Forest Opportunity Roadmap / Maine
Wood Energy

Innovative Natural Resource Solutions LLC and

Meister Consultants Group, A Cadmus Company

March 2018

Forest Opportunity Roadmap / Maine

http://www.mdf.org/ForestEconomy.php

The Wood Energy Committee of the Forest Opportunity Roadmap / Maine (FOR/Maine) project has contracted with Innovative Natural Resource Solutions LLC to prepare this report. The report provides background information on the wood energy market in Maine and provides an analytical modeling tool for specific cogeneration scenarios. This work will inform the FOR/Maine participants as they prepare a comprehensive strategic plan with policy recommendations for the entire forest industry that will be presented to the 129'th Legislature.

This report was prepared using Federal funds under award number 01 69 14749 from the Economic Development Agency of the United States Department of Commerce. The statements, findings, conclusions and recommendations are those of the authors and do not necessarily reflect the views of the Economic Development Agency or the United States Department of Commerce.

This report was prepared by Innovative Natural Resource Solutions LLC and Meister Consultants Group, A Cadmus Company. The information and analysis contained in this report is based upon our best professional judgement and on sources of information we believe to be reliable. However, no representation or warranty is made 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 of future events.

Table of Contents

Table of Figures

Table of Tables

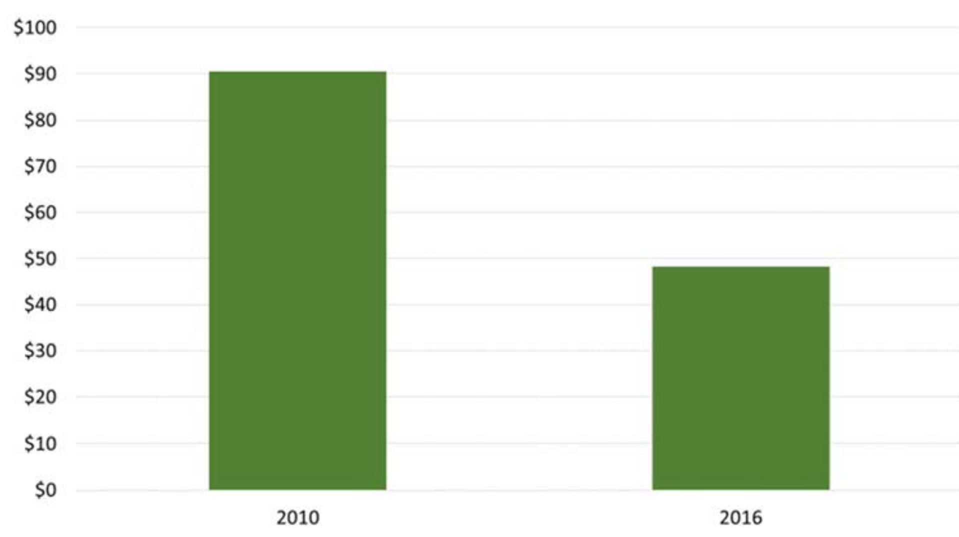
Executive Summary

Wood for energy production – electricity, heating and combined heat and power – is a critical part of Maine's forest industry. In 2010, 3.7 million tons of wood for energy market were produced from Maine timber harvests, representing 25 percent of all timber volume. By 2016, the harvest of biomass shrunk to 2.5 million tons, which represents 20 percent of a now smaller statewide harvest compared to 2010.

As a renewable energy source that - unlike wind, solar and hydroelectric generation – requires a steady stream of purchase fuel, wood energy has significant and ongoing economic benefits to the supply chain, in addition to its dispatchability. Over the past several years, Maine has lost significant markets for biomass, primarily due to lost energy generation at now-closed pulp and paper mills.

These lost markets have impacted the entire forest industry supply chain. Landowners have lost a market for low-grade stems and harvest residues (e.g., tops and branches). In 2010, Maine landowners received an estimated $11.9 million in stumpage payments for biomass; by 2016 this figure had declined by two-thirds, to $3.8 million. Loggers and truckers have suffered even more from the erosion of this market. In 2010 there was $90.5 million in economic activity associated with logging and trucking of biomass fuel; in 2016 this had shrunk to $48.2 million. Additionally, trucking jobs needed to supply biomass to mills and power plants shrunk from 440 full time equivalent positions to 221 during this same period.

Figure 1. Direct Economic Activity Associated with Biomass Shrunk from over $90 Million (2010) to $48 Million (2016)



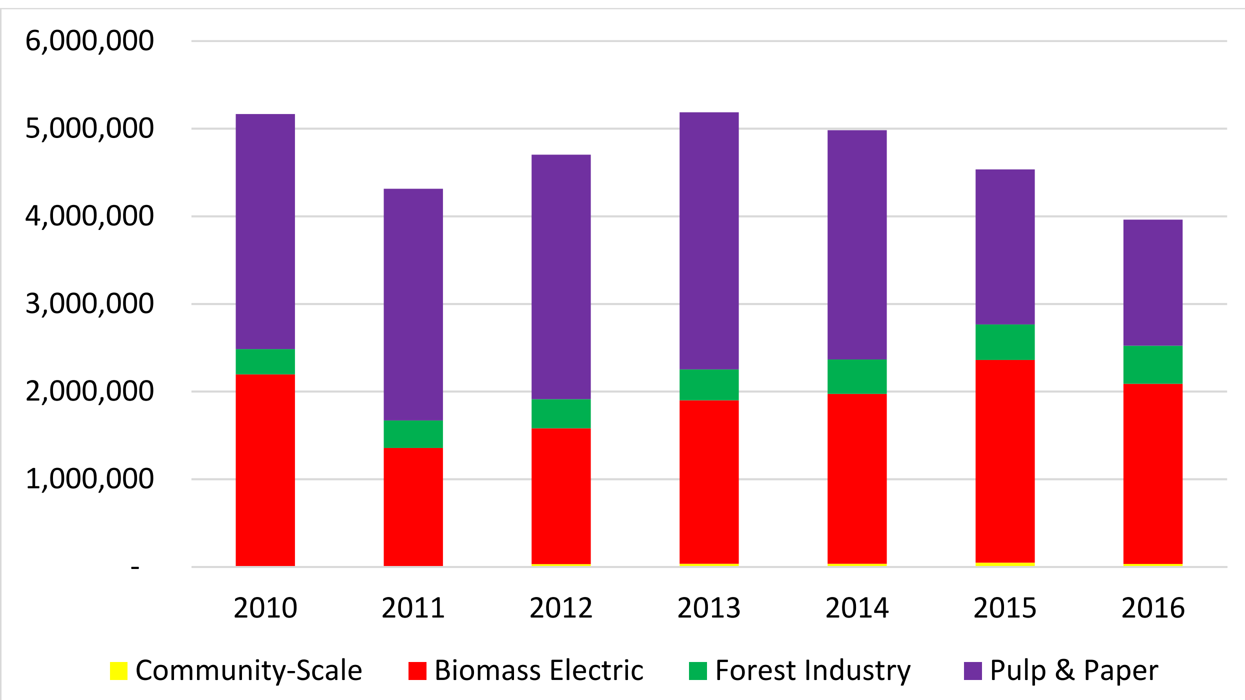
In addition to the economic impact, markets for low-grade wood – including biomass – are important for forest management. As other markets for low-grade wood have shrunk, particularly pulpwood, the biomass markets have become increasingly important to forest managers. While Maine takes steps to attract and develop new markets for all grades of wood, maintaining a market for low-grade provides long-term benefits.

As a forest management tool, markets for low-grade wood can be used to promote increased growth of high-value sawlog stems, and provide a resource that will be valuable for Maine sawmills and other users of high-quality stems in coming decades. For new manufacturers planning to use low-grade wood, they will clearly be relying upon the state's robust harvesting and transportation infrastructure to supply them. Maintaining this infrastructure has real value for the future enhanced viability and evolution of Maine's forest industry.

In addition to the benefits to landowners, loggers and truckers, biomass markets are an important outlet for sawmill residues. When a sawmill buys a log (a cylinder) and sells a board (a rectangle), byproducts are produced – chips, sawdust and bark. Maine sawmills produce an estimated 1.6 million tons of these sawmill residues annually, and disposing of this material in an economic manner is critical to the health of the state's sawmill industry. While chips, bark and sawdust are sold to other markets, an estimated 400,000 tons are used in energy applications: either electric, combined heat and power, or thermal. Loss of these markets could have a crippling impact on the state's thriving sawmill industry.

In 2010, a total of 5.2 million tons of wood were used in energy applications in Maine. This fuel came not only from timber harvesting activities, but also from sawmill residues and the bark and fines at pulp mills. Due to the loss of markets – primarily the loss of energy production at pulp and paper mills – this shrunk to less than 4 million tons in 2016.

Figure 2. Wood Used for Energy in Maine (green tons), 2010 - 2016



Maine is not alone in facing challenges to its biomass market. Other states have acted to support the growth or continued operation of large-scale biomass energy facilities. New Hampshire, Vermont and Connecticut have all issued long-term power purchase agreements to support biomass. New Hampshire has also tailored part of its Renewable Portfolio Standard to support the continued operation of existing stand-alone biomass electric facilities. California, in need of markets to support sustainable forest management and harvesting in fire-prone areas, has developed programs to support existing and incent new markets for biomass.

In addition to large-scale users, there are many community-scale applications for wood heat. Already a number of Maine schools, hospitals, campuses and businesses heat with either woods chips or pellets. Given current fossil fuel prices, there is significant opportunity for growth in this area, primarily because wood fuel is less expensive (often less than half the cost of propane, three-fourths the cost of oil, and at times less expensive than natural gas) on a dollar per MMBTU basis. Additionally, the price of wood fuel is very stable, particularly when compared to fossil fuel price volatility

Other states and countries have recognized the value of and opportunities to grow community-scale biomass thermal markets, and enacted policies to support such growth. Vermont, where over 30 schools are heated with wood and one-third of all students attend a school heated with biomass, provided increased building funds for schools using wood heat. Austria uses a combination of grants and tax credits to support thermal biomass applications, and in some areas has mandates for renewable heating in new construction and streamlined permitting for biomass thermal projects. New Hampshire, Massachusetts and New York all use meaningful rebates to support the installation of new, modern heating in community-scale application. Beginning in 2014, New Hampshire incorporated renewable heating into its Renewable Portfolio Standard, providing ongoing incentives for the use of wood heat. Massachusetts just launched a similar effort.

As part of the evaluation of how Maine's biomass industry can position itself for stability and growth in the future, the authors were asked to model specific situations that have the potential to grow new or support existing wood energy markets. These situations include:

- Changes to the state's Renewable Portfolio Standard (RPS), including
    - Increase in the level of RPS mandate from 10 percent to 15 percent;
    - Establish a 2% mandate for thermal energy (e.g., biomass heat); and
    - Establish an "economic benefit" tier of the RPS, restricted to biomass applications that provide economic benefit above the cost of the Renewable Energy Certificate;
- Co-location of manufacturing adjacent to an existing biomass facility, with the plant providing heat, steam and electricity to support the economic operation of the new facility;
- Development of new biomass combined heat and power facilities at existing Maine manufacturers, modelled after the state's *Community-Based Renewable Energy Pilot Program*; and
- Use of wood heat at public and private community-scale facilities.

These scenarios were modelled using several tests commonly applied in the energy policy and energy efficiency arenas, including:

- The “Participant Cost Test” (PCT);
- The “Ratepayer Impact Measure” (RIM) test;
- The “Total Resource Cost” (TRC) test (a combination of these two);

After thorough evaluation, multiple scenarios were identified that can be implemented to effectively support biomass markets in Maine. One option is the gradual increase of the state’s Renewable Portfolio Standard from 10 percent to 15 percent. The model indicates that this would result in 750,000 tons of new annual biomass demand, create 190 new jobs at biomass facilities and in the supply chain, and have benefits eight times higher than costs.

Co-location of new industry proximate to existing biomass facilities would provide increased demand for biomass, create new jobs, and again has benefits in excess of costs. Importantly, this solution may be implemented with modest public policy support; existing biomass plants in Maine (and across the Northeast) are actively looking for co-location partners.

Conversion of current heating systems from oil and propane to biomass (either chips or wood pellets) provides significant benefits. When the fuel savings from these facilities is paired with a Thermal Renewable Energy Certificate (T-REC), the payback period necessary to incent installation of these systems is decreased significantly, leading to increased use of biomass heating. In this scenario, 175,000 tons of annual biomass demand is established, 110 new jobs are created, and benefits exceed costs.

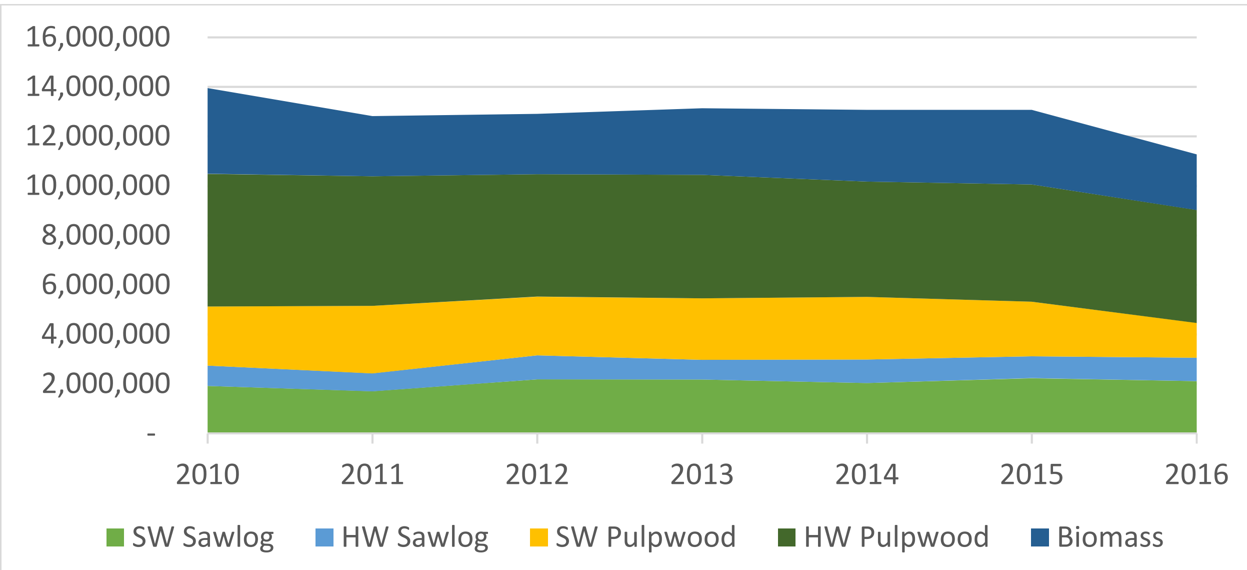
Because biomass energy uses locally produced fuel, it has significant and ongoing positive economic impact in the state and across the industry supply chain. There are multiple ways to use policy to support the goals of stable and growing biomass demand, increased use of locally derived energy, and support for the forest industry supply chain and infrastructure.

Biomass in Maine

Biomass, used in energy production facilities across Maine and in neighboring states and provinces, is one of many products that come from an integrated timber harvest in Maine. In addition to biomass, harvests produce pulpwood (both hardwood and softwood, used primarily in the manufacture of pulp and paper), traditional firewood (used primarily for home heating) and sawlogs (both hardwood and softwood, used in the manufacture of solid wood products).

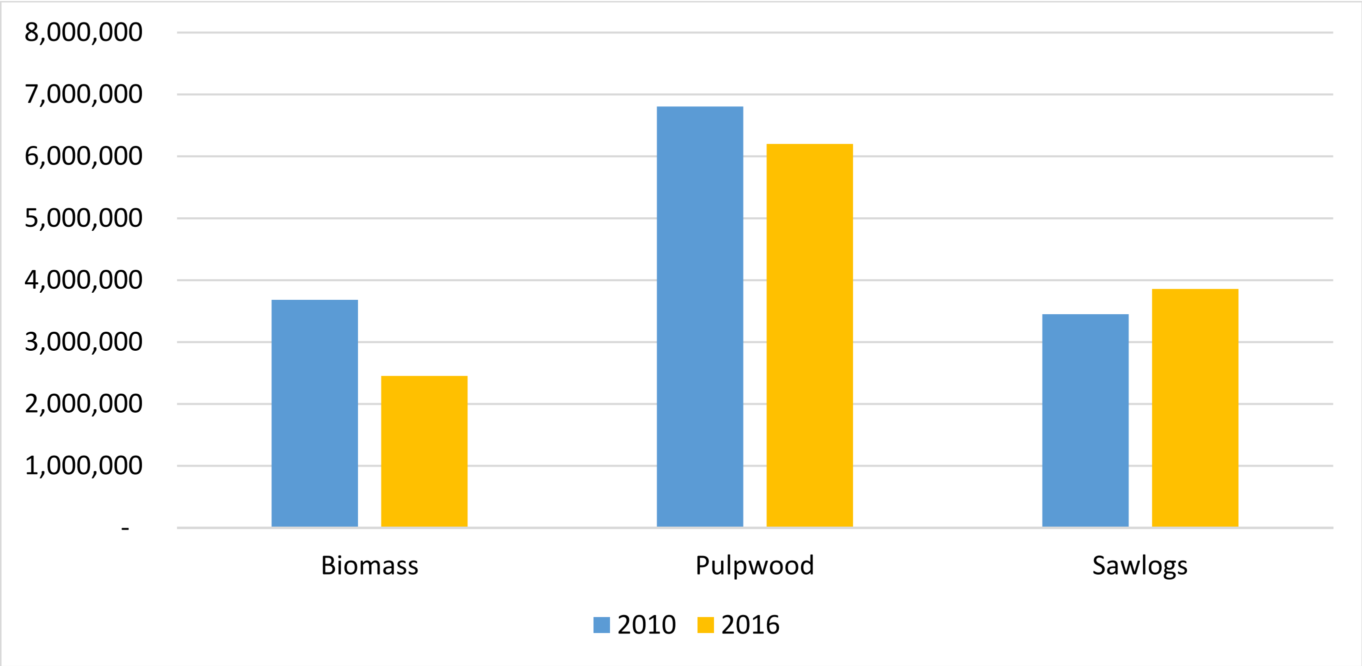
Due to market losses, particularly pulp mills, Maine has seen total harvest volume fall, from nearly 14 million green tons in 2010 to 11.3 million green tons in 2016.

Figure 3. Maine Timber Harvest Volume, by Product (green tons), 2010 – 2016[1]



[1] Data Source: Maine Forest Service. *Wood Processor Reports.* 2010, 2011, 2012, 2013, 2014, 2015, 2016. http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc Analysis by Innovative Natural Resource Solutions LLC.

Figure 4: Maine Timber Harvest Volume by Product (green tons), 2010 and 2016[2]



During the period 2010 through 2016, the absolute and relative volume of biomass harvest in Maine, as compared to total harvest, has declined. This has been due to loss of markets – notably biomass boilers at now-closed pulp and paper mills.

Table 1. Biomass and Total Harvest Volumes (green tons), 2010 - 2016[3]

	Biomass	Total Harvest	% Biomass
2010	3,464,006	13,950,186	25%
2011	2,428,247	12,816,172	19%
2012	2,438,336	12,909,471	19%
2013	2,693,201	13,137,807	20%
2014	2,894,764	13,069,542	22%
2015	3,010,703	13,068,518	23%
2016	2,247,006	11,272,565	20%

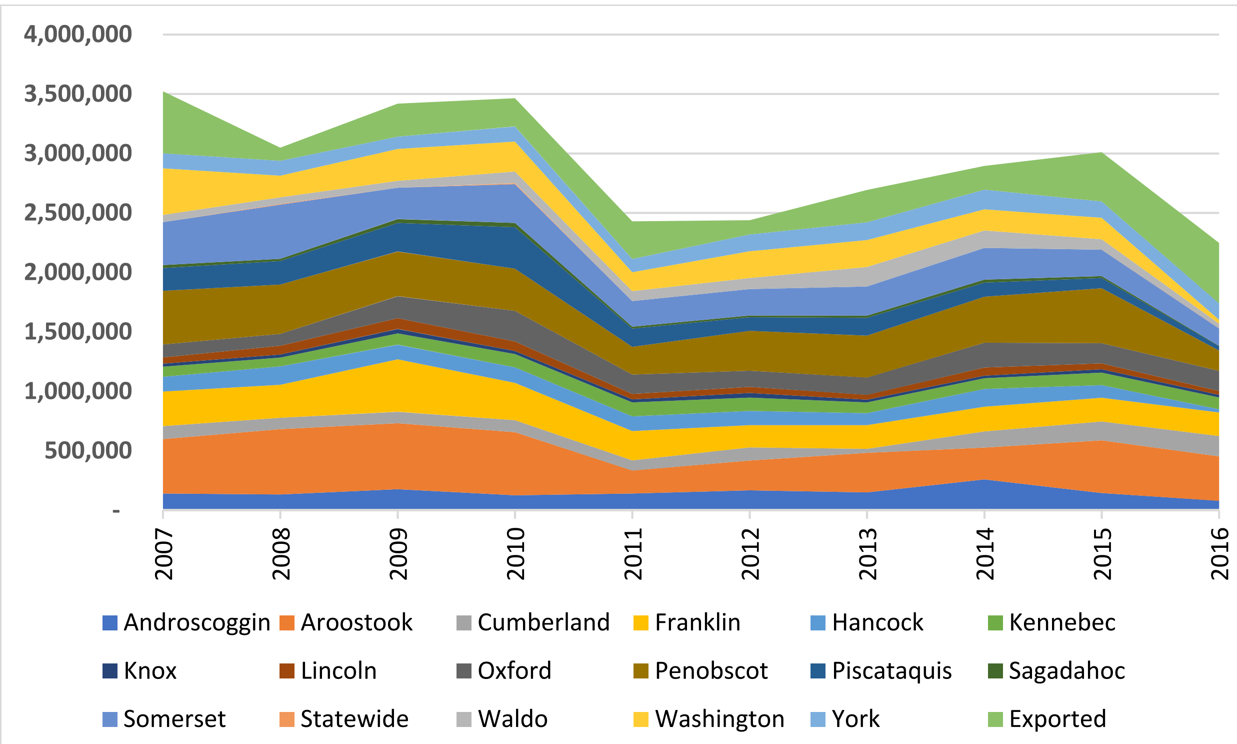
[2] Data Source: Maine Forest Service. *Wood Processor Reports.* 2016 (April 27, 2017), 2010 (January 30, 2012), and 2007 (October 28, 2008). http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc Analysis by Innovative Natural Resource Solutions LLC.

[3] Data Source: Maine Forest Service. *Wood Processor Reports.* 2010, 2011, 2012, 2013, 2014, 2015, 2016. http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc Analysis by Innovative Natural Resource Solutions LLC.

Comparable data is not yet available for 2017, but conversations with industry professionals suggest that the absolute volume of biomass harvest will be below the 2016 level of 2.25 million green tons. This is because a major mill increased its consumption of natural gas (thus displacing biomass), and some stand-alone biomass electric facilities operated at levels well below their capacity.

The following figure shows biomass by county, showing how local markets have changed over time.

Figure 5. Biomass Harvest by County, 2007-2016 (green tons)[4] [5]



[4] Data Source: Maine Forest Service. *Wood Processor Reports.* 2007 - 2016. http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc Analysis by Innovative Natural Resource Solutions LLC.

[5] "Statewide" is used by Maine Forest Service for wood for which they cannot determine the county of origin.

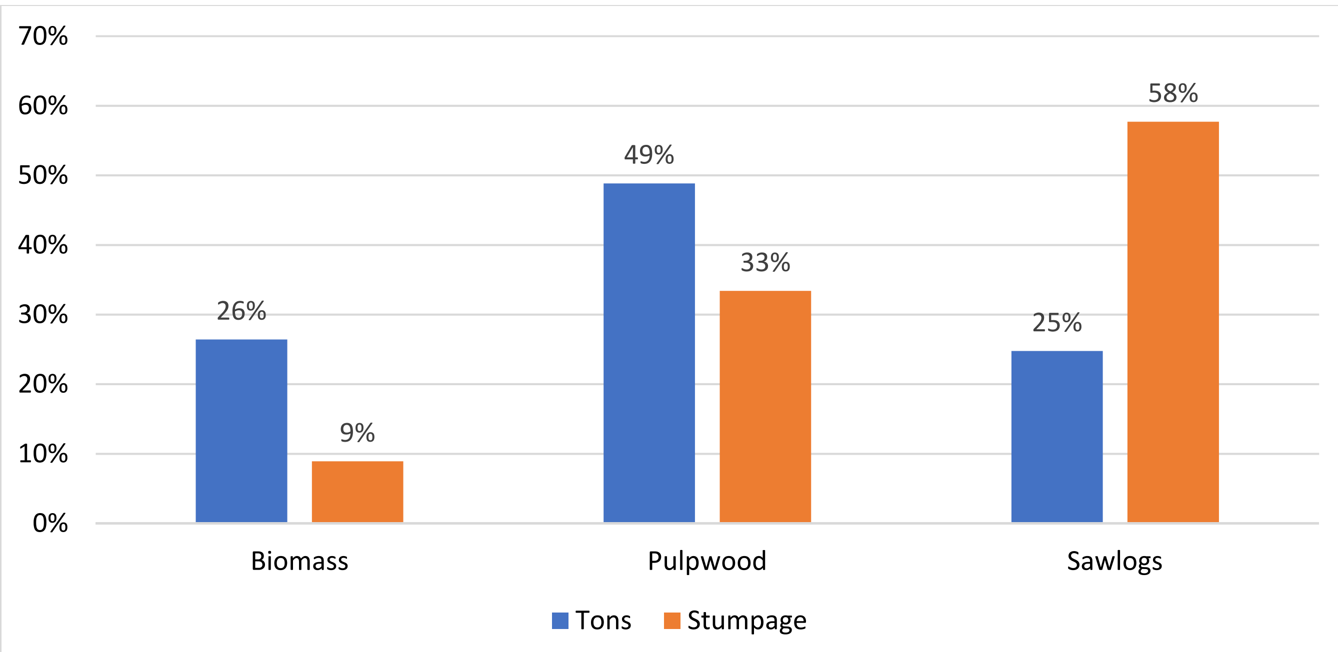
Supply Chain – Landowners

Maine landowners rely upon biomass as a market for low-grade products, including the ability to sell logging residues (tops and branches from stems harvested for other markets), cull stems (which do not meet the requirements for higher value products, such as pulpwood sawlogs, or even firewood), and species that do not have a local market.

Timber harvests generate three major groups of products – sawlogs (primarily used in lumber manufacturing), pulpwood (primarily used at pulp and paper mills), and biomass. Landowners are paid "stumpage" for these products[6] – in essence, the value of a stem standing in the woods, prior to being cut, hauled, processed and trucked to market.

Using information from the Maine Forest Service's annual *Wood Processor Reports*[7] and *Stumpage Price Reports*[8][9], the following charts show how biomass markets have changed since 2010. In 2010, the total Maine timber harvest was 13.9 million tons. Biomass (from timber harvesting only) represented over a quarter of the volume harvested statewide, and nine percent of the stumpage value.[10]

Figure 6. Volume and Stumpage Value, Maine Timber Harvest, 2010



[6] Of note – some larger landowners conduct "cut and haul" sales, where they pay loggers on a volume basis to harvest a range of products, and maintain control of the product until it is sold to a mill. For simplicity, we have assumed all sales are stumpage, using data from the Maine Forest Service's *Stumpage Price Reports* and *Wood Processor Reports*.

[7] http://www.maine.gov/dacf/mfs/publications/annual_reports.html#woodproc

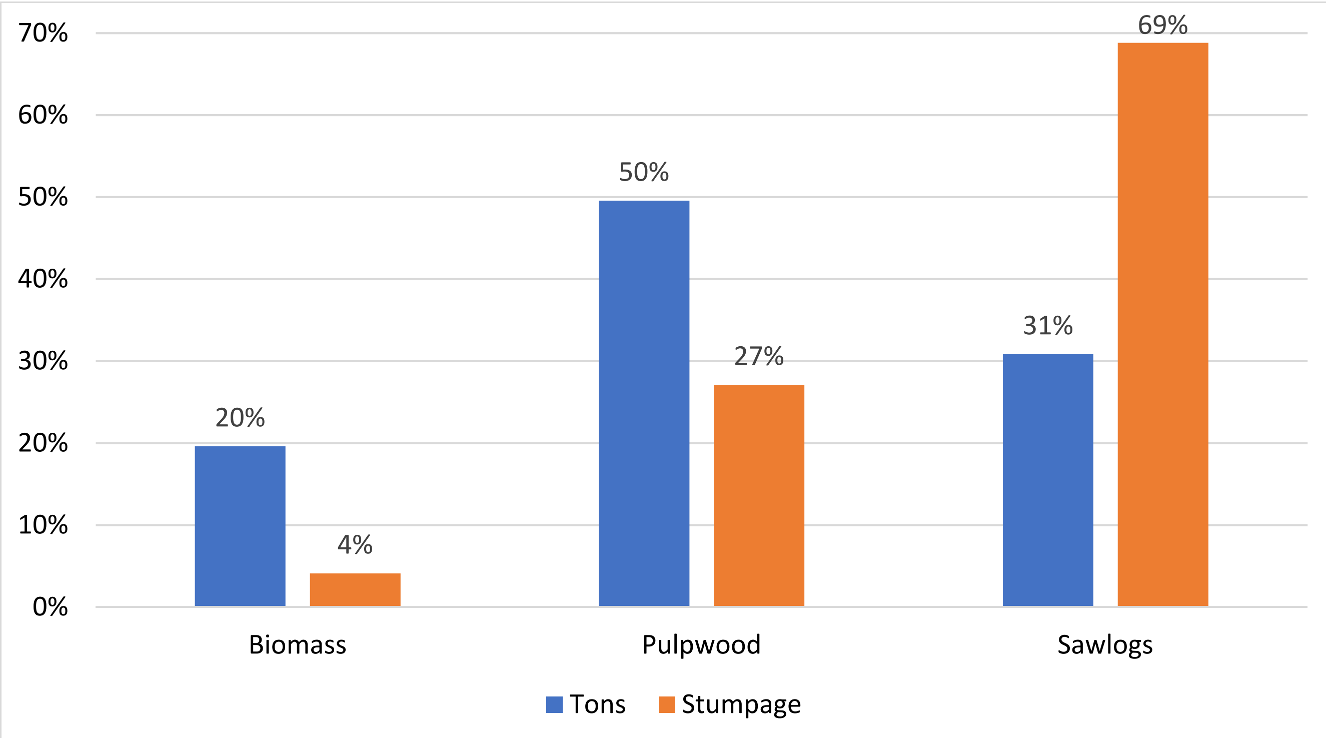
[8] http://www.maine.gov/dacf/mfs/publications/annual_reports.html#stumpage

[9] Some individuals have raised questions regarding the accuracy of this data; the authors have determined that this is the best time-series data available.

[10] This counts only in-woods harvested biomass, and does not include residual biomass (from sawmills, pulp mills, etc.)

By 2016 [11], the total statewide harvest volume had shrunk by 2.6 million green tons, primarily due to the loss of pulp mills and associated biomass units. Biomass represented 20 percent of this lower timber harvest, and the stumpage value paid to landowners accounted for only four percent of all stumpage.

Figure 7. Volume and Stumpage Value, Maine Timber Harvest, 2016



Once again using the Maine Forest Service reports, Maine landowners received $11.9 million in stumpage payments for biomass in 2010. Due to a loss of volume and stumpage value, in 2016 this figure had shrunk to $3.8 million, a loss of $8.1 million in annual revenue for Maine landowners. As shown below, landowners in every county (or county group)[12] lost revenue associated with harvested biomass between 2010 and 2016.

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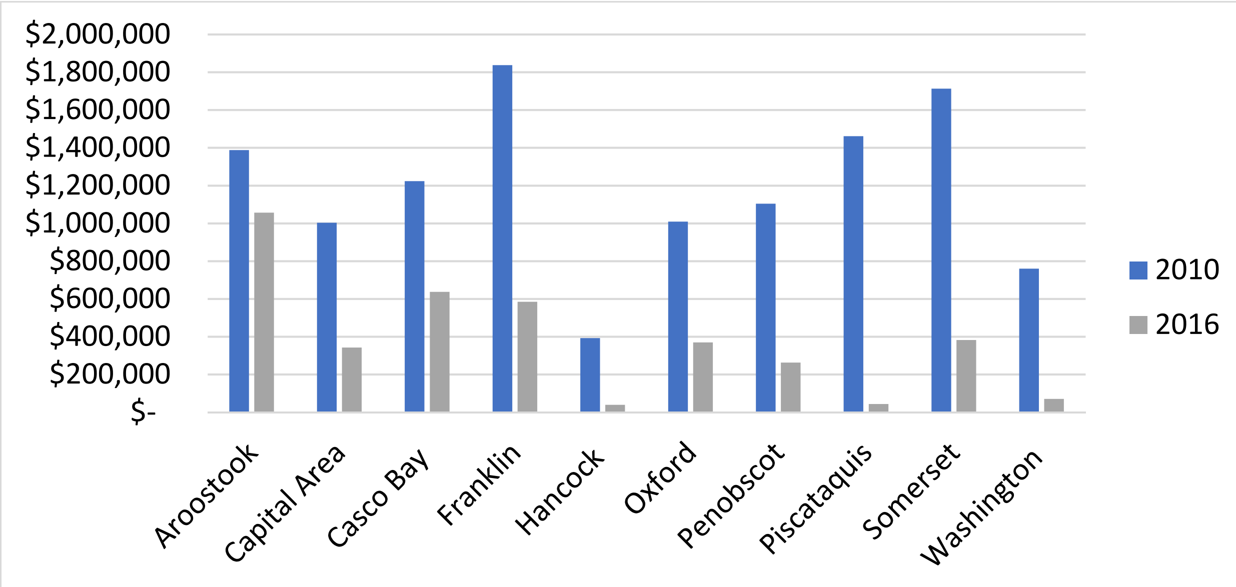
[11] 2016 is the most recent data currently available for the Maine Forest Service's *Stumpage Price Report* and *Wood Processor Report*.

[12] County groups are from the Maine Forest Service's *Stumpage Price Reports*: Capital Are includes Kennebec, Knox, Lincoln and Waldo Counties; Casco Bay includes Androscoggin, Cumberland, Sagadahoc and York Counties.

Figure 8. Total Biomass Stumpage Value by County, 2010 and 2016



Supply Chain – Logging

The logging industry is the critical link between landowners, foresters and wood-using industries. Maine has over 4,000 loggers, who work in the woods harvesting forest products for a range of markets. This includes both logging employees (who work for a logging company) and self-employed loggers (who work for themselves or in a partnership). This figure has decreased only slightly since 2010; clearly logging remains an important industry and a key part of Maine's forest industry.

Table 2. Logging Employment, 2010 and 2016[13]

	2010	2016
Loggers	2,364	2,245
Loggers - self-employed	2,046	1,784
Total	4,410	4,029

Biomass markets are obviously an important part of the timber harvest volume in Maine, representing a fifth of all harvest in 2016. Assuming it requires equivalent effort to harvest and process a ton of wood, regardless of product[14], this suggests that in 2016 biomass fuel supply was directly responsible for 805 logging jobs. Maintaining this logging infrastructure – people, equipment and knowledge – is important for capturing future opportunities for Maine's forest industry.

Loggers have made significant investments in biomass processing equipment (primarily chippers, which can cost more than half a million dollars), and have configured their operations around the ability to utilize tops, limbs, and off-spec stems as biomass. Maine loggers have made substantial investments in equipment for harvesting, skidding, processing and trucking wood to mills, including biomass. Based upon the volume of biomass harvested in Maine, INRS estimates that Maine loggers have invested more than $27 million[15] in chipping capacity. Given the number of loggers supplying biomass markets in Maine and neighboring New Hampshire, this is likely conservative.

As with stumpage for landowners, Maine loggers have lost significant economic activity with the loss of biomass markets (at both stand-alone biomass electric facilities and pulp and paper mills), and the associated drop in market price. In addition to stumpage fees paid to landowners (discussed above), cost components of biomass fuel production include equipment costs, labor, business overhead, trucking and diesel. After subtracting stumpage, Maine loggers lost $34 million dollars in annual economic activity between 2010 and 2016.

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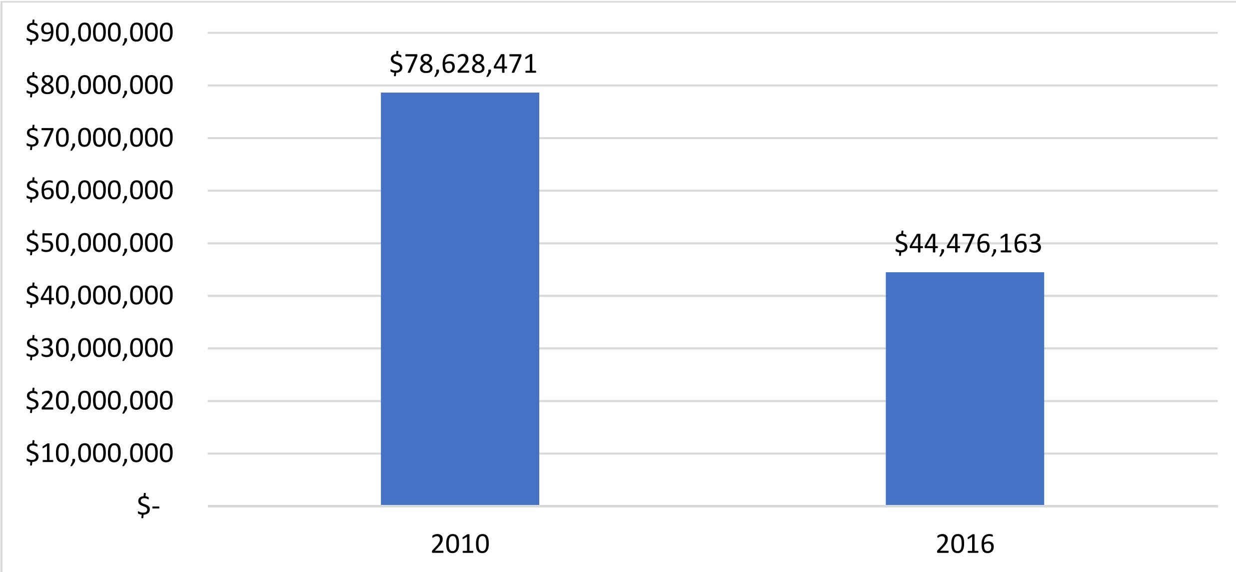
[13] Data from the Maine Department of Labor, Center for Workforce Research and Information, 2017 and self-employed logging was estimated using the U.S. Census Non-Employer Statistics.

[14] This assumption may be conservative, given the extra step of chipping required for biomass.

[15] Assumes 45 chippers with an annual capacity of 50,000 tons, with an average purchase price of $600,000.

Figure 9. Logging Activity Associated with Biomass Harvests, less Stumpage



Supply Chain – Trucking

Trucking of biomass is a critical component of the supply chain, and local markets provide an opportunity to optimize a trucking fleet.

The loading, transport and unloading of biomass takes about three hours, assuming it takes:

- Thirty minutes to position and load a truck with biomass;
- One hour to transport from the woods to the plant;
- Thirty minutes to wait in line and unload; and
- One hour to return to the woods.

Obviously, each of these times can change significantly depending upon several factors (distance to market, speed of chipper, wait time for unloading at the facility, etc.), but personal communication with loggers suggest that this is a fair average. Given limitations on Hours of Service for truckers, this means that an individual can deliver up to three loads of biomass daily.

All fuel arrives at wood-fired electricity plants directly via truck. Pulp and paper mills generate most of their fuel internally – the bark and fines that are generated during the conversion of pulpwood to chips. While variances can occur from mill to mill and seasonally, conversations with multiple pulpwood buyers suggest that pulp and paper mills generate three quarters of their biomass internally, and purchase the remainder[16].

Using the following assumptions:

- Three loads of fuel per day per truck;
- Five days of trucking per week;
- Forty operating weeks per year (accounting for weather interruptions to logging); and
- 30 tons of fuel per load.

There are 221 truckers dedicated to delivering wood fuel to large-scale energy facilities, down roughly half from 440 such positions in 2010. In reality, a larger number of truckers deliver wood to these facilities, combining to represent 210 full-time equivalent positions. That is because truckers can deliver multiple products (sawlogs, pulpwood, etc.), and short(er) haul biomass can be an important part of a strategy to optimize truck trips.

Table 3. Trucking Jobs Associated with Biomass Deliveries, 2010 and 2016

	2010	2016
Delivered Biomass (tons, estimated)	7,923,336	3,984,738
Trucking Jobs	440	221

[16] The exception is the paper mill in Westbrook, Maine, which does not use pulpwood and thus does not have any internal sources of biomass fuel.

Importance of Markets for Low-Grade Wood

Maine has lost significant markets for low-grade wood in recent years. Since 2014, pulp mills in Bucksport, Lincoln, East Millinocket, Old Town and Madison have closed. Pulpwood use at the mill in Jay has been reduced. Biomass energy facilities associated with most of these mills have also closed, resulting in reduced biomass use. Additionally, pulp mills with access to pipeline natural gas have reduced biomass fuel use, and some stand-alone biomass electric facilities have operated at reduced capacities. The loss of markets for low-grade wood in Maine since 2014 is estimated at 3.8 million tons annually. Of this, 2.6 million tons was pulpwood.[17]

Harvest of low-grade stems is a critical tool for forest management:

> *"Increasing the volume of trees in the better-quality classes is often an objective in forest management. With that objective, a range of other benefits are often realized, such as enhanced forest health, better visual quality and accelerated individual tree growth.*
>
> *Thinning timber stands purposefully manipulates light conditions to favor the growth of selected trees and will encourage tree regeneration. Lower quality trees are removed to favor higher quality trees or potentially higher quality trees. It is easy to sell high quality trees, but forest management is required to produce these trees in greater numbers and over a shorter period of time."*[18]

Low-grade wood is removed during every harvest in Maine. As markets for low-grade wood have shrunk, the percent of Maine's timber harvest that is low-grade has shrunk. In 2010 pulpwood and biomass combined to represent 80% of the state's timber harvest. In 2016, this had shrunk to 73%.

As other markets for low-grade wood have shrunk, the biomass markets have become increasingly important to forest managers. While Maine takes steps to attract and develop new markets for all grades of wood, maintaining a market for low-grade provides long-term benefits.

As a forest management tool, markets for low-grade wood promote increased growth of high-value sawlog stems, and provide a resource that will be valuable for Maine sawmills and other users of high-quality stems in coming decades. For new manufacturers planning to use low-grade wood, they will clearly be relying upon the state's robust harvesting and transportation infrastructure to supply them. Maintaining this infrastructure has real value for the future evolution of Maine's forest industry. As other states have recognized, "once a forest-based infrastructure is lost, it is difficult to rebuild."[19] As of today, Maine's forest industry infrastructure is a significant competitive advantage; retaining it is important for the future of the existing and emerging industry.

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[17] Innovative Natural Resource Solutions LLC and Meister Consultants Group. *Analysis of the Energy & Environmental Economics of Maine's Biomass Industry.* Prepared for the State of Maine's Governor's Energy Office. October 2017.

[18] http://msue.anr.msu.edu/news/low_grade_wood

[19] http://msue.anr.msu.edu/news/low_grade_wood

Maine Sawmills

Maine sawmills are a critically important part of Maine's forest product industry, and provide a market for high-value logs. As discussed earlier, sawlog revenue represents 69 percent of the stumpage to landowners, an estimated $119 million in 2016.

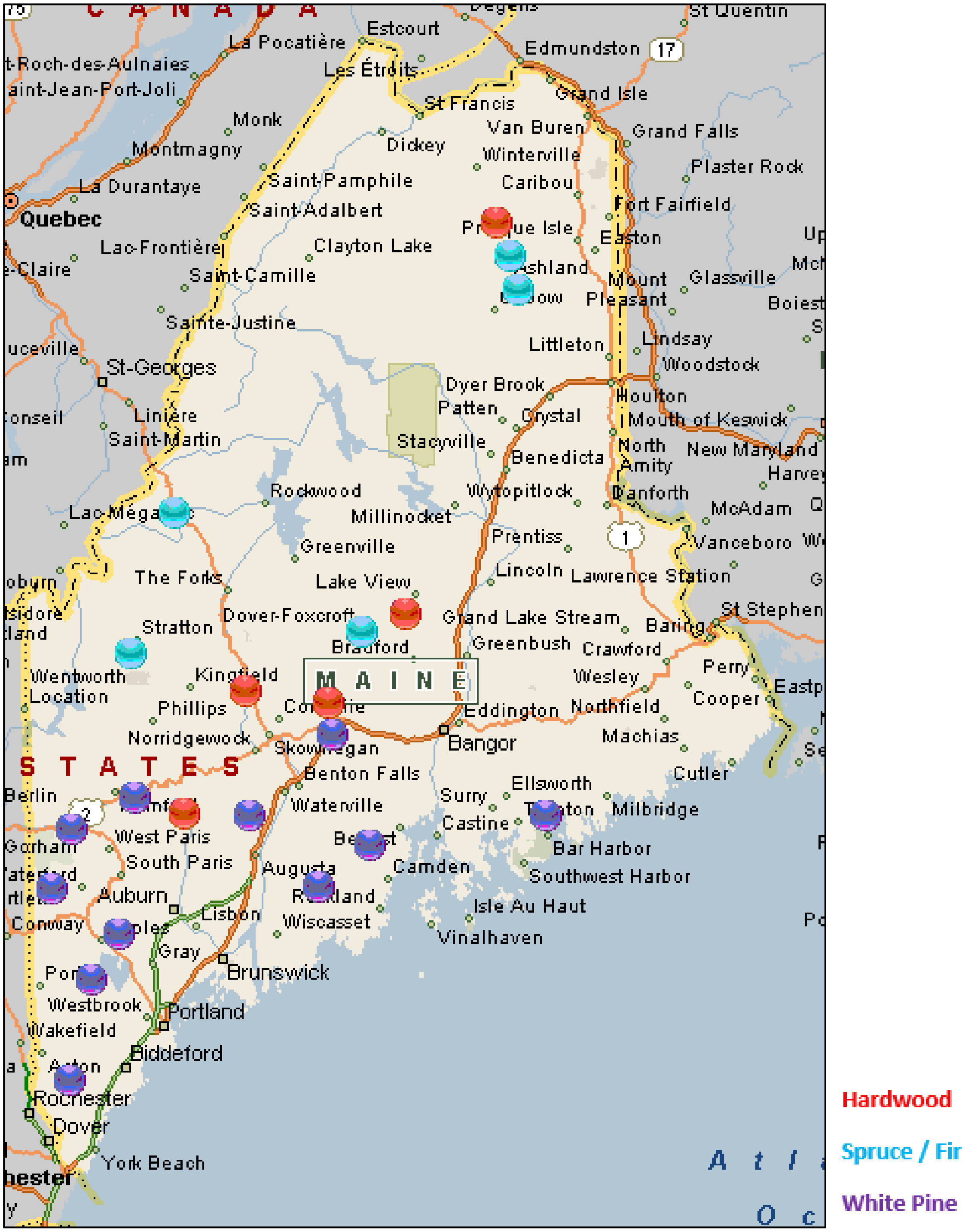
Maine has well over 100 sawmills and turning mills operating around the state[20]. The table and figure below show the largest mills.

Table 4. Major Maine Sawmills by Species Group

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

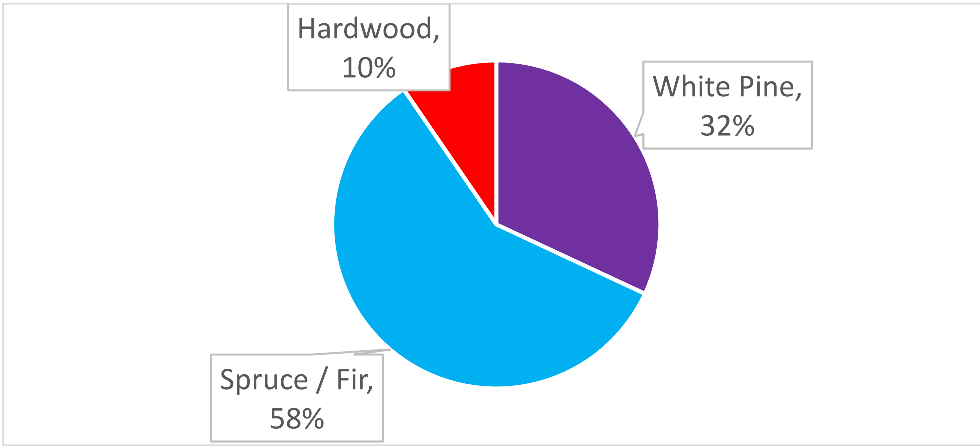
[20] Maine Woodland Owners. *2017 DIRECTORY OF MAINE'S STATIONARY AND PORTABLE SAWMILLS*. 2017. http://mainewoodlandowners.org/Portals/0/Articles/Documents/General%20Articles/Online_Portable_Sawmills.pdf

Figure 10. Major Maine Sawmills by Species Group



On a volume basis, a significant majority of wood sawn in Maine is softwood. This is primarily spruce-fir (in the Northern part of the state) and white pine (in the southern part). Hardwood mills account for an estimated ten percent of the major sawmill capacity in Maine; many smaller mills saw hardwood as well.

Figure 11. Maine Sawmill Capacity by species Group



When sawmills produce lumber, they do so by sawing boards out of a log, removing everything that isn't lumber. In doing so, the manufacturing process produce residues – chips, sawdust and bark. Every mill is unique, but a decent rule of thumb is for every thousand board feet of lumber produced, two tons of residues are produced—one ton of clean chips, and another ton of bark and sawdust[21]. Maine's annual sawmill production is roughly 800 million board feet (MMBF), which means roughly 800,000 tons of mill chips and another 800,000 tons of sawdust and bark are produced annually.

Sawmill chips, which are made from slabs sawn from debarked logs, are generally sold to paper mills. This has become more difficult over the past several years, as pulp mills have closed and markets for mill chips have shrunk. Softwood mills (both spruce-fir and white pine) in Maine and across New England have expressed significant concern about continued access to markets for clean mill chips, and are very concerned that the loss of another pulp mill could leave many sawmills without an outlet for chips. While this concern – and the loss of markets are real – it is important to note that we have not identified mills that have yet limited operations based upon a lack of markets for residues.

Sawdust, shavings and bark need markets as well. Sawdust and shavings can be used in several applications, including agricultural use (livestock bedding), wood pellet manufacturing, and as a raw material for particleboard manufacturing. Bark is often used in landscape applications, though this is a highly seasonal market and often not available to sawmills.

In addition to the above markets, biomass is a critical market for sawmill residue, and has long been an important market that can utilize residues and produce a product. At present, at least 20 mills provide wood fuel to stand-alone biomass power plants[22], and in conversations with mill managers, several mills have indicated that biomass plants are critical to the continued

[21] https://blog.forest2market.com/residues-becoming-a-problem-for-northeastern-mills
[22] Larry Richardson. *Biomass Energy Can Have Strong, Viable Future in Maine.* January 15, 2018.

profitable operation of sawmills in parts of Maine. While this has long been true to some extent, the importance of biomass markets has increased as other markets (notably pulp mills and the boilers that powered them) have closed while sawmills have simultaneously seen increasing markets – and therefore are producing increasing volumes of residues.

In addition to sawmill residue, most pulp and paper mills generate significant residue at woodyards – either on-site or off-site. Bark and "pins and fines" generated during the processing of pulpwood into chips for the digester are generally burned for energy at pulp mill boilers.

Maine sawmills and turning mills have reported in conversations that the amount they are getting paid for sawmill residue at biomass facilities is dropping, and can be significantly less than what those loggers who are producers of in-woods chips are receiving. This has been confirmed by at least one biomass buyer, and makes sense for several reasons:

- o Clean chips are from the outside (live) portion of a stem, and often have a higher moisture content than in-woods chips, which can contain drier wood from the center of a tree;
- o Bark has dirt accumulated when trees are skidded, and higher dirt content leads to higher ash and can increase wear on a boiler (this can be true of in-woods biomass as well, but the concentration of bark in that product is much lower);
- o Sawdust is small particles that do not perform well in some boilers (including stoker grates);
- o For these reasons, sawmill residue is often blended with other fuels to provide a better boiler fuel at a biomass plant.

- Sawmills must produce residues – they are necessary byproducts of making lumber. It is a non-discretionary product, unlike in-woods biomass, where tops, branches and cull tree can be left in the woods.

If mills don't have a market (at any value) for their residues, the worst-case scenario is being forced to pay a disposal fee. Tipping fees "range from $40 to $95 per ton at Maine's waste-to-energy facilities and landfills."[23] There is very real concern in the forest industry that what is now a modest revenue source (sales to a biomass plant) could become a cost center. In a highly competitive commodity market, this would put Maine sawmills at a disadvantage.

As discussed above, Maine sawmills produce an estimated 1.6 million green tons of residue annually – chips, sawdust, bark, shavings. If one quarter[24] of this (400,000 tons annually) is being sent to biomass plants at $12.50 per ton (roughly half of recent prices paid for in-woods chips), that represents $5 million in revenue to sawmills annually. If mills need to dispose of this same volume at the lowest fee noted above ($40 per ton, which does not include trucking), they

[23] https://www.maine.gov/decd/meocd/landfills/docs/Waste_CapacityReport%202017.pdf

[24] This assumption is based upon conversations with several sawmills. However, all note that this is a constantly fluctuating number, and that biomass plants – as a group – may be using more at times and locations, making this market even more important to sawmill operations. Better time-series data on sawmill residuals and markets would help Maine policy makers evaluate options for this important resource.

would be paying $16 million annually in disposal fees – a swing of $21 million annually in sawmill profitability.

For decades, a competitive advantage of Maine sawmills has been their ability to move their residues at attractive prices. That advantage has certainly shrunk, and there is concern that it might vanish with further loss of markets that utilize residues. On production of roughly 800 million board feet (MMBF) annually, increases the cost of production for Maine sawmills by over $26 per MBF. At a national composite lumber price of $471 per MBF[25], this represents 5.6% of the price. In a highly competitive commodity market, moving residues from a modest revenue center to a cost could price some Maine lumber out of the market, and advantage lumber produced other regions. In addition to the cost to sawmills, disposal of mill residues in landfills could create solid waste challenges due to limited landfill space, and works against Maine's solid waste goals.

Such a competitive disadvantage could threaten some of the nearly 2,000 jobs – representing $85 million in payroll[26] – that Maine sawmills provide. Importantly, most of these jobs are in rural areas, where there may be limited alternative employment opportunities.

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[25] The Random Lengths composite price is for structural lumber. http://www.randomlengths.com/woodwire/rl-lbr-pnl/ accessed on January 29, 2018.

[26] Maine Forest Products Council. *Maine's Forest Economy.* October 12, 2016. http://maineforest.org/wp-content/uploads/2016/09/Maines-Forest-Economy-10-12-2016.pdf

Maine Biomass Consumers

Maine has six stand-alone biomass electric facilities, biomass use at five operating pulp or paper mills, biomass thermal at a number of forest industries (often to provide heat for kilns, but can be more extensive), and community-scale facilities providing heat or heat and power to institutions. The figure and table below shows the volume of wood fuel used from 2010 through 2016 at these facilities[27].

Figure 12. Wood Used for Energy in Maine (green tons), 2010 - 2016[28]

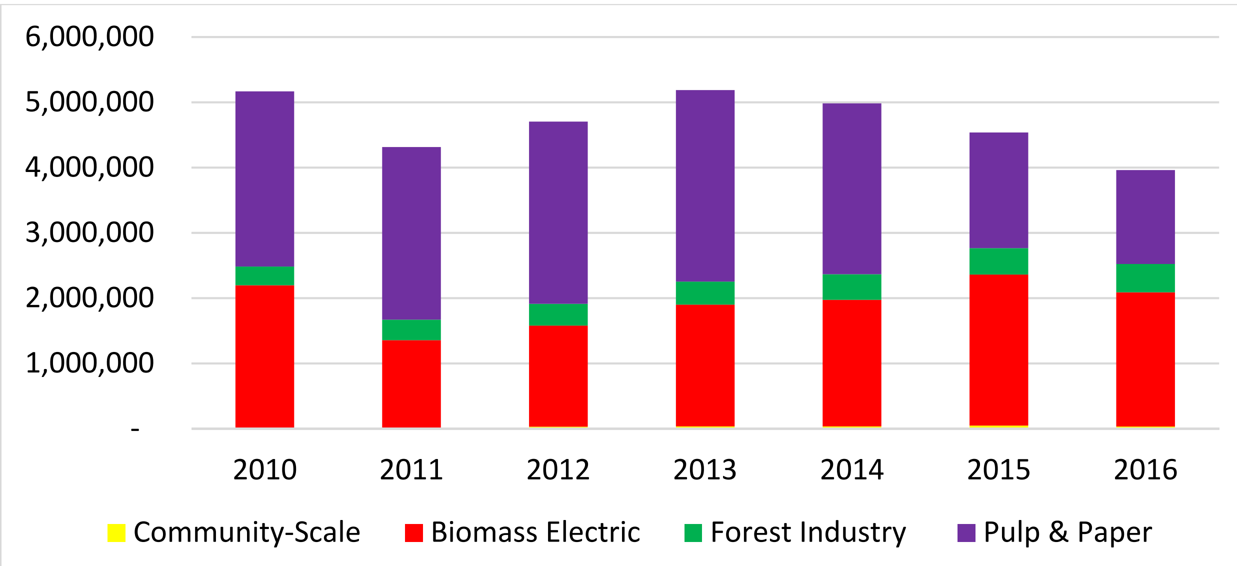

Table 5. Wood Used for Energy in Maine (green tons), 2010 – 2016[29]

	Community-Scale	Biomass Electric	Forest Industry	Pulp & Paper	Total
2010	958	2,194,586	288,574	2,682,342	5,166,460
2011	3,728	1,351,728	313,699	2,645,586	4,314,740
2012	29,852	1,550,098	332,161	2,789,923	4,702,034
2013	34,613	1,865,480	353,214	2,933,843	5,187,150
2014	33,704	1,938,823	393,874	2,615,830	4,982,231
2015	46,671	2,313,520	405,273	1,770,305	4,535,769
2016	32,981	2,054,803	435,572	1,437,585	3,960,941

[27] Note: Some community-scale facility use is not included here, as they do not have emissions profiles that require reporting of wood fuel use.

[28] Personal Communication. Marc Cone. Bureau of Air Quality, Director. Maine Department of Environmental Protection. December 15, 2017. File name *Biomass_Throughput_by_Facility_2010-2016_summary – corrected.xls*

[29] Personal Communication. Marc Cone. Bureau of Air Quality, Director. Maine Department of Environmental Protection. December 15, 2017. File name *Biomass_Throughput_by_Facility_2010-2016_summary – corrected.xls*

Importantly, these numbers are not a match to the harvest level numbers shown earlier. That is because these figures include mill residuals (e.g., bark, sawdust and chips – commonly used as fuel at forest industry and pulp and paper mills), as well as any biomass harvested out-of-state and imported.

The following map and table show the location and name of major biomass users. These are facilities large enough to have emissions reporting obligations to the Maine Department of Environmental Service – Air Resources Division.

Figure 13. Maine Biomass Users (Major)

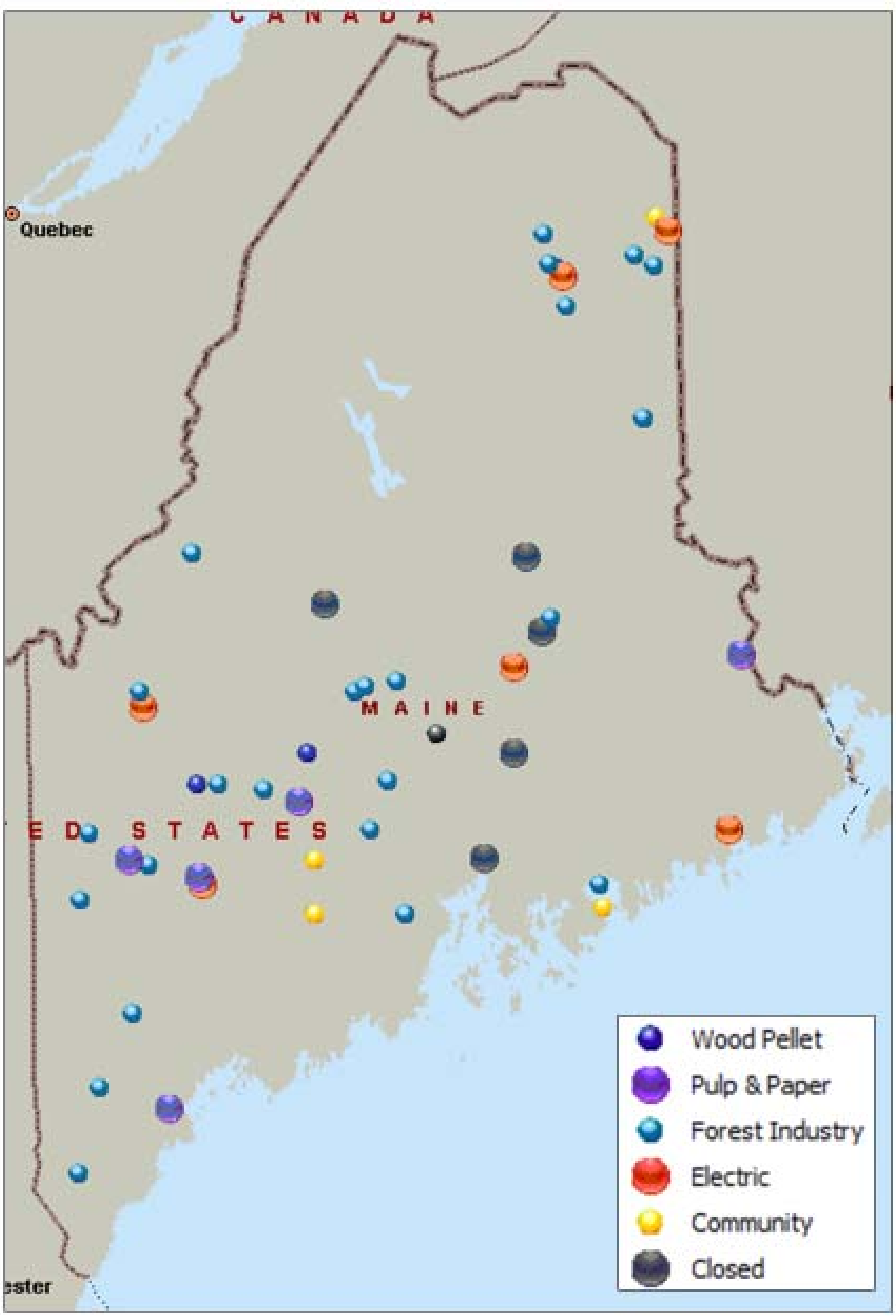

Table 6. Maine Biomass Users (Major)[30]

COMMUNITY SCALE

- COLBY COLLEGE
- LUCERNE FARMS
- THE JACKSON LABORATORY
- VA MAINE HEALTH CARE SYSTEM - AUGUSTA

BIOMASS ELECTRIC

- ~~GALLOP POWER GREENVILLE LLC~~
- REENERGY ASHLAND LLC
- REENERGY FORT FAIRFIELD LLC
- REENERGY LIVERMORE FALLS LLC
- REENERGY STRATTON LLC
- STORED SOLAR J&WE, LLC - JONESBORO
- STORED SOLAR J&WE, LLC - WEST ENFIELD

FOREST PRODUCT MANUFACTURING

- COLUMBIA FOREST PRODUCTS, INC.
- COUSINEAU WOOD PRODUCTS OF MAINE, LLC
- DUVAL ACQUISITIONS (US), INC. - GUILFORD
- HANCOCK LUMBER CO INC - PITTSFIELD
- HANCOCK LUMBER COMPANY - CASCO
- HANCOCK LUMBER COMPANY, INC. - BETHEL
- HARDWOOD PRODUCTS CO
- HUBER ENGINEERED WOODS LLC - EASTON
- IRVING FOREST PRODUCTS - ASHLAND SAWMILL
- IRVING FOREST PRODUCTS - DIXFIELD
- LIMINGTON LUMBER COMPANY
- LMJ ENTERPRISES LLC
- LOUISIANA-PACIFIC CORP - NEW LIMERICK
- MAIBEC LUMBER - MASARDIS
- MAINE WOOD CONCEPTS
- MAINE WOODS CO
- MOOSE RIVER LUMBER CO INC (now Pleasant River)
- PLEASANT RIVER LUMBER
- PRIDE MANUFACTURING CO
- PRL SANFORD, LLC
- ROBBINS LUMBER INC-SEARSMONT
- STRATTON LUMBER INC
- VIC FIRTH COMPANY
- WOOD PRODUCTS COMPLEX ANDOVER LLC
- ~~CORINTH PELLETS, LLC~~
- LIGNETICS OF MAINE, LLC - STRONG
- MAINE WOODS PELLET COMPANY LLC-ATHENS

[30] Facilities that are crossed out have closed since 2010

PULP & PAPER

- ~~BUCKSPORT GENERATION LLC~~
- CATALYST PAPER OPERATIONS INC. - RUMFORD
- ~~GNP EAST INC~~
- ~~LINCOLN PAPER AND TISSUE, LLC~~
- ~~MFGR, LLC - OLD TOWN~~
- S D WARREN CO - WESTBROOK
- SAPPI - SOMERSET
- VERSO ANDROSCOGGIN, LLC
- WOODLAND PULP LLC

Maine's Stand-Alone Biomass Plants

Jobs

Maine's six stand-alone biomass power plants directly employ roughly 148 individuals[31], professionals in the operation, maintenance and fueling of wood-fired systems. In addition to these individuals directly employed, multiple studies have shown that biomass energy creates significant economic activity in the supply chain and beyond. As the only renewable energy technology that needs a constant supply of procured fuel, this is both obvious and logical.

Multiple studies have calculated that the jobs impact from these – direct (at the plant), indirect (loggers and truckers supplying a facility) and induced (economic activity that results from the direct and indirect impacts) - are as high as 5 jobs per MW of biomass generation capacity[32], [33].

Maine has 213 MW of stand-alone biomass electric generation. Using the documented multiplier above, this means that these stand-alone plants support 1,065 jobs in rural Maine. This is in addition to the benefits they provide sawmills (as a residue market) and the 2,000 employees employed in that sector.

As discussed elsewhere, all the state's six stand-alone biomass plants are actively seeking co-location partners – users of steam, heat and electricity. Any such partners would create jobs as well, though the number would depend upon what type of facility and their use of forest-derived materials.

Property Taxes

Maine's stand-alone biomass electric plants are significant property tax payers in their host communities. The plants are assessed and taxed at different rates depending upon their size, condition and each host community's property tax rate. The six plants pay a combined $2.2 million in property taxes – roughly $10,600 per installed MW.

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[31] Innovative Natural Resource Solutions LLC and Meister Consultants Group. *Analysis of the Energy & Environmental Economics of Maine's Biomass Industry.* Prepared for the State of Maine Governor's Energy Office. October 2017.

[32] Pelecon Research. *The Impact of Burgess BioPower's Annual Operations on Berlin, Coos County, and The State of New Hampshire*. October 2017. http://www.advancenh.com/wp-content/uploads/2017/12/Burgess-BioPower-Economic-Impact-Report-1.pdf

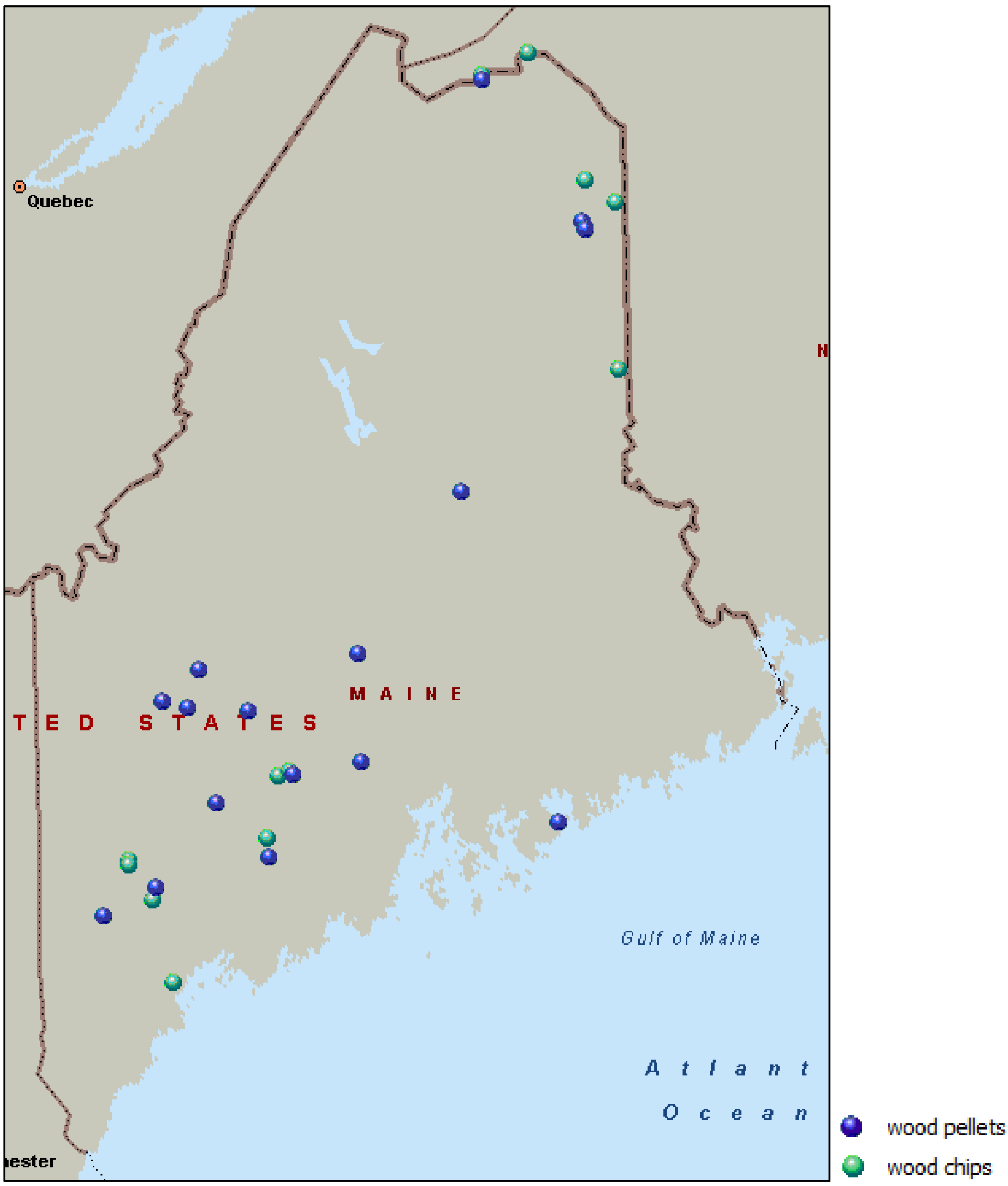
[33] Innovative Natural Resource Solutions LLC and Draper / Lennon, Inc. *Identifying and Implementing Alternatives to Sustain the Wood-Fired Electricity Generating Industry in New Hampshire.* Developed for the NH Department of Resources & Economic Development. January 2002. https://www.inrsllc.com/download/wood_firedelectricityinNH.pdf

Community-Scale Biomass

In addition to the facilities listed above, there are many smaller community-scale biomass heating projects in Maine. These facilities use biomass to provide heat (occasionally combined with power) to campuses, schools, hospitals and similar installations throughout Maine.

The following figure shows community-scale installations that utilize wood chips or pellets as a heating fuel[34].

Figure 14. Community-Scale Biomass Thermal Facilities



[34] It is likely that this map does not show all community-scale facilities. The Maine Statewide Wood Energy Assistance Team (http://www.woodheatmaine.org/about/) is developing a comprehensive list of community-scale wood energy facilities.

It is important to note that many community-scale biomass facilities use wood chips that are of a higher specification than what the industry generally considers as "biomass". Many community scale facilities – using from a few hundred to a few thousand green tons per year – make an economically rational choice not to invest in screens or resizing material, and instead purchase wood that is of higher and tighter specifications, often screened off-site or manufactured only from stems, not tops and branches. This fuel is more expensive than traditional "biomass".

Such facilities are, in fact, using what would otherwise be considered pulpwood, and competing at some level with pulp mills (though the volumes are *de minimus* when compared to the consumption at a pulp mill). This is particlarly true for community-scale biomass faciliteis that specify hardwood as the primary or exclusive fuel, given that hardwood pulpwood and hardwood chips remain a commodity for which there is significant competition in Maine.

Biomass Fuel Prices

The price biomass plants pay is set through the open market, and can vary based upon several factors, including weather, wholesale electricity markets, markets for other forest products, and distance to market. INRS conducts a quarterly survey of biomass prices in New England, speaking with both buyers and sellers of biomass to estimate the price on a quarterly basis. These prices are specific to large scale users of biomass (e.g., biomass electric, pulp and paper mills, etc.) that have truck dumps, can accept some reasonable volume of "overs" (pieces larger than a typical chip), and have a year-round demand that is relatively consistent.

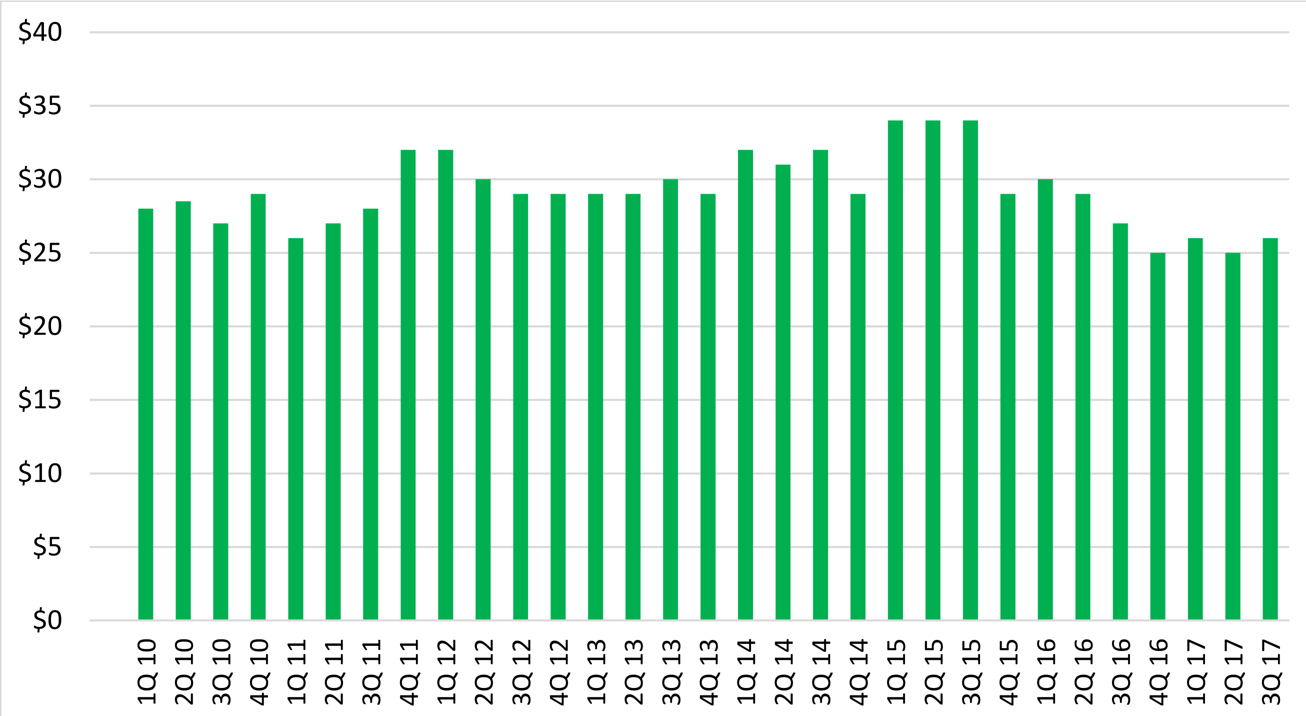
Figure 15. Biomass Fuel Being Unloaded at a Power Plant, Being Conveyed to Boiler

The following is a fuel specification for biomass fuel, typical of a large-scale user, typical of the fuel being discussed in this section.

- Forest-derived biomass fuel chips (from logging and land clearing operations), sawmill residue, bark and pallet grindings.
- 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
- No fuel derived from construction or demolition debris, painted wood or engineered wood

The figure below shows quarterly price estimates using only Maine biomass suppliers and consumers, on a weighted average. Importantly, this is an estimated market price – individual suppliers may be paid above or below these levels. While always moving slightly, since 2010 the average price per ton of biomass has stayed in band between $25 and $35 per green ton, with an average quarterly price over this period of slightly over $29.

Figure 16. Maine Biomass Price (dollars per green ton, delivered)



Thermal Biomass Fuels

Wood Chips

Prices for biomass fuel used in thermal energy projects differ from the prices above. For chip-projects, there is often little to no tolerance for overs (because most biomass thermal facilities do not have a screen or hog for removing and reprocessing off-specification material), tight controls on species used and moisture content, special delivery requirements (e.g., live floor truck), and restricted delivery times.

The following is a wood fuel specification from a school in New England[35], sent to potential suppliers.

- Clean, 100% wood residues from known sources, free from paint, chemicals, glues, metals, nails, or other non-wood substances. No rotten substances that are evidence of decomposition, no whole-tree chips;
- Green hardwood only. Sugar maple, oak, beech, and yellow birch preferred. *No softwood.*
- Moisture content <45%
- Chip size 2.5” x 1.5” x 5/8” maximum
- Delivery via live floor truck, length < = 53 feet, height < = 14 feet
- Delivery during off-school hours – before 7:00 AM or after 5:00 PM

There is currently an effort underway to develop a series of standardized wood fuel specifications for biomass fuel used in thermal applications[36]. There is an expectation that some standardization of biomass fuel specifications will assist in industry growth and consumer understanding, as well as a more open and transparent market.

Fuel for biomass thermal projects is not as open or transparent a market as typical biomass fuel, in large part because projects are generally supplied by a single supplier with a negotiated contract price. The smaller volumes, higher specifications, need for screening or other re-handling prior to delivery, specialized delivery requirement and increased customer service necessary for these projects increases the price of fuel. INRS is aware of Maine thermal biomass facilities paying from $45 to $70 per green ton (delivered) for their fuel. For analysis later in this report, a figure of $60 per ton ($6.34 per MMBTU) is used, but it is important to note there can be significant variation in pricing based upon the factors discussed above.

35 *Request for Proposals - Biomass Fuel Supply – Winnisquam (NH) School District.* 2009.
36 https://www.woodchipstandard.org/

Wood Pellets

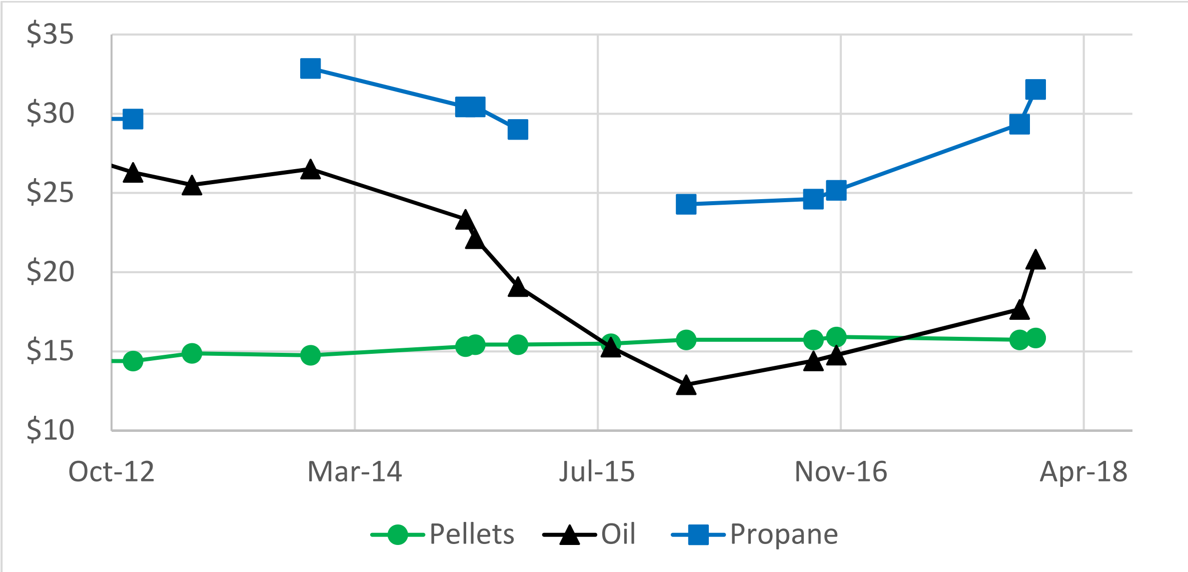
Wood pellets are produced at four facilities in Maine (Athens, Ashland, and Strong), as well as several facilities in other states and provinces nearby. Pellets are a refined and standardized product, and provide a consistent biomass fuel to the customer. Most individuals are familiar with wood pellets in bag form – many homeowners and others purchase 40 pound bags to feed pellet stoves and other appliances.

Figure 17. Wood Pellets

In addition to being available bagged, Maine homeowners and institutions can purchase wood pellets in bulk – delivered via truck and blown or augured directly into a storage system (generally a silo, but other storage options exist). This allows for the fuel to be delivered without handling by the customer – similar to the experience customers have with heating oil, propane or other fuels. This is typically for pellet appliances that heat the entire building – home, school, hospital, business or other.

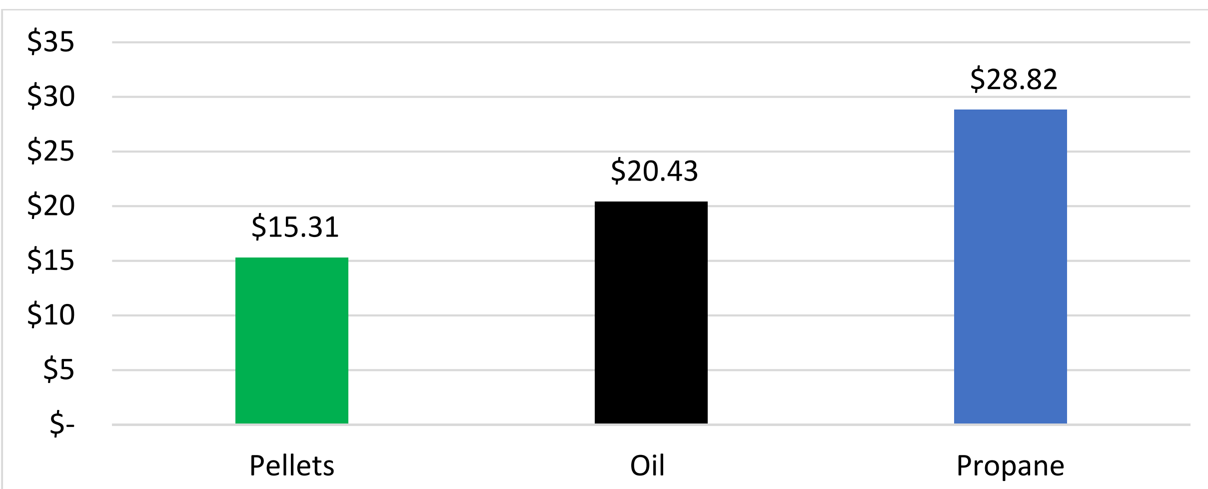
The Maine Governor's Energy Office publishes retail prices for several fuels, including wood pellets (bulk). Since 2012, reported prices are between $236 and $261 per ton. When compared on a dollar per MMBTU basis, this compares very favorably with oil (Maine's primary heating fuel) and propane.

Figure 18. Maine Fuel Prices, $ per MMBTU[37]



Since the beginning of the 2013 – 2014, wood pellets, using the figures above, have an average price (per unit of heat) well below that of oil and propane.

Figure 19. Average Maine Fuel Prices, October 2013 – Present, $ per MMBTU



The wood pellet figures reported by the Governor's Energy Office above are for small-scale delivery, primarily to homes. In discussions with both suppliers and consumers at larger facilities, it became clear that community-scale projects often pay prices lower than these because they are buying in larger volume, and have more efficient delivery. For analysis later, we have used a wood pellet price of $200 per ton, which is equivalent to $12.20 per MMBTU.

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[37] Data source: Maine Governor's Energy Office, Heating Fuel Prices. http://www.maine.gov/energy/fuel_prices/. Conversion to MMBTU by INRS assuming 91.3 mmbtu / gallon of propane, 138.8 mmbtu / gallon for home heating oil, and 16.4 mmbtu / ton for wood pellets.

Policy Support for Wood Energy Markets

Biomass Electric

Biomass is a renewable fuel, and as discussed earlier, an important part of Maine's forest economy. Maine is not alone in this perspective, and other states and regions have taken steps to support biomass electricity production.

Federal

At present, there is no direct policy mechanism to support new biomass electricity generation at the federal level. In the recent past, there have been two tax incentives – the Production Tax Credit and the Investment Tax Credit. Firms developing projects had to elect one or the other, and could not utilize both.

- The Production Tax Credit (Section 45 tax credit) provided a project ten years of federal tax credits of 1.3¢ per kwh[38] of electricity from "open-loop biomass" that was sold to an unrelated party (such as a utility, or a direct electricity customer)[39]. For purposes of this law, "open loop biomass" is biomass fuel from a forestry source and is any waste material (solid, cellulosic or lignin) derived from "mill and harvesting residues, precommercial thinnings, slash, and brush; solid wood waste materials, including waste pallets, crates, dunnage, manufacturing and construction wood wastes, and landscape or right-of-way tree trimmings; or wood bark and lignin material recovered from spent pulping liquors."[40] All (or nearly all) biomass fuel in Maine is "open loop". A projected needed to commence construction by the end of 2016 to qualify for the Production Tax Credit.
- Investment Tax Credit (Section 48 tax credit) provided a federal tax credit at the time commercial operations commenced equal to 30% of the project's qualifying expenses. Unlike the Production Tax Credit, this credit was available to projects that used the electricity generated for themselves, and did not require sale to an unrelated third party. As with the Production Tax Credit, a project needed to have begun construction prior to the close of 2016.

Both tax credits are no longer available for new projects, and were not part of the recent federal tax reform legislation.

New Hampshire

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[38] This figure is adjusted annually to account for inflation.
[39] http://www.bakertilly.com/services/renewable-energy/production-tax-credit-ptc-section-45
[40] IRS Notice 2006-88. https://www.irs.gov/irb/2006-42_IRB#NOT-2006-88

New Hampshire has taken two separate and distinct steps to support biomass electricity generation in that state. The state has eight biomass electricity plants, seven of which are operating.

- Six of these units are older plants, constructed in the 1980s, ranging in nameplate capacity from 15-24 MW. The New Hampshire legislature created a class in its Renewable Portfolio Standard (RPS) that was specifically for biomass and methane gas facilities up to 25 MW in nameplate capacity that began operations prior to 2006.

    - This "Class 3" of the state's RPS was clearly designed to provide support for a discrete set of existing biomass operations, including some or all of New Hampshire's legacy biomass units.
    - The Alternative Compliance Payment (ACP), effectively a price cap, was initially set at $45 per MWH for Class 3, and beginning in 2015 this Class was set at 8% of the state's RPS-eligible electricity load, though the NH Public Utilities Commission can modify this level downward if an insufficient number of Renewable Energy Certificates are expected to be generated.
    - In the 2017 legislative session, NH further restricted eligibility in the Class 3 RPS by limiting methane gas participation to facilities with a gross nameplate capacity of 10 MW of less from any single landfill.
    - Also in the 2017 session, the Class 3 ACP was raised to $55 for 2017, 2018 and 2019. It is expected that most qualified biomass facilities in New Hampshire will be able to operate during this period through a sale of electricity, RECs and capacity payments.

- In addition to the legacy biomass plants, the state also has two newer biomass electric facilities.

    - Schiller Station was a coal plant, operated by the state's largest electric utility, PSNH (now Eversource). The generation facility, located in Portsmouth, consisted of three 50 MW coal boilers and associated turbines. PSNH converted one of these units to biomass, and after coming online in 2006 the facility uses +/- 500,000 green tons of wood fuel annually. The two remaining coal plants are operational, but often do not dispatch for economic reasons. This facility was recently sold by Eversource as part of a state-mandated divesture of generation assets, and the future of this market is uncertain after a required 18 months of operation.
    - Burgess Biomass - located at the site of a former pulp mill in Berlin, NH – is a 75 MW generation facility that began operations in 2014. This plant was developed in large part to provide economic opportunity to New Hampshire's North Country, which has recently lost two pulp mills, and is

suffering economically. With NH Public Utilities Commission approval, NH-based utility PSNH (now Eversource) entered into a 20-year Power Purchase Agreement (PPA) with the following provisions:

- Electricity purchased at $69.80 per MWh, with an adjustment for fuel prices;
- Sale of 400,000 Renewable Energy Certificates per year, at pre-determined formula-based prices (a changing percent of New Hampshire's Class 1 Alternative Compliance Payment);
- Capacity payments at pre-determined levels;
- A provision capping ratepayer expenses at no more than $100 million over the course of the project. After this cap is reached, a complicated refund provision kicks in, with the effect being the plant operating at market rates for electricity sales. While initially expected to take up to 20 years (or more) to reach this threshold, the project is now on course to reach this $100 million upset limit in early 2020[41].

Vermont

Vermont has two utility-scale biomass power plants, on in the City of Burlington, and another in Ryegate. In 2012, a consortium of Vermont utilities entered into a 10-year power purchase agreement (expires in 2022) with the 21 MW plant located in Ryegate, with a levelized price of $97 per MWh for a combination of power, Renewable Energy Certificates, and capacity. This PPA has a fuel price adjustment to account for fluctuations in biomass fuel prices, and is set at a level expected to support operations for the duration of the PPA.

Connecticut

Beginning in 2005, Connecticut initiated "Project 150" (formerly Project 100), designed to establish 150 MW of renewable energy capacity in that state. Through a series of competitive Requests for Proposals, the state approved and the electric utilities in Connecticut awarded long-term power purchase agreements of 10 to 20 years. These PPAs were available to a range of technologies, including wind, solar, fuel cell, biomass, wave energy and fuel cells. Two biomass projects received awards under Project 150:

- a 37.5 MW biomass generation unit was built in Plainfield, Connecticut and began operations in 2013; and
- a 30 MW biomass generation unit was approved for Watertown, Connecticut but was never constructed.

In a later procurement, conducted under that state's PA 13-303 – Section 8 program, Connecticut entered into purchase agreements for part of the output of s facilities in New Hampshire and Vermont.

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[41] http://indepthnh.org/2017/11/20/no-longer-secret-berlin-biomass-plant-52-3-cost-to-consumers/

California

California's Public Utilities Commission recently launched the Bioenergy Market Adjusting Tariff (BioMAT), a feed-in tariff program for small bioenergy renewable generators less than 3 MW in size. The BioMAT program offers up to 250 MW to eligible projects through a fixed-price standard contract to export electricity to California's three large investor owned utilities (IOUs). Electricity generated as part of the BioMAT program counts towards the utilities' RPS targets.

50 MW of capacity under this program is reserved for "bioenergy using byproducts of sustainable forest management", including fuels from areas at high risk of wildfire. The remaining capacity (200 MW) is reserved for biogas and agricultural bioenergy projects.[42]

For woody biomass projects, the standardized feed-in tariff has reached and is now capped at $199.72 per MWh[43], a payment that includes electricity, renewable attributes and capacity.

According to project developers, "These attractive PPAs reflect the value the projects will provide to the local wildfire threatened communities", and combine environmental stewardship and sustainable energy production at the community scale.[44]

In addition to the BioMAT program, California also has a Biomass Renewable Auction Mechanism (BioRAM). The program directs the state's major investor-owned utilities to purchase 50 MW of output from qualified biomass facilities that procure wood from sustainable forest management, with a goal that wood fuel will come in part from dead and dying trees in high fire hazard zones. Under this program, procurement from new or existing biomass facilities is managed through bid process, managed by the utilities and overseen by the California Public Utilities Commission.

42 http://www.cpuc.ca.gov/SB_1122/
43 https://pgebiomat.accionpower.com/biomat/home.asp
44 http://biomassmagazine.com/articles/14805/phoenix-energy-projects-offered-ppas-from-pacific-gas-electric

Thermal Biomass

Vermont

Vermont is renowned in the biomass community for having a leading program of wood heat in schools. Over thirty schools use wood chips or pellets for their heating fuel, and an estimated one-third of Vermont students attend a school heated by wood.[45]

Vermont accomplished this by providing construction aid to schools that installed renewable heating systems, including biomass. This started in the 1990s at a 30 percent cost share, and rose in increments to as high as 90 percent of the cost of a biomass boiler (or other renewable heating technology).

The program that provided construction aid for biomass boilers has sunset, and the program is no longer available. However, some schools have installed wood pellet boilers since this program ended, instead working with third parties on performance contracting.[46] A localized cost-share incentive has been available in Windham County for the last 2 years as a result of funding made available through the closure of the Vermont Yankee nuclear power plant.

Austria

The European Union established a Renewable Energy Directive (RED), mandating that countries establish a plan to get 20 percent of their energy from renewable sources by 2020. This includes energy used in heating and cooling; biomass is projected to be nearly 80 percent of the renewable heating portfolio by 2020[47].

Within the EU, Austria is the leader in biomass thermal installations. Austria provides grants and tax credits of up to 30 percent of the cost solar thermal and biomass heating for businesses, and this has led to widespread adoption of wood heating technologies. Upper Austria meets nearly half of its heating demand using renewable technologies, primarily biomass. It is common for towns and cities to have biomass district heating, with a centralized plant providing heat to a large number of businesses and residences. Upper Austria has achieved success in this area through a combination of grants, mandates for renewable heating in some new construction, a simplified building code and streamlined permitting for renewable heating applications.

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[45] http://www.revermont.org/technology/bioenergy/modernwoodheating/

[46] Paul Frederick. *History of Vermont's Fuels for Schools Program.* Undated.

[47] Northeast States for Coordinated Air Use Management (NESCAUM). *New York State Wood Heat Report: An Energy, Environmental, and Market Assessment - Final Report.* NYSERDA Report 15-26. April 2016.

Rebate Programs for Biomass Thermal Installations

New Hampshire, Massachusetts and New York provide rebates for wood pellet (NH and NY) and wood pellet or wood chip (MA) boiler systems. The NH program, administered by the NH Public Utilities Commission, provides a rebate of 40% of the installed capital cost of a commercial wood pellet boiler system, with a total rebate cap of no more than $65,000. Systems must be under 2.5 MMBTU in size, and must have bulk pellet storage. The PUC provides an "adder" to offset the cost of heat meters, so that systems can qualify their heat output for thermal RECs. There is also an adder to help offset the costs of thermal storage, which is not mandatory. The source of funds for this rebate program is alternative compliance payments made by utilities and competitive suppliers under the Renewable Portfolio Standard. New Hampshire has provided funding for 48 boilers using this rebate program.

Massachusetts provides rebates of up to $250,000 for commercial wood pellet or wood chip boiler systems over 120 KBTU, and grants of up to $27,000 for commercial installations under 120 KBTU. The program is administered by the Mass Clean Energy Center, and businesses, nonprofits and government entities are eligible. The program provides "adders" for thermal storage, cascading boilers, distribution system efficiency upgrades, and district heating. The program has many stringent technical requirements. The source of funds is a portion of $30 million commitment of alternative compliance payments made by MA utilities and competitive suppliers under the MA Renewable Portfolio Standard and the Alternative Portfolio Standard, made to support renewable heating and cooling technologies and market development.

New York provides rebates of 40% of the installed capital cost and up to $200,000 for large (> 300 KBTU) commercial wood pellet boiler installations, under the Renewable Heat New York Program. Additional funds and a higher rebate percentage (45%) are provided for multi-boiler installations. 20% of the grant amount is withheld until the installation has a year of operation and is verified to meet minimum performance criteria. Additional stringent technical requirements apply. Funds for the rebate program come from proceeds from the Regional Greenhouse Gas Initiative.

Biomass Thermal Incentives in State Renewable Portfolio Standards:

The New Hampshire and Massachusetts Experience, with Recommendations for Maine Policy Makers

Summary

A comprehensive incentive recognizing thermal energy (heating and cooling) and combined heat and power from woody biomass energy systems has been incorporated into the New Hampshire Renewable Portfolio Standard, and the Massachusetts Alternative Portfolio Standard and Renewable Portfolio Standard (CHP). This section summarizes the structure and implementing regulations of these policies, and the impact on market development and growth to date. It offers recommendations based on experience with both states for consideration by Maine policy makers contemplating a similar policy incentive for thermal energy from woody biomass and combined heat and power.

Introduction and Background

State renewable portfolio standards have served as the principle policy mechanism for supporting expansion of renewable energy market development; 29 states and the District of Columbia now have state RPS or equivalent policy mandates.[48] Most state RPS programs focus exclusively on electricity generation from renewable energy. Few states outside of New Hampshire and Massachusetts have adopted a comprehensive recognition of renewable thermal technologies in their state RPS programs, although at least nine other states and the District of Columbia do recognize thermal technologies to limited degrees.[49]

NH was the first state to adopt a comprehensive fuel and technology neutral thermal provision, which it did in 2012 by passage of Senate Bill 218[50], with incentives applying to any new project that came into operation after January 1, 2013. Administrative rules developed by the NH Public Utilities Commission to promulgate this policy did not go into effect until December 2014. The MA legislature added recognition of renewable thermal technologies to its *Alternative Portfolio Standard* in 2014 by passage of Senate Bill 2214[51], for new projects that began operation after January 1, 2015. After a lengthy and contentious process, implementing regulations developed by the MA Department of Energy Resources were officially adopted on December 29, 2017.

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48 http://ncsolarcen-prod.s3.amazonaws.com/wp-content/uploads/2017/03/Renewable-Portfolio-Standards.pdf

49 https://www.cesa.org/assets/Uploads/Renewable-Thermal-in-State-RPS-April-2015.pdf

50 http://www.gencourt.state.nh.us/legislation/2012/SB0218.html

51 https://malegislature.gov/Laws/SessionLaws/Acts/2014/Chapter251

Structure, Function and Results of New Hampshire RPS for Thermal Energy

NH's RPS is structured with four distinct classes of qualifying technologies: Class I is new renewable generation, Class II is new solar photovoltaic generation, Class III recognizes pre-existing biomass electric and landfill gas generation, and Class IV recognizes pre-existing small hydro generation. Each class includes a mandated minimum percentage of total retail electricity sales that must be met by the state's regulated utilities and competitive electricity suppliers, collectively referred to as retail service providers. In general, these percentages increase over time until 2025, although the statute authorizes continuation of the RPS in perpetuity. Qualifying renewable electricity technologies and projects, such as wind, solar, biomass, geothermal, hydro etc., receive one renewable energy certificate (REC) for each megawatt-hour of electricity generation. The market is incentivized to develop new qualifying renewable generation projects, or retain pre-existing renewable generation such as biomass and hydro, by the revenue potential to the generator from the purchase of RECs by the retail service providers. The statute, NH RSA 362-F, also sets a ceiling price on the value of RECs, which varies from one class to another. Below this ceiling, RECs trade at prices that are a function of market supply and the demand (mandate) as set by law. If insufficient RECs are available to meet the retail service provider mandate, the providers must pay the ceiling price, also known as the alternative compliance payment. These revenues are dedicated to the Renewable Energy Fund[52], administered by the NH PUC in support of renewable electric and thermal project rebates and grants.

In 2012, the NH legislature added qualifying renewable thermal technologies as a "carve out" of the pre-existing Class I mandate, so that the total Class I mandate was not increased. They applied a lower ceiling price to the percentage of Class I that utilities had to meet with thermal RECs (T-RECs), the effect of which was to substantially lower overall ratepayer compliance cost for Class I. This fact was important to legislative support for adding thermal at a time when the ratepayer cost of utility RPS compliance was the subject of political scrutiny.

The thermal carve-out was significant, starting at 0.2 % of the NH electric load in 2013, and ramping up at a linear rate of 0.2% per year to 2.6 % by 2025. In 2013 the statewide electric load was about 11 gigawatt-hours, so each 0.1 % was equivalent to 11,000 megawatt-hours, or 11,000 T-RECs. Assuming the load stays stable through 2025, the thermal carve-out will require purchase of approximately 286,000 RECs annually by then. T-RECs were established with a ceiling price of $25.00/megawatt-hour, increasing annually by ½ of the Consumer Price Index. This price was viewed by the legislature as the minimum necessary to provide a sufficiently meaningful incentive for thermal technologies, including biomass, solar and geothermal. In 2017, T-RECs have a ceiling

[52] http://www.puc.state.nh.us/Sustainable%20Energy/RenewableEnergyFund.html

price of $25.46/megawatt-hour. Thus, the value of the T-REC incentive, based on maximum REC value, is over $50 million over the period 2013-2025 assuming no increase in electric load. However, in practice, T-RECs have been trading below the ceiling price, generally in the $20-23/megawatt-hour range.

If retail service providers are unable to meet their T-REC purchase obligation, they must pay the alternative compliance payment. These funds are deposited to the Renewable Energy Fund administered by the NH Public Utilities Commission(PUC), and used to support fuel and technology neutral rebate and grant programs to facilitate development of REC qualified electric and thermal projects. The NH PUC administers a wood pellet boiler rebate program for both residential and commercial customers utilizing these funds, and administers a competitive grant program that has funded 13 biomass heating projects since 2012.

As of December 2017, some 24 thermal projects have become qualified or are in the process of being qualified as T-REC generators. Nearly all are biomass heating projects, utilizing wood chips or pellets as fuel. These include eight public school districts, three non-profit rural hospitals, three county nursing home and correctional facilities, two college campuses, two private school campuses, and three private businesses. Here are two examples:

- A rural northern NH hospital installed a 4 MW (14 MMBTU) wood chip steam boiler system at its facility. Since 2014, the system has generated approximately 5,000 to 6,000 megawatt-hours of qualified renewable heat output annually. RECs are trading near the ceiling price, and thus the hospital is grossing approximately $120,000 to $140,000 annually, which nearly offsets the cost of their wood chip fuel.
- A rural central NH school district installed wood pellet boilers in four schools. Since 2014, the school district has been generating an average of 1,600 megawatt-hours of qualified renewable heat annually. Through a third-party aggregator, the school district can gross in excess of $35,000 annually on the sale of these RECs, a small but important revenue source as the school district struggles to contain property tax increases in response to declining enrollment.

There is no question that the economic incentive of T-REC qualification has had an important catalytic effect on project development and financing, as installation vendors routinely promote and apply the potential REC revenue to their project financial models. One county government is using T-RECs to leverage up front capital financing from the NH Community Development Finance Authority for the installation cost of an electrostatic precipitator so that it can meet the stringent particulate emissions standard of the RPS. Once the loan is paid back, the county will accrue 100% of the T-REC revenues.

The NH legislature chose not to require qualifying biomass heating systems to meet minimum output efficiency requirements, or mandate prescriptive standards around sustainable wood sourcing, or greenhouse gas emission reduction (as a matter of policy, the NH Department of Environmental Services views biomass energy as carbon beneficial). However, the NH law does require that systems meet a stringent particulate emissions standard. The legislature also did not discriminate against project classes based on size. However, practically speaking, the costs of compliance and administrative burden are prohibitive for small installations (generally under 300 kW, or 1 MMBTU).

Structure, Function and Results of Massachusetts APS for Thermal Energy

The MA legislature added thermal to its Alternative Portfolio Standard (APS) in 2014, following a two-year legislative process and evaluation of this policy[53] by the MA Department of Energy Resources. The law recognizes solar thermal (air and water), ground and air source heat pumps, and biomass (including solid biomass fuels such as wood pellets and chips, liquid biofuels, and biogas). MA also has an RPS but it is focused exclusively on renewable electric technologies such as wind and solar generation. In 2011, MA substantially revised its RPS regulations, the effect of which was to disqualify nearly all biomass electric generation in New England from selling RECs into the MA RPS, primarily by the imposition of a high minimum output efficiency requirement. However, this regulation will allow biomass combined heat and power so long as the combined output efficiency of both heat and electric generation exceeds 50%, and the fuel sourcing can meet forest sustainability standards.

With respect to biomass thermal technologies, the MA legislature opted to include stringent language in the enabling statute stipulating that systems meet emissions performance standards “that are protective of public health” and limit eligible technologies to only those that are “best-in-class commercially-feasible technologies”; require that systems result in a reduction of “life-cycle greenhouse gas emissions”; require “thermal storage or other means to minimize any significant deterioration of efficiency or emissions due to boiler cycling”, “fuel efficiency conversion standards achievable by best-in-class commercially-feasible technologies”; and, for forest-derived biomass, “requirements that fuel shall be provided by means of sustainable forestry practices.”

The inherent subjectivity of much of this language, combined with organized opposition to the recognition of biomass thermal in the APS from some advocacy groups, has resulted in a protracted and contentious rulemaking process that only recently resulted in final promulgation of the implementing regulations.

[53] http://www.mass.gov/eea/docs/doer/renewables/renewable-thermal-study.pdf

The APS thermal incentive applies only to "new" installations, defined as systems installed after January 1, 2015. As the regulations were only official as of December 29, 2017, there have yet to be any systems that have applied for qualification. It remains to be seen how and to what extent recently built wood chip or pellet heating systems will seek to qualify retroactively, and what beneficial impact the incentive will have on future project development. As in NH, if MA retail service providers that have an Alternative Energy Certificate (AEC) purchase obligation are unable to meet their obligation due to a lack of thermal AECs available, they will make alternative compliance payments. These historically have provided a source of funding for the Massachusetts Clean Energy Center[54] to administer grant and incentive programs.

The Maine RPS: Observations and Recommendations on the Addition of Thermal Renewable Energy

The State of Maine has considered the addition of thermal renewable energy to the Maine RPS (35-A MRSA 3210 (3-A) in the past. LB1468 in the 2014 session, as amended by the Senate, directed the Maine Public Utilities Commission to "Study the Potential Benefits and Barriers Involved in Making Renewable Thermal Technologies Eligible for Qualification in Maine's Renewable Energy Portfolio Standard". This bill passed the legislature but was vetoed by Governor LePage, and the veto was sustained. LD131 was introduced in the 2017 session as a placeholder for potential consideration of the addition of thermal renewable energy to the ME RPS, along with other potential policy changes recommended by the *Commission to Study the Economic, Environmental and Energy Benefits* of the *Maine Biomass* Industry, chaired by Senator Thomas Saviello[55].

Maine's RPS has two classes: Class I for "new"[56] renewable development (projects which commenced operation after September 1, 2005), and Class II, which recognizes qualified renewable generation that pre-dates this in-service date. In 2017, the utility purchase obligation is 10% of the state's electric load, or about 1.2 million MWH. Class I has an alternative compliance payment of $67.71. In 2014, the most recent year for which data are available, Class I RECs traded at between $1.72 and $22.33 per MWH, with an average cost of $8.56. Utilities met most of their Class I purchase obligation with biomass generation (over 92%), followed by wind (about 7%) and a small amount of hydro (<1%). The low market pricing of ME Class I RECs suggests that the utility purchase obligation is nearly fully subscribed. Class I plateaus out at 10% in 2017, and there is no provision in law to increase the Class I obligation. Assuming supply of ME qualified Class I RECs continues to increase as additional wind or other project development comes on line, it is reasonable to assume that ME Class I REC values will remain depressed or even devalue further.

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54 http://www.masscec.com/
55 https://legislature.maine.gov/uploads/originals/biomass-study-report.pdf
56 This may also include older facilities that have reached a reinvestment hurdle

This is an important consideration in designing a means of adding thermal to the Maine RPS. The current supply and demand dynamic in Maine Class I does not allow for a functional thermal "carve-out" in a way that can achieve lower ratepayer cost, as was the case in NH. And the market pricing of Class I RECs, at least based on 2014 data, is simply too low to act as a meaningful incentive for new renewable thermal market growth.

Thermal renewables technologies are fundamentally different from electric technologies in terms of market forces that influence their growth. Growth in renewable heating technologies is dictated largely by the cost of heating with conventional fossil fuels such as oil or propane, whereas renewable electric technologies are most directly influenced by the cost of electric generation from natural gas. Given this, it makes sense to consider creation of a separate new class for renewable thermal technologies in Maine. Or, alternatively, establish a "carve-out" of the existing Class I renewable electric mandate, but couple this with an increase in the utility purchase obligation beyond the current plateau of 10%, thereby creating new demand for Class I RECs and T-RECs. An alternative compliance payment could set a ceiling price on T-RECs at between $20-25/MWH to have a meaningful impact on market development. This is significantly lower than the current Class I ACP of $67.71. A T-REC valued at $20/MWH of qualified heat output translates into an incentive of about $82 per wood pellet ton, or about $44 per ton of wood chip fuel.[57]

Either approach will result in an increase in ratepayer financed utility compliance cost. Another consideration is what percentage of the Maine electric load should be allocated to renewable thermal, either as a carve-out or separate class. The percentage could be structured in a way to grow over time for 10-15 years to have meaningful catalytic impact on market development.

If utilities were unable to meet their purchase obligation and had to make alternative compliance payments, these funds would be deposited into the stewardship of Efficiency Maine Trust or other appropriate entity to provide rebates or capital grants to assist with upfront capital cost of projects that can generate future T-RECs. This way, investment of alternative compliance payments is being used to assist utilities in meeting their long-term RPS compliance obligation, with added economic and environmental benefits from development of renewable heating and displacement of imported fossil heating fuels in Maine.

[57] Assumes 4.0 MWH of heat energy per pellet ton (4% moisture content) at 85% output efficiency and 2.2 MWH of heat energy per wood chip ton (40% moisture content) at 75% output efficiency.

Under this T-REC implementation scenario, projects selling T-RECs and generating 1.32 million T-RECs over 10 years could displace about 33 million gallons of heating oil, to be replaced with 287,000 tons of wood pellets or 499,000 tons of wood chips.[58] Most of this project development would likely be concentrated in commercial, institutional and industrial heat use, including schools, office buildings, hospitals, apartment buildings, manufacturing facilities, and businesses using industrial process heat. This is not to exclude smaller commercial and residential building owners from participating, but practically speaking, the comparatively small amount of T-REC revenue (e.g. $400-600/year for a homeowner burning 5-8 tons of pellets per year) relative to the administrative and compliance costs maybe be insufficient to attract participation from among homeowners or small businesses. Massachusetts did explore “pre-minting” of thermal RECs, whereby a 10-year estimate of T-REC generation would be estimated based on system size, and a onetime lump sum up front payment awarded in lieu of annual payments based on heat output. The final MA rules do not allow for this for biomass heating.

[58] Assumes 115 gallons of #2 heating oil/pellet ton and 66 gallons per wood chip ton.

Guiding Principles for Development of a Thermal REC Incentive in the Maine RPS

What follows is a set of guiding principles based on observations from the NH and MA T-REC experience to date, in addition to those already suggested in the prior section. These are modified from recommendations provided to the Biomass Study Commission by the Maine Pellet Fuels Association.

1. **Encourage fuel and technology neutrality.** While the focus of this paper has been on biomass thermal technologies, recognizing thermal renewable energy could apply without prejudice to any legitimate renewable thermal energy technology, including biomass and solar.
2. **Provide access regardless of size and thermal output.** A thermal RPS program can provide a market-based incentive for renewable thermal technologies, which does not discriminate for or against projects based on their size or anticipated thermal REC output. In the best cases, projects of any size should be able to qualify, from small residential to large industrial. However, there can be practical limitations that may make qualification and verification of heat generation of small projects infeasible or uneconomic. Regulators may want to create different thresholds of technical requirements for different size classes of projects, while ensuring that fundamental accountability or integrity of the program is not compromised.
3. **Leave as much of the detail as possible to administrative rulemaking.** A thermal REC provision in an RPS will certainly require modifications and improvements over time to ensure that it provides a meaningful incentive and can address unanticipated changes in the market. The law and regulations can be devised to enable straightforward, efficient reforms through regulatory rulemaking, without lengthy legislative deliberation.
4. **Minimize or eliminate unreasonable and unenforceable technical requirements.** It is best to devise an initial thermal renewable provision with reasonable environmental or sustainability safeguards that can be cost effectively achieved. If experience dictates that safeguards need to be strengthened, they can always be revisited through the regulatory or legislative process. If the regulations set an unrealistic and unattainable expectation that the market is not ready to adopt, it may predispose the policy to failure from the beginning. In general, regulations should not be imposed that cannot be efficiently and cost effectively enforced by the responsible agency.
5. **Ensure that only new projects qualify for thermal RECs.** Legislation can set a future "begin service date" for eligible projects. Only projects commissioned and operating after that date should qualify for thermal RECs, so that the incentive supports and encourages new project development. Otherwise, pre-existing projects that came on line without the benefit of this incentive could flood the market and depress thermal REC price.

T-RECs Enterprise Fund

Renewable Energy Certificates (RECs) for thermal energy can be an important tool for supporting renewable heating, from biomass and other renewable energy sources. RECs for thermal energy (T-RECs) provide operating support through the generation and sale of certificates based upon the amount of heat used, and have the effect of lowering the operating cost for qualifying biomass heating systems.

However, operating costs for biomass heating are generally lower than fossil fuel boilers, particularly those that use oil and propane. That's because fuel costs make up the overwhelming majority of operating costs, and wood chips and wood pellets have a long history of being less expensive, on a dollar per MMBTU basis, than many competing fuels.

A key barrier to adoption of biomass heating can be the capital cost associated with a new biomass boiler – either wood chip or pellet. Depending upon size, fuel storage needs, emissions controls and other factors, a biomass boiler can be several times more expensive than a comparable fossil fuel boiler. RECs for thermal energy do nothing to help address the comparatively high cost of capital for biomass heating systems.

Recognizing this, a private, non-profit group in New Hampshire funded the *T-RECs Enterprise Fund* (www.t-recsfund.org), with the goal of converting future operating support (T-RECs) into capital for getting biomass projects built. The Fund contracts with a community scale institution to pre-purchase T-RECs for up to five years. The price for T-RECs is negotiated between the Fund and project, but they are sold at a discount to market in order to recognize the risk to the Fund that prices can change, and to account for the time value of money.

In this arrangement, the project is able to use money from the Fund to help offset capital costs, thus helping projects get built by addressing a core challenge for biomass heating systems. The Fund then owns T-RECs generated by the project for a negotiated period, and uses this revenue to replenish their pool of money and cover administrative costs.

The T-RECs Enterprise Fund was established with a commitment of $750,000 from the U.S. Endowment for Forestry & Communities. After successfully launching the Fund, the Endowment stepped away from the effort, which is now administered by New Hampshire's Community Development Finance Authority.

Model Future Scenarios

An Excel-based financial model was created to examine the costs and benefits for four potential biomass strategies that could be used to increase biomass demand and the demand for sawmill residuals in order to improve long-term viability of the industry. These strategies include:

(a) RPS Amendments:

i. Increase the current new renewable sources RPS target from10% to 15% by 2023, rising 1% per year.
ii. Institute a 2% thermal REC carve-out instead, analogous to New Hampshire.
iii. Institute a 5% increased thermal REC carveout that is like NH, but allowing only biomass technologies at a higher carveout percentage.

These changes would mandate higher usage of renewables and biomass, increasing residual demand.

(b) Co-location of non-Maine manufacturing plants to existing biomass power plant facilities in Maine:
New manufacturing plants coming into Maine have electrical and thermal loads that would increase demand.

(c) Co-location of new combined heat and power (CHP) facilities at existing manufacturing facilities in Maine:
Biomass-based CHP plants at existing Maine facilities would shift fuel oil thermal demand and grid-electricity toward using biomass to produce heat and power, increasing demand.

(d) Public and Private Institutional Wood Heat – Use of biomass heating at schools and businesses in Maine:
Fuel switching from thermal oil heat to thermal biomass would increase biomass demand.

From a policy perspective, these strategies are a mixture of market-based business-as-usual mandates (i.e. RPS requirements), and potential incentives (e.g. the Maine Community Renewables Program can support option (c)). The model examines the costs and benefits of each strategy, as well as these policy trade-offs.

The model evaluates each strategy's costs and benefits from an energy efficiency program perspective and examines the economic benefits to society of additional industry revenue through measurements such as GDP and job growth. Energy efficiency cost-benefit analyses have a long history, with well-established methodologies and assumptions that are used to evaluate energy efficiency program costs and benefits from a number of perspectives – participants, ratepayers, utilities, the state of Maine, and society as a whole. The model is based upon the California PUC's standard practice manual[59], modified to Maine's statutory requirements[60], and using publicly agreed assumptions[61] for these types of analyses.

Standard energy efficiency cost-benefit analysis practice is to evaluate the net present value (NPV) and benefit-cost ratio for several "tests" which reflect different perspectives on what is and is not included in costs and benefits, and who is paying. These tests include the "Participant Cost" test (PCT), the "Ratepayer Impact Measure" (RIM) test, the "Total Resource Cost" (TRC) test (a combination of these two), the "Program Administrator Cost" test (PACT), and the Societal Cost test (SCT). The analysis and model is focused on the first three tests, and especially the TRC, as this test is mandated by Maine statute to determine cost effectiveness[62]. Note, as well, that "there is no single best test for evaluating program effectiveness, and that the results of these tests provide different information about the impacts of programs from varying viewpoints"[63].

As this cost-benefit framework was initially developed to apply to energy efficiency programs, various modifications were made to account for the unique sets of costs and benefits presented by a biomass program (such as fuel switching). In particular, we examine the industry economic benefits of these biomass strategies, calculating additional biomass residual demand, revenue from sales of these residuals. This additional demand also increases jobs in the industry, and the income from these jobs are tallied.

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[59] California Standard Practice Manual, Economic Analysis of Demand-Side Programs and Projects, Oct 2001, California Public Utilities Commission.

[60] Efficiency Maine Triennial Plan for Fiscal Years 2017-2019, Efficiency Maine Trust, Dec 2015

[61] State of Maine Public Utilities Commission Docket No. 2015-00175, May 25, 2016, Efficiency Maine Trust Request for Approval of Third Triennial Plan

[62] 65-407 Maine Code of Regulations Chapter 380, Section 4.B.

[63] p ES-1, "Understanding Cost-Effectiveness of Energy Efficiency Programs: Best Practices, Technical Methods, and Emerging Policy Issues for Policy-Makers", Nov 2008, National Action Plan for Energy Efficiency, U.S. EPA.

Table 7. Cost-Benefit Calculation Scope

Test	Benefits	Costs
Participant (PCT)	• Utility or other incentives • Federal/state/local tax credits • Avoided retail energy costs • Avoided operating costs and capital of equipment not chosen	• Installation costs • Operating costs • Added retail energy costs
Ratepayer Impact Measure (RIM)	• Avoided supply costs • Avoided generation capacity costs	• Lost utility revenues • Utility incentives • Utility program costs
Total Resource Cost (TRC)	• All of above	• All of above
Maine Industry Benefits	• Maine sawmill residual demand revenue • Maine biomass job income	• Maine fossil fuel industry reduced revenue • Maine fossil fuel industry job income

Note: For biomass, the quantification of CO_2 emissions is difficult and controversial, as quantification depends on a wide variety of factors (e.g. water content, fuel density/composition, distance from fuel source to collection point, collection technology, age of biomass harvested, etc.) Therefore, emissions costs and benefits were not evaluated directly.

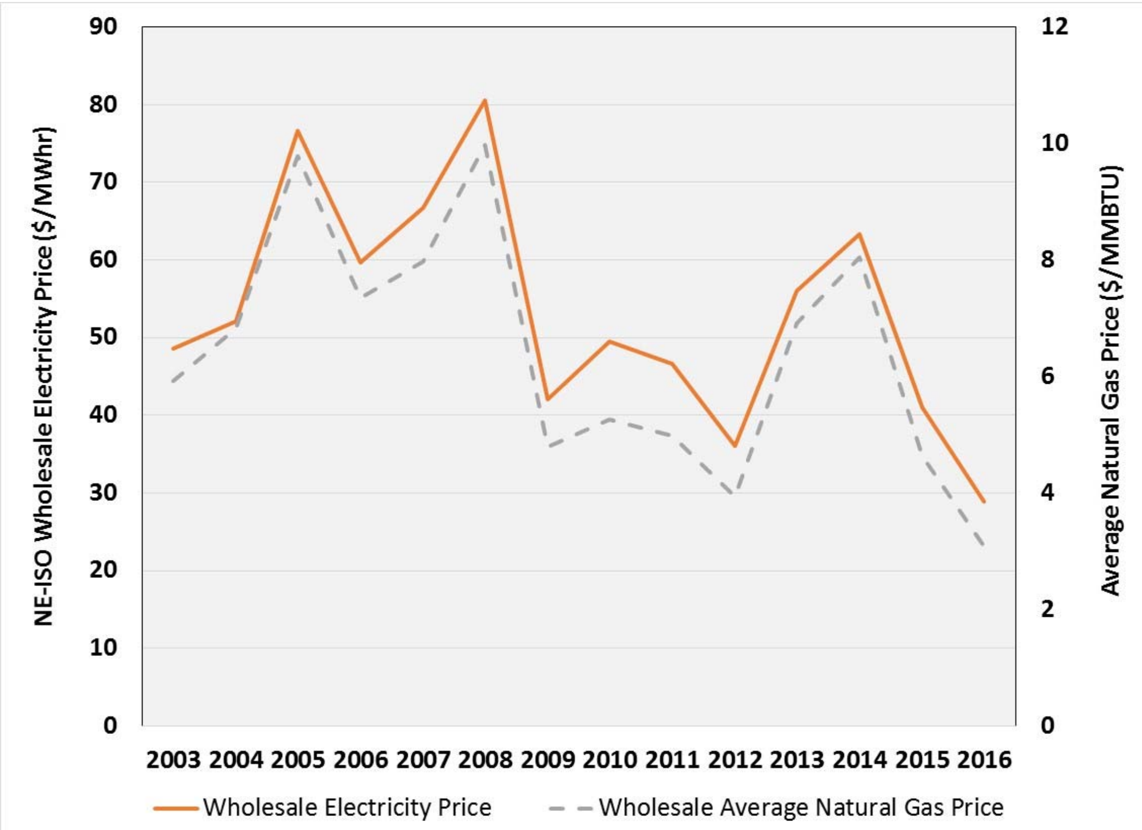
Similarly, some economic benefits were not evaluated directly, as these can be difficult to quantify. RIM, Implan, and REMI model direct-to-indirect job ratios, and are used to estimate indirect jobs. The property tax benefits of biomass are not evaluated as biomass boilers contribute minimally to total property value[64] for everything except stand-alone facilities. While we evaluate jobs income, the income tax benefits to Maine's government is not evaluated, as biomass worker's tax situations vary widely.

Some studies[65] claim that higher RPS levels will lead to higher electricity prices, which could have an adverse impact on Maine's economy; the theory is that left to its own devices, the free-market economy tends to deliver the highest quality products and services at the lowest possible prices to consumers. For Maine, however, this supposition appears to be incorrect based on the last decade of data on RPS levels[66] and electricity prices in Maine[67]. Higher RPS

[64] For example, a biomass boiler might cost $10,000 vs. a $250,000 home price, or 4%
[65] https://instituteforenergyresearch.org/analysis/rps-and-electricity-prices/
[66] http://programs.dsireusa.org/system/program/detail/452
[67] EIA

levels have coincided with lower electricity prices; in addition, electricity prices appear to be related more directly to natural gas prices than RPS levels[68] (see figure below). As a result, this potential macro-economic effect has not been modeled.

Figure 20. Relationship Between Maine Electricity Prices and Natural Gas Prices



[68] https://www.eia.gov/energyexplained/index.cfm?page=electricity_factors_affecting_prices; and https://www.utilitydive.com/news/rising-natural-gas-prices-power-sector-2017/429789/

For each scenario, we start with a "business as usual" case, estimating 2017 participant (i.e. the manufacturer, school, or business) operating costs and capital equipment costs. To calculate the "avoided" benefits shown in the table below, we must have a "counterfactual", which defines how businesses would address their heating and electricity needs in the absence of using the biomass strategy. These are defined in the table below.

Table 8. Counterfactual Configurations

Strategy		Counterfactual
3A	RPS Amendment	10% RPS
3B	Non-Maine manufacturer co-locating at Maine biomass power plant	Power and steam production using natural gas (as this is available widely throughout the U.S.); (a) manufacturer comes to Maine at a non-co-located location (b) manufacturer does not come to Maine
3C	Maine manufacturer installing CHP plant on-site	Electricity from ISO-NE grid, and thermal energy from fuel oil
3D	Institutional Wood Heat	Fuel oil for heating

Model Methodology

For each of the above strategies, we identified reference cases for further analysis. For task 3A, these correspond to a systemwide change from 10% to a 15% REC, a system-wide thermal REC carveout, or an increased thermal REC carveout. For Task 3b, this corresponds to 3 different sizes of manufacturing plants that would co-locate at a biomass power facility. For task 3C, this corresponds to 3 different sizes of CHP plants. For task 3d, this corresponds to different permutations of small/large school/business, seasonal or year-round operation, or burning pellets or chip fuel. The reference cases are further defined in the table below.

Table 9. Reference Case Definition

Reference Case		**Description**		
3A	RPS Amendment Increase to 15%			10% REC increases to 15%, 1% / year
	Thermal REC Carveout			2% of REC carveout
	Economic Benefit REC			5% of REC carveout
3B	ME bio power plant w/Mfg 1	thermal load is 230% times electrical load; 33MW* generic biomass plant		Manufacturer uses 5% of biomass plant electricity
	ME bio power plant w/Mfg 2			Same, but 10%
	ME bio power plant w/Mfg 3			Same, but 20%
3C	Mfg1 w/CHP plant	50% of power generated exported to the grid, 100% of thermal energy used by manufacturer		2 MW* CHP plant;
	Mfg2 w/CHP plant			5 MW* CHP plant
	Mfg3 w/CHP plant			10 MW* CHP plant
		Application	**Fuel**	**Size (MMBTU/hr)**
3D	Commercial biomass Measure #1	Small School	Pellet	1.5
	Commercial biomass Measure #2	Small School	Pellet	1.5
	Commercial biomass Measure #3	Small School	Chip	2.3
	Commercial biomass Measure #4	Small School	Chip	2.3
	Commercial biomass Measure #5	Large School	Pellet	3.1
	Commercial biomass Measure #6	Large School	Pellet	3.1
	Commercial biomass Measure #7	Large School	Chip	4.8
	Commercial biomass Measure #8	Large School	Chip	4.8
	Commercial biomass Measure #9	Small Business	Pellet	0.6
	Commercial biomass Measure #10	Small Business	Pellet	0.6

	Commercial biomass Measure #11	Small Business	Chip	1.3
	Commercial biomass Measure #12	Small Business	Chip	1.3
	Commercial biomass Measure #13	Large Business	Pellet	4.3
	Commercial biomass Measure #14	Large Business	Pellet	4.3
	Commercial biomass Measure #15	Large Business	Chip	6.7
	Commercial biomass Measure #16	Large Business	Chip	6.7

* When steam is siphoned off for CHP applications, the electricity capacity is reduced, depending on the quality of the steam being siphoned. We assume this loss is 15%[69].

[69] Personal communication, Mark Thibodeau – ReEnergy Holdings, February 14, 2018.

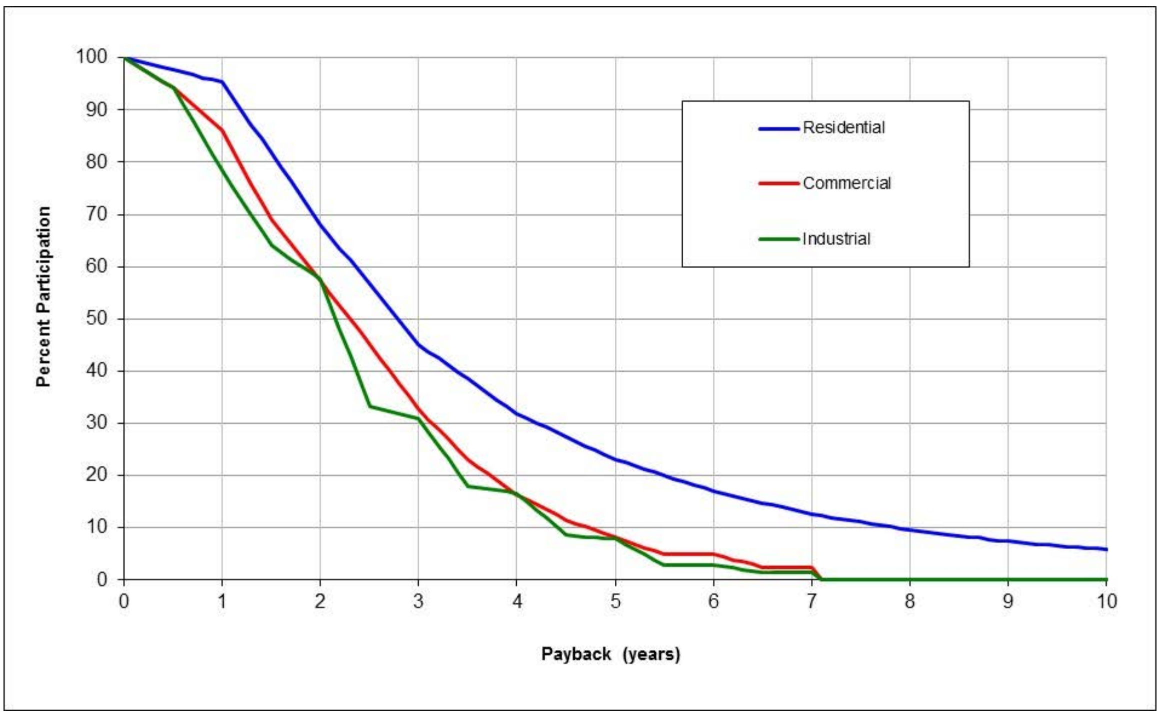
For each reference case, the biomass project economics of the participant (i.e. the manufacturer, school, or business) are evaluated. Installed costs, avoided capital equipment and fuel costs, biomass fuel costs, maintenance costs, and incentives (i.e. RPS payments, Maine Community Renewable Program), are all used to evaluate simple payback using the following formula:

$$Payback = \frac{(Installed\ Cost - Avoided\ CapEx - CapEx\ Incentives)}{(Avoided\ Fuel\ Cost + REC\ Incentives - Biomass\ Fuel\ Cost - Maintenance\ Cost)}$$

In general, a less than 3-year payback is considered a good investment by consumers, while payback periods longer than equipment lifetime are wholly uneconomical.

Fisher-Pry[70] analyzed market penetration and technology diffusion for a large variety of technologies, and related ultimate market penetration to simple first year payback, as shown in the following figure:

Figure 21. Fisher-Pry Market Penetration Curve



For each reference case, we found the total available market of entities in Maine that might use the strategy (e.g. total number of small schools). After calculating simple payback, we applied the "commercial" curve in Figure 1 to estimate total potential market penetration to find the number of installations that are likely to follow the strategy based on economics. By

[70] Michelfelder and Morrin, "Overview of New Product Diffusion Sales Forecasting Models" provides a summary of product diffusion models, including Fisher-Pry. Available: law.unh.edu/assets/images/uploads/pages/ ipmanagement-new-product-diffusion-sales-forecasting-models.pdf; see also Fisher, J. C. and R. H. Pry, "A Simple Substitution Model of Technological Change", Technological Forecasting and Social Change, 3 (March 1971), 75-88; and Paidipati et al, "Rooftop Photovoltaics Market Penetration Scenarios", Navigant Consulting, Inc., Feb 2008.

multiplying the total number of installations by biomass usage, additional biomass demand can be found. Biomass jobs and income impacts were then assessed based on this demand.

In the cases where fuel switching occurred, avoided fossil fuel revenue, jobs, and job income losses were calculated similarly.

Global Input Assumptions
To calculate the above costs, there are number of assumptions that are global, and hold for all 26 reference cases. These assumptions are shown in the table below.

Table 10. Global Model Assumptions

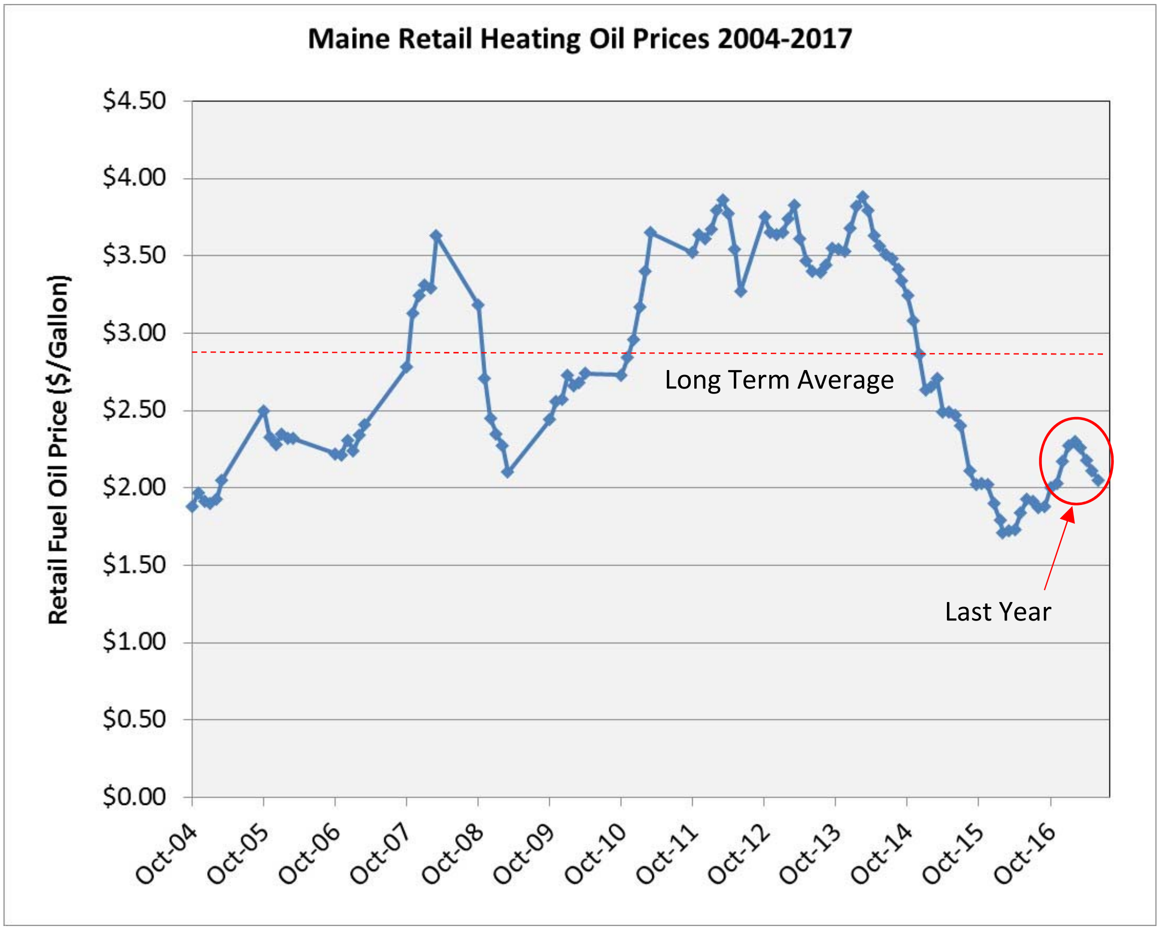
Assumption	Value	Source	Comment
Foreign Jobs/Income	22% of fossil fuel revenue/ income/ jobs will be in Maine	wholesale to retail Maine fuel oil price ratio, Energy Information Administration (EIA) For natural gas, the average of citygate:commercial and citygate:industrial price is roughly the same, so is assumed equivalent	Conservative, as distribution costs may include some non-Maine New England state content.
Inflation Rate	1.88%	Maine PUC docket No 2015-00175 Efficiency Trust Maine 3rd Triennial Plan	
Discount Rate	6.85%		Used to calculate Net Present Value (NPV)
Natural Gas Price	$7.70 /MCF	EIA	Average of last 12 months of available data
Fuel Oil Price	$2.18 /gallon	Maine Governor Energy Office GEO Heating Fuel Survey Statements	
Chip Price (High Volume)	$25 /ton		

Chip Price (schools, business)	$60 /ton	Schools also use an improved grade of chips	
Pellets	$200 /ton		Bulk - large volume users
Projections of Electricity Rates, Natural Gas Price, Fuel Oil Price, Biomass Price	(2018-2030) 20% higher 269% higher 315% higher 179% higher	EIA 2017 Energy Outlook, New England	Biomass based on Diesel projection @ 25% and inflation
Value of Steam	$5 /MMBTU	Estimates from existing plants	
RPS Price	$13.50 /MWh flat, 2018+	Average of ME, CT, RI, NH 2017-2018 REC price	
Total Available Market	3687 small businesses, 5120 large businesses, 512 small schools 30 large schools	Small Business Administration (SBA), Maine Education Department data on Maine school counts	
3C Manufacturers in Maine Total Available Market	1477 manufacturers in Maine, 320 with > 500 employees	SBA	
	21 large businesses with high thermal load and high operating hours with an old heating system	Divided the above 320 by average 15-year heating appliance lifetime	(one would not add a CHP system if a new heating system was just purchased)
Chip	9.2 MMBTU/ton (wet, 45% MC)	USDA Forest Service, Forest Products Laboratory and Pellet Fuels Institute. *Fuel*	

		Value Calculator. Fifth Edition. 2004.	
Fuel Oil	.1385 MMBTU/gallon	EIA	
Natural Gas	1.032 MMBTU/MCF	EIA	
Pellet	16.5 MMBTU/ton	http://extension.oregonstate.edu/lincoln/sites/default/files/home_heating_fuels_ec1628-e.pdf	
Direct Bio-industry Jobs	8/ 100,000 tons of demand (electricity)	Current employment @ ME biomass generation plants	
	63 / 100,000 tons of demand (thermal)		
Indirect Bio-industry Jobs	18 / 100,000 tons of demand (electricity)		
Fossil Fuel Jobs	13.1 / $1,000,000 revenue	Table I, RIMS II multipliers for Maine (based on 2006 US Annual Input-output data, and 2006 Regional data), http://www.maine.gov/labor/cwri/publications/pdf/GreenEconomyReport.pdf	average of all petroleum related job categories
Biomass Plant Lifetime	40 years	Tidball, et al, "Cost and Performance Assumptions for Modeling Electricity Generation Technologies", NREL Nov 2010	
CHP Plant, Chip/Pellet Boiler Lifetime	20 years	"Biomass heating, a practical guide for potential users", Carbon Trust, 2012	

Note, the average of last year's current fuel oil prices in Maine are at historical lows, in the $2.20 /gallon range, as shown in Figure 22 below. Monthly natural gas prices varied last year from $5.99 /MCF to a high of$ 9.37 /MCF; we base our estimates on annual averages. A sensitivity analysis (see below) is run to examine how the cost benefit results might change relative to higher or lower future prices than projected.

Figure 22. Maine Residential Fuel Oil Monthly Average Prices[71]



For each of the strategy-specific assumptions, we outline these below as we consider the results and assumptions driving these results for each strategy in turn.

[71] Maine Governor Energy Office

Model RPS Amendments (3A) - Increased RPS

Strategy 3A is for the Maine legislature to increase the current new RPS requirement from 10% to 15% by 2023, rising 1% each year. Benefit-Cost analysis results are shown in the table below.

Table 11. Strategy 3A: Increase RPS Amendment from 10% to 15% BCA Results

Participant Cost Test	Total NPV	Total NPV (same, w/100% biomass)	Comments
Benefits	$0	$0	
Costs	$0	$0	
BCA	--	--	
Ratepayer Impact Measure			
Benefits	$0	$0	
Costs	$84,227,000	$84,227,000	REC payments
BCA	0	0	
Ratepayer Impact ($/kWh)	0.000583	0.000583	
Residential Ratepayer Impacts (% increase)	0.43%	0.43%	
Industrial Ratepayer Impacts (% Increase)	1.11%	1.11%	
Total Resource Cost Test			
Benefits	$0	$0	
Costs	$84,227,000	$84,227,000	REC payments
BCA	0	0	
Industry Economic Impacts			
Benefits	$389,726,000	$442,865,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$46,796,000	$53,084,000	Maine fossil fuel industry revenue and job income losses
Combined TRC + Industry Impacts BCA Ratio	3.0	3.2	
2022 Additional Biomass Demand (tons)	753,900	856,700	
2022 Additional Biomass Industry Jobs	190	220	

Key assumptions driving the results are as follows:

Benefits

- We assume that each new MWh of the increased RPS requirement will be filled by biomass 88% of the time, based on the most recent data available[72]. The third column in Table 11 shows how the results would change if a 100% biomass RPS was enacted, comparable to New Hampshire's Class 3 REC.
- In 2018, with the 1% increase REC requirement, we multiply Maine's total electricity demand (11,449,000 MWh *93% (2018 v 2017 load per EIA)) times 1% times 88% times conversion factors[73], to result in 158,000 tons of new biomass demand. This translates to NPV of $301 million in local biomass industry revenue and $88 million of local biomass-industry income over the long term (2018-2047).

Costs

- REC Costs were determined by multiplying the above 11,449,000*93% Maine MWh in 2018 by 1% (the new REC percentage) times a REC price. REC prices have dropped recently, reflecting oversupply, and it has proven extremely difficult to accurately model future REC prices. New England ISO's 2015 predictions of REC pricing, deeply modeled, are invalid. Given this uncertainty, we hold REC prices constant from 2018 to 2047 at today's levels, assuming that future price reductions will fully offset inflation, as most commercial renewable technologies (solar, wind, biomass, hydro) are relatively mature. As part of the sensitivity analysis below, we then vary REC prices to higher or lower levels to examine their impact on the results. As can be seen from Table 11, the total net present value (NPV) over thirty years of this current price assumption is $84,227,000.
- Currently Maine biomass facilities can sell RECS into NH, ME, CT, and RI; we used average REC prices for these 4 states, as MA has recently excluded non-CHP biomass plants from participation in their Renewable Portfolio Standard. Connecticut recently announced plans to disallow some production from biomass plants in coming years; this adds uncertainty to future price dynamics for RPS programs in New England.

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[72] See Figure 7, State of Maine Public Utilities Commission 2017 Annual Report, Feb 1, 2018.

[73] 3.412 MMBTU/MWh / 9.2 MMBTU/wet ton / efficiency factor

Table 12. Maine Biomass REC Qualification by State

Facility	Town	Capacity (MW)	Status	Maine	CT	RI	NH
Athens Energy	Athens	7.1	Operating	✓		✓	
Greenville Steam	Greenville	19	Closed	✓	✓		
Irving Forest Products	Dixfield	0.7	Operating	✓			
Jackson Laboratories	Bar Harbor	0.6	Operating	✓			
Old Town Pulp Mill	Old Town	14.5	Closed	✓			
Old Town Pulp Mill	Old Town	2	Closed	✓			
Pleasant River Lumber	Jackman	0.5	Operating	✓			
ReEnergy - Ashland	Ashland	39	Operating	✓	✓		
ReEnergy - Fort Fairfield	Fort Fairfield	36	Operating	✓	✓		
ReEnergy - Livermore Falls	Livermore Falls	34	Operating		✓		
ReEnergy - Stratton	Stratton	46	Operating	✓	✓		
Rumford Paper Company	Rumford	37	Operating	✓			
SAPPI - Somerset	Skowhegan	31	Operating	✓			
SAPPI Westbrook	Westbrook	50	Operating	✓			
Stored Solar - Jonesboro	Jonesboro	27.5	Operating	✓		✓	
Stored Solar - WE	West Enfield	27.5	Operating	✓		✓	
Verso - Androscoggin	Jay	15	Operating	✓			
Verso - Androscoggin	Jay	18	Operating	✓			
Verso - Bucksport	Bucksport	24	Closed	✓		✓	
Woodland Pulp	Baileyville	confidential	Operating	✓			

- In addition to absolute price uncertainty, to determine the impact of a 15% REC for this strategy, one needs to compare REC prices with a 10% REC vs. those with a 15% REC. In the last 5 years of Maine's REC, the REC percentage has increased to 10%; but REC prices have fluctuated wildly. We assume that a higher percentage REC will cost the same as today's REC prices as a starting point, and examine other possibilities as part of the sensitivity analysis.
- An RPS will cause some fuel switching from some natural gas to renewables, resulting in lost revenue for the fossil fuel industry. New England ISO's fuel mix includes 41% natural gas, with ~ 70% of this cost representing fuel costs.[74] Per Table 10, we assume that 22% of this lost revenue will impact the local economy, resulting in $2 million in fossil fuel revenue and $962,000 in local fossil fuel income loss.

[74] https://www.iso-ne.com/about/key-stats/resource-mix; and https://www.eia.gov/outlooks/aeo/pdf/electricity_generation.pdf

In the BCA framework, the participant is typically a customer that makes an energy purchase, such as an energy efficiency upgrade, a distributed energy investment, or something similar. With a REC program, there is not a similar investment made by individual utility customers, so the PCT test does not apply. The RIM test BCA is zero, as benefits are zero and costs include REC incentives, as zero divided by X equals zero. Ratepayer impacts of these incentives are $.000058 /kWh higher bills (0.43% for residential, and 1.11% for industrial ratepayers). The TRC test, the sum of these two tests, is equivalent to the RIM. Economic benefits include additional biomass demand of 754,000 tons, yielding net industry revenue and jobs income of $342,000,000. Combining the TRC and Industry benefits has a net benefit-cost ratio of 3.0.

To "pass" an energy-efficiency BCA test, the net present value cost benefit ratio must be greater than 1. Regulators commonly make tradeoffs between different stakeholders (i.e. participants, ratepayers, society, etc.), with flexibility to accept individual lower BCA results to promote societal well-being. It is common for energy efficiency programs to lead to slight increases in ratepayer rates, as per the last paragraph, but there are no general rules of thumb regarding "how much is too much".

Thermal Renewable Energy Certificates

This strategy assumes that 2% of the electricity REC is to be carved out as a thermal REC, where 1 MWh of thermal energy is equivalent to 1 MWh of electricity. We assume that if Maine institutes a thermal REC, that Maine will be modelled upon New Hampshire's recent policy, as it is the only thermal REC program fully operational in the U.S.

New Hampshire's thermal REC resulted in 98% of RECs being satisfied by biomass technologies (rather than ground source heat pumps, air source heat pumps, or solar thermal technologies).[75] We therefore make the simplifying assumption that 100% of a thermal REC will go to biomass.

[75] New Hampshire Public Utilities Commission. NEW HAMPSHIRE RENEWABLE ENERGY FUND ANNUAL REPORT. October 30, 2017.

Table 13. Strategy 3A: Thermal REC BCA Results

Participant Cost Test	**Total NPV**	**Comments**
Benefits	$0	
Costs	$0	
BCA	--	
Ratepayer Impact Measure		
Benefits	$0	
Costs	$67,479,000	REC payments @ higher price
BCA	0	
Ratepayer Impact ($/kWh)	0.000467	
Residential Ratepayer Impacts (% increase)	0.34%	
Industrial Ratepayer Impacts (% Increase)	0.89%	
Total Resource Cost Test		
Benefits	$0	
Costs	$67,479,000	REC payments
BCA	0	
Industry Economic Impacts		
Benefits	$72,937,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$0	Maine fossil fuel industry revenue and job income losses
Combined TRC + Industry Impacts BCA Ratio	1.1	
2022 Additional Biomass Demand (tons)	109,300	
2022 Additional Biomass Industry Jobs	70	

The results for the Thermal REC carveout are similar to the 10%->15% REC, with a few exceptions:

- New Hampshire Thermal REC Alternative Compliance Payment (ACP) are set legislatively to be 50% of the Class 1ACP. When the thermal REC was created, REC prices were high, so this resulted in the thermal REC easing REC requirements on utilities, which eased bill passage. Now, however, electric REC prices are lower, so 50% of the ACP is higher than current REC prices. 50% of the 2018 Maine ACP is $32/MWh, which is higher than current REC prices trading in the $10-$14 /MWh range. This explains why REC costs in this strategy increased to an NPV of $67,400,000. Ratepayer impacts therefore rise to $.000467 /kWh (.34% residential, .89% industrial)
- Thermal efficiency is 67%, vs. 22% for electricity. This results in less biomass demand per MWh compared to the 10%->=15% REC.
- The thermal REC carveout results in lower biomass demand, 109,000 tons by 2022. This, in turn, results in lower biomass demand revenue, jobs, and biomass job income.

Increased Thermal REC

This scenario is identical to the thermal REC, except the carveout is 5% rather than 2%. We assume that the thermal REC price will be similar, 50% of the ACP.

Table 14. Strategy 3A: Increased Thermal REC, 5% carveout REC BCA Results

Participant Cost Test	**5% Carveout**	**10% Carveout**	**Comments**
Benefits	$0	$0	
Costs	$0	$0	
BCA	--	--	
Ratepayer Impact Measure			
Benefits	$0	$0	
Costs	$168,697,000	$337,393,000	REC payments @ higher price and % carveout
BCA	0	0	
Ratepayer Impact ($/kWh)	0.001168	0.002336	
Residential Ratepayer Impacts (%)	0.86%	1.71%	
Industrial Ratepayer Impacts (%)	2.22%	4.44%	
Total Resource Cost Test			
Benefits	$0	$0	
Costs	$168,697,000	$337,393,000	REC payments
BCA	0	0	
Industry Economic Impacts			
Benefits	$182,287,000	$364,618,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$51,976,000	$104,008,000	Maine fossil fuel industry revenue and job income losses

Combined TRC + Industry Impacts BCA Ratio	0.8	0.8	
2022 Additional Biomass Demand (tons)	273,200	546,300	
2022 Additional Biomass Industry Jobs	170	340	

The table above shows the impact of a 5% vs. 10% carveout level. Because we assume 88% of new RPS requirements will be filled by biomass in the absence of an increased thermal REC program, a higher carveout produces the effect of paying a higher REC price for a doubling of biomass industry revenue, jobs, and jobs income.

Existing Maine Biomass Power Plant Hosting New Manufacturing Facility (3B)

For this strategy, the costs and benefits of a manufacturing plant not currently located in Maine co-locating to an existing biomass plant are evaluated. There are currently six biomass plants operating in Maine, as shown in the table below:

Table 15. Maine Biomass Electric Plant Sizes

Town	Net Capacity (MW)
Livermore Falls	36
Stratton	45
West Enfield	25
Jonesboro	25
Fort Fairfield	33
Ashland	36
Average	**33**

As a starting point, manufacturers that use 5%, 25%, and 50% of the electricity produced by the biomass plant were modeled. At 82% capacity factor, typical for fully loaded plants, a 33 MW plant will produce 240,000 MWh.[76] Manufacturing plants modeled use 12,000, 60,000, and 120,000 MWh of electricity annually.

The ideal thermal profile for this application are manufacturers that use a significant volume of thermal energy on an around-the-clock basis, such as paper plants and pellet mills. We therefore start by modeling a factory that has thermal loads that are 230% of its electrical loads (which corresponds to a typical paper plant[77]).

The capital cost to run a waste steam pipe from an existing biomass plant a few hundred feet to a manufacturing operation is ~ $365,000-565,000.[78] Annual maintenance costs are assumed to be 4% of CapEx. Consultations with existing power plants selling steam indicate that the market value of this steam is approximately $5/MMBTU. The most likely fuel that would be used in a manufacturing operation for heat is natural gas, so this is the counterfactual.

The stand-alone biomass plant in Stratton sells electricity it generates to a neighboring sawmill at a negotiated rate that is lower than utility industrial retail rates. Similarly, we assume that a co-located manufacturer will purchase power at lower than retail rates, and the biomass plant will sell power at higher than wholesale rates.

[76] 33 MW x 82% x 8760 Hours/Year = 240,637 MWh
[77] https://energy.gov/sites/prod/files/2013/11/f4/pulppaper_profile.pdf
[78] Budgetary quotes from steam pipeline installer

We modeled two counterfactual scenarios. In the first, we assume that a manufacturer would located in Maine anyway, and then compare the benefits and costs of co-location at a Maine biomass plant. In this case, the above negotiated rate impacts ratepayers because the states' utilities lose revenue. In the second counterfactual, we assume that the manufacturer would not come to Maine, but for the benefits of co-location at a Maine biomass plant. In this case, the above negotiated rate does not represent a revenue loss for the state's utilities.

As shown in Table 16, the above relatively low CapEx and maintenance cost, coupled with relatively high thermal loads and savings, and high electricity usage and electricity savings, yield very low paybacks in the < 1-year range.

Table 16. Strategy 3B Payback Assumptions

CapEx	Thermal Savings	Electricity Savings	Maintenance Cost	**Payback (years)**
$365,000	$435,854	$122,648	$14,600	**0.7**
$465,000	$871,708	$245,295	$18,600	**0.4**
$565,000	$1,743,417	$490,590	$22,600	**0.3**

As shown, this indicates a very high penetration rate and market demand. Conversely, if thermal loads are only 100% of electricity usage, payback goes up to 1.2 years, still very attractive.

However, several factors limit this potential market growth for Maine. (1) There are only 6 biomass plants in Maine, with limited space and nearby land capacity to accommodate a large number of manufacturers; (2) Four of these biomass plants required $13 million in above-market support to continue operating for two years[79], so the risk for a new manufacturer moving in is high; and (3) if below market rates become prevalent, utilities are likely to bring suit to recover lost revenue. For all of these reasons, we model a maximum of 2 small, 1 medium, and 1 large plant for the total available market.

[79] Darren Fishell, "Maine's $13M bailout of biomass plants will mean jobs, but at a cost of $23,700 each", Bangor Daily News, Jan 27th, 2017 updated Mar 1st, 2017

Table 17. Strategy 3B: New Manufacturing Co-located at Existing Maine Biomass Plant (Counterfactual located in Maine)

Participant Cost Test	**Total NPV**	**Comments**
Benefits	$45,712,000	Thermal Savings
Costs	$1,711,000	Install Costs
BCA	26.7	
Ratepayer Impact Measure		
Benefits	$0	
Costs	$57,389,000	Utility Lost Revenue
BCA	0	
Ratepayer Impact ($/kWh)	0.000397	
Residential Ratepayer Impacts (% increase)	0.29%	
Industrial Ratepayer Impacts (% Increase)	0.75%	
Total Resource Cost Test		
Benefits	$45,712,000	Thermal Savings
Costs	$59,101,000	Utility Lost Revenue, Install Costs
BCA	0.8	
Industry Economic Impacts		
Benefits	$75,598,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$0	
Combined TRC + Industry Impacts BCA Ratio	2.1	
2022 Additional Biomass Demand (tons)	140,400	
2022 Additional Biomass Industry Jobs	40	

The addition of new large electrical and thermal loads that are satisfied by biomass plants results in 140,000 tons of biomass demand in 2022. This, in turn, results in biomass industry demand revenue, jobs, and income.

While the participant cost test BCA is greater than 1, the ratepayer impacts shown in **Table 17** are high due to the utility lost revenue assumed by the counterfactual. Under the second counterfactual-that the manufacturer would not locate in Maine except for the benefits of co-location-this lost revenue is zero. This is shown in the table below.

With low payback periods, participant benefits for this 3B scenario are very high with BCA ratios greater than 5 for the manufacturer, as the capital costs to enable making the biomass plant's thermal waste economically productive are relatively low. Ratepayers are unaffected, and TRC benefit cost ratio is greater than 5.

Table 18. Strategy 3B: New Manufacturing Co-located at Existing Maine Biomass Plants, (Counterfactual would not come to Maine otherwise)

Participant Cost Test	**Total NPV**	**Comments**
Benefits	$45,712,000	Thermal Savings
Costs	$1,711,000	Installation Costs
BCA	26.7	
Ratepayer Impact Measure		
Benefits	$0	
Costs	$0	
BCA	--	
Ratepayer Impact ($/kWh)	-	
Residential Ratepayer Impacts (% increase)	0.00%	
Industrial Ratepayer Impacts (% Increase)	0.00%	
Total Resource Cost Test		
Benefits	$45,712,000	Thermal Savings
Costs	$1,711,000	Installation Costs
BCA	26.7	
Industry Economic Impacts		
Benefits	$75,598,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$0	
Combined TRC + Industry Impacts BCA Ratio	70.9	
2022 Additional Biomass Demand (tons)	140,400	
2022 Additional Biomass Industry Jobs	40	

Existing Maine Manufacturing Site with New CHP (3C)

In this task, the feasibility of existing Maine manufacturing sites purchasing a new CHP plant are evaluated. The benefits of purchase of the CHP plant are to lower utility bills (as the CHP plant provides power) while using the thermal energy to provide steam. We assume that a new CHP plant will cost $2200/kW[80], with annual maintenance costs equal to 4% of CapEx. But because wholesale electricity prices are low in Maine, the payback periods are greater than 7 years, as seen in the first three rows of Table 19. Market penetration in this case will be zero.

However, if the ratepayer funded community renewable energy fund grants a CHP project a long term 20-year PPA price at above-market rates, the payback drops to less than seven years, into the potentially feasible range. However, only 15 MW of 60 MW funded by the Maine Community Renewable Energy program has been devoted to biomass projects over the last few years, and the maximum project size funded has been 10 MW. We therefore posit a single 10 MW biomass project as feasible for this strategy option, if funded by the Community Renewable Energy program with a 20-year PPA @ 84.50 $/MWh (per the latest project for this program). The paybacks with this new funding source correspond to the bottom three rows in the table below.

Table 19. Strategy 3C Payback Assumptions

CHP Plant Size	CapEx	Biomass Fuel Cost	Thermal Savings	Electricity Savings	Maintenance Cost	Payback (years)
2 MW	$4,400,000	$319,684	$396,872	$315,222	$176,000	20.3
5 MW	$8,750,000	$799,209	$992,180	$788,056	$350,000	13.9
10 MW	$17,500,000	$1,598,418	$1,984,359	$1,576,112	$700,000	13.9
	with 84.5 $/MWh Community Renewable Energy 20 -Year PPA					
2 MW	$4,400,000	$319,684	$396,872	$672,749	$176,000	7.7
5 MW	$8,750,000	$799,209	$992,180	$1,681,872	$350,000	5.7
10 MW	$17,500,000	$1,598,418	$1,984,359	$3,363,745	$700,000	5.7

[80] EPA Spark Estimator Model, 2015, https://www.epa.gov/chp/my-facility-good-candidate-chp for updates, and http://naturalgastechnology.org/resources/EPA_spark_spread_estimator.xlsm for version 1.2.

As seen in the following table, the Maine Community RE program allows a participant BCA of 1.3. Ratepayer impacts have a BCA <1, increasing rates by .000082 $/kWh. The TRC test BCA ratio is 1.3, with industry benefits of 22,600 tons of biomass demand.

Table 20. Strategy 3C: New CHP Co-located at Existing Maine Manufacturer, w/Community RE Funding

Participant Cost Test	**Total NPV**	**Comments**
Benefits	$52,271,000	Thermal Savings, Maine Community RE program Export Revenue
Costs	$25,517,000	Installed Costs, O&M
BCA	2	
Ratepayer Impact Measure		
Benefits	$37,348,000	Avoided Generation Capacity Costs, Avoided Energy Cost
Costs	$49,238,000	Lost Utility Revenue, Maine Community RE program Incentives
BCA	0.8	
Ratepayer Impact ($/kWh)	0.000082	
Residential Ratepayer Impacts (% increase)	0.06%	
Industrial Ratepayer Impacts (% Increase)	0.16%	
Total Resource Cost Test		
Benefits	$71,438,000	Sum of above benefits
Costs	$57,033,000	Sum of above costs
BCA	1.3	
Industry Economic Impacts		
Benefits	$10,396,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$11,314,000	Maine fossil fuel industry revenue and job income losses

Combined TRC + Industry Impacts BCA Ratio	1.2	
2022 Additional Biomass Demand (tons)	22,600	
2022 Additional Biomass Industry Jobs	10	

Public and Private Institutional Wood Heat (3D)

With this strategy, we examine the potential of public and private institutional wood heating to add to biomass residue demand, including the impact of a thermal REC on this market. Small and large schools and businesses are modeled rather than residential, as their higher volumes improve participant economics and biomass residual demand.

To model paybacks, two data sources are combined to form a database of installations, from which we derive installation size, cost, and maintenance cost. The American Recovery and Reinvestment Act (ARRA) seeded many biomass school and business projects in the 2010-2014 timeframe in Maine, providing 30%-50% capital equipment subsidies for demonstration projects[81]. The second source is from a biomass economics calculator provided by INRS for consumers to use to examine project payback and IRR for biomass projects. In this instance, the consumer inputs data into the calculator as a "what-if" before going forward with the project. Preserving confidentiality, we used consumers inputs from the last 5 years; note, these are "virtual" project costs, as we do not know whether all of these projects went forward. Overall, 40 projects are costed and sized (for large/small schools/businesses, and wood/pellet fuel).

[81] http://www.maine.gov/dacf/mfs/projects/mesweat/heating_w_wood_pellets.html

Table 21. Strategy 3D Payback Assumptions

Reference Case		Biomass CapEx	Avoided CapEx	Fuel Oil Avoided Cost	Biomass Fuel Cost	Annual O&M Costs	Thermal RECs	Payback (years)	
								w/o	w/
Small School	Pellet	$439,956	$83,929	$68,855	$51,867	$937	$30,439	22.2	7.7
Small School	Chip	$690,000	$281,400	$38,392	$18,717	$1,469	$16,972	22.4	11.6
Large School	Pellet	$921,000	$414,060	$282,479	$212,784	$4,469	$124,875	7.8	2.7
Large School	Chip	$1,431,429	$643,536	$157,504	$76,787	$6,946	$69,627	10.7	5.5
Small Business	Pellet	$166,486	$85,253	$35,046	$26,400	$899	$15,493	10.5	3.5
Small Business	Chip	$379,178	$194,167	$19,541	$9,527	$2,047	$8,638	23.2	11.1
Large Business	Pellet	$1,290,000	$579,953	$318,023	$239,558	$6,260	$140,587	9.8	3.3
Large Business	Chip	$2,010,000	$903,648	$177,322	$86,449	$9,754	$78,388	13.6	6.9

From

Table 21, the paybacks without a Thermal REC (the 9th column) are only favorable for large schools, with low market penetration. We therefore evaluated this strategy in conjunction with a thermal REC, with improved paybacks as seen in the right-most column in

Table 21, to improve its viability.

As a result of these improved paybacks, market demand is expected to be higher than the supply of thermal RECs (at a 2% carveout level). The total available market for this option therefore limited by the available thermal REC funding.

Table 22. Strategy 3D: Public and Private Institutional Wood Heat with a 2% Thermal REC carveout BCA Results

Participant Cost Test	**Total NPV**	**Comments**
Benefits	$366,198,000	Fuel Oil Avoided Cost, Avoided CapEx, Thermal REC Incentives
Costs	$201,043,000	Installed Costs, O&M, Fuel Supply
BCA	1.7	
Ratepayer Impact Measure		
Benefits	$0	
Costs	$67,479,000	Thermal REC payments
BCA	0	
Ratepayer Impact ($/kWh)	0.000467	
Residential Ratepayer Impacts (% increase)	0.34%	
Industrial Ratepayer Impacts (% Increase)	0.89%	
Total Resource Cost Test		
Benefits	$266,066,000	Fuel Oil Avoided Cost, Avoided CapEx
Costs	$237,251,000	REC payments, Install Costs, O&M, Fuel Supply
BCA	1.1	
Industry Economic Impacts		
Benefits	$216,924,000	Maine biomass industry revenue plus indirect and direct job income
Costs	$78,331,000	Maine fossil fuel industry revenue and job income losses
Combined TRC + Industry Impacts BCA Ratio	1.5	

2022 Additional Biomass Demand (tons)	174,500	
2022 Additional Biomass Industry Jobs	110	

Individual Scenario Results Summary

The results from the individual scenarios above are summarized and compared below.

Table 23. Individual Scenario Result Comparison

	Net NPV (TRC + Industry Benefits) ($MM)	2022 Tons Biomass (000)	Biomass Jobs	PCT	RIM	Industrial Rate Impact (%)	TRC	Combined TRC + Industry Benefits BCA
3A: 15% REC	259	753	190	--	0	1.11%	0	3.0
3A: 15% REC + 2% Thermal REC	5	109	70	--	0	.89%	0	1.1
3A: 15% REC + 5% Increased Thermal REC	-38	273	170	--	0	2.2%	0	.8
3A: 15% REC + 10% Thermal REC	-77	546	340	--	0	4.4%	0	.8
3B: Mfg. co-located @ Maine Biomass	76	140	40	26.7	0	0%	26.7	70.9
3C: CHP co-located @ Maine Mfg.	13	23	10	2.0	.8	.16%	1.3	1.2
3D: Wood Heat + Thermal REC	167	174	110	1.7	0	.89%	1.1	1.5

Upon examination, it is clear that strategy 3B, Manufacturer co-located at Maine Biomass plant, has the most industry benefits without impacting ratepayers, if new manufacturers can be attracted to Maine. If this is not feasible, option 3A (10-15% REC) or option 3D + 3A (thermal REC) offers the most benefit for low ratepayer cost.

Optimized Combination of Strategies

One optimized combination of strategies is therefore strategy 3A: Thermal REC, 3B: Manufacturer co-located with biomass plant, and 3D: Commercial and Institutional Wood Heat. To be more conservative, we posit a single medium scale (i.e. using 10% of a 33 MW Biomass power plant's output) manufacturer, rather than 1 each of small, medium, and large usage manufacturers as was explored for strategy 3B. The BCA result for this combination is shown below, and compared with a 3A: 10%-15% REC strategy alone. When these are combined, a doubling of REC payments (one for thermal, the other for electric) brings the BCA to less than one.

Table 24. Optimum Combination BCA Results vs. 3A (10%-15% REC)

Combination Thermal REC + 3B (Manufacturer co-located with biomass plant) + 3D: Commercial and Institutional Wood Heat			3A: 10-15% REC Alone
Participant Cost Test	**Total NPV**	**Comments**	
Benefits	$377,932,000	Fuel Oil Avoided Cost, Avoided CapEx, Thermal REC Incentives, Thermal Savings	$0
Costs	$201,508,000	Installed Costs, O&M, Fuel Supply	$0
BCA	1.9		--
Ratepayer Impact Measure			
Benefits	$0		$0
Costs	$67,479,000	Thermal REC payments	$84,227,000
BCA	0		0
Ratepayer Impact ($/kWh)	0.000467		0.000583
Residential Ratepayer Impacts (% increase)	0.34%		0.43%
Industrial Ratepayer Impacts (% Increase)	0.89%		1.11%
Total Resource Cost Test			
Benefits	$277,800,000	Fuel Oil Avoided Cost, Avoided	$0

		CapEx, Thermal Savings	
Costs	$237,716,000	REC payments, Install Costs, O&M, Fuel Supply	$84,227,000
BCA	1.2		0
Industry Economic Impacts			
Benefits	$240,151,000	Maine biomass industry revenue plus indirect and direct job income	$389,726,000
Costs	$78,331,000	Maine fossil fuel industry revenue and job income losses	$46,796,000
Combined TRC + Industry Impacts BCA Ratio	1.6		3.0
2022 Additional Biomass Demand (tons)	206,000		753,900
2022 Additional Biomass Industry Jobs	130		190

Sensitivity Analysis

For the optimum strategy and for a 10-15% REC alone, we varied the inputs to simulate unrealistic "all inputs are unfavorable" and "all inputs are favorable" cases, to examine how the results of the BCA would change. "All inputs" includes fossil fuel prices, the percentage of new RPS requirements that are biomass, REC prices, and market penetration – the factors in the above assumptions that are highly uncertain. Each variable was adjusted to be at its historical high or low as appropriate.

Table 25. Sensitivity Results, Thermal REC + 3B (Manufacturer co-located with biomass plant) + 3D: Commercial and Institutional Wood Heat

Participant Cost Test	Pessimistic	Nominal	Optimistic
Benefits	$123,503,000	$377,932,000	$1,895,276,000
Costs	$11,549,000	$201,508,000	$983,306,000
BCA	10.7	1.9	1.9
Ratepayer Impact Measure			
Benefits	$30,695,000	$0	$0
Costs	$212,000	$67,479,000	$77,275,000
BCA	144.8	0	0
Ratepayer Impact ($/kWh)	(0.000211)	0.000467	0.000535
Residential Ratepayer Impacts (% increase)	-0.15%	0.34%	0.39%
Industrial Ratepayer Impacts (% Increase)	-0.40%	0.89%	1.02%
Total Resource Cost Test			
Benefits	$54,066,000	$277,800,000	$1,795,144,000
Costs	$10,370,000	$237,716,000	$885,535,000
BCA	5.2	1.2	2
Industry Economic Impacts			
Benefits	$110,391,000	$240,151,000	$782,380,000
Costs	$3,454,000	$90,184,000	$562,674,000

Combined TRC + Industry Impacts BCA Ratio	11.9	1.6	1.8
2022 Additional Biomass Demand (tons)	143,800	206,000	561,800
2022 Additional Biomass Industry Jobs	90	130	350

The table above shows the result of this sensitivity, that the TRC BCA ratio remains above 1 in all cases, with a maximum ratepayer impact of a 1.02% increase for industrial customers, and .39% increase for residential customers. When REC prices increase by 4X in the pessimistic case, they are greater than 50% of the ACP, resulting in ratepayer savings and improved BCA.

Table 26. Sensitivity Results, 10—15% REC Only

Participant Cost Test	Pessimistic	Nominal	Optimistic
Benefits	$0	$0	$0
Costs	$0	$0	$0
BCA	--	--	--
Ratepayer Impact Measure			
Benefits	$0	$0	$0
Costs	$336,907,000	$84,227,000	$58,959,000
BCA	0	0	0
Ratepayer Impact ($/kWh)	0.002333	0.000583	0.000408
Residential Ratepayer Impacts (% increase)	1.71%	0.43%	0.30%
Industrial Ratepayer Impacts (% Increase)	4.43%	1.11%	0.78%
Total Resource Cost Test			
Benefits	$0	$0	$0
Costs	$336,907,000	$84,227,000	$58,959,000
BCA	0	0	0
Industry Economic Impacts			
Benefits	$419,897,000	$389,726,000	$359,555,000
Costs	$38,353,000	$46,796,000	$55,136,000
Combined TRC + Industry Impacts BCA Ratio	1.1	3.0	3.2
2022 Additional Biomass Demand (tons)	753,900	753,900	753,900
2022 Additional Biomass Industry Jobs	190	190	190

For the 10%-15% REC only, the ratepayer impact burden on stakeholders is highly dependent on volatile REC prices. Nevertheless, even with a 4X increase in REC price, the combined BCA ratio remains higher than 1.

Appendix A. Scenario Analysis Variable Inputs

The following table shows the input variable assumptions used in the scenario analysis.

Table 27. Scenario Analysis Input Variable Assumptions

Variable	Pessimistic	Nominal	Optimistic
REC Price Multiplier	4	1	.7
Penetration Level Multiplier	50%	100%	150%
Biomass Price Multiplier	110%	1	90%
Fuel Oil Price Adder ($/Gal)	-0.39	0	0.71
Nat Gas Price Adder ($/MCF)	-1.38	0	1.38
CHP Plant Export %	33%	50%	100%
Percent Biomass RECs	80%	88%	95%