Biomass Fuel Assessment for Middlebury College

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EXECUTIVE SUMMARY

Purpose

The purpose of this study is to determine the availability of 30,000 green tons per year of biomass to fuel Middlebury College's heating plant in a way that:

- Is available on a sustainable basis, and is grown, harvested and produced in an environmentally-sensitive manner
- Stimulates local economic development
- Supports the academic mission of the College.

Although it is possible that other sources of biomass may be locally available in the future, the scope of the project was limited to the most viable near-term option: wood from local forests and sawmills.

Suitable Land

Based on both ecological and economic factors, it was determined that the "woodshed" needed to supply Middlebury College with 30,000 green tons per year would include the portions of Addison and Rutland counties that are west of the spine of the Green Mountains and that fit specific land-suitability criteria.

Due to the cost of transporting biomass for energy, the Green Mountains and Lake Champlain were assumed to form logical boundaries on the east and west. Low-quality wood harvested in Chittenden County would more likely be purchased by Burlington Electric Department. Wood from Rutland County forests potentially could be transported by rail.

Analyses performed in the College Geography Department's GIS lab were used to identify and map forested sites that had soils without serious limitations (such as shallowness to bedrock, poor drainage, and low cation exchange capacity), slopes less than 60%, or elevation greater than 2500'. In addition, 75'-wide wetland- and surface water-buffers and lands with legal restrictions prohibiting timber extraction were considered unsuitable. Public land was also considered unavailable, since on Green Mountain National Forest, the bulk of public lands in the area, litigation against timber sales has basically stopped logging. Finally, to allow for the harvest-road network and protection of unmapped sensitive microsites (such as vernal pools and forest seeps), 10% of the suitable forested acreage was excluded from production. The amount of privately owned forestland suitable for sustainable intensive forestry was calculated to be 120,000 and 276,000 acres in Rutland and Addison counties, respectively.

Subtracting the land east of the spine of the Green Mountains leaves approximately 360,000 acres of privately owned forestland suitable for sustainable intensive forestry in the College's local woodshed.

Biomass Availability

Within the woodshed, four types of biomass sources were considered:

1. **Alternative to disposal in the "Stump Dump."** Land clearing**,** landscaping, land conversion and post-storm clean up often result in trees and branches that would go to a stump dump if they were not burned. Approximately 600 tons of wood are chipped annually at the Town of Middlebury stump dump.

2. **Mill residue.** The residue that results from sawing logs into boards is available from mills. Sawmills in Addison and Rutland counties produce and sell about 26,000 tons of mill residue annually. These "clean" chips can be used for paper, and International Paper Company's Ticonderoga Mill is a major buyer. Although some of the College's biomass could come from mill residue, the College would need to outbid existing buyers of mill residue, leaving those buyers looking for biomass from the land or from other mills farther away.

3. **Biomass from land that is currently being logged.** Low-quality wood can be removed from forestland during silvicultural operations that are primarily aimed at sawlog harvest. Because the current price for biomass is so low, the low-grade wood is often left on the site or sold for firewood. Although there are no good tallies of firewood, we estimate that nearly 40,000 tons of low-quality wood are left on site. Without displacing the current level of local firewood sales, there is potential for the College to meet its needs in the short term from a combination of mill residue and low-grade material that could be removed when higher-grade sawtimber is harvested. However, when oil prices rise, the demand for firewood could be strong enough to take all of the low-grade material from logging sites so the College would compete with the local firewood market.

4. **Biomass from land that is currently withheld from harvesting**. With outreach, assurances of "excellent forestry," and additional financial incentives, more people potentially could be convinced to cut trees from their land. This would result in more sawtimber to the mill, more mill residue, and more low-grade wood removed that could be sold to the College. Although we estimate there are roughly 120,000 tons grown annually on land in the woodshed that is not harvested, enticing landowners to harvest would require considerable training, marketing, and time. It is extremely important to note that sawmills in the area feel they are "supply constrained" because of the inclinations of the landowners.

Current Price

Currently, wood chips can be purchased for about $22-$34 per ton, delivered. The price has remained fairly constant over recent years, with only minor fluctuations. The major purchasers are International Paper Company (clean chips from mill residue) and several schools that burn chips for heat. Although there is a current supply constraint, the largest chip broker in the area believes that the fiber shortage will correct itself and he could find 30,000 tons per year for the College. There is no assurance that the operations would be either local or sustainable. The broker currently buys from sources in Vermont, New Hampshire, Maine, New York and Massachusetts.

Burlington Electric Department, which has procurement standards required by the Vermont Public Service Board in order to provide some assurance that the land is not damaged, reports that there is often a competitive supply problem in the winter.

Analysis of Biomass Scenario to Meet College Goals

The College's supply cannot come entirely from wood that would otherwise go to a stump dump and mill residue; some must come from the land. In order to meet the College's goals, forestry practices on the land must be economically and ecologically viable. We analyzed the following scenario for procuring biomass from the land:

- Biomass acquired only during integrated harvest.(Biomass harvest accompanies sawlog harvest—it does not replace it).
- Procurement standards implemented to protect the site.
- Roundwood (not chips) removed from the forest.

All trees in a forest serve many ecological functions. Although people often say that removing low-quality wood from the forest is good for the forest because it removes trees that compete for light and nutrients with high-quality trees, it is important to note that low-quality wood that is left on-site as both dead- and live-wood serves many irreplaceable ecological functions, including microhabitats, nutrient cycling and primary productivity. To utilize more of that wood sustainably would require instituting science-based standards as well as a means of monitoring compliance. For this reason, we have proposed detailed procurement standards.

The College would procure low-grade roundwood (not chips) from forests as part of integrated harvests during which the higher-grade sawlogs would be sold to a sawmill. The College's standards would apply to this integrated harvest. Therefore, they would not only ensure that the biomass is harvested sustainably, they also would ensure that the forest ecosystem is not degraded by the sawlog harvest. In many cases, application of the procurement standards would mean an improvement in harvesting practices on lands currently being logged.

The procurement standards would be implemented with a pre-harvest, on-site meeting and would be enforced with harvest monitoring. In addition, the College would maintain a list of recommended loggers and foresters, and would provide education and training for loggers, foresters and landowners.

Roundwood—not chips—would be delivered to Middlebury College to be chipped on site. This would protect the land by keeping chippers off the site and by making it possible to verify that the twigs, leaves and smaller branches (that contain a very high percentage of the nutrients) remain on the site. It would also be easier to store roundwood, thus relieving the seasonal supply problem.

To achieve the desired standard of logging, the logger as well as the landowner must be paid more. Currently, high-quality logging operators report that it generally is not worth pulling out low-quality material. If low-quality wood were to be removed from the site and sold as chips for $30 per ton, the chip operation would be subsidized by the sawlog sale. Loggers estimate the cost of cutting low-quality wood and moving it to a log landing, in accord with the procurement standards, would be about $35-$40 per ton of roundwood.

We calculate that a payment of $8 per ton to landowners would be an incentive to do two things: 1) sell the low-grade material to the College, and 2) achieve a higher level of management and logging on the land.

Based on this scenario, we estimate the price of roundwood, delivered to Middlebury College, to be $53-$58 (2003 dollars). The costs per ton are as follows:

$35-$40 logging costs
$8 to landowner to practice excellent forestry and meet procurement standards
$10 trucking costs
$53-$58 per ton of roundwood, delivered

In addition, the College would build into the price:
$0.50-$1 per ton for training, monitoring, and enforcement

Finally, this is roundwood—not chips. The College would purchase and operate the chipper, and that price should be factored into the full cost of supplying wood chips.

Future Price and Availability

Because the College would be using a fuel at a rate that it is being grown, the supply is known and fairly stable. In addition, the fuel is local and not subject to terrorism, pollution taxes, or international disputes.

However, future price and availability are still difficult to predict, mainly because demand for biomass to replace oil for heating is likely to increase, which would lead to a decrease in availability of biomass and an increase in price.

With sustainable forestry, the forests of Addison County alone cannot supply enough biomass to meet the needs of the College as well as those of other residents if oil prices rise sharply.

A comparison of the low-quality wood grown per year in Addison County and the potential demand for it makes this clear. If the assumption is made that oil prices will increase in the future and county residents will turn to firewood to replace one half of their residential heating needs, the demand for low-quality wood would exceed the amount grown per year in the county (Table 1). (The supply problem would be greater than this because a great deal of private land that is suitable is actually not available due the landowners' preferences.)

Table 1.

Estimated annual demand and growth of low-quality wood: Addison county only (Green tons)	
Current demand	38,081
College demand	30,000
New residential fuel demand	30,806
Total projected demand	98,887
Amount grown per year on suitable land	90,767

When the woodshed is expanded to include Rutland County, the supply could exceed the demand (Table 2).

Table 2.

Estimated annual demand and growth of low-quality wood: Addison + Rutland counties (Green tons)	
Current demand	121,412
College demand	30,000
New residential fuel demand	106,531
Total projected demand	257,942
Amount grown per year on suitable land	298,133

However, the larger woodshed leaves the College quite vulnerable to competition for biomass. If any similar facility were located closer to the forestland, the result could be either higher prices or reduced availability. While the College could enter into long-term agreements with landowners, this is not typically done as landowners sell land and are reluctant to encumber it.

Alternatives that could be explored include: energy conservation measures; reducing the biomass to be burned by the College so the radius of the woodshed is smaller; and looking at a combination of wood from the forest and other types of biomass or biofuels that could be sustainably grown on marginal agricultural land in the county.

Evaluating the Scenario Against the College's Goals

- Logging and management practices would be improved. Not only would the biomass be harvested carefully, but the logging practices commonly used for harvesting/removing sawtimber would be brought up to higher standards.

- Over $1 million would go directly into the local economy. Most of this would go to loggers who would have more work and who would be paid more to work to a higher standard. Some would go to landowners to pay for both the biomass and the higher standards of land management required. This money would then ripple through the local economy.

- The volume of sawtimber available to local mills would be likely to increase. In the short term, the payment for low-quality wood may make harvesting more attractive to landowners. In the longer term, removing low-quality trees would direct the forest's growth to higher quality trees so that in fifty years or so the annual growth of sawtimber per acre would be up to 150% of the current growth.

- 30,000 tons of chips per year procured by the College could significantly harm the local firewood business and the ability of others in the county to replace oil with wood.

- Replacing 2 million gallons of #6 fuel oil with 30,000 green tons of biomass, without accounting for the fuel involved in production of either oil or wood, would reduce net carbon emissions by about 50 million pounds per year.[1]

[1] If wood is burned at the rate it is grown, the net carbon emissions are considered to be zero. Estimates of carbon dioxide emissions vary from 24.7 to 26 pounds/gallon of distillate fuel oil.

"***Forests have always been a primary source of energy for mankind***"*(Andersson et al. 2002)*

PURPOSE

Middlebury College is currently in the planning stage for expansion of their heating plant complex. The current system heats the college complex by supplying steam heat, and generates electricity as a by-product of steam production. The current system is fueled by #6 diesel oil.

Based upon the planning process currently underway, Middlebury College would like to reach a decision on which of the following options to follow sometime in 2004. Although college enrollment is not expected to grow much beyond about 2,500, there are facilities projects underway which will require added heating demands and presumably greater electrical demands. Once the decision is reached, there is an anticipated implementation period of five years, so that the new facility would come on line sometime in 2008 or 2009.

One option would be to build a new plant with 130% capacity of current system designed to burn chips or gas from a biofuels gasification plant. The features of this plant would be:

- Consume 32,500 Tons per year.
- At 260 workdays per year this would be 125 Tons or 5 truckloads per day.
- It would co-generate about 2 MW of electricity.
- At this scale of operation, 24/7, 100% of fuel oil consumption would be eliminated
- Operating at 90% demand this plant would consume 29,250 Tons of chips per year.
- Operating at 110% of demand it would consume 35,750 Tons of chips per year.

The purpose of this report is to determine the availability of wood to fuel this plant. The analysis looks at the feasibility of procuring 30,000 green tons per year of forest biomass to fuel Middlebury College's heating plant in a way that:

- Is available on a sustainable basis, and is grown, harvested and produced in an environmentally-sensitive manner
- Stimulates local economic development
- Supports the academic mission of the College.

Although it is possible that other sources of biomass may become locally available in the future, the scope of the project was limited to the most viable near-term option: wood from local forests and sawmills.

ENERGY CONTEXT

The worldwide demand for energy products is growing, and is expected to almost double by 2050. Until 2010 the prices and supply of petroleum will probably remain fairly stable. Beyond 2010 the factors governing price, supply, and demand could change dramatically. There are two major overarching reasons for this: 1) the demand for petroleum is growing as the supply is diminishing, and 2) the supply will likely be exhausted between 2020 and 2030. As the depletion of petroleum is felt worldwide the world economy will switch increasingly to coal and coal byproducts—principally gas from coal gasification and fuels made from coal for internal combustion engines and for heating oils. The major deposits of coal and oil shales lie in North America, Russia, and China. In addition, it is increasingly likely that carbon taxes will be imposed in an effort to reduce emissions. Thus, as the petroleum reserves become exhausted and cost rises, a major realignment of energy suppliers and technologies will take place.

Vermont is among the top three states nationally in the proportion of total energy coming from wood and other biomass sources (Department of Public Service 1998). In 1993-94, about 21% of Vermont households said wood was their primary heating fuel. This percentage had been double—42%--in 1981-82 when oil prices had been reaching record highs. An additional 17% of households said they used wood as a supplemental fuel (Department of Public Service 1998).

The College's demand for 30,000 green tons of forest biomass per year is substantial. In order to appreciate this, consider the following:

- We estimate that Addison County residents burn a total of 26,000 tons of firewood—slightly less than 30,000 tons that the College would burn.
- It would require a pool of about 40,000 acres—or about one-third of all the suitable private forestland in Addison County—just to supply the College. Some of the suitable land is already supplying fuelwood; some of this land is not available due to the landowners' preferences.
- If other residents and businesses in the county burned wood at the same rate, it would require roughly four times more low-quality wood than grows annually on suitable private forestland in the county.
- If the residential households in the county doubled their use of firewood and Middlebury College looked for 30,000 tons per year from the county, the demand for low-quality wood would exceed the annual growth in the county (Table 3).
- If all the roundwood to be burned by the College in one year were stacked four feet high, it would cover eight football fields.

Table 3.

Estimated use of low-quality wood in Addison County with Middlebury College using an additional 30,000 tons and residential use of firewood increasing to replace 50% of residential fuel oil	
Residential firewood (green tons)	26,115
Chips for fuel (green tons)	3,991
Chips for pulp (green tons)	7,975
Total current demand	38,081
Middlebury College demand (green tons)	30,000
Residential heating oil use (gallons)	4,230,630
BTU equivalent in biomass (green tons)	61,611
Percent of heating oil replaced by wood	50%
Additional firewood demand (green tons)	30,806
New total demand (green tons)	98,887
Tons grown on suitable private land	90,767
Demand as percent of supply	109%

It is hoped that more of the increasing demand for energy can be met by renewables like wind, solar, biofuels, and conservation policies. For these reasons, and others too complicated to cover here, we believe that the objectives of the College, if achievable, would be a very wise strategic move in the near- and long-term interests of the College. It is important to note, however, that while the biomass growing today may be adequate to supply the facility, as the cost of petroleum increases, so will the competition for biomass.

Establishing the baseline for the College's current energy demands

The 2002/03 heating season was fairly severe; thus it is not unreasonable to take the energy demands for this season as a base line. In Fiscal Year 2002/03 the energy picture of the College is indicated in the following figures:

- The College heating plant consumed 1.7 million gallons of #6 diesel oil.
- At $0.81 per gallon this amounts to $1,380,000.00.
- A gallon of #6 diesel contains 150,000 BTU's so total consumption was 255 billion BTU. If the College had been using wood chips with 40% water content, the forest wood chip equivalent for the fossil fuels would have been about 25,000 tons of chips. (One ton of chips contains about 10.3 million BTU.)
- The cost at $60.00 per ton would have been $1,500,000 or about 9% more than the cost of fossil fuels.
- The MC heating plant co-generated about 3.5 MW of electricity.
- The total electrical demand, not including the above figure, was 20 GW or 20 million kWh. At $0.09 per kWh from CVPS that amounts to $1,800,000.00.
- Therefore, the total budget for heating oil and electricity was $3,180,000.00.

- It is not known what the fuel usage was for company and service vehicles for College business and maintenance.
- Assuming an average 25 pounds of carbon dioxide per gallon of fuel oil burned, 42,400,000 pounds of carbon dioxide were emitted from the heating plant in 2002/03.

DEFINING THE WOODSHED

Rationale for the Lands Sustainability Criteria

Sustainability criteria for the use and management of forests include ecological, social, and economic components. Our forestland suitability analysis focuses explicitly on environmental factors, but the choice of the two-county study area is clearly based on economic factors as well. Social factors, such as landowner management objectives and preferences regarding forest aesthetics, have not been explicit in the woodshed analysis, but these also are strongly inter-related with some economic and environmental factors and are discussed briefly elsewhere.

Ecological criteria for sustainability refer to forest health, productive capacity, soil and water, biodiversity, and carbon and nutrient budgets (Raison 2002). These criteria cover the spectrum of a forest's organisms, physical land-, air-, and waterscapes, and ecological processes. Sustainable resource extraction, therefore, is based upon not only how a forest is managed and utilized, but where in a forest different types and intensities of utilization occur. It is widely accepted that some forestlands are not capable of sustainable timber extraction, and among those that are capable, not all extraction systems are equally suited to all lands (Seymour and Hunter 1999, Lindenmayer and Franklin 2002). It is also recognized that for ecological sustainability there is a need to preserve representatives of all ecological land types—even those that may be highly suited to sustainable resource extraction—with conservation protections that prohibit resource extraction (Pressey et al. 1993, Noss and Cooperider 1994, Poiana et al. 2000).

Numerous physical site characteristics may be used to define and delineate lands suitable for sustainable intensive forestry. Our analysis has used characteristics for which spatial data were readily available. Given the wealth of geographic information available for Vermont, we were able to account for the most important physical factors.

Soil characteristics, topography, and elevation are of paramount importance in the assessment of which lands are suitable for sustainable biomass harvest, because the productive capacity of a forest and the resilience or fragility of a site are intimately linked to these physical characteristics (Richter 2000). The greater the removal of biomass from a site, the more likelihood there is for greatly altering the nutrient status and physical and chemical characteristics of the soil (Hendrickson 1988, Hornbeck 1992, Martin et al. 2000). Therefore, when harvests include removals of substantial amounts of low-quality wood for biofuel, it is especially important to be aware of the site's ability to retain nutrients and the soil's ability to maintain its physical structure and nutrient-holding capacity. Forest land value group (USDA-Natural Resources Conservation Service 2003), slope, and elevation data were used in the land suitability analysis to account for these important physical characteristics.

Water quality and aquatic ecosystems can be detrimentally affected by harvest activities in a forest, and more intensive harvesting has been seen to lead to increased leaching of nutrients into streams and increased stream temperatures (Hornbeck et al. 1986, Hornbeck et al. 1990, Richter 2000, Schaberg 2002). Streamside management zones that include riparian buffers and strict adherence to the state-sanctioned Acceptable Management Practices (AMPs) for stream crossings are very effective at reducing impacts on aquatic ecosystems (Hornbeck et al. 1986, Southern Center For Sustainable Forests 2000). On lands with 0-60% slope, Vermont AMPs call for a 50-150' buffers around streams, lakes, and ponds, with the wider buffers needed on steeper lands (VT FP&R 1987) Our analysis incorporated a standard 75' buffer around all surface waters. Wetlands were also buffered to a width of 75', as wetlands are recognized both as being important breeding and feeding habitat for numerous animals and as serving important functions for maintaining water quality (Water Resources Board 1990).

In Addison and Rutland counties, some forestland, both publicly and privately owned, is conserved by legal means. Conserved lands include both those that are available for resource extraction and those that are not. The USGS Gap Analysis Program has developed a classification that denotes the type of protection applied to conserved lands (Crist 2000). Protection status one and two denote that resource extraction is prohibited or very limited; lands with status three or four are available for resource extraction. The analysis of suitable lands, therefore, excluded all lands with protection status one or two. Such lands are typically reserves where natural ecological processes are permitted to operate with little human manipulation of vegetation, and these contribute to ecological sustainability and biodiversity protection at the landscape scale.

The suitable forestland analysis was constrained to private lands. Public lands were analyzed separately and are not considered to be part of the woodshed from which biomass can be reliably harvested for energy use. The bulk of public lands in the study area are part of Green Mountain National Forest. While only a small amount of the National Forest has protection status one or two, the remainder of the lands have recently been unavailable for timber extraction due to appeals and legal proceedings. Thus, since one cannot be confident that a constant supply of low-quality wood would be harvested from the national forest and be available for combustion, we do not consider National Forest lands as part of the suitable landbase. State-owned lands in the two counties are comprised of wildlife management areas where the principal goal is wildlife habitat management and not timber extraction. A very small percentage of the landbase is municipally owned. State and municipal lands may be able to provide a small amount of sustainably harvested biomass for fuel.

Methodology

The analysis to identify the forested lands suitable for biomass harvesting was conducted using ArcGIS software in the Middlebury College Geography Department's GIS (Geographic Information System) Laboratory. Land suitability was based on criteria discussed above in the rationale. Physical characteristics considered were slope, elevation, soils and distance from surface waters. Legal protection status of conserved lands was also considered.

The following GIS layers were used in the analysis:

Information	Data Layer Name	Source
Land cover	vtnhlc_7	University of Vermont Spatial Analysis Laboratory
County boundaries	BoundaryOther_BNDHASH	Vermont Center for Geographic Information (VCGI)
Slope and elevation	dem_24	Middlebury College Department of Geography
Soils	so_add & so_rut	Middlebury College Department of Geography
Conservation status	Conspri_071902	University of Vermont Spatial Analysis Laboratory
Surface waters	sw_line	Northern Cartographic
Wetlands	Wetland_vswi	VCGI
Watershed	WaterHydro_RIVBAS	VCGI

All data layers were constrained or “clipped” to the study area. Forest cover, derived from the land cover layer, was pooled into one type to include deciduous, coniferous, and mixed forest cover types. A slope model with categories of <30%, 30-60%, and >60% was developed from the digital elevation model (dem_24). Similarly, elevation classes of <2500’ and >2500’ were constructed. Wetlands and surface waters were buffered with a radius of 75’; thus, riparian buffers along streams and rivers extended 75’ on either side of the stream, and wetlands and ponds were buffered to 75’ around the periphery of the feature. Soils were grouped according to their “forest land value group” into two forest value categories—limited/very limited forestry potential (groups 6 and 7) and the more productive, less fragile lands (groups 1-5) (USDA-Soil Conservation Service 1991, USDA-Natural Resources Conservation Service 2003). Forest value groups are an integrated measure based on productivity and limitations of soils for timber harvesting; factors included in the classification are similar to and overlap with single characteristics that were used in the lands suitability analysis, such as slope and elevation, but also include soil drainage, organic soils, and shallowness of soils. Forest land value groups 6 and 7 comprise approximately 15% of the land in Vermont and represent soils with a relative value of 0 to 31 with 100 as the maximum value. Conservation status information was used to exclude lands that are protected from resource extraction (GAP protection status 1 and 2 (Crist 2000)). The layer was also used to distinguish between publicly and privately owned lands. The suitable lands model was developed from these data layers using intersection and union geoprocessing calculations.

Suitable Forestland Analysis Results

Addison, with its abundance of agricultural lands is 52% forested, whereas the more rugged terrain of Rutland County is 78% forested (Table 4, Map 1). The privately owned lands suitable for sustainable biomass harvesting in both counties combined totals 441,678 acres, which is 60% of the forested lands. Rutland County has more than twice as much suitable forest acreage than does Addison County. Because a portion of the suitable lands is needed for the forest road network and is thus not available for biomass production and because some fragile lands, such as vernal pools and forest seeps, are not accounted for in the spatial modeling, 10% of the suitable landbase was subtracted. Therefore, our landbase model estimates that slightly less than 400,000 acres—121,000 in Addison County and 276,000 in Rutland County—are potentially available for sustainable biomass harvesting. Over four-fifths of these lands have slopes less than 30%.

Table 4.

Forested private lands suitable for sustainable timber harvest

	Entire County			Suitable Landbase			Subtracting 10% for Forest Roads and Sensitive Features*		
	Area (acres)	Forested (acres)	Percent Forested	Slope <30%	Slope 30-60%	Total	Slope <30%	Slope 30-60%	Total
Addison County	516,944	270,051	52%	118,890	15,581	134,470	107,001	14,022	**121,023**
% of Forestland				44.0%	5.8%	49.8%	39.6%	5.2%	**44.8%**
Rutland County	604,491	472,553	78%	257,220	49,988	307,208	231,498	44,989	**276,487**
% of Forestland				54.4%	10.6%	65.0%	49.0%	9.5%	**58.5%**
Both Counties	1,121,436	742,604	66%	376,110	65,568	441,678	338,499	59,011	**397,510**
% of Forestland				50.6%	8.8%	59.5%	45.6%	7.9%	**53.5%**

* Sensitive features such as vernal pools and forest seeps were not able to be accounted for in landbase modeling

[INSERT MAP HERE (except electronic version)]

The marginal economics of transporting low-quality wood long distances suggest that wood harvested for chips from the east side of the Green Mountains may not be practical. If one looks at the suitable forestlands west of the Green Mountains in the two counties, the results show 104,000 acres in Addison County and 255,000 acres in Rutland County, for a total of 359,000 acres (Table 5).

Table 5.

Location of private forestlands suitable for sustainable timber harvest		
	West of the Green Mountains Spine (acres)	East of the Green Mountains Spine (acres)
Addison County	104,187	16,836
% of Suitable Lands in County	86%	14%
Rutland County	255,197	21,290
% of Suitable Lands in County	92%	8%
Both Counties	359,384	38,126
% of Suitable Lands	90%	10%

The single capability criterion that is responsible for eliminating the bulk of lands from the sustainable landbase is forest land value group, which integrates measures such as soil depth, nutrient-retention capacity, and soil drainage (Table 6, next page).

As single factors (not accounting for overlap), very steep slope eliminates only 1% of the forested land, high elevation disqualifies 7% of the lands, and water and wetland buffers eliminate 7-9% of the forestland.

Table 6.

Acreages of forested lands suitable and not suitable for timber harvest per single capability criteria

	Forested Lands Suitable					Forested Lands Not Suitable			
	Slope < 30%	Slope 30-60%	Elevation 0-2500'	Outside of Waters and Wetland 75' buffer	Forest Land Value Groups 1-5	Slope > 60%	Elevation > 2500'	Forest Land Value Group 6	Forest Land Value Group 7
Addison County	220,934	46,956	250,859	244,609	163,963	2,082	19,111	76,194	29,748
% of Forestland	82%	17%	93%	91%	61%	1%	7%	28%	11%
Rutland County	384,707	83,194	441,484	439,679	289,329	4,504	30,925	158,127	24,581
% of Forestland	81%	18%	93%	93%	61%	1%	7%	33%	5%
Both Counties	605,641	130,149	692,343	684,288	453,292	6,585	50,036	234,320	54,329
% of Forestland	82%	18%	93%	92%	61%	1%	7%	32%	7%

HOW MUCH WOOD WOULD THE WOODSHED GROW?

According to William Leak, the silviculturalist with the U.S. Forest Service who has written the guides to growth and production in northern hardwoods in Vermont and New Hampshire, an average, well-managed northern hardwood stand will grow about 2500 green pounds per acre per year, sustainably, with fairly intense management. When the stand has not been well managed in the past, about 32% of the volume will be high quality—USFS grades 1 and 2. This volume is best utilized as sawtimber. The remaining volume is lower quality and could be used for pulp, possibly pallets, or biomass.

After the stand has been managed intensively for 50 years or so, his research has shown that 52% of the volume would be high quality.

Therefore, the annual growth of low-quality wood would range from 1700 pounds (68%) to 1200 pounds (48%). Our analysis used 1500 pounds per acre per year, although we recognize that after 30 years of intensive management, this estimate should drop. As estimated below, the annual growth of low-quality wood suitable for burning is about 270,000 green tons per year in the woodshed. We estimate that roughly 110,000 tons of low-quality wood are currently sold (Table 7).

Table 7.

Annual supply and demand in the woodshed	
Supply: Annual Growth	
Suitable Acres	359,000
Growth/acre/year of low-quality wood (green pounds)	1,500
Growth/year of low-quality wood (green tons)	269,250
Demand: Annual Removals (green tons/year)	
Amount currently removed/year	
Wood chips (biomass or pulp)	4,138
Pulp roundwood	23,936
Firewood	81,518
Total current demand	109,592
Difference: Supply - Demand	159,658

The demand estimates are based on mill reports collected by the Vermont Department of Forests, Parks and Recreation, as well as state surveys conducted by the Public Service Department on the use of firewood. Because the data are collected on either a state or county basis, they have been factored to fit the woodshed. The demand numbers involve many assumptions and should be considered to be the best estimates we were able to make using available data.

LANDOWNERS IN THE WOODSHED

Farmers, non-timber corporations, and individuals own about 150,000 acres of timberland in Addison County and 360,000 acres of timberland in Rutland County. Forest industry owns 21,700 acres (9%) of the timberland in Addison County and 6,500 acres (1%) of the timberland in Rutland County. (Frieswyk and Widmann 2000, updated to reflect USFS acquisitions).

These industrial and non-industrial private forestlands are eligible for enrollment in the Vermont Use Value Assessment Program (UVA). In order to enroll their land, landowners must agree to manage their forestlands according to an approved forest management plan. The plans must comply with minimum acceptable standards for timber management and water quality protection (VT FP&R 2002). Most of these plans are written and implemented by private consulting foresters. Because management is anticipated—actually required—on land enrolled in UVA, this land is the most likely source of wood chips.

In Addison County there are 561 parcels and 54,674 acres of forestland enrolled in the Use Value Assessment Program (Brighton 2004). The average parcel has 97 acres of forestland and over 70% of the parcels have 100 acres of forestland or less.

In Rutland County there are 541 parcels and 80,047 acres of forestland enrolled in the Use Value Assessment Program (Brighton 2004). The average parcel has 147 acres of forestland and 58% of the parcels have 100 acres of forestland or less.

The private landowners have various objectives for owning their land. "Benefits other than timber production are most important to a majority of Vermont landowners. Eighty- six percent of private timberland acreage is owned by those who gave reasons other than timber production as their primary reason for owning timberland" (Widmann and Birch 1983). However, "owners of more than 90% of Vermont's timberland intend to harvest timber at some point in the future" (Widmann and Birch 1983).

A more recent national study found that only 1% of private forest owners – in the Northeast and North Central US – hold their land primarily for timber production, but these owners control 19% of private forest land" (Birch 1996). Respondents stating that they intend to harvest in the next ten years account for an estimated 35% of private forestland owners and 61% of the private acreage...In general, the 'new' individual private forest-land owner is younger, better educated and earns more than the owner of a decade ago...There has been a substantial decrease in the percentage of owners in 'blue collar' occupations and in the proportion of land held by these owners."

It is difficult for landowners practicing ecologically sustainable forestry to make money selling low quality hardwood stumpage in the long run**.** After enrolling the land in the Use Value Appraisal Program to lower the taxes, the average annual return to the land is around $7 per acre (Table 8, next page)

If the land were purchased for $700 per acre, this represents a 1% return on the investment. If any loan-repayment costs were included in the tally, the annual return would be negative. This financial situation is one reason that people who buy forestland in the area do so for motives other than timber production.

Table 8.
Net return to land on typical forest parcel based on the following parcel assumptions:

Acres	100	
Use Value (Taxable Value of parcel)	11,200	
Harvest every	10	years
Sawtimber volume removed every harvest	100,000	bf
Biomass volume removed every harvest	0	tons

Annual Expenses	**Parcel**	**Per Acre**
Taxes (Use Value Appraisal)	$280	$2.80
Certification	$0	$0.00
Road maintenance	$120	$1.20
Loan payment/return to capital	$0	$0.00
Annualized 10-year net revenue (see below)	$1,126	$11.26
Net annual return to land	$726	$7.26
Every 10 years--Expenses		
Management Plan	$520	$5.20
Boundary	$256	$2.56
Sale Administration	$3,200	$32.00
Logging	$20,000	$200.00
Trucking	$5,500	$55.00
Monitoring	$0	$0.00
Every 10 years--Revenue		
Sawtimber mill price	$40,737	$407.37
Wood to be chipped--stumpage	$0	$0.00
Net every 10 years	$11,261	$112.61

To have a secure supply of forest biomass over time from private timberland in Vermont in general and Addison and Rutland Counties in particular, it would appear to be essential that any forest biomass harvesting must enhance – or at least not compromise – other ownership objectives and values. These other values include land and timber investments, forest health, aesthetic enjoyment, recreational use, and wildlife habitat.

CURRENT MARKETS FOR FOREST BIOMASS

To characterize the existing market we conducted interviews with sawmills, chip brokers, loggers, foresters, other chip consumers, state agencies, and equipment manufacturers.

Existing sources of forest biomass can be divided between secondary sources of supply, mostly sawmill residue in the form of "clean paper chips", and primary sources, termed "roundwood" and/or "whole tree chips" (Fallon and Berger 2002). Roundwood and whole tree chips are the low-quality material obtained directly from the log landing of timber harvest sites.

Secondary Sources of Forest Biomass

When mills receive sawlogs for processing, first the bark is removed and ground into landscape mulch. The peeled logs are then squared and as the rounded and irregular slabs are removed they travel down a conveyor where they are ground into chips. The chips are sifted to specifications for "clean paper chips" (see photo 1, Appendix) and then blown into trucks for delivery.

Clean paper chips are ground and screened to supply a product of high uniformity for the pulp/paper market. Over the years, regional paper mills such as International Paper (IP) in Ticonderoga, NY and Finch Pruyn in Glens Falls, NY have placed the greatest demand on local mills for their waste material and have thus set the standard of uniformity. Other area purchasers of clean paper chips use them for combustion and heating instead, and have adapted their equipment to receive this higher quality product. Several area suppliers commented for this report that combustion equipment specified to consume only clean paper chips places unnecessary limits on the availability of burnable material. Their recommendation is to use equipment that is designed to accept a variety of grades, including but not limited to clean paper chips.

In 2001, the total of mill residue chips, produced in Addison and Rutland counties (with 28 mills reporting), was 25,600 green tons (Table 9) and represents 85% of the wood chips produced in the two counties (Vermont Department of Forests, Parks and Recreation 1997-2001). There has been a downward trend in this amount in recent years due to a reduction in the processing of sawlogs. Out of the eleven largest, local sawmills surveyed for this report, two could be counted on for a reliable, year-round supply of paper chips, provided that Middlebury College could purchase at a consistent frequency and price relative to the IP mill. Since the larger sawmills are constantly producing waste, they favor selling to customers like IP who require a year-round supply. The combined output of these two local sawmills, in 2002-2003, was approximately 16,000 tons of green chips (Sawmill interviews 2003).

International Paper is the area's primary consumer of mill residue; they leverage their dominant position by paying the low dollar for Vermont chips, averaging $20-$23/ton. (All prices quoted include delivery.) By contrast, 23 Vermont schools, with a combined consumption of 12,000 tons annually, pay an average of $30/ton for the same material.

It is important to note that the mill-residue chips produced by area sawmills are currently being sold. If Middlebury College were to outbid IP (or others) for chips, their demand would be shifted to a primary source – wood fiber directly from the land.

While sawmills are the high-volume producers of chips from waste, there are additional sources of supply of secondary (waste) material. These include approximately 600 tons annually that could be diverted from the Middlebury municipal "stump dump" and smaller amounts from other nearby townships. Also available for combustion are unspecified quantities of ground pallets, peeler cores, recycled "paper cubes" and furniture-shop waste. In the words of Bob Bender, President of ChipTec, a local manufacturer of wood gasification equipment, "We see fuel everywhere. While there is talk of a 'fuel shortage,' it's only because the type of fuel is too narrowly defined."

Table 9.

Wood chip production in Addison and Rutland counties	Year **2001**	
Mill Residue/Chips	25,600	Green tons
% of total chip volume	85%	
Whole-Tree Chips	4,600	Green tons
% of total chip volume	15%	
Total Chip Production	30,200	Green tons

Primary Sources of Forest Biomass

In Vermont, harvesting simply for the value of lower quality pulp or fuelwood is rarely done. It doesn't pay. However, during harvest operations for higher value sawlogs, under the right conditions, low quality pulp and fuelwood are sold off as "roundwood" or ground into "whole tree chips." While roundwood is delivered as logs to the end-user, to be stored and chipped as needed, the whole-tree chips are ground at the log landing. Depending on the equipment in use, even trees greater than 20" in diameter are picked up and fed into the chip-harvesters (see photo 2, Appendix).The whole-tree chips are blown into trucks and delivered to the end-user. Whole-tree chips differ from clean paper chips in that they contain small sticks, pieces of bark and soil debris. Several suppliers emphasized the importance of careful filtering mechanisms prior to combustion, so that chip consistency is high and maintenance time is reduced.

Most logging operators in Vermont do not maintain their own chip harvesting equipment, for a new unit, described above, lists at $225,000. Instead, loggers will typically contract with one of only a few chip harvesters operating in New Hampshire and Vermont. The largest such "chipper/broker" in Vermont, Green Mountain Chipping (GMC), produces between 40,000 and 50,000 tons annually. In 2002-2003, GMC was selling whole-tree chips for $24-$32/ton. This price reflects stumpage, harvest and chipping costs of approximately $12-$15/ton, and transportation costs averaging $6-$10/ton.

In 2001, the total of whole-tree chips and low-quality roundwood combined from logging operations in Addison and Rutland counties was 31,118 green tons. (Vermont Department of

Forests, Parks and Recreation 1997-2001). The large consumers in Vermont of both whole-tree chips and roundwood for chipping are Burlington Electric Department [BED], whose McNeil plant consumes between 200,000 and 400,000 tons annually, and Ryegate Power Station, in East Ryegate, VT, which consumes 250,000 tons annually. According to interviews with the manager of forestry at the McNeil plant, they are currently paying about $25/ton for chips and as much or more for roundwood. We were unable to verify the prices through independent sources.

Additional pricing information was obtained through interviews with local loggers and consulting foresters (Forester interviews 2003). From this we have learned that current conditions, including wet weather, which makes it difficult to transport logs or chips from the woods, increasing market demand for all varieties of pulp and fuelwood, and higher than average diesel fuel prices, have been contributing to the high cost of roundwood. Prices at the log landing around Addison County are currently $50-$60/cord or $20-$24/ton. Several years ago the average was $40/cord or $16/ton.

Table 10 summarizes information gathered about chip prices.

Table 10.

Biomass type	Suppliers	Known Customers	Cost/ton
Paper chip	Sawmills	IP, pulp mill	$22
	Broker	VT schools	$30
		Finch Pruyn, pulp mill	N/A
Whole tree chip	Loggers	Some VT schools	$30
	Chippers	some VT public bldgs	$24-$32
	Broker	BED, Ryegate Power	$24-$30
	Foresters		
Roundwood	Loggers	BED	N/A
	Broker	pulp mills	N/A
	Foresters		$20-$24

Transportation, Storage and Purchasing

Andersson et al. (2002) note that the key activity in production of energy from the forest is transportation, and that increased concentration of the biomass to a burner makes it economically feasible to invest in additional machines and new technologies. Currently in the Northeast, the primary method of chip transportation, both from sawmills and chip harvesters, is by tractor/trailer pulling a “live bed” or self-unloading trailer. The average load for these rigs is 28 to 30 green tons. Fuel consumption of these trucks averages five miles per gallon. If Middlebury College were to purchase 30,000 tons of chips annually, this would be equivalent to 4 truckloads per day, five days per week, fifty weeks of the year.

The area’s largest chip broker, Cousineaus, Inc., emphasizes that the College would significantly increase their supply options by addressing one key transportation and delivery issue. If the College were to invest in a trailer-tipping unit, installed at the college, Middlebury would be able to receive chips from a variety of sources and not just from those that own and maintain a fleet of live-bed tractor/trailers. The self-unloading trucks are expensive and are rare in Vermont.

Chip storage at the larger facilities such as BED is outside, in uncovered piles. BED typically stores a 3- to 6-month supply, which is the expected storage life of green chips. Vermont schools and other institutional buyers also store chips on site, but generally hold only a one- to two-week supply in winter and none in the summer months. BED also aggregates roundwood deliveries and stores the logs until they have a contract chipper convert the material to whole-tree chips.

Several options are currently available to Middlebury College to obtain biomass chips and roundwood within the existing supply chain. Favorable pricing and reliable supply could be achieved through direct purchasing at A. Johnson & Co., Bristol, and Gagnon Lumber, Pittsfield. Both of these mills operate live-bed trucks. If the College were to contract for the total output of these two mills combined, which produce 16,000 tons of clean-paper chips on a year round basis, the College would need to consider storage of two to three truckloads per week during the summer months. This would be the equivalent of 200-300 cubic yards per week, which may be prohibitive. In addition, the use of clean paper chips simply displaces the supply of other users who would then seek chips from the land without any procurement standards.

Another avenue to acquire chips is through a broker such as Cousineaus, Inc., Henniker, NH. This company brokers the sale of clean-paper and whole-tree chips from over 60 suppliers in the Northeast. For their many institutional clients, including schools, they provide "service guarantees" and arrange seasonal delivery. Currently they are selling in line with other sources at \$22-\$30 per ton delivered. Cousineaus expressed confidence that they would be able to supply the college with 30,000 tons per year. It should be noted, however, that a wide variety of sources and procurement methods are used and there is no way to guarantee the origin or sustainability of those sources.

Ash By-Product

A by-product of burning biomass for energy is ash, an inorganic, alkaline compound of plant nutrients. Although the average ash content of stemwood from hardwood trees is 0.2 to 0.8% dry mass, actual proportions and properties of ash that remains after combustion depend on the composition of chips (both tree species and parts of the tree utilized), the occurrence of impurities, furnace controls, and ash-separation apparatus (Hakkila and Parikka 2002). Disposal of ash presents both opportunities and problems. Recycling of ash back to the forest returns nutrients and can, therefore, reduce the depletion of nutrients and acidification associated with intensive biomass removal. Ash, with its high calcium and magnesium content may also be useful as a lower-cost alternative to commercial lime, but heavy metal contents may inhibit this use (Hakkila and Parikka 2002). If ash is disposed into a landfill, costs are incurred and no ecological benefit is gained. Regardless of the end fate of ash, a biomass-combustion facility must have a plan and equipment for handling it.

In Vermont, regulations require that operators obtain disposal permits if a facility produces above a certain amount of ash per year (amount unknown for December draft). Burlington Electric Department produces enough to require a permit, and they sell their ash to a paving company that uses it in a mix for roads (Tim Maker, personal conversation). The Vermont schools that burn biomass for heat do not produce enough ash to need a permit. They generate approximately one ton of ash per 1,200 tons of chips, approximately 0.08% of green chips burned (Tim Maker, personal conversation). The ChipTec gasifier that began operating in 1999 at Camp Johnson, the Vermont Air National Guard Base, is reported to produce only 1.35 gallons of ash per ton of wood chips (Brad Noviski personal communication).

Hakkila (2002) provided a brief summary of ash recycling. In order to make ash recycling economically and environmentally acceptable, the following issues are of importance: keeping wood clean of soil as it is removed from the forest, burning biomass as completely as possible, cooling ash to reduce fire risk, designing facilities for dust-free loading of trucks, and keeping wood ash separate from fossil fuel ash so as to avoid problems with heavy metal contamination and dilution of important plant nutrients. The governments of Sweden and Finland have developed guidelines and recommendations for ash recycling. In those countries, 1-5 tons of wood ash per hectare are applied to intensive harvest sites.

Insights

The interviews with mills, brokers, loggers and end-users provided considerable additional commentary. The sources contacted for this report were consistent in several areas:

- The region is experiencing a temporary fiber (biomass) shortfall. While all end users are still finding what they require, they are paying more than they have in the past and there exists some "supply anxiety" due to the high demand in the winter months.
- If the College were to incorporate biomass for heating their facilities, a variety of feedstocks, flexible off-loading for deliveries, and advanced screening and filtering are issues critical to supply reliability and reduced maintenance and downtime.
- Use of forest biomass is increasing in the region while known, harvested supplies are decreasing. By developing their own local supply sources, Middlebury College would have an opportunity to provide more energy security to meet its own needs.

WOOD HARVESTING SYSTEMS

There are essentially four steps in converting standing trees to roadside roundwood. In order to protect forest health, all of these steps require: excellent planning and timber sale layout; well-trained and properly compensated operators; and equipment that matches the site, weather and silvicultural method. The primary steps are:

- Felling, bucking, and limbing
- Bunching
- Skidding and forwarding
- Sorting and piling.

There are three primary systems that are used to accomplish these steps. Some timber harvesting operations involve the use of some or all of the elements of these different systems (Lansky 2002).

Conventional system

The conventional system generally involves the use of a chainsaw to fell trees. The logging operator then severs some or all of the limbs and low-value topwood and leaves them in place. Sometimes the useable portion of the tree is bucked into shorter lengths so the logs can be removed without damaging the residual stand. The logger attaches chokers to the end of the logs, and the logs are then bunched to a main skid road using a winch and cable mounted on a skidder, bulldozer, or farm tractor. A very skillful operator is needed to bunch logs without damaging residual trees. Basal wounds on trees serve as entry sites for decay fungi and bacteria. Even small wounds on trees can severely reduce their financial value. Few operators can successfully bunch with skidders. Bulldozers generally have better float and maneuverability. Horses can also be used successfully to bunch logs.

Bunched trees are then brought to the log landing either by skidding (i.e., dragging on the ground) or by forwarding (i.e., loading on wheeled beds). Forwarding is a relatively new advance in timber harvesting technology; it can improve productivity and significantly reduce soil compaction and rutting. The 4-axled forwarders (see photo 3, Appendix) are generally favored because they distribute their weight over a larger surface area, thereby reducing soil compaction and rutting. Ponse and Valmet 4-axled forwarders cost over $300,000 (Miller and others 2001).

The conventional system can work well for thinning, group selection, and shelterwood cuts on various types of terrain to a maximum of 60% slope. The logging costs associated with the conventional system range widely due to species, terrain, timber volumes, and timber quality. Northern Woodlands magazine (Summer 2003) states, "The cost for cutting and yarding normally ranges from $100/MBF [thousand board feet] to $250/MBF, but in some circumstances it can reach more than $500/MBF." This is roughly equivalent to $50 to $125 per cord and $20 to $50 per green ton of logs on the landing.

Logging costs of operations that were conducted in northern hardwood stands in Addison County and that complied with the Vermont Family Forest Foundation's ecologically sustainable forestry practices ranged from $240 to $350 per thousand board feet of logs on the landing (VFF 2003). This is roughly equivalent to $120 to $175 per cord and $48 to $70 per green ton. The conventional system is by far the most common but the future is unclear due to an aging workforce, safety, insurance, and other issues.

Mechanized feller/buncher system

The mechanized feller/buncher system involves a shear or saw mounted on an articulated or telescopic boom that is attached to a rubber-tired or tracked carriage. The booms can reach out up to 33 feet to grab, sever, and bunch trees. These bunched trees or hitches are then placed on the ground.

Grapple skidders commonly work in conjunction with feller/bunchers. The skidder backs up to the bunch of severed trees and then pulls the hitch 'tree length' to the landing area where they are delimbed and loaded. Primarily due to limitations of the grapple skidders, feller/buncher systems are generally not appropriate on terrain with slopes greater than 30%.

The feller/buncher system has a very high degree of productivity, but it can result in high residual-stand damage. The feller/buncher system removes the nutrient-rich fine branches and topwood and can result in nutrient depletion on some sites. Also, the feller-buncher system requires a very large log landing and requires truck roads that will permit large vans to enter the site. It has been estimated that it costs $2,000 to prepare a feller-buncher landing. The feller/buncher system is most appropriate for large acreages on level to moderately sloping terrain, where even-aged regeneration silvicultural techniques, such as patch clearcuts and group selection, are prescribed. There are few examples where the feller/buncher system has been used successfully in thinning northern hardwood stands. It would appear that the opportunities to use this system in Addison and Rutland Counties are very limited.

Cut-to-length system

The cut to length system is very popular in the management of conifer stands in Scandinavian countries. It is becoming increasingly popular in managing hardwood stands in the northern Lake States, where low value materials are being removed in low-volume, intermediate-thinning treatments (Miller personal communication 2003).

The system involves a harvester head mounted on an articulated or telescopic boom. Harvester-head booms can be mounted on tracked or wheeled carriages. Wheeled harvesters are generally preferred because they result in less ground disturbance. Some harvester booms can reach out 33 feet to grab and sever the tree and then cut the stem to length. Harvester heads can be "fixed-head" or "dangle-head." Dangle-head processors are preferred by some because they do not result in as much site disturbance. They do, however, require more maintenance. Cut-to-length, dangle-head harvesters on 6-wheeled carriages cost in the order of $400,000 (Miller and others 2001). Fixed-head processors are preferred by others because they think they do less damage to the regeneration. Fab-tech fixed harvester heads have been proven to be effective in northern hardwood forests and they require less maintenance.

The cut-to-length harvester places the stems individually or in piles. These are then picked up by a forwarder and brought to a landing. Under winter conditions, some crews that manually fell trees with chainsaws then mark the center of the logs with flagged stakes. This allows them to find the material even after substantial snow storms. This step is not necessary when mechanical harvesters assemble wood into piles. Forwarders can easily find this material at a later date and this “cold forwarding” could have significant benefits.

Cut-to-length harvesting with dangle-heads and 4-axled forwarders were tested in Michigan (Miller and others 2001). Serious, degrading, and minor injuries to the residual stand ranged from 9 to 13%. This residual stand damage happened under carefully controlled research conditions and on fairly level ground. Soil rutting occurred on 3 to 6% of the site. It is likely that residual stand damage and soil rutting would be higher – all other things being equal – in commercial timber harvesting operations in Vermont. This is more damage and rutting than would occur with an excellent operator using conventional logging systems, but less than would occur with the feller/buncher system.

In a hardwood thinning operation, the cost of production per green ton of logs placed on a landing in very flat terrain and with very short forwarding distances was about $15.00 per green ton or about $37.50 per cord (Miller and others 2001). Costs of harvesting on the mountainous terrain of Addison and Rutland County and in full compliance with sustainable forestry practices would likely be considerably higher.

Three operators of mechanical harvesting and forwarding systems, all of whom are well-known for their excellent timber harvesting in southeastern Vermont (see photo 4, Appendix), stated that the cost of putting roundwood on a log landing while following stringent forest management standards would be $30 to $40 per ton. (Furthermore, hand felling and limbing of the small, lowquality wood would cost more. A mechanized cut-to-length harvesting system would be necessary to meet these costs.)

The $30 to $40 per ton figure does not include a stumpage payment to landowners. The operators stated that low-quality stemwood and topwood were even more expensive to handle than high-quality logs. The removal of low-quality material is often ‘subsidized’ by the higher quality sawlogs even though landowners think they are being ‘paid’ $0.50 per ton for chipwood stumpage and $5 to $7 in stumpage per cord for low-grade hardwood/firewood. At the same time, high-quality logging in white pine stands cost about $120 to $180 per MBF and more in northern hardwood stands. The return to the landowner would have been greater if the low-quality wood were left on the site!

Russell Barnes, co-owner of Long View Forest Products, stated that with the existing markets, the only way for landowners and loggers to make money and to leave the forest in excellent shape is to “high-grade the extraction process”—meaning remove only the high-quality trees and leave the low-grade material in the forest. High-grading is a serious concern to foresters, for in practicing silviculture one goal is to improve the quality of timber for the next rotation. All operators agreed that if low-grade roundwood were purchased at $30 to $40 per ton on the landing they could afford to harvest more low-grade material. Such a market would allow them to harvest more of the smaller, low-quality trees while leaving material less than 4 inches in diameter on the site. Not only would high-grading be avoided, but the residual stand would also be more beautiful.

The three-axled forwarder that we viewed (see photo 5, Appendix)could easily move forward and back. It could haul up to 2,000 board feet of pine in a load and could haul up to 20,000 board feet from woods to landing on a 'good day.'

It is important to note that forwarding systems reduce the amount of bare mineral soil that is exposed compared to traditional skidding systems that drag logs attached to a cable., The forwarders, however, must travel over more ground than cable skidders. Small branches that are left behind help improve float of the vehicle and thus reduce soil compaction and erosion. It is an essential part of the forwarding system that this small material remain to minimize soil compaction, soil erosion, and stream sedimentation and to maximize the sites and weather conditions in which forwarders can operate sustainably. An additional advantage is that forwarders are ideal for carrying in and installing temporary bridges for stream crossings.

One operator stated emphatically that one could not afford to bunch wood conventionally, using small bulldozers, horses, or skidders, and then haul it to the landing with a forwarder. In order for forwarders to 'pay,' wood cannot be handled twice. However, none of the forwarder operations visited in southern Vermont had an excellent system of main haul roads throughout the sale area, and most of the skidding distances were 1,800 feet or less. It is possible that, with a different harvest area configuration, a combination of conventional logging and hauling by forwarder may be feasible in the woodshed.

The cut-to-length operations in southern Vermont are characterized by a high level of advanced planning, layout and preparation. Basal wounds are very limited.
During adverse weather conditions, crews flag the forwarder access routes. In some cases they girdle and/or fell any trees that should be killed but do not contain merchantable material and clear access. This way any trees that will be felled once the forwarder is on the site will have products in them.

This cut-to-length system can work on thinning, group-selection, and shelterwood cuts on terrain of 30% slope or less. Cut-to-length systems – at least in theory -- could work exceptionally well but they do not currently exist locally and they have some shortfalls when used in harvesting hardwood.

Ray Miller, Research Forester, Michigan State University commented: "Low-value materials being removed in low-volume, partial cuts provides challenging finances for loggers. It can be done and most of our local operators have made the change in the past few years. The smaller workforce compensates for the higher machine costs." He goes on to say "This equipment appears to be competitive in total costs of operation with more traditional harvesting systems."

All three cut-to-length operators stated that finding and then keeping high quality crews is exceptionally difficult. It is essential that work be steady throughout the year. One operator stated that finding good labor presented such a challenge that he has had to become increasingly mechanized.

ECOLOGICAL RATIONALE FOR PROCUREMENT STANDARDS

> *"Timber and forest sustainability are broader questions that underlie the issue of wood chip mills and timber sustainability…Whether these levels of timber growth and harvest are sustainable depends on the area used for comparisons, the amount of forest regeneration or conversion to other uses that occurs, the management intensity employed, and criteria used to measure meeting present and future needs. The broader questions of sustainability also should include forest benefits in additions (sic) to timber."*
> (Southern Center For Sustainable Forests 2000, p. 79)

Forests are complex ecological systems. To sustainably utilize biomass from forest ecosystems it is necessary to consider not only trees, but also the soil they grow in, nutrients required for plant growth and the way they cycle, and other biota in the forest. The procurement standards we present are aimed at promoting "excellent forestry" that allows for utilization of wood and for persistence of site productivity and biodiversity. Silviculture is the science of growing trees, and it is widely recognized that in order to practice excellent silviculture it is more important to think about what is left in the forest than what is removed. Seasonality of harvest and size of harvest area also affect the forest ecosystem and the extent of disturbance to it in the course of logging operations. It is, of course, important to consider how biomass is removed, with respect to both machinery employed and access roads for the machinery and people that harvest and transport the wood. In consideration of these and other issues, the procurement standards are organized into General Guidelines, Access Guidelines, and Vegetation Management Guidelines. Before introducing the standards, we present a brief synopsis of their ecological underpinnings.

Nutrients and Carbon

When undisturbed, northern hardwood forests are nutrient-conserving systems, and the sediments that flow into forest streams are among the lowest in North America (Bormann and Likens 1979). Forest utilization alters nutrient cycles, and any attempt at sustainable forestry must consider the impacts on nutrients. Nutrients are stored in roots, stems, branches and foliage of plants, in the litter on the forest floor, and in the mineral soil (Whittaker et al. 1979, Federer et al. 1989). The pool of nutrients such as nitrogen, phosphorous, calcium and potassium is much greater in the soil than in roots, above-ground vegetation, or the forest floor; hence, soil conservation and management is of paramount importance.

Within trees in northern hardwood forest, stemwood (trunks) contains 31% to 48% of the nutrient stock while branchwood accounts for 34% to 51% (Whittaker et al. 1979, Hornbeck and Kropelin 1982, Brynn 1991). Although foliage comprises only 1% to 3% of an ecosystem's biomass, it contains 5% to 19% of the nutrients, and accounts for 50% to 70% of the annual uptake of nutrients. Thus, the branches and foliage contain large proportions of a tree's nutrients and are key to nutrient cycling and nutrient conservation.

During and after logging, nutrient losses occur through direct removal of nutrients stored in the harvested biomass, increased erosion, and elevated levels of nutrients leached by stream waters for several years after logging (Hornbeck et al. 1990, Iseman et al. 1999, Martin et al.

2000, Southern Center For Sustainable Forests 2000). Timber harvests, including intensive timber harvests, typically remove a substantial percentage of the plant-available nutrient capital from a site; in whole-tree harvest, losses of various nutrients ranged from 30% to 85% of the available pool (Hornbeck and Kropelin 1982). Intensive utilization of wood for chips does not introduce different types of effects on soils and nutrients in forest ecosystems, but the higher utilization that it encourages increases the impacts to a forest stand (Richter 2000). Therefore, the choice of silvicultural technique has important repercussions on the maintenance of nutrients in a managed forest. Wood-chip harvests are often associated with clear-cutting of whole trees, including branches and in some cases leaves also. Martin et al. (2000) found that long-term (14-27 years) losses of calcium, nitrogen, potassium, and sulfur into stream waters were greater in intensive whole-tree clearcutting compared with stem-only, progressive strip cuts, a clearcutting method that proceeds in strips over several years. More intensive (whole-tree harvests) led to lower amounts of calcium, magnesium and nitrogen in post-harvest regrowing woody vegetation when compared with stem-only harvest (Hendrickson 1988).

Calcium is a nutrient of particular concern in northeastern forests (Brynn 1991, Horsley et al. 2002). One cause for concern is that sugar maple decline in eastern North America has been linked to nutrient deficiencies of calcium, magnesium and potassium, in concert with factors such as insect defoliation and drought (Horsley et al. 2002). When considering nutrient management in silviculture, it is necessary to realize that only a small portion of the total nutrient capital is in forms available for plant uptake. In intensive whole-tree harvests in northern hardwood and spruce-fir forests, less than 5% of the total calcium was removed, but the calcium that is actually available to the plants is substantially less than the total calcium (Hornbeck et al. 1990). It is also significant that the calcium leached by streams comes from the available pool, so increases in leaching in the first few years after tree harvest can have substantial impacts on the available nutrient pool. Hornbeck et al. (1990) state, “The concern is whether the available pool can sustain increased leaching losses and also provide optimum supplies for regrowth.” Different forest ecosystems show different patterns of nutrient cycling and post-harvest leaching (Iseman et al. 1999). For example, there is a direct relationship with greater calcium removal in oak types, because oaks tend to accumulate larger amounts of calcium than other species. In an oak forest in Connecticut, even a stem-only harvest would have removed 10% of the total calcium (Tritton et al. 1987, cited in Hornbeck et al. 1990). Hence, it is important to recognize ecosystem-specific differences in susceptibility to nutrient depletions under different harvest intensities and to modify silvicultural prescriptions accordingly.

In short, in order to adequately maintain nutrient pools and nutrient cycles it is necessary to leave foliage and branches dispersed in the forest. Many wood-chip harvesting operations remove whole trees from the forest, but studies of nutrient cycling, forest regeneration, and intensive harvesting, suggest that sustainability would be better served by topping and limbing trees on site and leaving tops and branches dispersed throughout the forest.

The effects of logging on soil, water, and nutrient pools depends largely upon the extent of mineral-soil exposure during logging; also important are length and steepness of slopes, soil texture, soil organic matter content, drainage, and amount of plant cover (Richter 2000). Martin (1988) found that soil disturbance had occurred on up to 93% of the site in mechanized whole-tree harvest operations. To minimize mineral soil exposure, leaching of nutrients into streams, and other impacts on soil, water, and nutrients, the details of a logging operation, such as road layout, biomass volume and type removed (i.e., stems, branches, foliage), and skill of operators, are of extreme importance (Hornbeck et al. 1986, Richter 2000). To practice sustainable forestry, it is therefore necessary to implement and monitor management standards to guide those operational details.

Professional foresters are trained to understand how to conserve forest soils and nutrients and protect both the terrestrial ecosystems where trees are being harvested and the aquatic ecosystems that exist within the forest matrix. Unfortunately in only slightly over 50% of logging operations in Vermont were professional foresters involved in the layout of roads, trails and log landings, activities that have great impact on the conservation of soils, nutrients, and water (Newton et al. 1990) . Acceptable or Best Management Practices have been adopted by many states, including Vermont (Anonymous 1987), and implementing them in a logging operation are a first step toward protecting soil and water.

Carbon cycling is of course a concern with regard to utilizing forest biomass to mitigate against atmospheric carbon deposition. (For a more detailed discussion of carbon storage and cycling in northeastern forests, see Irland and Cline's (1999) excellent review.) While only 30% of the forest carbon is held in the above-ground portion of trees, carbon in soils accounts for 60% of total forest carbon; the litter/debris of the forest floor contains the remaining 10%. Thus, management of forest carbon must consider both above-ground carbon and below-ground carbon. Considering the tree (trunk, branch and foliage) component of northern hardwood forests, managed stands were found to yield increased carbon compared to unmanaged stands, and intensive management led to faster carbon accumulation (Hornbeck and Leak 1992). Strong (1997, cited in Irland and Cline 1999), however, detected a trend of decreased total ecosystem carbon with increased harvest intensity in northern hardwood forests studied over a 40-year period. Over that time period, stands harvested according to light and moderate selection systems had more carbon than unharvested stands. Strong postulated that extensive opening of the canopy led to higher soil respiration rates and thus loss of carbon. Irland and Cline (1999) suggest that partial-harvest silvicultural systems that incorporate removals for biofuels may not be the most efficient technique with regard to carbon sequestration, but they do leave trees behind to replenish soil nutrient reserves and to provide shade that maintains lower rates of decomposition and soil respiration. Light to moderate harvests appear to be a balanced approach to achieve the many demands we make of forest ecosystems.

Biodiversity

Sustainable forestry must consider biodiversity also, for forest management and utilization have impacts on populations of all forest organisms. Different silvicultural techniques have different impacts on biodiversity in forest ecosystems (Seymour and Hunter 1999). The more intensive a harvest, the greater will be the immediate changes to biodiversity. Also, at the landscape scale, the more area that is intensively harvested, the more extensive will be the changes throughout entire, large-scale ecosystems (Lindenmayer and Franklin 2002). In northern hardwood and spruce-fir forests of northern New England, natural disturbances tend to affect small patches of forest, and large-scale, high-intensity disturbances are very infrequent (Lorimer 1977, Richburg and Patterson 2000, Cogbill 2001, Lorimer 2001, Seymour et al. 2002). Thus, the natural patch pattern that characterizes these forests is one of small, disturbed patches within a matrix of older forest. Therefore, creation of large open patches introduces a patch structure very different from the one natural to these forests. Small-patch silvicultural techniques best conserve the natural pattern.

Changes in forest structure and microclimate have consequences for all biota in a forest, even, or perhaps especially, the smallest ones that we rarely see and about which we know little. For instance, in two studies microclimatic changes on the forest floor after intensive harvests resulted in a greatly reduced microarthropod fauna (Richter 2000). In another invertebrate study, researchers found that whole-tree harvest reduced the species diversity of insects in streams and led to increased abundances of predatory species and decreased abundances of leaf-shredding species (Burton and Ulrich 1994, cited in Martin et al. 2000).

Management of biodiversity at the stand level is complex, but much of it revolves around stand structure. Foresters often refer to an older, more complex forest structural class as "sawtimber-sized" or "mature." Stands described by those structural names differ from what ecologists consider late-successional and old-growth forests in a number of important ways, including diversity of both species and age-classes, complexity of vertical (vegetation strata) and horizontal (canopy gaps) structure, depth and profile of litter layer, and amount, species, and decay-class of coarse woody debris (Hess et al. 2000). Species of birds (Askins 2000), salamanders (deMaynadier and Hunter 1995), and insects (Heliola et al. 2001) are known to find higher quality habitat in late-successional forests, and the habitat quality frequently appears to be related to structural characteristics of live vegetation, dead wood, and forest litter.

Dead wood is an extremely important aspect of the forest structure, and dead wood, or coarse woody debris, has been of particular recent interest to ecologists. Among its many ecological functions, coarse woody debris serves as seed germination sites, reservoirs of moisture, and habitat for numerous species of fungi, invertebrates, and vertebrates; it also plays important roles in nutrient conservation and cycling (Maser et al. 1979, Harmon et al. 1986, McCarthy and Bailey 1994, McMinn and Crossley 1996, McComb and Lindenmayer 1999). Coarse woody debris is a forest legacy that takes many decades to centuries to develop; its management must be carefully considered in order to achieve sustainability in managed forest ecosystems.

Hess and Zimmerman (2000) found significantly lower volumes of woody debris on sites that were harvested to feed chip mills, and McCarthy and Bailey (1994) reported that commercial thinning limited the amount of coarse woody debris in managed forest stands greater than 100 years old. The degree to which native biota that depend on late-successional forest characteristics can be conserved is a function of management; species that depend on microhabitat characteristics associated with late-successional forests, for instance salamanders in relation to deep litter layers and coarse woody debris, are likely to be negatively impacted by the shorter rotations and increased utilization that generally accompany harvests for wood chips (Hess et al. 2000). Woody debris conservation is possible in managed forests, although perhaps imperfectly so since features as important as large-diameter dead wood in later decay stages are often destroyed by machinery during logging operations. Procurement standards for woody debris management must go beyond leaving a certain amount of snag or den trees per acre; a diversity array (with regard to species, sizes, and decay classes) of these biological legacies must be maintained in an effort to provide for the full spectrum of dead wood structures in a forest ecosystem.

RECOMMENDED PROCUREMENT STANDARDS

"Green" Forestry Overview

"It is customary to fudge the record by regarding the depletion of flora and fauna as inevitable, and hence leaving them out of the account. The fertile productive farm is regarded as a success, even though it has lost most of its native plants and animals. Conservation protests such a biased accounting. It was necessary, to be sure, to eliminate a few species, and to change radically the distribution of many. But it remains a fact hat the average American township has lost a score of plants and animals through indifference for every one it has lost through necessity."

-Aldo Leopold, The Farmer as Conservationist

The following guidelines are intended for procurement of biomass for Middlebury College from upland forests in Addison and Rutland counties. Every effort has been made to comply with the following published principles of sustainability:

The Northern Forest Lands Council's (NFLC 1994) principles of sustainability for northern forests:

- Maintenance of soil productivity
- Conservation of water quality, wetlands, and riparian zones
- Maintenance or creation of a healthy balance of forest age classes
- Perpetuation of supply of timber, pulpwood, and other forest products
- Improvement of scenic quality by limiting adverse impacts of forest harvesting, particularly in high elevation areas and vistas
- Improvement of the overall quality of the timber resource as a foundation for more value-added opportunities
- Conservation and enhancement of habitats that support a full range of native flora and fauna
- Protection of unique or fragile areas
- Encouragement of opportunities for compatible recreation

The Vermont Forest Resources Advisory Council (FRAC) Working Group on Sustainability (WGOS 1996) developed 28 benchmark parameters for achieving the NFLC's principles of sustainability on Vermont forest lands. These benchmark parameters address:

- Condition of forest soils
- Extent of intensive biomass extraction
- Extent and condition of forested riparian zones and wetlands
- Biological diversity of aquatic insect communities
- Streamwater chemistry
- Tree size-class distribution
- Extent, economic value and cost of holding timberland in Vermont
- Public perception of aesthetic quality of Vermont's forested landscapes
- Forest health and vigor
- Net primary productivity and/or growth
- Timber quality

- Extent and condition of natural communities
- Status of invasive exotics
- Extent and condition of fragile and unique sites
- Extent and condition of forest-based recreation

The National Association of State Foresters' (2003) seven principles of a well-managed forest:

- Contribute to the conservation of biological diversity of the forest and the landscape in which it resides
- Maintain or improve productive capacity
- Maintain the health and vigor of the forest and its landscape/watershed
- Protect soil and water resources
- Consider carbon cycles
- Consider socio-economic benefits and impacts
- Comply with laws and legally adopted rules and implement applicable guidelines in states not using the regulatory approach.

Thus, the following guidelines proposed for Middlebury College are designed to:

- Protect the ecological health of the forests by protecting water quality, site productivity, and native biological diversity and by discouraging the spread of invasive exotics.
- Achieve ownership objectives by improving existing tree health and quality by improving timber quality and economic returns, securing desirable regeneration, and protecting non-timber values and aesthetics.
- Maintain community support for Middlebury College's efforts to reduce use of fossil fuels while maintaining and/or improving the health, productivity, and beauty of the landscape we call home.
- Assure access to a reliable supply of forest biomass over time.

General Guidelines

1. Work from an approved forest management plan and map.
2. Use well-maintained equipment to the maximum extent possible.
3. Use non-petroleum lubricants to the maximum extent possible.
4. Properly buffer special habitats such as cliffs, caves, talus slopes, beaver meadows, vernal pools, spring seeps, and remnant patches of old-growth forest.
5. Carefully monitor all operations for compliance.
6. Maintain aesthetics.

Access Guidelines

1. Access networks should comply fully with the "Acceptable Management Practices for Maintaining Water Quality on Logging Operations in Vermont" (VT FP&R 1987).
2. All skid trails, truck roads, and log landings should be flagged or otherwise marked prior to the inception of harvesting.
3. Use equipment that is as small as possible and that exerts the lowest possible ground pressure.
4. Use forwarders to transport logs to the landing to maximum extent possible.
5. The timber-harvesting access network -- including truck roads, skid trails and log landings -

- should be carefully designed and constructed and should not expose mineral soil on more than 10% of the treated area.
6. Skid trails, truck roads, and log landings that are located on easily compacted soils should only be used when the ground is dry or frozen.
7. Minimize the number and extent of truck roads and skid trails -- particularly in or near sensitive areas such as stream crossings, protective strips, and steep slopes.
8. Build and maintain access under dry summer conditions to the maximum extent possible.
9. Complete all required seeding by September 15 or earlier.

Vegetation Management Guidelines

1. Avoid biomass harvesting on Soil Groups 6 and 7.
2. The single-tree and small-group (up to one acre) selection methods should be used for communities with gap-phase replacement (e.g., northern hardwoods) and the irregular shelterwood method should be used for communities with stand-replacing disturbance regimes (e.g., spruce-fir).
3. Clear-cutting of patches larger than two acres should be avoided.
4. Retain cavity and/or snag trees. To address safety issues, this may be accomplished by clustering cavity and snag trees in areas such as riparian zones and wetlands and away from access roads and trails.
5. Retain large, down trees.
6. Grow the largest trees and use the longest rotations possible within site and log-quality limitations.
7. Any forest management in natural communities that are ranked as "very rare" (S1) or "rare" (S2) or in natural communities with little or no evidence of past human disturbance should be reviewed by a VT F&W Nongame and Natural Heritage Program Biologist.
8. When thinning or regenerating stands, favor native species over non- native species.
9. Use natural regeneration to the maximum practical extent.
10. Biological legacies of the forest community, such as coarse woody debris, soil litter, and large, very old trees, should be retained to aid in post-harvest recovery and to keep the forest from becoming "oversimplified."
11. Tree-felling should be limited to slopes of 60% or less.
12. Mechanical harvesting -- including 6-wheeled or tracked feller/bunchers and cut-to-length harvesters with low centers of gravity -- should be limited to slopes of 30% or less.
13. Leave all materials that are less than 4 inches in diameter on the site.
14. Promote a vertical stand structure that includes overstory, midstory, shrub, and herbaceous vegetation layers.
15. Residual stand damage -- including basal wounds, broken and/or scraped tops, and exposed roots – should be confined to 10% or fewer of the dominant or co-dominant trees.
16. All trees to be removed should be marked prior to the inception of harvest.
17. Avoid grazing by domestic animals.
18. Cutting cycles – the number of years between harvests on the same site – should be between 10 and 15 years minimum.
19. Harvest under frozen winter conditions and – only when special precautions are used to prevent damage – dry summer conditions.

MONITORING PROTOCOL TO ENSURE STANDARDS

Timber Sale Monitoring

The only way to assure that forest biomass has come from well-managed forests – and that Middlebury College is getting the sustainable forestry it is paying for – is to carefully monitor the supplying forests. Forest management plans, logger training, procurement specifications, and even third-party certification may complement on-site monitoring, but they should not replace on-site monitoring. On-site monitoring will be especially important in the early stages of procurement, until consulting foresters and logging operators are clear as to what is expected.

After a forest management plan has been developed and approved and before a harvest is conducted, a timber sale harvesting plan should be submitted. The brief plan should include the names of the landowner, logging operator, and consulting forester. It is likely that all logging operators and consulting foresters will need some training and orientation so they fully understand the process of selling forest biomass to Middlebury College and/or its suppliers.

The timber sale harvesting plan should list the stands to be operated in and the acres involved. The treatment for each stand should be listed, as along with tree-marking guidelines and any stand-specific special features or considerations. An estimate of the marked volumes to be removed should be included. VFF has found that timber sale harvesting plans such as these generally take less than 1 hour to complete. These plans serve as an excellent basis for creating a portfolio of forest biomass that is available, ready for harvest, and under contract.

Once the timber sale harvesting plan has been reviewed and approved by Middlebury College (and/or their agent), a timber harvesting certificate should be issued. The approved timber sales should be monitored prior to harvest, during harvest, and/or after harvest to assure that the procurement specifications are being adhered to fully. The on-site monitoring should be conducted by Middlebury College (and/or their agent). The monitoring should examine compliance with the timber sale harvesting plan, pre-harvest tree marking, access network design, contracts, and rare natural community specifications. Active and closed truck roads, skid trails, log landings, buffer strips and stream crossings should be examined for compliance with procurement specifications; issues and required or suggested corrective actions should be noted. Extent of soil erosion and impacts to sensitive and special habitat areas should be monitored. Silviculture should be examined as well as residual stand damage, downed wood, snag and den trees, mean stand diameter, and visual impacts. VFF has found that timber sale monitoring visits as described can be completed in less than two hours of on-site time per visit.

SEASONALITY AND CONSISTENCY OF SUPPLY

Many negative impacts resulting from timber harvesting can be reduced significantly when logging is conducted under frozen winter conditions. In some years, conditions appropriate for winter logging in the Champlain Valley can be short or even non-existent. However, on average, the daily high temperature in Burlington is below freezing during the months of December, January, and February (National Weather Service 2003). Logging under dry summer conditions can work well in some situations. At best, dry summer conditions exist from June 15 through September 1. Acceptable conditions for winter and/or summer logging exist less than half of the time in the Champlain Valley.

Repairing existing access and laying-out and building new access are most effectively accomplished under dry summer conditions. Areas that remain wet or seepy year-round are then able to be detected and these should be avoided in laying out roads and trails.

To promote the practice of logging only under frozen winter and, when appropriate, dry summer conditions, there should be a central aggregation facility where roundwood can be stored. This roundwood could then be stockpiled in log form until it is needed.

Careful timber sale planning and layout can improve consistency of supply. Timber sales can be active more of the time when access roads are properly located and properly drained.

Logging equipment that exerts low ground pressure can also significantly increase operability. Four-axled forwarders generally cause significantly less soil disturbance than skidders.

Six-wheeled timber harvesters with long booms can significantly reduce ground disturbance as well. Tree felling and bunching – even including those operations that use conventional bulldozer bunching methods – can often proceed satisfactorily even when conditions are inappropriate for forwarding and/or skidding.

The availability of other types of work when logging cannot proceed is an important part of sustainable forest management and a successful wood procurement system. When conditions are inappropriate for timber harvesting, forwarding and/or trucking, logging crews can and should be actively engaged elsewhere because loan payments are due even when the weather is wet.

Being willing to purchase chips and roundwood throughout the year would be advantageous to the College, because mills and other brokers would prefer to sell to a large institution that would buy what they had available at all times of the year . In addition, this would provide a more dependable source of year-round employment for the community of forest workers

PRICE OF BIOMASS FROM THE LAND

Conscientious loggers report that they cannot move low-quality material from the woods to the landing for less than $35/ton. The current price for roundwood at the landing is less than that.

To achieve the desired standard of logging, the logger as well as the landowner must be paid more. Currently, high-quality logging operators report that it generally is not worth pulling out low-quality material. If low-quality wood were to be removed from the site and sold as chips for $30 per ton, the chip operation would be subsidized by the sawlog sale. Loggers estimate the cost of cutting low-quality wood and moving it to a log landing, in accord with the procurement standards, would be about $35-$40 per ton of roundwood.

We calculate that a payment of $8 per ton to landowners would be an incentive to do two things:

1) sell the low-grade material to the College
2) achieve a higher level of management and logging on the land

This payment would provide some incentive for landowners to move from conventional forest practices to excellent forest practices. (Table 11, next page)

This would require the landowner to pay more for road maintenance, a more thorough management plan, and, most importantly, logging to meet the procurement standards. (Table 12, following page).

Table 11.

Net return to land of typical forest parcel: Average management based on the following parcel assumptions:

Acres	100	
Use Value (Taxable Value of parcel)	11,200	
Harvest every	10	years
Sawtimber volume removed every harvest	100,000	bf
Biomass volume removed every harvest	0	tons

Annual Expenses	**Parcel**	**Per Acre**
Taxes (Use Value Appraisal)	$280	$2.80
Certification	$0	$0.00
Road maintenance	$0	$0.00
Loan payment/return to capital	$0	$0.00
Annualized 10-year net revenue (see below)	$1,530	$15.30
Net annual return to land	$1,250	$12.50

Every 10 years--Expenses		
Management Plan	$480	$4.80
Boundary	$256	$2.56
Sale Administration	$3,200	$32.00
Logging	$16,000	$160.00
Trucking	$5,500	$55.00
Monitoring	$0	$0.00
Every 10 years--Revenue		
sawtimber mill price	$40,737	$407.37
wood to be chipped--stumpage	$0	$0.00
Net every 10 years	$15,301	$153.01

Table 12.
Net return to the land on typical forest: Sustainable forestry based on the following parcel assumptions:

Acres	100	
Use Value (Taxable Value of parcel)	11,200	
Harvest every	10	years
Sawtimber volume removed every harvest	100,000	bf
Biomass volume removed every harvest	750	tons
Annual Expenses	**Parcel**	**Per Acre**
Taxes (Use Value Appraisal)	$280	$2.80
Certification	$0	$0.00
Road maintenance	$120	$1.20
Loan payment/return to capital	$0	$0.00
Annualized 10-year net revenue (see below)	$1,726	$17.26
Net annual return to land	$1,326	$13.26
Every 10 years--Expenses		
Management Plan	$520	$5.20
Boundary	$256	$2.56
Sale Administration	$3,200	$32.00
Logging	$20,000	$200.00
Trucking	$5,500	$55.00
Monitoring	$0	$0.00
Every 10 years--Revenue		
sawtimber mill price	$40,737	$407.37
wood to be chipped--stumpage	$6,000	$60.00
Net every 10 years	$17,261	$172.61
Equivalent stumpage price (imputed)	$15,237	$152.37
Equivalent stumpage price if chip price added in	$21,237	$212.37

Based on this scenario, we estimate the price of roundwood, delivered to Middlebury College, to be $53-$58 (2003 dollars). The costs per ton are as follows:

$35-$40 logging costs
$8 to landowner to practice excellent forestry and meet procurement standards
<u>$10</u> trucking costs
$53-$58 per ton of roundwood, delivered

In addition, the College would build into the price:

$0.50-$1 per ton for training, monitoring, and enforcement

Finally, this is roundwood—not chips. The College would purchase and operate the chipper, and that price should be factored into the full cost of supplying wood chips.

FUTURE AVAILABILITY OF FOREST BIOMASS

If Middlebury College's facility were the only new use of forest biomass in the woodshed, there would be plenty of wood available (Table 13). Although we don't know how many acres of suitable land would not be available because of the preferences of the landowners, we have estimated that 25% of the acreage would be unavailable. The growth of low-quality wood on the remaining suitable land would exceed the removals, including 30,000 tons to Middlebury College, by 62,000 green tons.

Table 13.

Estimated use of low-quality wood in woodshed with Middlebury College using an additional 30,000 tons	
	Total
Residential firewood (green tons)	81,518
WT chips for fuel (green tons)	4,138
Chips for pulp (green tons)	23,936
Total current demand	109,592
Middlebury College demand (green tons)	30,000
New total demand (green tons)	139,592
Total grown in woodshed (green tons)	269,250
Percent of landowners willing to sell	75%
Total available (green tons)	201,938
Net (supply - demand)	62,345

If oil prices increase substantially, however, wood may once again become an important source of fuel for residential heating—as well as for businesses and institutions. If residents in the woodshed were to replace half of their fuel oil used for heating their homes with wood, the supply and demand picture would be quite different (Table 14, next page).

Table 14.

Estimated use of low-quality wood in woodshed with Middlebury College using an additional 30,000 tons and residential use of firewood increasing to replace 50% of residential fuel oil	
Residential firewood (green tons)	81,518
WT chips for fuel (green tons)	4,138
Chips for pulp (green tons)	23,936
Total current demand	109,592
Middlebury College demand (green tons)	30,000
Residential heating oil use (gallons)	13,205,965
BTU equivalent in biomass (green tons)	192,320
Percent of heating oil replaced by wood	50%
Additional firewood demand (green tons)	96,160
New total demand (green tons)	235,752
Total grown in woodshed (green tons)	269,250
Percent of landowners willing to sell	75%
Total available (green tons)	201,938
Net (supply - demand)	-33,814

In addition, because the woodshed needed to supply the College with 30,000 tons would need to be larger than "local," the larger woodshed would leave the College vulnerable to competition for biomass. If a similar facility were located closer to the forestland, the result could be either higher prices or reduced availability. While the College could enter into long-term agreements with landowners, this is not typically done as landowners are reluctant to encumber land and thus reduce their options for selling it if they so desire.

Alternatives that could be explored include: energy conservation measures; reducing the biomass to be burned by the College so the radius of the woodshed is smaller; looking at a combination of wood from the forest and other types of biomass or biofuels that could be sustainably grown on marginal or unused agricultural lands in the county (Purdue University) (Table 15).

Table 15.

Biomass crops that could be grown in Vermont	
Biomass Crop	**BTU/acre/year**
Canola/rapeseed	12,192,000
Sunflower	9,792,000
Mustard seed	5,856,000
Linseed/flax	4,896,000
Soy	4,608,000
Hemp	3,744,000
Corn	1,728,000
Algae	1,152,000,000

CONCLUSIONS

Replacing 2 million gallons of #6 fuel oil with 30,000 green tons of biomass, without accounting for the fuel involved in production of either oil or wood, would reduce net carbon emissions by about 50 million pounds per year.[2] This would be a substantial—almost miraculous—step toward meeting the goals of the Carbon Reduction Initiative.

In the short term, the forest biomass needed to supply the College would be available. It is likely that the College could utilize mill residues for some of its supply; the College would have to outbid International Paper Company, at $30 per ton or so. Procuring mill residues would not have any positive effect on the land, as no standards are applied to the harvesting of sawlogs and International Paper Company would need to find chips elsewhere. At least half of the College's supply would come from the land, at a cost of roughly $53-$58 per ton of delivered roundwood. With stringent procurement standards, the College could raise harvesting standards significantly on the land supplying this wood, and would thus not only reduce net carbon emissions, but also help to foster a more ecologically and economically sustainable forest products industry.

In addition, over $1 million would go directly into the local economy. Most of this would go to loggers who would have more work and who would be paid more to work to a higher standard. Some would go to mills. Some would go to landowners to pay for both the biomass and the higher standards of land management required. This money would then ripple through the local economy.

In the longer-term, assuming that oil prices rise and thrifty, resourceful Vermonters turn to the woods for fuel as they did during the energy crunch of the 1980's, there could be supply problems. Although the annual growth of low-quality wood exceeds demand, the available supply is less than the annual growth because many landowners are reluctant to cut trees on their land. At the 2003 demand level, it appears that the College could obtain 30,000 tons from land owned by people who are willing to harvest sawlogs. When demand increases, however, more land would need to be brought into active management. That would involve convincing owners that it is in their own and the environment's best interest to cut trees. This is not a trivial task.

Also, because the College's woodshed is necessarily large, the College would be quite vulnerable to competition for biomass. If any similar facility were located closer to the forestland, the result could be either higher prices or reduced availability. While the College could enter into long-term agreements with landowners, this is not typically done as landowners sell land and are reluctant to encumber it.

Finally, 30,000 tons of chips per year procured by the College could significantly harm the local firewood business and the ability of others in the county to replace oil with wood.

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[2] If wood is burned at the rate it is grown, the net carbon emissions are considered to be zero. Estimates of carbon dioxide emissions vary from 24.7 to 26 pounds/gallon of distillate fuel oil.

Although the College's procurement standards would result in better harvesting practices than would be expected from other harvests, on balance it may be more reasonable to look at a less ambitious conversion to forest biomass. This would:

1) make the woodshed more local;
2) make the College less vulnerable to shortages and competition;
3) place less demand on the forests; and
4) leave more potential for others in the area to burn wood.

If, for example, the College were to burn 20,000 tons of forest biomass per year, the potential would remain for the forests in the woodshed to also allow other residents to replace roughly 50% of the oil used for heating (Table 16).

Table 16.

Estimated use of low-quality wood in woodshed With Middlebury College using an additional <u>20,000 tons</u> And residential use of firewood increasing to replace 50% of residential fuel oil	
Residential firewood (green tons)	81,518
WT chips for fuel (green tons)	4,138
Chips for pulp (green tons)	23,936
Total current demand	109,592
Middlebury College demand (green tons)	20,000
Residential heating oil use (gallons)	13,205,965
BTU equivalent in biomass (green tons)	192,320
Percent of heating oil replaced by wood	0.5
Additional firewood demand (green tons)	96,160
New total demand (green tons)	225,752
Total grown annually in woodshed (green tons)	269,250
Percent of landowners willing to sell	85%
Amount available (green tons)	228,863
Net (supply - demand)	3,111

Although under this scenario the conversion from oil to biomass would be reduced by one third, the College's contribution to reducing carbon emissions, stimulating the local economy, and supporting the mission of the College would not decrease by an equal amount In the context of the entire local community, the contribution could be just as great, if not greater, for the College would play a role as a demonstration and incubator for broader local change. Replacing 1.3 million gallons of #6 fuel oil would reduce the College's carbon emissions by 33 million pounds per year—instead of 50 million. In combination with other local conversions from oil to wood, however, the carbon emissions in the area would be reduced by about 50 million pounds per year. Similarly, while the College would buy less forest biomass and therefore place less money directly into the local economy, it would leave room for local buyers to shift what they would normally pay for oil to their neighborhood logger.

The potential exists for the College to begin with burning biomass from existing forests and then phase in other types of biomass. By doing this, the college would help to build the local infrastructure needed to allow for more users to convert to wood and other biomass fuels. In addition, the procurement standards would be fully implemented, and people could see for themselves what excellent, ecologically sustainable timber harvesting looks like.

At the same time, the College could pursue sustainable energy plantations with trees and other biofuels that could be grown on marginal agricultural land in the area. The College's efforts in this would advance our knowledge and technology, while providing local farmers with additional income and winter work. As the energy plantations come on line and demand for forest biomass increases, the College could replace some of its forest biomass with plantation biomass. This would enable others in the local area to replace some oil with biomass and would allow the College to have a broader positive impact on local forestry, agriculture, and carbon emissions.

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APPENDIX 1.

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<u>APPENDIX 2</u>.

A 20,000-TON SCENARIO

The purpose of the draft assessment was to determine the availability of 30,000 green tons per year of biomass to fuel Middlebury College's heating plan in a way that could meet several criteria set out by the College.

The assessment concluded that, while it would be possible to obtain 30,000 green tons per year from Addison and Rutland Counties, a slightly less ambitious conversion might better achieve the College's goals.

The College's CRI committee discussed the 20,000-ton scenario suggested in the conclusions of the draft report and asked for more information. The following is the assessment team's response to the six follow up questions [below] posed by the committee:

1. Focusing on a demand of 20,000 tons per year that meet our green chip specification, what is a reliable cost per ton?
2. How long would it take to start growing trees as an energy plantation?
3. How many years would it take to get the VFF spec wood?
4. How much can we siphon from each of these sources and at what price before IP has to pay more:
    a. Available woodchips
    b. Available green woodchips
    c. Green woodchips with monitoring level described by VFF
5. What do we have to do to avoid competing with IP (or BED)?
6. Based on the research you've done to date, what is the feasibility, cost, and benefit of using alternative sources of plant material for biomass (canola, sunflower, etc.)?

SHORT-TERM PRICE AND COMPETITION (Questions 1,4,5)

With the exception of wood that goes to stump dumps, there is little surplus of harvested "waste" wood in the counties that Middlebury College could rely on. A supply of 20,000 tons would involve competing with existing users for chips, or going to the woods, or a combination.

1. Competing with existing users for chips

At the current time, there are about 26,000 tons of mill-residue chips that are produced in the two counties. These chips have current markets, although they are undervalued. The biggest customer, International Paper Company, buys mill-residue chips for less than the price of whole-tree chips, mainly because IP is a steady, year-round customer and there is no real competition.

Middlebury College could secure 20,000 tons of mill-residue chips by displacing International Paper and some schools that heat with wood chips. Theoretically, IP could pay up to the cost of the alternative source of pulp to its plant. This price is close to the price of whole-tree chips, around $30/ton. If Middlebury College were to bid more than this amount, and agree to take the chips year-round, it is likely the College could meet its entire demand from mill-residue chips and wood from stump dumps. ($31 X 20000 = $0.6 million)

However, this would not meet the College's goals. The main effect on the local economy would be to send slightly more money to the mills for the chips. The main effect on the forest would be to send IP to the land look for more low-value wood. There would be no change in harvesting practices.

2. Going to the land

To avoid displacing current chip buyers, Middlebury College would need to go to the land. With the College's recommended procurement standards, this would be considerably more expensive than buying mill-residue chips. It would also be more difficult, as the College would have to adopt and promulgate procurement standards; train loggers, foresters and landowners; set up a system for procuring wood; monitor harvests; and operate a chipper. We have estimated the cost of delivered roundwood to be $53-$58 per ton with the procurement standards in place. This price would increase the return to the landowner as an incentive not only to sell the low-value wood but also to require excellent forestry. It would also increase the return to the logger to meet harvest standards for the entire integrated harvest.

Procuring 20,000 tons from the woods, using procurement standards, would go farther to meeting the College's goals of ecological sustainability and stimulating the local economy. However, the cost would be nearly twice that of the mill-residue alternative. ($54-$59 X 20000 = $1.1-$1.2 million)

3. A combination

An alternative might be to procure a portion of the volume from each major source.

The College could pay a premium for mill-residue chips, using this as a stable supply. This would tighten the market, and drive up the price of mill-residue chips, which are currently undervalued, returning more to the wood industry.

The rest of the College's supply could come from the woods, using the procurement standards. As long as this demand is greater than 10,000 tons, it is likely to be significant enough to improve harvest standards in the area. Not only does this mean that the chips coming from the land would be harvested sustainably, but also that a higher-proportion of the mill-residue chips are from sustainably harvested wood as the standards apply to the sawlog portion of integrated harvests, as well as the low-quality wood.

The total price of the biomass would depend on the proportion coming from each source. A possible scenario would be:

Alternative to the stump dump	1,000 tons @ $25
Mill residue	9,000 tons @ $31
Low-value wood from integrated harvest	10,000 tons @ $58
Total	20,000 tons @ $44.20 average

(note that some of this biomass would be chips, some would be roundwood)

The first 1,000 tons could probably come from wood that would otherwise go to a stump dump, and the price would be low until the market heats up. At that point, the price for this is likely to be close to the price for chips from the land.

The mill-residue chips would cost more than IP is currently paying, mainly because IP would theoretically be able to pay up to the cost of the alternative source of wood.

10,000 tons of low-value wood could, theoretically, come from land on which sawlogs would be harvested anyway. According to our estimates, there are approximately 13,000 tons of low-value wood left in the forests annually during sawlog harvests. It is currently not worth removing. The higher price offered by the College would make it worthwhile to remove this wood. And, the procurement standards would ensure a high-quality integrated harvest.

It is important to note that this analysis is preliminary and is based on a compilation of conflicting data from many sources. While our calculations show that there is low-value wood left in the forests, we have heard that people in the firewood business have had a hard time finding wood this year. Similarly, state data show that the demand for wood chips has dropped in the past decade, yet buyers report a shortage, at least during the winter. Finally, there is no accepted source of projections of fuel prices so it is difficult to project future demand for biomass. Clearly, the market is not mature or well established and the effect of a surge in demand, like Middlebury College's, cannot be confidently predicted.

HOW SOON COULD WOOD BE PROCURED ACCORDING TO STANDARDS? (Question 3)

Assuming logging conditions are sufficiently dry and/or frozen, wood could be procured according to the recommended standards almost immediately. The most readily available forests would be those enrolled in Vermont's Use Value Assessment program. Additional data would generally need to be collected on these forests and management plans modified accordingly. Logging operators and forestry consultants would need to be given instruction on the procurement standards. Existing harvesting equipment could be used with improvements -- such as replacing skidders with forwarders – being phased in over time. Although wood could flow to the Middlebury College plant quickly, a minimum of one year of lead time is suggested in order to iron out all of the details and to assure compliance with procurement standards.

FUTURE BIOMASS: ENERGY PLANTATIONS (Question 2)

Once suitable and available sites have been identified, trees could be planted for energy plantations at the start of the next growing season. A great deal of research has been done on this subject.[3] Equipment, planting stock, and personnel for establishment of tree plantations are readily available. For example, Burlington Electric Department established a 5000-tree hybrid willow plantation in Burlington in 1997 and harvested the trees after 4 growing

[3] Mitchell, C. P., J. B. Ford-Robertson, T. Hinckley, and L. Sennerby-Forsse, editors. 1992. Ecophysiology of short-rotation forest crops. Elsevier Applied Science, London and New York.

seasons.[4] The yield was 35 green tons per acre, or 8.75 green tons of biomass per acre per year. The subsequent harvests can be made on three-year rotations. At this rate of growth, 10,000 tons of chips per year could be grown on approximately 1,200 acres. Total economic costs of delivered biomass from similar willow plantations in Delaware and Maryland ranged from $76 to $98 per dry ton.[5]

There is a great deal of information available on multiple species plantations and various cropping methods. A method that would be very interesting to test in Vermont is known as "coppice with standards." This method involves "standard" trees that are grown for high quality sawtimber on long rotations and "coppice" trees that are grown concurrently on 3 to 15 year rotations. This method has been used in England for over 1000 years![6]

With regard to the potential landbase for energy plantations, we conducted a cursory GIS analysis of Addison County. Whatever crop is grown for energy, woody or herbaceous, the terrain must be operable by machinery and soils must be reasonably fertile.[7] Much of the Champlain Valley portion of Addison County fits the necessary characteristics, as is reflected in the fact that 5% of the soils are nationally significant agricultural soils ("prime") and 34% are of state significance ("statewide"). Spatial data show that 159,500 acres, or 31% of the county, are in open field cover. The resolution of satellite imagery interpretation in spatial land-cover data was not fine enough to distinguish between hay meadows and pasture lands, and furthermore row crops and hay crops are often grown in rotation. So while GIS analyses show that nearly all of the agriculturally productive soils are non-forested, USDA agricultural census data for the same time period (1997) show that crops were harvested from 111,000 acres, or 21% of the county. A study of a sub-portion of the southern Champlain Valley, including some of the most intensively cultivated lands in Addison and southern Chittenden counties, showed that 5% of the land was in permanent pasture and 5% was in old-field shrub cover. If the subsample is representative of the valley terrain as a whole, the numbers add up to reveal that two-thirds of the open lands are currently harvested and the remaining third is evenly divided between pasture and successional field.

To answer the question of how much land would or could be available for energy plantations and what the economic effects would be, one needs to conduct socio-economic research. Suitable lands are available in the county, and some of them are in more extensive use (such as pasture) or are agriculturally abandoned. Whether any lands, be they in crop- or hay-lands, pasture or successional fields, would be available for establishing energy plantations is purely a matter of landowner choice. If the economics were favorable, it is fairly safe to predict that numerous landowners would be willing to utilize fields for energy production. The College itself has many fields that are currently under agricultural lease and would be suitable for

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[4] Burlington Electric Department. 2004. BED's Willow Crop Experiment. www.burlingtonelectric.com/SpecialTopics/willowtree.htm 1 p.

[5] Turhollow, Anthony. 2000 Costs of Producing Biomass from Riparian Buffer Strips. Enegry Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee. 60 p.

[6] Rackham, Oliver. 2001. Trees and Woodland in the British Landscape: The Complete History of Britain's Trees, Woods, and Hedgerows. Phoenix Press, London, England. 234 p.

[7] Richardson, J., R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. 2002. Bioenergy from Sustainable Forestry. Kluwer Academic Publishers, Boston, Massachusetts.

growing energy crops. At the rates of growth reported above, approximately 1% of the county's agricultural lands would be needed to produce 10,000 tons of chips per year.

ALTERNATIVE SOURCES: BIOFUELS (Question 6)

In response to questions raised by the CRI Working Group, this brief analysis will provide very general information about incorporating biodiesel into the fuel supply of the College.

Biodiesel is defined as a renewable, biodegradable, mono alkyl ester combustible liquid fuel derived from agricultural plant oils or animal fats. Biodiesel refers to the pure fuel before blending with diesel fuel. Biodiesel blends are denoted as, "BXX" with "XX" representing the percentage of biodiesel contained in the blend (e.g., B20 is 20% biodiesel, 80% petroleum diesel).

Feasibility

Biodiesel, made from soy oil is currently available for delivery in Middlebury. The biodiesel is imported by rail from Midwest refineries to Massachusetts and from there to Vermont via delivery truck. At the time of this report, there is one known distributor – a Vermont business, Global E Industries, Ltd., located in Cavendish. There has been increasing interest and market demand for biodiesel in recent months and it is expected that before January 2005, other distributors in Vermont will also be carrying a supply of Midwest biodiesel.

The production of biodiesel in the U.S. grew by 32% between 2002 and 2003 to approximately 20 million gallons. U.S. Department of Energy projections indicate that 2.5 billion gallons of biodiesel will be produced annually in the United States by the year 2020.[8] Biodiesel industry leaders are projecting that level of production may be reached sooner than 2020.[9]

Because of maintenance and cost issues The use of pure (100%) biodiesel or B100 in heating applications should not be considered. However, petroleum diesel blends containing 30% or less biodiesel can replace straight petroleum without any modification to equipment or adverse effect. Typically, B20 is a viable replacement for traditional fuel oil, and its use has resulted in reduced emissions in regional tests over the last three heating seasons.[10]

The feasibility of producing biodiesel in Vermont is currently under investigation by several for-profit and non-profit entities including Vermont's Alternative Energy Corporation, Inc., (in cooperation with UVM, The Intervale Foundation and Vermont Natural Ag Products), Global E. Industries, Ltd., Vermont Technical College, and the Vermont Biofuels Association. While growing seed crops for oil and converting this to biodiesel is now viable in the agricultural states of the Midwest, it has yet to be determined which crops are best suited to New England's soils and landscape and what efficiencies of scale would be optimal for biorefineries in the region. The organizations and individuals pioneering the research are

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[8] Source: National Biodiesel Board, http://www.nbb.org/
[9] Source: National Biodiesel Board, http://www.nbb.org/
[10] Source: Warwick Rhode Island School District study, URL http://www.rebuild.org/attachments/successstories/RhodeIslandBiodiesel.pdf

operating from the assumption that locally produced biofuels are ultimately feasible and economically viable.

What if Middlebury College were to reduce its consumption of petroleum diesel by 20% and replace that amount with locally produced biodiesel? How much land would be needed? And is it sustainable? For the reasons noted above we can present only a hypothetical answer, based on known local land use information and overlaying that with potential crop yield studies from other regions. Drawing on available data we know:

- The college is currently using 1.7 million gallons of #6 diesel annually.
- The amount of biodiesel needed to replace 20% is 340,000 gallons.
- A list of seed oil crops that have all been recognized for biodiesel potential and could be grown in Vermont has been developed (Table A-1, next page).
- The amount of oil available at harvest varies widely by crop resulting in biodiesel equivalents from 14 gallons per acre for corn to 102 gallons per acre for canola/rapeseed.[11]
- Considering the crops with the most likely current potential--sunflower, mustard and soybeans--the college would require between 4,000 and 9,000 acres for cultivation to procure 340,000 gallons of biodiesel annually.
- The USDA Census of Agriculture states that in 1997 there were almost 111,000 harvested acres of cropland in Addison County.[12] Therefore, the amount of cropland needed for the most likely crops represents between 3% and 8% of total acreage under cultivation in the county.

[11] source: Purdue University, Center for New Crops and Plants Products. Available at URL www.hort.purdue.edu/newcrop/searchengine.html

[12] source: USDA 1997 Census of Agriculture-County Data. Available at www.usda.gov/nass

Table A-1.

Addison County Energy Crop Summary				
Total cropland harvested acres in County	**Crop**	**Biodiesel (B100) gallons/acre average yield**	**Total acres needed to supply B20 to MC**	**Percent of total cropland harvested Acres in county**
110,894	canola	102	3,333	3%
	sunflower	82	4,146	4%
	mustard	49	6,939	6%
	flax	41	8,293	7%
	soybeans	38	8,947	8%
	hemp	31	10,968	10%
	corn	14	24,286	22%

Costs

The cost to dealers bringing B100 to Vermont from Midwest suppliers was approximately $1.95 per gallon in 2003.[13] An Internet search of retail—not wholesale or institutional--prices at the pump revealed a wide range from $2.00 to $3.30 per gallon for B100.

A local supplier of biodiesel blends for heating fuel noted that the biodiesel component cost for a B20 blend is fairly stable in current pricing while the price of petroleum is not stable and has been experiencing incremental increases on world markets. Any projection of future costs must keep in mind these factors and other points noted earlier pertaining to the volatility of petroleum prices due to a finite supply, increasing consumption, and strategic security issues in the coming decades.

Using today's prices, assuming the College were able to do the blending of 80% #6 diesel at $.81/gallon and 20% biodiesel at a projected price of $2.20/gallon, the resulting B20 cost would be $1.09/gallon, delivered.

As for the comparative cost of producing biodiesel locally, no information is available at this time.

Benefits

Biodiesel is the first and only alternative fuel to have a complete evaluation of emission results and potential health effects submitted to the EPA under the Clean Air Act. The study found that, compared to petroleum diesel, B20 reduced total hydrocarbons by up to 30%, carbon monoxide up to 20%, and total particulate matter up to 15%. Nitrogen oxide (NO_x) emissions were found to be either slightly reduced or slightly increased. The variance depended upon the equipment and testing methods used. In addition, the ozone forming

[13] Source: Conversation with Greg Liebert, President, VAEC. Middlebury, VT September 2003.

potential of the hydrocarbon emissions of B100 is half that of petroleum fuel, and since biodiesel contains no sulfur, emissions of sulfur dioxide are reduced to virtually zero.

When considering methods of reducing atmospheric carbon, since biodiesel is a fuel derived from organic materials, carbon dioxide is “taken up” by the annual production of seed oil crops and then released when the biodiesel is combusted. A study by the US Department of Energy (DOE) has found that replacing petroleum diesel with biodiesel reduces CO_2 emissions by 78.5%.

In a 1998 report, the USDA and the DOE compared the “cradle to grave” costs and benefits of various fuels for a more complete evaluation of energy supply choices.[14] The study concludes that for every one unit of fossil energy needed to produce biodiesel, 3.24 units of energy are gained. By contrast, petroleum diesel yields only 0.83 units of fuel product per unit of fossil energy consumed. Biodiesel contains the highest energy balance of any liquid fuel tested. For comparison, the energy balance of woody crops was reported as 21 for short-rotation willow, 18 for whole-tree chips from thinnings, and 25 for whole-tree chips from low-quality logging residues. [15]

While the information above relates to direct environmental benefits of incorporating biodiesel in an energy portfolio it does not factor in the socio-economic benefits (or costs) of this industry on local communities. In the meantime, to evaluate these opportunities, organizations in Vermont are proceeding with their research on the potential for job creation, agricultural sustainability and energy self-sufficiency within a biorenewables industry.

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[14] Source: National Biodiesel Board, http://www.nbb.org/pdf_files/LifeCycle_Summary.PDF

[15] Richardson, J., R. Björheden, P. Hakkila, A. T. Lowe, and C. T. Smith, editors. 2002. Bioenergy from Sustainable Forestry. Kluwer Academic Publishers, Boston, Massachusetts.