program Participants shall ensure that forest management plans include long-term harvest levels that are sustainable and consistent with appropriate growth-and-yield models." Indicators provide a list of topics that a forest management plan should include, which includes "recommended sustainable harvest levels for areas available for harvest".
- A program participant must provide "Documentation of annual harvest trends in relation to the sustainable forest management plan in a manner appropriate to document past and future activities."
- Objective 2. Forest Productivity – "To ensure long-term forest productivity, carbon storage, and conservation of forest resources through prompt reforestation, soil conservation, afforestation and other measures."
- Performance Measure 2.3 "Program Participants shall implement forest management practices to protect and maintain forest and soil productivity" through "process[es] to identify soils vulnerable to compaction, and use of appropriate methods to avoid excessive soil disturbance", the "Use of erosion control measures to minimize the loss of soil and site productivity", having "Post-harvest conditions conducive to maintaining site productivity (e.g. limited rutting, retained down woody debris, minimized skid trails)",

"Criteria that address harvesting and site preparation to protect soil productivity", and "Road construction and skidding layout to minimize impacts to soil productivity and water quality."

- "Program Participants shall meet or exceed all applicable federal, provincial, state and local water quality laws, and meet or exceed best management practices developed under Canadian or U.S. Environmental Protection Agency-approved water quality programs."
- Program Participants shall utilize a "Program or monitoring system to ensure efficient utilization, which may include provisions to ensure: a. management of harvest residue (e.g. slash, limbs, tops) considers economic, social, and environmental factors (e.g. organic and nutrient value to future forests) and other utilization needs".

(The Sustainable Forestry Initiative, Inc., 2010)