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Biomass and Biofuels in Maine: Estimating Supplies for Expanding the Forest Products Industry

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Biomass and Biofuels in Maine:
Estimating Supplies for Expanding the Forest Products Industry
(revised November 2007)

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Abstract

This paper estimates the renewable energy potential of Maine's forest resources, and how much energy these resources could potentially provide the state. Using the most recent state-specific data available, and a methodology similar to the Billion Tons Report, we find that ethanol production from Maine's forest residues could potentially provide 18% of Maine's transportation (gasoline) fuels with a fermentation wood to ethanol process. Making Fischer-Tropsch diesel (F-T diesel) using forest residues can replace 39% of Maine's petro-diesel consumption. Actual levels of biofuels that can be produced will depend on conversion factors and forestry residue removals that are subject to uncertainty.

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I. Introduction

Maine is the United State's most heavily forested state with 90% of its land classified as forestland. As wood biomass derived fuels technology moves forward, Maine's forests provide a tremendous potential source of renewable energy. However, a plentiful resource and evolving technology serve no value unless economically viable methods of harvesting, producing, and transporting cellulosic feedstocks can be realized. This report, *Biomass and Biofuels in Maine: Estimating Supplies for Expanding the Forest Products Industry*, examines the supply of forest removals, and their potential contribution as a renewable energy source for the transportation fuels sector in Maine and New England. Future reports will address the costs of harvesting, production and transportation of the forest removals themselves.

Objective

Biomass and Biofuels in Maine examines the renewable energy potential of Maine's forest resources, and how much energy these resources could potentially provide the State. Specifically, the objective is to calculate the quantity of *forest residues* likely available on a sustainable basis annually for the replacement of transportation fuels. In addition, since biofuel plants could potentially offer competitive prices for roundwood products (commercial and industrial quality wood) as the renewable energy market matures, the availability of roundwood as a renewable energy source is also considered. The energy contribution that forest residues and roundwood products could make towards transportation fuel consumption in Maine and New England are determined individually and as total forest removals. We use the Billion Tons Report (BTR) methodology but adjust for more up-to-date and accurate forest inventory data.

Data Sources for Maine

The two most up-to-date and extensive data sources for Maine's forest are the 2003 Forest Inventory and Analysis (FIA) data and the 2007 Resources Planning Act (RPA) data. Both of these data sources are accessed through databases available from the FIA National Program website. (USDA, 2007) The FIA data are available from three different databases, including Mapmaker 2.1 used for this report, and the RPA data are available from the Timber Products Output Mapmaker Version 1.0 database. (USFS, 2007)

The data provided by the FIA are compiled in 5 year cycles with 20% of Maine's forestland surveyed annually. The 2003 database consist of data collected from 1999 to 2003. The 2003 FIA data contains categories that are not measured in the RPA data and are useful in determining biomass inventory, such as measurements on rough and rotten wood and dry tons of live biomass in Maine's forest.

In 1974, the U.S. Congress called for an assessment of the country's national resources, creating the Resource Planning Act. Its purpose is "to obtain reliable information necessary to properly manage those resources and make informed policy decisions." The RPA data are recompiled every five years and they are more specialized than the FIA data, specifically tracking the volume of forest residues from logging and other removals, and roundwood product removals from Maine's forests. (USFS, 2007) Unlike 2003 FIA data, the RPA data provide more detailed data on removals. The 2007 RPA data are used for the biomass availability estimates calculated for this report.

Overview of Previous Reports for Maine

Three previous reports have estimated forest residue supplies with varying findings. Two of these reports have come from the Oak Ridge National Laboratory (ORNL). *Biomass Feedstock Availability in the United States: 1999 State Level Analysis* (BFA) was last updated in 2000, making it the least current estimate of the three reports. *Biomass as Feedstock for a Bioenergy and Bioproducts Industry: The Technical Feasibility of a Billion-Ton Annual Supply*, known as the Billion Tons Report (BTR), was published in 2005, making it the most recent estimate. These ORNL reports provide national analysis, using national estimates, to determine biomass supplies, while also providing some state level data. The third estimate comes from the *State of Maine Ethanol Pre-Feasibility Study* prepared on behalf of the Finance Authority of Maine (FAME) by BBI International, published in 2002.

The FAME and BFA reports provide estimations of biomass supplies for different prices delivered. Both reports list dry tons at <\$30, <\$40, and <\$50 per dry ton delivered. While each report used different assumptions when estimating available forest residues, there were similarities in their methods. Both the BFA and FAME reports generated their estimates by using an updated version of the 1984 McQuillan model. It is an unpublished model that measures marginal cost-supply curves for wood wastes and residues. It is considered to be a useful model for generating forest residue supply curves, but is difficult to update and users must recognize its limitations.

The BFA report lists quantities of 806,000 dry tons, 1,182,000 dry tons and 1,529,100 dry tons of forest residues as prices increase. The BFA price figures, which are in 1995 dollars, include collection, harvesting, chipping, loading, hauling and

unloading costs, a stumpage fee and a return for profit and risk. (Walsh, et al., 1999) We calculate the BFA supply elasticity as 1.35.

The BFA report first categorizes forest residue by its components: logging residues, rough, rotten, and salvable dead wood (excluding excess saplings and small pole trees), hardwood or softwood, hauling distance, machine operability constraints and volume. The BFA report then revises the forest residues quantity for recoverability based on constraints on equipment retrieval efficiencies, road access to a site and impact of site slope on harvest equipment choice. The report uses 1997 RPA data. (Walsh, et al., 1999)

The FAME report lists quantities of 1,251,000 dry tons, 1,182,000 dry tons and 2,750,000 dry tons of forest residues as prices increase. (BBI International, 2002) FAME states that its delivered price data are consistent with price data collected from timber harvesters in Maine. (BBI International, 2002) FAME does not state the dollar year for its prices, nor does it state the different costs that make up its price numbers. Using these price and quantity estimates, we calculate that FAME is using a price supply elasticity of 1.80. This means that a rise of 10% in the price paid for biomass would increase the amount available by 18% over the range of \$30 to \$50. We have no basis to determine which level of price responsiveness (BFA or FAME) is more accurate. Additional research is warranted to estimate more accurately the price responsiveness of forest residues.

The FAME report's supply numbers are much higher than the BFA report, except for the quantity at <\$40 per dry ton delivered where the numbers are exactly the same at 1,182,000 dry tons (Table 1). (BBI International, 2002) In addition to this discrepancy, the FAME report indicates a lower amount of dry tons available at <\$40 than the amount at <\$30. Given that the biomass supply for each price is a cumulative number (<\$40/dry

ton delivered is the sum of <\$30 and <\$40/dry ton delivered), it is impossible for the supply at <\$40/dry ton to be lower than the supply at <\$30/dry ton. This creates questions about the validity of the FAME numbers.

Table 1: FAME and BFA Supplies for less than \$30, \$40 and \$50 Delivered

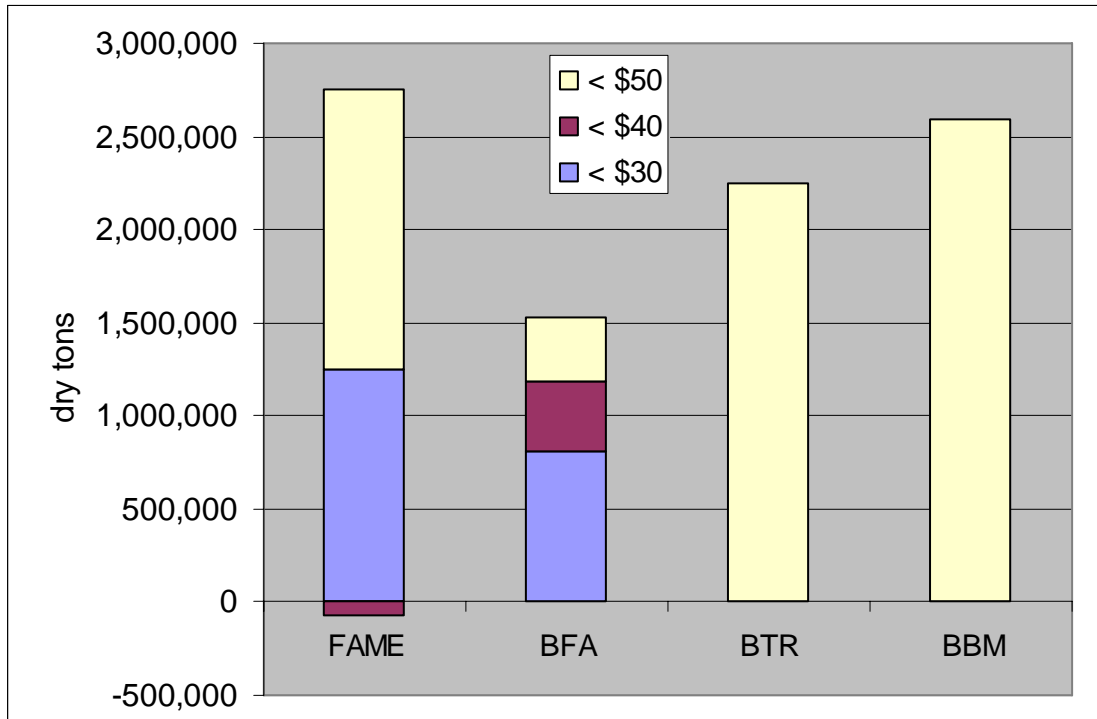
SUPPLY OF MAINE FOREST RESIDUES (DRY TONS)				
Report	Supply at <\$30/dry ton delivered	Supply at <\$40/dry ton delivered	Supply at <\$50/dry ton delivered	Supply Elasticity*
FAME	1,251,000	1,182,000	2,750,000	1.80
BFA	806,000	1,182,000	1,529,100	1.35

*Our estimate based on the data in Table 1.

The state of the art in biomass and biofuel supply research is the 2005 Billion Tons Report (BTR). This report, done by ORNL on behalf of the U.S. Department of Energy and U.S. Department of Agriculture, was intended to analyze the amount of biomass that is potentially available *nationally* for renewable energy usage. ORNL determined in the BTR that 1.3 billion tons of biomass is potentially available annually on a sustainable basis. This supply would be able to provide 30% of the country's energy needs from renewable biomass energy sources. The BTR considered biomass from agriculture, forest residues, fuel treatment thinnings, milling residues, urban wood waste and municipal solid waste as potential renewable energy sources. (Perlack, et al., 2005) As a nationally-focused report, the data and methods were necessarily chosen to work for all fifty states. Maine has its own state-specific data that can improve the estimated biomass feedstocks resources available in Maine.

Supply estimates for all three reports, as well as our own (noted as BBM), are displayed in Figure 1.¹

Figure 1: Maine Forest Residue Estimates



II. Methodology

Determining Logging Residue Supplies

The methodology used in calculating forest residues availability in Maine's forest is based on the BTR's assumptions and the RPA data. The first step in determining sustainable and extractable forest residues is taking the total volume of forest residues in Maine's forests and converting it from cubic feet per year into dry tons per year. This conversion is done based on the national average provided by the BTR of thirty dry

¹ The authors would like to note that there a draft Maine Forest Service document currently being prepared as a Maine Agricultural and Forest Experimentation Station (MAFES) publication that will provide additional background on published and available data specific to Maine.

pounds per cubic foot of logging and other removal residues. (Perlack, et al., 2005)

These calculations are then multiplied by the BTR percentages for accessibility and recoverability.

Accessible forest residues are determined under the assumption that residue collection is completed at the same time as harvesting. Therefore, it is assumed that all residues are one hundred percent accessible. Sixty-five percent of logging residues and fifty percent of other removal residues are assumed to be recoverable. The technology, equipment and economical constraints of recovering residues are the primary reason a significant percentage of accessible forest residues are considered non-recoverable.

A sustainable harvest level is a harvest level that can be maintained at an even flow over time. Sustainable logging is defined by several different measurements of harvesting and growth. (Wagner, 2007) Sustainability is also a concern when removing forest residues from the forest. (Perlack, et al., 2005) Sustainable harvesting of forest residues is different because it involves harvesting biomass that is traditionally left in the forest to decompose. The main factor in determining sustainable removals of forest residues is the amount of residues that can be removed while still leaving enough on the forest floor to provide sufficient nutrients to the forest and replenish the soil. Multiplying accessible forest residues by the BTR recoverability percentages provides the estimated sustainable and extractable annual forest residue removals.

Determining Biofuel Supplies

The first conversions determined in calculating biofuel supplies are the energy contents of biofuels relative to petroleum-based fuels, which we have calculated using the same conversion factors that are used by the Bioenergy Feedstock Development

Programs at ORNL. Ethanol's value is determined by dividing the heat content, in British Thermal Units (BTUs) of one gallon of ethanol by the heat content of one gallon of gasoline.

Potential biofuel availability is determined based on the potential annual forest residue and roundwood product removals. Roundwood products supply is determined by taking 2007 RPA data on cubic feet of annual roundwood removals, and assuming 85 cubic feet per cord of wood. (Laustsen, 2007b) The next assumption is 1.25 dry tons per cord of wood which results in annual dry tons of roundwood product. (Laustsen, 2007b) Forest residue and roundwood product removals are added together to give total annual removals from Maine's forest.

The gallons of ethanol determined for this paper are based on the report *Synthesis of Transportation Fuels from Biomass: Chemistry, Catalysts, and Engineering* (STFB). STFB states that the National Renewable Energy Laboratory's method yields 320 liters of ethanol per metric dry ton of biomass from a hydrolysis and fermentation process. This yield translates to 77 gallons of ethanol per dry ton of wood. (Huber, et al., 2006)

The gallons of Fischer-Tropsch Synthesis diesel (F-T diesel) yielded from annual biomass removals are based on the Energy Research Centre of the Netherlands (ECN) yield of 120 liters of F-T diesel per metric ton of biomass from a Fischer-Tropsch Synthesis of biomass-derived syn-gas (F-T syn-gas). This yield translates to 29 gallons of F-T diesel per dry ton of wood. The F-T syn-gas method provides lower fuel yields than the hydrolysis and fermentation yields; however, the F-T process also generates synthetic natural gas and electricity as byproducts (Huber, et al., 2006), neither of which are addressed in this report.

The gallons per dry ton yields are multiplied by the biomass supply numbers to calculate potential biofuel production estimates. The production estimates from the fermentation process are multiplied by the rack price of ethanol to estimate potential revenue. The total production from the syn-gas process is multiplied by the rack price of diesel to estimate potential revenue from F-T diesel. Each fuel's energy per gallon compared to petroleum-based fuel and total BTU per gallon calculations are multiplied by the biofuel production estimates to calculate each biofuel's petroleum-based fuel equivalent in terms of energy content and total BTU's of energy. The equivalent gallons of petroleum-based fuel created from each process estimate and each removal type are divided by the total 2006 gasoline consumption for Maine and New England to give the percentage of gasoline consumption that biofuels derived from forest removals could potentially replace. An overview of these calculations can be found in Table 2.

Table 2: Biofuels Formulas

<p>Potential Biofuel Supply: Total Biofuel supply = dry tons biomass x process yield (gallons/dry ton)</p>
<p>Potential Revenue: Total revenue = dry tons biomass x process yield x rack price of biofuel</p>
<p>Potential Replacement of Petroleum-based Fuels with Biofuel: Petro-fuel replaced by selected biofuel = (biofuel supply x biofuel to petro-fuel energy ratio) / total region petro-fuel consumption</p>

III. Results & Discussion

Forest Residues

We have calculated that the total sustainable and extractable forest residues are 2.6 million dry tons per year. Nearly all of the dry tons come from logging residues. Only 694 dry tons come from other removal residues. This is different from calculations

made on a national level. The BTR states that, on a national level, forest residues are about three quarters logging residues and 1 quarter other removals. (Perlack, et al., 2005) However, the total volume of residue removals in Maine for the 2007 RPA data year is over 99.9% logging residues. The “Other Removals” category is intended to capture additional residues that result from land clearing, precommercial thinnings, or timberland clearing. These activities in Maine, if captured at all, are for the most part already captured within the “Logging Residue” category and create little additional volume opportunity.

Biomass to Biofuel

Our estimate of the amount of ethanol that can potentially be produced from forest removals is determined by modifying a preliminary analysis by Wagner. (Wagner, 2007) Cellulose only represents 45% of the dry weight of the woody biomass. The energy content of the remainder is not accounted for in the analysis.

The energy content of biofuels relative to gasoline are determined by dividing the heat content of one gallon of ethanol (75,700 BTU) by the heat content of one gallon of gasoline (115,000 BTU). (ORNL, 2007) Ethanol has 66% as much energy as gasoline per gallon. The F-T diesel does not have a difference in heat content when compared to petroleum-based diesel (petro-diesel); both have approximately 130,500 BTU per gallon.

For this paper, we estimate 2.6 million dry tons of forest residues and 8.3 million dry tons of roundwood products per year. These two removal categories add together to give combined annual removals from Maine’s forests of 10.9 million dry tons. The biomass to biofuel yields of 77 gallons of ethanol per dry ton of woody biomass and 29

gallons of F-T diesel per dry ton of biomass multiplied by our calculated biomass supply estimates are provided in Table 3.

Table 3: Biofuel Supply Estimates by Process and Removal Type

HYDROLYSIS & FERMENTATION			
	Gallons of Ethanol	Gasoline Equivalent	Billion BTUs
Forest Residues	198,231,014	130,487,720	15,006
Roundwood Product	634,950,852	417,963,300	48,066
Total Removals	833,181,866	548,451,020	63,072
F-T OF BIOMASS DERIVED SYN-GAS			
	Gallons of F-T diesel	Petro-Diesel Equivalent	Billion BTUs
Forest Residues	74,336,630	74,336,630	9,701
Roundwood Product	238,106,569	238,106,569	31,073
Total Removals	312,443,200	312,443,200	40,774

Transportation Fuel Consumption

In 2005 (the most recent data available) Maine consumed 716 million gallons of gasoline (Energy Information Administration, 2005) and 192 million gallons of petro-diesel. (Energy Information Administration, 2005) The New England region (Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, and Vermont) consumed 6.5 billion gallons of gasoline (Energy Information Administration, 2005) and 1.3 billion gallons of petro-diesel in 2005. (Energy Information Administration, 2005) The biofuel equivalents of Maine and New England 2005 petroleum-based fuel consumption are listed below in Table 4.

Table 4: Petroleum-based fuel consumption and biofuel equivalent for Maine

2005 GASOLINE CONSUMPTION			
Region	Gallons Consumed	Ethanol Equivalent Gallons	BTU Equivalent (billion BTUs)
Maine	715,680,000	1,087,228,534	82,303
New England	6,542,718,000	9,939,399,868	752,413
2005 PETRO-DIESEL CONSUMPTION			
Region	Gallons Consumed	F-T diesel Equivalent Gallons	BTU Equivalent (billion BTUs)
Maine	192,192,000	192,192,000	25,081
New England	1,258,320,000	1,258,320,000	164,211

Transportation Fuel Replacement

Ethanol production from Maine's forest residues could potentially provide 18% of *Maine's* transportation (gasoline) fuels with a fermentation wood to ethanol process. Incorporating roundwood products would provide an additional 58% thereby making total removals equal to 77% of gasoline consumption.² Making F-T diesel using forest residues can replace 39% of Maine's petro-diesel consumption. Roundwood products could provide an additional 124%, and total removals could thereby provide 163% of petro-diesel consumption.

Maine ethanol from forest residues could provide 2% of New England's transportation fuel needs through fermentation. Ethanol from roundwood products could also replace another 6% of gasoline consumption, with total removals replacing 8% of gasoline consumption. F-T diesel created from a syn-gas process using forest residues

² Totals may not equal sum of components due to independent rounding.

could replace 6% of New England’s petro-diesel consumption. Roundwood products could replace another 19% and total removals could thereby replace 25% of petro-diesel consumption. Figures 2-4 provide an overview of the fuel consumption that can be substituted in Maine and New England with the different forest products.

Figure 2: Percent of Petroleum-based Fuel Consumption that can be Substituted with Renewable Fuels from Forest Residues Removals

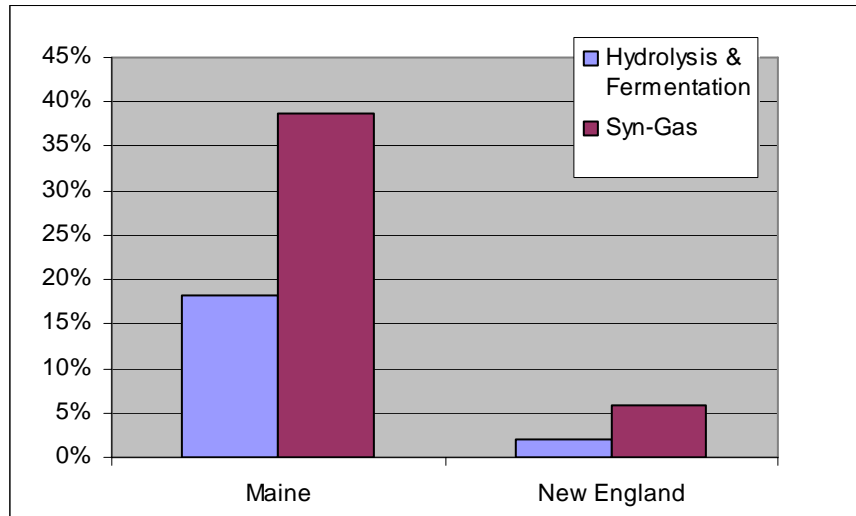


Figure 3: Percent of Petroleum-based Fuel Consumption that can be Substituted with Renewable Fuels from Roundwood Product Removals

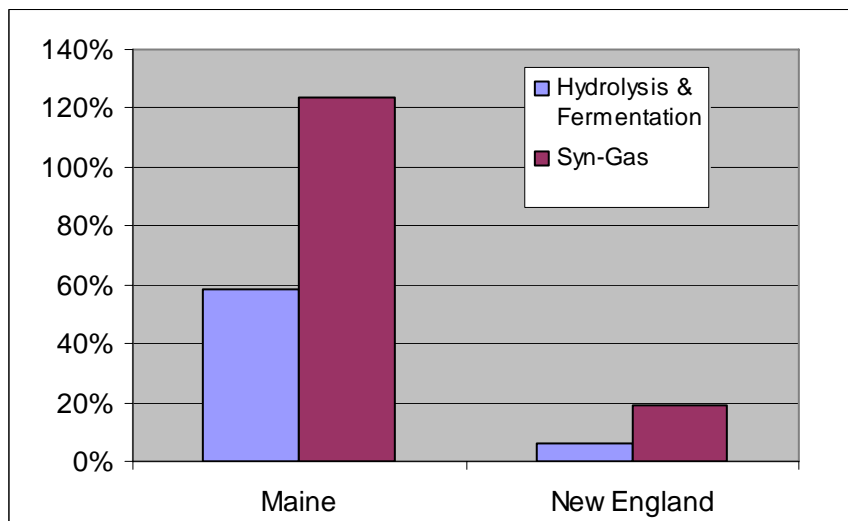
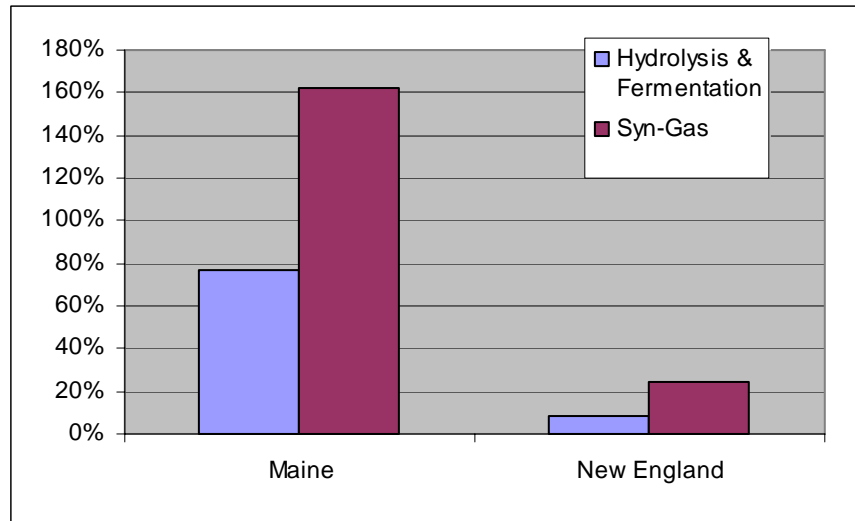


Figure 4: Percent of Petroleum-based Fuel Consumption that can be Substituted with Renewable Fuels from Total Product Removals



Potential Revenues with Biomass Feedstock Replacing Petroleum in Maine

Assuming an ethanol rack price of \$2.33 per gallon (2007), potential revenue from the sale of ethanol produced from forest residues is \$461 million. That translates to \$884 of revenue per harvested acre of Maine timberland. Revenue from ethanol derived from roundwood products is \$1.48 billion dollars or \$2,833 per harvested acre of timberland. Combined removals could bring revenue of \$1.9 billion or \$3,717 per harvested acre of timberland.

Potential revenue from the sale of F-T diesel, using forest residues and assuming a rack price of \$2.25 per gallon (Energy Efficiency and Renewable Energy Biomass Program, 2007), is \$167 million averaging \$321 per harvested acre of timberland. Potential revenue from F-T diesel produced from roundwood is \$536 million or \$1,027 per harvested acre of timberland. Potential revenue from total removals is \$703 million or \$1,348 per harvested acre (Table 5). It is important to remember that these revenues are based on the value of biofuels. What portion of this revenue would accrue to

landowners and what to logging, transportation, and biorefinery operations is not known. Additionally, other products such as specialty chemicals and power generation, can be produced in a biorefinery providing additional revenues.

Table 5: Summary of Potential Revenues Available from Maine Forests

POTENTIAL REVENUES FROM BIOMASS TO BIOFUEL			
	Forest Residues	Roundwood	Total Removals
Ethanol	\$460,986,223	\$1,477,213,157	\$1,938,397,611
Revenue per harvested acre	\$884	\$2,833	\$3,717
FT Diesel	\$167,257,418	\$535,739,781	\$702,997,199
Revenue per harvested acre	\$321	\$1,027	\$1,348

Biofuel revenue estimates are based on August and September 2007 fuel prices. For comparison, in 2004, the annual revenues from Maine's forests for "forest-based manufacturing" was \$307 per acre. (North East State Foresters Association, 2004) While our estimated potential revenues from ethanol at \$884/acre are substantially higher, an ethanol biorefinery involves new technology and carries a higher risk. Capital and input costs are also not equivalent.

Replacing Petroleum-based fuels in Maine and New England

Due to Maine's low population size and abundance of woody biomass, it has the potential to replace a large percentage of its own non-renewable energy use with renewable energy from its forest and become a much more energy self-sufficient state. The BTR determined that 30% of the country's energy needs could be met from utilizing all biomass sources. Maine could meet 18% of its transportation fuel needs through forest residues alone.

The New England region has much greater energy consumption than Maine, thus the offset of non-renewable fuel usage throughout New England from Maine forest removals is far less. If all of Maine's annual forest removals (roundwood and residues) were converted into ethanol, it would replace 8.4% of New England's gasoline consumption.

IV. Conclusion

Forest residues are a form of biomass that is of low value to traditional forest industries. However, forest residues are potentially very valuable to the emerging renewable energy industry. If not utilized for biofuels, the majority of forest residues are left on the forest floor to decompose. If the residues are retrieved based only on the recovery estimates outlined in this report, 2.6 million dry tons of forest residues could potentially contribute up to one-third of Maine's transportation fuel supply through its conversion into ethanol, or three-quarters of Maine's fuel supply for diesel with F-T diesel. There have also been studies done that indicate an integrated system of recovering forest residues greatly increases the amount that can be recovered, up to 90 percent of the available forest residues. (Perlack, et al., 2005) This could increase the amount of recoverable dry tons available from Maine forests by almost 1 million. The potential that forest residues could become a sustainable source for renewable energy use is reason enough for continued research into their economic viability.

Future steps should be to determine the spatial distribution of Maine biomass in a more evenly distributed format than the county level distribution provided by the data sets for this report. Looking at biomass concentration by county is deceiving because of the uneven sizes of counties in Maine. FIA databases enable researchers to determine the

available biomass within the radius of a specific set of latitude/longitude coordinates. This mapping function would be useful in generating GIS maps of biomass location in Maine. GIS mapping of biomass location and concentration, with an overlay of relevant transportation routes and adjacent populations would contribute to identifying ideal locations for biofuel facilities in Maine. Generating price curves by obtaining reliable price data on forest residues that would divide the biomass supply estimates calculated for this white paper by different delivered prices is another future step that should be taken. Additionally, conversion technology factors and evaluation of total energy impact should be studied. These steps will contribute to more specific and accurate biomass supply estimations.

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Acronyms

- BFA – Biomass Feedstock Availability: 1999 State Level Analysis
- BTR – Billion Tons Report
- BTU – British Thermal Unit
- ECN – Energy Research Centre of the Netherlands
- FAME – Finance Authority of Maine
- FIA – Forest Inventory and Analysis

FTS – Fischer Tropsch Synthesis

Fischer-Tropsch Synthesis diesel (F-T diesel)

MFS – Maine Forest Service

ORNL – Oak Ridge National Laboratory

RPA – Resources Planning Act

STFB – Synthesis of Transportation Fuels from Biomass

TPO - Timber Products Output

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