Wood Feedstock Supply for Biobased Materials in Maine

Prepared for the Environmental Health Strategy Center and Biobased Maine



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Introduction

This document serves as an independent assessment of wood availability, and factors influencing availability and pricing, for potential bioproduct manufacturing in Maine. This is not intended to serve as an assessment for any particular facility, and should not be relied upon for that purpose.

Innovative Natural Resource Solutions LLC was hired by Environmental Health Strategy Center and Biobased Maine to compile this report. INRS has significant experience working with the region's forest industry, loggers and landowners, and has a strong working knowledge of historic, existing and potential markets for wood in Maine and in the region.

The analysis and information in this report is based upon our best professional judgement and on sources of information we believe to be reliable. However, no representation or warrantee is made by Innovative Natural Resource Solutions LLC as to the accuracy or completeness of any of the information contained herein. Nothing in this report is, or should be relied upon as, a promise or representation as to the future.

Innovative Natural Resource Solutions LLC

Founded in 1994, Innovative Natural Resource Solutions LLC (INRS) is a full-service consulting firm specializing in the forest industry, natural resource conservation, and renewable energy.

INRS has worked with many parties on the development of new biomass energy, pulp and paper, biofuel and bioproduct facilities around the country. The firm is currently working or has recently worked with developers of biomass or biofuel projects in Maine, New Hampshire, New York, New Jersey, Florida, South Carolina, Oregon and California.

The company principals are professional foresters and a resource economist, and have played key roles in the development, financing, evaluation, purchase and sale, and operation of biomass energy facilities throughout the United States and Maritime Canada. INRS advises firms with a combined annual fuel use of over 20 million tons of biomass on fuel procurement strategies and wood resource availability. INRS biomass fuel supply studies have been used in the regulatory approval of three biomass electric conversion projects by Dominion Resources, the financing of a biomass electric conversion by Northeast Utilities, and the purchase of operating biomass electric units by a number of public and private companies.

Eric Kingsley, primary author of this report and a lead in INRS' biomass practice, has conducted over 100 biomass fuel resource assessments. Kingsley has served as an expert witness on biomass energy issues, including fuel supply, before regulatory bodies in New Hampshire, Georgia, Virginia and Vermont. Kingsley has also worked extensively on financing of biomass energy projects utilizing federal New Markets Tax Credits, and served for five years as a board member, and one year as President, of CEI Capital Management, Ltd., one of the nation's largest New Markets Tax Credit allocates.

Wood Feedstock Supply for Biobased Materials in Maine

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Executive Summary

Maine is at a unique moment: there has never been a better time in the state's history to develop a project or technology that uses low-grade wood, particularly softwoods. This is because Maine's forests grow significantly in excess of harvest levels, the state has a supply infrastructure that can supply facilities efficiently, and the recent loss of roughly four million tons of market for wood products (caused by the closure or reductions at pulp and paper mills) means that landowners, loggers and mills are eager to supply new market entrants.

Maine has nearly 17 million acres of timberland, covering four-fifths of the state. Ninety-four percent of this timberland is privately owned. According to the latest data from the USDA Forest Service's Forest Inventory & Analysis, net growth exceeds removals (harvests) by roughly 6 million tons per year on Maine timberland. Most of this volume is softwoods.

In addition to this volume of unutilized material, an estimated 3.8 million tons of harvest residue (tops, branches, etc.) is generated annually. While not all of this is available, about half, or nearly 2 million tons per year, is potentially available for use in a bioproduct facility.

Maine sawmills, which have been steadily increasing production since 2009, produce an estimated 800,000 tons of clean chips, plus a similar amount of sawdust and bark. Markets for mill residue, particularly from softwood mills, has declined significantly in the past three years. Maine sawmills are currently concerned about their ability to find sustainable outlets for mill residues, which is necessary for them to continue operations.

Any bioproduct manufacturer that located in Maine would integrate with the state's incumbent forest industry, which despite some recent losses remains diverse and robust. They would benefit from the supply chain – landowners, loggers, foresters, and truckers. A new facility would at some level compete with and benefit from other forest product manufacturers – sawmills, pulp mills, and biomass electricity facilities.

Market Structure for Forest-Derived and Mill Residue

Whole–tree chips and sawmill chips are by-products of other processes, and markets such as bioproduct facilities can provide an important outlet.

On timber harvesting operations, the loggers are generally looking to harvest sawlogs (for lumber) and pulpwood (for paper mills, and potentially for bioproduct facilities), both generally higher value products than whole-tree chips. However, much wood does not meet the rigid specifications for these higher value markets (for example, a length of tree may be crooked, have rot, or have a split in it). For this wood, as well as all tops and branches, loggers have two choices:

(i) Return the wood to the forest and allow it to decay, or
(ii) Chip the wood that does not meet sawlog and pulpwood specifications.

In areas where there is a viable bioproduct or biomass market, many loggers purchase portable whole tree chippers and chip vans (truck trailers designed to have chips blown in) in order to access this market. For firms engaged in land clearing, their need to remove most or all trees from a site makes a market for chips a necessary part of conducting their operations (N.B., land clearing wood is generally a small component of Maine's overall supply).

In general, when a single tree is harvested, several products can be derived[i].

- The bottom length (generally eight to sixteen feet) is often straight and has relatively few defects such as knots or branches. This section is generally a sawlog, and is sent to a sawmill for lumber production. If of a smaller size than local sawmills require, or if it has a number of defects, it may be diverted to markets described below.

- The next lengths (again, often eight to sixteen feet) may become a variety of products. If it is straight and has few defects, it may be a sawlog and will be sent to a sawmill. If it is smaller than the size sawmills require, or has many defects (rot, knots, split, etc.), it will be sent to a pulp mill for paper manufacturing, assuming such local markets exist. If it is not straight (and thus cannot be cleanly debarked) it will be chipped for use in biomass production or mulch, or left in the woods if those markets are not economically available. Some of this material may be appropriate as feedstock for biofuels and bioproducts.

- The tops and branches can be chipped for bioproduct or biomass energy markets, chipped for mulch markets, or left in the woods.

Figure 1 shows the sections of a single tree and the products derived[ii]; Figure 2 shows how parts of a single harvest can support multiple markets, and Figures 3 through 6 show parts of a logging operation that will produce whole-tree chips.

Figure 1. Schematic of Products Derived from a Single Tree

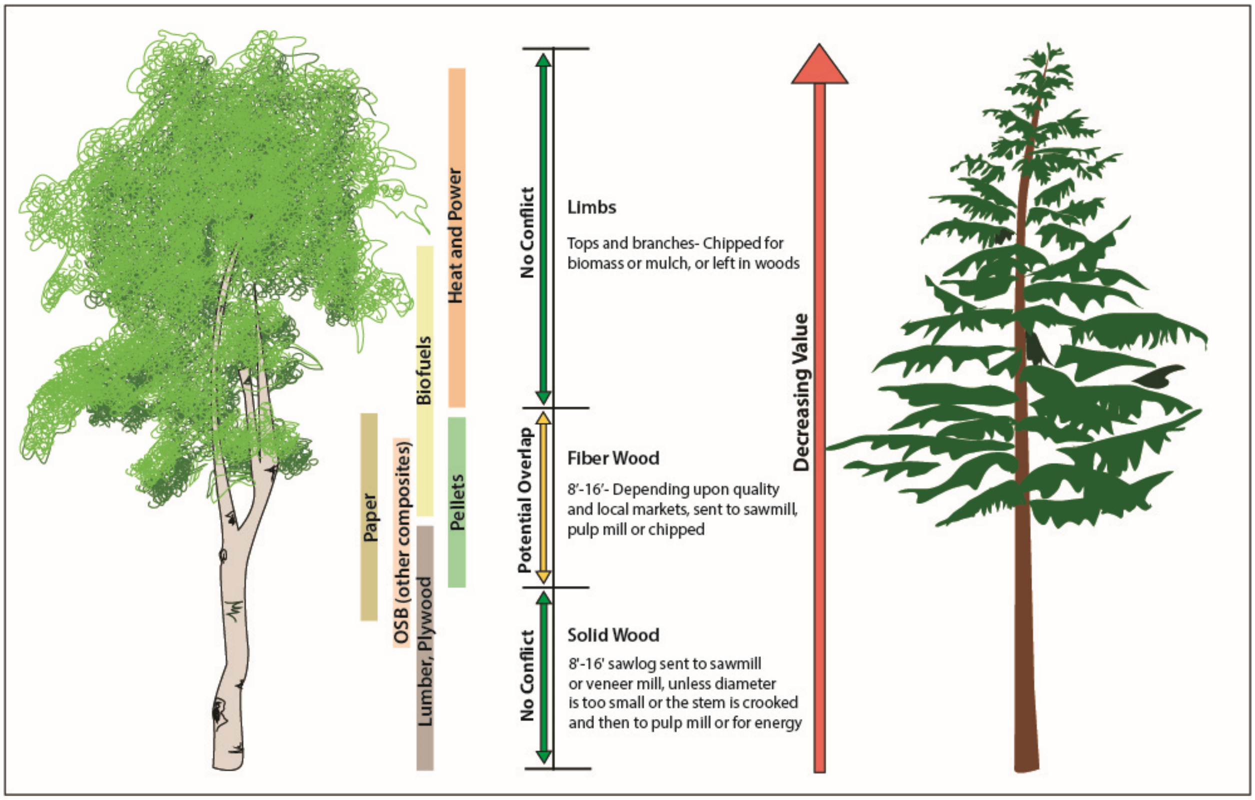


Figure 2. Multiple Products from a Single Timber Harvest

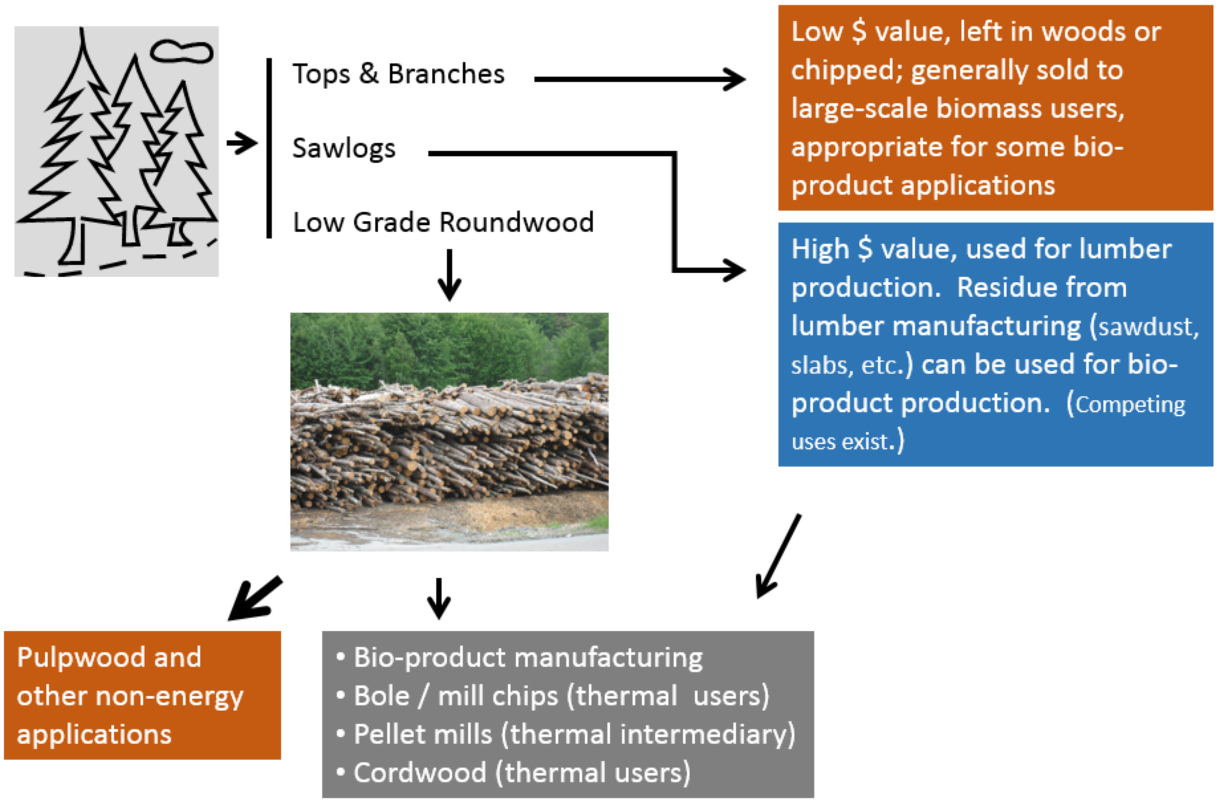


Figure 3. Log landing with slasher (left), chipper (right), and wood sorted by product.

Figure 4. Wood sorted for chipping.

Figure 5. Close-up of chipper on log landing.

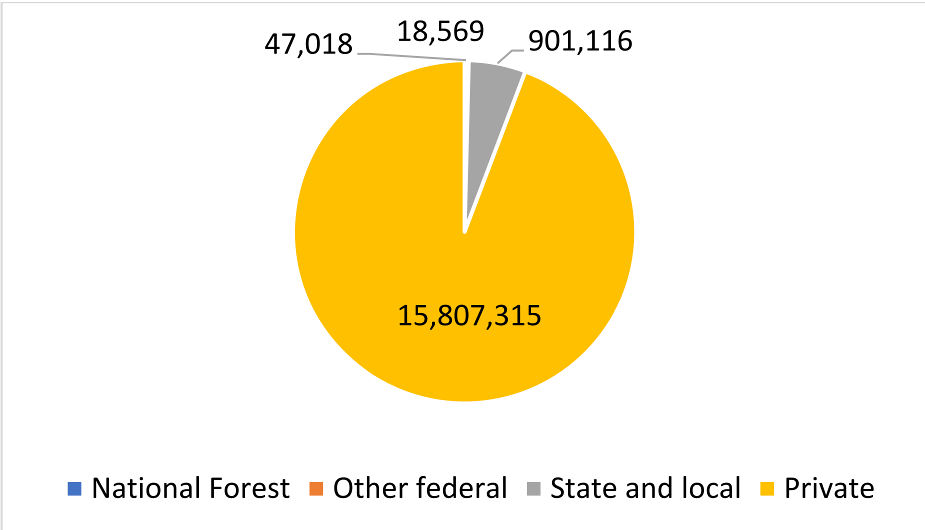
Figure 6. Trailer for whole-tree chips, with opening for chipper to blow chips into.

Feedstock Supply Assessment

Maine is the most heavily forested state in the nation, with roughly 16.8 million acres of timberland, defined as land capable and legally available for growing commercial forest products[iii]. This accounts for roughly 81 percent of the land in Maine[iv].

The vast majority of this timberland – an estimated 15.8 million acres – is privately owned. The State of Maine and local governments own nearly 1 million acres of timberland, with the remainder owned by the National Forest Service (White Mountain National Forest) or other federal agencies.

Figure 7. Timberland Ownership by Type



Private landowners are a highly preferable landownership class from a wood supply perspective, as they can cut wood absent political and government budget considerations, and react rationally to market signals.

Of private timberland in the state, roughly 10 million acres is in some form of corporate ownership[v]. Generally speaking, these are entities that own and manage land as a business, with the growth and management of forest products a core part of the business. These lands are often referred to as "industrial forests", and are the predominant ownership type in the state north of Route 2. These ownerships may be managing multiple harvests on their lands on a year-round basis, and can be an extremely reliable source of wood fiber.

The remaining private timberland, nearly 6 million acres, is in non-corporate ownership – generally family forest owners. An estimated 88,000 individuals or families own 10 or more acres of timberland in Maine[vi]. Family forest owners are the predominant ownership class in the southern portion of the state, but family forestland holdings can be found throughout Maine. Individuals and families own timberland for a variety of reasons, including but not limited to the production of forest products. Family forest owners often conduct harvests only every +/- 20 years, but the vast number of such owners can form a continuous and reliable supply.

Regions of Maine

Maine is a large state, and in order to evaluate regional differences the resource analysis that follows separates the state into three distinct regions (when data allows):

- Southern and Midcoast,
- Northern and Downeast, and
- Western.

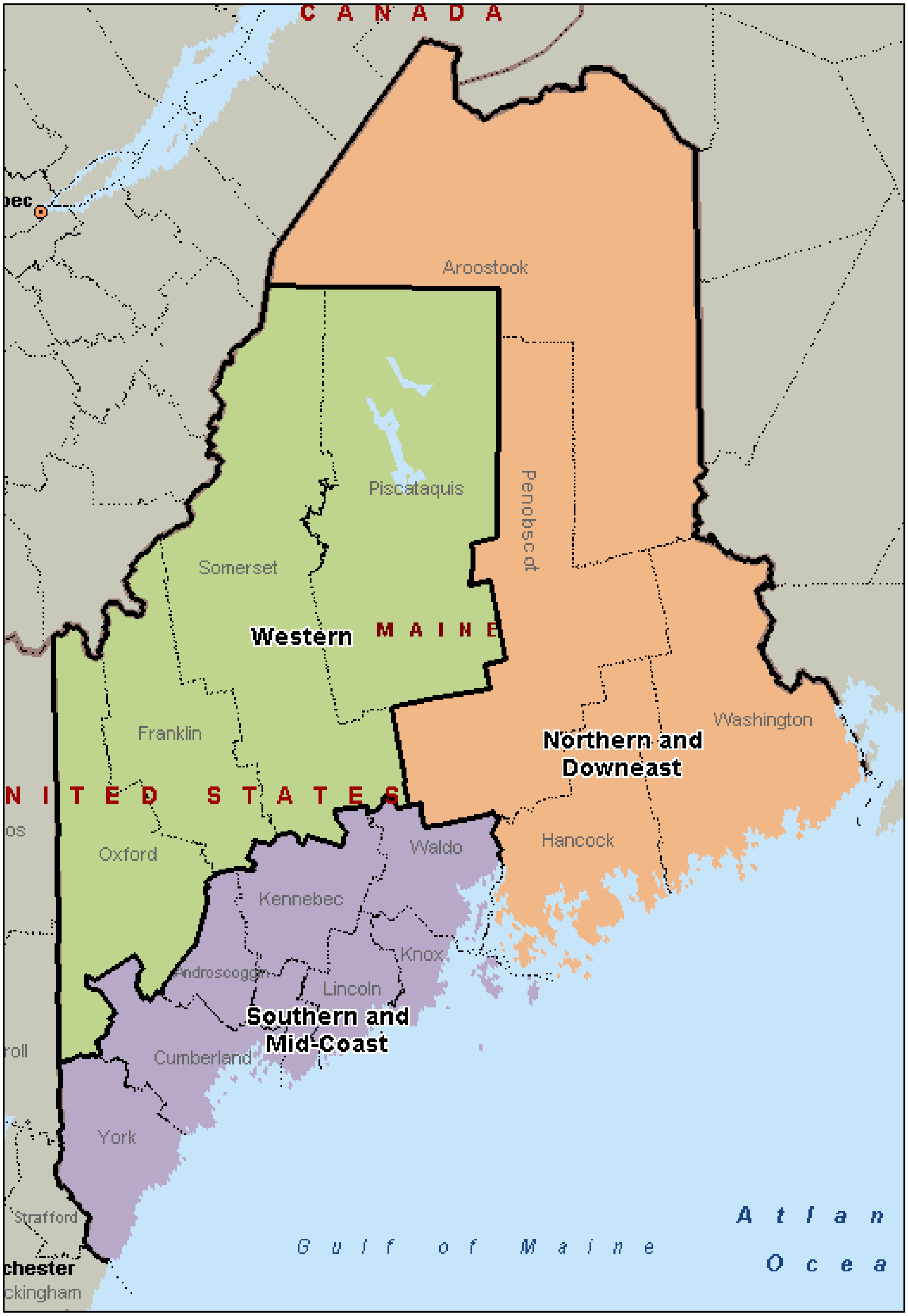
While these regions were grouped to reflect differences in forest type, landowner groupings and markets, there is nothing sacrosanct about these divisions, and it is critical to note that a single market may pull feedstock from multiple regions of Maine, as well as from beyond the borders of Maine.

The following table and figure show which Maine counties are located in each of these regions.

Table 1. Counties in Three Regions of Maine

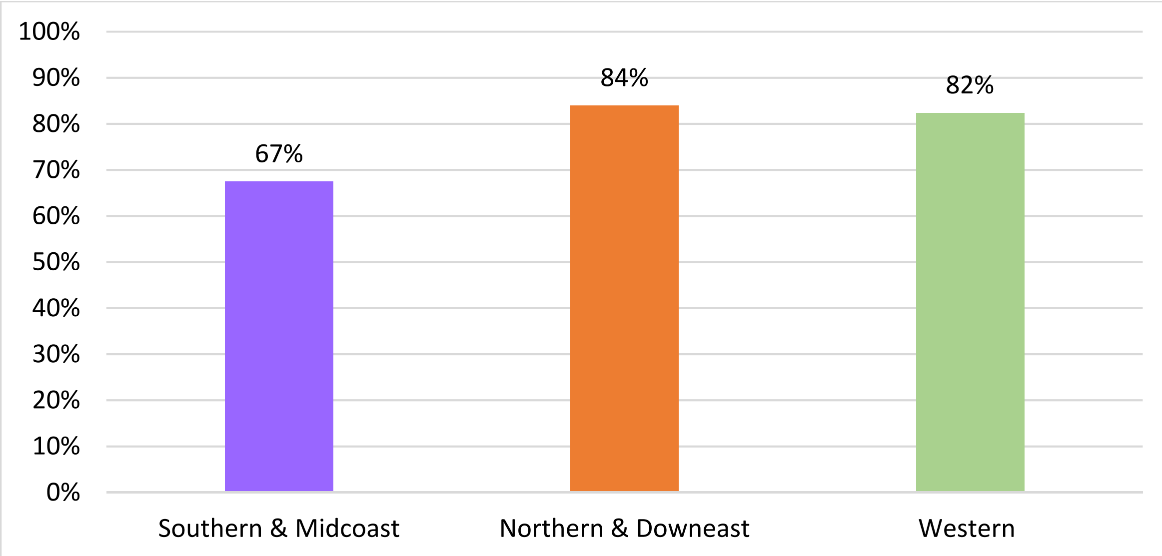
Southern & Midcoast	**Northern & Downeast**	**Western**
Androscoggin	Aroostook	Franklin
Cumberland	Hancock	Oxford
Kennebec	Penobscot	Piscataquis
Knox	Washington	Somerset
Lincoln		
Sagadahoc		
Waldo		
York		

Figure 8. Regions of Maine



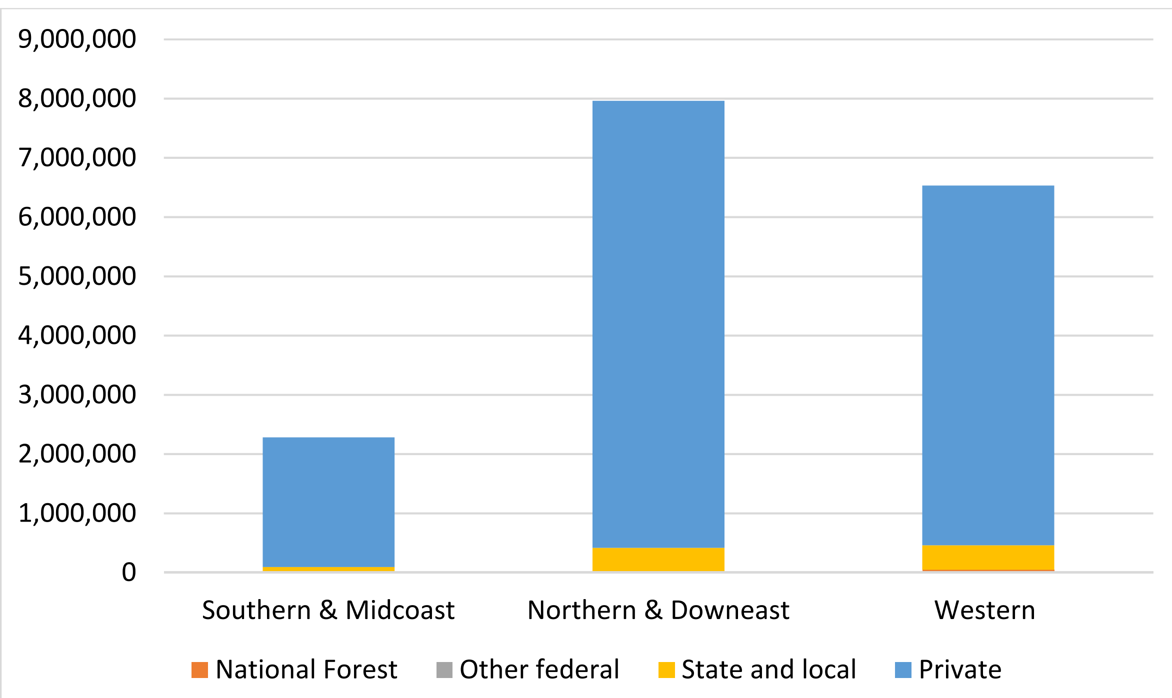
All regions of Maine are heavily forested, with at least two-thirds of all land classified as timberland in each region.

Figure 9. Percent Timberland by Region



Each region is primarily privately owned, with all regions having 93% or more of timberland in private ownership.

Figure 10. Timberland Ownership Group by Region (acres)



Forest Inventory & Analysis

INRS used the USDA Forest Inventory and Analysis ("FIA") EVALIDator tool (version 1.6.0.03a[vii]) to estimate for:

- Annual Net Growth (growth less mortality);
- Annual Removals (generally timber harvests, but can also be regulatory, fire or other reasons);
- Species type;
- Slope.

The Forest Inventory and Analysis (FIA) group within the US Forest Service collects data annually from a subset of permanent plots on a grid density of approximately one plot for every 6500 acres of timberland. This data is used to provide an estimate of changes in the forest resource over time. A complete re-inventory of all plots occurs roughly every five years. INRS used the most recent complete FIA information, which uses data collected from 2012 through 2016 and represents the latest available complete cycle. The data does not represent a single year, but rather an annualized number based upon the years 2012 through 2016.

The Forest Inventory and Analysis data is based upon sampling, and not a full inventory of all land and timber. As a result, there are sampling errors associated with the use of this data; INRS here report the mid-point of each estimate.

Growth and Removals

The following tables and figures show annual Net Growth (total growth less mortality), Removals, and a calculated Growth less Removals. This data reflects the volume of wood, by species group, that is potentially available with all current markets active (current markets account for the "removals").

Statewide, annual net growth in excess of harvest levels is roughly 6 million green tons. The majority of this is in "other softwoods" (primarily spruce – fir), and pine (primarily white pine), but all species groups show annual net growth in excess of harvest levels on a statewide basis, and all regions have total net growth well above harvest levels.

The tables and figures below show growth and harvest levels by species group on a statewide and regional basis (see Appendix A for a listing of species in each Species Group). Of importance, all regions of Maine have net growth in excess of removals.

Table 2. Growth and Removals by Species Group – Statewide and by Region (green tons)

Statewide

	Net Growth	Removals	Growth - Removals
Pines	2,485,923	1,193,578	*1,292,345*
Other softwoods	9,518,196	5,603,367	*3,914,829*
Soft hardwoods	4,398,388	3,892,081	*506,307*
Hard hardwoods	4,592,400	4,185,805	*406,595*
Total	*20,994,907*	*14,874,831*	*6,120,077*

Southern & Midcoast

	Net Growth	Removals	Growth - Removals
Pines	737,950	486,312	*251,639*
Other softwoods	693,181	509,280	*183,901*
Soft hardwoods	891,786	434,681	*457,105*
Hard hardwoods	1,247,334	478,742	*768,592*
Total	*3,570,252*	*1,909,015*	*1,661,237*

Western

	Net Growth	Removals	Growth - Removals
Pines	738,879	506,538	*232,341*
Other softwoods	3,557,821	2,336,424	*1,221,397*
Soft hardwoods	1,580,813	1,557,351	*23,462*
Hard hardwoods	1,917,571	2,132,971	*-215,400*
Total	*7,795,084*	*6,533,284*	*1,261,800*

Northern & Downeast

	Net Growth	Removals	Growth - Removals
Pines	1,009,094	200,728	*808,366*
Other softwoods	5,267,194	2,757,662	*2,509,531*
Soft hardwoods	1,925,789	1,900,050	*25,739*
Hard hardwoods	1,427,495	1,574,092	*-146,597*
Total	*9,629,572*	*6,432,532*	*3,197,040*

Figure 11. Statewide Net Growth and Removals by Species Group (Green Tons)

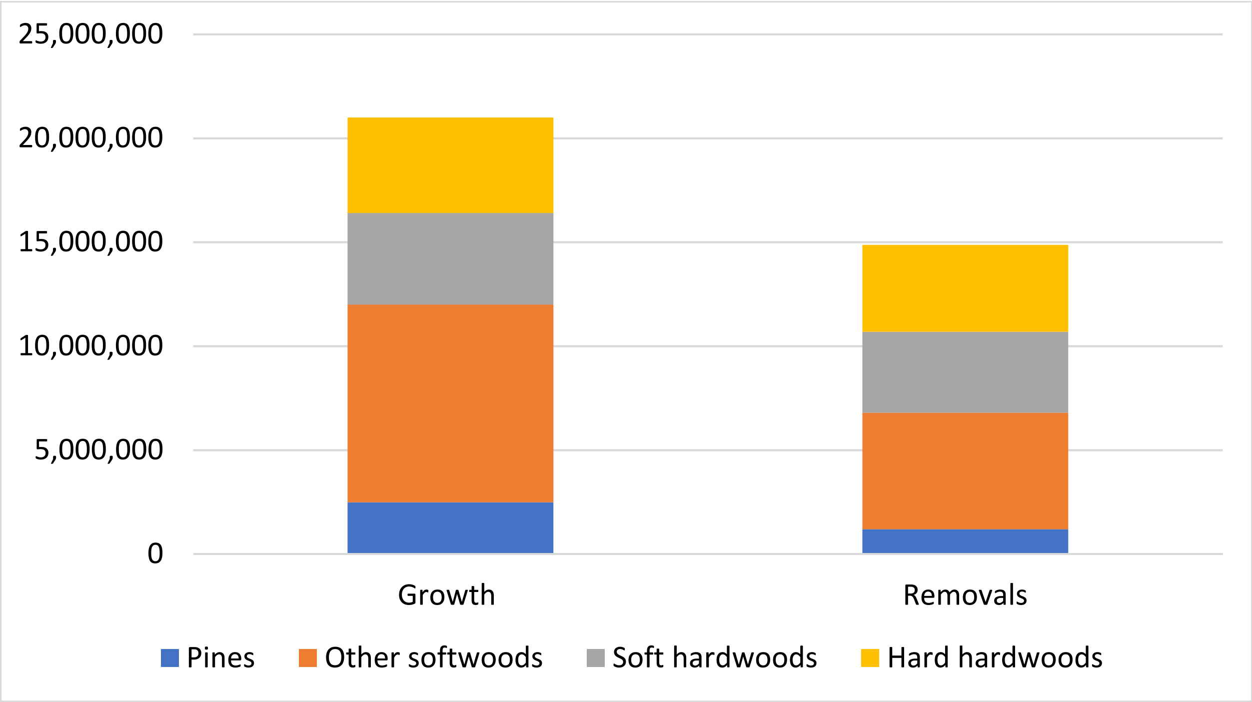
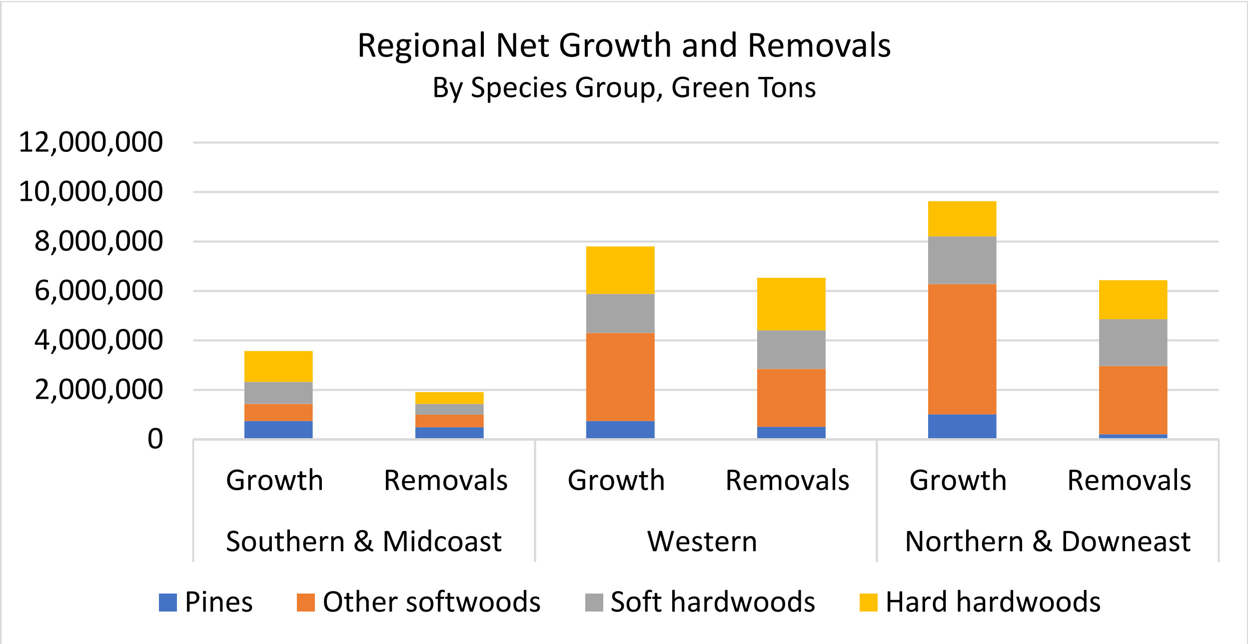


Figure 12. Regional Net Growth and Removals by Species Group (Green Tons)



Forest Residues

Forest residues refers to the portions of a harvested tree that cannot be utilized in other markets. Generally, this refers to tops and branches from stems harvested for roundwood use (sawlogs and pulpwood). After the higher-value roundwood is separated, any unmerchantable pieces can then be chipped directly into a truck for delivery to a consuming facility (generally stand-alone biomass plants, or biomass boilers at forest industries).

To date, the use of forest residues has been largely for energy production, and the industry has adopted a fuel specification:

- **Forest-derived biomass fuel chips** (from logging and land clearing operations)
- Chip size:
    - Maximum size – 2.5 inches in any direction
    - Maximum percent oversize – 10% by volume, with a maximum size of 6”
    - Maximum fines (<+ 1/32”): 10%
- Expected moisture content (as delivered):
    - 40% to 55%, unless otherwise indicated
- Average BTU content at 45% moisture content: 4,625 BTU/pound

Importantly, forest residues are generally not species separated, but instead represent a mix of the material being harvested on a particular site. Consumers should assume a mix of species, with bark and sticks. As wood is usually skidded (dragged) from the point of harvest to a landing, there is also some modest volume of dirt in biomass chips. These issues do not impact the use of biomass chips for combustion, but may need to be addressed for some bioproduct and biofuel application.

Figure 13. Wood Being Skidded to a Landing

Because forest residue consists of the tops and branches of stems harvested for other markets – as well as cull trees - the volume of forest residue potentially available to the market is a function of harvesting for other purposes. Based upon USDA Forest Service information, INRS has assumed that forest residue is 31% for hardwood trees and 20% for softwoods[viii].

Based upon recent harvests, nearly 4 million green tons of harvest residue is generated annually in Maine.

Table 3. Estimated Forest Residue Generation, by Region (Green tons)

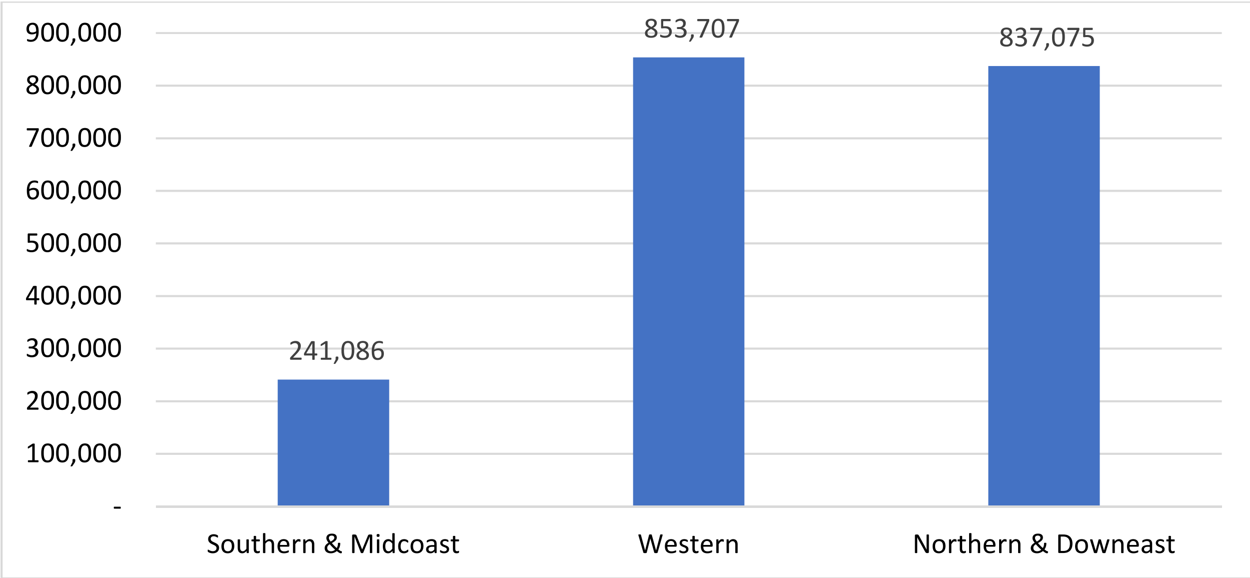
	Statewide	Southern & Midcoast	Western	Northern & Downeast
Pines	238,716	97,262	101,308	40,146
Other softwoods	1,120,673	101,856	467,285	551,532
Soft hardwoods	1,254,807	140,141	502,090	612,576
Hard hardwoods	1,249,540	142,913	636,731	469,896
Total	*3,863,736*	*482,173*	*1,707,414*	*1,674,150*

While nearly 4 million green tons of harvest residue is generated annually, not all of this can or should be captured. Various biomass harvesting recommendations suggest that some level of harvest residue be left on-site for nutrient replenishment and habitat benefits[ix x], and some tops and branches are used by loggers to line skid trails and increase equipment flotation on soft ground. Additionally, research conducted at the University of Maine suggests that there are limits to what volume of forest residue can be practically captured using traditional timber harvesting equipment[xi]. For these reasons, it is assumed that no more than 50% of residue can be captured and brought to market.

Maine's timber harvest is estimated to be conducted 80% by whole-tree systems[xii], which are well suited for the capture of biomass. Roughly 15% of the harvest occurs via cut-to-length systems, and the remaining portion is harvested with hand crews and cable skidders. Neither of these harvest systems is well suited for the capture of biomass, though some loggers have done so successfully[xiii].

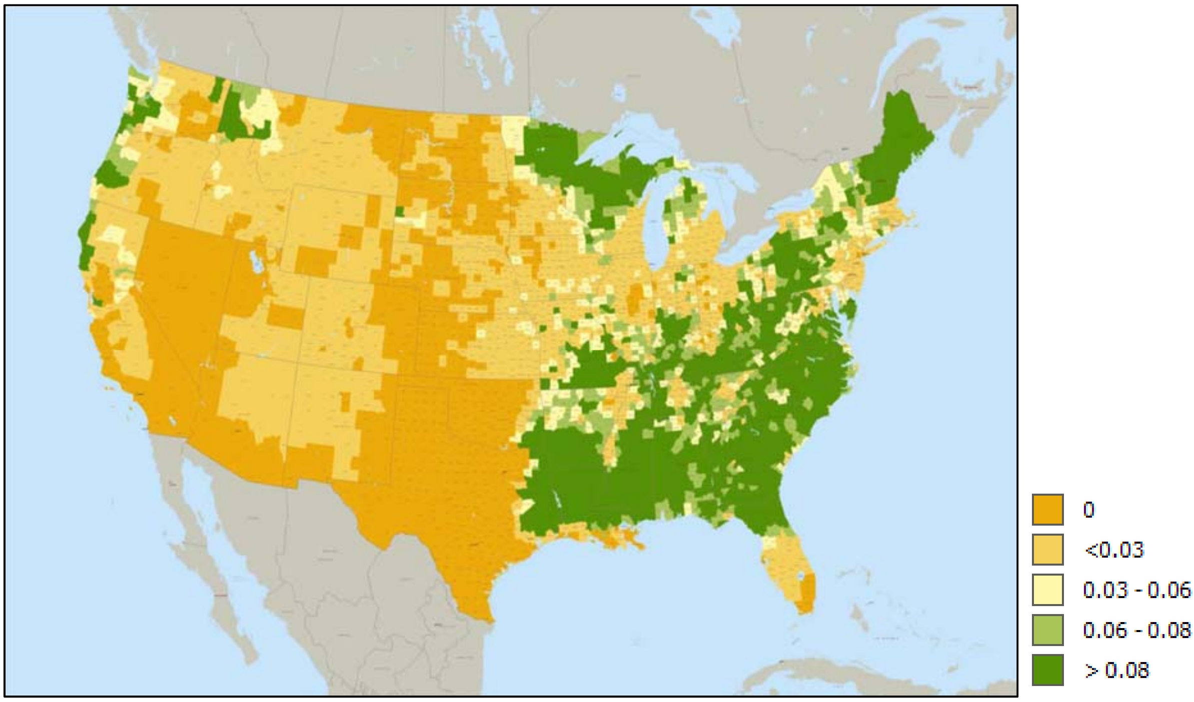
Given an assumed capture rate of 50%, the following figure shows forest residue generation by Region.

Figure 14. Forest Residue Availability by Region, 50% Capture Gate (Green Tons)



Of note, all Maine counties are in the top quintile for annual generation of forest residue (green tons per acre per year) of all counties nationally.

Figure 15. Forest Residue Density (green tons / acre / year) by County[xiv]



Standing Volume

In addition to estimating the annual net growth and harvest levels in Maine forests, the Forest Inventory & Analysis allows an estimate of the standing volume of all growing stock[xv] in the forests. Statewide, there are roughly 550 million green tons of standing volume on Maine timberland, with a little more than half in softwood.

The following figures show standing volume by region.

Figure 16. Standing Volume by Region (green tons)

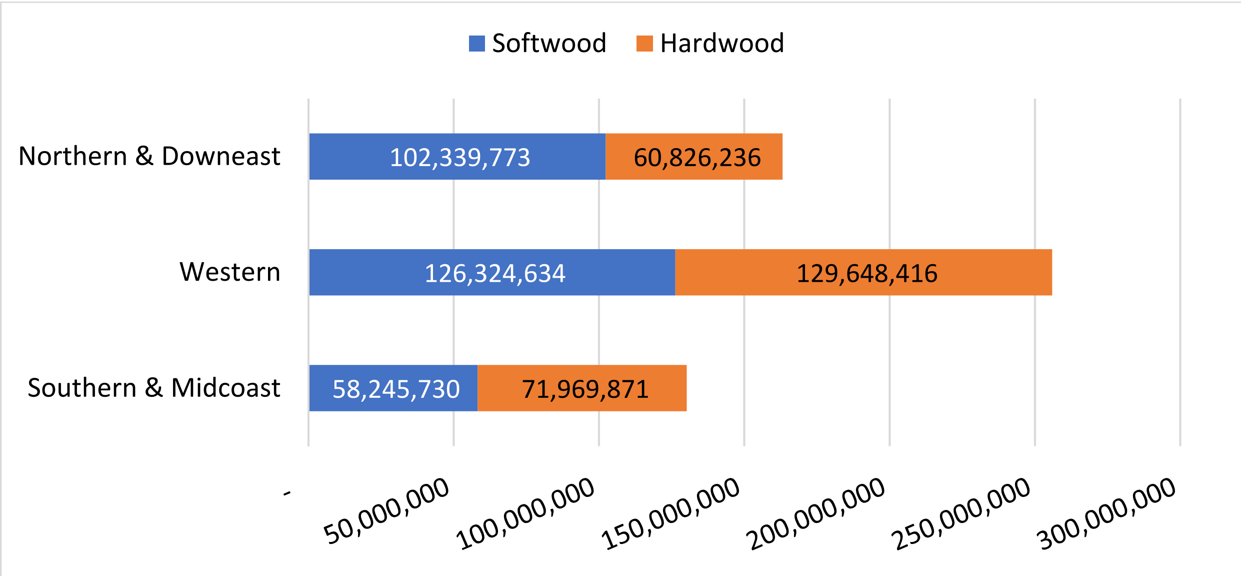
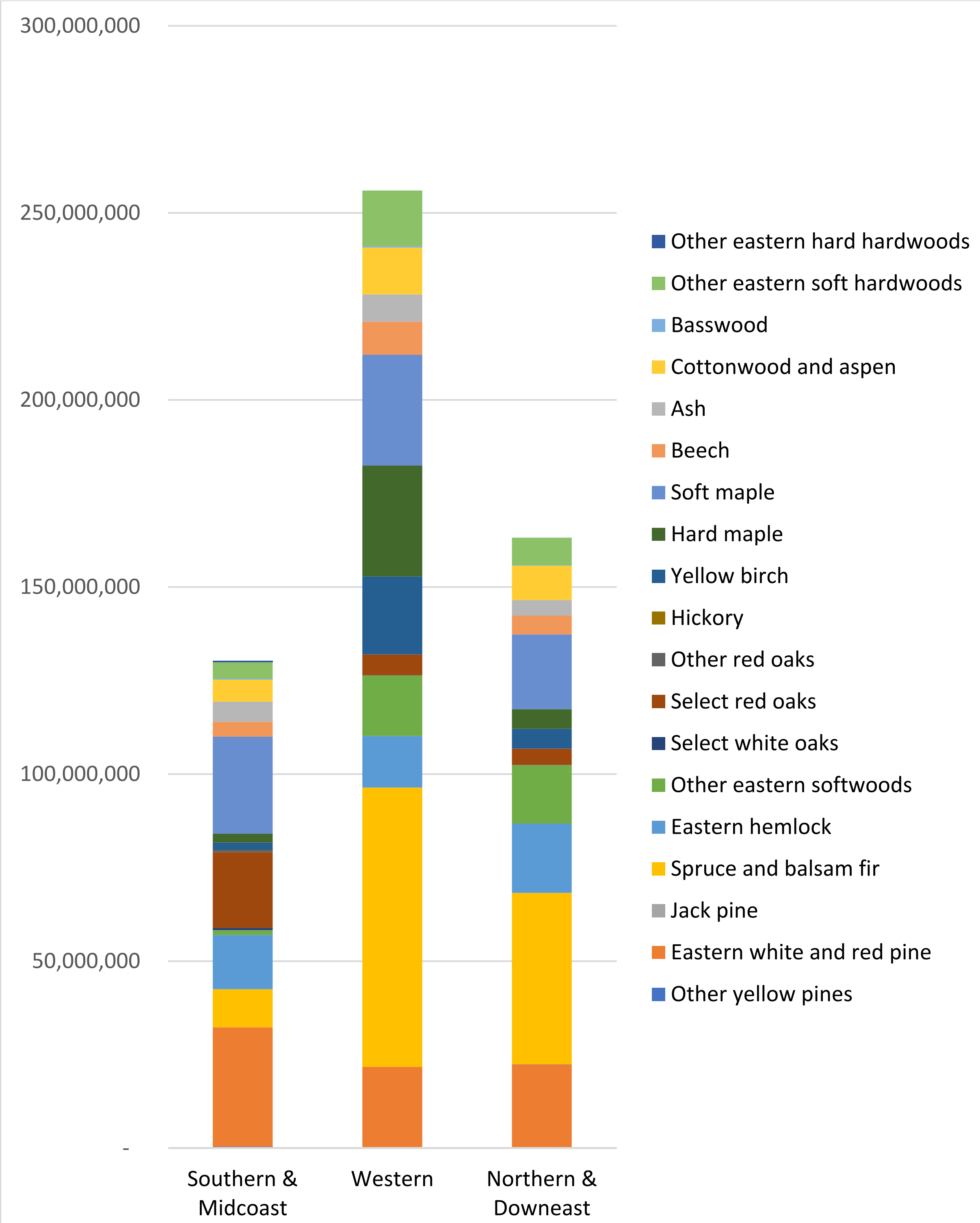
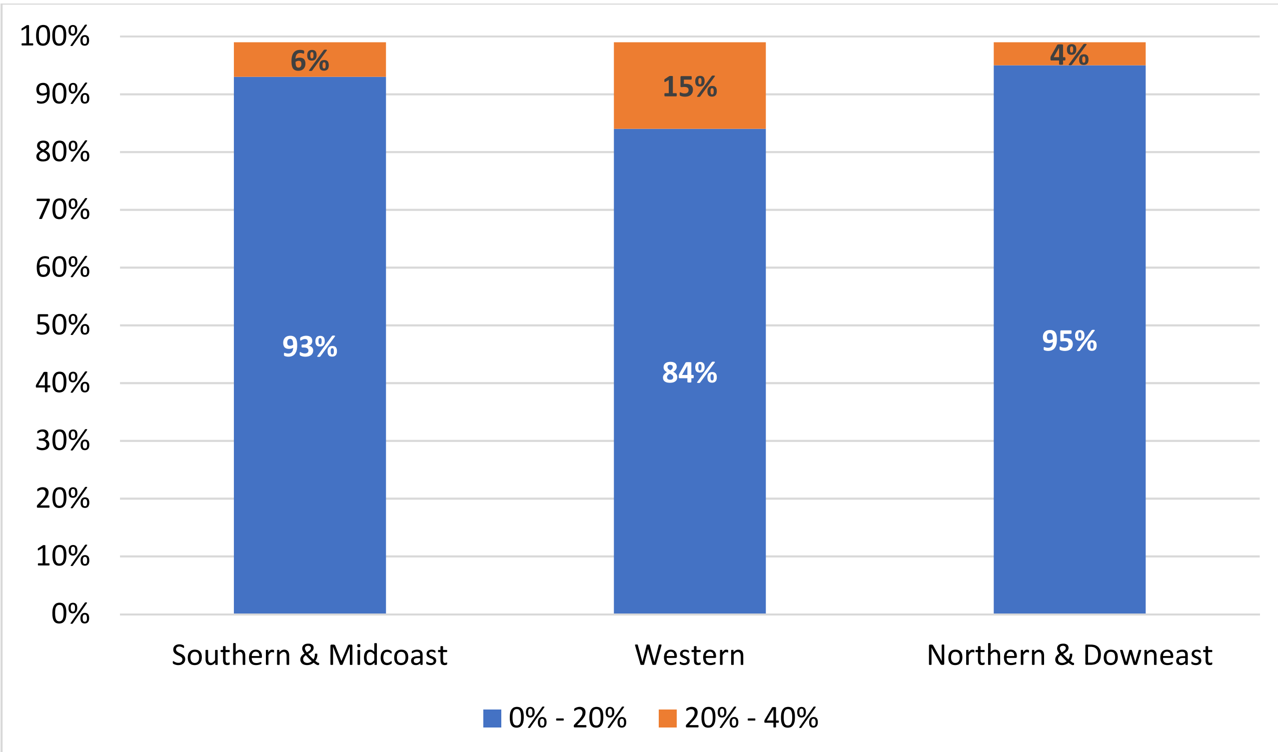


Figure 17. Standing Volume by Species Group and Region



Forest Inventory & Analysis data also shows that the vast majority of timberland in each region is on a slope that is operable by standard logging equipment. Steep slopes that can present operational limitations or challenges in other parts of the country are rare in Maine. In each region, at least 84% of timberland is on a slope less than or equal to 20 percent, and almost all of the remainder is on a slope less than or equal to 40 percent. All of this land is generally considered operable with conventional and mechanical logging equipment.

Figure 18. Slope by Region

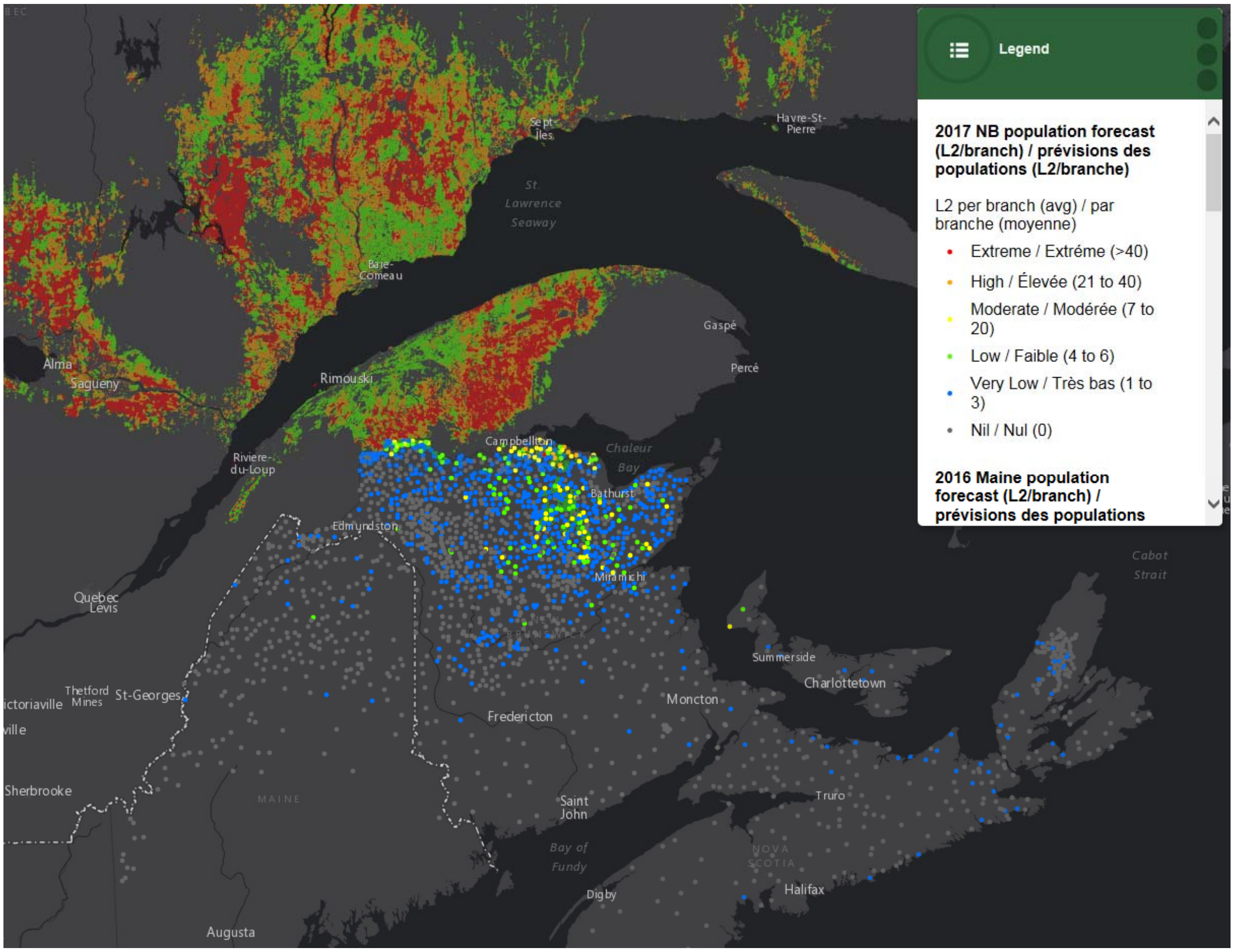


Spruce Budworm

Spruce Budworm is a native moth, which defoliates fir and spruce trees while in caterpillar stage. This moth has cyclical population levels, and has reached epidemic levels – causing significant loss of tree growth and mortality, three times in the last century. The last major outbreak in Maine was in the 1980s, and an outbreak from moderate to severe is expected in the coming years.

Portions of Quebec and New Brunswick, both of which border Maine, are currently experiencing Spruce Budworm outbreaks. Quebec has seen defoliation of spruce-fir stands growing steadily since 2008, and there is every expectation that parts of Maine will be impacted as part of this outbreak[xvi].

Figure 19. 2017 Spruce Budworm Population Forecast[xvii]

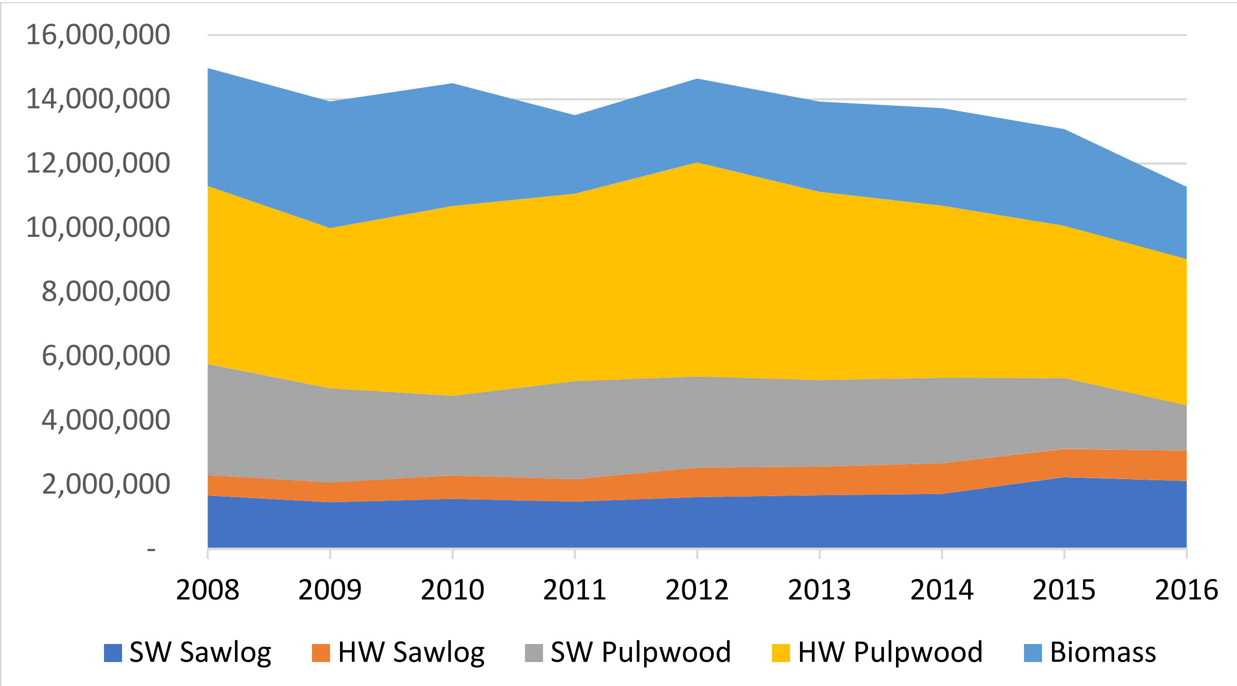


For a number of reasons - including spruce-fir forest condition, forest management, logging infrastructure, and monitoring capability – the coming outbreak is expected to be different than the most recent one, and likely less sever. Modelling has been conducted to understand the likely impact of the coming outbreak[xviii], and suggest that "projected total volume loss over the next 40 years following an outbreak…is 12.7 million cords from a severe outbreak to 6.4 million cords for a moderate outbreak half of that intensity."[xix] Assuming 2.3 tons per cord, this is between 15 million and 29 million tons of wood, over a 40-year period. If this volume was spread evenly (which is improbable), this represents up to 725,000 tons of softwood annually that is potentially in the market due to budworm-related harvest activities. To put this in context, pulpwood markets for spruce-fir have decreased by nearly 1.5 million tons annually since the mid 2000's[xx], with markets for this species group lost at pulp mills East Millinocket, Millinocket, Bucksport, Jay[xxi] and Madison. With or without a spruce budworm epidemic, Maine has an abundance of softwood, including but not limited to spruce-fir, available for utilization by forest industries.

Existing Forest Industries

Maine has a robust and diverse forest industry, with pulp and paper mills, sawmills, biomass energy facilities, wood pellet manufacturers, engineered wood facilities and others providing markets for a wide range of products. In 2016, Maine harvested 11.2 million green tons of wood – sawlogs, pulpwood and biomass.

Figure 20. Maine Timber Harvest by Product, 2008 - 2016[xxii] (tons)

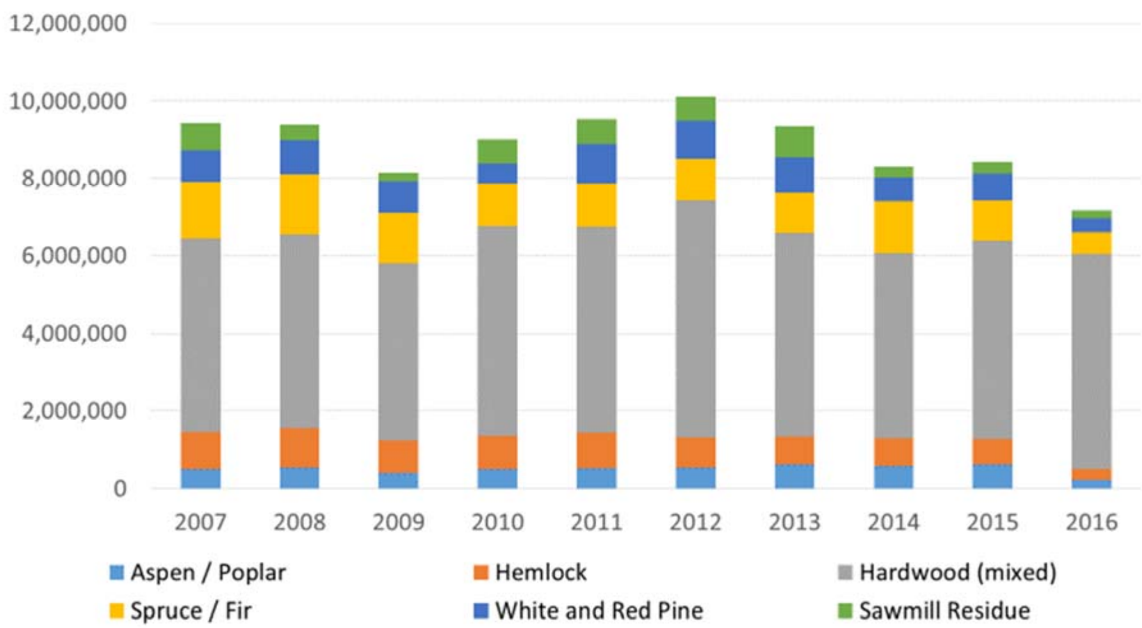


These industries are part of a dynamic forest industry ecosystem that supports the growth, management, harvesting, transportation and processing of forest products. The supply infrastructure that a biobased materials facility would use to procure materials. Forest industries may be competitors, suppliers (e.g., mill residue), and partners (e.g., co-location), and any biobased facility needs to be cognizant of the entire market.

Pulp & Paper Industry

In 2016, Maine pulp and paper mills used an estimated 7 million green tons of pulpwood. This figure has dropped from around 10 million green tons. This is due to the closure of capacity reductions at several pulp mills in the intervening years.

Figure 21. Maine Pulpwood Consumption by Species, 2008 - 2016[xxiii] (tons)



The following figure and table show Maine's pulp mills, including a number of facilities that have closed in recent years.

Figure 22. Maine Pulp & Paper Mills, including those closed since 2014

Table 4. Maine Pulp and Paper Mills

Facility (A)	Androscoggin Mill
Owner	Verso Corporation
Location	Jay, Maine
Wood Use (estimated)	800,000 green tons, hardwood and pine
Products	Coated freesheet and specialty grades
Status	Operating
Notes	In late 2015 reduced production and wood consumption, cutting production of groundwood and dropping some paper grades. Former wood consumption was roughly 2.2 million green tons.

Facility ®	Rumford
Owner	Catalyst Paper
Location	Rumford, Maine
Wood Use (estimated)	2 million green tons per year
Products	Coated freesheet and coated groundwood
Status	Operating
Notes	Facility has been working to move away from commodity grades and toward customer-focused specialty grades.

Facility (S)	SAPPI - Skowhegan (also Somerset, Hinckley)
Owner	SAPPI Fine Papers
Location	Skowhegan, Maine
Wood Use (estimated)	2.3 million green tons (mostly hardwood, some spruce-fir)
Products	Coated freesheet
Status	Operating
Notes	Generally considered one of North America's most efficient coated paper mills, the paper mill was commissioned in 1982 (pulp mill in 1974), making it one of the newest mills in Northern America. In the late stages of building a new wood yard and chip processing facility, and has announced the rebuild of a paper machine. Total capital investment for these two projects nearly $200 million.

Facility (W)	Woodland Pulp
Owner	International Grand Investment Corporation
Location	Baileyville, Maine
Wood Use (estimated)	1.5 million green tons of hardwood
Products	Market pulp, tissue
Status	Operating
Notes	The ownership group recently completed the commissioning of two new tissue machines on site, with St. Croix Tissue representing an investment of roughly $150 million

Facility (B)	Bucksport Mill
Former Owner	Verso Corporation
Location	Bucksport, Maine
Wood Use (estimated)	450,000 green tons
Products	Coated groundwood
Status	Closed in December 2014, sold for scrap
Notes	New biomass unit on-site currently idle, facility dismantled

Facility (E)	Great Northern Paper – East
Former Owner	Cate Street Capital
Location	East Millinocket, Maine
Wood Use (estimated)	400,000 green tons, all spruce-fir
Products	Directory (uncoated groundwood)
Status	Closed in February 2013, sold for scrap

Facility (L)	Lincoln Paper and Tissue
Former Owner	Lincoln Paper and Tissue (privately held)
Location	Lincoln, Maine
Wood Use (estimated)	450,000 green tons, hardwood and spruce-fir (sawdust)
Products	Tissue
Status	Closed, stopped being a market for wood following a boiler explosion in November 2013, sold for scrap

Facility (M)	Madison Paper
Former Owner	UPM-Kymmene Inc.
Location	Madison, Maine
Wood Use (estimated)	350,000 green tons of softwood
Products	Supercalendared
Status	Idle, closed May 2016

Facility (O)	Old Town
Former Owner	Expera Specialty Solutions
Location	Old Town, Maine
Wood Use (estimated)	800,000 green tons (hardwood)
Products	Market pulp
Status	Closed in 2015, on-going efforts to repurpose the site, but unlikely to be used for pulp production

Biomass Power Plants

Maine has 6 operating[xxiv] stand-alone biomass power plants. These facilities take forest residue (as well as some sawmill residue, and chipped roundwood) to generate electricity. In the current electricity market, biomass plants face challenging economics[xxv], and may find co-location with a biobased manufacturer mutually advantageous. A biomass plant could provide heat and electricity, as well as potentially other services, while the biobased manufacturer helped bolster the facility's revenue.

The following figure and table show Maine's stand-alone biomass electric facilities, and their estimated annual wood fuel use (green tons, assuming 90% capacity factor).

Figure 23. Stand-Alone Biomass Power Plants in Maine

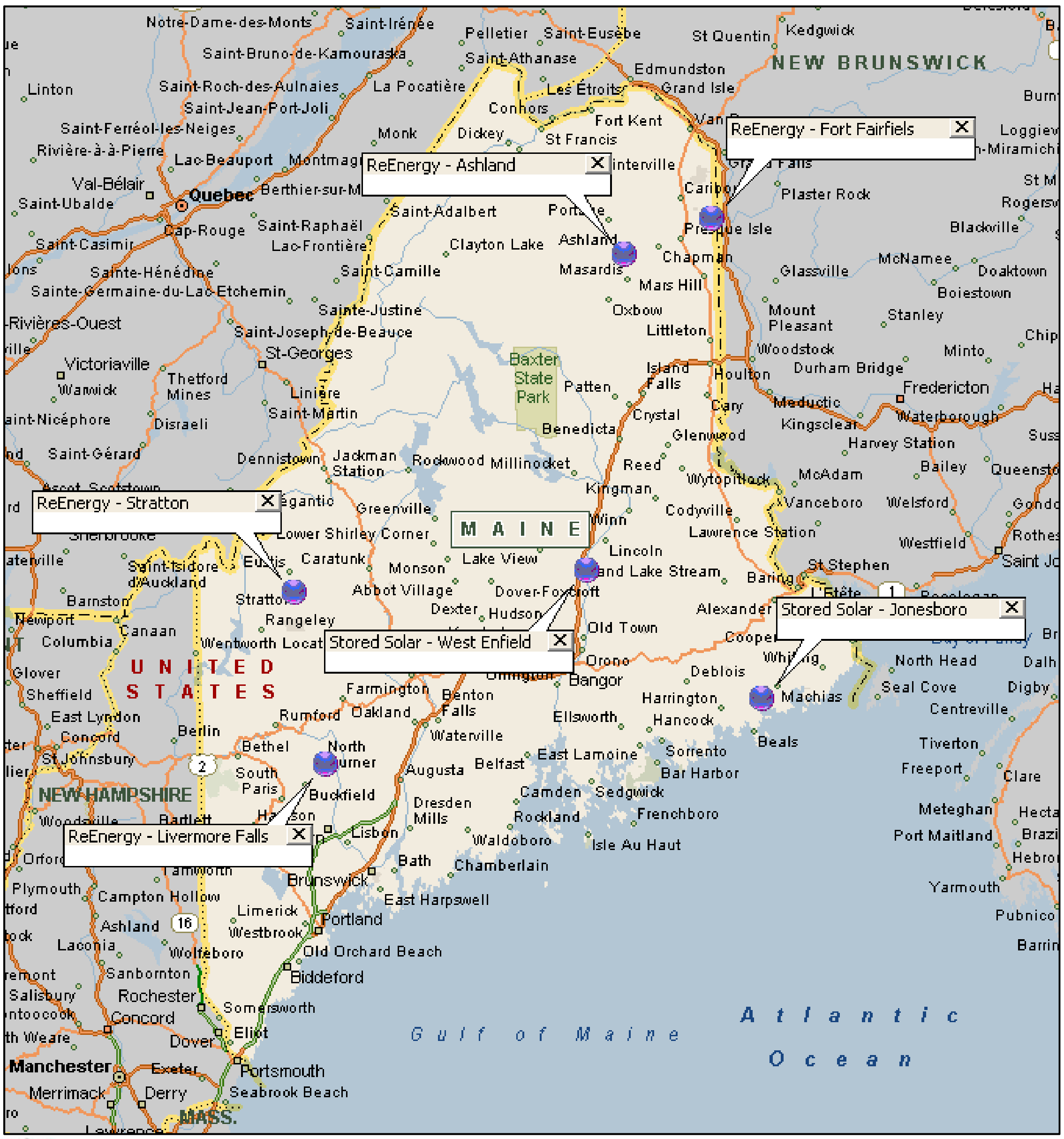


Table 5. Stand-Alone Biomass Power Plants in Maine

Company	Town	MW	Estimated Wood Use (green tons)
ReEnergy	Ashland	37	500,000
ReEnergy	Fort Fairfield	32	425,000
ReEnergy	Livermore Falls	37	500,000
ReEnergy	Stratton	45	600,000
Stored Solar	Jonesboro	25	320,000
Stored Solar	West Enfield	25	320,000

In addition to these stand-alone biomass electricity facilities, many forest industries use biomass to meet some of their energy needs. This includes all operating pulp mills, as well as a newly commissioned biomass combined heat and power facility at Maine Woods Pellets (Athens) and a facility currently under construction at Robbins Lumber (Searsmont).

Sawmills

Sawmills purchase logs and produce lumber, and are positioned around the state based upon locally available species. In addition to producing lumber, sawmills produce chips as a necessary by-product of their operations. While each mill is slightly different, it is estimated that one green ton of clean chips (no bark) are generated for each thousand board feet of lumber produced[xxvi]. The following figure and table show the location of major sawmills in Maine.

Figure 24. Major Maine Sawmills (White Pine, Hardwood, Spruce-Fir)

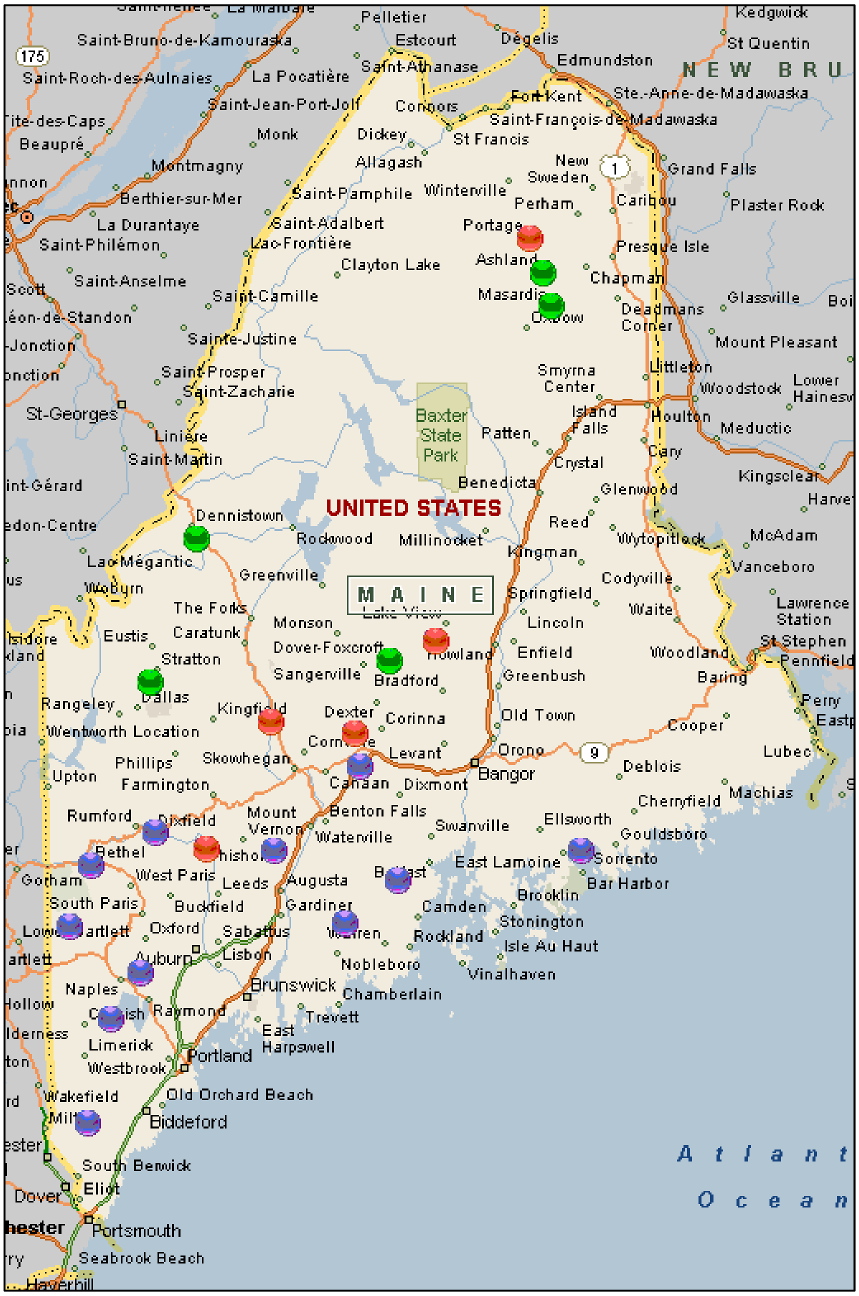


Table 6. Major Sawmills in Maine (Estimated Production in MMBF)

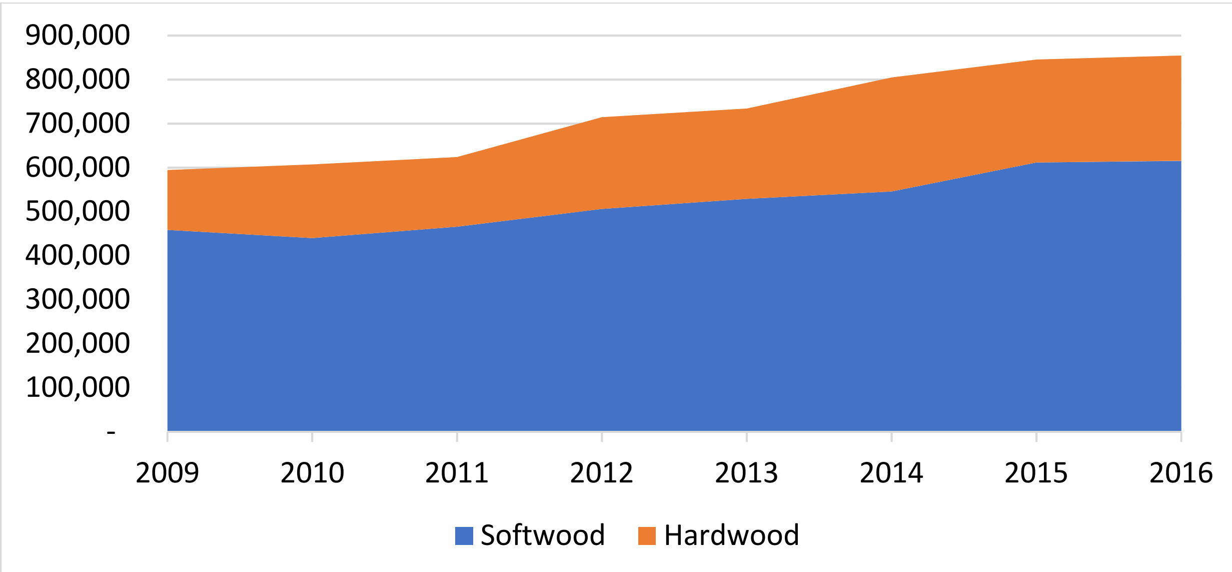
Mill	Town	Hardwood	White Pine	Spruce / Fir
Kennebec Lumber Company	Solon	✓		
Lumbra Hardwoods, Inc.	Milo	✓		
Maine Woods Company	Portage Lake	✓		
Pallet One of Maine	Livermore Falls	✓		
Sebasticook Lumber Company	St. Albans	✓		
Hammond Lumber Company	Belgrade		✓	
Hancock Lumber Company, Inc.	Pittsfield		✓	
Hancock Lumber Company, Inc.	Casco		✓	
Hancock Lumber Company, Inc.	Bethel		✓	
Irving Forest Products	Dixfield		✓	
Limington Lumber Company	East Baldwin		✓	
Lovell Lumber Company	Lovell		✓	
NC Hunt, Inc.	Jefferson		✓	
Pleasant River Lumber Co.	Hancock		✓	
Pleasant River Lumber Co.	Sanford		✓	
Robbins Lumber, Inc.	Searsmont		✓	
Irving Forest Products	Ashland			✓
Maibec Lumber, Inc.	Mesardis			✓
Pleasant River Lumber Co.	Jackman			✓
Pleasant River Lumber Co.	Dover-Foxcroft			✓
Stratton Lumber, Inc.	Stratton			✓
Total		*76*	*259*	*509*

These mills have a combined production capacity of over 800 million board feet. This means that roughly 800,000 green tons of mills chips are produced annually. These mill chips need to be utilized for sawmills to continue operations, and many mills (particularly softwood mills) are challenged to find economic outlets given the loss of markets at pulp mills and biomass plants.

Mill chips may be a particularly attractive feedstock for some biobased manufacturers, given that the material is bark-free and naturally separated by species or species group (e.g., hardwoods).

Since 2009, Maine sawmills have been processing ever increasing volumes of sawlogs on an annual basis[xxvii], and thus creating increasing volumes of mills chips, sawdust and bark. The loss of markets for mill chips at pulp mills across the state, coupled with uncertainty over some current market, may present a unique opportunity for a bioproduct manufacturer to secure mill chips on a secure volume and price basis. This is particularly true for softwood mill chips, which have lost a greater percentage of their previous market in recent years.

Figure 25. Volume of Sawlogs Processed by Maine Forest Products Industry (MBF)



Pricing

Factors Influencing the Price of Biomass Fuel

The following factors influence the pricing and availability of low-grade wood, and changes in any of these factors can have an impact on biomass fuel prices.

- Diesel costs are one of the largest single inputs to forest-derived wood. Every step of the process – felling, skidding, chipping and transport – uses diesel to power machinery. As diesel costs rise and fall, chip prices move in concert. As a rule, it takes slightly over 2 gallons of diesel to harvest, process and transport 1 green ton of wood chips. A more detailed discussion of diesel impacts follows.

- Changes in other forest markets – lumber, pulp and paper, wood pellets, and other biomass electricity projects in particular – can result in changes in competition for wood fuel and production of residues, resulting in associated changes in delivered prices.

- Specific and localized weather events can have a meaningful short-term impact on the price and availability of biomass fuel. Precipitation in the form of rain, snow, and ice can hinder the ability of suppliers to harvest, process, and deliver biomass.

Diesel as a Component of Biomass Production Costs

As noted above, diesel fuel is a significant cost input to the price of biomass. Diesel is used in both in-woods operations (felling and skidding), operations at the log landing (handling and chipping), and transport to the facility.

INRS has developed a formula for estimating the fuel used and diesel cost component of biomass fuel, based upon distance to market, payload size, and fuel cost. As a rule of thumb, slightly over two gallons of diesel fuel are used in the production of a single green ton of biomass. However, this varies considerably by the type and age of equipment, operator decisions, harvest prescription, skidding distance, distance to market, and other variables.

The table below shows the estimated typical diesel cost component of production of forest residues - both for in-woods operations (felling, skidding, handling and chipping) and transportation – at a range of diesel fuel costs. This methodology assumes diesel consumption fixed at 1.27 gallons per green ton for all in-woods activity (felling, skidding, handling and chipping) with trucking shown at a range of distances.

Table 7. Diesel costs in biomass production

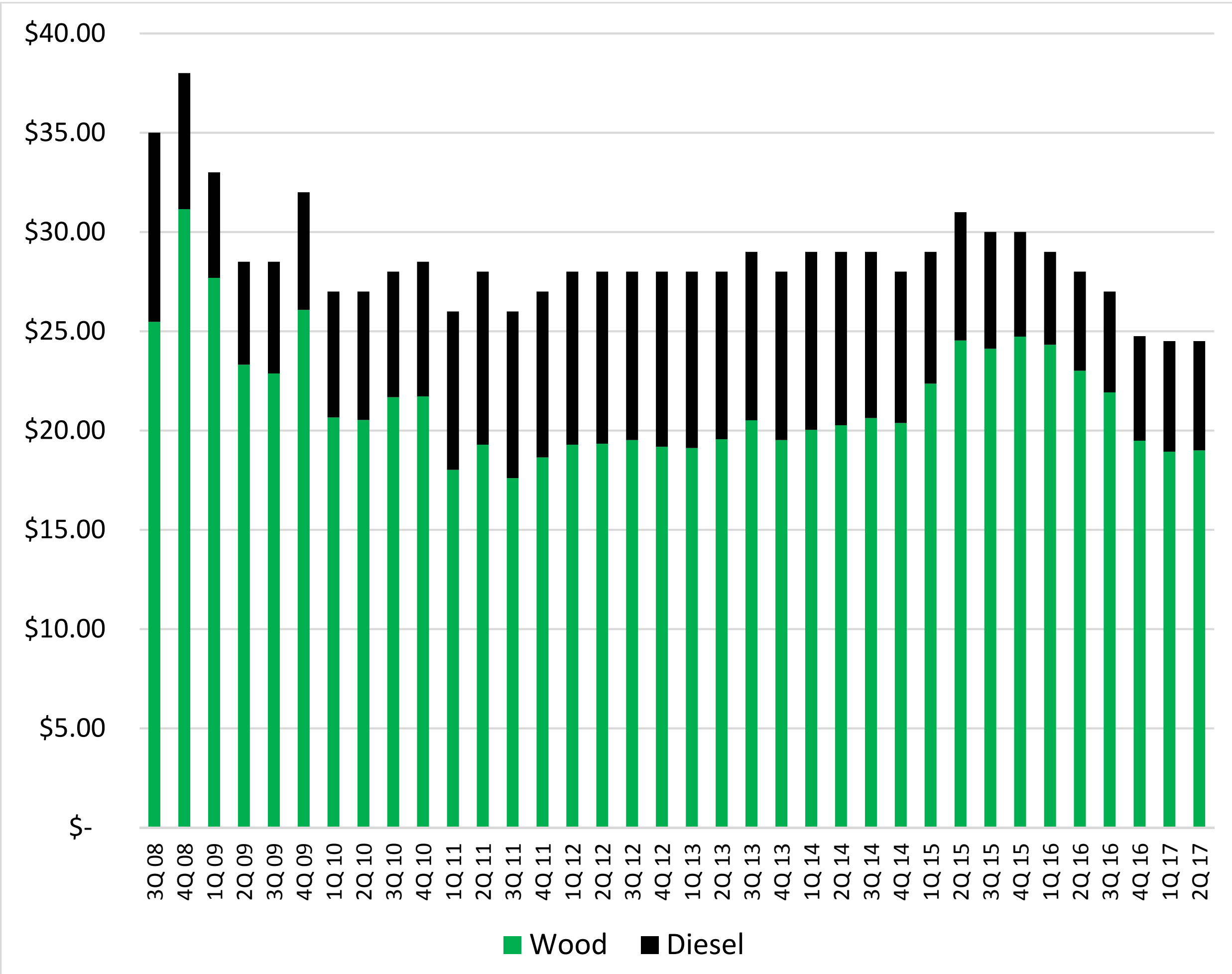
$ per gallon	In-Woods	Miles (one way)									
		10	20	30	40	50	60	70	80	90	100
$1.60	$2.03	$0.26	$0.53	$0.79	$1.05	$1.32	$1.58	$1.84	$2.11	$2.37	$2.63
$1.80	$2.29	$0.30	$0.59	$0.89	$1.19	$1.48	$1.78	$2.07	$2.37	$2.67	$2.96
$2.00	$2.54	$0.33	$0.66	$0.99	$1.32	$1.65	$1.98	$2.30	$2.63	$2.96	$3.29
$2.20	$2.79	$0.36	$0.72	$1.09	$1.45	$1.81	$2.17	$2.53	$2.90	$3.26	$3.62
$2.40	$3.05	$0.40	$0.79	$1.19	$1.58	$1.98	$2.37	$2.77	$3.16	$3.56	$3.95
$2.60	$3.30	$0.43	$0.86	$1.28	$1.71	$2.14	$2.57	$3.00	$3.42	$3.85	$4.28
$2.80	$3.56	$0.46	$0.92	$1.38	$1.84	$2.30	$2.77	$3.23	$3.69	$4.15	$4.61
$3.00	$3.81	$0.49	$0.99	$1.48	$1.98	$2.47	$2.96	$3.46	$3.95	$4.44	$4.94
$3.20	$4.06	$0.53	$1.05	$1.58	$2.11	$2.63	$3.16	$3.69	$4.21	$4.74	$5.27
$3.40	$4.32	$0.56	$1.12	$1.68	$2.24	$2.80	$3.36	$3.92	$4.48	$5.04	$5.60
$3.60	$4.57	$0.59	$1.19	$1.78	$2.37	$2.96	$3.56	$4.15	$4.74	$5.33	$5.93
$3.80	$4.83	$0.63	$1.25	$1.88	$2.50	$3.13	$3.75	$4.38	$5.00	$5.63	$6.26
$4.00	$5.08	$0.66	$1.32	$1.98	$2.63	$3.29	$3.95	$4.61	$5.27	$5.93	$6.58
$4.20	$5.33	$0.69	$1.38	$2.07	$2.77	$3.46	$4.15	$4.84	$5.53	$6.22	$6.91
$4.40	$5.59	$0.72	$1.45	$2.17	$2.90	$3.62	$4.35	$5.07	$5.79	$6.52	$7.24

In this table, the left column (blue) represents a range of possible diesel fuel prices, per gallon. The second column (yellow) shows the modeled in-woods diesel cost (diesel use associated with the felling, skidding and processing of fuel from stump to truck), and the green columns show the diesel cost for round-trip transportation (loaded in one direction, empty on the return) for a 27-ton load at a variety of distances. For example, if diesel is $2.20 per gallon, the in-woods diesel cost is estimated to be $2.79 and the diesel used in transportation at 70 miles is estimated to be $2.53. The total cost for diesel per green ton of chips would thus be $5.32.

Biomass Prices

INRS tracks prices of biomass fuel (primarily forest residue) on a quarterly basis. Prices vary by market, but generally track in a relatively narrow range. Across New England, biomass prices currently average just below $25 per green ton (delivered), with Maine facilities currently paying in a range centered between $25 and $27. The figure blow shows average delivered price, by quarter, from 3Q 2008 through 2Q 2017. This figure separated out the impact of diesel (assuming 2.1 gallons of diesel per delivered green ton), but it is important to note that mills pay an “all-in” price, and do not disaggregate payments.

Figure 26. Biomass Prices by Quarter, 3Q 2008 – 2Q 2017 (per green ton, delivered)



Based upon INRS experience and market indications, biomass prices are roughly as low as they can go on a sustainable basis, with payment of about $25 roughly covering the costs associated with harvesting, processing and transporting a ton of forest residues. Prices may drop below this level for brief periods of time, but it is not prudent to expect that prices can be sustained below this level for forest-derived biomass in Maine.

Pulpwood Prices

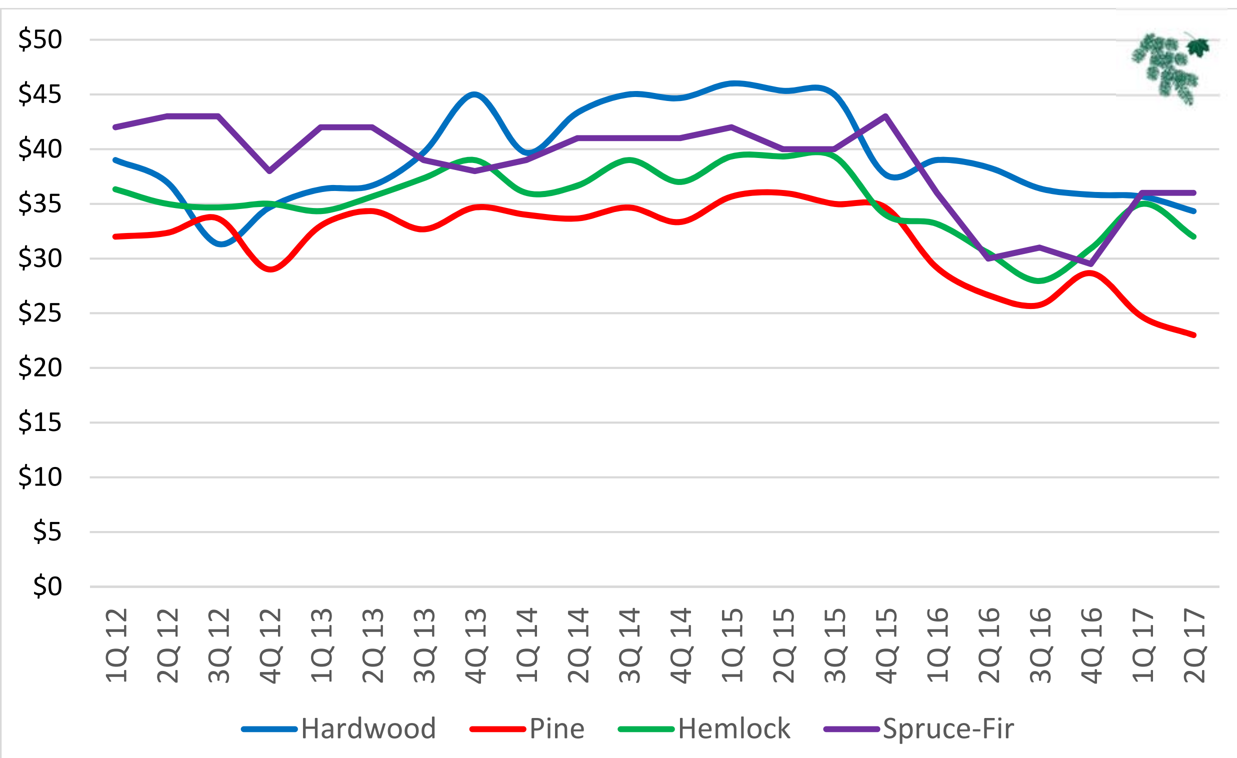
As with biomass, INRS tracks pulpwood pricing across New England by quarter. Pulpwood is roundwood, produced during a timber harvest, that is not of a size or quality for sawlog markets. Some bioproduct facilities may focus their procurement on pulpwood, because it can be species-separated (unlike biomass chips) and can be debarked.

In Maine and across New England, hardwood pulpwood can be highly competitive, but softwood pulpwood (pine, hemlock and spruce-fir) markets have declined significantly. While slightly lower New England-wide, Maine hardwood pulpwood process range from $40 to $50 per green ton, with slightly higher prices for select species (notably aspen).

Softwood prices are lower – and will likely remain lower until and perhaps even if new large-scale markets are developed. New England prices for softwood range from $24 to $40 per tons, depending upon geography and species. In Maine, pine pulpwood prices are in the low $30s, hemlock and spruce-fir in the high $30s per green ton. These represent quarterly average prices, as reported, and individual facilities may pay above or below these figures at different times, or to different suppliers.

However, it is critical to note that in many parts of Maine, suppliers do not have access to any softwood pulp markets, and would welcome the ability to supply a market, potentially at lower prices than shown below.

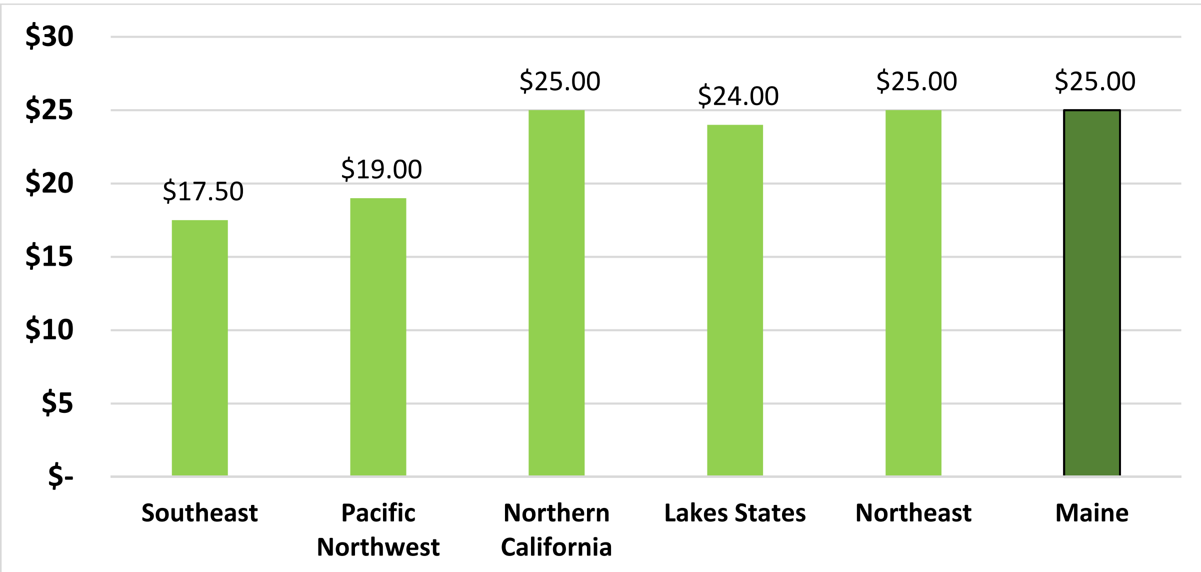
Figure 27. New England Pulpwood Prices, 2012 – 2017.



Comparative Prices by Region

Markets for biomass chips (which can be a feedstock for many bioproduct applications) exist in most forested regions of the country. Biomass feedstock from forest operations is used at stand-alone electric generation units, at some biomass heating installations, and as an energy source at forest industries. Prices vary regionally, as show below. Regional prices can be influenced by a number of factors, including competing and complimentary local markets, ease of timber harvesting operations, logging equipment in use regionally, regulatory constraints and trucking distance.

Figure 28. Biomass Price by Region, 3Q 2017[xxviii]



While the above shows regional pricing, it is important to note that pricing for biomass feedstocks – and other low-grade forest products – can be extremely localized. For example, while most locations in the Southeast pay below $20 per green ton (delivered), INRS is aware of a facility in that region that currently pays in the mid-$30s for biomass material.

Residue from sawmill activities (chips, sawdust and bark) can be priced as above, or have its own pricing dynamics, based upon local conditions. For example, in areas with few competing uses, sawmill chips can be purchased inexpensively, because sawmills cannot stop chip production without stopping lumber production. This is the situation currently for softwood sawmills in parts of Maine and New England. Conversely, in areas with competing markets, sawmill residue can secure a premium to biomass prices, as it is species segregated (at least partially) and debarked, thus making it attractive for some pulp mills and other users. Hardwood sawmills in Maine currently have multiple, higher value markets they can sell chips to.

Securing Long-Term Wood Supply

Wood supply is a critical piece of developing a biofuel or bioproduct product, and wood is usually the largest operating expense in such endeavors. However, unlike most commodities and energy sources (oil, natural gas, coal, etc.), wood (or futures) cannot generally be securely purchased on long-term, fixed (or known) price contracts. There are a number of reasons for this, including:

- A disconnected supply chain, where no one party (e.g., a logger) controls other parts of the supply chain (e.g., land) sufficiently to guarantee future supply;
- Inability of suppliers to accurately forecast and hedge against changes in their cost structure, particularly volatility in diesel prices, a major component of biomass fuel prices;
- For suppliers that may consider entering into long-term supply agreements, they are often small (by financing standards) and not viewed as sufficiently credit-worthy to enter into long-term contracts.

For project developers, and the institutions that finance them, the lack of a secure and known-price wood supply can be a major obstacle to development. Developers are understandably nervous, and sometimes unwilling, to spend many millions of dollars on new projects without knowing, with a high degree of certainty, what the wood supply and costs will be[xxix].

When Maine's paper mills were built, mills often owned the land, and loggers worked directly for the mill. This provided the mills with a secure source of feedstock, and gave mills significant control over their wood costs. In the decades since these mills were constructed, there has been significant disaggregation in the forest industry – most timberland in Maine is now owned by private owners – either corporate or family – that do not operate forest products manufacturing facilities. Loggers are independent contractors, and are not in the employ of either the landowner or the mill. Trucking from the woods to market may be conducted by the logger or an independent trucking company, and wood may be processed (for example, debarked and chipped) by independent businesses unconnected to the landowner, logger or mill.

While long-term contracts – with both volume and value fixed or subject to a formula – have proven extremely difficult, firms have taken steps to make wood supply costs increasingly predictable.

- Some firms have provided funding to suppliers to purchase specialized equipment need to service a market (e.g., in-woods chippers), and retained a modest portion of the payment for wood received in order to service the equipment debt. Pioneered in Maine by Boralex, a biomass firm that sold its facilities to ReEnergy Holdings, this approach is detailed as a case study in Appendix B.

- As discussed elsewhere in this report, diesel is the most volatile input cost to the delivered price of low-grade forest products, such as those likely used as biofuel feedstock. Diesel is used in the felling, skidding, processing and transport of wood.

While not itemized, it is generally accepted that the mill is indirectly paying the cost of diesel, and that this cost impacts the delivered price. Some firms have turned to the futures market to manage diesel risk[xxx]. By using the futures market to purchase options, wood buyers can manage wood price volatility attributed to changes in diesel prices.

- When pulp and paper mills have sold their land in Maine and nearby states, these sales have often been encumbered by "Fiber Supply Agreements" (FSA), that provide guaranteed or preferential access to fiber from the lands for a fixed period of time. While each FSA is different, and all are confidential, some mills have retained a portion of their wood supply through the use of these agreements, and may be using them to manage costs as well. The situations that led to these FSAs is unique, and does not likely provide a replicable model.

- In the Northern portion of the state, generally north of U.S. Route 2 / Route 9, there are a relatively small number of landowners and land managers. A project developer may be able to form relationships with one or more of these landowners to secure the necessary volume (and potentially price) for some or all of the feedstock necessary for a facility. The presence of these large landowners and their professional management teams provides an opportunity not available in many other states.

Sawmill residues (chips, sawdust and potentially bark), particularly from softwood mills, may present an opportunity for bioproduct developers to secure long-term supply agreements for feedstock. As discussed earlier, sawmills need to have an outlet for their residues in order to continue producing lumber. Given the loss recent and potential of markets, particularly for softwood, sawmills may be willing to enter into long-term supply agreements that provide both parties with volume and price stability.

Finally, it should be noted that some recently proposed projects in Maine have worked with loggers and landowners to "guarantee" wood fiber or fuel for their projects, with the expectation of long-term volume and price stability. While these have been proposed, and INRS has worked to develop some of these, it is important to note that to date no such long-term agreements, encompassing both volume and price, have been successfully executed and implemented.

Appendix A – Species by Species Group

	Common Name	Genus	Species
Pines			
	eastern white pine	*Pinus*	*strobus*
	jack pine	*Pinus*	*banksiana*
	pine spp.	*Pinus*	*spp.*
	pitch pine	*Pinus*	*rigida*
	red pine	*Pinus*	*resinosa*
Other Softwoods			
	Atlantic white-cedar	*Chamaecyparis*	*thyoides*
	balsam fir	*Abies*	*balsamea*
	black spruce	*Picea*	*mariana*
	blue spruce	*Picea*	*pungens*
	Douglas-fir	*Pseudotsuga*	*menziesii*
	eastern hemlock	*Tsuga*	*canadensis*
	eastern redcedar	*Juniperus*	*virginiana*
	fir spp.	*Abies*	*spp.*
	Fraser fir	*Abies*	*fraseri*
	hemlock spp.	*Tsuga*	*spp.*
	larch spp.	*Larix*	*spp.*
	northern white-cedar	*Thuja*	*occidentalis*
	Norway spruce	*Picea*	*abies*
	red spruce	*Picea*	*rubens*
	spruce spp.	*Picea*	*spp.*
	tamarack (native)	*Larix*	*laricina*
	white spruce	*Picea*	*glauca*
	white-cedar spp.	*Chamaecyparis*	*spp.*

Common Name	Genus	Species
Soft Hardwoods		
American basswood	*Tilia*	*americana*
American elm	*Ulmus*	*americana*
American sycamore	*Platanus*	*occidentalis*
ash spp.	*Fraxinus*	*spp.*
balsam poplar	*Populus*	*balsamifera*
basswood spp.	*Tilia*	*spp.*
bigtooth aspen	*Populus*	*grandidentata*
black ash	*Fraxinus*	*nigra*
black cherry	*Prunus*	*serotina*
boxelder	*Acer*	*negundo*
butternut	*Juglans*	*cinerea*
cottonwood and poplar spp.	*Populus*	*spp.*
eastern cottonwood	*Populus*	*deltoides*
elm spp.	*Ulmus*	*spp.*
gray birch	*Betula*	*populifolia*
Lombardy poplar	*Populus*	*nigra*
paper birch	*Betula*	*papyrifera*
pumpkin ash	*Fraxinus*	*profunda*
quaking aspen	*Populus*	*tremuloides*
red maple	*Acer*	*rubrum*
river birch	*Betula*	*nigra*
Siberian elm	*Ulmus*	*pumila*
silver maple	*Acer*	*saccharinum*
silver poplar	*Populus*	*alba*
white basswood	*Tilia*	*americana*
white willow	*Salix*	*alba*
yellow-poplar	*Liriodendron*	*tulipifera*

Common Name	Genus	Species
Hard Hardwoods		
American beech	*Fagus*	*grandifolia*
birch spp.	*Betula*	*spp.*
black locust	*Robinia*	*pseudoacacia*
black maple	*Acer*	*nigrum*
black oak	*Quercus*	*velutina*
black walnut	*Juglans*	*nigra*
blackjack oak	*Quercus*	*marilandica*
blue ash	*Fraxinus*	*quadrangulata*
bur oak	*Quercus*	*macrocarpa*
cherrybark oak	*Quercus*	*pagoda*
green ash	*Fraxinus*	*pennsylvanica*
maple spp.	*Acer*	*spp.*
mulberry spp.	*Morus*	*spp.*
northern pin oak	*Quercus*	*ellipsoidalis*
northern red oak	*Quercus*	*rubra*
Norway maple	*Acer*	*platanoides*
oak spp.	*Quercus*	*spp.*
overcup oak	*Quercus*	*lyrata*
pecan	*Carya*	*illinoinensis*
pignut hickory	*Carya*	*glabra*
pin oak	*Quercus*	*palustris*
post oak	*Quercus*	*stellata*
rock elm	*Ulmus*	*thomasii*
shingle oak	*Quercus*	*imbricaria*
sugar maple	*Acer*	*saccharum*
swamp white oak	*Quercus*	*bicolor*
sweet birch	*Betula*	*lenta*
walnut spp.	*Juglans*	*spp.*
water oak	*Quercus*	*nigra*
white ash	*Fraxinus*	*americana*
white oak	*Quercus*	*alba*
willow oak	*Quercus*	*phellos*
winged elm	*Ulmus*	*alata*
yellow birch	*Betula*	*alleghaniensis*

Appendix B – Investing in Supply Infrastructure – A Case Study

The following is adapted from a case study INRS prepared highlighting the way one biomass firm uses equipment financing to strengthen their supply chain[xxxi]. This case study, prepared for the Massachusetts Technology Collaborative, examines the practices of Boralex, a firm with wood-fired power plants in Maine and New York. Boralex is considered a leader in this supply chain strategy.

> The financing program is a "lease to buy" agreement, where payment is based on wood deliveries (i.e., $/ton). The program is available to any reputable contractor who is interested in establishing an in-woods biomass processing operation. Each agreement is tailored to meet the mutual needs of the contractor and the facility. The agreements are governed by a contract that states the annual volume to be delivered to the biomass facility and respective prices. The typical contract length is five years with an annual volume of approximately 50,000 to 60,000 tons[xxxii]. The annual volume is expected to be delivered in a 40 week time period[xxxiii]. Volume obligations and delivered prices are renegotiated annually to provide flexibility for the contractor and the power plant. The contractor is responsible for negotiating the purchase price with the equipment dealer, and the power plant pays the invoice for the machine plus the cost of the manufacturer's recommended parts inventory.
>
> Under the terms of the agreement, the contractor pays back the principal, and interest at 7.0%, through wood deliveries. The contractor is not required to make an equipment payment if they do not deliver wood. When a load of chips or hog fuel is delivered, a dollar per ton amount (e.g., $2.50/ton) is withheld from payment to the contractor and credited towards money owed on the machine (see table below). With prior approval from the power plant, the contractor can use the equipment for deliveries to competing facilities, however, the contractor is required to make the same dollar per ton equipment payment to the power plant on the volume. The ownership title transfers to the contractor and payment withholding ceases when the money owed equals zero. Once the contractor owns the machine, they are still required to fulfill their annual volume obligation for the remaining term of the contract, but they do not need the power plant's prior approval to make deliveries to other wood-fired power plants.
>
> The contractor has the option to forfeit the agreement prematurely, however, doing so eliminates all accrued ownership in the financed equipment. If the wood-energy industry becomes uncompetitive and all of the power plant's wood-energy facilities close, a force majeure clause would be triggered, thus elevating the obligation for the contractor to continue to make equipment payments. In the occurrence of such an event, the contractor has the option to pay the remaining balance on the equipment liability, however, they are not required to.

Table 8. Cash flows with facility financing of biomass equipment (example)

Load #	Price per Delivered Ton	Equipment Payment per Ton	Volume (Tons)	Total Revenue	Payment to Contractor	Money Owed on Equipment
						$ 300,000
1	$ 24.00	$ 2.50	30	$ 720	$ 75	$ 299,925
2	$ 24.00	$ 2.50	27	$ 648	$ 68	$ 299,858
3	$ 24.00	$ 2.50	28	$ 672	$ 70	$ 299,788
4	$ 24.00	$ 2.50	29	$ 696	$ 73	$ 299,715
5	$ 24.00	$ 2.50	30	$ 720	$ 75	$ 299,640
6	$ 24.00	$ 2.50	32	$ 768	$ 80	$ 299,560
7	$ 24.00	$ 2.50	26	$ 624	$ 65	$ 299,495
8	$ 24.00	$ 2.50	28	$ 672	$ 70	$ 299,425
9	$ 24.00	$ 2.50	30	$ 720	$ 75	$ 299,350
10	$ 24.00	$ 2.50	31	$ 744	$ 78	$ 299,273

The contractor is required to pay for inland marine insurance, and all operating costs (e.g., labor, maintenance and repair, fuel, etc.) associated with the financed machine. The contractor is also directly or indirectly (i.e., via subcontractors) responsible for the ownership and operating costs related to loading (e.g., excavator, loader on crane carrier, etc.), transport (e.g., tractor trucks, chip vans, etc.), and any support equipment/assets (e.g., pick-up truck, garage, etc.). The wood-fired power plant pays a diesel fuel surcharge based on the prior month's fuel price movement. The Energy Information Administration's "weekly retail on-highway diesel price" data[xxxiv] is used to determine the surcharge.

Boralex indicated that while the program requires more oversight, communication, and financial risk than traditional means of procuring wood material, it sends a message to their contactors/suppliers that they think the wood-energy industry has a strong future and that they want a long-term relationship with them. Four contractors have already reused the program, thus indicating they are pleased with the arrangement.

Endnotes

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[i] While this is a general description of the variety of products that can be derived from a single tree, it is important to note that the characteristics of an individual tree, combined with local markets, may make all or most of it unsuitable for lumber manufacturing, and then all of the tree would be used for pulp and chip markets, or left in the woods.
[ii] *Note:* This tree is used for illustration purposes only. Forest-grown trees look significantly different than this diagram, with longer trunks and less "crown", or leafy top.
[iii] Timberland excludes any forested lands where commercial timber harvesting is prohibited by statute or regulation
[iv] *Data Source:* USDA Forest Service, Forest Inventory & Analysis. Miles, P.D. Mon Jun 19 15:10:37 CDT 2017. Forest Inventory EVALIDator web-application Version 1.6.0.03. St. Paul, MN: U.S. Department of Agriculture, Forest Service, Northern Research Station. [Available only on internet: http://apps.fs.fed.us/Evalidator/evalidator.jsp]
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[xiii] RE Consulting and Innovative Natural Resource Solutions LLC. *Forest Harvesting Systems for Biomass Production.* Prepared for the Massachusetts Division of Energy Resources & the Massachusetts Department of Conservation & Recreation. June 2007. http://www.mass.gov/eea/docs/doer/renewables/biomass/bio-init-report-r1.pdf
[xiv] Innovative Natural Resource Solutions LLC. Biomass Resources in the United States. 2007.
[xv] All live trees 5.0 inches (12.7) cm) DBH or larger that meet (now or prospectively) regional merchantability requirements in terms of saw-log length, grade, and cull deductions. Excludes rough and rotten cull trees. *Forest Inventory and Analysis Glossary*. https://www.nrs.fs.fed.us/fia/data-tools/state-reports/glossary/default.asp
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[xix] Ibid
[xx] Internal data, Innovative Natural Resource Solutions LLC.
[xxi] Note: The mill in Jay, Maine continues to operate, but at a significantly reduced capacity from a decade ago.
[xxii] Maine Forest Service *Wood Processor Reports*, 2008 through 2016. Conversion to tons by Innovative Natural Resource Solutions LLC, using information contained in the MFS *Wood Processor Reports*. http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc
[xxiii] Maine Forest Service *Wood Processor Reports*, 2008 through 2016. http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc
[xxiv] In this context, "operating" means having the interconnection and staff to operate, and may or may not reflect if a facility is generating electricity at the moment.
[xxv] See, for example, Innovative Natural Resource Solutions LLC. *Biomass Markets in Maine: Current Challenges and Opportunities.* Presentation at Biomass Energy Summit hosted by E2 Tech Council and GrowSmart Maine. March 23, 2017. https://www.slideshare.net/erickingsley/biomass-markets-in-maine-inrs-3242017
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[xxviii] Wood Resources International. *North American Wood Fiber Review.* Third Quarter 2017. (Note – data converted from dry tons to green tons by INRS, using WRI's recommended conversion multiplier. Data for Maine from INRS, based upon quarterly market surveys.)
[xxix] Empire State Forest Products Association. *Establishing Long-Term Supply Agreements for Wood Energy Facilities*. June 2008. https://www.na.fs.fed.us/werc/pubs/090113_longterm_biomass_supplies.pdf
[xxx] https://www.slideshare.net/erickingsley/managing-diesel-risk-overview-presentation
[xxxi] Excerpted from: RE Consulting and Innovative Natural Resource Solutions LLC. *Renewable Biomass from the Forests of Massachusetts: Forest Harvesting Systems for Biomass Production.* Prepared for the Massachusetts Technology Collaborative. June 2007. http://www.mass.gov/eea/docs/doer/renewables/biomass/bio-init-report-r1.pdf
[xxxii] This volume applies to large chippers or grinders. The typical annual volume obligation for a smaller chipper is 10,000 to 15,000 tons.
[xxxiii] This equates to an average daily delivery of approximately eight to nine loads.
[xxxiv] http://tonto.eia.doe.gov/oog/info/wohdp/diesel_detail_report_combined.asp