New Hampshire
Bio-oil Opportunity Analysis

September
2004

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This material was prepared with financial support from the New Hampshire Office of Energy & Planning. However, any opinions, findings, conclusions, or recommendations expressed are those of the Contractor and do not necessarily reflect the views of the New Hampshire Office of Energy & Planning and do not constitute an endorsement of products or services mentioned.

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Introduction

This *Bio-oil Opportunity Analysis* is intended to provide New Hampshire state government, forest industries, community groups, citizens, bio-oil facility developers and others information on the opportunity that bio-oil production may provide in New Hampshire. This research, part of New Hampshire's ongoing effort to identify and explore opportunities to secure sustainable markets for low-grade wood, is a companion to the *Bio-oil Commercialization Plan* produced by Cole Hill Associates.

This *Opportunity Analysis*, when used in concert with the *Commercialization Plan* (see Appendix) contains many of the aspects of a commercial feasibility study, though not all. Because of the public nature of this analysis, the analysis does not definitively identify where a site would be located, what loggers or others would supply the facility, who would manage the facility, or contain contracts for product produced. Instead, this analysis highlights the available wood resource, potential opportunities and challenges associated with bio-oil development in New Hampshire, and provides an introduction to the technology used to produce bio-oil. The *Commercialization Plan* explores the risk factors, capital necessary, existing North American companies producing bio-oil, and economic analysis / *pro forma* statements of bio-oil production in New Hampshire.

During this process, Innovative Natural Resource Solutions LLC (INRS) worked closely with the New Hampshire Office of Energy and Planning (and formerly the Governor's Office of Energy & Community Services), the New Hampshire Department of Resources & Economic Development, BEDCO and Cole Hill Associates. During this process, some parties, including INRS, signed a confidentiality agreement with one company, Ensyn, in order to better understand their technology and how it might fit in New Hampshire. Cole Hill Associates also signed a confidentiality agreement with DynaMotive, another firm that produces bio-oil. Information from both of these firms was used to inform the development of this Opportunity Analysis, but in no way is confidential or proprietary information revealed in this document.

The team that worked on this project, including the New Hampshire Office of Energy and Planning, BEDCO, Cole Hill Associates and Innovative Natural Resource Solutions LLC believe that this document provides a better understanding of both the challenges and opportunities that bio-oil presents, and hope that others will find this work helpful in moving economic development and renewable energy forward in rural New Hampshire.

> *Innovative Natural Resource Solutions LLC (INRS) believes the information in this report to be correct, based upon information sources we deem to be reliable. Given the dynamic nature of wood markets and the rapid changes in bio-oil production technology, INRS does not warrant the information in this report against all errors or inaccuracies.*

Executive Summary

This *Bio-oil Opportunity Analysis* is intended to provide New Hampshire state government, forest industries, community groups, citizens, bio-oil facility developers and others information on the opportunity that bio-oil production may provide in New Hampshire. This analysis, part of New Hampshire's ongoing effort to identify and explore opportunities to secure sustainable markets for low-grade wood, includes the *Bio-oil Commercialization Plan* produced by Cole Hill Associates.

"Bio-oil" is an organic, liquid fuel produced through a process known as pyrolysis. Pyrolysis is a thermal process that rapidly heats biomass (such as wood) in an oxygen-free environment to a carefully controlled temperature, and then very quickly cools the volatile products formed during the reaction. This procedure produces three products: a liquid, char, and gas. While this analysis reviews all three of these products, the technology that is the subject of review in this opportunity analysis -- fast pyrolysis -- is specifically designed to maximize the output of liquid, or "bio-oil".

Bio-oil can be burned to produce heat and electricity, and many see it as an intermediary to a number of higher-value chemicals, pharmaceuticals, and food additives. While some work has been conducted in this area, most of the chemicals that could be derived from bio-oil have not been isolated at the commercial level, and doing so may prove extremely challenging.

For the purposes of this analysis, it is assumed that a bio-oil facility would use forest-derived whole-tree chips and sawmill residue as feedstock. Availability and pricing of feedstock in three areas are detailed in order to provide an understanding of the wood resources available in three regions of the state. Low-grade wood is anticipated to be available on a sustainable basis in the three regions analyzed.

All scenarios considered in the commercialization plan assume sale of electricity. For this reason, a detailed analysis of current premium markets for renewable electricity in the region is provided, with a specific emphasis on opportunities for biomass. A New Hampshire bio-oil facility could qualify to participate in the high-value renewable energy markets in Massachusetts, Rhode Island and could likely qualify in Connecticut. Participation in these markets would provide a meaningful premium for electricity generated, and would contribute to the success of a bio-oil project.

Bio-oil represents one opportunity for New Hampshire as it seeks to maintain a market for low-grade wood. Economic and other assumptions used in this study support a conclusion that bio-oil production and marketing are feasible economically and environmentally under the circumstances specified herein. The spreadsheet models in this study are available from the Office of Energy & Planning.

Introduction to Bio-oil

1.1. What is "Bio-oil"?

"Bio-oil" is an organic, liquid fuel produced through a process known as pyrolysis. Pyrolysis is a thermal process that rapidly heats biomass in an oxygen-free environment to a carefully controlled temperature, and then very quickly cools the volatile products formed during the reaction. This procedure produces three products: a liquid, char, and gas. While this analysis reviews all three of these products, the technology that is the subject of review in this opportunity analysis -- fast pyrolysis -- is specifically designed to maximize the output of liquid, or "bio-oil".

Typical Output of Products by Type of Pyrolysis[1]

Process	Liquid	Char	Gas
Fast Pyrolysis	75%	12%	13%
Direct combustion	30%	35%	35%
Gasification	5%	10%	85%

The liquid that results from fast pyrolysis is referred to by a variety of names including pyrolysis liquid, pyrolysis oil, bio-oil, bio-crude-oil, bio-fuel-oil, wood liquids, wood oil, liquid smoke, wood distillates, pyroligneous tar, pyroligneous acid, and liquid wood.[2] For this entire report, the liquid product that results from fast pyrolysis is referred to as "bio-oil".

1.2. Benefits of Bio-oil

In the year 2000, 59% of New Hampshire's primary energy consumption was from fossil fuels; if current trends continue, fossil fuels are expected to comprise 69% of the state's primary energy consumption by 2020.[3] Bio-oil, because it is produced from renewable resources and has a different emissions profile than coal or oil, has a number of benefits for the state that fossil fuels do not.

Biomass power, which accounted for 3.8% of the electricity generated in New Hampshire in 2000[4], has long provided electricity, heat and steam to the state's industries and citizens. However, biomass power faces challenges in terms of energy-efficient power generation and ability to manage and transport the fuel source. Traditional biomass conversion technology is combustion in either stoker- fed grates or fluidized bed combustors with a water / steam cooled boiler. New Hampshire's existing commercial

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[1] Czernik, Stefan. *Review of Fast Pyrolysis of Biomass.* Presentation by National Renewable Energy Laboratory, Department of Energy. Concord, NH. August 16, 2002.
[2] Bridgewater, Tony. *A Guide to Fast Pyrolysis of Biomass for Fuels and Chemicals.* PyNe Guide 1, Aston University, (UK), March 1999.
[3] Governor's Office of Energy and Community Services. *New Hampshire Energy Plan.* November 2002.
[4] Ibid

wood-fired power plants all use stoker-fed grates to achieve combustion. Nominal efficiency for this technology is 21%, using a biomass feedstock with 50% moisture content[5]; combined cycle combustion can improve this efficiency by as much as 40%.[6] In a recent study for the New Hampshire Department of Resources and Economic Development, it was estimated that it costs New Hampshire's wood-fired power plants roughly $0.054 / kWh to produce electricity[7]. Current wholesale electricity prices average below this level, and are not expected to reach a point where wood-fired power plants are modestly profitable until around 2013[8]. Proponents of bio-oil claim that their product, when combusted in high efficiency turbines, offers significant advantages over traditional combustion technology.

Because it is a liquid, bio-oil can be transported, stored and handled using equipment designed to handle more traditional fuels. This represents a potentially significant advantage over traditional solid fuels (whole tree chips, for example), because it is expensive and cumbersome to transport and handle moist, bulky biomass for use in energy generation. Further, bio-oil is in some cases compatible with the existing fossil fuel and electricity generation infrastructure in North America, and allows entry of a biomass-based fuel into areas traditionally dominated by fossil fuels.

The impact of bio-oil production and potential benefits to the environment and local economy add to its attractiveness. By providing a market for local forestry products and by locating in proximity to the state's timber base, a bio-oil plant could be a significant contributor to rural economic development. Further, because bio-oil is produced from a renewable feedstock, it is considered by many to be carbon-neutral, and does not contribute to greenhouse gas emissions. This may make it possible for a bio-oil production facility, or a facility using bio-oil to generate electricity, to participate in certain programs designed to encourage renewable energy generation, or to receive financial incentives for reducing atmospheric emissions of carbon. The economic and environmental impacts and benefits of bio-oil production and use are covered in depth later in this opportunity analysis.

1.3. Methods of Manufacturing Bio-oil

Bio-oil can be produced from any biomass waste material. In most applications, this biomass must be dried to low moisture content and ground to a very fine size. One developer of bio-oil production technology, DynaMotive, has bench tested over fifty feedstocks to date, including wood, wood manufacturing residue, agricultural products

[5] All moisture content reported is "wet weight basis", or as is. In other words, 50% moisture content means that half of the weight is water.
[6] DynaMotive Energy Systems Corporation and R. Thamburaj of Orenda Space Corporation. *Fast Pyrolysis of Biomass for Green Power Generation.* First World Conference and Exhibition on Biomass for Energy and Industry. 2000.
[7] Innovative Natural Resource Solutions LLC and Draper / Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.* January 2002.
[8] Governor's Office of Energy and Community Services.

and residues, municipal solid waste, pulp mill sludge, peat, and newsprint[9]. DynaMotive is focusing their development efforts on wood and sugarcane bagasse in an effort to maximize yield and minimize process development risk[10]. Another firm, Ensyn, has tested hardwoods, softwoods, hardwood bark, softwood bark, corn fiber, bagasse, and waste paper for the production of bio-oil.[11]

There are a number of fast pyrolysis methods used to convert biomass into bio-oil; each of these methods has advantages and challenges[12]. Some of these methods are reviewed in greater depth later in this opportunity analysis.

Type of Pyrolysis Unit	**Strengths**	**Challenges**
Fluid Beds	• Good temperature control • Easy scalability • Well understood technology • In commercial operation	• Small particle sizes needed • Heat transfer to bed at large scale not proven
Circulating Fluid Beds	• Good temperature control • Large particle sizes possible • Suitable for very large throughput	• Hydrodynamics more complex than other types • Char combustion requires careful control • Heat transfer to bed unproven at large scale
Rotating Cone	• Centrifugal force moves heated sand and biomass up cone	• Heat transfer to bed unproven at large scale • Small particle sizes needed
Vacuum Pyrolysis	• Much lower temperature required	• Liquid yield of 35 – 50% much lower than other technologies

There are other types of fast pyrolysis reactors that have been developed or are in the early stages of research and development; however, these reactors are not approaching commercial readiness, and therefore are not considered in this opportunity analysis. At this time, there are fluid bed, circulating fluid bed, rotating cone, and vacuum pyrolysis in operation in commercial, pilot plant, academic, or laboratory settings worldwide.

9 DynaMotive Energy Systems Corporation. *Bench Tested BioTherm Feedstocks.*
10 DynaMotive Energy Systems Corporation and R. Thamburaj of Orenda Space Corporation.
11 Ensyn Group, Inc. *Bio-oil Combustion Due Diligence: The Conversion of Wood and Other Biomass to Bio-oil.* June 2001.
12 See, for example, Czernik, Stefan or Bridgewater, Tony.

1.4. Qualities of Bio-Oil

Bio-oil is a dark brown mobile liquid with roughly 54% the heating value of #6 fuel oil. Its heating value compares with air-dried wood, methanol, and ethanol.

Comparative heating value of fuels[13]		
	MJ/l	BTU/U.S. gallon
Bio-oil (wood)	21.0	75,500
Bio-oil (bark)	22.7	81,500
Fuel Oil (#6)	38.9	153,200
Fuel Oil (#2)	35.2	138,500
Methanol	17.5	62,500
Ethanol	23.5	84,000

Bio-oil can range in color from dark green or dark red through black, depending upon the feedstock and process used to manufacture the product. Bio-oil has a distinct smell, often described as acrid and smoky. Bio-oil is composed of hundreds of different chemicals, ranging from volatile compounds like formaldehyde and acetic acid to more stable phenols and anhydrosugars.[14]

Bio-oil contains between 15% and 40% water (by weight), depending upon the process used to produce and collect the liquid. Bio-oil is immiscible with petroleum-derived fuels (though has some potential for blending with petroleum if appropriate technologies are used). The liquid is chemically unstable, and breaks down over time or when exposed to high heat. As bio-oil ages, the viscosity increases, the volatility decreases, and eventually phase separation may occur[15]. This chemical instability does not prevent bio-oil from being used in commercial applications, but does mean that it must be transported, stored, and used in a time frame and manner that accommodates this property.[16]

[13] Ensyn Group, Inc. *Bio-oil Combustion Due Diligence: The Conversion of Wood and Other Biomass to Bio-oil.* June 2001.
[14] Bridgewater, Tony. *A Guide to Fast Pyrolysis of Biomass for Fuels and Chemicals.* PyNe Guide 1, Aston University. March 1999.
[15] Czernik, Stefan.
[16] Bridgewater, Tony.

Typical Properties of Wood-Derived Bio-oil[17]	
Moisture content (by weight)	15% - 30%
pH	2.5
Elemental Analysis	
Carbon	56.4%
Hydrogen	6.2%
Oxygen (by difference)	37.3%
Nitrogen	0.1%
Ash	0.1%
Solids (char)	0.5%

[17] Bridgewater, Tony.

1.5. Chemical Properties of Wood-derived Bio-oil

Chemical properties and composition of wood-based bio-oil products from leading producers (self-reported)

	DynaMotive Pine / Spruce 100% wood[18]	**DynaMotive** Pine / Spruce 53% wood / 47% bark[19]	**Ensyn (Red Arrow)** Mixed hardwoods[20]
pH	2.3	2.4	*
<u>Percent by weight</u>			
Water content	23.3	23.4	24
Lignin content	24.7	24.9	*
Cellobiosan	2.3	1.9	*
Glyoxal	2.3	1.9	*
Hydroxyacetaldehyde	9.4	10.2	*
Levoglucosan	7.3	6.3	*
Formaldehyde	3.4	3.0	*
Formic acid	4.6	3.7	*
Acetic acid	4.5	4.2	*
Acetol	6.6	4.8	*
Solids content	<0.10	<0.10	*
Ash content	<0.02	<0.02	0.16
<u>Percent by weight</u>			
Carbon	*	*	54.5
Hydrogen	*	*	6.4
Nitrogen	*	*	0.18
Sulfur	*	*	<0.03
Oxygen (by difference)	*	*	38.9
Density (kg/L)	1.20	1.19	1.20
Caloric value (MJ/kg)	16.6	16.4	17.5
Kinematic viscosity (cSt @20°C)	73	78	*
Kinematic viscosity (cSt @60°C)	*	*	10
Kinematic viscosity (cSt @80°C)	4.3	4.4	*

* Not reported in the literature

[18] DynaMotive Energy Systems Corporation and R. Thamburaj of Orenda Space Corporation. *Fast Pyrolysis of Biomass for Green Power Generation.* First World Conference and Exhibition on Biomass for Energy and Industry. 2000.
[19] Ibid
[20] Struzl, Ray of Manitowoc Public Utilities.

2. Applications of Bio-Oil

In addition to use as a fuel for power and heat, bio-oil can serve as the base for the manufacture of a wide range of organic chemicals. These uses are introduced here, and applicable uses discussed in depth later in this opportunity analysis.

2.1. Bio-Oil as a "Green Fuel"

The nearest term commercial use of bio-oil is in generation of power and heat. With modest equipment modifications, bio-oil can be substituted for fuel oil or diesel in a number of static applications including stationary diesel engines, gas turbines, boilers and furnaces. Bio-oil has been successfully test co-fired with coal, providing 5% of the BTU value to a 20 MW boiler[21]. Bio-oil has a successful record of utilization in commercial boilers to provide industrial process heat and drying, and is approved for use in district heating utility boilers in Sweden[22]. ORENDA Aerospace Corporation has tested bio-oil in its 2.5 MW combustion turbine-powered generator.[23]

Bio-oil is derived from renewable resources, and is considered a renewable fuel. Because of this, a facility using bio-oil to generate electricity for sale may qualify for some programs designed to encourage renewable energy, such as Renewable Portfolio Standards (RPS) in neighboring states. An RPS is a regulatory requirement that any supplier of electricity must derive a specified portion of that electricity from renewable energy sources. Maine, Massachusetts, Rhode Island and Connecticut all have RPSs that allow biomass power plants to participate; Massachusetts and Connecticut have specific provisions that encourage the construction of new facilities that use biomass to generate electricity[24].

2.2. Chemicals

A wide range of "green chemicals" can be extracted from bio-oil[25], and are an attractive possibility to producers of bio-oil because they generally offer much higher value added compared to fuels and energy products. Chemicals can be isolated, extracted and processed to meet customer specifications, and it is likely that the remaining bio-oil will still retain some value as a fuel. In order to recover specific chemicals for value-added use, it is necessary that these chemicals be present in the bio-oil in large enough quantity

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[21] Struzl, Ray of Manitowoc Public Utilities. *The Commercial Co-firing of RTP Bio-Oil at the Manitowoc Public Utilities Power Generating Station.* June 1997.
[22] Hogan, Ed. *The Pyrolysis Biorefinery Concept for the Production of Green Fuels and Chemicals.* Presentation by CANMET Energy Technology Centre, Natural Resources Canada. August 16, 2002.
[23] Button, Frank of Orenda Aerospace Corporation. *Orenda Aerospace Corporation: Overview.* Presentation in Concord, NH. August 16, 2002.
[24] Database of State Incentives for Renewable Energy. *States with a Renewables Portfolio Standard.* April 2002.
[25] Bridgewater, Tony.

to make recovery economic. For wood-based bio-oil, such chemicals include hydroxyacetaldehyde, acetic acid, formic acid, levoglucosan and levoglucosenone[26].

These chemical compounds have the potential to serve as the basis for a wide variety of chemicals. Food flavorings are extracted from bio-oil in a number of countries, including the United States. Researchers are also working on developing natural resins and polymers for use in engineered wood products; these have already undergone mill trials[27]. Additional tested uses of bio-oil include: as a base for organic wood preservatives, as an ingredient in slow-release fertilizer used in commercial agriculture, as an octane enhancer and as a hydrogen source. A product has been developed using bio-oil that serves as an emissions control agent for SOx and NOx in coal combustors[28].

At a recent forum on bio-products in Maine[29], a number of chemicals and co-products were identified that can be derived from biomass, including through the pyrolysis process. These included fatty acids (used as lubricants), sterols and gallic acid (used in the pharmaceutical sector), maltol (used as a food additive), proanthocyanidins (an anti-oxidant), and taxans (used in pharmaceuticals). The following graph, presented at the forum[30], shows co-products chemicals that may be derived from biomass, and the price these chemicals may derive in the marketplace.

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[26] Radlein, Desmond, of Resource Transforms International Ltd.. *Chemicals and Materials from Bio-oil.* June 1999.
[27] Boulard, David C. *Bio-oil: The New Crude.* Presentation by Ensyn in Concord, NH. August 16, 2002.
[28] Radlein, Desmond of Resource Transforms International Ltd
[29] *Maine Bio-Products Forum: Converting Cellulose Into Sales*. University of Maine, Orono. March 2, 2004.
[30] Chornet, Esteban. *River Valley Pyrolysis Project.* March 2, 2004. University of Maine, Orono.

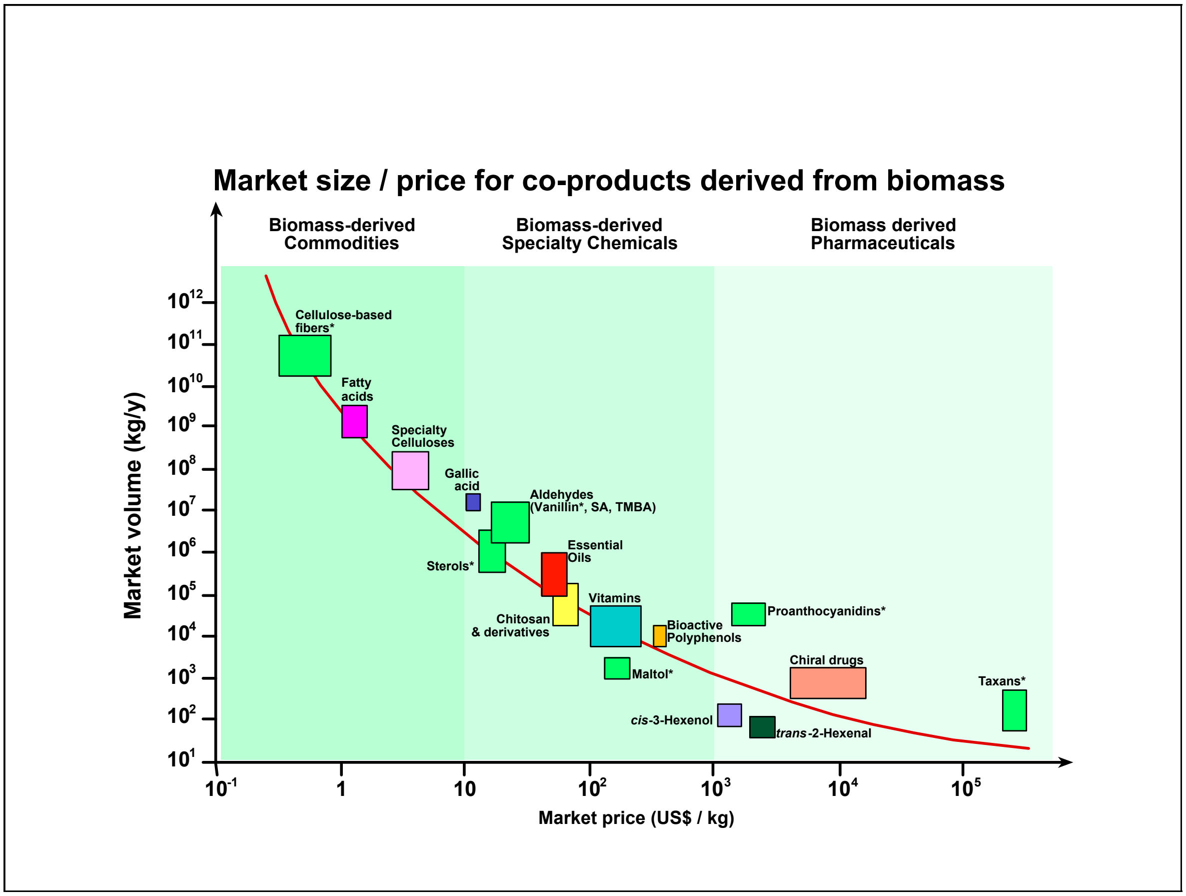

Figure 1. Potential Co-Products Derived From Biomass

While “green chemicals” represent a significant potential market for bio-oil producers, it is important to note that many of these chemicals have not been successfully isolated from bio-oil, and the processes necessary to isolate certain chemicals may prove uneconomical.

2.3. Bio-Refinery

Some advocates of bio-oil see it as the core product of a “bio-refinery” or “bioplex”, where an economically optimum combination of energy, chemicals and materials are manufactured[31]. This is an integrated approach where the forest industry (and potentially the agricultural sector and municipalities) provides the feedstock and are the users of energy and chemicals from the facility. The energy and utility industries provide investment, and serve as customers and distributors of energy and fuels. In the bio-refinery model, the government and manufacturing sectors play secondary roles, providing policy support and markets for the output. While offering future potential if a bio-oil manufacturing facility is established in New Hampshire, the feasibility of establishing a complete bio-refinery is beyond the scope of this study.

[31] Hogan, Ed.

3. Markets for Low-Grade Wood in New Hampshire

3.1. Importance of Markets for Low-Grade Wood

New Hampshire's forests – eighty percent of which are privately owned[32] – have a significant volume of low-grade and commercially undesirable trees. Analysis of the USDA Forest Service Forest Inventory and Analysis conducted by the New Hampshire Division of Forests & Lands show that between 37% and 44% of all standing timber in the state is considered "low-grade".

For the purposes of this discussion, "low-grade wood" is wood that does not generally meet the specifications for sawlogs (to be sawed into lumber) or veneer. "Low-grade" wood markets in New Hampshire consist primarily of pulpwood (used in paper manufacturing), whole-tree chips (used to generate electricity), and fuelwood (firewood, primarily for home heating). Previous work for the NH Department of Resources & Economic Development has documented the importance of markets for low-grade wood to sustainable forestry, the conservation of open space, wildlife habitat and the state's forest industry.[33] In testimony before the New Hampshire legislature in 2003, State Forester Philip Bryce summed up the value of markets of low-grade wood this way:

> "Markets for low-grade wood are essential to the practice of sustainable forestry…Without adequate markets for low-grade wood, there will be limited opportunity to maintain and improve the quality of timber upon which our forest products industry depends."[34]

The State is not alone in this concern. The largest landowner in New Hampshire is the White Mountain National Forest (WMNF), with large holdings in Coos, Grafton and Carroll counties. The WMNF manages roughly half of its land (over 780,000 acres in New Hampshire and Maine) for uses that include timber production. Tom Wagner, Supervisor of the WMNF, has noted that:

> "Removal of low-quality trees [low-grade wood] helps meet one of our long-term multiple-use goals, which is to produce high quality northern hardwood and softwood timber."[35]

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[32] USDA Forest Service. *The Granite State's Forests: Trends in the Resource,* Northeast Research Station Publication NE-INF-141-00. 2000.

[33] Innovative Natural Resource Solutions LLC and Draper Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.* Prepared for the NH Department of Resources and Economic Development. January 2002.

[34] Letter from the NH Division of Forests & Lands on House Bill 787 to Rep. John Thomas, Chair, NH House Committee on Science, Technology and Energy. March 5, 2003.

[35] Letter from the White Mountain National Forest on House Bill 787 to Rep. John Thomas, Chair, NH House Committee on Science, Technology and Energy. March 4, 2003.

In addition to landowners and land managers, sawmills also rely upon low-grade markets for two reasons. First, these markets provide an outlet for mill residue, the byproducts of lumber manufacturing. Mill residue includes chips produced when round logs are sawed into lumber, sawdust, and bark. It is estimated that in 2000, New Hampshire sawmills produced over 300,000 tons of mill residue[36]. Obviously, this residue must find an outlet in order for sawmills to continue operating. A second benefit to sawmills is that robust and diverse markets for all wood – including low-grade wood – provide for economically viable timber harvesting and thus help secure the present and future log supply that a sawmill needs.

3.2. Harvest Levels for Low-Grade Wood

Low-grade wood is harvested on every logging job in the state. In earlier work conducted for the New Hampshire Department of Resources and Economic Development, loggers and foresters reported that between 20% and 80% of the volume (not value) of wood harvested during a logging job is considered "low grade"[37]. Low-grade wood includes hardwood and softwood pulpwood, whole-tree chips, and fuelwood (firewood) used in residential or commercial (generally maple sugaring) applications.

The New Hampshire Division of Forests & Lands (NHDFL) has recently started compiling information that landowners provide to the state following a timber harvest. These "Report of Wood Cut" forms, filed by a landowner in compliance with New Hampshire RSA 79, are part of the collection mechanism for the timber yield tax. As part of this filing, landowners indicate the volume and type of wood harvested. NHDFL now has this information compiled for the tax year 2001, and is in the process of compiling additional years of information.

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[36] Innovative Natural Resource Solutions LLC and Draper Lennon, Inc. *Feasibility Analysis of Medium Density Fiberboard Manufacturing in New Hampshire.* Prepared for the NH Department of Resources and Economic Development. July 2001.

[37] Innovative Natural Resource Solutions LLC and Draper Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.*

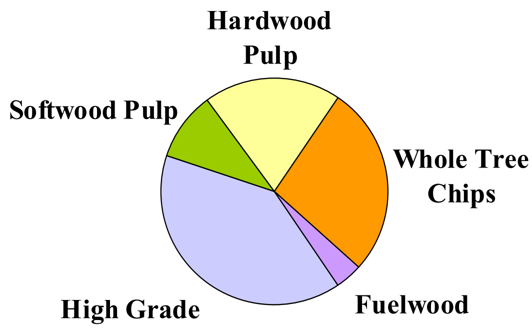
Cords of Wood Harvested by Type, Tax Year 2001[38]

County	Softwood Pulp	Hardwood & Aspen Pulp	Whole Tree chips	Fuelwood	Low Grade Total	High Grade	Total	Percent Low Grade
Grafton	42,859	48,148	106,230	9,172	206,409	93,174	299,583	**69%**
Coos	34,280	135,491	18,097	2,450	190,317	87,583	277,900	**68%**
Merrimack	11,989	27,660	60,879	9,056	109,584	79,489	189,072	**58%**
Carroll	13,223	25,187	35,365	4,665	78,440	52,789	131,229	**60%**
Hillsborough	5,021	2,329	48,151	7,032	62,532	60,716	123,248	**51%**
Rockingham	4,799	2,793	28,775	5,408	41,775	28,453	70,228	**59%**
Sullivan	5,070	3,827	19,509	4,006	32,412	34,234	66,646	**49%**
Belknap	5,868	8,253	15,361	2,047	31,530	27,664	59,194	**53%**
Cheshire	3,743	3,680	15,033	6,396	28,852	41,348	70,201	**41%**
Strafford	4,892	4,019	9,317	3,182	21,409	19,708	41,118	**52%**
Total	***131,744***	***261,386***	***356,716***	***53,413***	***803,259***	***525,160***	***1,328,419***	***60%***

In tax year 2001, which ran from April 1, 2001 to March 31, 2002, sixty percent of the volume of wood harvested in New Hampshire was low-grade. The percentage of low-grade wood varied by county, with a low of 41% of harvest "low-grade" in Cheshire county and a high of 69% of wood harvested in Grafton county considered "low-grade". The differences by region are probably attributable to differences in access to markets for low-grade wood – with the northern part of the state having better access to a variety of low-grade wood markets than the western portion of New Hampshire. It should be noted that a higher percentage of "low-grade" wood is harvested than is standing; this is because during many forest management operations the healthier and higher-grade trees are left to grow while low-grade wood is harvested and removed.

New Hampshire landowners harvested 356,716 cords of whole tree chips in tax year 2001 – roughly equivalent to 891,800 tons of wood chips. This represented over one quarter of all wood harvested (by volume) in New Hampshire. Whole tree chips represent the largest category of low-grade wood harvested in every county except one – Coos. (In Coos County, with significant amount of land historically owned by paper companies and geographic proximity to a number of markets for pulpwood, more hardwood pulp and softwood pulp were harvested.)

[38] Personal communication with Matt Tansey, NH Division of Forests & Lands. July 3, 2003.



Based on Tax Year 2001 Reports of Cut
Source: NH Division of Forests and Lands

Figure 2. Wood Harvested in New Hampshire, 2001

3.3. Existing Markets -- Wood Energy

Whole-tree chips, one quarter of the wood harvested in New Hampshire in 2001, are used in wood-fired power plants. The table below, drawn from air emissions compliance reports[39], shows that existing wood energy plants have historically provided a market for over one million tons of whole-tree chips annually.

[39] New Hampshire Department of Environmental Services, Air Resources Division.

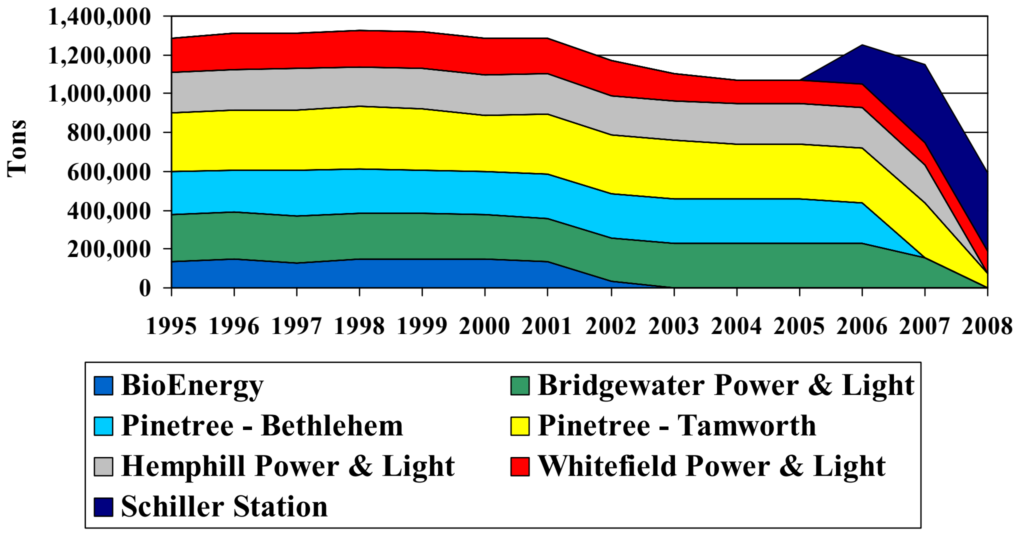
				tons				
	1996	1997	1998	1999	2000	2001	2002	2003
BioEnergy*	148,121	127,076	148,589	149,720	145,557	136,925	33,143	-0-
Bridgewater Power & Light	241,141	241,207	236,342	236,750	229,320	221,650	224,050	225,600
Pinetree - Bethlehem	216,136	234,677	229,901	222,175	226,600	225,133	229,571	233,810
Pinetree - Tamworth	308,094	314,218	318,524	316,530	286,178	313,174	299,900	304,031
Hemphill Power & Light	210,689	211,023	203,575	203,877	207,577	204,890	201,603	201,670
Whitefield Power & Light	187,609	186,159	187,508	186,959	187,392	186,920	182,832	164,023
Total	*1,311,790*	*1,314,360*	*1,324,439*	*1,316,011*	*1,282,624*	*1,151,767*	*1,137,956*	*1,129,134*

Note: BioEnergy's fuel consisted of roughly 70% forest-derived fuel (whole tree chips and sawmill residue) and 30% urban wood (primarily ground pallets). All other plants use forest-derived fuel exclusively.

The market for whole tree chips provided by New Hampshire's existing wood-fired power plants is expected to shrink, in future years. Innovative Natural Resource Solutions LLC (INRS) has projected total fuel use, based upon historic fuel use and dates of rate order terminations, for the years 2003 - 2009. This analysis *assumes* that facilities will close and/or cease purchasing forest-derived chips at the termination of their rate orders (with the exception of Whitefield Power & Light, which has continued operations following termination of its rate order and subsequent agreements). It is possible that wood-fired power plants could continue operating and using whole-tree chips following termination of their rate orders under a number of scenarios, including:

- Significant changes to the competitive electricity market,
- Public policy changes to support existing wood-fired power facilities,
- Meaningful and stable fuel (wood) price reduction,
- Reinvestment in facilities that allow them to operate more efficiently and qualify for other states' renewable energy incentives, or
- Other changes to the economics of these plants.

It is also possible that wood energy facilities will continue operations at significantly less than current capacity, generating only when electricity markets allow profitable operations. The following wood use projection does not account for any of these variables, and should be considered a "lowest case" scenario from the perspective of total wood use at existing facilities.



Source:
1995 - 2003, NH Department of Environmental Services
2004 - 2009, INRS Projections Based on Historic Fuel Use and Rate Order Termination Dates

Figure 3. Tons of Wood Burned, NH Wood-Fired Power Plants

Assuming closure of facilities at the termination of their rate orders[40], the market for whole tree chips provided by New Hampshire wood-fired power plants will shrink dramatically in coming years.

3.4. Existing Markets -- Paper

New Hampshire has two significant in-state mills that use pulpwood : the Fraser mill in Berlin and Wausau mill in Groveton. Additionally, New Hampshire forest landowners sell their wood to pulp mills in Maine, New York, and nearby Canada.

New Hampshire's annual pulpwood harvest tripled from 200,000 cords in 1965 to nearly 600,000 cords in 1995[41]. Since then, pulpwood production has declined. In 2001, pulpwood harvest had shrunk to just under 400,000 cords[42]. It must be noted that the pulp mill in Berlin – the state's single largest consumer of wood – closed in 2001 when then-owner American Tissue entered bankruptcy proceedings. The mill did not begin

[40] Facilities may continue to operate due to investments in new technology, participation in regional renewable power programs, changes in fuel type or costs, changes in the wholesale electricity market, or other factors.
[41] 1965-1997 data - Irland, Lloyd C., Paul Sendak and Richard Widmann. *Hardwood Pulpwood Stumpage Price Trends in the Northeast.* USDA Forest Service, Northeast Research Station, General Technical Report NE-286. May 16, 2001.
[42] Personal communication with Matt Tansey, NH Division of Forests & Lands. July 3, 2003.

pulping operations again until 2003, under new ownership. It is certain that the closure of this mill, and the highly public uncertainty that led up to it, caused a reduction in statewide pulpwood harvests in 2001.

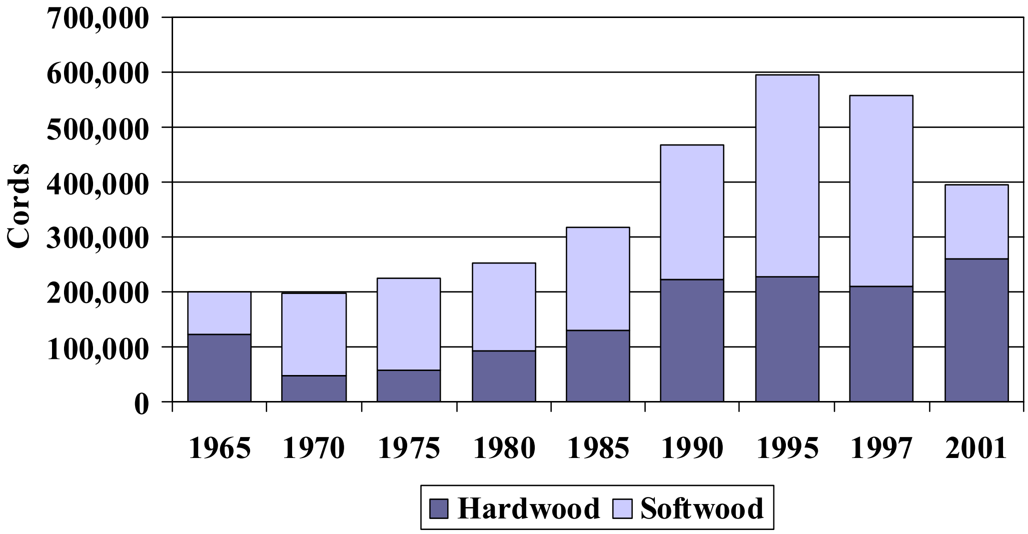


Figure 4. New Hampshire Pulpwood Production, 1965 – 2001 (selected years)

3.5. Potential Future Markets

3.5.1. Schiller Station (Northern Wood Power Project)[43]

In addition to the pulp and paper industry, as well as the potential for a bio-oil facility that is the subject of this opportunity analysis, Public Service of New Hampshire (PSNH) has proposed a renewable energy project that would utilize wood. PSNH is retiring one of three 50 MW coal-fired boilers at Schiller Station in Portsmouth and replacing it with a fluidized bed boiler that is capable of burning wood or coal. Schiller Station is expected to start burning wood in mid-2006.[44]

PSNH has publicly indicated that the *Northern Wood Power Project* at Schiller Station could use up to 400,000 green tons of wood each year[45]. This proposal received approval

[43] *Disclosure*: Innovative Natural Resource Solutions LLC is working with Public Service of New Hampshire on parts of the Schiller Station proposal.
[44] Public Service Company of New Hampshire. *Renewable Energy for New Hampshire: Northern Wood Power Project.* City of Portsmouth (NH) – Zoning Board of Adjustment. May 4, 2004.
[45] Testimony of Gary Long, President of Public Service Company of New Hampshire, before the New Hampshire House of Representatives Science, Technology & Energy Committee on House Bill 787, March 5, 2003.

from the New Hampshire Public Utilities Commission[46], and has obtained local approval from the City of Portsmouth.[47] As this bio-oil opportunity analysis is being finalized, PSNH has placed an order for some of the equipment necessary to use wood fuel at the facility, the P.U.C. is being appealed in the New Hampshire Supreme Court by some of the existing wood-fired power plants, and the necessary air permit is pending.

3.5.2. Chip Export

According to published reports, Sprague Energy is planning to use its port facilities in Portsmouth, NH to export fuel chips to Europe.[48] According to the published report, fuel chips would be purchased in Henniker and transported to Portsmouth. If this venture goes forward, it is anticipated that this could represent a market of up to 140,000 tons per year. It should be noted that the export of chips is highly sensitive to changes in currency exchange rates, and this potential future market may fluctuate accordingly.

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[46] NH Public Utilities Commission Order No. 24,276. February 6, 2004 *and* NH Public Utilities Commission Order No. 24,327.

[47] More information on this project can be found at PSNH's website or in the public files at the NH Public Utilities Commission, Docket DE-03-166

[48] Goot, Michael. "Newington firm eyes world wood chip market." *Foster's Daily Democrat.* August 13, 2003.

4. Feedstock Availability and Pricing

4.1. Introduction

The availability and pricing of wood for a bio-oil facility is a crucial piece of information for determining the feasibility of a bio-oil facility in New Hampshire. In an effort to better understand the availability and price of wood in different parts of New Hampshire, communities have been selected to serve as representatives of three regions of the state. These communities are Whitefield (northern NH), Bridgewater (central NH), and Keene (southwestern NH). The following pages contain information on timber growth within a 75-mile radius of each community; the availability of sawmill residue within a 50-mile radius of each community; and the presence of other large consumers of low-grade wood within a 50-mile radius of each community. It should be noted that these communities were selected to represent certain regions of New Hampshire, and do not necessarily represent decisions to consider locating a bio-oil facility within these particular communities.

In general, New Hampshire has a significant amount of low-grade wood[49]. The state's five operating wood-fired power plants, pulp mills in Berlin and Groveton, as well as energy and pulp markets outside of New Hampshire provide a number of outlets for this material. At present, the logging and trucking infrastructures exist to harvest, process and transport whole-tree chips, pulpwood, and sawmill residue. It is possible that, as some of the wood-fired power plants cease operations, this infrastructure will decline, particularly for whole-tree chips.

4.2. Land Ownership

Each section on land ownership describes the types of landowners (public, industrial, non-industrial) in the vicinity of each community.

- Non-industrial forest landowners, the most common type of landowner in New England, can own from one acre to hundreds of thousands of acres. Each landowner manages land for different reasons and with different economic requirements, so it is very difficult to make statements about management on certain parcels of land. However, taken as a whole, non-industrial private landowners are the primarily supplier's to New Hampshire forest industries, and as a group provide a steady and consistent level of timber to the market.
- Industrial lands are owned and managed primarily for the purpose of timber production, and are owned by firms with forest products manufacturing facilities. Harvested timber that does not fit the manufacturing facility's species or grade parameters, or is in excess of the facility's needs, is often sold to other forest industries.

[49] Frieswyk, Thomas and Richard Widmann. *Forest Statistics for New Hampshire: 1983 and 1997*. USDA Forest Service, Northeast Research Station Resource Bulletin NE-146. April 2000.

- Speaking broadly, public lands in the region harvest less timber *on a per acre basis* than other types of landowners. This is because most public lands are managed for multiple benefits, and timber production is generally one of many competing and compatible land uses (others would include recreation and wildlife habitat, for example).

4.3. Other Industries Using Low-Grade Wood

In New England, the major industries that use low-grade wood are wood-fired power plants and the region's pulp mills[50]. New Hampshire has eight wood-fired power plants, five of which are presently operating. These five facilities use a little over one million tons of wood each year. Four of these facilities operate under rate orders, which in effect guarantee that power from these facilities will be sold at a predetermined (and generally above-market) price. As these rate orders expire, these facilities face a very uncertain future in the competitive generation market.[51]

New Hampshire has two pulp mills, both located in the northern part of the state. These mills, located in Berlin and Groveton, have a historic wood use of 1.4 million tons of wood per year. New Hampshire landowners also sell wood to mills in other New England states, New York, and nearby Canada. It is estimated that New Hampshire harvests a total of 2.8 million tons of pulpwood each year[52].

4.4. Timber Growth

The USDA Forest Service conducts an inventory and analysis of timber growth on a statewide basis every ten to fifteen years. This inventory, known as the Forest Inventory and Analysis (FIA), is in the process of becoming updated on an annual basis. However, this annualized information is not yet available for New England states. As a result, all information provided on harvest and removals is based on earlier FIA data:

- New Hampshire, 1997
- Maine, 1995
- Massachusetts, 1998
- Vermont, 1997

Information is provided for growth and removals (timber harvests and land use change) for a 75-mile radius of each community. With roads that are not always direct, it is assumed that a 75-mile radius provides trucking routes of 100 miles or less, a reasonable distance for transporting moisture-heavy low-grade wood.

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[50] Innovative Natural Resource Solutions LLC and Draper/Lennon, Inc. *Use of Low Grade and Underutilized Wood Resources in New Hampshire.* Prepared for the NH Department of Resources and Economic Development. January 2001.

[51] Innovative Natural Resource Solutions LLC and Draper/Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire*. Prepared for the NH Department of Resources and Economic Development. January 2002.

[52] Howard, James. *U.S. Forest Products Annual Market Review and Prospects, 1999-2000.* USDA Forest Service, Forest Products Laboratory, Research Note FPL-RN-0278.

4.5 Whole Tree Chips

Whole-tree chips are the product used to fuel most biomass-fired power plants in the region. Whole-tree chips are produced by running treetops, branches, and other wood through a chipper located at the landing of a logging operation. Whole-tree chips can be made from any species, and species are generally freely mixed. Though it varies by season and species, whole-tree chips are generally considered to have 40% - 50% moisture content (in other words, roughly half their weight is comprised of water).

Because of their use in the region's wood-fired power plants, as well as in some industrial boilers, there is good data on whole-tree chips prices in New Hampshire. The New Hampshire Timberland Owners Association reports prices for a wide variety of forest products, including whole-tree chips, on a quarterly basis[53]. This information is reported for three regions of the state, and is self-reported by members engaged in the forest industry.

Past work on low-grade markets for forest products has assumed an $18/ton price for whole-tree chips, based upon historical data. This remains a good long-term price assumption on a statewide basis. However, prices vary by region of the state, based upon competing markets, supply infrastructure, weather, and other factors. For each region (northern, central and southern New Hampshire), information is provided on historic prices.

At present, the vast majority of whole-tree chips are sold on the open market, without long-term contracts that assure a fixed market and price for suppliers. It is possible that, if a facility were to provide long-term contracts to suppliers that assured a market and price, whole tree chips could be procured for less than current pricing.

4.6. Sawmill Residue

Sawmill residue is the by-product of lumber manufacturing, produced when round logs are sawed into boards. Sawmill residue is generally in two categories : chips and sawdust. Because bark is removed from logs prior to sawing, mill residue generally has very low bark content. It should be noted that mill chips have relatively high moisture content, generally from 50-60% depending upon species and time of year, because the chips are largely from the outside layers of the tree, where moisture content is the highest. Green sawdust has moisture content of roughly 40-50%, depending upon species, season and other factors. As a very limited quantity of dried sawdust is available in the region, all sawdust referenced in this analysis should be considered "green".

Sawmill residue information was determined through phone calls to major mills in each area, followed by estimates of residue production at other mills based on their known equipment type. The information is not comprehensive, as some mills refused to provide

[53] New Hampshire Timberland Owners Association. "Quarterly Forest Products Market Report" section of the *Timber Crier*. 1995 – 2004.

information for this analysis. However, in each 50-mile radius reviewed for this opportunity analysis, mills representing at least 80% of the lumber production in that region are accounted for. All sawmills contacted for this analysis currently have markets for their residue : pulp mills, biomass energy facilities or both.

Many sawmills consider information regarding their residue production, as well as price, to be proprietary. In order to obtain accurate and useful information from sawmills, INRS committed to sawmills to provide data in aggregate form only, in a way that no information could be attributed to a particular mill.

At present, some sawmill residue (both mill chips and sawdust) is sold on the open market without long-term contracts that assure a fixed market and price for mills. It is possible that, if a facility were to provide long-term contracts to mills that assured a market and price, mill residue could be procured for less than current pricing.

4.7. Whitefield, NH

The Town of Whitefield is located in Coos County, the northernmost county in New Hampshire. A fifty-mile radius around Whitefield includes parts of Coos, Grafton and Carroll counties in New Hampshire; parts or all of Essex, Orleans, Caledonia, Lamoille, Washington, and Orange counties in Vermont; part of Oxford County in Maine; and a very small part of the Province of Quebec.

4.7.1. Land Ownership

The entire White Mountain National Forest is located within 50 miles of Whitefield. New Hampshire's largest state forest, Nash Stream, is located within 50 miles of Whitefield. Additionally, large tracts of industry-owned and investor-owned land are located within 50 miles of the town, as well as large areas of forestland in New Hampshire, Vermont and Maine owned and managed by non-industrial private landowners.

4.7.2. Other Industries Using Low-Grade Wood

Northern New Hampshire has the state's most robust market for low-grade wood. This is because a number of paper mills and wood-fired power plants operate in or near the region. The following facilities that purchase or use significant volume of low-grade wood are located within 50 miles of Whitefield:

- The Burgess Pulp Mill is located in Berlin, NH. This mill, currently owned and operated by Fraser Paper, restarted operations in the Spring of 2003. Traditionally, this mill has used over 1 million tons of pulpwood annually. At present, this mill is purchasing hardwood pulpwood for its operations.
- Whitefield Power and Light is a 13.8 MW wood-fired power plant located in the town's industrial park. This facility, which consumes almost 190,000 tons of whole-tree chips each year, had its rate-order bought out by Public Service Company of New Hampshire in 2001. It is currently owned by Conduit Energy LLC, and is in the process of adding new emissions control equipment in order to qualify for premiums associated with an out-of-state a renewable portfolio standard.[54]
- Pinetree Power – Bethlehem is a 15 MW wood-fired power plant in Bethlehem, NH. This facility, which operates under a rate order that expires in November 2006, uses roughly 220,000 tons of whole-tree chips annually.
- Pinetree Power – Tamworth is a 20 MW wood-fired power plant in Tamworth, NH in Carroll County. This facility, which operates under a rate order that expires in March 2008, generally uses over 300,000 tons of whole-tree chips annually.
- Bridgewater Power is a 15 MW wood-fired power plant in Grafton County. This facility, which operates under a rate order that expires in August 2007, uses over 230,000 tons of whole-tree chips each year.

[54] Tucker, Edith. "Whitefield Power & Light; Permit sought for emission reduction unit." *Coos County Democrat.* August 18, 2004.

- Ryegate Power Station is a 22 MW wood-fired power plant in Ryegate, Vermont. This facility, which operates under a rate order that expires in 2012, uses roughly 250,000 tons of whole-tree chips, mill residue and wood chipped on-site each year.
- In addition to these facilities, several paper companies have log yards and/or chipping facilities within 50 miles of Whitefield. Carrier Chipping has a facility in Shelburne that primarily supplies MeadWestvaco's mill in Rumford, Maine; International Paper has a log yard in Freedom, NH that supplies its Jay, Maine mill, and SAPPI has a chipping facility in Ossipee, NH used to supply its Maine mill.

4.7.3. Timber Growth

With existing markets for sawlogs, veneer and low-grade wood, the area within a 75-mile radius of Whitefield, New Hampshire has timber growth in excess of removals (from timber harvest or land conversion). It should be noted that within this radius is the entire White Mountain National Forest, which has seen declining timber harvests in the past decade, and future harvest levels from this land are uncertain.

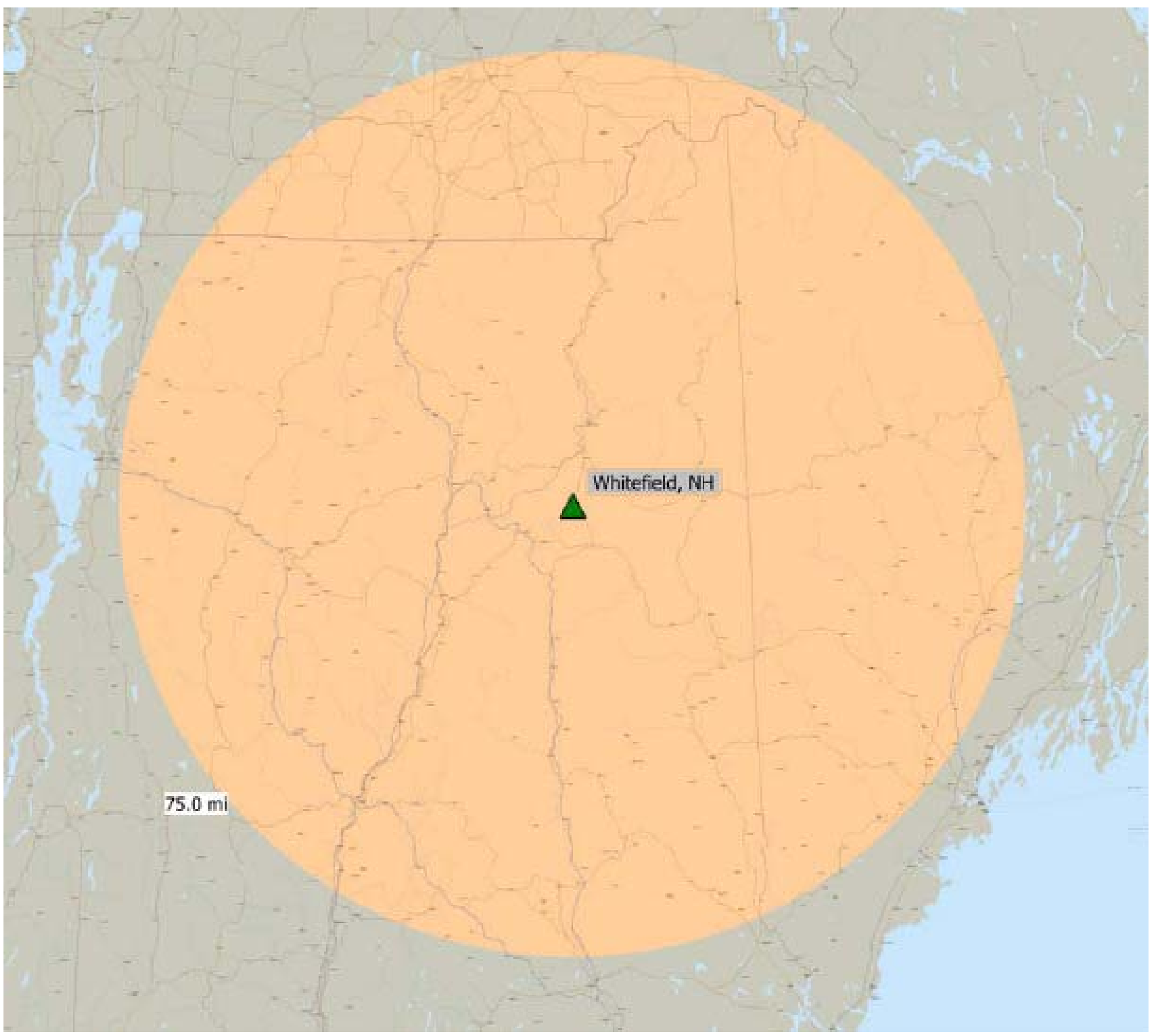


Figure 5 . 75 Mile Radius - Whitefield, NH

FIA data show that, for all species, annual growth exceeds removals by 1.4 million tons. Growth is greater than removals for all major species in the region except spruce and fir, yellow birch, paper birch, and poplar. The species red maple, sugar maple, white pine and hemlock show significant net growth (growth less removals).

Estimated annual forest growth and removals within a 75-mile radius of Whitefield, NH

Source USDA Forest Service Forest Inventory and Analysis for New Hampshire, Vermont, Massachusetts, and Maine*. All live trees >4.9"diameter at breast height.

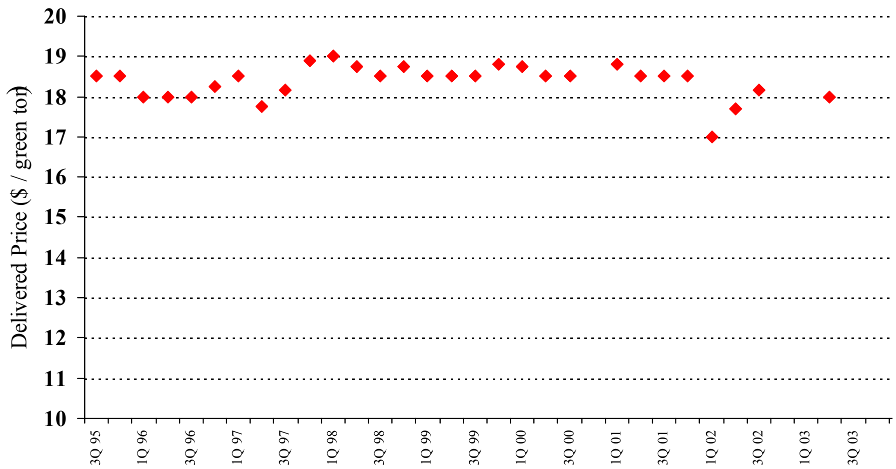
	Net Growth[55]	Harvest Removals	Land Use Removals	Net Change
	tons			
Spruce-Fir	578,382	(863,799)	(95,896)	(381,313)
White Pine	804,513	(411,348)	(43,565)	349,600
Hemlock	392,218	(158,944)	(27,492)	205,782
Other Softwood	68,621	(46,081)	-	22,540
Red Maple	966,955	(398,045)	(18,842)	550,068
Sugar Maple	734,393	(272,358)	(34,412)	427,624
Yellow Birch	219,776	(200,995)	(20,953)	(2,172)
Paper Birch	119,692	(229,779)	(72,066)	(182,153)
Beech	357,882	(190,626)	(11,042)	156,214
White Ash	180,868	(76,104)	(7,861)	96,904
Poplar species	149,485	(198,885)	(5,751)	(55,151)
Oak species	337,480	(172,885)	(5,934)	158,661
Other Hardwood	84,729	(27,835)	(1,713)	55,181
All Species	*4,994,995*	*(3,247,682)*	*(345,527)*	*1,401,786*

4.7.4. Whole Tree Chips

Northern New Hampshire has the state's strongest and most consistent market for whole-tree chips. Between the third quarter of 1995 and the first quarter of 2003, the average price for whole tree chips in this region was $18.40 per green ton, delivered.

* USDA FIA information is presented in cubic foot form. Data were converted to tons using the conversion factors 85 cubic feet of solid wood equals 1 cord, 1 cord equals 2.3 tons of softwood, and 1 cord equals 2.6 tons of hardwood.

[55] "Net growth" refers to the gross growth of a species in the forest less mortality (natural death) and other natural losses.



Data Source: *NHTOA Timber Crier*

Figure 6. Delivered Price, Whole Tree Chips, Northern NH (per ton)

4.7.5. Sawmill Residue

A number of sawmills operate within a 50-mile radius of Whitefield. There are hardwood, white pine, spruce-fir and other mills in this region. These mills produce roughly 188,000 tons of sawmill residue each year, including almost 30,000 tons of sawdust. Self-reported weighted average pricing (delivered) for this residue is $18.00/ton for hardwood mill chips, $27.50/ton for softwood mill chips, and $10.50/ton for sawdust. At present, this residue is used in either paper mills of wood-fired power plants in the region.

	Sawmill Chips							
	White Pine	Red Oak	Other Softwood	Other Hardwood	Total Softwood	Total Hardwood	Sawdust	Total
Annual Tons	93,900	3,480	2,220	59,520	96,120	63,000	29,760	188,880
Daily tons	257	10	6	163	263	173	82	517

4.8. Bridgewater, NH

The Town of Bridgewater is located in Grafton County, and is used as a proxy for central New Hampshire. A fifty-mile radius around Bridgewater includes parts or all of Coos, Grafton, Carroll, Strafford, Belknap, Rockingham, Merrimack, Hillsboro, Cheshire and Sullivan counties in New Hampshire; parts of Caledonia, Orange and Windsor counties in Vermont; and parts of York and Oxford counties in Maine.

4.8.1. Land Ownership

Much of the White Mountain National Forest is located within 50 miles of Bridgewater. Outside of this federal ownership, most of the land in New Hampshire, Vermont and Maine owned and managed by non-industrial private landowners. This region also includes the developed or rapidly developing areas of Manchester, Concord, Dover/Rochester, and Hanover/Lebanon.

4.8.2. Other Industries Using Low-Grade Wood

Central New Hampshire's market for low-grade wood faces an uncertain future. The following facilities that purchase or use significant volume of low-grade wood are located within 50 miles of Bridgewater:

- Bridgewater Power is a 15 MW wood-fired power plant in Grafton County. This facility, which operates under a rate order that expires in August 2007, uses over 230,000 tons of whole-tree chips each year.
- Whitefield Power and Light is a 13.8 MW wood-fired power plant located in the town's industrial park. This facility, which consumes almost 190,000 tons of whole-tree chips each year, had its rate-order bought out by Public Service Company of New Hampshire in 2001. It is currently owned by Conduit Energy LLC, and is in the process of adding new emissions control equipment in order to qualify for premiums associated with an out-of-state a renewable portfolio standard.[56]
- Pinetree Power – Bethlehem is a 15 MW wood-fired power plant in Bethlehem, NH. This facility, which operates under a rate order that expires in November 2006, uses roughly 220,000 tons of whole-tree chips annually.
- Pinetree Power – Tamworth is a 20 MW wood-fired power plant in Tamworth, NH in Carroll County. This facility, which operates under a rate order that expires in March 2008, generally uses over 300,000 tons of whole-tree chips annually.
- Hemphill Power & Light is a 13.8 MW wood-fired power plant in Springfield, NH in Sullivan County. This facility, which operates under a rate order that expires in November 2007, generally uses a little over 200,000 tons of whole-tree chips annually.

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[56] Tucker, Edith. "Whitefield Power & Light; Permit sought for emission reduction unit." *Coos County Democrat.* August 18, 2004.

- Ryegate Power Station is a 22 MW wood-fired power plant in Ryegate, Vermont. This facility, which operates under a rate order that expires in 2012, uses roughly 250,000 tons of whole-tree chips, mill residue and wood chipped on-site each year.
- In addition to these facilities, paper companies have log yards and / or chipping facilities within 50 miles of Bridgewater. International Paper has a log yard in Freedom, NH that supplies its Jay, Maine mill, and SAPPI has a chipping facility in Ossipee, NH used to supply its mill Maine. Cousineau Forest Products and HHP, both located in Henniker, NH also purchase and move significant quantities of low-grade wood, supplying a variety of markets.

4.8.3. Timber Growth

With existing markets for sawlogs, veneer and low-grade wood, the area within a 75-mile radius of Bridgewater, New Hampshire has timber growth in excess of removals (from timber harvest or land conversion). It should be noted that within this radius is much of the White Mountain National Forest, which has seen declining timber harvests in the past decade, and future harvests from this land are uncertain.

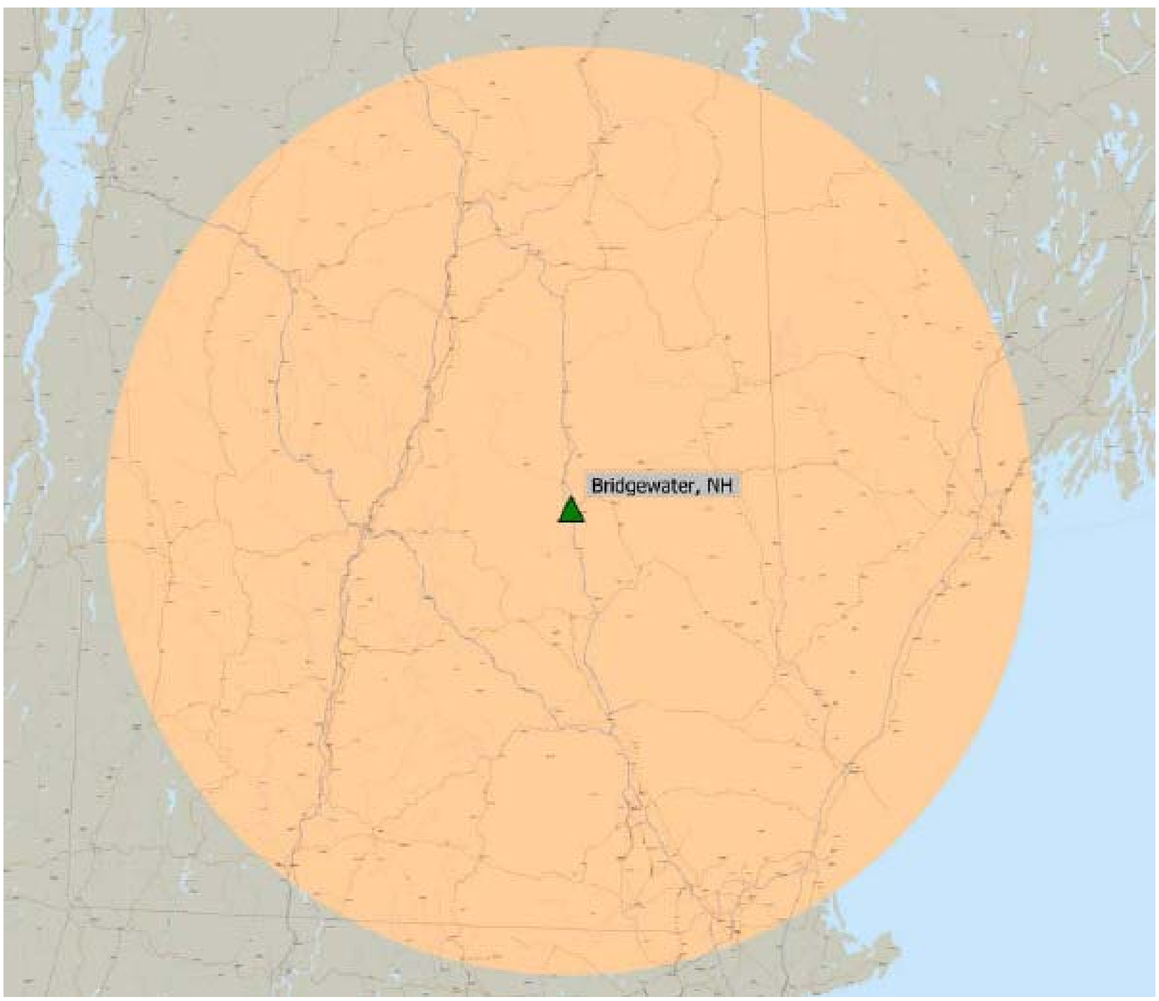


Figure 7. 75 Mile Radius – Bridgewater, NH

FIA data shows that, for all species, annual growth exceeds removals by 2.2 million tons. Growth is greater than removals for all major species in the region except spruce and fir, paper birch, and poplar. The species red maple, sugar maple, white pine and hemlock show significant net growth (growth less removals).

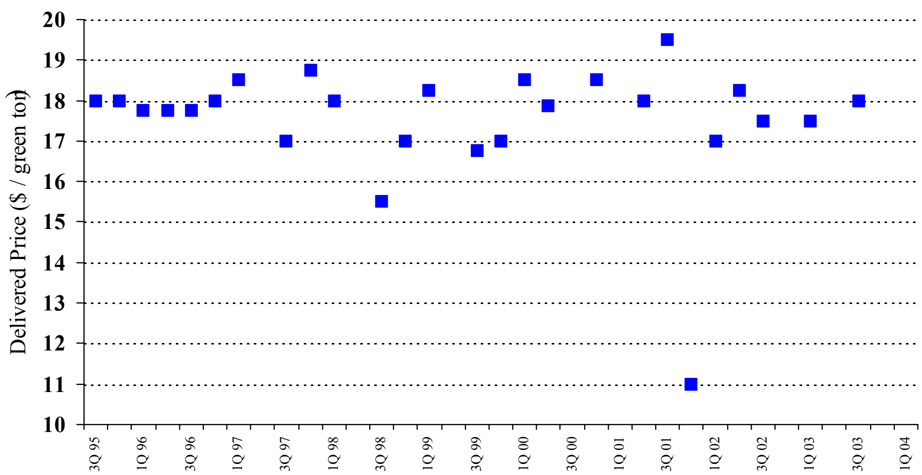
Estimated annual forest growth and removals within a 75-mile radius of Bridgewater, NH

Source USDA Forest Service Forest Inventory and Analysis for New Hampshire, Vermont, Massachusetts, and Maine*. All live trees >4.9" diameter at breast height.

	Net Growth[8]	Harvest Removals	Land Use Removals	Net Change
		tons		
Spruce-Fir	394,085	(314,099)	(94,462)	(14,476)
White Pine	1,119,451	(500,615)	(108,776)	510,059
Hemlock	475,640	(170,687)	(28,764)	276,189
Other Softwood	70,624	(44,836)	(2,814)	22,973
Red Maple	1,233,593	(424,075)	(29,426)	780,092
Sugar Maple	588,762	(191,329)	(31,995)	365,438
Yellow Birch	181,235	(64,113)	(30,160)	86,962
Paper Birch	8,198	(154,562)	(70,139)	(216,504)
Beech	337,449	(198,181)	(11,134)	128,134
White Ash	188,454	(68,701)	(2,845)	116,908
Poplar species	53,101	(126,482)	(5,751)	(79,132)
Oak species	458,732	(258,654)	(49,461)	150,616
Other Hardwood	174,598	(64,633)	(6,026)	103,939
All Species	*5,283,921*	*(2,580,969)*	*(471,753)*	*2,231,199*

4.8.4. Whole Tree Chips

Central New Hampshire currently has several markets for whole-tree chips. Between the third quarter of 1995 and the first quarter of 2003, the average price for whole tree chips in this region was $17.50 per green ton, delivered.



Data Source: *NHTOA Timber Crier*

Figure 8. Delivered Price, Whole Tree Chips, Central NH (per ton)

4.8.5. Sawmill Residue

A large number of sawmills operate within a 50-mile radius of Bridgewater. There are hardwood, white pine, other mills in this region. These mills produce roughly 265,000 tons of sawmill residue each year, including almost 46,000 tons of sawdust. Self-reported weighted average pricing (delivered) for this residue is $24.00/ton for hardwood mill chips, $27.50/ton for softwood mill chips, and $9.00/ton for sawdust. At present, this residue is used in either paper mills of wood-fired power plants in the region.

	Sawmill Chips							
	White Pine	Red Oak	Other Softwood	Other Hardwood	Total Softwood	Total Hardwood	Sawdust	Total
Annual Tons	127,380	11,100	15,600	35,160	75,300	142,980	46,260	264,540
Daily tons	349	30	43	96	206	392	127	725

4.9. Keene, NH

The City of Keene is located in Cheshire County, and is used as a proxy for Southwestern New Hampshire. A fifty-mile radius around Keene includes parts or all of Cheshire Sullivan, Grafton, Rockingham, Merrimack, and Hillsboro counties in New Hampshire; parts or all of Windsor, Rutland, Bennington, and Windham counties in Vermont; parts or all of Berkshire, Franklin, Hampshire, Franklin, Hampden, Worchester and Middlesex counties in Massachusetts.

4.9.1. Land Ownership

The vast majority of land in New Hampshire, Vermont and Massachusetts that is within 50 miles of Keene is owned and managed by non-industrial private landowners. A significant portion (the southern portion) of the Green Mountain National Forest in Vermont is within 50 miles of Keene. This region also includes the developed or rapidly developing areas of Manchester and Nashua, NH and Lowell, Worcester, Fitchburg/Leominster, and the northern part of the Springfield region in Massachusetts.

4.9.2. Other Industries Using Low-Grade Wood

Due to the distance to New England's paper mills and many wood-fired power plants, Southwestern New Hampshire traditionally has the weakest markets for low-grade wood. The following facilities that purchase or use significant volume of low-grade wood are located within 50 miles of Keene:

- Hemphill Power & Light is a 13.8 MW wood-fired power plant in Springfield, NH in Sullivan County. This facility, which operates under a rate order that expires in November 2007, generally uses a little over 200,000 tons of whole-tree chips annually.
- Pinetree Power – Fitchburg is located in Westminister, MA. This 17 MW facility uses whole tree chips (many from land clearing), as well as pallets, paper cubes and methane from a nearby landfill to generate electricity.
- In addition to these facilities, Cousineau Forest Products and HHP, both located in Henniker, NH purchase and move significant quantities of low-grade wood, supplying a variety of markets.

4.9.3. Timber Growth

With existing markets for sawlogs, veneer and low-grade wood, the area within a 75-mile radius of Keene, New Hampshire has timber growth in excess of removals (from timber harvest or land conversion).

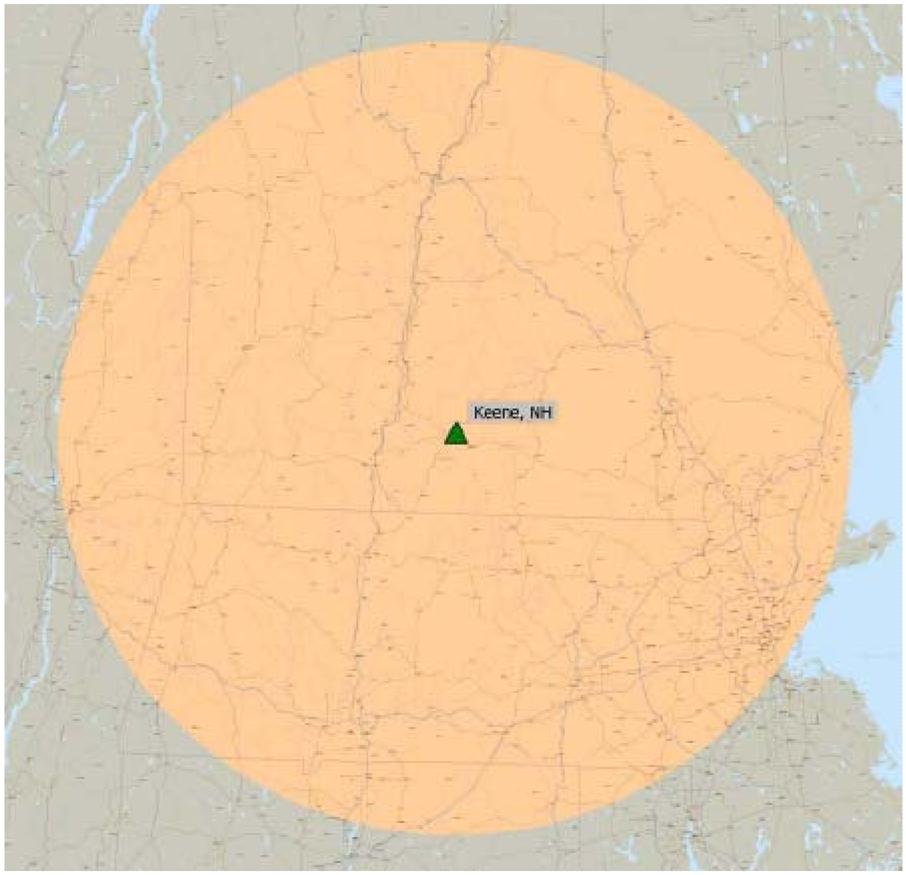


Figure 9. 75-Mile Radius – Keene, NH

FIA data show that, for all species, annual growth exceeds removals by 2.2 million tons. Growth is greater than removals for all major species in the region except paper birch, oak and poplar. The species red maple, beech, white pine and hemlock show significant net growth (growth less removals).

Estimated annual forest growth and removals within a 75-mile radius of Keene, NH

Source: USDA Forest Service Forest Inventory and Analysis for New Hampshire, Vermont, Massachusetts, and Maine*. All live trees >4.9" diameter at breast height.

	Net Growth[8]	Harvest Removals	Land Use Removals	Net Change
		tons		
Spruce-Fir	142,789	(52,684)	(2,165)	87,941
White Pine	913,533	(296,619)	(296,511)	320,404
Hemlock	589,558	(82,881)	(17,886)	488,791
Other Softwood	59,908	(4,627)	(42,455)	12,826
Red Maple	1,021,800	(247,398)	(114,125)	660,278
Sugar Maple	331,424	(123,607)	(29,212)	178,605
Yellow Birch	124,525	(25,664)	(97,607)	1,254
Paper Birch	(5,659)	(69,282)	(7,494)	(82,435)
Beech	308,268	(42,915)	(18,139)	247,214
White Ash	246,113	(63,715)	(10,186)	172,212
Poplar species	14,652	(32,271)	(7,219)	(24,838)
Oak species	640,732	(269,115)	(575,242)	(203,626)
Other Hardwood	499,628	(86,962)	(94,518)	318,148
All Species	*4,887,271*	*(1,397,740)*	*(1,312,758)*	*2,176,773*

4.9.4. Whole Tree Chips

Historically, Southern New Hampshire has the weakest market for whole-tree chips and other forms of low-grade wood. Between the third quarter of 1995 and the first quarter of 2003, the average price for whole tree chips in this region was $16.40 per green ton, delivered. Since the third quarter of 2000, reported whole tree chip prices have been consistently below $18 per green ton, and have generally been $15 per green ton.

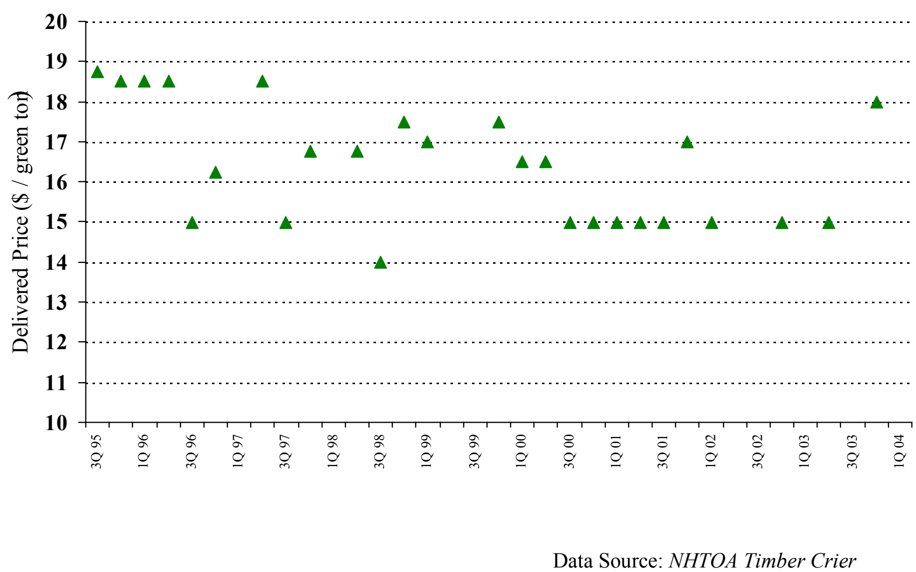


Figure 10. Delivered Price, Whole Tree Chips, Southern NH (per ton)

4.9.5. Sawmill Residue

A significant number of sawmills operate within a 50-mile radius of Keene. Mills in this region saw hardwood, white pine and other softwood species. These mills produce roughly 226,000 tons of sawmill residue each year, including over 60,000 tons of sawdust. Self-reported weighted average pricing (delivered) for this residue is $23.00/ton for hardwood mill chips, $21.00/ton for softwood mill chips, and $9.50/ton for sawdust. At present, this residue is used in either paper mills or wood-fired power plants in the region, or sold to local farmers for animal bedding.

	Sawmill Chips							
	White Pine	Red Oak	Other Softwood	Other Hardwood	Total Softwood	Total Hardwood	Sawdust	Total
Annual Tons	80,640	15,180	18,600	45,360	66,120	99,240	60,540	225,900
Daily tons	221	42	51	124	181	272	166	619

5. <u>Energy Issues For Possible Bio-oil Production Facility</u>

A bio-oil facility operating in New Hampshire would have the opportunity to sell electricity in the region's wholesale market. The following chapter discusses this market, the possibility that a premium could be realized through the sale of both electricity and renewable energy certificates, and other energy issues important for a bio-oil facility developer to consider.

5.1 Selling Wholesale Electricity in New Hampshire

New Hampshire electricity markets are part of the broader ISO-New England (ISO-NE) market, which serves the six New England States – Connecticut, Rhode Island, Massachusetts, Vermont, Maine and New Hampshire. Formed to manage a restructured and competitive market for wholesale electricity, duties of the ISO include "providing independent, open and fair access to the region's transmission system", and "facilitating market based wholesale electric rates."[57]

Any generation facility seeking to sell electricity at the wholesale level would need to interconnect with the electricity transmission and distribution system, often referred to as "the grid", and sell electricity through the ISO New England system. It would be possible to sell electricity directly to a neighboring facility or facilities without accessing the electricity grid-- and therefore not going through the ISO system -- but this approach has limitations.

Throughout this effort to evaluate the feasibility of locating a bio-oil facility in New Hampshire, there has been considerable discussion of locating a bio-oil production facility at the Whitefield Industrial Park in Whitefield, NH. One reason for this interest has been the presence of Whitefield Power & Light Company, a wood-fired power plant. This facility, with historic contracted generation of 13.8 MW, recently accepted a buyout of its PURPA rate order[58], and operated under an agreement with the New Hampshire Timberland Owners Association that expired in the summer of 2003[59].

Whitefield Power & Light has a connection to the New England electricity grid, and it may be possible for a bio-oil production company facility to purchase access to the facility and use this connection or to co-locate with the facility and negotiate use of the grid connection. There are also non-operating wood-fired power plants in Barnstead and Alexandria that may be possible sites for electricity generation using bio-oil. As a result of previous buyout agreements, some of these sites may have restrictions on their ability to generate power for the wholesale market[60].

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[57] ISO New England website, www.isone.org
[58] New Hampshire Public Utilities Commission Order No. 23,840. November 9, 2001.
[59] Stock, Jasen. Letter of the New Hampshire Timberland Owners Association to the NH Public Utilities Commission, Docket No. DE 01-089. September 23, 2002.
[60] Innovative Natural Resource Solutions LLC and Draper/Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.* January 2002.

5.2 Wholesale Electricity Market in New Hampshire

ISO New England publishes a wealth of historic data on wholesale electricity transactions in the region. One of the most useful historical pieces of information is the monthly average clearing price, which provides the average wholesale price paid for electricity in each month. While wholesale electricity prices vary widely from day-to-day and hour-to-hour, the monthly average clearing price provides a fair perspective of historic market activity. Since January 2002, wholesale electricity prices have ranged from a low of $25.17/MWH ($0.025/kwh) in February 2002 to a high of $69.42/MWH ($0.069/kwh) in February 2003. ISO New England is currently not reporting monthly average clearing prices more recent than February 2003.

Monthly Average Electricity Clearing Price, New England[61]

Year	Month	$ / MWH
2001	January	$62.74
2001	February	$43.07
2001	March	$50.18
2001	April	$38.84
2001	May	$43.59
2001	June	$37.33
2001	July	$52.66
2001	August	$43.52
2001	September	$33.82
2001	October	$31.07
2001	November	$27.57
2001	December	$27.22
2002	January	$26.31
2002	February	$25.17
2002	March	$31.18
2002	April	$30.71
2002	May	$34.43
2002	June	$30.06
2002	July	$34.52
2002	August	$46.43
2002	September	$41.17
2002	October	$43.11
2002	November	$39.79
2002	December	$46.35
2003	January	$60.18
2003	February	$69.42

[61] ISO New England website, www.isone.org. ISO New England is not reporting more recent data on a monthly basis at their website.

5.3 Regional Markets for Renewable Power

In addition to selling electricity into the wholesale market, a bio-oil producer could potentially receive a premium for electricity generated using a renewable fuel. According to the *Database of State Incentives for Renewable Energy*, thirteen states have enacted renewable portfolio standards[62]. Three states in New England – Connecticut, Massachusetts and Maine – have "renewable portfolio standards" (RPS), which essentially mandate that any supplier of electricity operating in the state must derive a certain portion of that electricity from renewable sources. Each state defines what qualifies as "renewable" for purposes of their portfolio standard, so that generation that qualifies in one state does necessarily qualify in other states. Generation based in New Hampshire can sell its renewable energy certificates (RECs) to customers in any state in the NEPOOL region (New Hampshire, Vermont, Maine, Massachusetts, Connecticut, and Rhode Island), and in some circumstances may be able to sell RECs outside of this region as well.

5.3.1 New Hampshire

New Hampshire does not presently have a renewable portfolio standard. The New Hampshire General Court has considered establishment of such a standard on at least two occasions, and to date has chosen to address renewable energy issues through other policies. The *New Hampshire Energy Plan*, released in November 2002, recommends establishment of an RPS[63], but this has not occurred.

5.3.2 Maine

Maine has a renewable portfolio standard that requires that 30% of the electricity sold by suppliers come from either renewable generation or "efficient resources" – the highest such standard in the nation.[64] However, prior to establishment of an RPS, Maine derived roughly 45% of its power from renewable resources, primarily biomass and hydroelectric. Maine's RPS allows a great deal of generation that does not qualify for participation in the renewable portfolios of some other states. According to industry sources, the supply of electricity eligible to participate in Maine's RPS is eight times the demand.[65] If an electrical generating facility using bio-oil produced electricity at low costs when compared to other renewable generation, it is possible that Maine's RPS may provide a market. However, because of the existing overcapacity of renewable generation, this would be difficult and a price premium would likely be modest, if it existed at all.

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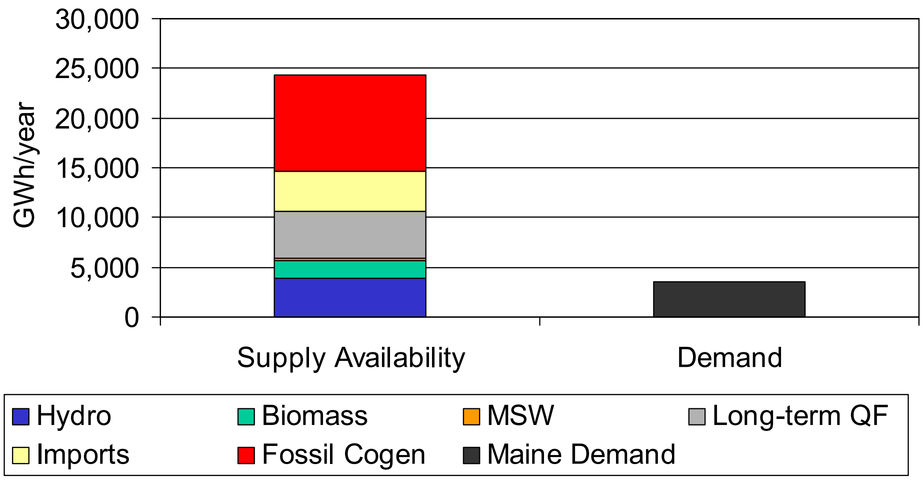
[62] www.dsireusa.org

[63] Governor's Office of Energy & Community Services. *New Hampshire Energy Plan.* November 2002.

[64] Governor's Office of Energy & Community Services. *New Hampshire Energy Plan.* November 2002.

[65] Turkel, Tux. "Renewable Energy Back on Front Burner." *Maine Sunday Telegram.* April 6, 2003.



Data Source: Independent Energy Producers of Maine

Figure 11. Comparison of Eligible Supply and Demand, Maine RPS

Maine is currently reviewing its programs to encourage renewable energy, including its Renewable Portfolio Standard[66]. Changes to the Maine RPS could make this a more attractive opportunity for participation by a bio-oil facility, and should be reviewed again if a facility is closer to construction.

5.3.3 Massachusetts

Massachusetts has a renewable portfolio standard that requires 1.5% of electricity be procured from eligible providers in 2004, with the percentage required climbing annually until at least 2009, when 4% renewable power will be required. However, the Massachusetts RPS has a number of eligibility criteria that may restrict participation by a generator using bio-oil. These rules would apply to any electric supplier wishing to access Massachusetts's RPS market.

> **Eligible Biomass Fuel**: Bio-oil is an eligible fuel source, as the definition of biomass fuel includes "neat liquid fuels that are derived from" sources such as "brush, stumps, lumber ends and trimmings, wood pallets, bark, wood chips, shavings, slash and other clean wood that are not mixed with other solid waste."[67]

[66] Maine Public Utilities Commission. *DRAFT Report and Recommendations on the Promotion of Renewable Resources.* 2003.
[67] 225 CMR 14.02: Definitions – Renewable Portfolio Standard

New Renewable Generation Unit: If a bio-oil production facility developed a new electricity generating facility, where bio-oil was used to generate electricity, it is anticipated that this would qualify under the Massachusetts RPS[68]. The rules call for "low-emission, advanced biomass power conversion technologies" [69] using an eligible biomass fuel. If a bio-oil facility were further along in the planning stages, it might be advisable to receive an advisory ruling from the Massachusetts Department of Energy Resources to confirm that the particular production *and* generation technologies qualify as a "low-emission, advanced biomass power conversion technology", as required by RPS rules[70]. The Massachusetts Department of Energy Resources (Mass DOER) has indicated, in a preliminary fashion, that the use of bio-oil would qualify as an "advanced biomass conversion technology", though the *combined* emissions from both the pyrolysis process and electricity generation would need to meet the emissions standards[71]. It is believed that a bio-oil production facility and associated generator would meet this emissions standard, but a final determination would depend upon facility-specific information and be the task of the Mass DOER.

Use of an Existing Wood-fired Facility: New Hampshire's eight existing wood-fired power plants are not eligible for the Massachusetts RPS. The RPS rules specifically state that "pile burn, stoker combustion or similar technologies shall not constitute an advanced biomass conversion technology" [72]. However, it may be possible to re-power an existing biomass facility -- such as the facility in Whitefield or other now-closed facilities in Barnstead, Alexandria or Hopkinton – as a bio-oil facility and qualify for the Massachusetts RPS.

In April 2004, the Massachusetts Division of Energy Resources issued a guideline that makes it clear that existing wood-fired facilities that re-tool with "advanced" biomass generation (including bio-oil, subject to emissions criteria) are eligible for full participation in the state's RPS[73]. Given this ruling, it may be advantageous, where possible, to use the

[68] On March 9, 2004 the Massachusetts Division of Energy Resources issued an advisory ruling conditionally approving a bio-oil facility (production and generation) proposed by Renewable Oil International at a sawmill in western Massachusetts for participation in that state's Renewable Portfolio Standard.

[69] 225 CMR 14.05 (1)(a)6.a: Eligibility Criteria for New Renewable Generation Units – Renewable Portfolio Standard

[70] 225 CMR 14.05 (1)(a)6: Eligibility Criteria for New Renewable Generation Units – Renewable Portfolio Standard

[71] Personal communication with Howard Bernstein, Biomass Energy Program Manager, Massachusetts Department of Energy Resources. June 26, 2003.

[72] 225 CMR 14.05 (1)(a)6

[73] Massachusetts Division of Energy Resources. *Guideline on the MA RPS Eligibility of Generation Units that Re-tool with Low Emission, Advanced Biomass Technology.* April 16, 2004.

existing interconnection and other facilities of an established wood-fired power plant to manufacture and combust bio-oil.

Co-firing at an Existing Facility: For purposes of the Massachusetts RPS, co-firing refers to supplementing RPS-eligible renewable fuels – in this case bio-oil – along with RPS ineligible fuels, such as coal. Co-firing has seen increasing interest from utilities nationwide in order to help control certain emissions, meet environmental fuels requirements, or stabilize fuel price[74]. If bio-oil was co-fired with coal, as has been tested in other states[75], the percentage of generation derived from bio-oil might be eligible for the Massachusetts RPS, if the generation technology met RPS standards [76]. However, it is critical to note that facilities co-firing biomass fuels (including bio-oil) with coal are required to meet strict emissions criteria: "If using an Eligible Biomass Fuel, the entire Generation Unit must meet the requirements of a low emission, advanced biomass power conversion technology."[77] This requirement may make co-firing a practical impossibility from an RPS perspective.

Price Premium for Renewable Generation in Massachusetts: Massachusetts uses tradable certificates to assure compliance with its RPS. The certificates are traded separately from the energy, and provide additional revenue for generators of renewable electricity. According to forecasts developed for the Massachusetts DOER, the "base case" (anticipated situation) forecast shows certificates trading in the neighborhood of $25/MWH, or 2.5¢/kWh through 2012[78]. High- and low-priced scenarios show certificates valued at as little as $1/MWH to as much as $45/MWH. (It should be noted that this analysis was complete prior to the significant changes to Connecticut's RPS, which occurred in June 2003. It is possible that the increased demand from Connecticut for RECs will push Massachusetts REC prices higher.) The analysis also notes that there may be significant short-term volatility in certificate prices; the forecast is intended to capture general market conditions. Current market data show that these certificates traded for $38.00/MWH for 2003, and forward trading for 2005 has certificates valued between $40.00 and $50.00 MWH[79]. These certificate prices, when combined with revenues from electricity sales and other products, could help make a bio-oil facility in New Hampshire economically viable.

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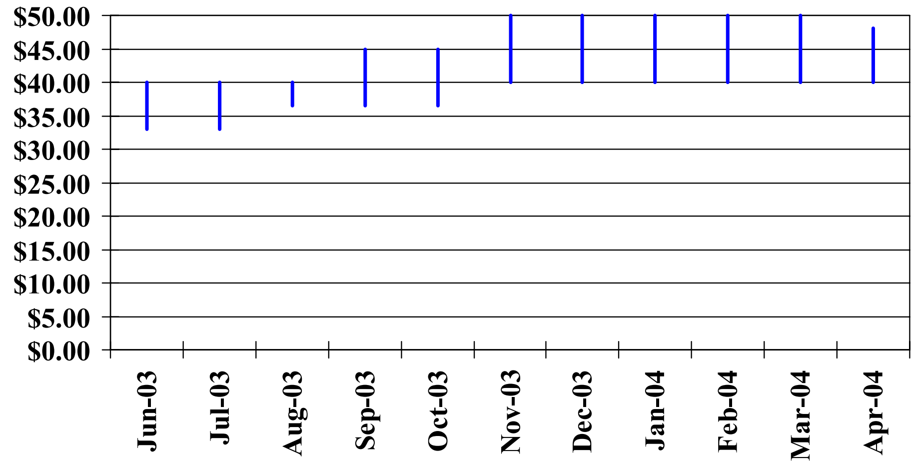
[74] Innovative Natural Resource Solutions LLC and Draper / Lennon, Inc. *Use of Low-Grade and Underutilized Wood Resources in New Hampshire.* Prepared for the NH Department of Resources & Economic Development. January 2001.
[75] Struzl, Ray of Manitowoc Public Utilities. *The Commercial Co-firing of RTP Bio-Oil at the Manitowoc Public Utilities Power Generating Station.* June 1997.
[76] 225 CMR 14.05 (3)(a): Co-firing With Ineligible Fuels Waiver – Renewable Portfolio Standard.
[77] 225 CMR 14.05 (3)(b)
[78] Grace, Robert C. (of Sustainable Energy Advantage) and Karlynn S. Cory (of LaCapra Associates). *Massachusetts RPS: 2002 Cost Analysis Update – Sensitivity Analysis.* December 16, 2002.
[79] Evolution Markets LLC. *Monthly Markets Update, REC Markets.* March 2004.



Data Source: Evolution Markets LLC Monthly Market Update, Compliance REC Markets

Figure 12. 2005 Massachusetts Renewable Energy Prices

5.3.4 Connecticut

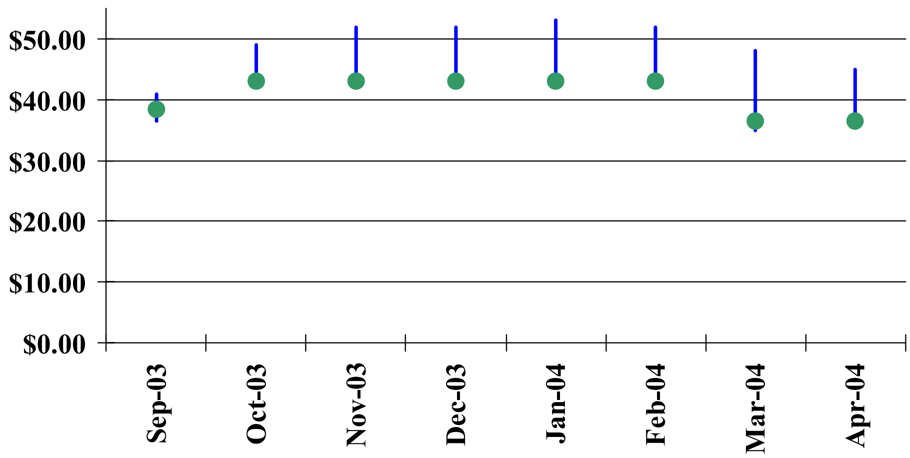
Connecticut has a renewable portfolio standard that calls for 6% of electricity sold in the competitive marketplace to come from renewable generation in 2000; this increases to 13% by 2009. Connecticut has two classes of renewables; generation from "new, sustainable biomass" -- a category for which a new bio-oil facility may qualify – receives preference over some other types of renewable power. In the 2003 legislative session, Connecticut changed its RPS to mandate participation by most electricity providers in the state.[80] This legislation clarified the rules for participating in the Connecticut RPS, including:

- For a Class One facility (the preferred category, which also includes solar, wind, landfill gas and fuel cells), biomass must be harvested "in a sustainable manner";
- For a Class One facility, emissions of NOx must be equal to or less than .075 pounds per million BTU of heat input;
- Changes the percentage of renewables (from both Class One and Class Two categories) required each year, but also requires utilities to provide renewable power as a component of their "transition service", thus expanding the number of customers who will purchase renewable power;

[80] Connecticut General Assembly Senate Bill No. 733. 2003.

- Allows purchase of renewable power from New England and New York, and allows purchase from some Mid-Atlantic states if they adopt an RPS similar to Connecticut's.

In early trading, Connecticut Class One certificates are trading between $36.50 and $45.00 / MWH for 2005[81]. Class Two certificates, which include biomass facilities that do not meet the Class One standards, are trading at a nominal amount, with prices ranging from $0.25 to $1.00/MWH.[82]



Data Source: Evolution Markets LLC Monthly Market Update, Compliance REC Markets

Figure 13. 2005 Connecticut Class 1 Renewable Energy Prices

It should be noted that the definition of renewable power in Connecticut does not directly address liquid fuels derived from biomass, but such a facility would presumably be treated as a biomass facility, and subject to the RPS eligibility requirements for biomass generating facilities. If a bio-oil facility were closer to development, it would be advisable for the developer to request a formal advisory ruling on this matter from the Connecticut Department of Public Utility Control.

[81] Evolution Markets LLC. *Monthly Markets Update, REC Markets.* November 2003.
[82] Evolution Markets LLC. *Monthly Markets Update, REC Markets.* July 2003.

5.3.5 Rhode Island Renewable Portfolio Standard

In June, 2004, Rhode Island established a renewable portfolio standard[83]. This RPS begins in 2007, and increases annually until 2019. It contains provisions for both new and existing renewable generation.

Year	Existing	New
2007	2.0%	1.0%
2008	2.0%	1.5%
2009	2.0%	2.0%
2010	2.0%	2.5%
2011	2.0%	3.5%
2012	2.0%	4.5%
2013	2.0%	5.5%
2014	2.0%	6.5%
2015	2.0%	8.0%
2016	2.0%	9.5%
2017	2.0%	11.0%
2018	2.0%	12.5%
2019	2.0%	14.0%

Eligible Biomass Facility: To qualify as "new" for purposes of the Rhode Island RPS, a biomass facility must have begun operation (or have incremental new renewable output derived through capital investment) after 1997, use "eligible biomass fuels and [maintain] compliance with current air permits"[84]. Eligible biomass means "fuel sources including brush, stumps, lumber ends and trimmings, wood pallets, bark, wood chips, shavings, slash and other clean wood that is not mixed with other solid wastes… or neat bio-diesel and other neat liquid fuels that are derived from such fuel sources."[85]

Price Premium. As the Rhode Island RPS has just been established, there is no pricing available at this time. There is a price cap of $50.00 per REC (2003 dollars), which will be adjusted annually for inflation.

[83] State of Rhode Island General Assembly. *S. 2082. An Act Relating to Public Utilities and Carriers – Renewable Energy Standard.* June 29, 2004.
[84] State of Rhode Island General Assembly. *S. 2082. An Act Relating to Public Utilities and Carriers – Renewable Energy Standard.* June 29, 2004.
[85] Ibid

5.3.6 Overall Demand for Compliance RECs in New England

Publicly available information suggests that demand for RECs in Massachusetts and Connecticut will outpace supply the coming years. In public testimony[86], New Hampshire PUC staff analysis indicated that REC demand in Massachusetts and Connecticut is expected to exceed supply for the years 2003 – 2010. This analysis assumed that Cape Wind, a proposed 420 MW offshore wind farm, and Schiller Station's proposed biomass program both came on line for 2006, and that no other new facilities entered this market. New participants in the REC market, or changes in existing and proposed renewable energy facilities, could alter this analysis.

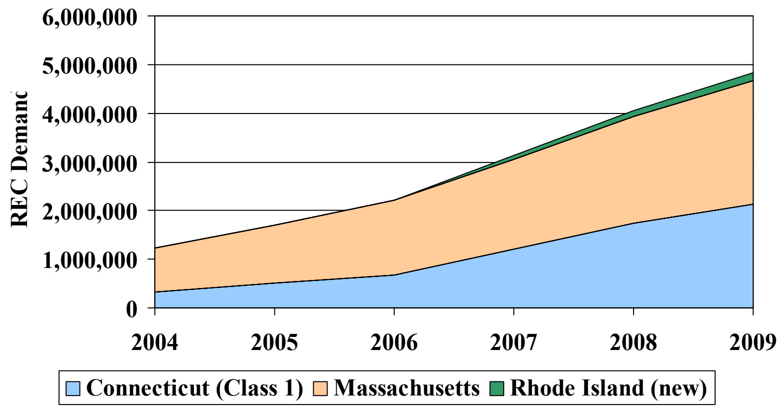


Figure 14. Anticipated New England High-Value REC Demand 2004 - 2009

[86] NH PUC Docket DE-03-166

5.4 Carbon Credits

There has been significant interest from stakeholders in the possibility of raising revenue through the sale of "carbon credits". In many policy discussions, energy derived from sustainably harvested biomass is considered "carbon neutral" – the emissions of carbon are offset by carbon sequestered by forest growth.[87] Carbon is emitted from the combustion of wood to generate power – an estimated 42.8 pounds of carbon for each 100 pounds of dry wood burned – but an equal amount of carbon is sequestered over a 60 to 100 year re-growth period.[88] It should be noted that not all regulatory frameworks recognize biomass as "carbon neutral". For example, as part of their electricity generation emissions reporting to consumers, energy suppliers in Massachusetts are required to report actual "smokestack" carbon emissions from biomass plants, and not count future carbon sequestration associated with sustainable forest management.[89]

Because of its "carbon neutral" emissions profile, there has been significant interest from proponents of biomass energy to participate in carbon offset markets – in effect deriving revenue from the carbon not emitted. At this writing, carbon offset markets in the United States are in the formative stages, and the revenue associated with carbon offsets is modest. Nationally, carbon offsets can presently be sold for between $1.00 and $2.00 per ton, and these transactions are generally used to satisfy voluntary reductions or are speculative transactions.[90] The Oregon-based Climate Trust has solicited carbon reductions for as high as $6.00 per ton, but projects are generally funded at a lower level.[91]

However, it is highly unlikely that trading carbon credits would be in the economic interest of a bio-oil facility. This is because it is generally accepted that energy producers must choose to participate in either the carbon market or the renewable energy credit market, but cannot participate in both. When a renewable energy producer sells a green credit, they sell all of the non-price attributes associated with the generation – "including but not limited to the unit's fuel type, emissions, vintage and RPS eligibility."[92]

The sale of a renewable energy certificate, combined with the sale of carbon credits, is referred to as "partial double sale". In this instance, the purchaser of the renewable energy certificate reasonably expects to own and control all generation attributes, but one attribute – carbon emissions – is sold to another party. While each state addresses this

[87] Innovative Natural Resource Solutions LLC and Draper/Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.* January 2002.
[88] Maine State Planning Office and University of Maine. *State of Maine Climate Change Action Plan*. 2000.
[89] Personal Communication with Susan Weber, Massachusetts Department of Environmental Protection. April 14, 2003.
[90] Personal communication with Mark Trexler, Trexler and Associates. August 19, 2003.
[91] Personal meeting with Sean Clark, The Climate Trust, March 23, 2004.
[92] 225 CMR 14.02: Definitions – Renewable Portfolio Standard

issue separately, the Green Electricity Marketing Guidelines prepared by the National Association of Attorneys General discourage this practice.[93]

Because the attribute associated with carbon- neutral generation - emissions – is sold as part of participation in a renewable portfolio standard, it is likely that the separate sale of carbon credits is not permitted. For example, participants in the Massachusetts RPS are required to assure that "New Renewable Generation Attributes have not otherwise been, nor will be, sold, retired, claimed or represented as part of electrical energy output or sales, or used to satisfy obligations in jurisdictions other than Massachusetts."[94]

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[93] Holt, Ed. "Renewable Energy Certificates and Generation Attributes." *Regulatory Assistance Project Issuesletter.* May 2003.
[94] 225 CMR 14.09: Compliance Filings for Retail Electricity Suppliers

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