TO CHIP OR NOT TO CHIP:
TIMBER RESIDUE SUPPLY IN MICHIGAN'S UPPER PENINSULA

By

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ABSTRACT

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Timber residues are one potential feedstock that can contribute to meeting legal mandates for renewable electricity and liquid transportation fuels. Michigan's Upper Peninsula produces significant timber and could potentially supply timber residues as a bioenergy feedstock. Timberland ownership is concentrated in the hands of relatively few large firms and other entities. This thesis uses interviews with managers of the largest private and public timberland holdings in the Upper Peninsula to elicit how their managerial objectives affect managers' willingness to supply residues for chipping by loggers. A breakeven price analysis incorporating transport costs from commercial forest land generates a set of supply functions for timber residues within 100 road miles of two major pulp mills in the Central Upper Peninsula.

Results from interviews indicate that residue supply will come from corporate, profit-driven firms, rather than from conservationist or publicly owned timberlands where amenity goals take precedence over timber residue supply. A breakeven price of $36-39 per green ton of biomass would be needed to supply 200,000 tons of timber residues under the most likely harvest scenario. Key costs hinge on the harvest method and transportation distance from the forest site and to demand sites. Regions with lower chipping costs like those that utilize whole tree harvesting over the cut-to-length system and those that have more dispersed demand points have better potential for residue supply.

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To God be the glory.

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KEY TO ABBREVIATIONS

AFM: American Forest Management

CFP: Commercial Forest Program of Michigan

CLC: Compass Land Consultants

FRTC: Forest Residues Transportation Costing Model

GIS: Geographic Information System

KEAs: Key Ecological Attributes

MDNR: Michigan Department of Natural Resources

MGF: Michigan Geographic Framework

NEPA: National Environmental Policy Act

PMH: Productive Machine Hour

REIT: Real Estate Investment Trust

ROI: Return on Investment

SMH: Scheduled Machine Hour

TNC: The Nature Conservancy

TIMO: Timberland Investment Management Organization

UP: [Michigan's] Upper Peninsula

USFS: United States Forest Service

1. Meeting Bioenergy Demand with Timber Residues

Timber residues are one potential feedstock that can contribute to meeting legal mandates for renewable electricity and liquid transportation fuels. As a byproduct of timber harvest, this feedstock comes at low marginal cost. Like corn stover and other residues, timber residues avoid many of the negative consequences associated with bioenergy crop production, including land-use change associated with converting agricultural land into dedicated bioenergy cropland and its resulting impacts on food prices (Gurgel et al., 2007; U.S. DOE, 2011). Residues also tend to be the cheapest source of cellulosic biomass. Corn stover is available for as low as $30/ton at the farmgate (Graham et al., 2007) or for $43-$52 per dry ton delivered (Perlack and Turhollow 2003). For corn stover, these numbers can rise as high as $63 and $75 per dry ton delivered when additional costs such as nutrient replacement and corn production costs are included (Brechbill et al. 2011). While corn stover as a biomass source is limited by the level of corn produced in any given year, at current yields corn stover has potential to make a significant contribution. Wheat straw residues provide another source of biomass but have other more economically attractive uses, such as livestock bedding, that detract from the quantity that could be supplied under current circumstances. By contrast, timber residues, an oft-overlooked supply source, have potential to be supplied at high levels while also having limited competitive value elsewhere.

Timber residues are defined as the remaining tops and branches that are left behind after a stand thinning or timber harvest. A stand thinning is a forest management practice where slower growing or defective trees are removed from the forest area (timber stand), to provide more space for the remaining trees to grow, resulting in higher availability of water and soil nutrients to those trees that remain. A timber harvest is the scheduled removal of a selection of mature trees from the timber stand to be cut and sorted into varying grades and eventually transported to a mill. Timber residues are a byproduct of this existing timber market and are most commonly left on the ground at the site of harvest or delimbing (either in the stand or at a landing where logs are gathered). As a byproduct of an existing production chain, these residues are relatively low cost and low risk compared to other sources of renewable energy (Hughes, 2000).

Figure 1: Timber Residues near Escanaba, MI, August 2014 (photo S. Swinton).

The quantity of residues available depends on the level of timber removals in any given year. In 2016, the U.S. Forest Service reported that growth of timber stock continued to exceed removals, despite the area of timberland in the United States remaining relatively stable (USFS 2016). More timber leads to the possibility of higher harvest levels, which leads to more residues. Several studies have estimated that significant amounts of timber residues (both in-forest and sawmill residues) are available throughout the United States (Galik et al., 2009; Mueller et al., 2009; Tyndall et al., 2011). Most famously, the recent Billion Ton Report (2016) used forest inventory and analysis data to create an empirical model to estimate potential forest residues and thinnings available from all current productive, managed timberland in the conterminous United States. They reported that at prices of up to $60 per dry ton, 103 million tons per year of biomass resources are potentially available from timberlands in 2017 (U.S. DOE, 2016).

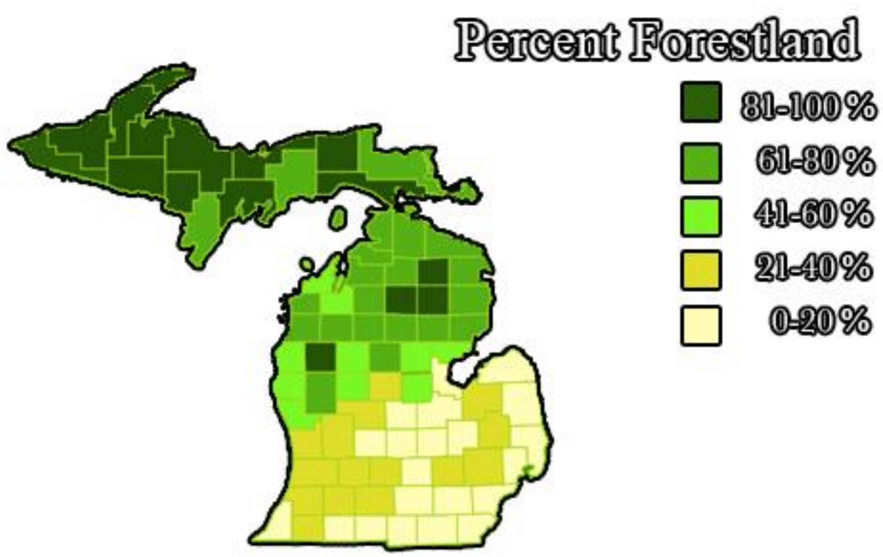
However, while this estimate provides a sort of upper bound for the quantity of residues that could be physically removed under optimal market conditions from timber sources in the United States, it does not take into account differing harvest motivations among timber managers and how they may affect quantity supplied.

1.1 Timber Residues in Michigan

Studies of drivers of residue supply cover much of the Midwest (Aguilar et al., 2014; Becker & Eryilmaz, 2013; Bergtold et al., 2014), but Michigan and Wisconsin are rarely included. Most studies of the region focus on non-industrial private landowners (Butler et al., 2010; GC et al., 2011; Dulys et al., 2016). Little attention has been given to residue harvesting behavior and motivations of timber managers of large-scale corporate, conservationist, and public timberland ownerships, especially in the Northern Tier of the United States. Much more attention has been given to the Southern United States (Joshi et al., 2013; Joshi et al., 2011; Gruchy, 2012; Aguilar et al., 2014), which comprise about 80% of total forestland in the country (NRC, 2011). Even in this region, however, the focus continues to be on non-industrial private landowners. This gap is conspicuous, given that these large-scale holdings make up substantial portions of the nation's productive timberlands.

Over 20 million of Michigan's 37.4 million acres are forested (Figure 2). Of this forestland, timberland makes up 95% (19.3 million acres), 45% of which is in the Upper Peninsula (UP), despite the UP making up only 29% of the land in Michigan (Pugh et al, 2016). Timberland includes any forestland that is capable of growing 20 cubic feet of commercial wood per acre per year.

Figure 2: Percent of Michigan Forestland by County in 2014[1]



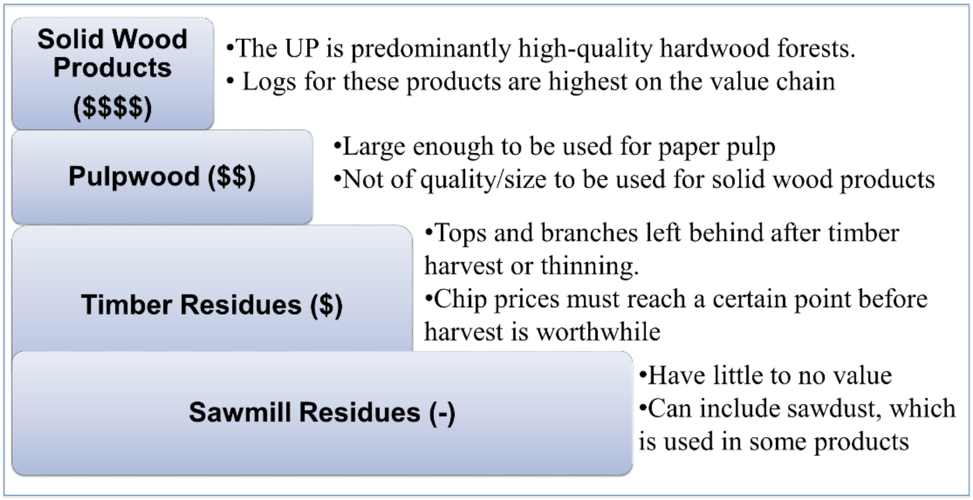
[1] Data Source: Michigan Forest Products Council (2014)

Over half of UP timberland is privately held (63%), while the remainder is held by the federal (13%) and state (24%) government. Private holdings include those of large corporate firms, conservationist or institutional organizations, and non-industrial private landowners. Federal and state timberlands include the areas of federal and state forests that are designated for timber harvest (Mueller et al. 2009). While there are thousands of private landowners in Michigan, landholdings are highly concentrated among a few firms. Indeed, the six firms I interviewed for this study hold 1.5 million acres—about a third of the UP's private timberland.

Large-scale private timberland owners fall into three broad categories: Timberland Investment Management Organizations (TIMOs), Real Estate Investment Trusts (REITs), and other large corporate or institutional ownerships. A REIT is a company that owns or finances income-producing real estate, such as timberland. REITs typically pay out all their taxable income as dividends to shareholders, and shareholders pay the income taxes on those dividends. A TIMO is a management group that aids institutional investors in managing their timberland investments. A TIMO acts as a broker for institutional clients. The primary responsibility of TIMOs are to find, analyze and acquire investment properties that would best suit their clients. Once an investment property is chosen, the TIMO is given the responsibility of actively managing the timberland to achieve adequate returns for the investors. In short, TIMOs and REITs both manage land to turn a profit for an owner or shareholder, while other large corporate firms are often family-owned timberland management firms or a conservationist or environmental organization. Among these large timberland ownerships there are differing managerial objectives, the most obvious divergence in goals being between the conservationist or environmental groups—who may still do some timber harvesting to meet various conservationist goals—and firms involved largely in timber harvesting activities for profit. Like non-industrial private timberland owners, these large timberland ownerships each have their own specific goals and objectives for the timberland they own or manage. These goals influence their treatment of residues and whether or not they include residues in a timber sale to a logger. If management is indifferent to removal, the logger chooses whether to chip and sell residues.

For those firms involved predominantly in timber harvesting activities (TIMOs and REITs), there is a clear supply chain for forest products. Figure 3 demonstrates this hierarchy of timber products in the Upper Peninsula. Broadly, there are two types of products that come out of the timber stand: High-value sawlog products and low-value residues, which can include tops, branches, sawdust from mills, and in some cases larger trees that fall below certain quality or size thresholds. Sawlog products include solid wood products like high-value sawtimber, veneer logs, and other logs that pass a certain size and grade threshold, as well as smaller logs and those that are damaged or of lower quality that are harvested as pulpwood for use in making paper. Trees that are smaller still (that are not left to grow or are unsuitable for pulpwood) are referred to as ‘whole-tree biomass’ and can be chipped with other residues, used as firewood (in the case of some public lands), or left to rot. The remaining biomass located at the timber stand (e.g. tops, branches, bark), are referred to as timber residues. In the Upper Peninsula, these residues can be gathered and processed at the timber stand into woodchips and sold to pulp mills, where they can be co-fired with coal to fuel the production of paper pulp. Sawmill residues that are generated at the mill where the timber is further processed are the lowest value product in the timber value chain. These internally-generated residues can also be co-fired with coal to fuel paper pulp production.

Figure 3: Hierarchy of Timberland Products in Michigan's Upper Peninsula



Solid wood products have a wide range of value depending on size, quality, region, and species. In general, sawtimber and veneer logs are several times as valuable as pulpwood. The standard metric of value for unharvested, standing timber is the "stumpage price" that a logger would pay a landowner for the right to harvest that tree. Stumpage prices typically do not include residue harvest unless residue stumpage is made explicit. The average 2017 stumpage prices for sawtimber in the southern United States ranged from just under $20 to over $30 per ton. Pulpwood stumpage prices fall much closer to the $10 per ton range (Timbermart, 2017). In contrast, residue stumpage prices range anywhere from $2 to $5 per ton. As the nearest product on the forest value chain to timber residues, it is possible that pulpwood will face some competition when residue prices are high. This has many implications for the timber value chain, including potential shocks to the paper industry that are not explored in this thesis. Given the relative nearness in value, however, there is huge potential for additional biomass supply should trees previously harvested for pulpwood become available at residue prices or should energy prices rise (Du and Runge, 2014; Zhang et al., 2010).

The remaining thirty-seven percent of timberland in the Upper Peninsula is held publicly, in national or state forests. These lands are managed by federal or state employees of the U.S. Forest Service (USFS) or Michigan's Department of Natural Resources (MDNR). Managers of these public forests follow their respective forest plans, pursuing various environmental goals (e.g. habitat creation and preservation, fire prevention, and forest restoration), and conducting timber harvests as allowed by the forest plan. Given the holding size and influence of these large-scale firms, organizations, and public forest managers, it is clear there is substantial potential for timber residue supply by these entities.

2. Objectives

The goal of this study is to identify and explore the conditions and circumstances under which large-scale timberland managers in the Upper Peninsula would supply residues for energy purposes. While the significance and sheer size of the timber industry in Michigan makes it an attractive place to conduct this study, the unique large-holder ownership structure of timberland in the Upper Peninsula creates an economic environment in which one firm or group (or a few medium-size or larger firms), can have a large impact on the timber market and by extension, the biomass market. Given the significant supply potential of these managers, I set out to gain a better understanding of the firm-level goals and market conditions that play into the decision to supply timber residues by answering the following research questions:

1. How do managerial objectives vary across different types of timberland management structures?
2. Given their managerial objectives, under what conditions would corporate timberland managers or institutional land managers **make timber residue biomass available** for chipping and sale to a mill?
    a. Under what conditions would loggers choose to engage in chipping activities to supply biomass for energy?
3. How much timber residue biomass would large-scale timberland managers be willing to supply from Michigan's Upper Peninsula as the market price of residues increases?

3. Conceptual Model

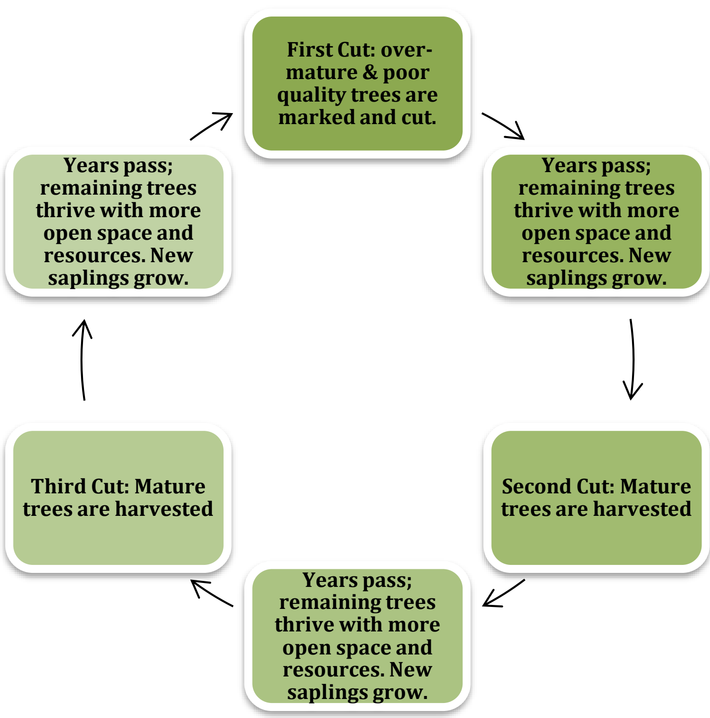
3.1 Objectives of Timber Managers

To properly construct the conceptual framework for this study, a basic understanding of the timber production process is needed (Pattanayak et al., 2002). As introduced in the first chapter, there is a hierarchy of timber products ranging from high value (e.g. sawtimber, veneer logs) to low value (e.g. timber residues, sawmill residues). Aside from revenue from timber products, timberland managers may seek to produce non-timber amenities. Each of the organizations explored in this thesis manages their land to maximize utility through these different income and amenity goals, with the weight placed on each goal differing across managers (Beach et al., 2005). These preferences directly influence landowner willingness to supply and the subsequent quantities supplied from each.

Income from timberland in the case of large-scale holdings comes from many activities. In the case of a timber REIT, an "owner" (investor) might see gains through dividends, rising asset value, or some other form of payout organized via a broker or mutual fund participating in a private REIT's offering. An "owner" (institutional investor) involved with a TIMO earns a target rate of return. In this way, the TIMO operates similarly to other private timberland owners that might hire a manager to achieve a certain level of income on their behalf.

For REITs, TIMOs, and other large corporate firms, the manager's activities at the forest level impact the level of income or returns coming back to the owners. Figure 4 illustrates the general management cycle for timberland in the case of TIMOs, REITs, and other large private corporate managers. While time horizons for harvest differ across firms, the management cycle is largely the same. Managers of each firm work to balance growth of high-quality timber for later harvests with profitability goals in the near-term. This results in a cycle of harvests, thinnings, and growing phases targeting the highest-value makeup of each harvest across the management cycle of the stand. Each of these decisions impacts the outcomes of this cycle going forward, affecting growth and quality of the forest that is left behind. Within these decisions, the removal of timber residues play but one small part. Moreover, as residues are the lowest value product in the hierarchy, managers give the least attention to potential residue harvesting opportunities and the impact their timber harvesting decisions might have on residue supply in the future.

Figure 4: General Management Cycle for Natural Regrowth Forest



Amenity value from timberland in the case of large-scale timberland holdings also comes from many activities. Managers of public forestlands endeavor to maintain natural habitat for various species, preserve old-growth forests, and clear land to provide various other ecosystem services like carbon storage, scenic landscapes, and watershed services. Conservationist groups have similarly specific goals for the provision of forest amenities, such as wildlife habitat creation and maintenance.

Timberland managers seek most broadly to maximize utility from their timberland on behalf of the landowner. Utility might depend only on income derived from management activities, as in the case of the more industrialized timber management operation. In the case of non-industrial private forestland managers utility would depend on both timber income and output of non-market timber amenities (Beach et al. 2005). I identify three different categories of large-scale timberland managers in the Upper Peninsula, characterized by different preferences for timber income generation or amenity value creation:

1. **Corporate Timberland Managers**: These managers manage timberland intensively for timber production.
2. **Private Conservationist Timberland Managers:** These managers manage timberland intensively for a specific set of amenity goals.
3. **Public Timberland Managers**: These managers manage state and federal forestlands for both timber production and amenity goals.

I identify large-scale firms in each category and test their subsequent willingness to supply residues using interview data in chapter four.

3.2 Willingness of Timber Managers to Allow Residue Harvest

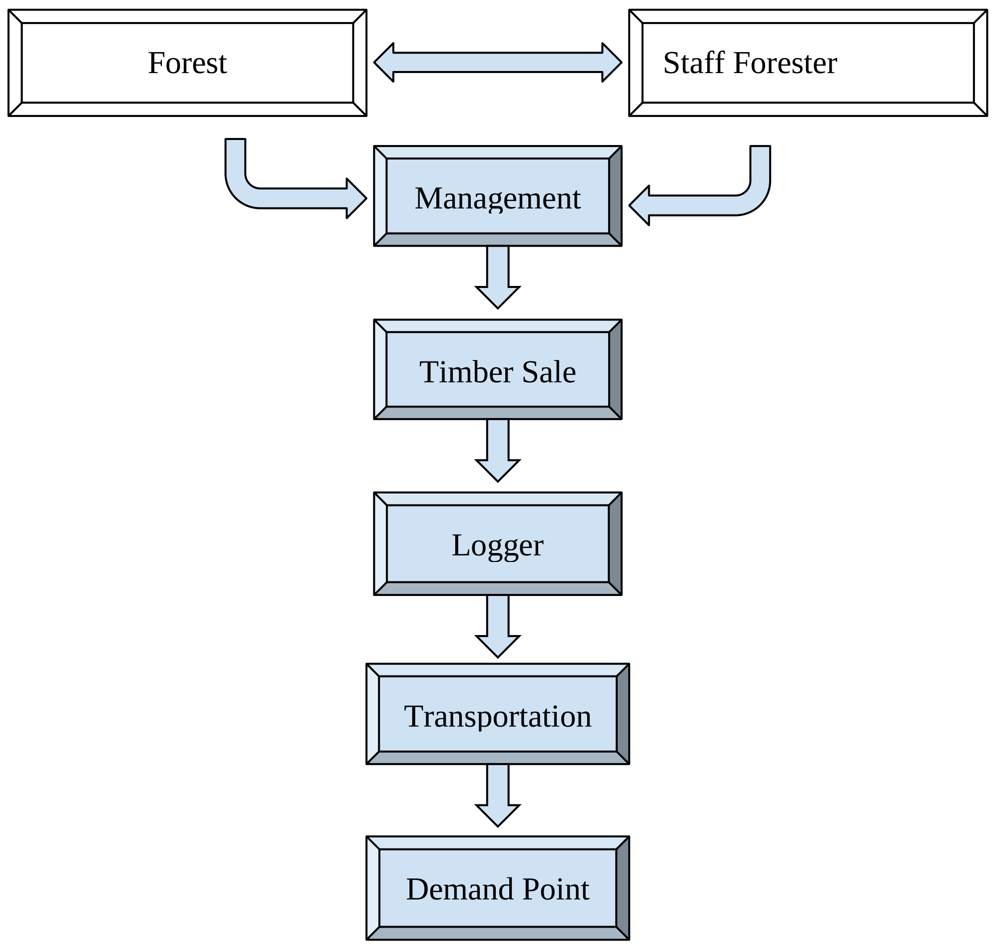
Income generated during a timber harvest depends on the hierarchy of timber products from the forest and their respective prices and harvest quantities. Veneer and sawlogs generate the most revenue per unit, followed by pulpwood, and—at the bottom of the hierarchy—timber residues. As a byproduct of current harvest or thinning, and given this hierarchy, the choice to harvest residues is secondary to existing harvest plans for timber. In a market where residues are more competitive with pulpwood, this dynamic could change.

To make the decision to harvest residues, timberland managers consider potential trade-offs. Depending on the way timber and residues are sold and the technology used to harvest and process them, these tradeoffs differ widely.

3.2.1 Timber Sales

There are two ways a firm can handle a timber sale with respect to timber residues: 1) through a stumpage sale or 2) through contract logging. These two methods differ mainly regarding timber ownership at any given point though the general process remains the same. The figure below depicts this process, which is followed by all managers interviewed in this study.

Figure 5: Overview of the Timber Sale Process



Given the sheer magnitude of the timberland managed by these groups, it is necessary that each management unit has a management plan. Across interviewees or area of lands managed, these differ considerably depending on management objectives and are developed both by the managers and with the help of consulting foresters or internal foresters on staff. Timber sales are facilitated as needed to meet the goals outlined in the management plan, which reflect the goals of the owner. The two types of timber sale are described below.

A stumpage sale is the sale of all marked standing timber in an area and is conducted at the stump while the timber is still standing, giving it its name. In the case of a stumpage sale, residues may or may not be included, depending in part on current market conditions and on the goals outlined in the management plan. If a firm includes residues in the stumpage sale, however, the logger purchasing the stumpage must own or have access to a chipper to process the residues, which is often prohibitive under current market conditions and results in fewer bids. A tree chipper is a portable machine used for processing tree limbs or trunks into smaller woodchips, as seen in Figure 6.

Figure 6: Chipper and Chip Van Operated by Carey Logging.[2]

[2] Image downloaded from http://www.call-carey.com/grinding-chipping in August 2017.

A “timber-only” stumpage sale occurs when residues are of negligible value or in cases where the manager wishes to leave residues on the forest floor to meet other management objectives.[3] When a manager sells all timber to a logger as stumpage, the price they receive from the logger is the negotiated timber stumpage price and the logger retains the right to the harvested timber.

In the case of contract logging, a logger is paid to harvest or thin the stand, processing the marked standing timber and residues as indicated by the manager. The manager may have the logger transport the timber to the final demand point or hire separate transportation services. They may or may not sell residues to the current logger or a different logger for processing in the contract, but will retain ownership of the timber regardless.

For simplification purposes in this thesis, I assume that managers sell all timber in the stand in the form of stumpage to loggers (on a price “per stump” basis), rather than engaging in contract logging. Whether residues are included in the stumpage sale depends largely on the manager’s goals and the type of harvest technology the logger uses to harvest the timber.

3.2.2 Harvest Technology

There are multiple harvest methods currently utilized on timberlands in the Upper Peninsula, and each has a different effect on costs and the future value of timber in the stand. The harvesting method refers to the processing technique used to bring the timber to the logging access road. Methods are differentiated by the amount of processing that goes into removal,

[3] Bill Gimler (Forest Timber Program Manager, USFS Hiawatha National Forest), interview by S. Klammer and S. Swinton on June 23rd, 2016, Gladstone, MI.

including delimbing and debarking. There are three methods that interviewees reported using to harvest timber in the Upper Peninsula: the cut-to-length method, the tree-length method, and the whole-tree method. In this study, I treat tree-length as another form of cut-to-length since the results for timber residue dispersal and gathering costs are the same. However, they are mechanically different processes, as described below.

Under the cut-to-length harvesting method, trees are felled, delimbed, and bucked (cut) into logs (e.g. veneer logs, sawlogs, pulpwood) wherever they are felled. Their residues are left in that spot on the floor of the forest stand. The logs are then moved (usually by forwarder) to the logging access road or roadside, where minimal additional processing takes place before they are transported to their final destination. This method can be used in all silvicultural systems and is increasingly popular.

The growing popularity of the cut-to-length system is the result of several appealing features. The system requires minimal roadside landing space since processing predominantly takes place within the stand, often also resulting in better sorting and storage of various wood assortments since it does not need to be handled again later or by another worker. Due in part to this and in part to more precise equipment, the chance of contamination and breakage of the timber is much lower than with other systems. In an area rich in high-value hardwoods that are predominantly selectively cut (like that of Michigan's Upper Peninsula), these benefits overshadow those of other systems. Under the cut-to-length system, however, residues are dispersed across the tree stand, making them more costly and difficult to retrieve for chipping. Retrieval of residues under this system involves another trip into the forest and high risk of damaging the forest floor, saplings, and standing timber left behind after a selective cut.

Figure 7: Cut-to-length Harvest

Under the tree-length method, trees are felled, delimbed, and topped in the stand. Cable or grapple skidders are then used to move the delimbed tree to the landing where the timber is processed. The tree-lengths are then bucked (cut) to length and sorted into pulpwood and sawlogs at the landing, or are left tree-length to be transported to and processed at the mill. This method is most often associated with clearcutting and results in residues remaining distributed across the stand, much like in the cut-to-length system. If the logger is cutting the timber to length before final transportation begins, this method will require a larger landing.

Under the whole-tree method, trees are felled and transported to the landing by cable or grapple-skidders with branches and tops intact. Additional processing is done at the landing. This eliminates the need to go back into the stand to gather residues if desired for chipping, significantly reducing gathering costs and some transportation costs. Timber residues are most often harvested when this system is in use, given the relative ease of collection compared to other systems.

Figure 8: Whole-tree Harvest and Processing

It is clear that the cost and risk of harvesting residues depends on the chosen harvest method. In the case of large-scale timberland managers in the Upper Peninsula, we assume that managers with motivation for timber income will supply residues when it increases firm profit. Income-motivated firms will therefore supply timber residues subject to at least covering the additional marginal cost of residue harvest. From the perspective of a large-scale timber manager, this marginal cost takes the form of damage done to standing timber during residue removal, which depends on the harvest method used. For the whole-tree method, the marginal cost of harvesting residues is negligible, but due to residue gathering costs and potential damage to young standing trees, the marginal cost of gathering residues in a cut-to-length system may be several dollars per ton. The firm's marginal revenue takes the form of a stumpage price charged to loggers for the right to collect and chip residues.

Therefore, so long as the stumpage price paid by the logger to the manager for residues exceeds the cost of damage to the stand from residue removal, managers will make timber residues available for harvest. Once this condition has been met and residues have been sold through a stumpage sale to the logger, the question of how much to harvest becomes the logger's.

3.3 Timber Residue Supply

Timber residue supply in the Upper Peninsula depends on a combination of factors from both managers and loggers, including the manager's decision to make residues available for chipping and the logger's decision to chip residues. It is clear that residue supply is a function of residue price and all costs incurred by the logger from the start of a chipping job until they deliver the chips to the final demand point in addition to productivity of the timber stand. In order to derive an indicative supply function, we conduct a break-even analysis to address the second research question about the conditions under which managers would make residues available for chipping and the conditions under which loggers would chip them.

The quantity of residues that loggers choose to chip and deliver to a demand point depends on the price received for chipped residues by loggers and the costs loggers incur to gather, chip, and haul residues to their final destination as well as the stumpage price. Assuming they are profit-maximizers who face a convex cost function and a linear revenue function, in the short run, loggers will harvest residues up until the point where marginal revenue equals marginal cost, or where marginal cost increases enough to eliminate potential profit from further harvest, as in the case of forest parcels that are too far from a mill. In the long run, loggers will supply timber residues (and purchase the necessary chipping equipment) when expected revenues are greater than the total cost of chipping residues, including additional fixed capital costs (e.g. chipper purchase price), or where price paid at the mill for chips is equal to or greater than average total cost.

A logger that does not own a chipper would only consider purchasing one if they are confident that they will be able to at least cover the purchase price (amortized over 5 years as is typical in the industry), plus additional ownership and operation costs of chipping activities with interest to cover a loan as well as a certain return on investment (ROI) reflecting the logger's rate of return to fixed costs, risk, and management. The logger's break-even price for supplying timber residues (P_{resd}) is equal to the average total cost of chipping activities (C_{resd}):

$$P_{resd} = C_{resd} \tag{1}$$

With $$C_{resd} = (P_{Stump} + C_{gath} + C_{chip} + C_{haul})(1 + r) \tag{1.1}$$

Where P_{Stump} is the stumpage price to purchase residues from a landowner, C_{gath} is the cost per green ton of gathering residues from the stand after a timber harvest, C_{chip} is the cost per green ton of chipping the residues, C_{haul} is the cost per green ton of transporting the chips from the roadside to the demand point (a function of distance), and C_{resd} is the break-even cost per green ton of supplying residue chips to the demand point. r is the rate of return that the logger requires to compensate their investment, risk, and management effort (ROI). Loggers in this study reported needing a 15% ROI on top of standard equipment investment considerations to divert resources away from regular timber harvesting operations, which are more profitable. This cost function and residue price determine the quantity of residues supplied.

Once equipment has been purchased, the logger will simply seek to cover the variable costs of chipping activities. A logger that has already incurred the up-front cost of the chipper will realistically face a lower break-even price than that of the logger described above, since the break-even price will no longer have to cover the annualized fixed cost of investment. For this logger to consider offering a bid or engaging a contract or a partial job of chipping residues, the price received per ton of chipped residues at the mill must at least cover all other production costs (variable ownership, such as insurance, and operation costs), purchase price of residues from the owner, and the cost of shipping the chips to the nearest mill.

Therefore, residue supply will depend on the cost of provision. Transportation costs in particular can make up a large portion of the cost to supply residues, varying widely with both the distance from the timber stand to the roadside and from the roadside landing to the demand point. Factors like road quality and speed limits, in addition to factors like labor cost and fuel rates add additional layers of variability to cost of provision. In the Upper Peninsula especially, where there are wide swaths of undeveloped land with limited road access and limited demand points for woodchips, these transportation costs can be especially cumbersome. Break-even analysis is used in conjunction with GIS mapping of commercial forest land and its timber productivity (varying by county) to formally estimate supply in chapter 5.

4. Objectives of Timber Managers and Their Attitudes toward Residue Harvest

Research question one asks how managerial objectives vary across different types of timberland management structures. Such *how* questions are well suited to a case study approach especially when sample size is small, as in the case of large-scale timberland managers in the Upper Peninsula (Yin 2013). Interviews are conducted to gain an in-depth understanding of the intricacies of the timber market in the region to answer research question one. As outlined by Yin (2013), a case study inquiry:

- copes with the technically distinctive situation in which there will be many more variables of interest than data points,
- relies on multiple sources of evidence, with data needing to converge in a triangulating fashion,
- benefits from the prior development of theoretical propositions to guide data collection and analysis.

Just six firms and organizations managed over a third of the privately owned forestland in the Upper Peninsula at the time of this study. Given that there are a small number of timberland owners with more than 25,000 acres and even fewer loggers engaged in chipping operations on a large scale, it made the most sense to directly ask decision makers our research questions in a case-study interview framework guided by our conceptual model. To expand on the data collected from these managers and loggers, we were also able to interview other key informants.

4.1 Identifying the Interviewees: Managers

Great care was taken to identify the largest timberland holdings and their managers. Some of the major players such as state and federal foresters were easily identified, while corporate and conservationist lands and managers were not. Publicly available data on current land ownership and size in Michigan is of variable quality and accuracy. Much of what is readily available is outdated, given the rapidly changing nature of the timber and pulpwood industry over the last decade (Miller et al., 2007). The number of acres that TIMOs and REITs manage is especially variable at any given time, as they gain new investors or buy and sell chunks of land as the opportunity arises. As of February 2016, the vertically-integrated timber REIT Weyerhauser Company acquired lands previously owned by timber REIT Plum Creek in a high-publicity merger (Bhatt, 2015). Meanwhile, the Forestland Group (Heartwood Forestland Funds) transferred approximately 355,500 acres to the Hancock Timber Resource Group during the summer of 2016 to be held in two separate Limited Liability Companies, greatly reducing The Forestland Group's commercial forest holdings.[4] The Forestland Group was subsequently unable to participate in this study.

The majority of the privately-held large tracts of timberland have been consistently enrolled in Michigan's Commercial Forest Program (CFP), in the past, making this an appropriate starting point for the identification of large-scale timberland managers. The CFP is a voluntary program that greatly reduces the tax burden on enrolled lands, giving private landowners an incentive to retain and manage forestland for long-term timber production. Participants must have an accepted long-term management plan and are also required to grant public access to enrolled lands for hunting and fishing. (MDNR 2014; Miller et al., 2007).

[4] Shirley Businski (Forest Resources Division, MDNR), e-mail to author, March 14, 2017.

Utilizing information gathered from publicly available sources such as the United States Forest Service (USFS) as well as the MI Department of Natural Resources (MDNR), the top 10 largest landowners enrolled in the CFP were identified. This list can be seen in Table 1:

Table 1: Top Ten Commercial Forest Landowners in Michigan as of January 1st, 2016[5][6]

Landowner	Acres
Plum Creek (Weyerhaeuser)	555,116
GMO Threshold Timber	422,767
Forest Land Group	395,818
Keweenaw Land Association, LTD.	156,162
Molpus (MWF Ned Lake & Lake Sup. Timber)	151,191
Longyear/Turner/JML Heirs	65,478
The Nature Conservancy	25,651
Cleveland Cliff Iron Company	14,647
Vulcan Timberlands, Inc.	13,991
Riverside Forest, LLC	10,554
	1,812,875

The multi-case sampling strategy focused on the population of landowners in Michigan's Upper Peninsula with more than 25,000 acres enrolled in the commercial forest program (less than a twentieth of the holding size of the largest CFP-enrolled firm). There were seven such landowners, each of which was contacted for inclusion in this study. Of those seven, all but The

[5] Shirley Businski (Forest Resources Division, MDNR), email to author, March 14th, 2016.
[6] Acreages may not be exact due to backlog of ownership changes not entered in the DNR system at this time.

Forestland Group were available for in-person interviews or interviews over the phone. This resulted in a final sample including 78% of the 1,772,000 acres in the sampling frame of CFP landowners of over 25,000 acres. In addition to these timberland management firms and organizations, the public timberland holdings of the MDNR (2 million acres), and USFS (1 million acres), were also included.

All large-scale commercial forest owners practice forest stewardship that falls under requirements for various—voluntary—sustainable forestry programs such as the Forest Stewardship Council (FSC) or Sustainable Forest Initiative (SFI). In particular, the SFI requirements include measures to protect water quality, biodiversity, wildlife habitat, species at risk and forests with exceptional conservation value. The forest management standard applies to any organization in the United States or Canada that owns or manages forests (SFI 2015). In contrast, FSC is a worldwide program that places additional requirements in all areas, limiting such activities as clearcutting while also requiring certain levels of outreach with local communities and other affected parties, a requirement not present in SFI.

Table 2 below lists all interviewed firms and their respective acreages with a brief description. For those groups that do not manage their own lands, the manager (the interviewee), is indicated. Tables 3 and 4 provide comparable information for conservation organizations and public foresters.

Table 2: Interviewed Firms (Corporate) and the Number of Commercial Forest Acres Held in Michigan's Upper Peninsula as of March 2016

Firm Name	Description	Acres
Corporate		
Molpus Timberlands Management, LLC	Molpus Timberlands Management, LLC., is a TIMO that manages over 1,600,000 acres of timberland. Around 151,000 of those are in the UP. Their Lake Superior office is located in Houghton, MI.	151,191
GMO Threshold Timber	GMO Threshold Timber is a TIMO out of Boston that owns 400,000+ timberlands in the UP. They employ consulting firm American Forest Management (AFM) in Houghton, MI as the timber manager for their lands. AFM manages the GMO forest lands like most timber consulting firms in the US, "from stump to market".[7]	422,767
Keweenaw Land Association	Keweenaw Land Association is a small, publicly-traded timberland and mineral rights company. They manage over 150,000 acres of highly productive timberland in the UP and are located in Ironwood, MI.	156,162
JMLongyear	JMLongyear is a 130-yr-old family-owned business headquartered in Marquette, MI. They are a timberland and mineral rights company that functions in both Michigan and Canada. They currently manage around 65,000 acres of timberland in the UP and run some of their own logging and sawmill operations.	65,478
Weyerhaeuser	Weyerhaeuser is one of the largest private owners of timberland in the world. They are a timber REIT that owns more than 13 million acres of productive timberland in the U.S. Weyerhaeuser recently merged with Plum Creek, another large timber REIT and took over their 550,000 acres of CFP lands in the UP. Weyerhaeuser's regional offices are now located in the Plum Creek offices of Escanaba, MI.	555,116

[7] Eric Stier (Michigan Region Manager for American Forest Management), interview by S.Klammer and S. Swinton, June 22, 2016, AFM Headquarters, Atlantic Mine, MI.

Table 3: Interviewed Organizations (Conservationist) and the Number of Commercial Forest Acres Held in Michigan's Upper Peninsula as of March 2016

Firm Name	Description	Acres
	Private Conservationist	
The Nature Conservancy (TNC) (Managed by Compass Land Consultants)	The Nature Conservancy is a leading conservation organization that operates on a global level. Their mission is to protect ecologically important lands and waters for nature and people, including the hardwood forests of northern Michigan. Their commercial forest lands are managed by Compass Land Consultants, a forestland consulting firm that manages land in both the US and Canada. They currently manage 375,000 acres across Michigan and Wisconsin, including TNC commercial forest lands like those of the Two Hearted Forest Reserve. Only 25,651 of their extensive acreage are currently enrolled in the Commercial Forest program in Michigan.	25,651

Table 4: Public Managers and the Number of Acres of Timberland Held in Michigan's Upper Peninsula as of March 2016

Firm Name	Description	Acres
	Public	
Michigan Department of Natural Resources	The state of Michigan manages the largest dedicated state forest system in the nation with 3.9 million acres (Michigan State Forest Management Plan, 2008). Of this, there are just under 2 million acres of timberland managed by the MDNR in the Upper Peninsula.	1,940,000
United States Forest Service	The United States Forest Service manages approximately 2.3 million acres of forest land in the Ottawa and Hiawatha National Forests of the Upper Peninsula. Over 1 million acres are available for timber production (Mueller et al., 2009).	1,070,000

4.2 Identifying the Interviewees: Loggers

Much like in the case of the large-scale timberland managers in the Upper Peninsula, there is a very small population of loggers engaged in chipping on any scale in the region. According to those in the industry, only around 4-5 logging firms are still chipping in the Upper Peninsula. Only three of these are producing chips in large volumes[8]. As with managers, using the case study approach in the case of these loggers copes with the technically distinctive situation in which there will be many more variables of interest than data points (Yin, 2013).

Loggers were identified through correspondence with the Michigan Association of Timberman as well as through managers of large-scale timberland holdings in the Upper Peninsula. Through these contacts, the owner of one of the only commercial logging firms in the Upper Peninsula that still engages in chipping on a large scale, Jim Carey of Carey Logging, was interviewed. Carey Logging is a timber harvesting and forest management company active in chipping, custom grinding, trucking, excavating, and road construction, in addition to other related activities.

4.3 Additional Sources

The introduction to this section stated that exploration of the research questions requires in-depth understanding of the intricacies of the timber market in the region. Managers, and the firms and organizations they represent, are only one well-connected part of this timber market. Loggers, foresters, and consultants make up other pieces. Each of these individuals contributed

[8] Jim Carey (President, Carey Logging), phone interviews and email correspondence by S. Klammer from July 12, 2016 until April 20, 2017.

valuable information and insight regarding the current state of the timber market and the timber residue supply potential in the region to aid in answering the research questions:

- Don Peterson, Executive Director, The Sustainable Resources Institute (SRI): SRI is "a non-profit corporation specializing in natural resource research, education, training and certification." (SRI, 2016). Don contributed extensive knowledge of timber market conditions in Michigan, both present and past.
- Karen Potter-Witter, Professor Emerita, Department of Forestry, Michigan State University: Karen's research and extension work is in timber and woody biomass supply, forestry investment analysis and taxation and private forestland policy analysis. She is a fellow of the Society of American Foresters, Board Member of the Michigan Forest Association, the Michigan Technological University President's Council of Alumnae.
- Michael Vasievich, Adjunct Associate Professor, Department of Forestry, Michigan State University: Mike worked for the USDA Forest Service for 32 years as a research scientist and project leader. He has led and participated in several broad-scale ecological and social assessments and many regional, national, and international cooperative projects.
- Ray Miller, Manager, MSU Forest Biomass Innovation Center: The center serves as the university's headquarters for forestry research on both its own forests and on cooperators' land throughout the Upper Peninsula. Ray has been involved with woody biomass production in Michigan since 1978, he leads Michigan's Statewide Wood Energy Team, and he is a member of the US Department of Energy's Biomass Research and Development Initiative Technical Advisory Committee.

- Shivan, GC, Department of Forestry, Michigan State Univericity: Shivan is a doctoral student in the Department of Forestry at Michigan State University. She has contributed to several research studies on the forest products industry in Michigan.
- Warren Suchovsky, Owner and Operator of Suchovsky Logging: Warren is a forestland owner and logger who has over 50 years of experience in the field and in the region.

4.4 The Interviews: Managers

The study consisted of nine in-person interviews and three phone interviews conducted in May and throughout the summer and early fall of 2016 with 11 key informants from the three distinct manager groups: corporate, private conservationist, and public. The interviews were conducted across the Upper Peninsula, often in the regional headquarters of the operation or out in the woods during a timber harvest. These interviews ranged from 40 minutes to over an hour and consisted of questions from an interview script (Appendix A), designed before the interview leg of the project began. Each of the managers interviewed occupied different positions within their firm depending on the business and availability of those who were willing to meet with the researchers. Each had substantial timber management experience and extensive knowledge of the timber industry and their own firm's operations.

The interview script was comprised of five different sections at a total length of three standard-sized pages. The first section introduced the researchers and identified the Great Lakes Bioenergy Research Center and this specific collaborative research activity between University of Wisconsin and Michigan State University with the goal of generating an idea of "the conditions under which landowners (or loggers) would supply biomass/slash for bioenergy."

Following that brief introduction, the manager was then asked if he could be recorded and information gathered during the interview attributed to him in any subsequent publications or presentations. This marked the beginning of interview.

The next section consisted of background questions that attempted to explore the manager's specific background and experience with biomass and in the forestry world more generally. The manager was asked about the corporate decision-making structure of the firm when it comes to forestland use, the firm's business model (whether they contract with loggers or have their own vertically coordinated logging branch, land use division within the firm, etc.) and if (and how), they currently handle timber residues, especially for bioenergy uses. Considerable time was spent delving into the latter question. If the manager reported currently harvesting timber residues, he was then asked about current contract terms. If the manager said no, he was asked several follow-up questions in section three of the interview (shown below). These were asked in addition to more numerically specific questions regarding composition of timberland holdings and current acreage. These acted to both frame the physical nature of the firm as well as the managerial objectives of the manager's firm at large, addressing our first research question. With this information as to management structure and objectives in mind, the interview moved on to section three.

Sections three and four of the interview were dedicated to the second research question and presented two different hypothetical follow-up scenarios regarding the manager's utilization of biomass under different market conditions. The first is shown below:

Figure 9: Follow-up Interview Scenario

3. Follow-up Supply Scenario #1

- **Have you considered (harvesting/increasing harvest) of timber residues?**
  - **Suppose that market demand for timber slash jumped so dramatically that you began seriously to consider harvesting residues at time of timber harvest**.
    - What would be the biggest barriers to harvesting & selling slash?
    - What kind of contract terms would you need?
      - Term of contract (years)
      - Location (At harvest site? Delivered?)
      - Price (what unit? Per ton? Per acre?)

Section five asked additional questions regarding whether the manager could imagine a scenario in which they would supply land to grow dedicated woody bioenergy crops and what conditions would be needed for them to consider it. This piece of the interview script is not explored further in this thesis.

4.5 The Interviews: Carey Logging

Jim Carey of Carey Logging participated in interviews similar to those conducted with managers. In these interviews, however, the focus was on Carey Logging's decision-making structure and objectives when it comes to selecting harvesting methods. From there, he was asked to describe Carey Logging's current treatment of residues (referred to as slash among loggers), including current market conditions such as price and potential conditions under which they would consider engaging in chipping activities in the future. These interviews were designed to answer the second and third research questions.

Subsequent correspondence with Carey Logging included the collection of specific cost data pertaining to chipping activities and industry-level information about harvesting technology utilization. This information is used in the break-even analysis and supply estimation portions of chapter 5.

4.6 Interview Results

Stated objectives of managers differ widely, and these differences are reflected in their decisions. Publicly available mission statements, securities documents from firm websites, as well as direct quotes and interview notes collected from managers, key informants, and loggers are used to classify each firm or organization into one of the three separate categories identified in chapter three: corporate, private conservationist, and public. From this same information, each manager's relative willingness to supply timber residues is also identified. This is analyzed from two angles: 1) whether there exist clear profit objectives reported in the interviews that are core to the firm's or organization's management structure and 2) whether there exist clear amenity objectives reported in the interviews that are core to the firm's or organization's management structure. Based on interview testimony, the effect that these objectives have on residue supply is also considered.

4.6.1 Managerial Objectives: Corporate Firms

Corporate timberland managers are interested in maximizing value from timber income on behalf of landowners and/or investors. Much of Michigan's timberland has been purchased by large TIMOs and REITs that have continued to become more consolidated. By definition, both TIMOs like Molpus and REITs like Weyerhaeuser fall squarely into the corporate category alongside more traditional private timber management firms. Molpus Operations Manager Keith Williams explains the primary difference between a TIMO and a REIT,

> "[REITs] are publicly traded. Investors buy shares and look for dividends as return on investment, but TIMOs have investors who own the land directly themselves or they participate in a fund. The typical TIMO lifecycle is 10-15 yrs. REITs have an undefined investment lifecycle."[9]

Timber REITs exemplify the profit-driven firm. Weyerhaeuser, which transitioned into a REIT in 2010, recently merged with Plum Creek and is the largest private timberland owner in the United States and in Michigan. Like many other REITs, Weyerhaeuser is publicly traded on the New York Stock Exchange and features high returns for investors as one of its primary goals. On the Vision and Values page of Weyerhaeuser's website under "How We Win", this returns-driven management structure describes a combination of steps, including, "Deliver the most value from every acre: Whether it's timber, real estate, recreation or conservation, we make the most of all our land assets." And "Optimize Capital: We are disciplined about allocating capital to high-return projects that will generate value for our shareholders." (Weyerhaeuser 2017). Other shareholder documents on the site also highlight the importance of high returns. When

[9] Keith Williams and Mark Korkko (Operations Manager and Michigan Property Manager, Molpus Timberlands Management, LLC), phone interview by S. Klammer and S. Swinton June 10th, 2016

asked what conditions would need to be met before they would engage in a new investment, Charlie Becker of Weyerhaeuser (the Senior Resource Manager for the Lake States at what was formerly timber REIT Plum Creek) stated that, "We're not against doing anything if there's a market for it."[10] Becker also discussed potential amenity value, explaining that Weyerhaeuser follows SFI guidelines that promote sustainable forest management not because Weyerhaeuser has any particular motivation for providing amenities, but because it is a cost of doing business:

> "Being a member of SFI is just a 'cost of doing business'. It's not necessary, it doesn't affect [Weyerhaeuser's] costs, but it shows that you have good stewardship practices. So it's important."[11]

Longyear and Keewenaw Land Association also discussed the importance of being certified under SFI or FSC to be competitive in the marketplace while making it clear that they target returns as their primary goal. Keeweenaw Land association is a small publicly-traded timberland and mineral rights company. According to its operations manager, Mark Sherman, when it comes to residue supply, "The two questions are 1. Can we make money and 2. Can we do it without damaging standing timber? If yes, foresters implement."[12] Longyear's marketing and sales manager, Jacob Hayrynen, reported a similar timber-value maximization approach to residue supply.

As institutional asset managers, TIMOs like Molpus operate similarly. Molpus Operations Manager Keith Williams summed this up in a preliminary interview when he

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[10] Charlie Becker (Weyerhaeuser), interview by S. Klammer and S. Swinton, June 20th 2016, Weyerhaeuser Office, Escanaba, MI

[11] Charlie Becker (Weyerhaeuser), interview by S. Klammer and S. Swinton, June 20th 2016, Weyerhaeuser Office, Escanaba, MI

[12] Mark Sherman (Operations Manager, Keweenaw Land Association), phone interview by S. Klammer on July 13, 2016.

explained the motivation behind a TIMO: "[The] ultimate goal is to return to investors a stated goal of investment. [Molpus is] really just a money manager that uses timberland as a vehicle to reach that goal."[13]

American Forest Management (AFM), manager, Eric Stier, paints the clearest picture of the differences of these firms compared to conservation organizations or public timberlands. As a traditional consulting firm, AFM doesn't own timberlands, but it manages them on behalf of GMO Threshold Timber, a TIMO out of Boston. According to Stier, "[AFM] will manage for *any* reason [besides timber harvest], so long as we get paid."[14] He explained that some AFM-managed lands are managed for objectives like hunting, fishing, and recreation. In the case of the GMO Threshold Timber lands in this study, the management objectives focus on timber harvest and profit metrics. This testimony makes it clear that, although these corporate firms may provide some amenities in keeping with Commercial Forest Program rules and SFI or FSC certification, they do it because good stewardship is good business, not because they are amenity-driven. It is clear from this evidence that these firms care about maximizing profit from the timber stand and will supply residues when it furthers that goal.

4.6.2 Managerial Objectives: Conservationist Organizations

Private conservationist timberland managers manage for some specific set of amenity goals. These managers seek to meet these amenity goals as outlined by the landowner. One landowner included in the interviews falls into the conservationist category. The Nature

[13] Keith Williams and Mark Korkko (Operations Manager and Michigan Property Manager, Molpus Timberlands Management, LLC), phone interview by S. Klammer and S. Swinton June 10th, 2016
[14] Eric Stier (Michigan District Manager, Amercian Forest Management), interview by S. Klammer and S. Swinton, June 22, 2016, AFM Regional Offices, Atlantic Mine, MI.

Conservancy (TNC) is a well-known nonprofit, tax-exempt charitable organization that "is the leading conservation organization working around the world to protect ecologically important lands and waters for nature and people (The Nature Conservancy, 2017)." Jon Fosgitt of Compass Land Consultants (CLC) explained in an interview that while managing TNC lands, their primary focus is on biodiversity and restoration of the forest.[15] CLC uses Key Ecological Attributes (KEAs), which are standards developed by TNC to measure the restoration of forests. A list of these attributes developed by TNC is shown in Figure 10 below (TNC, 2010).

[15] Jon Fosgitt (Forest Management Specialist, Compass Land Consultants), interview by S. Klammer and S. Swinton on June 24, 2016, Jon Fosgitt's home office, Curtis, MI.

Figure 10: List of Key Ecological Attributes Used by The Nature Conservancy (TNC 2010)

	Standard Key Ecological Attributes
Size	Length of native riparian vegetation
	Population size & dynamics
	Presence of key communities or seral stages
	Size / extent of characteristic communities / ecosystems
	Size of system
Condition	Abundance of food resources
	Actively breeding [birds, etc.]
	Biological legacies
	Characteristic Plant Communities
	Characteristic Species - [specify which, e.g., Gunnison sage grouse, rare plants in general, or a particular rare plant)
	Community architecture
	Depredation & parasitism
	Indicator Species - [specify which]
	Intactness of ecological systems
	Native fish assemblege
	Native riparian vegetation
	Pollination
	Population structure & recruitment
	Presence / abundance of key functional guilds
	Presence / abundance of keystone species
	Primary productivity
	Riparian community composition and diversity
	Soil/Sediment Erosion-Deposition Regime
	Species Composition / dominance
	Species Composition/ abundance
	Successional dynamics
	Trophic structure
Landscape Context	Connectivity among communities & ecosystems
	Fire Area-Intensity Regime
	Fire regime - (timing, frequency, intensity, extent)
	Hydrologic regime - (timing, duration, frequency, extent)
	Landscape pattern (mosaic) & structure
	Nutrient concentrations & dynamics
	Soil / sediment stability & movement
	Soil / sediment structure & chemistry
	Surface Water Flow Regime
	Water / soil temperature
	Water chemistry
	Water level fluctuations

Fosgitt explains that TNC came into ownership of perpetually middle-aged forests that had a number of things missing that they wanted, but they did not have a way to quantify it, so they came up with KEAs. To meet these various KEAs, CLC might girdle trees so they die standing, cut some trees to get rare ones to grow, or even cut trees just to leave them on the ground. TNC land managers do not face any specific logging restrictions, but they do not conduct any timber harvests without a clear attribute-improving outcome or outcomes in mind. Even harvest time is figured into the equations, as with other firms. According to Fosgitt, "Winter harvest is preferred to protect the understory, or maybe we'll do a summer harvest because we want to disturb the soil and expose the mineral seed bed that some species require to regenerate." To summarize, at the end of the day, "It's all about improving these metrics [KEAs]."

TNC is not completely without consideration for profit, however. According to Fosgitt, return on investment is not a primary goal, but they [TNC] "want to prove that conservation is financially sound as well."[16] He explained that CLC does do some cutting on TNC lands and does sell the timber when it is appropriate (for meeting amenity goals), though at nowhere near the volume that a TIMO or REIT might. TNC also does not currently allow the removal of tops and branches for chipping, as removal does not align with their overall forest health goals or KEAs. For TNC, Key Ecological Attributes are their primary concern. Anything outside of that is secondary to their overall conservation agenda. It is clear that in the case of conservationist timberland management organizations, amenity value creation is the primary objective and willingness to harvest residues is low. Indeed, TNC currently forbids the harvest of timber residues, so they do not represent a potential source of energy biomass supply.

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[16] Jon Fosgitt (Forest Management Specialist, Compass Land Consultants), interview by S. Klammer and S. Swinton on June 24, 2016, Jon Fosgitt's home office, Curtis, MI.

4.6.3 Managerial Objectives: Public Timberland Managers

Public land managers, federal and state foresters, are similarly held to a set of ecological and conservationist amenity goals. The National Forest Management Act requires that the USFS manage National Forest System lands for a variety of uses on a sustained basis to ensure in perpetuity a continued supply of goods and services to the American people. The Act also establishes analytical and procedural requirements for developing, revising, and amending forest plans (Hiawatha National Forest Land and Resource Management Plan, 2006). The specifics of these goals for each National Forest are outlined in their respective Forest Plan and span several years. These plans can be accessed through the USFS website for each respective forest.

There are two national forests in Michigan's Upper Peninsula: The Ottawa National Forest and the Hiawatha National Forest. The Ottawa National Forest contains 1.0 million acres of land in the Western Upper Peninsula, of which 488 thousand acres is available for timber production (Ottawa National Forest Land and Resource Management Plan, 2006). The Hiawatha National Forest (split into two units within the Eastern Upper Peninsula) contains 1.3 million acres of land, of which 578.5 thousand acres is available for timber production (Hiawatha National Forest Plan, 2006). The 2006 Forest Plan is the plan currently in use. I interviewed Bill Gimler, the Forest Timber Program Manager at Hiawatha. According to Gimler and other informants, management structure is very similar across forests.

Within each forest plan, Gimler explained that there are designated 'suitable acres' that can be harvested for timber. Foresters decide which of these acres are suitable to harvest. However, every timber harvest proposal must pass the requirements of the National Environmental Policy Act (NEPA). NEPA ensures that environmental information is made available to the public during the decision-making process and before any action is taken. This disclosure helps public officials make decisions that are based on an understanding of environmental consequences and take actions to protect, restore and enhance the environment (Hiawatha National Forest Plan, 2006). According to Gimler, these steps, while necessary, slow down the timber harvest process considerably, meaning that residue harvest is the last thing on their mind. Gimler explains that "The full NEPA process probably takes about 2 years." [17] The full process, beginning to end, is something like this: First, the forest plan action requires a 'purpose and need' under NEPA. Then there is a NEPA pre-assessment, which includes an Environmental Assessment, which has several steps (such as public meetings), and can be very time consuming, followed by the decision notice. "Then there's marking [the timber] and appraisal (which is cost, contract, road packages, etc.). Then, when we put it out for formal advertisement for stumpage, we might approve top removal here, and if we do, buyers can decide whether or not to harvest it and chip it." The buyer then must request permission to take the top wood, however, and then amend the contract. Finally, a timber sale contract is awarded to the chosen logger.

These laws and policies, in conjunction with wildlife concerns and management objectives that take precedence, make it very difficult to harvest timber. Gimler reports that they operate at around only 37% of Hiawatha's Allowable Sale Quantity (the quantity of timber that may be sold from the area of suitable land covered by the forest plan for a time period specified by the plan). He explains that while some may want to manage USFS timberlands for timber revenue, it just simply is not possible with their current priorities (like fighting forest fires), and

[17] Bill Gimler (Forest Timber Program Manager, USFS Hiawatha National Forest), interview by S. Klammer and S. Swinton on June 23rd, 2016, Gladstone, MI.

resources. According to Gimler, “the goal is to get it back to the natural forest, and if we happen to make money along the way, great.”[18]

This testimony makes it clear that national forest managers currently operate very similarly to private conservationist firms like TNC, chiefly managing not for timber income but rather for amenity objectives. Both report motivation for timber income as secondary to their conservationist, amenity goals, making it clear that manager willingness to supply timber residues is low.

State forest management, however, does not fit completely into this characterization. The state of Michigan manages the largest dedicated state forest system in the nation with 3.9 million acres (Michigan State Forest Management Plan, 2008). There are about 798 thousand acres of timberland managed by state and local governments in the Western Upper Peninsula, and approximately 1,142 thousand acres in the Eastern Upper Peninsula (Mueller et al. 2009). Like USFS foresters, MDNR foresters follow state forest plans and regional plans that outline over-arching objectives.

According to state Timber Sale Specialist Doug Heym, “We follow a process that is comparable to NEPA, but with much fewer rules.”[19] This process is called Compartment Review. State forestlands are divided into 15 management units which are then divided into compartments of around 1000-3000 acres. These compartments are organized into 10 different groups, of which one is the focus for each planning year. This chosen area is inventoried by foresters, and decisions are made to implement the regional state forest plan with input from

[18] Bill Gimler (Forest Timber Program Manager, USFS Hiawatha National Forest), interview by S. Klammer and S. Swinton on June 23rd, 2016, Gladstone, MI.
[19] Doug Heym (Timber Sale Specialist, Michigan DNR), phone interview by S. Klammer on August 24th, 2016.

wildlife managers and through the Compartment Review process. According to Heym, while NEPA is very specific, there is no comparable regulation and legislation that the MDNR must follow. They have largely developed their own rules, which are much less stringent. This enables MDNR managers to move more quickly than the USFS to conduct more timber harvests. This relative speed means that once other management goals are met, managers can turn their attention to harvesting suitable acres and generating timber revenue. It also means that for most timber sales, the DNR includes residues in most bids if they think it might generate some additional profit. However, according to Heym, "[They're] having difficulty getting bids on those sales because there's not a high enough demand."[20] According to this testimony, I conclude that willingness to supply residues from MDNR timberlands is greater than that of the USFS and conservationist organizations that aim to meet more amenity objectives though still considerably lower than that of large corporate firms that are subsequently the focus of the timber residue supply analysis in this study.

[20] Doug Heym (Timber Sale Specialist, Michigan DNR), phone interview by S. Klammer on August 24th, 2016.

5. Potential Supply of Timber Residues for Bioenergy in Michigan's Upper Peninsula

Research question two explores the conditions under which managers will supply residues and the conditions under which loggers will chip residues. Research question three addresses timber residue supply. Interview testimony makes it clear that managers of private corporate, profit-driven firms are the most willing to supply timber residues so long as they are covering costs. With this result in mind, potential supply of timber residues in Michigan's Upper Peninsula is calculated in this chapter using data of parcels currently enrolled in the CFP and break-even analysis of the costs to supply residues, starting with the manager and ending with the logger at the final demand point.

5.1 Break-even Analysis

In the case of the income-motivated land manager, the objective is to maximize profit from timber harvest over the firm's specific time-horizon. Corporate managers will supply residues so long as revenues from residue harvest are greater than costs. Recall from Equations (1) and (1.1) that the breakeven residue price is defined as the price that covers all costs, where costs are the sum of the stumpage price (P_{Stump}), in-parcel gathering, (C_{gath}), chipping (C_{chip}), and hauling from the forest parcel to the biomass demand point (C_{haul}):

$$C_{resd} = (\boldsymbol{P_{Stump}} + C_{gath} + C_{chip} + C_{haul})(1 + r) \qquad (1.1)$$

To calculate this break-even price (equation 1), I conduct a break-even analysis using data from a logging firm currently engaged in chipping activities on a large scale to provide additional insight into the costs of provision of timber residues, including stumpage price, gathering costs, chipping costs, hauling costs, and ROI considerations. Each piece of the cost function for delivered residues is quantified using interview testimony and data from Carey Logging and additional forest service and general forestry sources to determine the cost of supplying residues and the subsequent quantity supplied at each break-even price.

5.1.1 On-Site Costs: Gathering and Chipping Residues

Before a timber harvest begins, the logger and manager agree to a stumpage sale that may or may not include the removal of timber residues. If it does, then the price premium for the residue removal, P_{Stump}, is the first part of onsite costs. In the case of TIMOs, REITs, and other corporate firms where logging jobs are conducted through a stumpage sale, managers are primarily concerned with covering the cost of potential damage to standing timber from residue harvesting activities under the dominant cut-to-length harvesting system. In the Upper Peninsula, one logger estimates that 90% of natural regrowth timber area harvested uses the cut-to-length method.[21] Given this potential risk of damage, timberland managers require an up-front payment to compensate the risk of forest damage from residue harvest. This payment takes the form of a stumpage price, which was collected from managers during the interview process.

The next on-site cost, C_{gath}, is estimated using average residue gathering costs reported during interviews with Carey Logging under the two different harvesting scenarios: cut-to-length and whole-tree harvesting. The latter results in a gathering cost of zero, as residues are already collected in piles at a centralized landing in the forest stand. Cut-to-length harvest results in

[21] Jim Carey (President, Carey Logging), phone interviews and email correspondence by S. Klammer from July 12, 2016 until April 20, 2017.

higher gathering costs, since equipment must re-enter the stand after timber harvest and gather the residues for chipping.

Once residues are gathered, they must be chipped before they can be transported to the demand point. To calculate the cost of chipping residues (C_{chip}), a machine rate cost analysis is conducted for chipping residues at the roadside (USDA, 2017). A machine rate is a calculated hourly charge for owning and operating a piece of capital equipment. Under the machine rate method, costs are averaged over the ownership life of the asset to estimate a constant hourly charge (Brinker et al. 2002). The general formula for the cost of chipping residues (C_{chip}) is as follows:

$$C_{chip} = o + p + l \qquad (2)$$

Where o is machine ownership cost per green ton, a function of capital costs including purchase price, insurance rate, interest rate, and salvage value.

p is machine operating cost per green ton, a function of fuel and other variable equipment costs like chipper blades and repair or maintenance.

l is labor cost per green ton, a function of base wage and employee benefits.

C_{chip} is the chipper machine rate, or the cost per green ton of owning and operating a chipper.

Costs are divided between scheduled machine hours and productive machine hours. Fixed equipment costs, labor costs and other ownership costs are incurred on a scheduled machine hour basis. The variable costs of operating equipment are incurred on a productive machine hour basis. Scheduled machine hours (SMH) are the time during which equipment is scheduled to do productive work, including set-up and loading time that occur when the machine is not actively in use. Ownership and labor costs are calculated based on the number of scheduled hours. Productive machine hours (PMH) are the part of the scheduled time during which a machine is performing the scheduled work—and consuming resources like fuel—and determine operating costs. The ratio of the productive time to the scheduled time for a machine (PMH/SMH) is the utilization rate of the machine. This utilization rate determines the life of the machine. Higher utilization results in a shorter lifespan. At the utilization rate of 90% reported by Carey Logging, the two rates do not differ dramatically. The productive machine hour rate is used going forward and is slightly higher in general due to additional labor and ownership costs incurred during set-up and tear-down when the chipper is not officially in use. This hourly rate is converted into the cost per ton of chipped material depending on productivity of the specific machine. All rates are adjusted based on the utilization rate.

To calculate this chipping component of on-site costs, cost information collected from Jim Carey of Carey Logging is used in coordination with industry cost data gathered from the USFS or MDNR to generate a machine rate. Data provided includes both estimates of average total costs as well as individual variable costs for the 2016 operating year.

Three analyses are conducted to explore potential differences in chipping costs across common operations. Each of the following chipping cost analyses was conducted twice: once with long run considerations (including ownership costs), and once for the short run, where ownership and equipment purchase costs are excluded from the analysis.

According to Carey Logging, in the long-run, when ownership and equipment purchase costs are included in the machine rate, loggers face two different equipment purchasing scenarios: 1) a chipper is productive enough to be replaced or 'traded in' for a new chipper every five years, or 2) a chipper is used until the end of its life rather than replaced (life varies with utilization). As both scenarios are reportedly common in the UP, both situations were considered.

Data gathered from Carey Logging applied to the first scenario, in which a chipper is used relatively heavily and then traded in when productivity begins to drop.[22] The first scenario is conducted again using industry cost data gathered from the USFS and MDNR to serve as comparison for Carey's reported values. This same industry cost data is also used to estimate chipping costs under the second utilization scenario not experienced by Carey Logging. I break down the average costs of chipping under each scenario using the different parameter assumptions and compare them to Carey's reported costs.

Ninety percent equipment utilization (PMH/SMH), an operating rate of 30 tons/hr, and the use of a Bandit 2590, 540 horsepower Chipper are assumed under all 3 scenarios:

Machine Rate 1A—Heavy Use with Trade-in (Carey): This analysis uses Carey's reported average fixed, variable costs, and labor costs (with benefits). Under this

[22] Data from Carey was reported in average totals for various categories including average fixed and variable cost per productive hour, labor with benefits per scheduled hour, average number of tons chipped per chipper per hour, and a range of average transportation costs.

scenario, the chipper is heavily utilized (1800 PMH), for 5 years before being traded in at 40% salvage value for a new chipper.

Machine Rate 1B— Heavy Use with Trade-In (USFS/MDNR): This analysis uses fixed and variable costs gathered from both the chipper manufacturer and USFS or MDNR resources. Under this scenario, the chipper is heavily utilized (1800 PMH), for 5 years before being "traded in" (40% salvage value) to the manufacturer for a new chipper.

Machine Rate 2— Limited Use with No Trade-In: This analysis uses fixed and variable costs gathered from both the chipper manufacturer and USFS or MDNR resources. Under this scenario, the chipper is used on a very limited basis (1000 PMH), and is subsequently not traded in. The chipper is used until the end of its useful life (0% salvage value).

The rates above only reflect the cost of running a chipper in the long run, or C_{chip}. Short-run break-even cost is calculated using the same analyses while excluding fixed equipment costs to calculate an estimate of average variable cost to chip. The delivered chip cost, or break-even price, includes this chipping cost added to transport costs for a given operation, purchase (stumpage) price for residues, any gathering costs incurred, and some level of ROI on behalf of the logger.

5.1.2 Transportation Costs

The last piece of the break-even analysis is transportation cost, C_{haul}. Early interview data made it apparent that large quantities of residues should not be expected from public forest lands any time in the near future, limiting the data frame to commercial forest lands. General estimates of transportation costs were gathered during interviews but were highly variable depending on distance from the demand site. To estimate transportation costs while allowing them to remain sensitive to distance and varying route conditions, geographic information systems software (ArcGIS), is used to develop a comprehensive network of roads and lands enrolled in the Commercial Forest Program to and from specific demand points in the Upper Peninsula. Cost calculations are done under two scenarios: 1) assuming costless backhaul, where the logging firm can utilize chip vans for some other kind of transport during the return trip, or 2) assuming no backhaul, where the logging firm faces higher transportation costs to cover the cost of returning the empty chip van to the origin site. The road network developed in ArcGIS is used in conjunction with the USFS Forest Residues Transportation Costing Model to calculate one-way and round-trip costs per mile from each commercial forest parcel to a demand point.

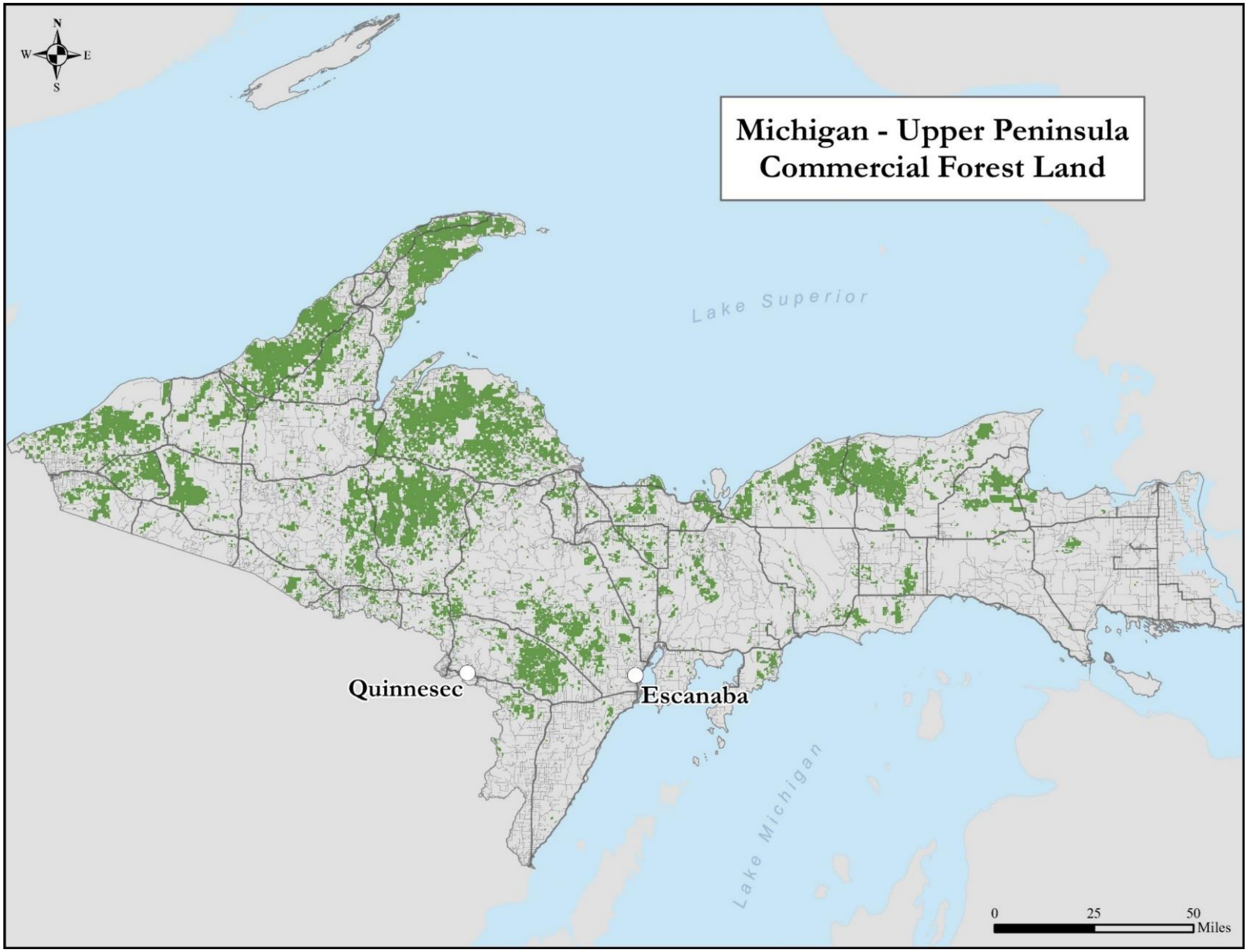
The major regional demand points for woodchips as a bioenergy source in Michigan's Upper Peninsula are the Quinnesec and Escanaba Verso paper mills.[23] Both mills are owned and operated by the Verso Corporation, a leading North American producer of printing papers, specialty papers, and pulp (Verso Co., 2017). The Quinnesec Verso mill utilizes approximately two times as many woodchips as the Escanaba Verso mill, which predominantly utilizes sawmill residues from its every day operations. While actual utilization numbers for each of the mills are proprietary, Verso's Biomass Purchaser Robert Ashbacher reported that they are purchasing only about a third of what they were two years ago.[24] The locations of each mill are shown in Figure 11.

With the help of analysts at the Center for Remote Sensing and Geographic Information Systems (GIS) in the Department of Geography at Michigan State University, two GIS data

[23] Don Peterson (President, Renewable Resource Solutions), interview by S. Klammer and S. Swinton, June 21, 2016, RRS Headquarters, Crystal Falls, MI.
[24] Robert Ashbacher (Biomass Purchaser, Verso Co.), phone interview by S. Klammer, Jan 3rd 2017.

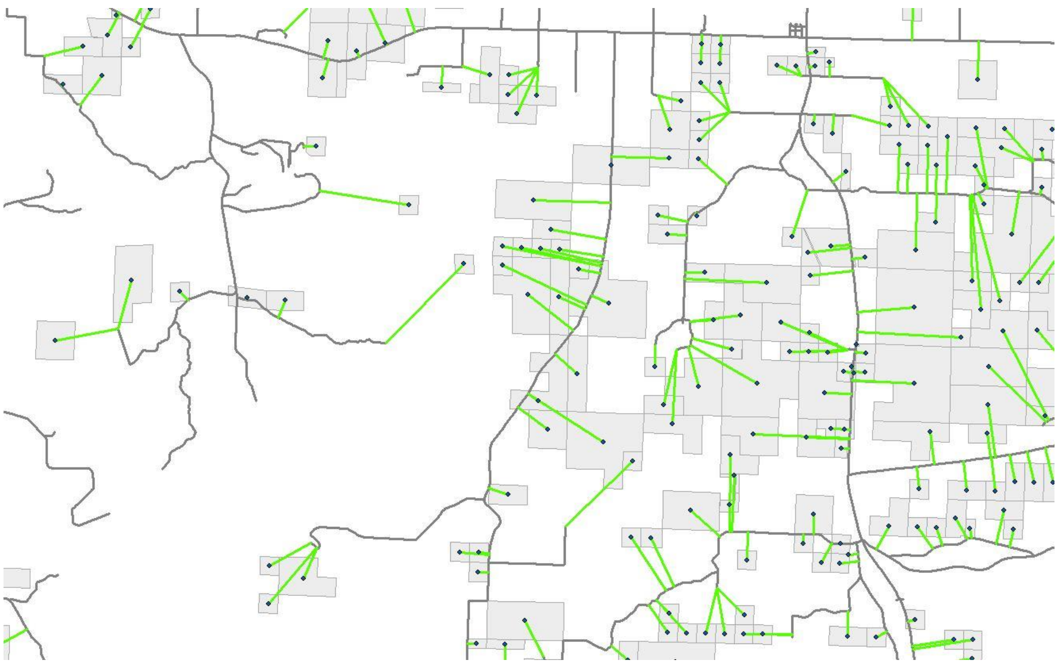
sources were used to measure distances from forest plots to the paper mills along the road network: A data layer from the MDNR's Open Data database that included all of the Michigan Commercial Forest Act lands was accessed in October of 2016 (MDNR, 2016), and a data layer from the state of Michigan's GIS Open Data database showing all roads from the Michigan Geographic Framework (MGF) base map was accessed in its most recent form in April of 2017 (Center for Shared Solutions and Technology Partnership, 2017). This data was trimmed to reflect only the roads in the Upper Peninsula as of December 2016 to create an accurate picture of commercial forest land in relation to roads in the region at the time.

Figure 11: Commercial Forest Program Land with Roads Framework



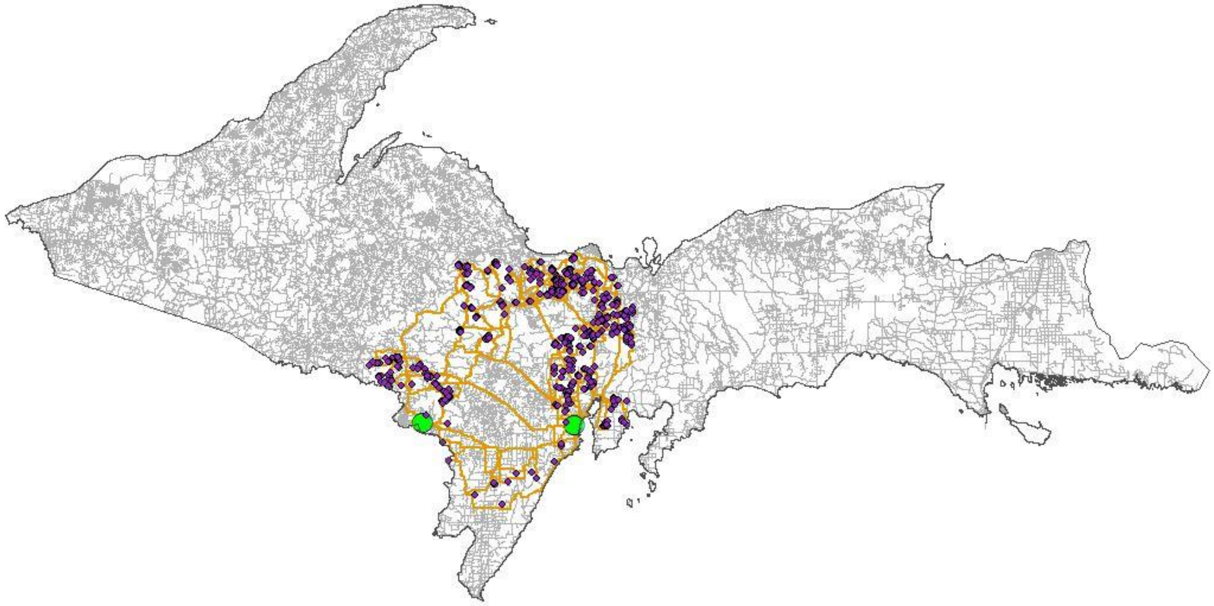
The process for converting the GIS data into wood chip transportation costs included several steps. First, centroids were created for each of the commercial forest polygons. These points were then connected to the State of Michigan's Roads Framework network through the creation of an access line (shown in green below), that runs from the centroid of the polygon to the closest established roadway. The resulting plot-level map looks like the example in Figure 12.

Figure 12: Commercial Forest Program Plot-Level Depiction of Roads Network in the Upper Peninsula



The resulting network depicted in Figure 13 shows the routes (orange) that connect the commercial forest parcels within 50 miles (purple) with the mills (green). The two mill locations are approximately 50 miles apart.

Figure 13: Commercial Forest Plot to Mill—Roads Network Sample



The resulting network identifies the shortest distance between each commercial forest parcel and each of the two mills. To convert these distances into costs, the U.S. Forest Service's Forest Residues Transportation Costing Model (FRTC) is used. The FRTC model allows users to compare alternative methods of moving biomass from the forest to a wood-using facility. It allows users to estimate loading and hauling costs for different types of equipment, evaluate the best mix of equipment, compare different hauling routes, and examine reloading or two-stage hauling opportunities. The model uses values and production rates that are drawn from current studies of particular machines on specific operations (Rummer 2005). Since this study is only interested in the second-stage transportation cost of moving residues from the roadside to the Escanaba or Quinnesec mill, only a part of the model is used and specific values changed to reflect data gained from our interviewees and informants.

Using the FRTC model, transportation costs were calculated with consideration for road-type, controlling for potential cost per ton-mile differences resulting from low-quality roads or roads with lower speed limits. The model has 5 road-type classifications: unimproved forest (10 mph), gravel – improved (15 mph), 2-lane paved (30 mph), state highway (50 mph), and interstate (60 mph). The roads in the GIS network are identified using Census Feature Class Codes and fit to one of these categories in the model according to road type. The Road Feature Class, A, is used. Only categories with drivable roads are included. Those for walking paths or limited access roads are excluded from the analysis (categories A7 and A9) (Ross 2017).

Using the roads network, the proportion of total distance traveled on each road type is calculated for the shortest commercial forest parcel-to-mill route to estimate road-type sensitive cost per ton. These proportions are averaged across each five-mile distance interval from parcels to each mill, from zero to one hundred. Transport beyond one hundred miles is very unlikely given prohibitive costs. The FRTC model is then used to calculate a total transport cost for each interval. This number is the residue transportation cost per green ton, C_{haul}, for the shortest route from the commercial forest parcel to mill for the given distance. This number, added to on-site costs and ROI considerations, is the break-even price of delivered residues per green ton.

5.2 Supply Analysis

The cost analyses from the previous sections are combined to generate timber residue supply functions, addressing the third and final research question. The marginal costs of supplying the two Verso mills with chips from successively more distant harvest sites generated in the GIS analysis above are paired with county-level timber stock and harvest data to estimate the quantity of residues available at a break-even price at each distance. This gives us supply functions that are sensitive to road distance.

Based on total average roundwood[25] production by county for Upper Peninsula timberlands and interview testimony, the available quantity of timber residues from each site can be estimated. These average annual harvest removal ratios (see Appendix B) were obtained from the USFS Forest Inventory EVALidator (Miles 2017).[26] Data from the EVALidator applies to all timberlands in the Upper Peninsula, not just commercial forest lands. Timberland is defined as, "Forest land that is producing or is capable of producing crops of industrial wood and not withdrawn from timber utilization by statute or administrative regulation. (Note: Areas qualifying as timberland are capable of producing at least 20 cubic feet per acre per year of industrial wood in natural stands.)" (Miles 2017). The harvest removal ratios are used to compute average timber harvest rates per acre for each county in the Upper Peninsula, which captures differing timber productivity across regions.

Timber residues represent a relatively fixed proportion of timber harvested. The assumed rate of timber residue production per unit of roundwood harvested comes from interview testimony by Eric Stier at American Forest Management, "An acre can generate maybe about 1 ton of biomass for about 4 tons of roundwood."[27] This rate, combined with acreage data from Michigan's Commercial Forest Program and county-level timber harvest productivity data from EVALidator, is used to estimate total residues available from the commercial forest land that is

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[25] Roundwood products include logs, bolts, or chips cut from trees for industrial and non-industrial uses (sawlogs, veneer logs, pulpwood, etc.).
[26] Harvest quantities reported in the EVALidator are in cubic feet. Volume is converted to dry tons using a factor of 30 dry pounds per cubic foot per the 2011 Billion Ton update (U.S. Department of Energy, 2011), or 60 green pounds per cubic foot, assuming a moisture content around 50%.
[27] Eric Stier (Michigan District Manager, Amercian Forest Management), interview by S. Klammer and S. Swinton, June 22, 2016, AFM Regional Offices, Atlantic Mine, MI.

located within a specified distance to each of the mills. Total residue supply is then combined with the break-even cost analyses to generate 100-mile annual timber residue supply curves for both the Escanaba and the Quinnesec mills.

5.3 Break-even Analysis Results

Income-motivated managers will supply timber residues only if the stumpage price (P_{Stump}) paid by loggers for the right to chip the residues covers the potential damage (C_{damage}) to standing timber from removals. In turn, loggers need to receive a break-even price (C_{resd}) at least as great as the market price (P_{resd}) in order to be willing to chip timber residues. They will chip up to the quantity at which marginal revenue equals marginal cost, but that marginal cost will be higher if they do not already own and operate a chipper. I conduct a break-even analysis as outlined above to formally calculate these costs and determine timber residue supply quantity from commercial forest lands in the Upper Peninsula.

5.3.1 On-site Costs

While the cut-to-length method makes it costlier to harvest residues, interviewees report that under current market conditions the foregone value of residues is too low to offset the sawlog cost savings from the use of the more efficient cut-to-length equipment. Especially in the hardwood stands that prevail in the Upper Peninsula, the potential cost to timberland managers of damage to standing timber from loggers doing full tree harvest or a making second trip out to the woods to gather residues is often not worth whatever stumpage price the logger is willing to pay. If it is not profitable, each timberland manager interviewed reported that they would not supply residues, except in rare instances. This profit-driven mindset of corporate timberland managers was apparent during a journey to an active timber harvest on Molpus lands outside of Houghton, Michigan. While watching a cut-to-length harvesting operation, Molpus Division forester Rob Oldt explained that it is the most efficient method for harvesting timber. He also confirmed that the cut-to-length method results in higher residue gathering costs, since residues are left across the stand. This cost is represented in the analysis as the cost of gathering residues under this harvest method, or $C_{gath.}$ A cut-to-length harvester can be seen in Figure 14.

Figure 14: Cut-to-length Harvesting at Molpus Timberlands Management, Houghton, MI

According to Longyear manager Jacob Harynen, "In hardwood stands we hate to bring full trees out [due to risk of damage], so we don't utilize tops."[28] In cases where they could receive a high enough payment to make the risk of damaging standing timber worthwhile, however, he reports that they would consider supplying residues. Each of these firms, including Molpus and Weyerhauser, report needing a stumpage price of $2-$5 per ton of residues to consider supplying residues. Carey Logging reported an average onsite gathering and hauling cost (C_{gath}) of collecting residues of around $8 per green ton under the cut-to-length method or $0 under the whole-tree method. Both stumpage price and cost of gathering estimates are on the conservative end of gathered estimates and could easily increase by several dollars per ton depending on the firm and the specific harvest.

The three different chipping cost analyses described in section 5.1.1 were not significantly different, varying in range by less than a dollar per green ton. Some of the existing difference in costs between the first scenario and the second and third could be a result of rounding errors (many of Carey's costs were gathered informally while he was on the job), and the inclusion of additional overhead costs that were not part of the latter two analysis (and were unreported in Carey's estimates). The results of the three analyses for both the short run and the long run are shown in Table 5. In Table 6, a more detailed look at the machine rate result for Scenario 1A is given.[29]

[28] Jacob Harynen (Marketing and Sales Manager, Longyear), interview by S. Klammer and S. Swinton on June 23, 2016, Corporate Office, Marquette, MI.
[29] For complete machine rate workbooks with itemized costs, contact S. Klammer.

Table 5: On-site Chipping Costs Under Different Assumptions

	1. Logger (Carey)	2. Logger (Industry-heavy use w/ trade-in)	3. Logger (Industry-limited use, no trade-in)
Long-Run	**$6.19 /ton**	**$5.36 /ton**	**$5.95/ton**
Short-run	**N/A***	**$4.06 /ton**	**$4.06 /ton**

*Carey's reported costs included amortized chipper costs.

Table 6: Results for Chipping Cost Scenario 1A

Total Machine Rate: Carey Logging, Inc.

This sheet contains calculations developed based off of reported total costs for various parts of operations from Jim Carey, CEO & owner of Carey Logging, Inc.

	Carey's Reported costs	
Fixed and Var Total =	$150.00 /PMH	$135.00 /SMH
Labor (inc. benefits)=	$32.00 /SMH	$35.56 /PMH
Total =	$185.56 /PMH	$167.00 /SMH
Per ton =	$6.19 /tonPMH	$5.57 /tonSMH
Chipper Operating Rate:	30 tons/hour	
Jim's reported cost*:	**$6.19** /tonPMH	

Long-run analyses include fixed equipment costs. For the logging firm that already owns a chipper, however, these costs are already incurred and the firm realistically will continue chipping so long as they can cover variable chipping costs. When fixed equipment costs were excluded from the chipping cost analyses, chipping costs fell by over a dollar from over $5/green ton to around $4/green ton. While this is not a small drop in costs, this analysis focuses on long-run cost per ton because acquiring chipping equipment would be necessary for a significant expansion of timber residue harvesting in the Upper Peninsula.

Altogether, the on-site costs portion of the break-even analysis resulted in a residue cost at the roadside of about $10 per green ton in the long run under a whole-tree harvesting operation ($C_{gath} = 0$), and about $18 per green ton in the long run under a cut-to-length harvesting operation. This makes it clear that harvest technology plays a large role in on-site costs.

5.3.2 Transportation Costs & Timber Residue Supply

The GIS analysis shows that approximately 1.11 million and 1.14 million acres of commercial forest lands are located within 100 miles of the Escanaba and Quinnesec mills, respectively. 1.38 million acres are available within 100 road-miles of either mill when considered together, due to considerable overlap between the road-distance analyses for the two mills, which are located only 50 miles apart. Cumulative acreages for each 5-mile distance range can be seen in Table 7 below.

As outlined in section 5.2, average annual timber harvest data by county is combined with acreage data to compute parcel-level timber production that is then aggregated to estimate timber supply from CFP lands. This is shown under “Roundwood” in Table 7. Under “Residues”, the estimated output of timber residues from this land is shown, assuming a collection rate of one ton of biomass for every four tons of roundwood.[30]

[30] Eric Stier (Michigan District Manager, Amercian Forest Management), interview by S. Klammer and S. Swinton, June 22, 2016, AFM Regional Offices, Atlantic Mine, MI.

Table 7: Distance-based Estimates of Roundwood and Timber Residue Quantity Available Annually for the Quinnesec and Escanaba Mills (in green tons)

	Quinnesec Only			**Escanaba Only**			**Both**		
Miles	Cum. Acres	Roundwood	Residues	Cum. Acres	Roundwood	Residues	Cum. Acres	Roundwood	Residues
0	-	-	-	-	-	-	-	-	-
5	119	112	28	80	32	8	199	144	36
10	610	570	143	960	386	97	1,569	956	239
15	5,905	4,877	1,219	11,564	4,620	1,155	17,389	9,498	2,374
20	28,452	19,923	4,981	37,645	15,859	3,965	66,097	35,782	8,946
25	69,697	46,928	11,732	67,418	31,083	7,771	137,115	78,011	19,503
30	112,272	77,064	19,266	116,131	58,337	14,584	222,913	132,567	33,142
35	138,779	97,018	24,255	171,691	88,339	22,085	267,855	163,256	40,814
40	174,648	123,111	30,778	250,460	136,021	34,005	324,494	203,723	50,931
45	209,670	151,391	37,848	298,401	169,756	42,439	371,389	239,588	59,897
50	252,747	190,535	47,634	334,469	194,931	48,733	431,562	290,856	72,714
55	338,506	273,426	68,356	365,996	217,337	54,334	523,094	376,125	94,031
60	460,940	383,723	95,931	410,870	248,666	62,166	642,380	486,140	121,535
65	536,304	452,756	113,189	457,570	280,224	70,056	740,119	569,576	142,394
70	638,515	549,856	137,464	502,486	315,977	78,994	855,381	677,400	169,350
75	723,839	624,221	156,055	548,516	350,994	87,748	941,829	754,452	188,613
80	816,346	706,304	176,576	610,756	399,353	99,838	1,024,593	830,033	207,508
85	941,333	821,296	205,324	736,447	504,844	126,211	1,156,717	951,194	237,798
90	1,016,730	885,847	221,462	851,459	606,947	151,737	1,227,983	1,012,604	253,151
95	1,081,074	939,633	234,908	967,213	711,670	177,917	1,297,331	1,068,407	267,102
100	1,142,556	986,439	246,610	1,107,810	837,138	209,284	1,381,995	1,130,136	282,534

Using the GIS road network and the USFS FRTC model, one-way transportation costs assuming backhaul from the roadside to the Escanaba or Quinnesec Verso mills are calculated. These ranged from $1.59/green ton for a 5-mile one-way trip to $10.10/green ton for a 100-mile trip. Average transportation cost per ton-mile for the entire 100-mile radius is about $0.13.[31] Routes were made up of 91% US/State Highway, 8% two-lane paved, and only 1% unimproved forest road. No interstates overlap the analysis area. Commercial forestlands located within 100 road-miles of the Escanaba and Quinnesec mills are shown in figures 15 and 16.

[31] Wisconsin roads were excluded from the analysis and could realistically result in lower costs for parcels located on the southwestern border. Moreover, transportation costs are highly dependent on stand proximity to a final demand point, making it likely that some market dynamics between the southwestern UP and northeastern Wisconsin were not captured by this analysis.

Figure 15: Road Distance of Michigan Commercial Forest Parcels from the Escanaba Mill

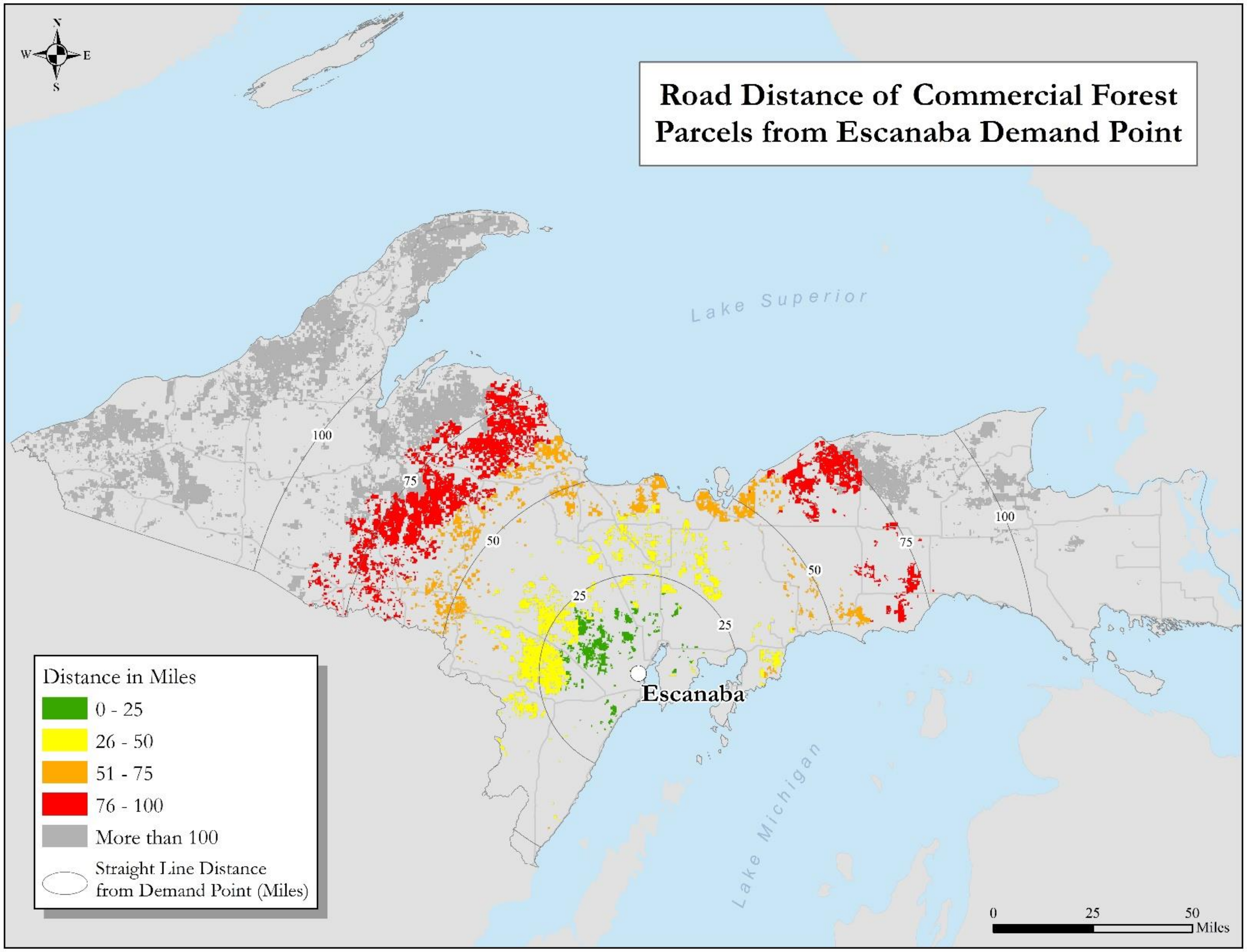
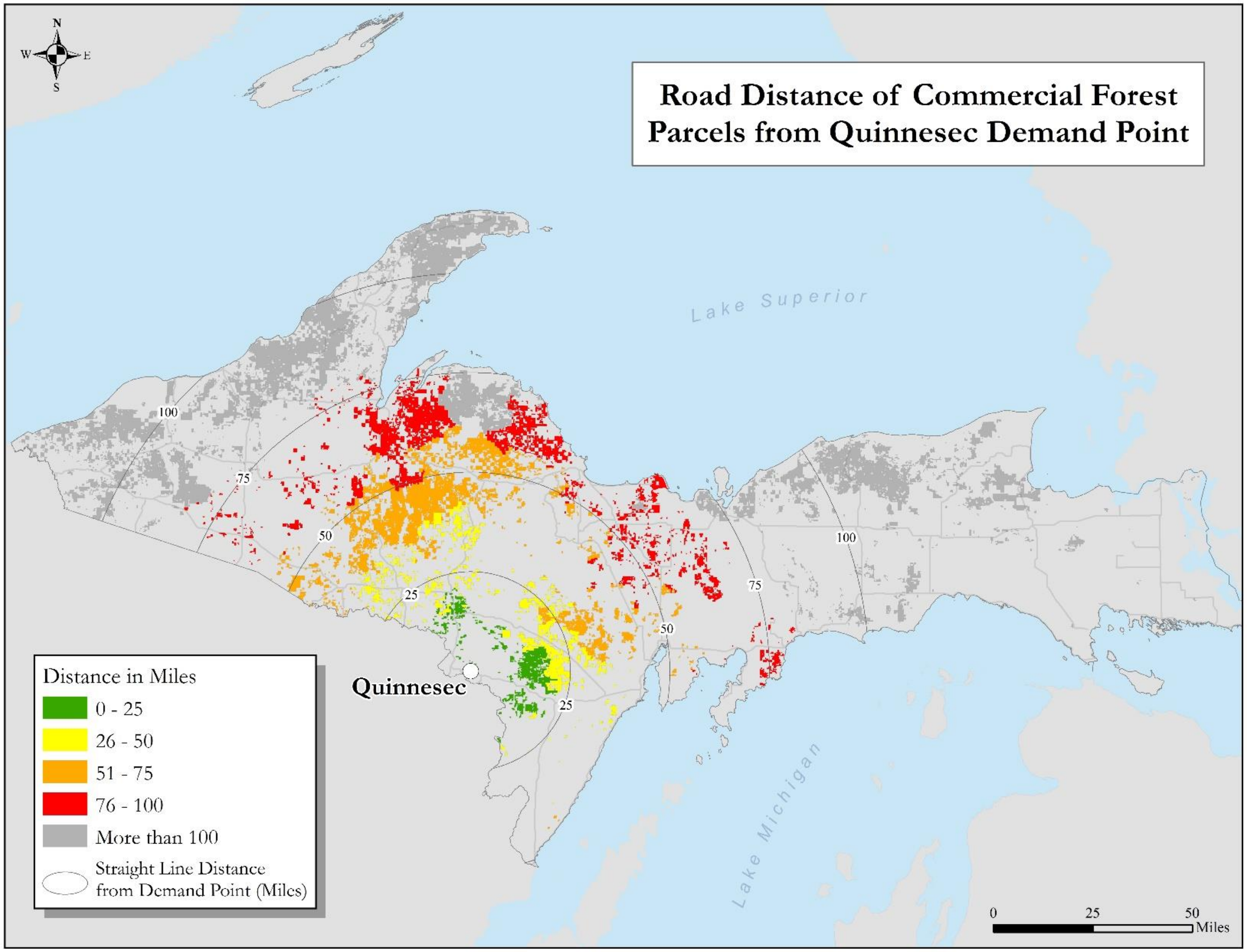


Figure 16: Road Distance of Michigan Commercial Forest Parcels from the Quinnesec Mill



The final component of the break-even cost of chipped residues is ROI. As explained in the conceptual model, loggers in this study reported needing a 15% ROI on top of standard equipment investment considerations to be willing to divert resources away from regular timber harvesting operations, which are more profitable. Transportation costs and residue supply quantities were used in conjunction with the roadside residue costs calculated above and ROI considerations of 5%-15% to generate supply curves for both mills under 3 harvest technology scenarios. Five percent is the standard minimum real rate of return on investment while 15% is the target return on investment reported by several of the interviewees. Five percent ROI considerations are used for the following graphs. Graphs with 15% ROI considerations can be found in Appendix C.

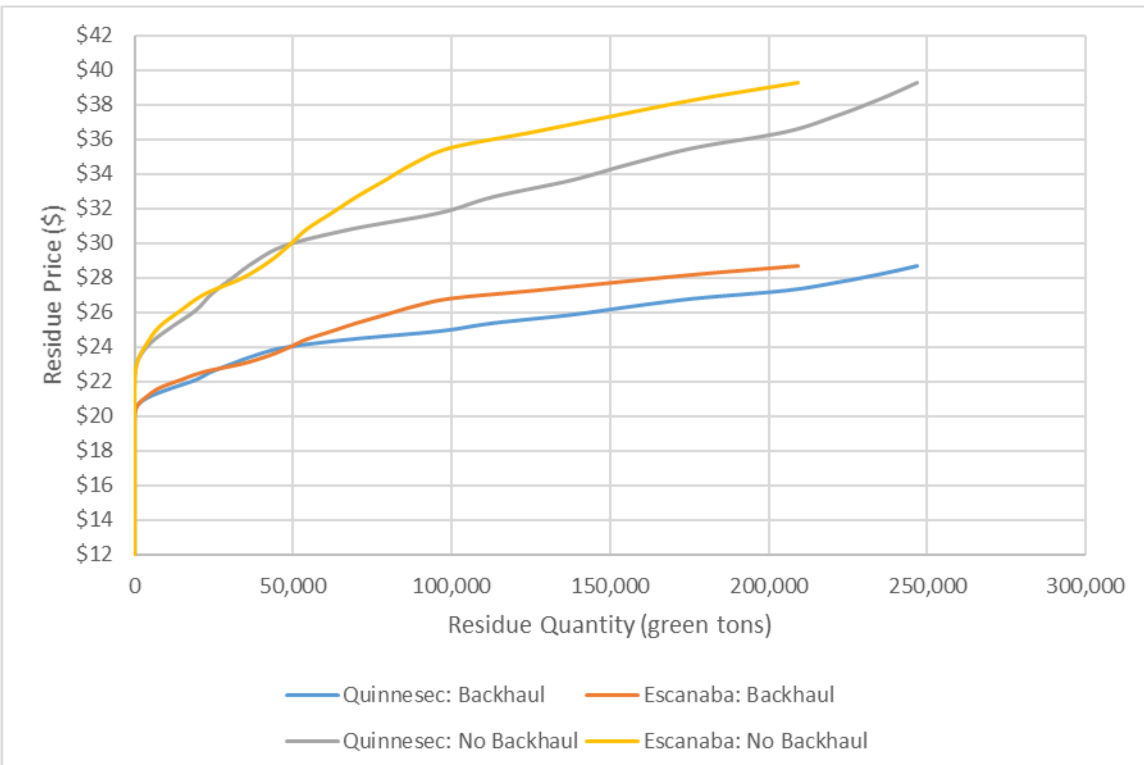
The first scenario takes place assuming 90% cut-to-length harvesting methods and 10% whole-tree harvesting methods (the current regional mix as reported by Carey Logging). Under this scenario, and assuming costless backhaul, the break-even price needed to cover the costs of supplying 200,000 green tons of residues per year is around $27/green ton at the Quinnesec Verso mill and $29/green ton at the Escanaba Verso mill.

There is very little opportunity for backhaul using chip vans, however, making it very unlikely that transportation costs will be this low. When transport costs are doubled, break-even costs increase considerably. [32] Under this scenario, the break-even price needed to cover costs of supplying 200,000 green tons of residues per year is around $36/green ton at the Quinnesec

[32] This is consistent with average 2-way transportation costs reported by Carey Logging, using a 120 yd chip van with a 33/ton base payload.

Verso mill and $39/green ton at the Escanaba Verso mill. At the current mill price of around $29 or $30 per green ton[33] for residues, only about 50,000 green tons could be supplied.

Figure 17: 100-mile Annual Timber Residue Supply Under 90% Cut-to-length and 10% Whole-tree Harvest

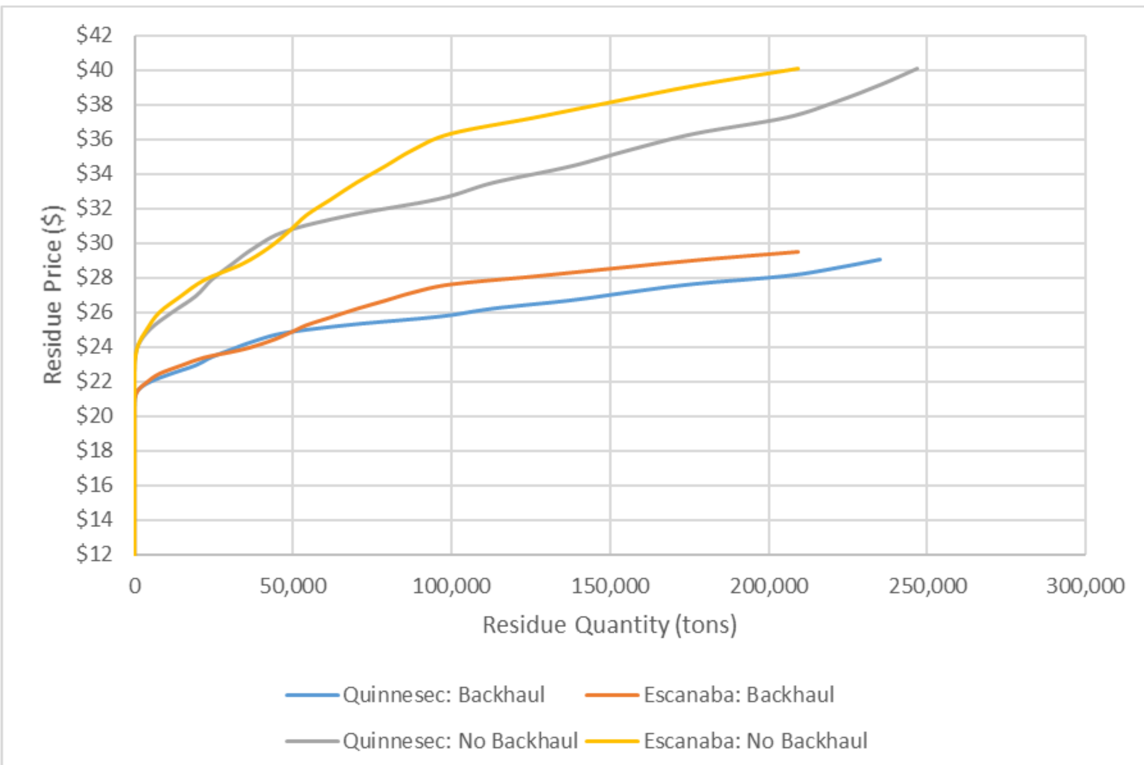


The second scenario assumes that all timber harvests are conducted using 100% cut-to-length harvesting techniques. This scenario does not differ largely from the first, with the break-even cost of supplying 200,000 green tons of timber residues per year falling between $28 and

[33] Robert Ashbacher (Biomass Purchaser, Verso Co.), phone interview by S. Klammer, Jan 3rd 2017.

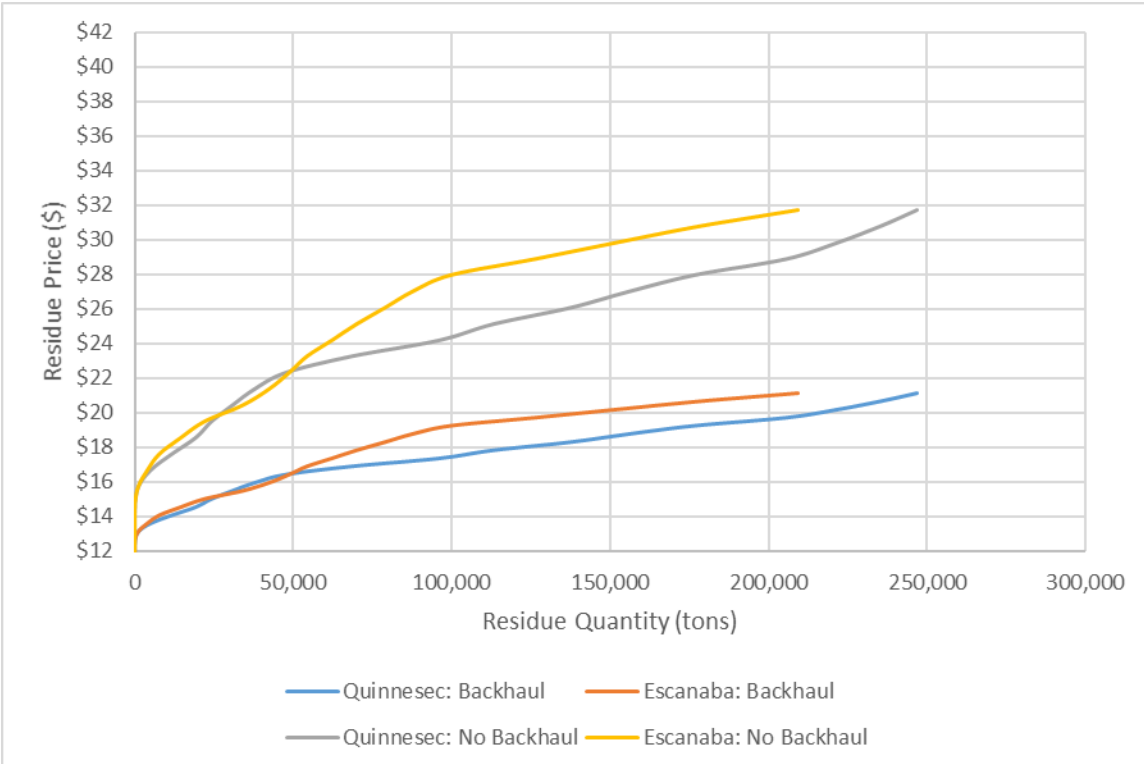
$30 per green ton to both mills with backhaul or from $37/green ton at the Quinnesec mill to $40/green ton at the Escanaba mill with no backhaul (Figure 18). Higher costs in scenarios one and two are a result of higher gathering costs.

Figure 18: 100-mile Annual Timber Residue Supply Under 100% Cut-to-length Harvest



The third scenario would provide the lowest cost timber residue supply. When all timber harvests are conducted using whole-tree harvesting techniques where tops are consolidated in piles at a landing during timber harvest, the break-even cost of supplying 200,000 green tons of residues from commercial forest lands annually is around $20-$21 per green ton to both mills, one-way. This increases to between $29 and $32 per green ton with no backhaul (Figure 19).

Figure 19: 100-mile Annual Timber Residue Supply Under 100% Whole-tree Harvest



.

6. Conclusion

Compared to other cost studies on agricultural crop residues, the break-even prices developed in this thesis are quite competitive, ranging from around $18 per green ton ($37 per bone dry ton[34]) at the roadside to $22-$40 per green ton ($46-$83 per dry ton), under the most pessimistic scenario assuming gathering costs for all residues supplied and round-trip transportation costs (5-100 miles). These numbers are competitive with many corn stover cost estimates found in the literature. As discussed in the introduction, corn stover is available at prices as low as $30/ton at the farmgate (Graham et al., 2007) or anywhere between $43 and $52 per dry ton delivered when transporting them between 22 and 62 miles (Perlack and Turhollow 2003). Brechbill and Tyner (2011) found that total costs per dry metric ton for biomass with a transportation distance of 60 km range between $63 and $75 for corn stover, higher than the estimated $58 per dry ton faced by loggers in this study under a 100% cut-to-length harvest with no backhaul when transporting timber residues a similar distance. Yet while these breakeven prices might be competitive with estimates for other agricultural residues like corn stover, markets for either struggle to develop.

Early interviews with managers and key informants made it apparent that those directly involved in the industry view the current lack of residue harvesting as a demand-side problem. Jim Carey explained in our first interview that “before natural gas prices fell and killed chipping” chip prices were high enough at the mill to justify the investment. Now, however, chip prices

[34] Prices have been converted from a green ton basis to bone dry ton basis for comparison with corn stover, which is frequently reported in terms of dry tons. From average moisture content estimates gathered from Bob Ausbacher of Verso Co., I assume a moisture content for chips of 48%. Freshly felled coniferous wood has a moisture content of between 55 and 60%, one summer seasoning reduces the moisture content by 10 to 15%. Freshly felled ash has a low moisture content of between 35 and 40%, other hardwood species have moisture content between 45 and 50% (Wood Energy 2006).

have fallen to levels where logging firms must rely on long-standing relationships with mills and contracts guaranteeing what he describes as "prices that are just enough to get by" if they continue to chip. Because of this, he reports that only 3-4 loggers are chipping residues on a very small scale compared to what it was just a few years ago.[35] Other key informants like Don Peterson of the Sustainable Resources Institute tell a similar story. According to Don, the places that show promise for bioenergy are "the places without natural gas."[36] This narrative fits with current natural gas prices, which are generally on the lower end of price estimates for residue chips. While chip prices range from $2.56 to $4.65 per million BTUs of energy, natural gas spot prices have been around $2 to $3 in recent years (U.S. EIA, 2017).

Even those loggers that are producing chips are not doing so at capacity. Biomass Purchaser Robert Ashbacher reported that under current market demand conditions Verso's residue chip suppliers "produce about a third of what they're capable of producing."[37] Carey says that they would happily chip more if demand increased, but he does not foresee the market improving in the future as even the few mills that utilize residues in the region have switched to natural gas or updated technology: "The [mill] in Escanaba used to use 1,000 tons a day but shut down a boiler due to inefficiency. It uses the bark now from production as fuel." Given the lack of demand points for residues in the region, changes like the one Carey described have huge implications for the market. According to consultant Jon Fogitt (manager of the TNC lands): "If any of the mills in the UP went out, it would be devastating." Fosgitt explained that

[35] Jim Carey (President, Carey Logging), phone interviews and email correspondence by S. Klammer from July 12th, 2016 until June 6th, 2017.
[36] Donald Peterson (Executive Director, Sustainable Resources Institute), interview by S. Klammer and S Swinton on June 21st 2016, Crystal Falls, MI.
[37] Robert Ashbacher (Biomass Purchaser, Verso Co.), phone interview by S. Klammer, Jan 3rd 2017.

“diversification of secondary markets is understandably a concern,” referring to Verso, which currently owns both mills.

While interviews pointed to low natural gas prices and a lack of demand points as the source of the demand lag, the empirical analysis suggests that on the supply side, technological change toward cut-to-length harvesting and high transportation costs also plays a role. Profit-driven managers at Molpus, AFM, and Longyear all discussed how harvest technology has also contributed to shaping residue supply. Since these managers largely care about covering potential damages to their standing timber from residue removal plus some desired return, the widespread use of cut-to-length harvesting equipment means stumpage prices for residues are likely to remain high, contributing significantly to on-site costs for loggers who wish to harvest residues. Moreover, cost conditions can vary considerably from region to region, depending on the make-up and state of the local timber market and the players in it. For instance, it is likely that transportation costs are higher in areas with less-developed roads systems, adding an additional layer of variability to the cost of supplying timber residues.

For a byproduct like timber residues, the viability of commercial supply depends entirely upon those cost conditions and what producers can do to benefit from supplying those residues. If chip prices should rise, residues could become a coproduct rather than a byproduct, facilitating a switch among loggers to methods and equipment that generate more chips. As Jim Carey observed: “The future of chipping is with the loggers. They have to decide to invest before anyone else can do anything, and to do that there has to be a market.”

APPENDICES

APPENDIX A: Interview Script for Managers

1. Introducing Questions
   - **Explain Purpose**. Collab between UofW and MSU with funding from the US Department of Energy to try to get idea of the conditions under which landowners (or loggers) would supply biomass/slash for bioenergy. We are trying to understand how this part plays into bioenergy supply for the future….we want to understand how they think about these things for future research.
   - **Explain their role**. Ex: Would like to ask them a few questions since we've identified them as a key player in our interest area.
   - **Ask permission to:**
   - 1. Record
   - 2. Attribute
2. Background questions

   Interviewee:

   - **Can you tell me a little about your current role in this business?**

   Company:

   - **What is the corporate decision-making structure, particularly when it comes to forest land use?** (is there a person or department that does this, or is it a board decision, etc…)

   - **Can you tell me a little about your business model?** Try to get the interviewee talking, to indirectly and organically answer questions below.
     - How many acres in northern tier (important question, since this changes all the time and we want a good idea of size. Plum Creek/Weyerhauser has been selling a lot of land)
     - How is land use divided (is it all managed for timber harvest?)

- How do you decide on what timber to harvest? Where to harvest? When to harvest?
- Do you work with a particular logger/do you own your own logging/mill operation?
- Do you currently require the harvest of biomass/slash (small diameter stuff)? Why/why not?
  - If yes, ask about their current contracts for woody biomass supply (what kind, what for, etc) and how long they run.

  *If NO, this is a good time to move into Follow Up Scenarios (choose #1 or #2 depending on responses to these last questions).

3. Follow-up Supply Scenario #1
   - **Have you considered (harvesting/increasing harvest) of timber slash?**
     - **Suppose that market demand for timber slash jumped so dramatically that you began seriously to consider harvesting slash at time of timber harvest.**
       - What would be the biggest barriers to harvesting & selling slash?
       - What kind of contract terms would you need?
         - Term of contract (years)
         - Location (At harvest site? Delivered?)
         - Price (what unit? Per ton? Per acre?)

4. Follow-up Supply Scenario #2 (Specifying Questions)
   - **Can you imagine a scenario where you considered renting out your land for someone else to grow biomass crops for energy?**
     - Under what conditions would you seriously consider doing this?

5. Other info to gather to help with the above (though perhaps slightly riskier/not as necessary to flat-out ask
   - Under what terms do you currently sell timber products?
   - Do you have a long-term net revenue or return-on-investment target?
   - What would you have to make per acre to be interested in making the switch to bioenergy crops that was mentioned above?

APPENDIX B: County-level Average Annual Harvest Removal Ratios Gathered from the USFS EVALidator

Table 8: County-level Average Annual Harvest Removal Ratios Gathered from the USFS EVALidator

County Name	Region	Average Annual Harvest Removal Ratios (green tons per acre)
Keweenaw	W	0.320
Houghton	W	0.943
Ontonagon	W	0.478
Gogebic	W	0.913
Baraga	W	1.096
Iron	W	1.114
Marquette	C	0.770
Dickinson	C	0.935
Menominee	C	0.516
Alger	C	0.494
Delta	C	0.402
Schoolcraft	C	0.745
Luce	E	0.917
Chippewa	E	0.581
Mackinac	E	0.440

APPENDIX C: Supplementary Figures and Tables

Figure 20: 100-mile Annual Timber Residue Supply Under 90% Cut-to-length and 10% Whole-tree Harvest, 15% ROI

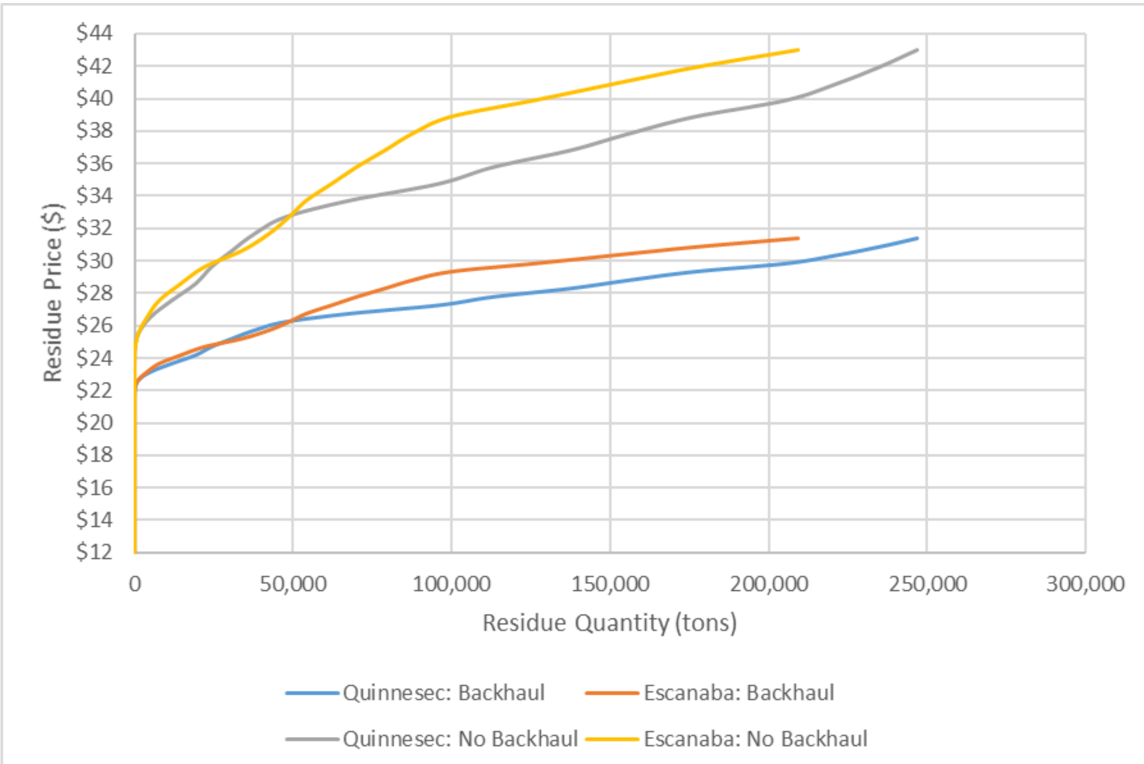


Figure 21: 100-mile Annual Timber Residue Supply Under 100% Cut-to-length Harvest, 15% ROI

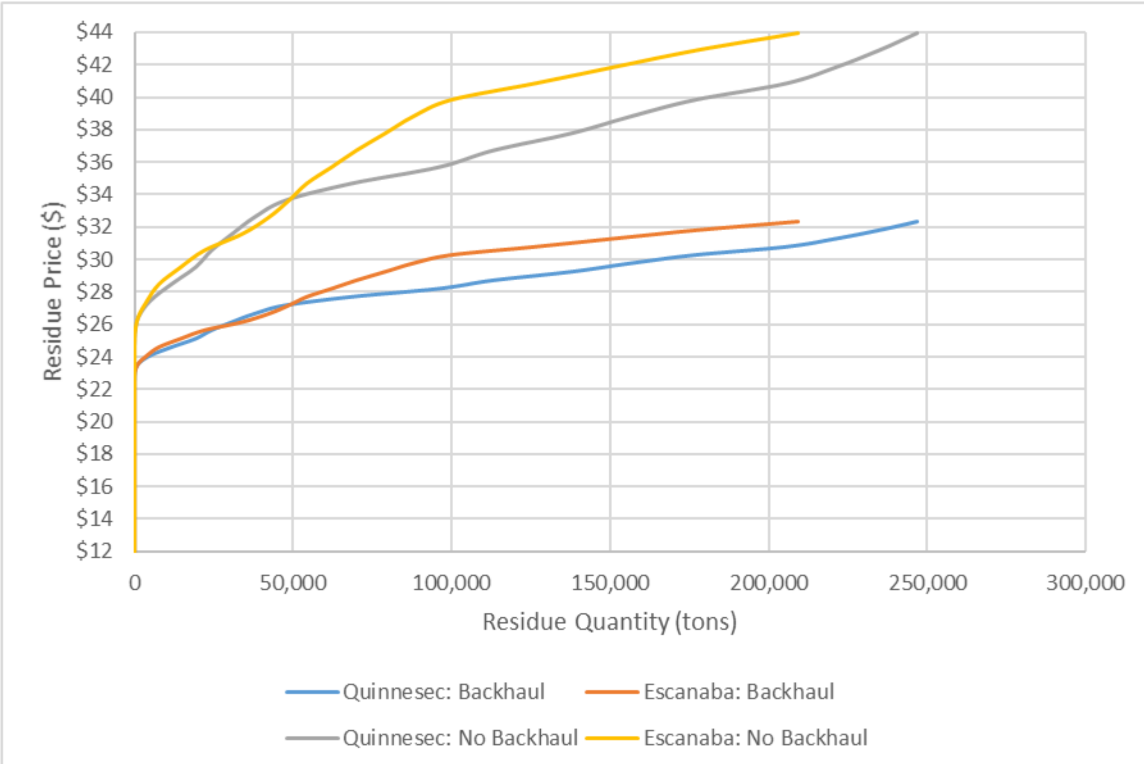
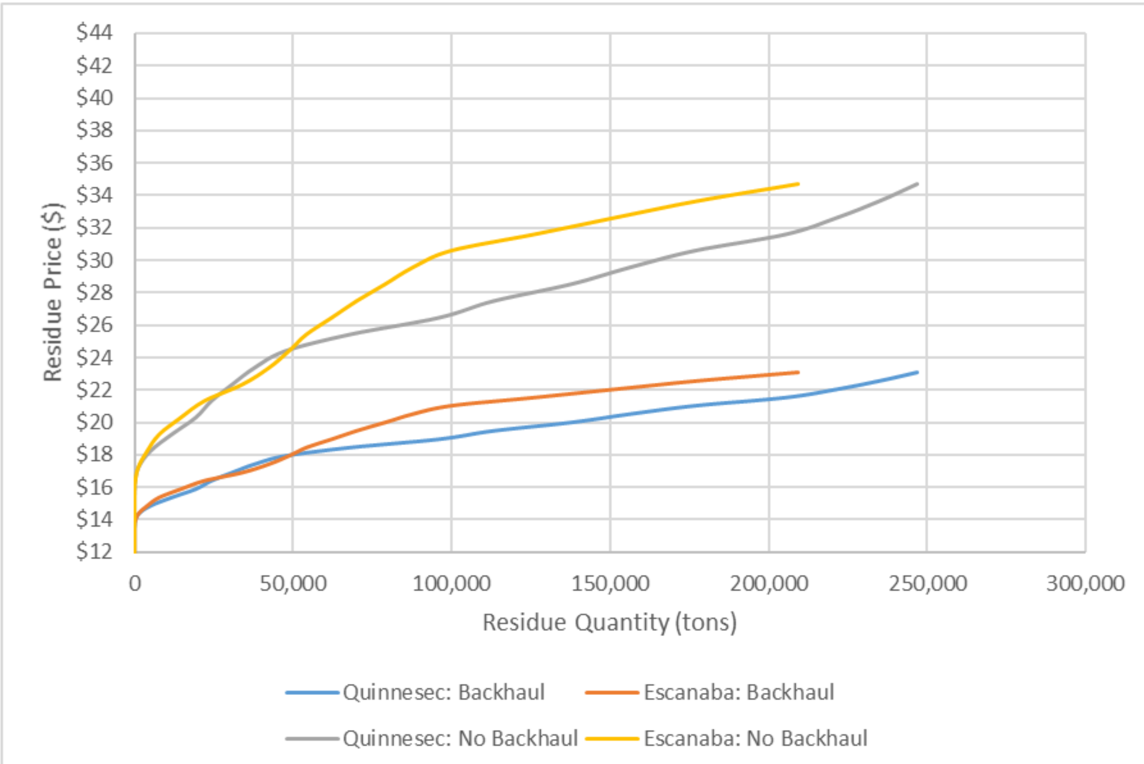


Figure 22: 100-mile Annual Timber Residue Supply Under 100% Whole-tree Harvest, 15% ROI



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