MA DOER:
FINAL REPORT
Biomass Resource Evaluation
Appendix A

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1 INTRODUCTION

This report documents an analysis of the availability and current pricing for a select group of biomass fuels that would be eligible for participation in the Massachusetts Renewable Portfolio Standard ("**RPS"**) under proposed RPS regulatory changes. The report also provides guidance on the availability and reliability of certain biomass fuel types that are available only intermittently, such as biomass from forest salvage activities following major storm or insect/disease events.

1.1 PROJECT PURPOSE

ANTARES conducted an analysis of available biomass resources for biomass electric generation units in New England that are potentially eligible to participate in the Massachusetts Renewable Portfolio Standard ("**RPS"**) under changes proposed on April 5, 2019 by the Massachusetts Department of Energy Resources ("**DOER**"). ANTARES served as a subcontractor to Sustainable Energy Advantage, LLC ("**SEA**") for this effort, as part of a larger evaluation commissioned by the **DOER**. The larger effort's purpose was to assess whether it was feasible for biomass electric generating units to cost-effectively operate when using at least 95% of their fuel from forest salvage and non-forest derived residues, as defined in proposed Massachusetts RPS rules (225 CMR 14.00 and 225 CMR 15.00). SEA provided the list of candidate facilities, their operational status, gross and net electric generating capacity, and biomass fuel requirements under biomass dispatch scenarios evaluated for this study. ANTARES estimated the volume of forest salvage and non-forest derived residues potentially available to biomass electric generation facilities and the cost to deliver them to candidate biomass units.

1.2 STUDY LIMITATIONS AND CAVEATS

Supply quantities are based on publicly available, county-level data that do not fully capture annual variability in biomass resource generation. Price estimates are based on current, regional values for the U.S. Northeast with the main point of price differentiation being transportation costs. Contract price and quantity values, which are not available for review, ultimately will determine site specific fuel costs. The study therefore may not fully capture all site-specific opportunities or barriers that may make or break the economics for a given project.

Future competition for eligible fuel resources between candidate facilities for participation in the Massachusetts RPS and other existing biomass using facilities is likely to be a factor in future pricing for biomass fuels in the region. This study did not quantitatively examine future price volatility associated with changes in eligible biomass supply sources and market conditions associated with the proposed biomass dispatch scenarios. The report also does not evaluate the timeframe or infrastructure investment required to support a transition from current biomass supply sources to a biomass fuel procurement strategy that relies on 95% or more of forest salvage and non-forest derived residues.

Expansion of recovery and processing infrastructure and supplier network development for the target fuel supplies is needed to ramp up to levels required to support reliable biomass electric generation facility operation at historical or expanded dispatch levels. In addition, the elimination for all but up to 5% of fuel input of multiple current fuel categories that historically have been mainstays in the industry would increase the availability of biomass supply for generators choosing not to participate in MA RPS program. However, this change would also put increased pressure for eligible feedstocks and would expand the distance generators may procure fuel sources. Both of these factors may increase biomass delivered costs to an extent that is not fully captured in current market data. Therefore, the estimates of biomass fuel cost provided should be considered as a best-case scenario for biomass generators, assuming existing generation facilities continue operating at current or increased dispatch levels. There is no comparable historical analogue that can be used to fully gauge the magnitude of price volatility that biomass fuel users may face under the proposed Massachusetts RPS rule changes. This study provides context based on other market-changing events that have occurred and their impacts on biomass fuel pricing.

1.3 BIOMASS FUEL RESOURCES EVALUATED

The choice of biomass resources permits evaluation of scenarios where biomass electric generation units could avoid a 50% overall minimum efficiency requirement, if greater than 95% of the fuel is sourced from forest salvage and non-forest derived biomass. This study evaluated the availability and cost of the following biomass sources to biomass power plants potentially able to meet DOER's proposed eligibility requirements:

1. **Forest products industry residues.** Bark, sawdust, and other manufacturing byproducts associated with primary and secondary forest products manufacturing. Excludes chips used for higher value-added pulp and engineered wood products applications.
2. **Conversion of forest to agricultural land use.** Wood biomass available from estimated forest land area converted to agricultural land use.
3. **Right-of-way clearing and private tree trimming.** Wood biomass generated from road and right-of-way maintenance, park maintenance, and private tree trimming wood.
4. **Orchard trimmings.** Pruned branches, stumps, and whole trees from maintenance activities associated with agricultural wood waste materials.
5. **Forest salvage.** Biomass from dead, dying, or damaged trees removed due to pests or pathogens, ice storms, or other injurious agents associated with a declaration, rule, or order of a major threat to forest health or public or private resources by the U.S. Department of Agriculture ("**USDA**") Animal & Plant Health Inspection Service ("**APHIS"**), the USDA Forest Service, or other state or federal agencies.

Note that since these resources are the focus of the study, the analysis presented below assumes that all biomass feedstock used at the candidate facilities comes from these materials. Although 5% of fuel that could come from other eligible biomass sources, those fuels were outside of the scope of the analysis and their inclusion is not expected to have a material impact on the availability or cost of fuel.

1.4 DEFINITION OF STUDY AREA AND FACILITIES EVALUATED

Exhibit 1 lists the candidate units for which biomass availability and cost is evaluated. The candidate sites include six existing units which, when subjected to a screening analysis, were determined in a distinct phase of the evaluation to have the potential to both qualify for and respond to Massachusetts RPS eligibility changes, as well as one hypothetical new proxy biomass unit, considered to be sited at the intersection of I-90 and I-91 in Massachusetts to represent a site with relatively ample access to biomass fuel.

The table in Exhibit 1 shows the average heat input for the period from 2010 to 2018 as reported by each facility to the U.S. Department of Energy (**"DOE"**) Energy Information Administration (**"EIA"**) on Form 923[1] and assuming a biomass energy content of 5,100 British thermal units per green pound (**"Btu/lb"**)[2] except for the hypothetical new facility, which is based on fuel use calculated based on an assumed heat rate of 13,500 Btu per kilowatt-hour (**"kWh"**) of electricity generation and a net capacity of 35 megawatt of electric capacity ("**MWe**").

Exhibit 1: Biomass Fuel Users in the Project Wood Supply Shed and Vicinity

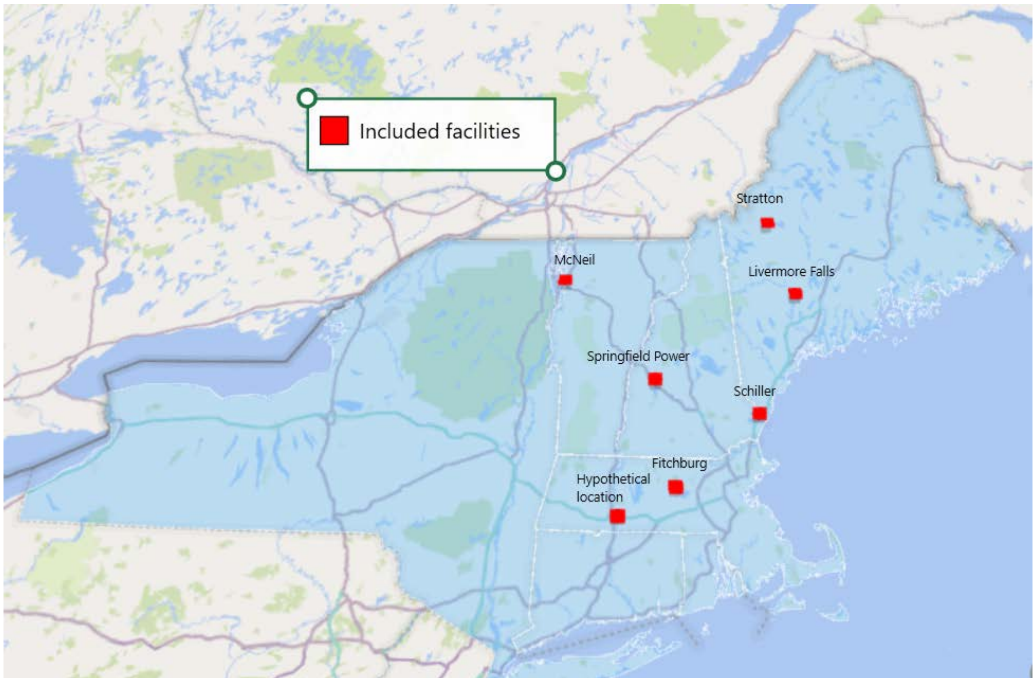
Facility name	Location	Net electric capacity (MWe)	Plant heat rate (Btu/kWh)	Biomass use - historic (Green tons/ year)	Biomass use – 90% capacity (Green tons/year)
McNeil Station	Burlington, VT	50.0	14,649	387,000	566,000
Stratton	Stratton, ME	45.7	13,032	374,000	460,000
Schiller Station	Portsmouth, NH	42.8	15,449	478,000	511,000
Livermore Falls	Livermore Falls, ME	34.0	13,162	330,000	346,000
Springfield Power	Springfield, NH	17.0	13,639	184,000	179,000
Fitchburg	Athol, MA	16.3	16,575	182,000	208,000
Hypothetical plant	I-90 and I-91	35.0	13,500	365,000	365,000
	Total	**240.7**		**2,300,000**	**2,635,000**

Exhibit 2 provides a map showing the location of facilities evaluated. Shaded areas show the states for which biomass resources are included in this study.

[1] DOE EIA Form 923 data available on-line: https://www.eia.gov/electricity/data/eia923/

[2] Per MA DOER GHG assessment 2012 model. This is consistent with 40% fuel moisture and 8,500 Btu per dry pound energy content.

Exhibit 2: Map of generation units and states included in biomass supply and cost assessment



States included in biomass resource assessment shaded in blue: CT, MA, ME, NH, NY, RI, VT

2 BIOMASS FUEL RESOURCE GENERATION

2.1 DATA SOURCES AND METHODS

This section describes the data sources and analytical approach used to estimate eligible biomass resource generation for candidate biomass electric generation units.

2.1.1 Biomass Resource Generation Assumptions

Exhibit 3 documents data sources and methods used to estimate biomass resource quantities. The analysis relied upon publicly available county-level data from a variety of sources.

Exhibit 3. Data sources and methods used to estimate biomass generation quantities

Resource type	Source
Forest salvage	Forest salvage biomass quantities based on historical usage from the MA DOER RPS[1]. County-level estimated removals of dead, non-merchantable trees from USDA Forest Service Forest Inventory Analysis (FIA) data[2], regardless of RPS eligibility, to be provided for comparison for final report.
Land use change (forest to agricultural)	Estimated county-level forest land cover change to all other land cover types from USDA Forest Service FIA data[2] (average percent change from 2014 – 2018). This value was then multiplied by percent land cover change from forest to agricultural land cover in the U.S. Northeast based on estimates from the USDA CropScape system[3]. Land cover change area multiplied by average biomass per acre of forest land from the USDA Forest Service FIA database[2] to provide county-level estimated biomass values. Land use change from forest to agricultural uses represented 9% of total forest land cover change.
Forest products industry residues	USDA Forest Service Timber Products Output Database[4] for 2012 on mill residue generation, excluding residues used for fiber applications (pulp and engineered wood products). Non-fiber uses represent 86 percent of mill residue generated in the study region.
Utility tree trimmings	Estimated using a combination of data from the DOE 2016 Billion Ton Report[5] and DOE National Renewable Energy Laboratory (NREL) estimates of solid biomass[6] for the U.S. on a county-level. NREL urban wood waste estimates include wood waste from MSW, right-of-way tree trimming and private tree trimming and C&D wood. Billion Ton report estimates of wood waste from MSW and C&D sources subtracted from NREL urban wood waste values to provide right-of-way and private tree trimming wood quantities (by difference).
Orchard trimmings	Annual quantities estimated from the DOE Billion Ton Report, based on USDA NASS data and typical orchard removal and replanting cycles

Sources referenced in exhibit:

[1] (MA DOER, 2019)

[2] (USDA Forest Service, Forest Inventory & Analysis Program, 2019)

[3] (USDA National Agricultural Statistics Service Cropland Data Layer, 2019)

[4] (U.S. Department of Agriculture, Forest Service, 2012)

[5] (M. H. Langholtz, 2016)

[6] (A. Milbrandt, 2014)

2.1.2 Biomass Fuel Properties

Facility reported fuel heat input and heat rates from the DOE EIA Form 923 for the period from 2010 to 2018 were used to estimate representative biomass generator fuel energy input requirements by the candidate facilities. The current Massachusetts DOER GHG guidance spreadsheet uses a generic biomass fuel energy content assumption of 5,100 Btu/green lb[3]. This value is used as the basis for estimated fuel energy use in green tons shown in Exhibit 1. This number is consistent with moisture for green wood biomass or mill residues at 40 percent moisture, wet basis, and a biomass energy content expressed in Higher Heating Value (“**HHV”**) of 8,500 Btu per dry pound (“**Btu/dry lb**”), or 17 million Btu per dry ton (“**MMBtu/dry ton”**).

In ANTARES experience, the average moisture content for as-received biomass varies by fuel source is typically around 50% moisture content, which is somewhat higher than 40% moisture content assumed in DOER’s 2013 lifecycle greenhouse gas emissions tool. Exhibit 4 provides the values used to estimate biomass use in tons and cost per unit of energy content in this study.

Exhibit 4: Summary of Biomass Fuel Moisture and Heat Content Assumptions

Material type	Heat content (MMBtu/ dry ton)	Moisture content (% wet basis)	Heat content (MMBtu/ green ton)
Forest harvest residues[1]	17.0	50%	8.50
Orchard trimmings[2]	17.0	50%	8.50
Forest salvage[1]	17.0	50%	8.50
Tree trimming, right-of-way clearing[1]	17.0	50%	8.50
Mill residues[3]	17.0	45%	9.35
Land clearing[1]	17.0	50%	8.50

Sources for assumptions referenced in exhibit:

[1] Consistent with as-harvested moisture of live trees including bark. A survey of several species common in New England shows moisture ranging from 44 to 58 percent (Patrick Miles & W. Brad Smith, USDA Forest Service Northern Research Station, 2009).

[2] Consistent with apple species (Patrick Miles & W. Brad Smith, USDA Forest Service Northern Research Station, 2009).

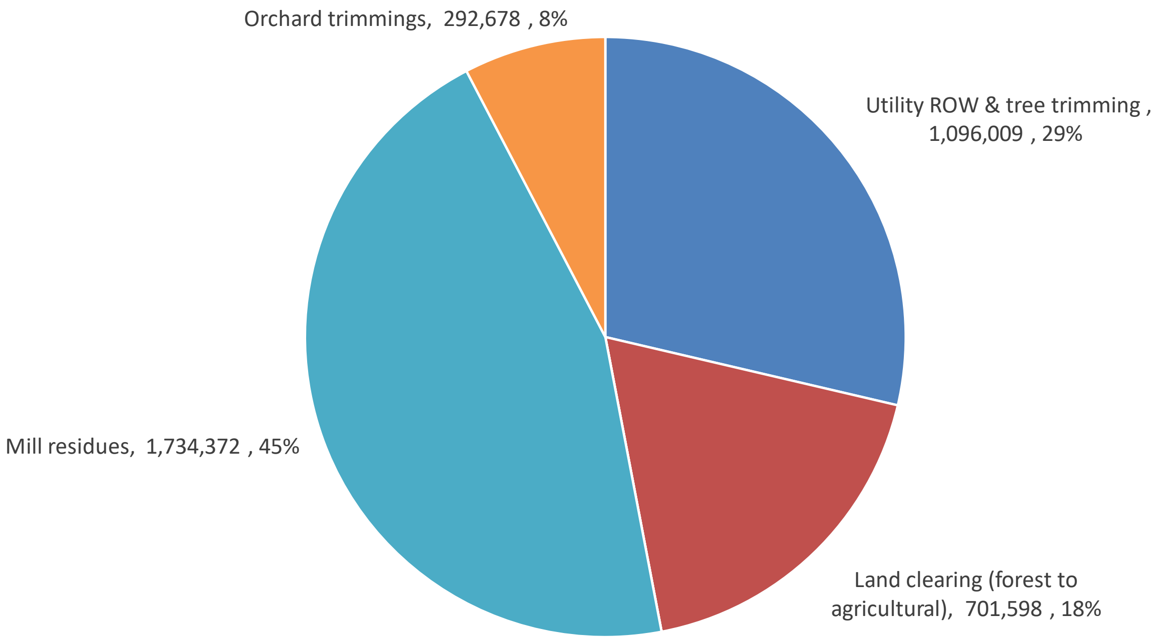
[3] Bark moisture in as-harvested conditions can be higher than wood moisture. In practice, mill residue moisture is often lower than as-harvested moisture as it can lose moisture while in storage. The extent of the moisture reduction depends on storage conditions.

[3] Unless otherwise noted, biomass quantities and heat content in this report are presented in terms of green, or as-received tons.

2.2 RESULTS

Total current generation of target fuel quality biomass within the study region is an estimated 3.8 million green tons per year (Exhibit 5) and 34,915 Billion Btu/year (Exhibit 6).

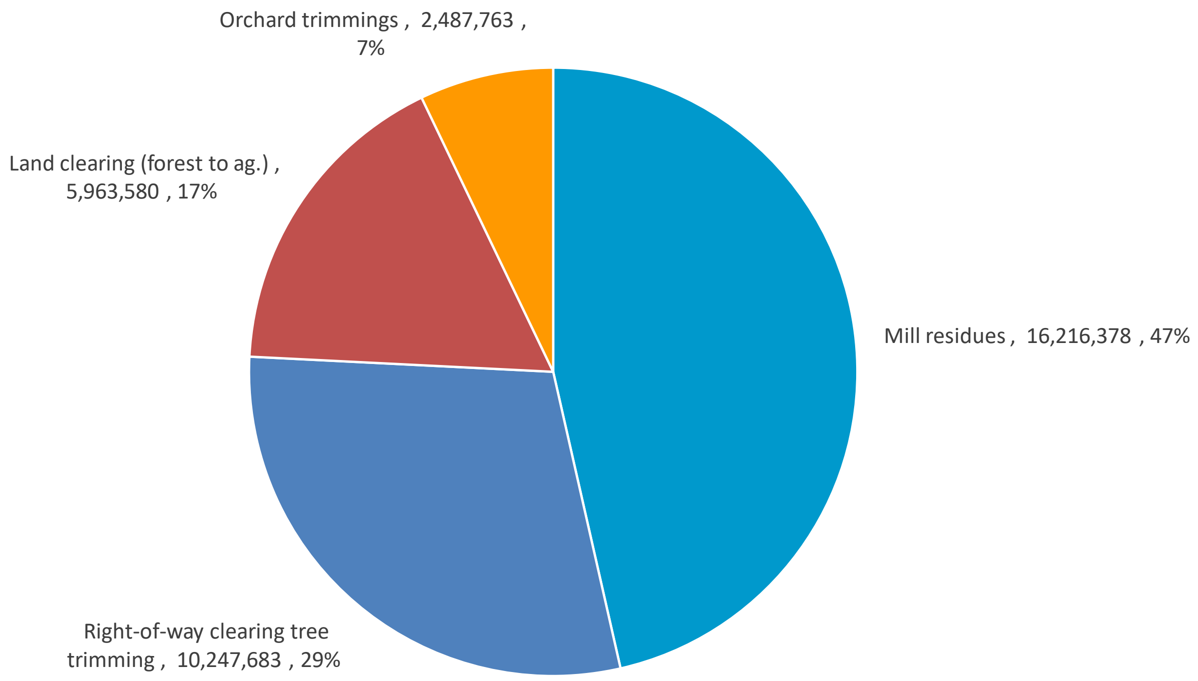
Exhibit 5: Eligible biomass fuel generation in New England and New York (green tons/year)



State	Mill residues	Right-of-way clearing and tree trimming	Land clearing – forest to agriculture	Orchard trimming	Total
CT	25,103	120,326	30,235	8,984	184,647
MA	14,328	348,653	70,225	10,382	443,588
ME	343,257	45,347	62,266	10,088	460,959
NH	345,356	46,314	36,674	5,008	433,351
NY	920,591	476,970	442,029	250,842	2,090,431
RI	35	33,419	2,511	1,038	37,002
VT	85,704	24,981	57,657	6,336	174,678
Total	**1,734,372**	**1,096,009**	**701,598**	**292,678**	**3,824,657**

Note: Forest salvage material used in the Massachusetts RPS is limited to 11,880 tons total over the 5-year period from 2013 to 2017 and represented less than 1% of total biomass in the program during this time. As such, the quantity of this feedstock is not shown in the figure due to the de minimus contribution at predictable timeframes. Additional information about forest salvage is provided in Section 4.1.

Exhibit 6: Eligible biomass fuel generation in New England and New York (MMBtu/year)



State	Mill residues	Right-of-way clearing and tree trimming	Land clearing – forest to agriculture	Orchard trimming	Total
CT	234,708	1,125,044	256,998	76,364	1,693,114
MA	133,967	3,259,908	596,914	88,247	4,079,036
ME	3,209,453	423,998	529,263	85,748	4,248,462
NH	3,229,074	433,035	311,729	42,568	4,016,405
NY	8,607,521	4,459,666	3,757,249	2,132,157	18,956,593
RI	323	312,465	21,341	8,823	342,952
VT	801,332	233,568	490,086	53,856	1,578,842
Total	**16,216,378**	**10,247,683**	**5,963,580**	**2,487,763**	**34,915,404**

Note: Forest salvage material used in Massachusetts RPS represented less than 1% of total biomass in the program over the 5-year period from 2013 to 2017.

3 BIOMASS FUEL PRICING

This section presents an analysis of delivered biomass fuel prices for the candidate biomass electricity generation units. The analysis uses biomass supply data, published biomass prices and trucking costs for biomass to estimate delivered prices.

3.1 DATA SOURCES AND METHODS

This analysis relied on FOB prices[4] plus estimated transportation costs[5] from each county centroid to candidate generation units to estimate the current, delivered cost of biomass at each facility location. The FOB fuel costs were derived from the most recent (Q2 2019) values from the North American Wood Fiber Review, a subscription-based publication that tracks market prices and trends in per ton delivered biomass fuel price values. The FOB costs were generally determined by deducting estimated trucking costs from delivered costs, based on an assumed average 40-mile trucking distance to the end user facility. This applied for all sources except for forest salvage and biomass from utility right-of-way clearing and private tree trimming. Forest salvage is assumed to be available for trucking costs only, and the FOB cost for utility right-of-way clearing materials from right-of-way contractors is discounted at 25% compared to other sources. This is consistent with ANTARES experience with procurement of urban and right-of-way materials at other utility-scale biomass plants. Trucking costs were calculated using ANTARES internal trucking cost-model and round-trip road transportation distances from county centroids to generating unit locations modeled using Geographic Information Systems (GIS) tools. Section 2.1.2 describes fuel property assumptions used to convert per ton biomass delivered costs to an energy content basis. Appendix A provides additional details on the trucking cost model and FOB fuel prices.

The delivered costs for biomass from each county were sorted in order of increasing cost on an energy content ($/MMBtu) basis and ranked for each candidate facility to create a biomass fuel ‘supply curve’. The weighted average cost of fuel per MMBtu and per ton for different supply quantities was then calculated. Generally, biomass fuel procurement staff for each facility strive to secure the least-cost fuel supply available, but competition for fuel sources, variability in annual biomass generation and other factors make it unrealistic for a facility to secure solely the least-cost biomass supply available in their area on a consistent basis. Therefore, the least-cost biomass supply, based on the fuel produced in the area around a facility and ranked in order of increasing cost, should be considered a floor price for biomass. In other words, the optimal procurement (an assumption that results in a lower fuel cost than would occur if competition and other factors are considered), could be assumed to use only the cheapest fuel sources, requiring only a 1:1 ratio of supply to demand. A high price case here is represented by the weighted

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[4] FOB refers to free on board, or freight on board. It represents the price of the biomass at the mill gate or road side, not including the cost to transport it to the end-user.

[5] At current fuel prices. The potential for future changes in diesel fuel prices was ignored in the analysis.

average fuel for a supply shed that supports an annual biomass supply equal to twice its current demand (a 2:1 ratio). For the base case for this analysis, we assume that the supply shed size and delivered price is consistent with a supply shed that generates 1.5 times the demand required by the facility (a 1.5:1 ratio). To illustrate, two demand cases are presented: 1) Operation at historic levels, and 2) Estimated fuel use at 90 percent of gross electric capacity. This considers competition for biomass fuel but also assumes that fuel procurement managers are able to secure a large proportion of the least-cost fuel in their supply shed. The resulting fuel supply curve is also used for the analysis of potential economic production levels in other parts of the analysis by SEA.

3.2 RESULTS

Exhibit 7 show the results of the biomass fuel price analysis for the least-cost, base case, and high cost scenarios based on historic fuel use. Exhibit 8 shows the price analysis results for cases where the project operates at 90% capacity.

Exhibit 7: Summary of weighted average delivered biomass fuel price analysis – operation at historic levels

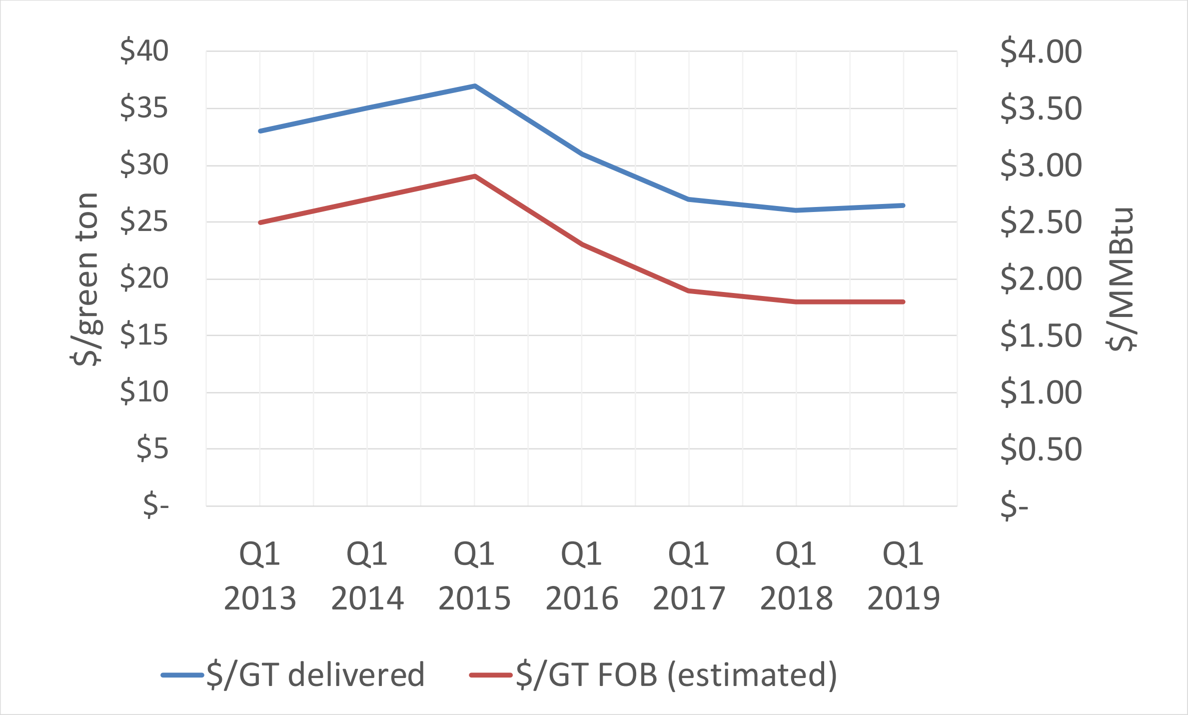
	Least-cost case (1:1)			Base case (1.5:1)			High cost case (2:1)		
Facility name	$/MMBtu	$/ton	Supply shed radius (miles)	$/MMBtu	$/ton	Supply shed radius (miles)	$/MMBtu	$/ton	Supply shed radius (miles)
McNeil Station	$3.49	$32.18	94	$3.65	$33.60	129	$4.02	$37.15	132
Stratton	$3.65	$34.06	88	$3.86	$35.91	134	$4.27	$39.54	209
Schiller Station	$3.21	$29.47	120	$3.96	$36.57	135	$3.97	$36.68	153
Livermore Falls	$3.50	$32.45	89	$3.63	$33.71	109	$3.82	$35.36	129
Springfield Power	$3.17	$29.28	94	$3.35	$30.87	111	$3.51	$32.33	120
Fitchburg	$2.57	$23.40	48	$2.78	$25.52	60	$2.94	$26.93	71
Hypothetical plant	$3.27	$29.78	139	$3.47	$31.69	146	$3.68	$33.79	169

Exhibit 8: Summary of weighted average delivered biomass fuel price analysis – operation at 90% capacity

	Least-cost case			Base case			High cost case		
Facility name	**$/MMBtu**	**$/ton**	**Supply shed radius (miles)**	**$/MMBtu**	**$/ton**	**Supply shed radius (miles)**	**$/MMBtu**	**$/ton**	**Supply shed radius (miles)**
McNeil Station	$3.62	$33.32	124	$4.02	$37.15	132	$4.46	$40.93	185
Stratton	$3.72	$34.67	93	$4.08	$37.85	137	$4.72	$43.65	230
Schiller Station	$3.27	$30.09	107	$4.08	$37.55	155	$4.08	$37.55	155
Livermore Falls	$3.50	$32.45	89	$3.63	$33.71	113	$3.84	$35.49	129
Springfield Power	$3.17	$29.28	94	$3.35	$30.87	111	$3.46	$31.80	113
Fitchburg	$2.66	$24.32	55	$2.85	$26.15	65	$3.00	$27.46	74
Hypothetical plant	$3.27	$29.78	139	$3.47	$31.69	146	$3.68	$33.79	169

Exhibit 9 shows historic delivered biomass fuel prices in the U.S. Northeast. Comparing these historic prices with the analysis results shown in the tables above, it is apparent that although the projected fuel price estimates for the candidate facilities in this study are generally higher than the current market prices, they are in line with the higher fuel prices in the region that were experienced a few years ago. It is important to note that these historic changes do reflect changes in demand, but do not reflect any major changes in fuel source eligibility (as considered in this study).

Exhibit 9. Historic delivered biomass fuel prices in U.S. Northeast



Source: North American Wood Fiber Review, woodprices.com

A key finding is that the reduced overall biomass supply significantly increases the one-way haul distance (as indicated by the supply radius) required to meet the fuel requirements over typical levels. Typically, most biomass power generation units secure the vast majority of their fuel from within a 50 mile radius, and only secure low cost-opportunity fuels from distances of 75 miles or greater. Price estimates in this study could be low if multiple candidate project sites with a significant degree of supply shed overlap compete for eligible biomass resources or if complications in supply logistics due to long haul distances result in increased delivery and management costs.

4 PROPOSED RULE CHANGE IMPACTS

This chapter describes two issues relevant to biomass supply availability. These issues are treated qualitatively as it is beyond the scope of this assessment to do a full analysis of the factors affecting the robustness of the biomass supply chain associated with the proposed RPS changes.

- **Factors affecting forest salvage availability**: Available data do not support a quantitative assessment of the potential for forest salvage operations to meet biomass supply eligibility requirements, and logistical and regulatory barriers exist that tend to prevent maximizing the use of wood salvaged from forest pest and pathogen outbreaks or major weather events. We present information on barriers and opportunities for forest salvage material utilization.
- **Regulatory requirements and operational practices for right-of-way clearance**: The proposed rule change would require increased reliance on biomass fuels from sources such as utility right-of-way clearance. This study describes some of the regulatory and operational issues related to utility right-of-way clearance, a major component of the supply of biomass from right-of-way clearance, and private tree care overall.

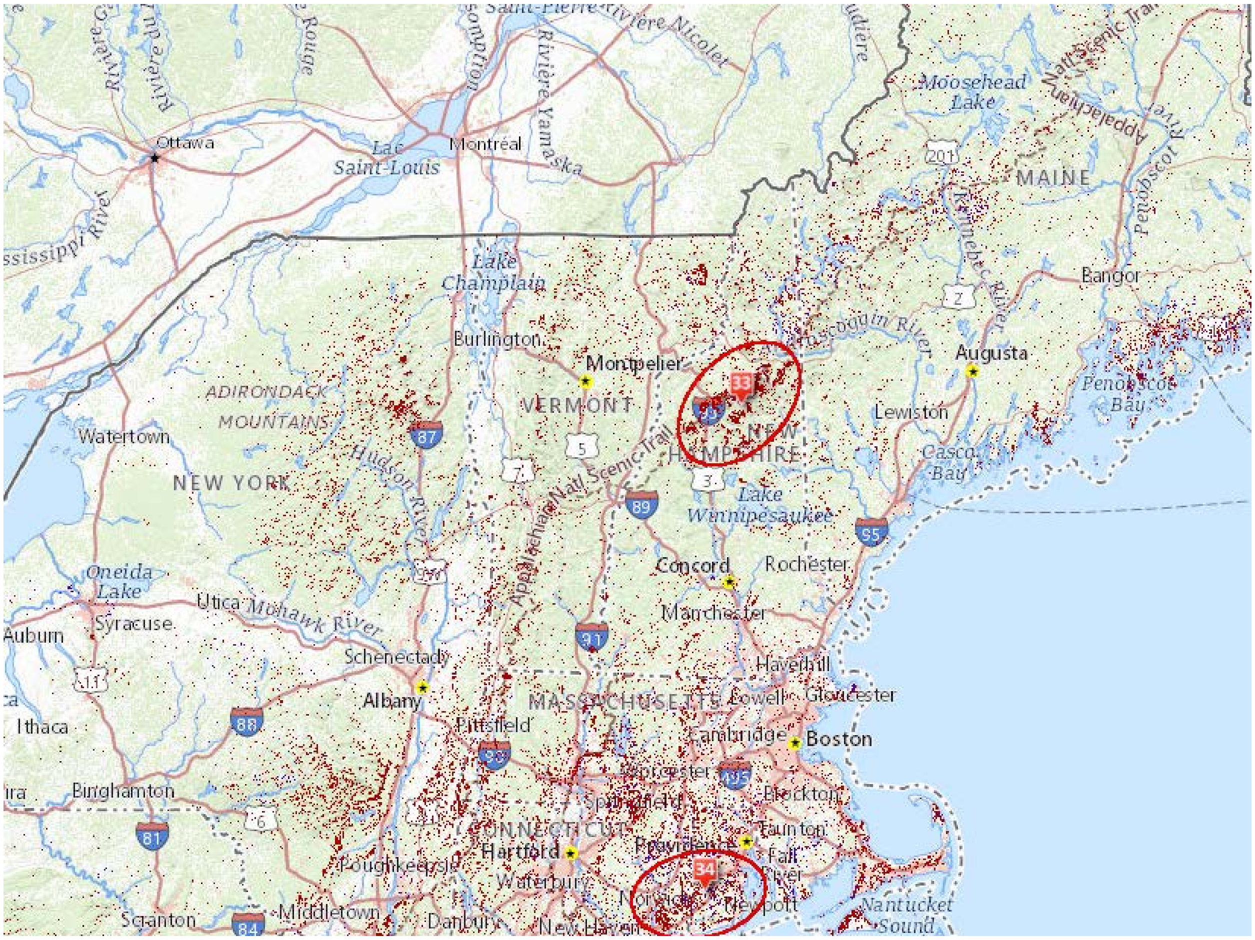
4.1 FACTORS AFFECTING FOREST SALVAGE AVAILABILITY

County-level data is not available on biomass sourced from forest salvage operations associated with federal or state disaster or forest health emergency declarations or orders. While it is clear that the quantity of material generated from forest pest and disease outbreaks can be significant at times, there are hurdles associated with integrating this material into a reliable supply chain for a biomass generating unit.

One major source of biomass from forest salvage is tree removal associated with efforts to mitigate forest pest and disease outbreaks. Some destructive forest insect pests in New England include the Emerald Ash Borer (“**EAB”**), Asian long horned beetle, and winter moth. The USDA Forest Service conducts insect and disease risk and hazard mapping to inform decision-making regarding forest pest prevention, suppression and restoration activities. The National Insect and Disease Risk Map[6] shown in Exhibit 8 highlights some specific areas of concern in New England.

[6] USDA Forest Service, National Insect and Disease Risk Map, https://usfs.maps.arcgis.com/apps/MapTour/index.html?appid=ade657567ff445d5bb3aaa7d898d9fb9

Exhibit 10. Distribution of forest pest disease risks from National Insect and Disease Risk Map



Red circled areas show where outbreaks of Emerald Ash Borer (33) in areas of New Hampshire present risks, while Rhode Island and eastern Connecticut are experiencing Winter Moth outbreak (34).

The Massachusetts RPS requires that eligible forest salvage biomass come from areas where the USDA APHIS, the USDA Forest Service other state or federal agency has issued a declaration, rule, or order. Land management agency responses to forest insect and disease outbreaks in New England and New York differs from that in regions of the U.S., such as the Rocky Mountain region, where the response to pests such as the mountain pine beetle has been to fund large-scale removal of affected trees on federal lands. In New England, the response by agencies such as APHIS to some high-profile tree pest and insect disease outbreaks has been to increase monitoring on public and private land and issue quarantines that limit movement of wood from affected trees between different jurisdictions (e.g., counties) to reduce the potential for spreading disease or insect infestations. The quarantines vary for different pests and diseases and may or may not affect movement of biomass products between jurisdictions.

Wood movement quarantines can affect the availability of biomass that otherwise would be an eligible biomass fuel under the Massachusetts RPS rules. Movement of ash tree logs is seasonally limited in both Vermont and New Hampshire (Vermont Department of Forests, Parks and Recreation, 2018), (Kyle Lombard, NH Division of Forests and Lands, Piera Siegert, NH Department of Agriculture, Markets & Food, 2018). While chipping affected ash trees for boiler fuel is sanctioned as an acceptable strategy for managing ash trees in some locations (e.g., Vermont), the removal of individual or groups of affected trees does not consistently generate enough biomass segregated from other, unaffected tree species to fill a truckload that can be transported to a biomass facility. Aggregation of ash logs at a central storage and processing site may run afoul of quarantine restrictions on ash log movement. Therefore, it is logistically difficult for tree maintenance companies to meet conditions attached to movement of ash logs and cost-effectively make them available as biomass fuel. There also appears to be an administrative hurdle for suppliers associated with determining whether the biomass can comply with the RPS eligibility requirement. The pathway and responsibility for compliance is not readily apparent or it may be considered to be too high an administrative burden.

Another major source of forest salvage material is wood salvaged from weather events (e.g., ice storms or other major weather events). Some locations in North America experience at least some ice accumulation every 1 to 2 years on average, though most areas have return intervals of 5 years or more (Bragg, Shelton, & Zeide, 2003). Although ice storms with minimal ice accumulation do not result in much damage to the forest, severe ice storms can result in significant forest impacts. Major ice storms are estimated to occur about every 5 years in Northern New England States (Smith & Musser, 1998). This timeframe is consistent with recent disaster declarations, as data from FEMA shows there have been 4 severe ice storm events in the North East since 1998 (FEMA, n.d.). Several of these ice storms caused catastrophic damages over very large areas. For example, the ice storm in 1998 affected 17 million acres of forestland in NY, VT, NH, and ME (Miller-Weeks, Eagar, & Petersen, 1999). Although the amount of damage to the forests within the area varied greatly, on a regional level it was estimated that approximately 12% of the trees with diameter at breast height (DBH) ≥ 5” were severely damaged and unlikely to survive.[7] The 2008 ice storm was reported to have a similar effect on the trees and forests in the region (New York State Department of Environmental Conservation, n.d.).

Other severe weather events such as hurricanes can also impact forests and result in downed trees, however they do not typically result in large scale impacts in the northeast region, since the amount of damage to the forest is generally correlated with the intensity. Hurricane wind damage to forest is therefore more likely to occur in the southeast where hurricanes are both more frequent and have higher intensities.

Major ice storms can generate massive amounts of wood biomass. However, the timing of the cleanup is dictated primarily by safety and infrastructure considerations, rather than material

[7] DBH stands for diameter at breast height, and is a standard metric used to categorize tree size and maturity.

recovery and use. Most of the material generated from storms and other severe weather events is removed in the months following a disaster, and the window for recovering and using biomass before significant deterioration in quality is limited to a period of months, not years. In the years following a storm, the amount of biomass generated from cleanup and recovery is more limited and it is more difficult to verify that cleanup material is associated with a particular disaster declaration. These factors, combined with the unpredictable timing and geographic scope of major weather events, limits the extent to which severe weather events can contribute to a predictable resource for a biomass energy facility that has a consistent, 24/7 demand for fuel if it is operating as a baseload unit. That said, any biomass energy facility is well-served to increase their readiness to respond to severe weather events to take advantage of possible periods where high volumes of low-cost wood fuel that may be generated over a short timeframe as a result of these events. Preparation can include developing contractual relationships with cleanup contractors and planning for overflow material storage and reclamation.

In part due to the barriers described previously, use of forest salvage material in the Massachusetts RPS historically has been very limited, with only 11,880 tons of fuel reported used from this source over the 5-year period from 2013 to 2017 (MA DOER, 2019). This represented less than one percent of biomass fuel used by facilities participating in the Massachusetts RPS during this period. Because of the intermittent nature major weather events and the constraints on practical use of wood salvaged from pest and pathogen outbreaks, the amount of eligible material from forest salvage operations is likely to continue to be small and/or intermittent in nature. Clarification or modification of the rules and the eligibility process may increase the availability of wood biomass from these sources while preserving the intent of the RPS rule.

4.2 UTILITY RIGHT-OF-WAY VEGETATION CLEARING AND BIOMASS

The resource analysis includes estimates of biomass availability from activities such as utility right-of-way clearance, private tree trimming, and road right-of-way maintenance. This type of material historically has made up, on average, 12 percent of biomass for participants in the Massachusetts RPS between 2013 and 2017.

There are a number of considerations regarding the potential availability of this resource for use as a fuel for biomass energy plants. The Federal Energy Regulatory Commission ("**FERC**") sets regulations that govern the minimum vegetation clearance distance (**"MVDC"**) that is required to be cleared of vegetation around transmission lines with various capacities. The most recent version is FAC-003-04.[8] The regulations have been updated in the way they calculate the right-of-way clearance values over time, and there have been some marginal changes in recent years. Any major changes in the extent of utility right-of-way clearance activities are likely to be made in response to a FERC enforcement action in response to utility service interruptions. FERC does

[8] FERC Order FAC-003-04 Transmission Vegetation Management. https://www.ferc.gov/industries/electric/indus-act/reliability/vegetation-mgt/fac-003-4.pdf

not specify how transmission entities conduct their management. Transmission entities prepare operational plans for managing right-of-way areas, and typically these entities work with contractors to perform much of this work. The amount of vegetation generated from these activities depends on where the transmission entity is in terms of its cycle of vegetation clearing. Contractors typically do a significant amount of vegetation management when areas around lines are initially cleared and then on a periodic basis thereafter. As such, a decade or more time may pass before enough biomass builds up to justify a repeated mechanical treatment. In between these years, contractors typically do smaller amounts of tree removal for maintenance purposes or use herbicidal control of vegetation. The amount of biomass generated during the initial clearing or in later years when vegetation has regrown can be significant, and contractors will seek to find suitable markets for any resulting biomass, including the bioenergy industry. In strategic areas where significant quantities of biomass are available, the market downturn for end-users in recent years may make this material available at a discount as contractors struggle to find outlets. For maintenance jobs that involve removal or trimming of individual or groups of trees, that material may be lopped and scattered or chipped and blown on-site, especially when the quantities are limited or there are no nearby markets.[9]

The biomass availability is dictated by vegetation plan implementation, not biomass markets. As such, although this resource may present an opportunity for low-cost biomass in some areas of the Northeast, any real estimate of quantity in a specific region requires a full evaluation of where different entities stand in terms of implementation of their vegetation management plans. If more of this material is used for bioenergy in future years, issues will need to be addressed during the ramping up phase to get the supply chain and quality control process in place to attempt to coordinate vegetation management cycles with biomass facility needs to the extent it can be done without jeopardizing safety and utility operations.

Overall, biomass generation from right-of-way clearing and maintenance activities has the potential to make up a significant component of a biomass supply for a generation facility, but by itself is not a sufficient supply source due to the factors described above. Particularly at times when a large supply of this material is available in a particular area, the cost may be relatively low making it an attractive biofuel supply. However, the variability in the quality of material can detract from up-front cost savings in the purchase price. It is also worth noting that if there is increased demand for biomass from utility right-of-way clearing associated with implementation of the proposed MA RPS rule, it is likely to diminish any discount in cost of this material.

[9] Markets for right-of-way clearing and maintenance materials include mulch and firewood, in addition to biomass fuel.

5 SUMMARY OF KEY FINDINGS AND CONCLUSIONS

This section summarizes key findings and implications of the analysis for the feasibility of continued operation of existing biomass generation units and addition of one or more new facilities in the future under the proposed RPS rule changes.

5.1 ADEQUACY OF SUPPLY TO MEET PROJECTED DEMAND

A common industry benchmark used to assess the adequacy of a biomass resource to support a biomass energy project is that two times (2x, or 2:1 ratio) the project's fuel demand is available in the supply shed. The 2:1 supply/demand ratio accounts for variability in annual biomass generation associated with variation in forest products industry output, fluctuating demand from other biomass markets, and long-term industry trends towards improved conversion efficiency that reduce overall biomass residue supplies.

The total energy content of eligible biomass resources within the New England region is 1.5 times the annual energy input content required by the generation units considered as candidates to participate in the Massachusetts RPS, assuming the facilities run at historic levels. This supply/demand ratio does not account for use of eligible biomass sources by other biomass electric generating units that are located in the New England region but are not being considered as candidates for participation in the Massachusetts RPS. There are multiple, other large biomass electric generating units in New England that compete for readily available low cost resources such as mill residues. Therefore, the effective supply/demand ratio for eligible biomass resources is likely significantly lower than the 1.5 value.

These results suggest that on a regional basis, the available eligible biomass supply presents significant risks related to supply reliability and price volatility, again assuming the candidate facilities operate at historic levels using only feedstocks eligible under the proposed RPS rules.

The feasibility and economics of serving the Massachusetts RPS under the proposed rule changes is impacted by the shift in both the quantity and composition in the eligible resource base. Forest residues, whole tree chips from forest thinning, and most biomass from land use change (except from forest to agricultural land) would not be eligible fuels unless the facilities meet a stringent efficiency requirement. Past Massachusetts RPS data indicates that facilities in New England participating in the Massachusetts RPS obtained 38 percent of their biomass fuel from forest residues during the period from 2013 through 2017. Annual estimated forest residue generation in New England based on the DOE Billion Ton report is 8.8 million tons per year, or 2.3 times the total quantity of forest salvage and non-forest residues eligible for participation in the Massachusetts RPS under the proposed rule changes. These facilities also secured 26 percent of their fuel from land use change. An estimated 9 percent of the biomass generated from land clearing was associated with conversion of forest to agricultural land use, the only source of eligible biomass fuel from land use change under the proposed RPS rule changes. This means that more than 90 percent of the biomass generated from land clearing would also be ineligible under the proposed RPS rules. In all, more than 60 percent of the biomass fuel sources used historically by biomass energy producers serving the Massachusetts RPS program would be ineligible for candidate biomass facilities unless the facilities meet the stringent efficiency requirements. However, there is a limit in how much of thinning feedstocks could be used because at some point, a facility using only thinnings would not meet the lifecycle GHG emission reduction requirements.

While the fuel composition for the candidate facilities may not be identical to that used by existing Massachusetts RPS biomass participants, it is fair to suggest that the candidate facilities also rely heavily on relatively low cost forest residues and material from land clearing. Each of the candidate facilities would need to make significant changes in their procurement practices and likely would need to work with a larger number of smaller fuel suppliers, increasing the logistical challenges and costs for their biomass fuel.

The biomass supply/demand ratio for individual candidate facilities within the New England region will vary from the regional value due to the geographic distribution of eligible biomass resources and end users. There can be circumstances where it is appropriate to relax the typical 2:1 supply/demand ratio. An example may be where a specific facility has a combination of long-term contracts and access to a wide variety of supply sources that can help defray risks associated with annual variability in annual biomass markets. However, the proposed RPS changes limit the number and variety of supply sources/suppliers that facilities will need to negotiate with for biomass supplies.

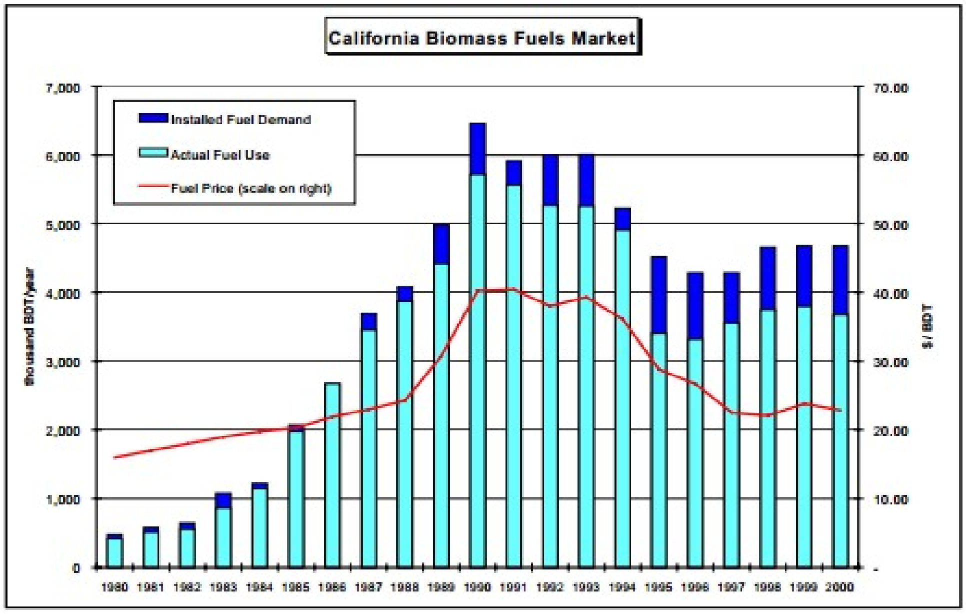
5.2 BIOMASS PRICING

The analysis results show that the estimated delivered price of fuel for the resources considered in this study are in most cases significantly higher than current published biomass fuel costs, although they are generally within the range of the higher prices experienced within the last several years. In nearly all cases, the size of the supply shed from which candidate facilities would need to secure fuel is significantly larger than what biomass generation units typically draw from, increasing biomass transportation and overall delivered costs.

A site-specific assessment of competition and other market factors that would permit a more refined estimate of fuel costs for each candidate facility was outside the scope of this analysis. Price estimates do not capture all future market volatility that could occur should the proposed RPS rules take effect. These effects will differ spatially across the New England region but also temporally, as major market players enter and leave the marketplace in response to changes in biomass fuel availability, cost and other factors. There are no recent events that provide a complete analogy to the impacts that implementation of the proposed rules would have in New England biomass fuel markets. However, the biomass market development in California in the 1980s provides a case study for price increases in response to large increases in biomass fuel demand relative to the available supply of fuel.

Exhibit 11 shows how prices changed in response to the dramatic growth of the industry in California. During the period from 1980 to 1990, there was a 13-fold increase in demand, which resulted in a 2.5 fold increase in wood fuel prices (at the peak price period in 1990). The price point did adjust downward over time as additional supplies entered the market.

Exhibit 11 Wood Fuel Price Implications of Increasing Demand in California: 1980 to 2000



Source: Morris, Gregory, NREL, Biomass Energy Production in California: The Case for a Biomass Policy Initiative, November, 2000, On-line: *http://www.nrel.gov/docs/fy01osti/28805.pdf*

The proposed MA RPS policy changes would significantly constrain eligible biomass resources if all of the candidate facilities were to participate in the Massachusetts RPS market. The corresponding restriction in biomass supplies (due to the more stringent fuel eligibility requirements) is not as large as the massive increase in demand in California in the 1980s. Nevertheless, unexpected price volatility in initial years after new RPS rules take effect could still occur.

5.3 KEY TAKEAWAYS

Key takeaways from the analysis, based on the results, include:

- None of the candidate electricity generation facilities is likely to be able to meet a 50% overall efficiency requirement,[10] so participation in the Massachusetts REC market will require them to secure 95% of their fuel from non-forest residues and forest salvage;
- Restricting usage to these fuel categories significantly reduces the overall biomass resource and the number of parties that facilities would be able to secure fuel from;
- The ratio of supply to demand for the eligible biomass resource presents significant risks to the candidate facilities in terms of consistent availability of biomass fuel if all of the candidate facilities continue to operate at historic or increased dispatch levels;
- Because of the reduced supply of biomass, the size of the supply radius that the candidate facilities would need to draw from to meet their fuel requirements has significantly increased compared to typical supply sheds that similar facilities draw from;
- The modeled price of biomass for facilities is in most cases higher than current prices due to the increase in transportation costs, but except for a few cases is in line with the higher historical market values for the U.S. Northeast experienced as recently as 2015; and
- The increased supply radius can have unpredictable impacts on supply reliability and cost implications for biomass energy facilities.

The last bullet point in the above list is perhaps the most significant finding. It is possible that impacts of competition and increased supply logistics management could combine to make future biomass costs significantly higher than output from the cost model results. However, the implications of supply interruptions can have very significant impacts on the ability of the candidate facilities to reliably participate in the Massachusetts REC market. These risks suggest that smaller facilities, with a lower fuel requirement, would fare better in terms of management of fuel supply costs under the proposed RPS rules.

[10] The conversion efficiency for biomass power generation plants is typically around 21-26% (corresponding to a heat rate of 12,000 – 15,000 Btu/kWh, HHV). Even highly efficient plants would not be able to achieve a 50% overall conversion efficiency using existing technologies, unless a material amount of the thermal energy generated was used in a co-generation or combined heat and power facility. This may be possible in a ‘thermal-led’ application where a very large and highly-concentrated thermal demand is immediately proximate to the plant; however, the power-led existing biomass facilities by virtue of their location are ill-equipped to access the volume of thermal load needed for such a substantial boost in their efficiency. The lack of response to this opportunity historically (with a 60% efficiency threshold) is one indicator of the low likelihood of achieving such efficiencies. Further, attempts in recent years by several of the larger biomass-to-electricity facilities in the region to attract adjacent thermal load have yet to be successful under times of more favorable economics, and we have not seen any indication from existing plant owners that a 50% threshold is technically feasible.

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Appendix A. Biomass Quantity and Cost Data

Biomass FOB Cost

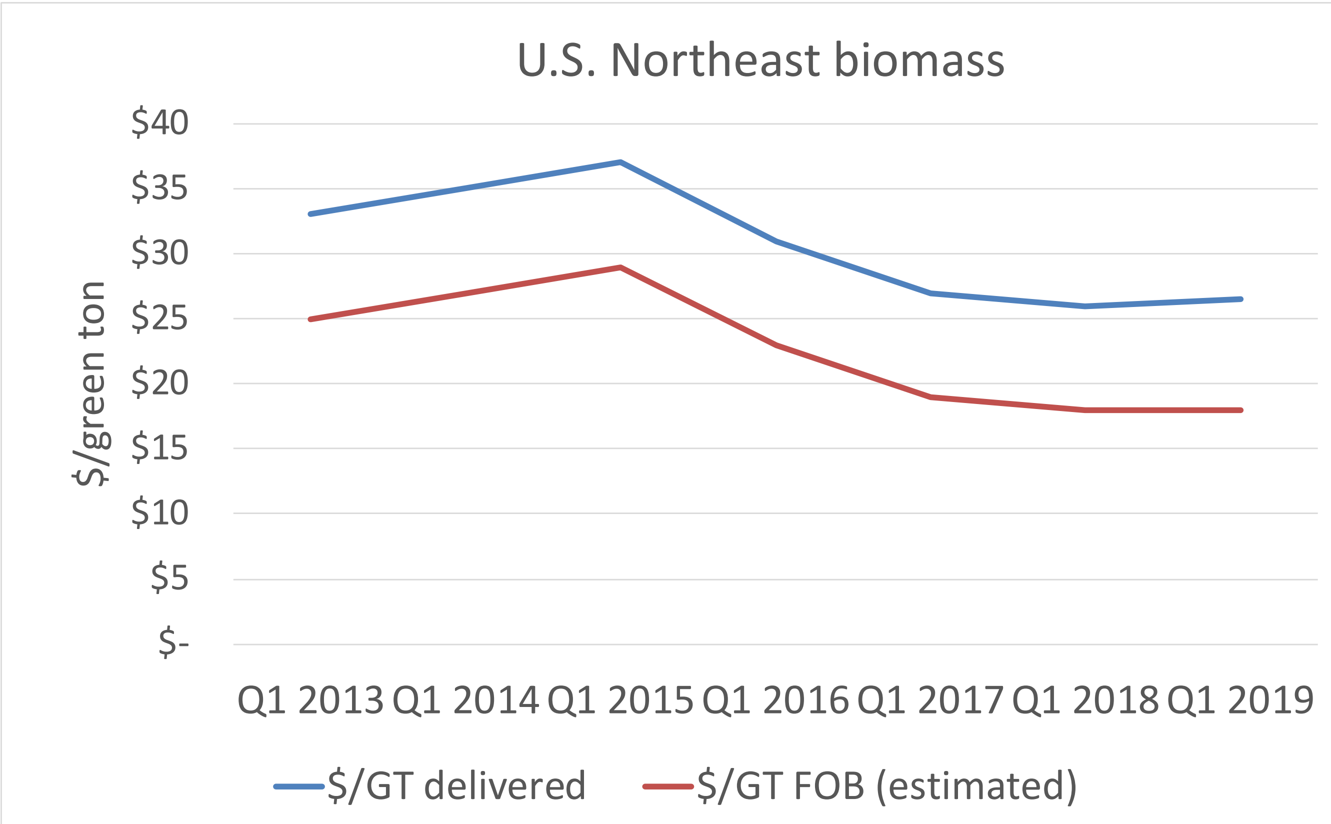
Material category	Material type	FOB price including stumpage ($/green ton) (note 1)	Moisture content (% wb) (note 2)	Heat content (MMBtu/dry ton)	FOB Price ($/MMBtu)
Residues	Orchard trimmings	$18.00	50%	17.0	$2.12
Residues	Forest salvage	$0	50%	17.0	$-
Residues	Tree trimming, right-of-way clearing	$13.50	45%	17.0	$1.44
Residues	Mill residues	$18.00	45%	17.0	$1.93
Residues	Land clearing	$18.00	50%	17.0	$2.12

Notes: (1) Stumpage is a price paid to the landowner for the right to remove biomass from land. Landowners will typically not charge for forest salvage wood and it can be obtained for the cost of transportation. Therefore it has an FOB price of $0 per ton. (2) Moisture content percentage is provided on a wet basis (wb).

Transportation cost assumptions

Truck payload (as-received tons/load)	30
Transport cost ($/ton-hour) at $3/gal diesel	$4.13
Average road speed (mph)	40

Published delivered and estimated Freight on Board (FOB) biomass prices for U.S. Northeast



Q2 2019 delivered price: $26/green ton. Estimated FOB cost: $18/green ton

Delivered price source: North American Wood Fiber Review. Woodprices.com

FOB price estimated by deducting round-trip trucking costs at $0.10/ton-mile (40 one-way miles)