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Maine Bioproducts Business Pathways: Ethanol Comparison & Transportation Analysis

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Abstract

Ethanol can be produced at Kraft pulp and paper mills using the near-neutral process developed at the University of Maine. In addition to ethanol, there are additional products that may be produced, including natural gas. This report compares some characteristics of ethanol produced with wood via fermentation versus that by corn. We also identify various means of transport available to Kraft pulp and paper mills in Maine, including pipelines, trucking and rail.

While the use of pipelines for natural gas and crude oil in Maine is well established, few Kraft pulp and paper mills will find it compelling at the outset to transport any product via pipeline given volume requirements and consistently high biofuels prices needed to justify fixed-cost pipeline expenditures. Rather, since Maine's pulp and paper mills already have well-established relationships with both rail and trucking services, any marginal expansion of their product lines to include liquid or gas products should rely primarily on their existing product transportation infrastructure. As many Kraft pulp and paper mills evolve increasingly large and effective biorefinery capabilities, the subsequent shipment of biofuels could be beneficial both to the mills and to the transport companies that will get them to market, providing the foundation for larger scale biofuels production and transportation infrastructure in the years to come.

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Any errors within the report are purely the responsibility of the authors alone.

Introduction

Recent work regarding the feasibility of producing cellulosic ethanol and other products has made it clear that a definitive analysis identifying a specific process or business model as the only successful biorefinery is unlikely(Mao, et al. 2008; Dickerson and Rubin 2008; van Heiningen 2006; Larson, et al. 2006). Instead, Maine can be better served by identifying promising processes, products and routes through which business can capitalize on what is best known about these processes at this time.

Building from the *Maine Bioproducts Business Pathways* (MBBP) (Dickerson and Rubin 2008), this study evaluates in further detail the aspects of the MBBP that could not be addressed in full due to the complexity and/or lack of information available when the initial research was begun. As such, we address four additional topics:

- Environmental analysis of wood-based cellulosic ethanol as compared to corn-based ethanol;
- Gas Fuels from a biorefinery;
- Pipelines in Maine; and
- Transport costs.

1. Greenhouse gas and energy analysis of wood-based cellulosic ethanol compared to corn-based ethanol

The Energy Independence and Security Act of 2007 (EISA), signed on December 19, 2007, has a mandate for 36 billion gallons of renewable fuels by 2022. Of this amount, 21 billion gallons is to be made from cellulosic ethanol and other advanced biofuels (2007; U.S. Department of Energy, Energy Information Administration, 2007). In 2005, total U.S. ethanol production was 3.9 billion gallons, or 2.9 percent of the total gasoline pool (U.S. Department of Energy, Energy Information Administration, 2007). The interest in ethanol as an alternative fuel source stems in large part from the ease with which it can blended (up to 10%, known as E10) in gasoline with no damaging effects on vehicles themselves. In addition to E10, there are also a significant number of flex-fuel vehicles in Maine capable of using E85 as a fuel. (Linnell 2009)

Currently, virtually all ethanol in the U.S. is produced by fermenting corn, primarily in the Midwestern states. While there have been a number of studies demonstrating that corn-based ethanol is (modestly) better environmentally than petroleum-based fuels, there remains concern with using food-based plants for fuel.[1] As part of the continuing research and development of cellulosic ethanol, an analysis of the full scale of emissions and other environmental impact of producing advanced biofuels is often required. In most cases, a life cycle assessment (LCA) is used for the analysis. While a full LCA is beyond the scope of this paper, we have evaluated certain environmental impacts of cellulosic ethanol versus corn-based ethanol.

Argonne National Laboratory has a modeling program known as GREET (Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation) that has been used as the basis for life cycle analysis (LCA) of different fuel types and pathways, including petroleum and alternative

[1] See Delucchi (2009) for a summary of the many Life Cycle Assessments.

fuel production (Transportation Technology R&D Center Argonne National Laboratory). We use GREET1.8b to provide a comparison of cellulosic ethanol from wood vs. ethanol made from corn (both using fermentation), to facilitate previous comparisons to those studies. One million BTU of fuel delivered is the basis of comparison in our GREET modeling. However, there are some inherent limitations to using GREET with regards to forest land. The GREET program, like most LCAs performed with regards to cellulosic ethanol, looks primarily at fast growing crops that are managed much like traditional farming, for example, switchgrass. The use of wood from forests has not been studied in depth, making many of the assumptions found in the life cycle assessments for cellulosic ethanol not directly applicable to Maine's forest land. This is an important consideration, as land use change has been found to be one of the largest contributors to greenhouse gas emissions when looking at bio-based fuels (Delucchi University of California, Davis, 2006; Wang, et al. 2007; Kammen, et al. 7 September 2007 version). Most LCAs, including GREET, assume that the land used to produce crops for cellulosic ethanol had been idle or pastureland prior to being converted to biomass farming. This has a direct impact on the assumptions made regarding carbon sequestration in the plants, the use of pesticides and fertilizers (if needed), and the carbon in the biomass itself (Systems Assessment Section Center for Transportation Research Argonne National Laboratory, September 2008). Maine biorefineries, building from Kraft pulp mills, will be using trees already being harvested for the lumber, pulp, and paper industries. Thus, there will be little emissions that can be attributed to land use change.

Using GREET and the base year 2010, the following figures (Figure 1-Figure 3), show a comparison of ethanol made from corn vs. that made from wood.[2]

[2] 2005 is the base year for current Department of Energy (DOE) call for proposals, including LCAs, which require that life cycle greenhouse gas (GHG) emissions of any proposed fuel result in at least a 85% reduction of GHG emissions relative to gasoline. We ran the GREET1.8b model using both 2005 and 2010 numbers, and the results were equal. Thus, 2010 projections are shown here as it is the year closest to when these fuels may be used in Maine.

Figure 1: Energy Consumption to Produce Cellulosic Ethanol from Wood and Corn Ethanol

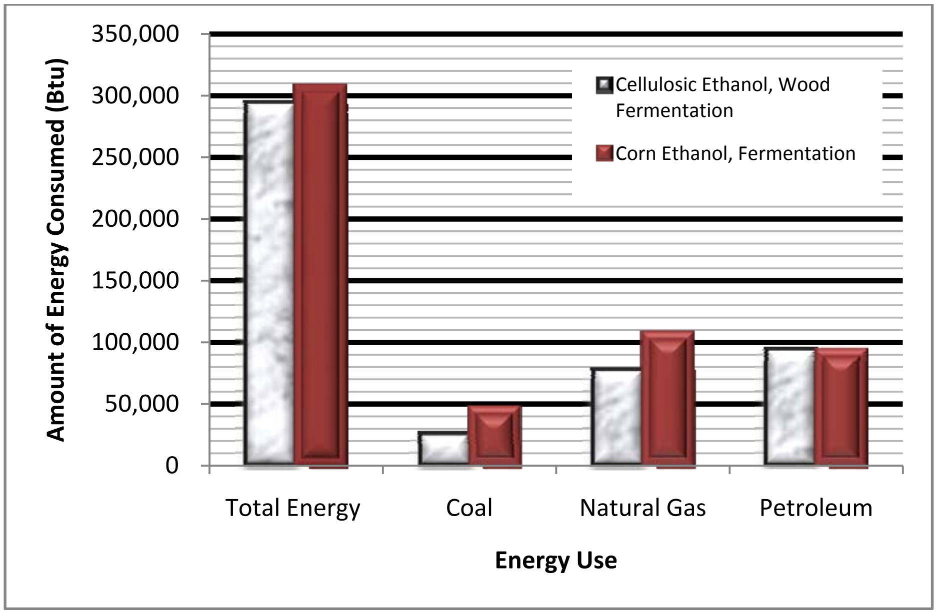


Figure 2: Carbon Dioxide (CO_2) Emissions for Cellulosic Ethanol from Wood and Corn Ethanol

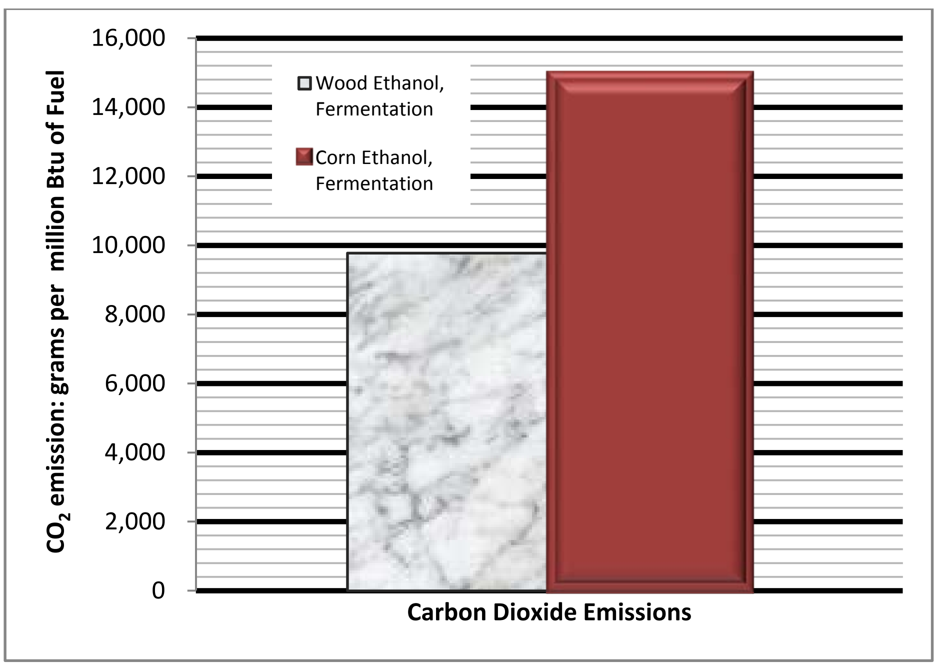
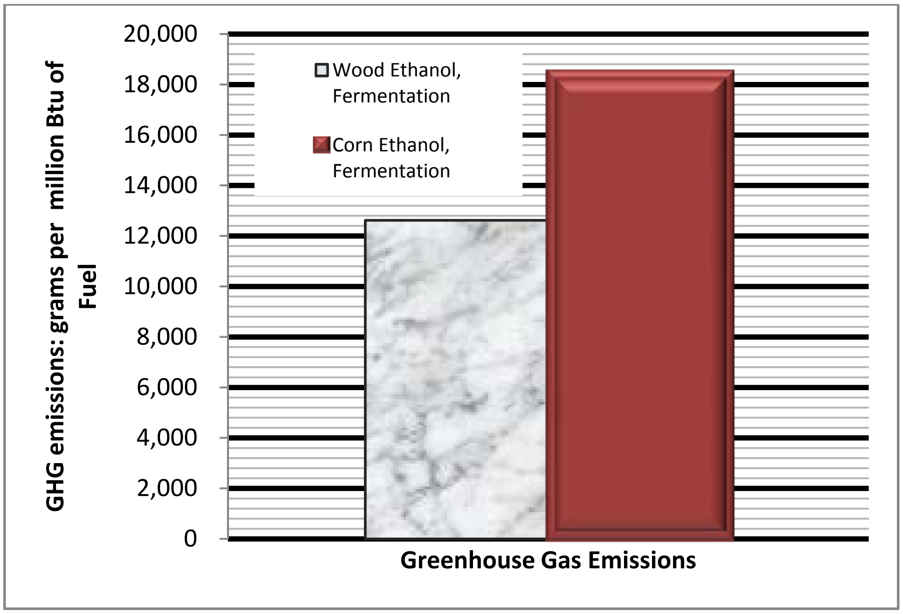


Figure 3: Greenhouse Gas (GHG) Emissions for Cellulosic Ethanol from Wood and Corn Ethanol



As seen in all three figures (Figure 1-Figure 3), cellulosic ethanol has lower greenhouse gas emissions[3], lower carbon dioxide emissions, and uses less energy in the production of the ethanol than corn ethanol. There are a number of reasons for this, not the least of which being that harvesting the wood (even when it's assumed to be switchgrass, not wooded forest land) is less energy and chemically intensive than farming corn. Moreover, the lignin inherent in the wood is used as an offsetting source of energy for running the cellulosic facility (Wang, et al. 2007).

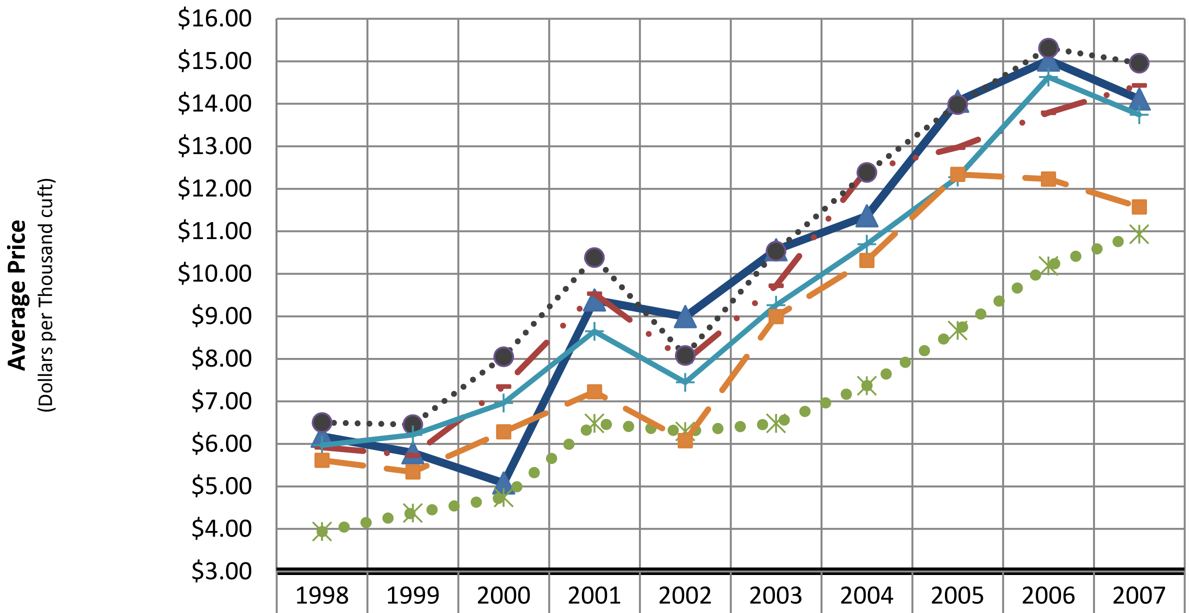
2. Gas Fuels from a Biorefinery

It is generally accepted that the sustained and growing demand for natural gas throughout North America means that the U.S. will increasingly need to find both additional sources of supply as well as implement conservation strategies (National Petroleum Council Committee on Natural Gas 2003). This is especially true not just for Maine, but for all of New England, which has no natural gas production (Federal Energy Regulatory Commission, 2007). The entire region is dependent upon imports from other parts of the U.S. and other countries.

Not only is Maine not able to produce its own natural gas, it has one of the highest average prices for natural gas transported via pipeline (Gaul Energy Information Administration, 2004). In 2007, 44,552 million cubic feet of natural gas was sold in Maine (Energy Information Administration, 2003-2008), at a total cost of $746 Million. Figure 4 provides a comparison of natural gas prices in Maine with the other New England states.

[3] Greenhouse gas emissions are "Emissions of CO2-equivalent greenhouse gases - primarily carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O)." Argonne National Laboratory, "Argonne GREET Model." Last updated: NA. Webpage describing the Greenhouse Gases, Regulated Emissions, and Energy Use in Transporation (GREET) Model. Accessed: 19 March 2009; 17 June 2009. Webpage: http://www.transportation.anl.gov/modeling_simulation/GREET/.

Figure 4: New England Natural Gas Prices
(average of industrial & commercial price)



	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007
Maine	$6.18	$5.79	$5.08	$9.39	$9.00	$10.57	$11.37	$14.06	$15.03	$14.11
New Hampshire	$5.92	$5.73	$7.35	$9.54	$7.95	$9.72	$12.45	$12.97	$13.79	$14.44
Vermont	$3.94	$4.38	$4.74	$6.49	$6.30	$6.49	$7.37	$8.67	$10.19	$10.94
Massachusetts	$6.51	$6.46	$8.05	$10.39	$8.08	$10.54	$12.39	$13.98	$15.31	$14.96
Rhode Island	$5.97	$6.22	$6.97	$8.65	$7.45	$9.27	$10.70	$12.28	$14.63	$13.75
Connecticut	$5.61	$5.34	$6.29	$7.23	$6.08	$9.00	$10.32	$12.34	$12.23	$11.58

Sources: (Energy Information Administration, 1967-2008a; Energy Information Administration, 1977-2008; Energy Information Administration, 1980-2008; Energy Information Administration, 1967-2008b; Energy Information Administration, 1967-2008c; Energy Information Administration, 1967-2008d)

As discussed in previous reports (Dickerson and Rubin 2008; van Heiningen 2006) the initial products that are being evaluated in a Kraft Pulp Mill biorefinery are often liquid fuels and products, including ethanol, acetic acid, and second tier products such as biocrude (Dickerson and Rubin 2008; van Heiningen 2006; Larson, et al. 2006). While these liquid fuels are important, there is some interest in producing gas fuels such as methane, a primary component of natural gas, since much of the underlying infrastructure regarding the transportation of natural gas is already established. The technology required to convert biomass to methane is mature, building on the gasification of coal. Most recently, a facility in Germany built by CHOREN has begun to produce liquid fuels from biomass, with natural gas as a precursor to the final product (Rapier 2008; CHOREN Industries). Although this technology is ready to go, it does have a high capital cost, and will make sense only if the cost for oil is consistently greater than $100/barrel (Bilodeau 2009).

We have found little direct study of using woody biomass on a large scale to produce natural gas, with much focus instead being on liquid fuels. Further research that specifically looks at producing natural gas in a Kraft pulp mill in which natural gas is a major product, rather than liquid fuels and chemicals, is needed to better understand the economics and processing.

3. Pipelines in Maine

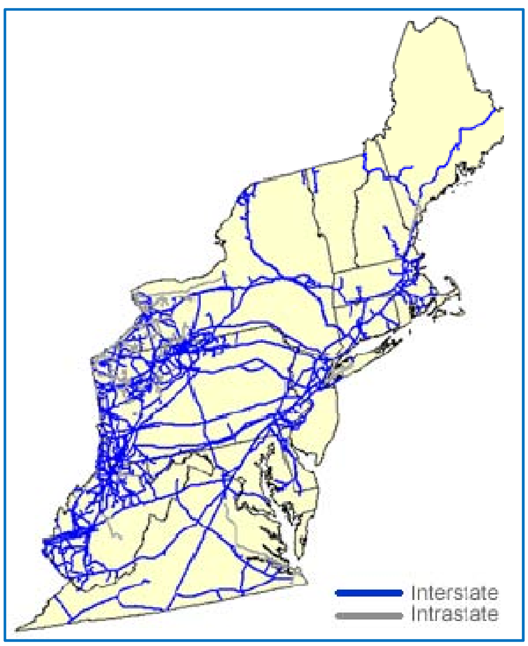
Although the majority of freight transport in Maine is via truck, pipelines do make up a small percentage of the shipped tonnage (Cambridge Systematics Inc. 2002). Maine has both natural gas and crude oil pipelines. The industry restructuring required by the Federal Energy Regulatory Commission (FERC) in the 1980s has meant that most pipeline companies in the U.S. are involved only in transporting goods through those pipelines (Energy Information Administration, 2007; Infrastructure Cross Cutting Team 2007; North American Energy Working Group, 2002). As a result, a biorefinery in Maine using a pipeline would need to contract with both the pipeline company, as well as with a facility/utility on the other end of the pipeline that would use the natural gas.

3.1 Natural Gas Pipelines in Maine

Maine has 607 miles of natural gas pipeline, (Energy Information Administration, 2007) made up of three interstate pipelines, all of which are regulated by the Federal Energy Regulatory Committee (FERC). These three pipelines are:

- Portland Natural Gas Transmission System (PNGTS);
- Maritimes & Northeast Pipeline, owned by Spectra Energy;
- Granite State Gas Transmission Company (Office of the Maine Public Utilities Commission, 2009). Figure 5 identifies the natural gas pipelines in use in the Northeast.

Figure 5: Northeast Region Natural Gas Pipeline Network



Source: Energy Information Administration (2007) "About U.S. Natural Gas Pipelines - Transporting Natural Gas," June 2007, Accessed: 10 November 2008 http://www.eia.doe.gov/pub/oil_gas/natural_gas/analysis_publications/ngpipeline/northeast.html

A biorefinery connecting to a natural gas pipeline would have to either connect directly to the pipeline, much like the gathering lines that are used in a natural gas field, or connect at a compressor station via truck delivery. If the natural gas produced at a biorefinery were not directly connected via pipeline, it is possible that it could be trucked to a point where it could then be added to the pipeline. In order to do this, the natural gas would have to be cooled to a liquid state and then re-gasified when it is added to the pipeline (Haag 2009). At this time, it is not clear that any compressor stations in Maine have the capability to accept deliveries via truck, and it's been confirmed that the existing Maritimes & Northeast Pipeline would not able to accept natural gas at compressor stations. (Thompson 2009)

There are additional factors for natural gas that must be considered, including the quality of the gas and the connection itself. The natural gas from a biorefinery would be able to directly connect with the mainline pipeline only if it matched the characteristics of the gas already in the pipeline. If this were not true, the biorefinery natural gas would have to be further processed to remove any impurities (Energy Information Administration, 2007).

3.1.1 Portland Natural Gas Transmission System (PNGTS)

The Portland Natural Gas Transmission System (PNGTS) provides bidirectional natural gas service between Quebec and western and southern Maine (Cambridge Systematics Inc. 2002). The last 100 miles of pipeline, from Wells, Maine to northern Massachusetts is run jointly with a Maritimes and Northeast Pipeline system (discussed in Section 3.1.2) (Energy Information Administration, 2007). A description of the pipeline sizes and types of line for PNGTS is provided in Table 1.

Table 1: PNGTS Pipelines in Maine

North - Section Facilities, sole owner and operator		
Location	*Number of Miles*	*Pipe size and Type*
Pittsburg, NH to Westbrook, ME	143.8	24 inch diameter; Mainline
Albany Township, ME to Rumford, ME	26.9	12-inch diameter; Rumford lateral
Rumford, ME to Jay, ME	16.6	12-inch diameter; Jay Lateral
Joint Facilities with Maritimes & Northeast, part owner		
Location	*Number of Miles*	*Type of pipe*
Westbrook, ME to Dracut, MA	101.3	30-inch diameter; Joint Mainline
Westbrook, ME	3.8	12-inch diameter; Westbrook Lateral

Source: (Portland Natural Gas Transmission System, 2009)

3.1.2 Maritimes and Northeast Pipeline

The entire Maritimes and Northeast pipeline is 730 miles, and extends from natural gas production facilities in eastern Canada through New England. The U.S. part of the pipeline begins in Calais, ME, and extends to Wells, ME (Energy Information Administration, 2007). A summary of the Maritimes and Northeast Pipelines facilities and pipelines is provided in Table 2.

Table 2: Maritimes and Northeast Pipelines and Facilities in Maine

Sole owner and operator		
Location	*Number of Miles*	*Type of pipe*
Westbrook, ME to U.S. – Canadian Border in Baileyville, ME	205	NA
Adjacent to existing Baileyville, ME pipeline	~1.7	30-inch diameter loop.
Location	*Type of facility*	
Baileyville, ME	Compressor Station and Meter Station	
Richmond, ME	Compressor Station	
Eliot, ME	Compressor Station	
Westbrook, ME	Compressor Station	
Searsmont, ME	Compressor Station	
Brewer, ME	Compressor Station	
Woodchopping Ridge, ME	Compressor Station	
Joint Facilities with Portland Natural Gas Transmission System, joint owner		
Location	*Number of Miles*	*Type of pipe*
Westbrook, ME to Dracut, MA	~100	30-inch diameter; Joint Mainline

Sources: (Cambridge Systematics Inc. 2002; Spectra Energy, 2009; Maritimes & Northeast Pipeline, 2009)

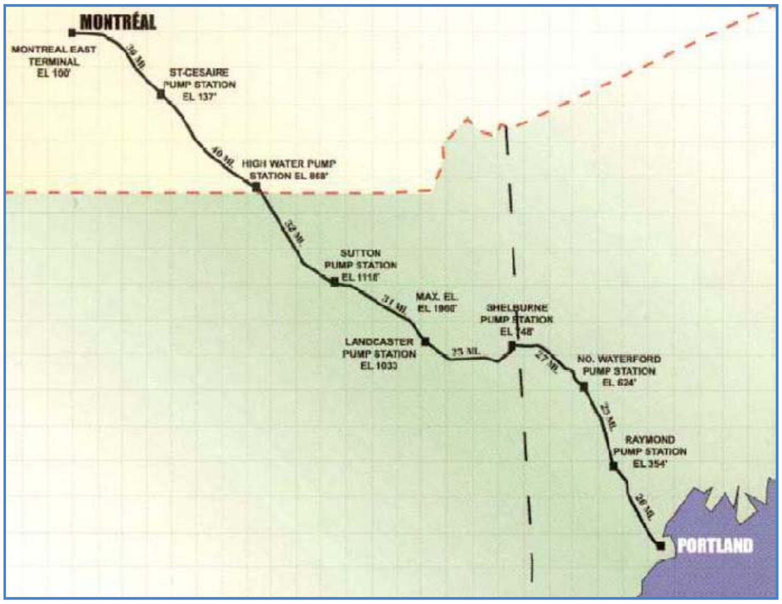
3.1.3 Granite State Gas Transmission Company

The Granite State Gas Transmission Company (GSGTC) provides natural gas to the southern portion of Maine (Energy Information Administration, 2007), connecting with Unitil, the largest state-regulated local distribution gas utility. While GSGTC is regulated by FERC, according the Maine Public Utilities Commission, “Granite is so intermingled with Unitil's local distribution facilities that some argue it should be considered part of them, rather than an interstate pipeline.” (MacLennan 2009). No further information about GSGTC was found.

3.2 Crude Oil Pipelines in Maine

Oil pipeline service in Maine to transport crude oil and is owned by Portland-Montreal Pipe Line (PMPL), which is made up of two companies: Portland Pipe Line Corporation and Montreal Pipe Line Limited (Portland Montreal Pipe Line, 2009). The pipeline route is shown in Figure 6.

Figure 6: Portland-Montreal Pipe Line Route



Source (Portland Pipe Line Corporation & Montreal Pipe Line Limited, 2008)

The pipeline right-of-way has three separate sized pipelines: a 12-inch diameter line, an 18-inch diameter line, and a 24-inch diameter line. The 12-inch line was taken out of service in 1984. The pipelines run approximately 236 miles from Maine to Quebec, and share the right-of-way (from Shelburne, NH to Westbrook, ME) with the PNGTS natural gas pipeline (Portland Pipe Line Corporation Portland Pipe Line Corporation, NA).

PMPL has two tank farms, one at each end of the pipeline: South Portland, ME and Montreal, Quebec. In South Portland, two vessels carrying in excess of one million barrels of crude oil can be unloaded at the same time, and the tank farm has storage capability of approximately 3.5 million gallons in 23 tanks (Portland Montreal Pipe Line, 2009). The Montreal, Quebec facilities have a “delivery system and six storage tanks with 1.7 million barrels of moveable storage capacity” (Portland Pipe Line Corporation & Montreal Pipe Line Limited, 2008).

PMPL has plans to reverse the flow of the existing 18-inch diameter pipeline from Montreal into South Portland, where the crude oil would be loaded onto barges for shipment to other parts of the U.S. If there is sufficient support by shippers, this transition is planned to be in service by the 2^{nd} quarter of 2010 (Portland Pipe Line Corporation & Montreal Pipe Line Limited, 2008).

3.3 Transport via pipelines for Maine Biorefineries

While it is feasible to use pipelines to transport the products made from a biorefinery, it is unlikely that the amount of product produced (at least initially) would be enough to economically justify the expense of installing a pipeline to the biorefinery site. The extension of a pipeline requires a major capital investment, and to justify such a project would necessitate a large volume of gas for a long period of time. (Haag 2009)

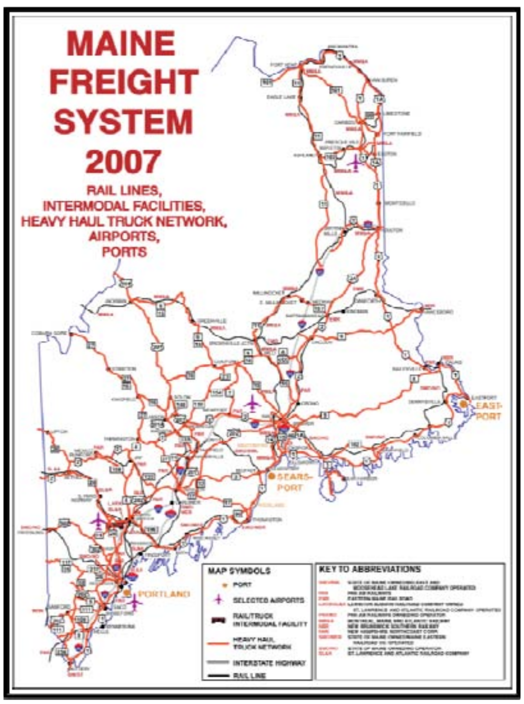
If the product produced matched what is currently sold in the market (for example, diesel fuel or home heating oil), it may be more feasible to transport the product via established tanker truck and rail than through a pipeline, as the infrastructure for the pipeline would need to be installed at the biorefinery.

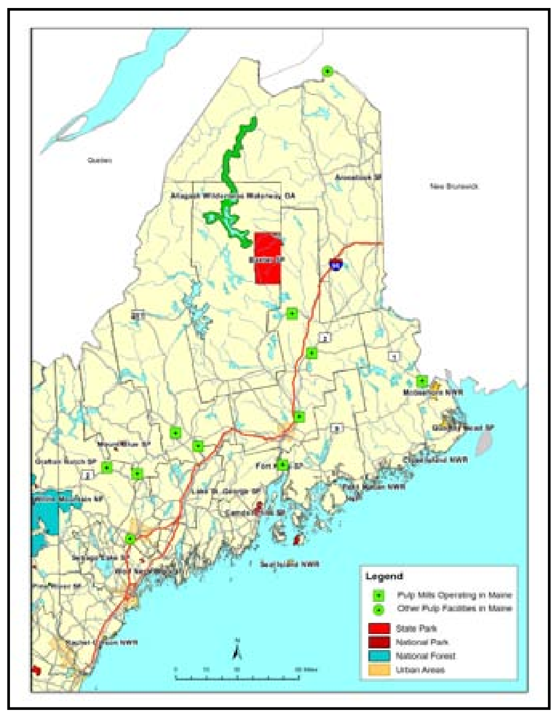
4. Transport costs

Although the majority of freight in Maine is moved via truck (Cambridge Systematics Inc. 2002), there is substantial use of rail by the pulp and paper industry. However, shipping biorefinery products would be significantly different than for from pulp and paper products, given the obvious differences in the physical make-up of the products: solid materials vs. liquid and gas.

Figure 7 shows both the freight system in use in Maine, as well as the location of pulp and paper mills.

Figure 7: Maine Freight System and Pulp & Paper Mills





Sources: (Maine Department of Transportation, NA-a)
(Dickerson and Rubin 2008)

4.1 Rail lines in Maine

The pulp and paper industry in Maine has a long history of using rail lines to move products, with an estimate that approximately 65% of rail freight traffic is directly associated with the larger pulp and paper mills in Maine (HNTB Corporation December 2007). Rail companies are classified by the Surface Transportation Board as Class I, II or III railroads, based on their annual operating revenues (Board Surface Transportation Board). There are seven Class I railroads in the United States responsible for most of the freight movement within the country. None of these seven operate in Maine. The classification of railroad types is as follows:

- Class I - $250 million or more
- Class II - $20 million or more
- Class III - $0 to $20 million (Board Surface Transportation Board)

There are three Class II railroads in Maine, and all connect with Class I carriers (Cambridge Systematics Inc. 2002). Table 3 identifies Maine rail companies, with a further description of the Class II railroads.

Table 3: Railroad Companies in Maine

Railroad	Coverage, Maine Mileage, Description	Type of Railroad
Montreal, Maine & Atlantic Railway (MMA)	414 miles; Intermodal Terminal in Presque Isle. Connection to Chicago, via Class I service. Direct service to Montreal.	Class II
St. Lawrence & Atlantic Railroad (SL&A)	Connection to Chicago, via Class I service. Direct service to Montreal.	Class II
Springfield Terminal Railway/Guilford Transportation/Pam Am	372 miles; Intermodal Terminal in Waterville. Has interconnections to 4 Class I railroads.	Class II
Maine Eastern Railroad[1]	92 miles	Class III
New Hampshire North Coast Corporation[2]	1 mile	Class III
NB Southern Railway/Eastern Maine Railway Company[3]	105	Class III

1: MDOT has returned 90 miles of that trackage to active operation (Brunswick to Rockland and Augusta) through a lease and operating agreement with Maine Eastern Railroad (a subsidiary of the Morristown & Erie Railroad) in the fall of 2003. Maine Coast RR provided freight and excursion service from 1991-2000. Safe Handling Rail provided service from 2001-2003 (Maine Department of Transportation, NA-b).

2: No additional information regarding this rail line is available.

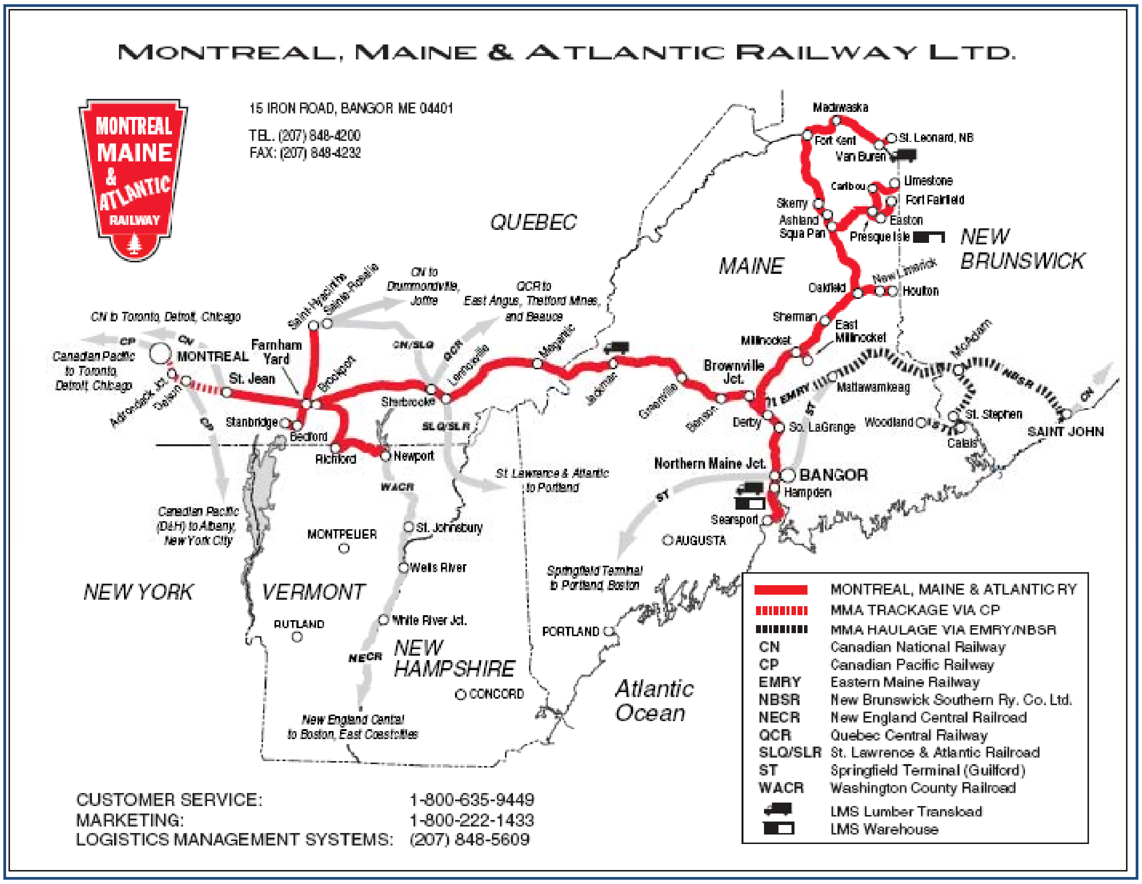
3: "NB Southern Railway and Eastern Maine Railway are separate operating entities because we operate in 2 different countries but this is not seen from a commercial standpoint." (Kane 2009)

Sources: (Cambridge Systematics Inc. 2002; Kane 2009; Burns ; MaineDOT)

4.1.1 Montreal, Maine & Atlantic Railway

The Montreal, Maine & Atlantic Railway (MM&A) has been in operation since 2003, when Rail Line Inc. (a rail management company), purchased the former Bangor & Aroostook Railroad (BAR), and renamed it (Montreal, Maine and Atlantic Railway; Rail World, Inc; Rail World, Inc). The pulp and paper industry is the major source of freight for MM&A, and it connects with nine other railroads, including Class I lines (Montreal, Maine and Atlantic Railway). The route map of the Montreal, Maine & Atlantic Railway is shown in Figure 8.

Figure 8: Montreal, Maine & Atlantic Railway

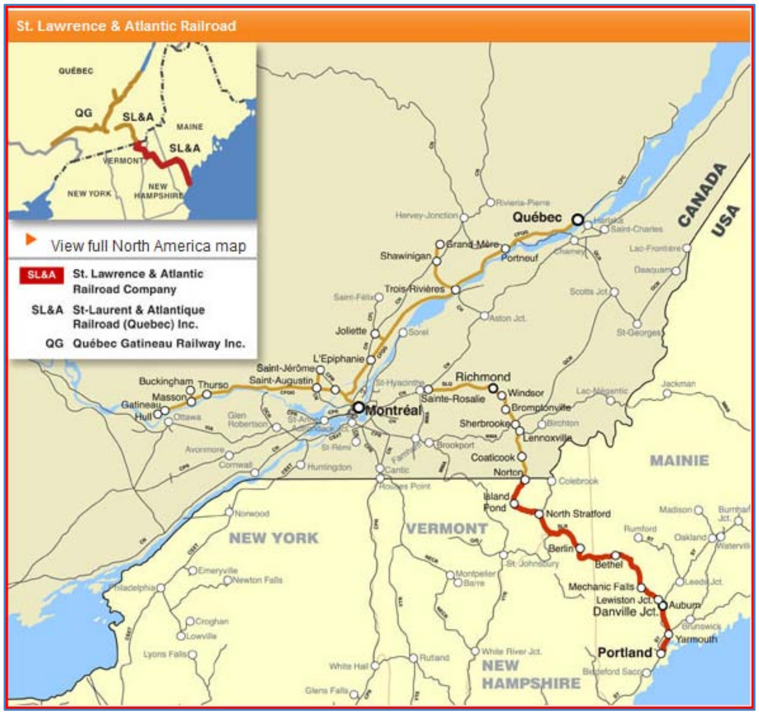


Source: (Montreal, Maine and Atlantic Railway)

4.1.2 St. Lawrence & Atlantic Railroad

The St. Lawrence & Atlantic Railroad (SL&A) is a subsidiary of Genesee & Wyoming Inc. (Genesee & Wyoming Inc.). SL&A is affiliated with Canadian National (CN) Railroad, a large rail line serving all of North America (Canadian National Railway Company, 2009). The SL&A line runs from Portland, ME to Montreal, Canada (Maine Department of Transportation, NA-b). SL&A also connects with Pan Am Railways, thereby providing direct rail link to many of the paper mills (Genesee & Wyoming Inc.). A map of the rail line for the SLA is provided in Figure 9.

Figure 9: St. Lawrence & Atlantic Railroad Route Map

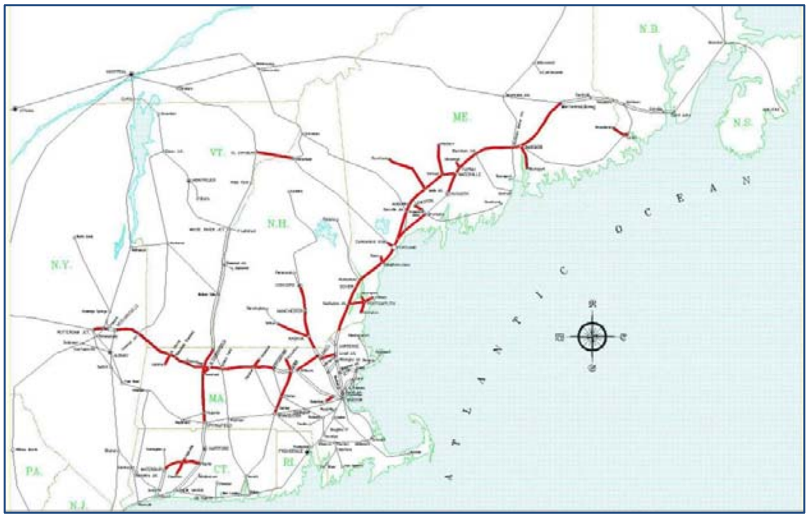


Source: (Portland Pipe Line Corporation & Montreal Pipe Line Limited, 2008; Genesee & Wyoming Inc.)

4.1.3 Pan Am Railway

In 2006, the rail operations of Guilford rail were renamed Pan Am Railways, with Guilford Transportation Industries putting all their rail systems under the same name (Kalmbach Publishing Co, 2006; Wikipedia, 2009). Pan Am Railways provides service to the majority of the paper mills in Maine, as well as direct service to the port of Portland (Cambridge Systematics Inc. 2002). Pan Am connects with four different Class I railroads (all outside of Maine), as well as other regional and short line railways within Maine (Cambridge Systematics Inc. 2002). A map of the rail line for Pan Am Railways is provided in Figure 10.

Figure 10: Pan Am Railways Route Map



Source: (Pan Am Railways)

4.2 Transport costs

The pulp and paper industry in Maine has long relied on railroads and truck freight to deliver their products, and it is likely the same relationships would continue with the products from a biorefinery, at least in the near term. Table 4 provides the generalized transport costs used (per ton mile) to calculate transport costs from pulp facilities in Maine. Table 5 notes the costs based upon per gallon of truck or rail car capacity.

Table 4: Generalized Liquid Transport Cost – Assumptions

Type of Expense	Trucking ($ per ton mile)	Rail ($ per ton mile)
Loading/Unloading: price per gallon	0.02	0.015
Fixed Cost: price per 100 gallons		8.80
Distance Dependent Costs. Includes fuel, insurance, maintenance and permitting	1.30 per mile/truckload	0.0075 per mile/100 gals
Time Dependent Costs	32 per hr/truckload	
Capacity: in Gallons	10,000	29,000
Miles per gallon	5	
Ton Miles per gallon		423
Cost of diesel fuel	$2.50	$2.50

Assumption: The cost of transporting all liquids is considered to be the same on a volumetric basis.
Source: (Meyer 2008b; University of California Davis, 2008).

Table 5: Generalized Transportation Costs for Liquid Products from Pulp Facilities in Maine

Facility	Town	Trucking costs per gallon of truck capacity			Rail costs per gallon of rail car capacity		
		Auburn	Bangor	Portland	Auburn	Bangor	Portland
Cascades Auburn Fiber, Inc	Auburn	$0.02	$0.04	$0.03	$0.02	$0.02	$0.02
Domtar Industries Inc	Baileyville	$0.06	$0.04	$0.06	$0.02	$0.02	$0.02
Fraser Papers Inc.	Madawaska	$0.08	$0.06	$0.09	$0.02	$0.02	$0.02
Katahdin Paper Company, LLC	East Millinocket	$0.06	$0.03	$0.06	$0.02	$0.02	$0.02
Lincoln Paper & Tissue	Lincoln	$0.05	$0.03	$0.05	$0.02	$0.02	$0.02
Madison Paper Industries	Madison	$0.04	$0.03	$0.04	$0.02	$0.02	$0.02
NewPage Mill	Rumford	$0.03	$0.04	$0.04	$0.02	$0.02	$0.02
Red Shield Environmental, LLC	Old Town	$0.04	$0.02	$0.05	$0.02	$0.02	$0.02
Sappi Fine Paper North America	Skowhegan	$0.03	$0.03	$0.04	$0.02	$0.02	$0.02
Verso Paper: Androscoggin Mill	Jay	$0.03	$0.04	$0.03	$0.02	$0.02	$0.02
Verso Paper: Bucksport Mill	Bucksport	$0.04	$0.03	$0.04	$0.02	$0.02	$0.02

Note: We used the address for Safe Handling, Inc. for distances to Auburn and the zip codes for Bangor and Portland (Congress St) for the respective distances.
All pulp facilities are on a rail line, but loading and offloading capabilities have not been confirmed.
Source: (Dickerson and Rubin 2008)

5. Summary

The inclusion of ethanol as part of energy use in the United States is required by EISA. It is almost certain that the use of cellulosic ethanol will be necessary to meet the legal requirements outlined in EISA, and obtaining that ethanol from woody biomass can be part of meeting those requirements. An analysis of energy consumption, carbon dioxide emissions, and greenhouse gas emissions when producing cellulosic ethanol via wood fermentation compared to corn ethanol via fermentation indicates that there is a benefit to producing ethanol via lignocellulosic feedstocks. Further work needs to be performed to determine the full costs and benefits of cellulosic ethanol, ideally through using a full-scale life cycle assessment.

Maine has no natural gas of its own, and it relies on inter- and intra-state pipelines to ship natural gas into the State. These two factors help explain why Maine has one of the highest average prices for natural gas in New England. Using woody biomass to produce natural gas is a known process, albeit one that has a significant capital expense. Further research on producing natural gas in a Kraft pulp mill, one that addresses the amount of biomass needed, the scale of the operation, and compatibility with pulping operations are necessary to determine if this is a route that will allow a Kraft pulp mill to evolve into a biorefinery producing gas.

While the use of pipelines for natural gas and crude oil in Maine is well established, it is unlikely to be cost effective for Kraft pulp and paper mills to transport any product via pipeline until their biofuel production volumes and incremental expected profits would justify such new capital expenditures. The infrastructure of the pipelines and compressor stations would have to be modified, and this would make sense only if there were a significant volume of either natural gas or biocrude that could be consistently produced for the long-term. Given the range of products that may be possible from Kraft mills, and the economic analysis that each mill should perform for their operations, it is expected that the product optimal product mix will vary considerably among Kraft mills throughout the state in the coming years.

Maine's pulp and paper mills already have well-established relationships with both rail and trucking services. Expanding their product line to include liquid products can be seen as part of the evolution of many Kraft pulp and paper mills into biorefineries. The subsequent shipment of these products could be beneficial both to the mills and to the transport companies that will deliver the products to market.

While there are general numbers for transportation, and subsequently a general understanding of distance dependent transport costs, Maine specific transportation costs for liquid products needs to be determined. Further research is required to fully evaluate the Maine specific transportation costs to Kraft pulp mills, thereby identifying the most expensive and/or most price sensitive factor in transport costs. This should include an analysis of the price of diesel fuel for transport with regards to trucking and rail, and a better understanding of when those transport costs may exceed that of pipeline expenditure costs, thereby enabling a better understanding of whether pipelines can be part of the transportation options for Kraft pulp mills.

Finally, further research including LCAs and economic analysis should be conducted on the next generation of products that can be produced at Maine biorefineries, including fuels like butanol, diesel fuel, jet fuel and other products like specialty chemicals.

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