

Business Activities, Decision-Making, and Barriers to Viability of the Forest Biomass Harvesting Industry in Washington State

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Abstract

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Using forest biomass- the leftover byproducts of forestry operations- as an energy source potentially presents a win-win alignment of environmental goals, economic growth, and business success. This research explores the thoughts and actions of businesses involved in the harvest, collection, processing, and transportation of forest biomass to energy production facilities. Drawing on interviews with 21 firms in the industry, this research characterizes the industrial organization, activities, and decision-making of forest biomass harvesting businesses, and examines economic and policy barriers to the viability of the forest biomass-to-energy industry.

The state's forest biomass-to-energy industry is organized around contractual relationships between landowners, the processing firms that collect, grind, and transport the biomass, and the

energy producers which ultimately consume the biomass. Several types of barriers to entry characterize the forest biomass-to-energy industry, including equipment costs and the learning curve encountered by new processing businesses. In general, businesses' decision-making is driven by profit calculations, although economic models of supply and demand may not fully incorporate businesses' strategic responses to risks and policy incentives. Landowners and processors differ in key aspects of their biomass harvesting activities and strategy: landowners are less tolerant of taking risks, less likely to own biomass harvesting equipment, and less motivated by short-term profits than processing contractors. Policies intended to support the forest biomass-to-energy industry, such as the federal Biomass Crop Assistance Program and the state business and occupation (B&O) tax credit for forest-derived biomass, have not been sufficient to overcome countervailing economic forces limiting forest biomass harvest.

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Chapter I. Background

Using forest biomass- the leftover byproducts of forestry operations- as an energy source potentially presents an arena where environmental goals, economic growth, and business successes can align. In Washington State, a broad political coalition reflecting these varied goals has tended to support efforts to increase the use of forest biomass in energy production. Several state government entities, including the legislature and the Commissioner of Public Lands, have adopted a goal of supporting the use of forest biomass in energy production (WA DNR 2012; WA Legislature 2013b). However, in spite of several policy actions intended to support the industry, and in contrast to the hopes of many of those in the forest products industry, the use of forest-derived biomass for fuel and energy production has not yet achieved widespread use or become broadly economically viable. As one biomass businessman noted, using forest biomass residuals as an energy source is a “warm and fuzzy” concept that grabs the attention of many policy-makers and stakeholders, but getting the logistics and economics of forest biomass-to-energy to actually work out in practice is easier said than done, and full of potential pitfalls.

This research characterizes the industrial organization, activities, and decision-making of forest biomass harvesting businesses. The findings in this research about forest biomass businesses also serve as a foundation for the examination of economic and policy barriers to the more widespread use of forest biomass in energy production.

One motivation for this research was the hope that a better-grounded assessment of the day-to-day functioning of forest biomass businesses could help identify targeted legislative or program administration improvements that would help the state better achieve its goal of supporting the biomass-to-energy industry. In addition, should new technologies utilizing forest biomass as a

fuel source become commercially viable, a deeper understanding of landowners and biomass processors' existing harvesting practices and infrastructure will be useful to understanding the business environment encountered by new biomass-consuming industries.

1. Biomass Types and Sources

Biomass can be used as a fuel source for industrial processes that require heat or steam, and can also be used as an electric co-generation or stand-alone power source at paper mills, power plants, and similar industrial facilities. Woody biomass material used in energy production can come from a variety of sources, including sawdust from the cutting of dried lumber, bark and other woody materials stripped off during whole-log processing in forest-product mills, residual materials (including pulping liquors) from paper-making, and wood waste from urban uses like construction. “Hog fuel” is the industry term for woody biomass deriving from any of the above sources (other than sawdust and pulping liquor) that is ground up for use in energy production. This research primarily focuses on one source of hog fuel: forest-derived biomass, which is the “logging slash” byproducts of timber harvesting and land-clearing operations, such as tree limbs, stumps, and tops. These materials are generated at the site of initial log harvest operations, and tend not to have other higher-value commercial uses. “Forest-derived biomass” includes wood from a variety of sources, including (a) industrial tree farms where forestlands are re-planted after logging operations, (b) forest lands owned by individuals, (c) orchards and agricultural sources, (d) forestlands cleared for housing developments or for conversion to farmland, and (e) urban forest waste streams, such as leftovers from municipal landscaping and vegetation-management activities. Although this study's focus is on forest-derived hog fuel, woody biomass derived from forest product milling activities are discussed to the extent that industry participants referenced both types of biomass in explaining certain aspects of their industry.

The manner in which forest biomass is harvested depends on logistical considerations that are specific to the harvesting site, including the type of logging equipment used. In general, biomass harvesting involves the piling of tree tops, butts, branches, defect-laden logs, and other woody material unmarketable for sawmilling or paper pulping. This piled material is then either ground up at the logging operation site into hog fuel for use in energy production, or is transported off-site prior to being ground into hog fuel. Throughout this study, the term “harvest” refers to the general process of collecting, piling, grinding/chipping, and transporting forest biomass to energy facilities. Biomass harvesting can include activities undertaken either by landowners, logging contractors, or biomass contractors. The forest biomass harvesting supply chain also sometimes includes intermediate bulk materials processors who dry, mix, segregate or screen woody materials for use in energy production.

Forest biomass that is converted into hog fuel can be combusted in boilers to produce heat or steam for industrial processes like lumber drying or paper production, to generate electricity, or for use in a combined heat and power operation. Forest biomass, like other organic material, can also be used for purposes such as composting, livestock bedding, and erosion control. Finally, there is potential for forest biomass-derived cellulosic ethanol and other new commercial applications of bioenergy technologies, although there are not currently any commercial-scale facilities operating in Washington which use forest biomass in the production of liquid fuel.

One impediment to the use of forest biomass in energy production is that it may not be price-competitive with other energy sources. It is particularly costly to collect residual forest biomass at the site of logging operations, process it into a dense, easily-transported form, and then transport it to facilities that produce bioenergy. As a result, a recent report on the Washington forest biomass-to-energy industry- “The Washington Forest Biomass Supply Assessment,”

produced by the University of Washington and TSS Consultants for the Washington State Department of Natural Resources (Perez-Garcia et al. 2011) - indicated that a substantial percentage of biomass generated by logging activity is not operationally feasible to harvest.

2. Biomass-to-Energy Policy Environment

The development of the bioenergy sector, including technologies that use forest biomass in energy production, is considered by many in the climate change field, including the International Panel on Climate Change (IPCC), to be a potentially important component of global efforts to reduce atmospheric levels of greenhouse gasses (Sims et al. 2007). Energy produced from forest biomass also represents a prospective revenue source to the forest products industry, which seeks to remain profitable in the face of larger macroeconomic trends that have decreased the industry's relative economic importance in Washington State.

There is a complex and frequently shifting set of statutory laws, agency regulations, and tax incentives that influences Washington's forest biomass-to-energy industry. These policies affect where and how much biomass is harvested, how biomass is transported to energy production facilities, where facilities are located, how they will operate, and how expensive biomass-generated heat, steam and power is in comparison to other energy sources.

2.1 Washington Regulations

There are a number of regulations in place in Washington that potentially influence the biomass-to-energy industry. For example, in order to be constructed and operated, facilities which burn biomass must obtain air emission permits issued by the Department of Ecology or local air regulation authorities. Likewise, the Energy Independence Act (2007 c.1 s. 1: Washington Initiative Measure 937) established, among other requirements, that by 2016 nine percent of all

electricity used in the State come from alternative energy sources, including biomass-derived energy that meets certain criteria.

2.2 Washington Economic Policies

Washington has enacted several economic policies specifically intended to increase the harvesting of forest biomass for use in energy production. The biomass-to-energy sector has demonstrated widespread policy support at the state level, with both the head of the State Department of Natural Resources and the legislature declaring their support for the industry (WA DNR 2012; WA Legislature 2013b).

One existing biomass policy is the state business and occupation (B&O) tax credit for each ton of biomass transported to an energy production facility for the production of heat, steam, power, or fuel. The B&O tax credit became effective on July 1, 2010, and had a value of three dollars per green ton until July 1, 2013, when it increased to five dollars per green ton. The tax credit will expire on June 30, 2015, although the legislature retains the discretion to re-enact or extend it. The tax credit is used to offset B&O taxes that firms would otherwise pay the state for their B&O tax liabilities, and credits claimed above liabilities can carry forward for up to two years. Overall, a relatively small number of forest biomass tax credits (compared to estimated actual statewide harvesting volumes) have been claimed in Washington since the credit became available. The Washington Forest Biomass Supply Assessment estimated biomass harvest levels of 439,000 to 538,000 bone-dry tons in 2010, but firms only claimed tax credits for 153,801 green tons in 2011 and 137,680 green tons in 2012. A bone dry ton contains roughly twice the biomass as is contained in a green ton; therefore, roughly only 20% of the estimated biomass harvest has been claimed for tax credit purposes.

2.3 Federal Economic Policies

The federal government has also enacted policies to support the use of forest biomass in energy production. One important example is the Biomass Crop Assistance Program (BCAP), which was authorized by the U.S. Congress as part of the 2008 Farm Bill, and implemented by the U.S. Department of Agriculture (USDA) (United States Code). BCAP included a program in which businesses that collected, harvested, stored and transported biomass received matching payments of up to \$45 per dry ton of biomass on a 1-to-1 basis (USDA 2012). First implemented in 2009, the matching payments portion of BCAP has been inactive since fiscal year 2010, after Congress capped BCAP funding and USDA ceased program implementation as a result (Stubbs 2011). If Congress were to remove the funding cap on USDA's implementation of BCAP, the matching payments program could theoretically re-emerge. However, the re-emergence of BCAP or similar federal subsidies appears unlikely in light of the BCAP's ambiguous goals and numerous implementation flaws identified by both USDA and external program evaluations (USDA 2012). The extent to which these various economic and regulatory policies have influenced businesses' forest biomass harvest decisions is unknown. One goal of this study was to assess the effectiveness of policies at incentivizing additional forest biomass use in energy production.

3. Research Questions

This study investigated three primary research questions:

- I. How can the activities of forest biomass harvesting businesses and the organizational structure of the biomass-to-energy industry be characterized?
- II. What drives businesses' short and long-term decision-making with respect to forest biomass?

III. What are the economic and policy barriers to the more widespread use of forest biomass for energy production?

The results and discussion chapters present several categories of findings for each of the above research questions. Under research question I, the findings were categorized into (1) recent and current market conditions in the biomass-to-energy industry, (2) the supply chain structure of the biomass-to-energy industry and the types of businesses in the industry, and (3) the types of activities businesses engage in, and the type of equipment and infrastructure they possess. Under research question II, the findings were categorized into (1) the motivations and decision-making processes that explain firms' entrance into the biomass-to-energy industry, (2) biomass business short-term harvest decision-making processes, and (3) businesses long-term strategic decisions, including businesses' willingness to take risks and make investments. Under research question III, this study's findings were categorized into (1) businesses' perceptions of broad economic and policy barriers to the future viability of biomass-to-energy, (2) businesses' perceptions of how aspects of specific economic policies impede or facilitate industry development, and (3) businesses' perceptions of specific regulatory barriers to biomass-to-energy industry viability.

Chapter II. Literature Review

Little qualitative research to date has focused on forest biomass harvesting businesses in Washington. To better understand the context in which this industry functions, two primary types of literature were reviewed. First, the three research questions pursued in this study are shaped by a literature review of general economic theories relevant to industrial organization, business decision-making, and business interactions with government policies. Second, this literature review also examines the application of those broad economic theories to specific studies of

industries related to the Washington biomass-to-energy industry, such as studies of contract loggers in the Northwest and studies of biomass harvesters elsewhere in the United States.

The literature reviewed in section 1 on industrial organization theories primarily supplies context to Research Question I (characterization of biomass-to-energy business activities and industrial organization). Section 2 of this literature review, which explores how economic theory explains the decision-making processes of firms, is primarily presented in order to contextualize research question II (firms' decision-making processes). Finally, section 3 of this literature review explores the interactions between businesses and government, in order to contextualize research question III (economic and policy barriers to industry viability).

1. Industrial Organization Theories and Firm Activities

This study's characterization of the forest biomass-to-energy industry's business activities and industrial organization (research question I) was shaped by the literature reviewed in this section.

The literature in this section includes theoretical explanations for the presence of firms in particular industries, businesses' movement into and out of those industries, and the findings of previous studies of Northwest forest biomass and logging contractor businesses. Much of the literature reviewed in this section, such as the discussion of firm entrance and exit from industries, is helpful in both characterizing biomass-to-energy industrial organization (research question I), and in contextualizing firms' strategic decision-making (research question II).

1.1 The Role of Firms and Decisions to Produce or Contract

Various competing schools of economic thought seek to explain the presence and role of individual firms within an industry. One school of economic theory useful in contextualizing this research is the transactional cost theory pioneered by Coase (1960). This branch of economic

theory posits that the arrangement of firms of various sizes within an industry will reflect the point at which the costs of intra-organizational transactions become equally costly as external transactions (Conner 1991); in other words, the size and number of firms in an industry reflect calculations of the efficiency with which firms can perform an activity internally as compared to the costs of contracting out the activity. Under this school of thought, contractors may structure relationships with the firms that hire them so as to maximize transactional efficiency, including through the use of performance measures and stipulations that cover future transactions between the contracting parties (Ibid). Several studies of business production decisions have supported this theory by confirming that firms often make decisions to contract or produce based on the comparative transactional efficiency of each option in the specific situation at hand (Bidwell 2012). In particular, asset specificity-- or the degree to which the assets required for a particular activity are specific to the production of a single good-- is a positive predictor of decisions to contract for or purchase the good, rather than produce it in-house (Ibid).

Forestry business operations can be viewed as a series of distinct transactions, creating multiple opportunities in the supply chain for forest products businesses to make “produce or contract” decisions (Wang & van Kooten 1999). In general, the forest products industry is susceptible to nature-driven production fluctuations; a strategy of subcontracting volatile operations may allow mills to remain flexible to changing supply and product market conditions, and to allow mills and landowners to cost-effectively deploy additional harvesting resources during peak production times (Prudham 2002). Allen et al. (2008) investigated the structure of the related contract logging industry in the inland Northwest (including Washington), and noted the industry’s nearly-exclusive reliance on contract loggers to supply both the labor and logging equipment required for log harvest. Lee (2013) noted that many small forest landowners in

Washington hire contractors to perform forest biomass supply chain functions such as piling, chipping, and transporting logging residuals. Elsewhere in the Northwest, logging contractors in Idaho operated under tenuous contracts with mills, which could be capriciously withdrawn or altered by the mill without repercussion (Coulter 2009). While open bidding to logging contractors is a common arrangement in the forest products industry in the Northwest, “preferred suppliers” among contractors may also emerge: contractors that consistently meet landowner and mill expectations may benefit from a more consistent stream of project contracts (Coulter 2009). The decisions of a few locally-monopolistic mills may heavily affect local prices, whereas the comparatively abundant contractors competing locally tend to lack pricing power (Ibid). Larger logging contractors may be able to dictate more favorable pricing terms in local markets, thereby giving them a strategic advantage over smaller contractors (Ibid).

1.2 The Entry and Exit of Businesses from Industries

In general, economic theory predicts that where firms perceive that the price for a good in a marketplace exceeds the total production costs, firms will enter the market and compete with existing firms to produce that product (Lutz 2010). At the point at which a sufficient number of firms have joined the market to drive prices down so that they no longer exceed costs, the price and quantity of the good will reach equilibrium in the market, and new firms will no longer be incentivized to join the industry (Dilek & Top 2012). Likewise, when the price offered for a good in a market falls below the costs of producing it, firms will leave the industry and production volumes will fall until the costs of producing the good no longer exceed the market price. In such instances of broad market downturns, firms across economic sectors may suffer the loss of institutional knowledge (McKinsey 2010).

The body of research reviewed by Caves (1998) shows that a number of factors can influence the underlying rationale and successfulness of firms' entrance and exit from an industry. Caves reports that larger firms may be less likely to exit an industry entirely, while firms that enter new industries tend to be smaller.¹ Firms that are new to an industry are likely to experience disproportionately high industry exit rates compared to longer-established firms (Ibid). Firms that enter a new industry with industry-specific work experience may be less likely to fail, and may also be more likely to receive start-up capital (Ibid). Firms entering an industry may be unsure of their success, and may be initially unable to judge what size they should be in order to optimally compete in the new industry (Ibid). Industries that feature high firm entrance rates are also likely to feature high rates of firm exit (Ibid). Likewise, capital-intensive industries may feature higher rates of failure for new entrants (Ibid).

Firms seeking to expand their businesses into new markets may encounter temporary or long-term barriers to entry that decrease their likelihood of participating in the market, the scope of their participation in the new market, or the speed at which they enter the market (Karakaya & Stahl 1989). These barriers to entry simultaneously provide an advantage to incumbent firms in the market (Ibid). Incumbent firms may seek to erect barriers to entry to protect their market position, but barriers to entry can also be naturally occurring phenomena resulting from the characteristics of a particular marketplace (Dilek & Top 2012; Lutz, 2010). Types of barriers to entry that established firms enjoy can include economies of scale, cost advantages owing to experience, start-up capital requirements, government policy, and a successful differentiation of a product or service from that of competitors. The existence of barriers to entry does not mean that firms cannot attempt to enter markets, since many new market entrants may ultimately

¹ Caves also notes that there is a question of causality: smaller firms may be more likely to fail when they enter, but alternately, new firms may opt to make small investments at first because their chances of success are small.

become more successful than established firms. Rather, the existence of barriers to entry simply implies that the act of entering the market has been made more difficult by aspects of the pre-entry status-quo, and that firms which attempt to enter the industry may be subject to higher rates of failure (Karakaya & Stahl 1989; Caves 1998). In the forest products industry, logging contractors' equipment requirements pose a relatively low barrier to entry because contractors sometimes may only need a few pieces of equipment, although modern harvesting operations are more costly (Coulter 2009).

Note also that in some cases, barriers to entry may also constitute barriers to exit: capital investments in certain assets represent non-recoverable sunk costs, and may effectively require firms to remain in a market, at least in the short run, because of an inability to divest of their equipment (Shapiro & Khemani, 1987). Entry and exit barriers can be intertwined: restrictions on the exit of incumbent firms also increases the magnitude of entry barriers, as the retention of existing firms presents additional competition for prospective market entrants (Ibid).

In terms of previous study of firms' entrance and exit from the Northwest forest products industry, a reduction in the number of mills in Idaho was not accompanied by a proportional reduction in the number of logging contractors (Coulter 2009). This lack of firm exit contributed to excess logging contractor capacity, and hurt the profitability of firms remaining in the sector (Ibid). Logging contractors may be placed on quotas limiting the volume of their deliverables at mills, and these quotas may be too low for contractors to maintain profitable operations (Ibid). However, in general, the loss of institutional knowledge is a subject of concern to observers of forestry industry in the Pacific Northwest (Franklin 2013). The demographic composition of the contract logging sector in the region and nationwide is reported to be skewed towards older men who may be exiting the industry (Allen et al. 2008; Baker & Greene 2008).

1.3 Forest Biomass Business Activities in the Northwest

There has been limited previous research into the Northwest's forest biomass businesses, and particularly little study of biomass processing contractors. The Washington Forest Biomass Supply Assessment (Perez-Garcia et al. 2011) noted that biomass harvesting systems and equipment vary widely by operator and site. This diversity mirrors the variation in the log harvesting systems and equipment that generates the available biomass. Logging contractors in the U.S. tend to operate on a job-to-job basis for landowners, rather than planning over the longer-term (Coulter 2009). Contracts with mills also tend to be on a short-term basis (ibid). Paula and colleagues (2011) found that forest landowners with larger acreages are more likely to harvest or supply biomass for bioenergy. Becker and colleagues (2011) confirmed the conventional wisdom that forest biomass harvest must be integrated with timber harvest to be an economically viable activity, and does not usually occur in the absence of the processing of other, more valuable forest products. Logging contractors tend to operate below their potential productive capacity, perhaps due to the weather-restricted seasonality of harvesting, which limits the potential return on investment from equipment (Coulter 2009).

2. Forest Biomass Harvest Decision-Making

To support the quest to understand the decision-making processes of firms in the biomass industry (research question II), this section reviews how economic theory explains firms' decision-making behaviors. This section also reviews why economic models of supply curves that predict business decision-making while relying on simplifying assumptions might not accurately reflect business behavior in practice.

2.1 Firm Decision-Making as Predicted by Economic Supply Curves

As mentioned in the background chapter, the Washington Forest Biomass Supply Assessment (Perez-Garcia et al. 2012), investigated the logistic and economic considerations influencing biomass harvesting, such as biomass market price, hauling distance, logging equipment, road condition, and season. The Supply Assessment also estimated current and potential future biomass harvesting volumes for Washington, and, in doing so, calculated a model of the forest biomass supply curve in Washington. This model relies on a standard assumption in perfect-competition economic models that a supplier (landowner) elects to produce (harvest biomass) in instances when a transaction will exceed a breakeven price.

There is some evidence from previous studies of the forest biomass-to-energy industry that supports the Supply Assessment's reliance on the basic assumptions of perfect competition, and suggests that the Supply Assessment's models are likely to largely hold true in Washington's forest biomass-to-energy industry. Biomass contractors operating elsewhere in the United States were found to be highly financially oriented, with harvesting decisions being driven by market prices and access to local hog fuel markets (Stone et al. 2011). The Assessment's qualitative results of researchers' interviews with harvesting contractors also suggest that contractors focus on profits and other financial metrics when making decisions (Perez-Garcia et al. 2012).

2.2 Firm Decision-Making as Predicted by Behavioral Economics

Perfect competition economic models of supply and demand serve as an approximation of the actual supply and demand behaviors carried out in the economy. The approximations of actual supply and demand behaviors used in perfect competition models' rely on certain simplifying assumptions, including the assumptions that actors have access to full information and that firms will make rational profit-maximizing decisions (Friedman 2002; Coulter 2009). There are a

variety of limitations to the assumptions embedded in perfect competition economic models. Firms may hold motivations other than short-term profit maximization (Friedman 2002.). Even if profit maximization is the goal underpinning the firm's operational decisions, the firm may fail to successfully make decisions in a profit-maximizing manner. In fact, business decisions may be better explained by the operational rules of thumb relied upon by individuals within the firm, rather than vigilant firm-wide calculations of profit (Nelson 1991; Friedman, 2002). Firms are not single-minded in their decision-making process, and may be structured to include organizational groups with different goals or focuses (Bidwell 2012); intra-firm communication gaps may produce internally-inconsistent or sub-optimal decisions, or individuals within the firm may make decisions that reflect personal rather than firm-wide goals. Individual firms will differ in their ability to innovate, both technologically and organizationally, and to foresee strategic pathways that maximize firm profits (Nelson 1991). Finally, where actors lack information or operate in an uncertain environment, they may not act calculatedly so as to maximize expected value, but may instead accept losses or reduce profits in order to avoid risk (Friedman 2002).

In employing simplified economic models to understand supply and demand behavior, the question is not whether the models accurately forecast reality: even practitioners relying on the models tend to acknowledge that models are not perfectly accurate, and that assumptions such as "perfect information" possessed by firms are more a theoretical construct than an approximation of reality. Instead, the more relevant question is the degree to which embedded assumptions render models' predictions inaccurate for a particular circumstances or industry. Part of the reason that this study probes firms' harvest decision-making processes is to better understand the accuracy of simplifying assumptions as applied to the biomass-to-energy industry.

A few studies indicate that certain characteristics of Northwest forest biomass businesses may in fact limit the accuracy of perfect competition models of the forest biomass industry. Lee (2013) reported that family forest landowners in Washington are motivated to harvest biomass in order to avoid slash burning cost and liability, a desire to improve forest aesthetics, and “do the right thing” by achieving ecological outcomes (Lee 2013). These landowners also hinted at a possible willingness to break even or lose money on biomass harvest transactions in order to achieve other land management objectives (Ibid). Likewise, the Washington Forest Biomass Supply Assessment noted that certain landowners will subsidize biomass harvest when burning is restricted by local air quality or to accommodate other land management goals (although the Assessment’s supply curve does not account for these motivations) (Perez-Garcia et al. 2011). In addition, one previous study noted that poor communication between Northwest landowners, mills, and loggers may lead to harvesting inefficiencies (Coulter 2009).

In sum, there is a theoretical argument to be made that firms’ individual decisions do matter. Firm decisions may, in fact, lead to observed behaviors different from those predicted under the assumption that firms in perfect competition are essentially identical, and can easily determine the correct combination of resource and decisional inputs to achieve efficient production levels (Nelson 1991; Connor 1991). Thus, while the supply curve constructed in the Washington Forest Biomass Supply Assessment is a strong tool to estimate harvest volumes, those estimates may diverge from observed harvest activities due to the obfuscation or omission of variables that would account for firms’ actual decision-making processes.

With respect to forest biomass harvest in Washington, some reasons that harvest decision-making behavior might diverge from predictions based on simplifying economic models include:

- The influence of motivations other than transactional profits that lead to biomass harvesting;

- Potential differences in how harvesters view the value of tax credits and avoided costs versus the “cash in hand” provided by market prices;
- The functional necessity for firms- or individuals acting on behalf of the firm- to make decisions without having the perfect knowledge of the future that would allow for profit maximization from each decision; and
- Firms’ responses to perceived uncertainty in the biomass policy and market environment, which may induce risk-averse firms to curtail biomass infrastructure investments.

3. Potential Barriers to the Viability of the Forest Biomass-to-Energy Industry

This section explores the literature in two areas that might inhibit the viability of the forest biomass industry. First, this section notes how businesses make strategic decisions under circumstances characterized by uncertainty (also relevant to research question II’s examination of firms’ decision-making). Second, this section reviews how businesses tend to respond to economic incentive policies and other government interventions in market sectors.

3.1 The Strategic Responses of Businesses to Risk and Uncertainty

Circumstantial evidence suggests that there is likely to be a high degree of uncertainty in the economic environment for forest biomass-to-energy, which is affected by oil and electricity prices, federal environmental policies, and other market factors out of businesses’ control.

Circumstantial evidence also suggests the likely existence of uncertainty in the biomass harvest policy environment: several of Washington’s biomass-supporting policies are embedded in the tax code and are scheduled to expire. In general, the expiration of tax code provisions has been identified as a source of uncertainty for businesses because of the often last-minute nature of legislative decisions regarding the extension of specific tax provisions (Baker et al. 2008).

The sparse literature on the forest biomass industry also supports the idea that the industry is likely to be pervaded by uncertainty. Although Dirkswager and colleagues (2011) found that Minnesota biomass companies perceived biomass as presenting a promising new business opportunity, the authors also noted that instability in the market and price of biomass might be undermining future expansion of processing activities. Likewise, Stone and colleagues (2012) found that forest biomass contractors in Maine perceived uncertainty in the hog fuel market, partially as a consequence of policy changes.

If there is uncertainty regarding the strength of expected consumer markets for hog fuel, or uncertainty over the long-term stability of incentives or other government policies relied upon by firms, it presents a potential cost to firms. Where there is uncertainty, businesses may wait to make new investments: policy uncertainty could reduce the willingness of risk-averse firms to invest in capital-intensive actions that take advantage of the incentives (Engau & Hoffman 2009). Because capital investments may be practically irreversible, firms operating in uncertain conditions may defer capital investment decisions until after a legislative decision is made or until market conditions stabilize (Bernanke 1983). Firms may adopt inaction as a risk-reducing strategy (Bachmann et al. 2010), or may invest minimally in initial trial investments to position themselves for larger future investments if favorable circumstances eventually develop (Bowman & Hurry 1993). Postponing investments or decisions in the face of uncertainty entails risk too: competitors may gain an advantage if their investment proves successful (Courtney et al. 1997). Firms' responses to uncertainty may depend on the degree to which they perceive uncertainty, and if they interpret uncertainty as a threat to their business (Engau & Hoffmann 2011).

Specifically regarding bioenergy industry responses to policy incentives, any increases in biomass-based energy production may be contingent on both the magnitude of the incentive's

benefits, and the risks and costs associated with utilizing the incentives. White et al (2013) found that firms' perceptions of uncertainty with respect to future energy policy had led to the abandonment of biodiesel industry investments. Similarly, contract loggers were more likely to invest in innovative new harvesting technology where they had higher levels of scheduled work on the horizon (Allen et al. 2008).

3.2 The Perceived Effects of Government Policies on Business Behavior

In general, businesses may view government interactions with their industry in a negative light. A recent survey of international business executives found that government affects their business more than anyone except customers, and that government actions can have profound financial impacts on their businesses' operations (Dua et al. 2010). Passing laws and enforcing regulations were found to be the most impactful government activity in the minds of executives, with the enforcement of those regulations viewed as having a predominantly negative effect on industries (Ibid). Many executives in the survey found government officials to be uninformed about the economics of their industries (Ibid). With respect to government incentives relevant to forest biomass harvest in Washington, biomass firms in Maine were reported to universally dislike the BCAP program (Stone et al. 2011). Maine biomass firms thought that BCAP had made mills dependent on cheap feedstock and caused a lasting drop in hog fuel prices; the study's authors concluded that the subsidy had been ineffective and potentially harmful to the industry (ibid).

While businesses may hold generally negative perceptions of government intervention in their industries, how they respond to specific policies-especially economic policies designed to help their industry- may be a different matter. As a general rule, the goal of economic incentive policies, such as tax credits, is to change the behavior of private firms, who are assumed under microeconomic theory to make decisions with a goal of maximizing profit (Friedman 2002). Tax

preferences which allow firms to lower overall tax payments and increase profits may change the firms' behavior so as to qualify for the tax preferences. Tax incentives are an increasingly utilized policy to encourage industry behavior with respect to achievement of environmental goals (Gunningham et al. 1998). The findings of Cotti and Skidmore (2010) on the effects of state corn-ethanol subsidies support the notion that tax incentives can lead to increased bioenergy production. Although some tax incentives appear to induce targeted behavioral changes, firms may frequently qualify for and receive tax credits that were not a precondition to their performance of that activity (Kahn 1996; Gillingham 2006); as applied to the case of the forest biomass B&O tax credit, firms might have harvested the same level of biomass as they would have without the incentive.

4. Summary of Literature Review

This literature review begins by contextualizing research question one's characterization of the industry and the activities of the businesses it contains. This portion of the literature review summarizes industrial organizational theory's treatment of firms' decisions to produce directly or to contract, and also reviews the barriers to entry that firms experience upon joining a new industry. A summary of previous studies of Washington biomass businesses then follows.

In order to set up research questions two's focus on business decision-making processes, the review includes literature which notes that perfect competition economic theory and simplified models of supply and demand tend to predict that firms will decide to produce goods like biomass up to the point at which the marginal costs of production are no longer exceeded by the market price. The literature review then outlines several qualifications to the accuracy of supply and demand-driven predictions of business behavior. These qualifications offer potential

explanations for why the decision-making behaviors of firms might differ in practice from the predictions of simplified economic models.

Finally, in order to contextualize research question three's focus on the barriers to the greater use of forest biomass in energy production, the literature review explains the possible responses by firms to economic and policy uncertainty, and reviews how government policies might influence business behavior.

Chapter III. Methodology

This chapter describes (1) the rationale for using interviews to answer this study's research questions and the format of the interviews, (2) how firms were targeted for participation in this study, (3) how individuals within each firm were selected for an interview, (4) the procedures by which qualitative interview data was transcribed, coded and analyzed, and (5) the coding process used to draw important categorical distinctions regarding businesses' roles in the supply chain and tolerance of risk.

1. Interview Method

Interviews were the primary source of data collection for this study. As a research method, topical interviews consist of a series of open-ended questions that allow participants to share their thoughts and perspectives on a particular time and place (Rubin & Rubin, 1995). Previous research into Washington's forest biomass industry has primarily been quantitatively focused (Perez-Garcia et al. 2011), and little is known about the motivations, thought-processes, and perceptions of firms that influence their behavior. As a result, this research relied on an open-ended and qualitative interview approach. The interviews contained a series of mostly open-ended questions designed to encourage biomass industry participants to share their perceptions of

the industry and their assessments of firm activities. By adopting an open and flexible question format, interview respondents were encouraged to explain their motivations and thought-processes in a more in-depth manner than might be possible using a more structured approach, such as a survey (Rubin & Rubin, 1995). The qualitative interview format used in this research also facilitated the identification of novel, unanticipated research themes in responses, and allowed for the flexibility to adapt to the context of individual interview respondents (Ibid). With a comprehensive look at the body of interviews conducted in this study, the knowledge shared by subjects could be used to identify themes common to industry participants (Ibid).

The development of an interview guide (Appendix A) ensured consistency across interviews, although the sequence and format of questions was not rigidly adhered to. Deviating from the interview guide when the researcher deemed it necessary allowed interview conversations to focus on the areas that the respondent perceived to be important. In addition, if initial broad questions did not elicit responses specific topics that the research endeavored to examine, the interview guide contained prepared follow-up questions probe these specific areas of respondent knowledge (Rubin & Rubin, 1995). In the frequent instances where the interview respondent's comments led in unpredicted thematic directions, additional follow-up questions not contained in the interview guide were asked. Prior to interviewing, School of Environmental and Forest Sciences graduate students and a member of the biomass harvesting industry pre-tested the wording of questions. The study proposal and interview format was reviewed and approved by the UW Institutional Review Board.

2. Participating Businesses

Representatives were interviewed from a total of 21 firms that participated in some capacity in the forest biomass-to-energy industry. Two sources of public records were used to identify firms

involved in the harvesting of biomass for energy use. First, Washington State Department of Revenue documents provided a list of 34 firms engaged in biomass harvesting which applied for the B&O tax credit in fiscal year 2011 or 2012. Second, a Freedom of Information Act Request to the U.S. Department of Agriculture yielded a list of 21 additional firms that had been engaged in harvesting forest-derived biomass as of 2009, but which did not apply for the B&O tax credit. Due to the small size of the industry, contact was attempted with all 55 firms identified as being in the forest biomass industry as a result of their participation in either of the two programs. Firms were initially contacted by phone; firms which did not respond to initial inquiries received at least two follow up attempts at recruitment into the study, including via email if company contact information was available. Interviews were conducted with all firms who agreed to participate in the study.

Several factors explain why there was a 38% response rate of targeted entities that ultimately ended up being interviewed. First, numerous potential interview respondents declined to be interviewed; most who declined to participate indicated that they were too busy to participate. Second, as many as 6 firms appearing on the two government-provided lists appeared to no longer be in business. Third, certain business names on the lists appeared to be entities incorporated as land-ownership investment vehicles, and did not operate as independent participants in the biomass markets. Instead, the forestry activities of these land-owning entities were carried by either a third party or an umbrella company under which they were incorporated. In the several instances where legally-separate incorporated entities were not being managed individually, a single forester or forestry consultant working on behalf of those multiple entities was interviewed. Taking into account interviews which accounted for the management of multiple firms, the effective response rate of this study was 21 out of 50 possible firms, or 42%.

3. Individuals from Each Business Selected for Interviews

Interviews were conducted during the fall of 2012 and the spring and summer of 2013. No obvious differences emerged between the groups interviewed during the two separate time periods. Interviews were conducted in person at the interview respondent's place of work or locally-convenient coffee shops whenever possible; however, logistical considerations rendered it more practicable to conduct six of the interviews by phone.

Within each firm, individuals targeted for interviews were identified and recruited using information on firms' websites, direct communication (via telephone and e-mail), and snowball techniques. Because the interviews probed strategic business decisions, interviews were sought with high-ranking officials or others with an ability to speak to their company's decision-making processes or their on-the-ground biomass harvesting decisions (Engau & Hoffmann 2009). In most instances, only one individual from each firm was asked to characterize the firm's perceptions and activities; where possible, this was the owner or the person in a best position to discuss main topics of interview. Because of the diversity of firm sizes, structures, and business models operating in the biomass harvesting industry, the job titles of interview respondents included foresters, silvicultural consultants, grinding operator contractors, corporate executives, and business owners.

4. Data Analysis

Interviews were recorded and transcribed completely. Because several interviews were conducted at noisy work sites or by telephone, occasionally short portions of responses were inaudible and accordingly could not be transcribed. In the few instances where multiple employees of a firm were interviewed, their responses were integrated and coded as a single interview representing the firm.

Qualitative coding was the primary method of analyzing interview data in this study. Coding is the practice of applying short words or phrases that assign meaning to broader concepts that arise in the underlying data (Saldaña 2013). The transcripts of interviews conducted in this study were coded using inductive codes developed from themes that emerged during interviews, as well as using deductive codes based on concepts established in literature analyzed prior to beginning the interview process (ibid). A provisional coding scheme based on literature-derived response expectations was outlined, and additional codes were added as needed in order to accurately capture interview responses (Rubin & Rubin, 1995).

As dictated by the diversity of subject areas covered in interviews, transcripts were coded eclectically using a variety of coding methods. Provisional coding was used prior to the initiation of interviews in order to develop a list of codes anticipated to be encountered during interviews (Saldaña 2013). Simultaneous coding practices were used, where segments of interview data were coded with multiple codes simultaneously, if appropriate (Ibid). Attribute coding was used to categorize basic descriptive information about businesses, such as their geographic location and equipment ownership (Ibid). Structural codes, which translated the literature-driven research questions into the coding schemes, were used to categorize firms' activities and perceptions of the future viability of the hog fuel market, among other subjects (Ibid). Finally, causation coding was used to help identify interview participants' perceived explanations of certain aspects of the industry, such as to explain why hog fuel market prices had dropped in recent years (Ibid). The codes applied to interview data in this study are presented in Appendix C.

Interviews were coded iteratively, and codes were added, deleted, refined, and consolidated throughout the coding process. Each interview was reviewed twice in full for coding purposes. Using NVivo software, codes of interview responses were grouped under thematic categories

and analyzed to deduce trends (Rubin & Rubin 1995), and narrative identification techniques were used to further tease out themes (Coffey & Atkinson 1996). The research's conclusions draw on trends identified in the coding results, including through use of descriptive statistics.

This study featured several methodological limitations that bear on the applicability of the results presented in the following pages. First, even though the overall size of the industry is small, it is difficult to draw broad conclusions about the industry or to produce statistically significant results based on an interview pool of 21 businesses. Second, only a subset of participants that had participated in BCAP or applied for the state B&O tax credit were interviewed, even though the researcher attempted to contact all firms. This introduces the possibility that the research suffers from self-selection bias, if the individuals from firms who participated in the study differed from those who opted not to participate. Third, the universe of interview respondents did not include any biomass firms that had not participated in either BCAP or the B&O tax credit, and no firms were interviewed that may have joined industry after the BCAP matching payments ceased or since the latest B&O tax credit returns were issued.

5. Categorization of Interview Respondents during Coding

During the coding process, a variety of codes which categorized interview responses were assigned, including two categories important to interpreting this research's results. This section explains how firms were categorized according to their role in the biomass-to-energy supply chain, and according to their level of risk tolerance.

5.1 Supply Chain Role

Based on interview responses, businesses were assigned one of three supply chain roles:

“landowner “processor” or “mill”. Within these broader categories, firms were assigned a single

or multiple codes describing their role in the biomass-to-energy supply chain. Forest “landowners” were defined to include (a) real estate developers harvesting logs and biomass without an intention of reforesting the lands after harvest, (b) tree farms that tended to actively re-plant forestland after harvest, and (c) forestry consultants or institutional managers acting on behalf of passive financial investment vehicles. “Processors” include firms that (a) collect biomass, (b) pile biomass, (c) grind or chip biomass, (d) broker biomass sales, or (e) transport biomass to energy producers. Because landowners contract with outside firms for almost all biomass processing activities, the terms “processor” and “contractor” tend to be used interchangeably in this study. Finally, although this study did not target mills for interviews, three “mill” businesses (two landowners with harvesting operations, and one landless harvester) also operate boilers at forest product processing facilities which are used to produce steam, heat, or electricity. These entities consume some of the biomass they harvest and process, although none of the three entities harvest biomass exclusively for use in the energy facility they own.

5.2 Risk-Tolerance

Firms were asked about their thought process with respect to taking risks, to self-assess their willingness to take risks, and to report the degree to which they viewed risks as threatening to their business’s viability. This method of probing the risk tolerance of firms draws on the methods used by Engau and Hoffmann (2009) in a survey that probed firms’ strategic responses to uncertainty caused by prospects of the adoption of a global climate policy. In this research, responses were qualitatively coded based on firms’ self-reported levels of risk tolerance, and informally categorized responses as follows: Firms which indicated a propensity for taking risks without mentioning caveats were coded as risk-loving (A typical response of a firm coded as “risk-loving:” *“business-wise I am pretty bold. I’ll blindfold myself and jump right in.”*). Firms

which discussed some willingness to take risks but discussed tradeoffs and cost-benefit calculations were characterized as risk neutral (A typical risk-neutral response: “*It all depends. I think we demonstrated that we are very willing to take risks, we’re not willing to display risky behavior, I think that’s different.*”). Firms which used terms like “conservative” to describe their approach to risk, or which explained a company strategy in which risks are mitigated or pushed off on other firms in the supply chain were coded as “risk averse” (A typical response: “*I run this business like I’m going out of business tomorrow... with a huge failsafe all of the time.*”).

Chapter IV. Results

The categories of results found pursuant to each research question are summarized in Chart 1.

Chart 1: Categories of Results for Each Research Question

Research Question	1. How can the business activities and the organizational structure of the forest biomass industry be characterized?	2. What drives businesses’ short and long-term decision-making with respect to forest biomass?	3. What are the economic and policy barriers to the more widespread use of forest biomass for energy production?
Categories of Results Presented	(1) Recent and current economic conditions in the biomass-to-energy industry. (2) The organizational structure of the biomass-to-energy supply chain. (3) The activities and equipment of forest biomass harvesting businesses.	(1) Businesses’ decision-making processes and motivations to enter the biomass industry. (2) Biomass businesses’ short-term harvest decision-making. (3) Biomass businesses’ long-term strategic decision-making, including willingness to take risks and make investments.	(1) Business perceptions of broad policy and economic barriers to the future viability of the biomass-to-energy industry. (2) Businesses’ perceptions of the specific aspects of existing biomass-focused economic policies that act as barriers to industry viability. (3) Businesses’ perceptions of existing regulatory barriers to industry viability.

Interview respondents frequently mentioned a several aspects of forest biomass harvesting that help provide context to businesses' activities, decision-making processes, and perceptions of barriers to biomass harvesting viability. First, many businesses view biomass either as a resource when the price of hog fuel is high, or as a waste product when the price of hog fuel is low. Second, biomass varies in quality as an energy source, and its value may be somewhat diminished by a high moisture content or the presence of impurities such as rocks or soil. Third, nearly all respondents noted that the high cost of transporting biomass from forest sites to energy production facilities is critical to understanding the industry structure and firms' decision-making processes. Appendix D includes an in-depth discussion of these factors.

1. Characterization of Forest Biomass-to-Energy Business Activities and Industry Organization in Washington

The results in this section (1) summarize businesses' perspectives on the recent history and current status of their forest biomass harvesting activities in Washington, (2) describe the biomass-to-energy supply chain and the economic niches firms occupy, and (3) describe the equipment and infrastructure companies use to harvest biomass for energy production.

1.1 The Forest Biomass Market: Recent History and Current State of the Forest Biomass-to-Energy Industry

Both the industry's recent history and current state of affairs bear great contextual importance in explaining the activities and perspectives of biomass industry participants. This section (1) explores the factors that have led to recent fluctuations in the economic value of forest biomass, (2) explains that the market price of forest biomass is currently too low for harvesting to be economically viable on a broad scale, (3) explains why market conditions vary geographically

across the state, and (4) evaluates the opportunistic circumstances in which industry participants report that forest biomass harvesting is currently a viable activity.

Market Price History

The market price for hog fuel has undergone two notable fluctuations during the past decade, according to interview respondents. First, beginning as early as 2006, the price of hog fuel in Washington began to rise substantially, and in-woods harvesting activity increased in tandem. However, respondents reported that after hitting peak levels of biomass harvest around 2010, the price of hog fuel fell dramatically and levels of in-woods grinding dropped precipitously. Interview respondents tended to cite at least one of three primary dynamics (one policy change and two economic factors) in explaining the changes that have taken place in Washington's forest biomass market. First, the winding-down of the Biomass Crop Assistance Program (BCAP) policy eliminated a substantial financial incentive to the harvesting of forest biomass, which is discussed in greater detail in Results section 3. Second, respondents explained that forest biomass demand and market price also decreased because of a drop in the price of two energy feedstocks (natural gas and mill-derived residual biomass) that can be burned by energy production facilities in lieu of forest biomass. Third, respondents reported that the recent closure of two of the State's biomass-consuming mills has reduced both biomass energy production capacity and market demand for forest biomass. Appendix E contains additional explanation of respondents' perceptions of the influence of these three factors on the hog fuel market

Dismal Market Conditions

At the time that interviews were conducted from fall 2012 through summer 2013, almost all (17 of 21) respondents indicated that the market for forest-derived biomass had evaporated almost

entirely, and that in-woods grinding activity was taking place only sporadically. Times have been tough recently for interview respondents, especially those that had invested heavily in the biomass-to-energy business. Many described the current state of the market in harsh terms that belied the difficulties presented by current circumstances; for example, one interview subject exclaimed,

It sucks, man, because this is all I've done for a long time, and it's dead. It's dead.

Six interview respondents mentioned that they, or contractors that they worked with, had left or planned to leave Washington's forest biomass industry. Some respondents left the industry to pursue other lines of work, while other respondents indicated that they planned to try to harvest biomass in a different state where business conditions were better. Of the respondents still active in biomass harvesting, several mentioned that energy producers had given them a limited weekly tonnage quota for biomass deliveries.

The weak market for hog fuel also changed how contractors and landowners think about biomass: Interview respondents indicated that they are currently see biomass as a waste product to be disposed of, rather than as a resource to be exploited. As one biomass processor explained,

Our business is strictly wood grinding....What it's turned into is more of a wood waste removal process, more so than a biomass process. When we come in, we make biomass that is primarily to get rid of the wood; the days of going in and making biomass for the purpose of making biomass are really nonexistent anymore.

The Importance of Geography to Understanding Businesses' Current Harvesting Activities

A number of facilities that use biomass for energy production are dispersed throughout the State of Washington (Appendix F). Longview, Port Angeles, Aberdeen, Tacoma, Wallula, and Port Townsend all host one or more mills that are significant producers of biomass energy; these mills were the facilities most frequently mentioned by interview respondents. Interview responses

indicated a regional variation in the number of landowners, harvesting contractors, and biomass transporters supplying biomass to each energy producer.

Most contractors harvested biomass from both industrial tree farms and real estate development projects. By contrast, only a few contractors harvested biomass sourced from small, private landowners. Three contractors, all operating in Eastern Washington, sometimes harvested biomass from orchards and other agricultural sources.

A majority of respondents noted that having a local energy-producing consumer of biomass was a critical determinant of hog fuel market conditions. As one respondent put it,

It's real simple math...where there are co-gens [electric co-generation facilities], things are good.

Respondents described the state's hog fuel market as acting like series of local markets, each centered on a local energy-producing hog fuel consumer. However, respondents also reported spillover effects between the markets, as the closure of the Kimberly-Clark mill in Everett impacted the hog fuel market well beyond that mill's transportation-logical harvesting area.

Current Market Bright Spots

Although the forest biomass harvesting industry has recently operated at reduced capacity, in-woods grinding and transporting of biomass does still occur in certain places and circumstances. Forest biomass harvesting tends to take place as a result of two main distinguishing factors: the geographic location of the biomass or the motivations of landowners other than immediate profit from biomass harvest transactions.

The northern portion of the Olympic Peninsula, which roughly encompasses the area from Port Townsend to Forks, is the one geographic region of the state where respondents reported that forest biomass harvesting consistently occurs. One landowner explained that the region's geography, with water on three sides and Olympic National Park to the south, makes transportation difficult, and renders the north peninsula "*somewhat of an island*" isolated from conditions in the rest of the state. Four of five respondents with substantial operations in the region indicated that biomass harvest continued to remain economically viable there, and that it was a practice commonly integrated into local land-management decision-making.

Elsewhere in the state, forest biomass harvesting under current market conditions is more sporadic. In these regions, forest biomass harvest only occurs if the landowner is willing to subsidize the hog fuel price offered by energy producers by paying the rest of the contractor's harvest and transportation costs. A landowner may be willing to subsidize biomass harvest if it helps it achieve management goals other than immediate revenue realization, such as creating preferred aesthetics for the property, creating jobs, or preserving habitat. One circumstance where respondents reported that biomass harvesting currently takes place is on real estate development sites, where the landowner may need land to be cleared free of biomass in order to develop or sell the property as housing or farmland. By comparison, on tree farms where the establishment of re-planting space is a major reason for slash removal, there may be greater toleration of some biomass remaining scattered across a site. Interview respondents reported that biomass harvest also occurs on lands owned by Indian tribes or the federal government, where land managers hope to create wildlife habitat or remove invasive species. Finally, biomass harvest may occur in instances or localized areas where a permit required to burn the slash cannot be obtained, or where the landowner perceives a risk to neighboring properties by

burning. Respondents noted that these harvesting sites tend to be near suburban or exurban developments, or within urban growth boundaries.

Summary of Key Findings

Interview respondents reported that biomass harvesting for energy production peaked in volume several years ago in Washington, at a time when hog fuel was more valuable. In the last three years, the low price for hog fuel has rendered forest biomass harvest nearly infeasible. Interview respondents explained the recent decline of the forest biomass industry by mentioning the presence of cheap processing mill residuals, the low price of natural gas, the closure of two large biomass energy-producing mills, and the cessation of the Biomass Crop Assistance Program. Respondents reported that forest biomass harvesting is economically viable in the North Olympic Peninsula, and remains sporadically viable elsewhere when landowners are willing to absorb a financial loss from harvesting transactions in order to support their other management objectives.

1.2 Characterizing Biomass Industry Organization: Supply Chain Description and Firms' Roles

This section (1) reviews the roles in the biomass supply chain filled by the interviewed businesses, (2) describes the contractual relationships between landowners and processing contractors, and (3) describes the contractual relationships between processing contractors and energy producers.

Business Roles in the Supply Chain

As described in the Methodology chapter, this study categorized firms as fulfilling at least one of three primary supply chain roles: landowner, processor, or mill. Chart 2 summarizes the biomass-to-energy supply chain roles filled by the 21 subjects interviewed in this study. Many

firms filled multiple supply chain roles, such as landowners that owned harvesting equipment, or grinders that also owned a mill; as a result, the rows in chart 2 are not summative.

Chart 2: Supply Chain Roles of Firms Interviewed

Supply Chain Role	Supply Chain Role Sub-Category	Number of Firms Interviewed
Landowners		9
	Tree Farm Owners	6
	Real Estate Developers	2
	Forestry Consultants Managing for Passive Landowners	2
Processors		13
	Biomass Grinders and Chippers	11
	Biomass Pilers and Collectors	6
	Biomass Brokers	2
Mills		3
Total		21

Almost all landowners extensively contracted out biomass processing tasks, although landowners' logging teams sometimes facilitated harvest by collecting and piling biomass after logging. Of the nine landowners, only one could grind biomass as an in-house operation.

Most biomass contractors had the capacity to perform multiple activities associated with the processing stage of the supply chain. Of the 11 interviewed firms that operate grinders, the majority also aggregated and piled in-woods biomass material. Likewise, the majority of grinders

possessed the capacity to transport biomass, although many grinders supplemented by partially contracting out some of their transportation needs.

Landowner-Processor Contracting

Contracting is a pervasive practice in Washington's forest products industry: all nine landowners in this study employed contractors to harvest logs, biomass, or both. The structure of the working relationships between landowners and the firms they contract with is important to characterizing the state's biomass harvesting industrial structure. In general, landowners and contractors described themselves as operating within a small, close-knit, and sometimes-insular community. As one landowner noted,

It's kind of a good old boys² network...people tend to stay in the same jobs a long time.

Several processors noted the importance of developing a local network of connections to help obtain jobs from landowners. Contractors also noted the value of local connections in arranging the necessary equipment and sub-contractors to ensure an efficient connection of the collection, piling, grinding, and transportation components of the energy production supply chain. This section reviews the geographic and structural patterns of landowner-harvester contracts, and the selectivity with which processors are contracted by landowners.

Geographic Patterns of Contracting. Landowners harvest in fixed areas determined by their landholdings. By contrast, although contractors mainly operate within localized areas, most will take jobs statewide. Contractors' mobility is limited by two factors. First, the cost of deploying biomass harvesting equipment and employees to harvesting sites presents a logistical limitation, although these limitations may be surmountable for large harvesting jobs. Secondly, contractors

² The moniker here is entirely appropriate because the interview respondents in this research were predominately male, by a 10-1 ratio.

may stay near a home region of operations because of the importance of networking and earning landowner trust to contractors' ability to secure work.

Temporal and Structural Contracting Patterns. Harvesting contracts between landowners and processors tend to be short term. Contracts were largely oriented around harvests from particular units of land, while the longest harvest contract reported by interview respondents was one year.

Contracts have traditionally been structured so that processors pay landowners a "stumpage" for the value of the material removed, but landowners sometimes pay processors for the material's removal instead. Contracts where the processor pays stumpage to the landowner rest on an assumption that the processor's harvest and transport costs would be recouped by the sale of the hog fuel to the mill. This type of contract was most common on tree farms where landowners were unwilling to pay substantially for biomass to be removed, and would revert to slash burning if market forces dictated. By contrast, contracts where payment flows in reverse (from the landowner to the contractor) were premised on an assumption that the value of hog fuel would be insufficient to cover the contractor's processing and transportation costs. This type of arrangement was most common with real estate development landowners (who faced high costs or opportunity costs associated with keeping biomass residuals on properties), although one tree farm landowner reported an instance of paying for the removal of biomass from a unit.

Harvesting contracts tend to be informal, with few immediate sanctions if a party violates contractual terms. In informal "handshake" arrangements, one processor explained,

the loggers, the landowners, will call me and say hey we've got these piles need to get them off the property for one reason or another, and then they just dump it all on me and I call the people I know and we get it done.

A few landowners indicated that they were interested in entering into longer-term supply agreements with energy facilities. However, respondents did not report that any such contracts

had come to fruition. Several respondents mentioned that one impediment to setting longer-term contracts was the need to agree on an appropriate “escalation” provision to change the stumpage paid to landowners in the event that hog fuel market prices changed substantially. Landowner reluctance to commit to a certain supply of biomass regardless of the strength of lumber markets was another impediment. As one landowner noted,

You don't want to be cutting trees just for the sake of meeting your biomass contract.

Selectivity in Contracting. Landowners and processors differed in the breadth with which they worked with other firms in the industry. Landowners tended to either contract exclusively with a single biomass harvester, or relied upon a small group of contracted harvesters. Landowners also reported a preference for hiring contractors that they have successfully hired in the past and trust. By contrast, contractors tend to work for a larger number of ownerships, although several contractors indicated that they work regularly for a particular landowner or group of landowners.

The pattern of landowners contracting with a small universe of biomass processors can be partially explained by landowners' perceptions of the varied competency and sophistication of contractors. Firms widely recognized a few particular contractors as leaders and innovators in biomass industry. In particular, nine different respondents mentioned that one specific contractor was at the forefront of biomass harvesting activities in the state, with firms describing the business with phrases like “innovative,” “professional,” “efficient,” “nicest equipment,” and “the best.” This firm had effectively established a local monopoly over biomass harvesting in its region of Washington. Local landowners noted that this contractor had no local competition; local landowners worked exclusively with this firm for their biomass harvesting needs.

By contrast, in other portions of the state, several landowners indicated that they are skeptical of contractors until they have proven their ability to achieve the landowner's goals. Landowners

with this skeptical outlook may prefer to entrust business to a select group of contractors that they have grown to trust, and who know company procedures. One landowner explained:

You tend to get a few contractors that you can rely on... so they understand exactly your rules, and you don't have to retrain them every time you do it, and so we may have in each area I don't know probably two or three contractors you rely on fairly heavily, and then just stay pretty consistently with them... Both from a safety standpoint and from an environmental standpoint you like people that you've kind of built up and understand what is required from your operation and what you're trying to do... so you tend to stay probably [with] the contractors you develop over a fairly long period of time.

In terms of contractor sophistication, respondents reported that within the forest products industry, biomass contractors are generally viewed as the least esteemed type of forest products outfit. One contractor related that he and

a couple of logging outfits, we almost got in a fistfight with one day because they were likening us to cockroaches, because what we do in is come in and we'd scavenge everything that was leftover.

Some landowners questioned the ability of existing contracting outfits to meet the future needs of the biomass-to-energy, should biomass technology develop to a point where there was high biomass demand from energy facilities. One landowner explained his concerns:

One scary part of kind of moving towards larger-scale collection of this material... is how do you get there? Because now we are going from one guy that is out there with his couple trucks and he's got some sort of modified backhoe with a big claw on it trying to grab this stuff... to something that's much more sophisticated and organized and well capitalized to get all of this material off there, and there's a cost associated with that.

Processor- Energy Producer Relationships

This section reviews the contracting patterns between energy producers and biomass processors, the role of brokers in facilitating sales of hog fuel to energy producers, and contractors' tendency to dislike and distrust the energy producers whom they supply.

Interview respondents universally reported that mills contract primarily with processors, rather than directly with landowners.³ Contracts between mills and processors are occasionally as long as annual in duration, and may set a certain baseline delivery volume. However, respondents noted that the provisions of those long-term contracts tend to leave mills with the flexibility to reduce that baseline volume or hog fuel price to match the mill's immediate needs, and do not provide contractors with any long-term guarantee of price or delivery volume. More frequently, contracts are 30 days or shorter in length, in order for mills to guard against losses in the event of market fluctuations. Processors reported that they tend to supply forest biomass to whichever mills it can be profitably processed and transported.

To mitigate some of the fluctuation in mill demand, at least two brokers of biomass material emerged to fill a market niche in ensuring that the biomass harvested by contractors could find an energy-producing outlet. However, several firms noted that the shortness and instability of the contracts between biomass processors and energy producers also reverberates up the supply chain, and leads to shorter contracts between grinders and landowners, since contractors tend to be reticent to commit to removing biomass for landowners if they do not have a guaranteed market where it can be cost-effectively delivered.

Contractors expressed surprising vitriol towards energy-producing mills. Five of 13 processors made unprompted comments during interviews about unfavorable experiences working with local mills. Contractors viewed certain mills as particularly cutthroat, but generally saw mills as unrepentantly exploitative of the current biomass market weakness. As one contractor explained,

The mills, when they smell blood, they are like sharks. And they smell blood.

³ This study did not specifically target energy producers/mills for interviews, although a few landowners and processors with mill operations were interviewed. The conclusions drawn in this section were drawn solely from conversations with biomass processing contractors, rather than the mills themselves.

Another contractor added that mills are

all about making money. They don't care who they step on or run over along the way, like any giant corporation. Nameless, faceless fucking goons.

Several contractors viewed the mills as willing to exploit their size and relative position of negotiating strength in setting up short-term hog fuel supply contracts enabling them to renegotiate on more favorable terms as market conditions allowed. As one contractor explained,

dealing with any large company like that, it is always ironclad in their favor. And if you think you are going to renegotiate and change that, to put it in your advantage, or make it fair, you are fooling yourself, it isn't the way it works.

Summary of Key Findings

In general, respondents described the biomass-to-energy industry as close-knit and insular. Firm roles are best categorized as forest landowners, processing contractors, and energy producers. Contractor relationships with energy producers tended to be fraught with distrust and instability. Respondents largely described the relationships between contractors and landowners in more favorable terms, although some landowners harbored skepticism of the trustworthiness and sophistication of certain contractors. Contracts between landowners and processors, and processors and energy producers all tended to be short-term, and subject to amendments.

1.3 The Activities and Equipment of Forest Biomass Harvesting Companies

This section (1) examines the role played by biomass-to-energy in the context of firms' other business activities, (2) reviews the equipment firms use in order to harvest biomass, and (3) examines how the capital and operation costs of harvesting equipment affects firms' harvest activities.

Biomass-to-Energy in the Context of Other Business Activities

Because landowners only reported harvesting biomass as a supplementary activity to the primary revenue-generating activity of log harvesting, income derived from biomass harvesting

diversified their revenue streams. For all landowners interviewed, biomass-for-energy operations comprised a small amount of firm revenue, and biomass harvesting functioned as an auxiliary component of their business's overall operations.

Like landowners, biomass was only one component of the overall business of most processing contractors. Many landowners noted that, especially in light of the weakness and uncertainty in the hog fuel market, firms have been forced to branch out in order to survive:

You can't just go ahead and grind hog fuel, and try to make a living. It just won't work. You've got to multi-task.

Several contractors described their business strategy as opportunistic, and that their jobs required them to perform whatever services landowners or others were likely to ask of them:

do a little of this, and a little of that, whatever it is to make a buck.

Nevertheless, contractors were more likely than landowners to view biomass harvesting as an important component of their overall business, with 8 of 13 contractors viewing biomass-for-energy as either currently or recently important to their business's overall success. One consequence of biomass harvesting's relative importance to contractors is that contractors have borne the brunt of the current weakness of the hog fuel market.

The 13 processing firms interviewed engaged in a variety of activities aside from forest biomass harvesting. Each of the following activities was mentioned by multiple interview respondents as a component of their business operations:

- Contract logging;
- Transporting and brokering mill-derived hog fuel to be used for energy-production;
- Chipping biomass or transporting chipped biomass for non-energy production uses, including paper-making;
- Real estate development, construction, and landscaping, including the preparation or transportation of woody or rock materials for those purposes;

- Burning slash, in instances where biomass harvesting did not take place; and
- Re-planting forestlands after harvesting is complete.

Processing firms also diversified their biomass operations by using biomass material for purposes other than energy production. Although respondents reported that energy producers are the largest consumer of hog fuel and that energy production is the end use most important to determining overall hog fuel market prices, other uses of biomass material did provide an important market niche for certain businesses:

- Four interview respondents reported involvement in the production of compost from biomass, including two firms which manufactured compost from biomass, and two firms which processed or transported hog fuel for eventual use in compost;
- Three firms processed biomass for used in erosion control or landscaping purposes; and
- Three firms processed biomass for use as livestock bedding or for other agricultural uses.

Variety of Types of Equipment

Processing contractors reported owning the majority of biomass equipment, since landowners tended to contract out biomass processing and other operations requiring substantial equipment capacity. As previously discussed, processing firms tended to feature diverse business revenue streams; in order to carry out those varied business activities, processing firms relied on a diverse array of equipment, including:

- Grinders;
- Bulldozers;
- Excavators;
- Chip vans;
- Semi-trailers; and
- Logging equipment

The grinder, which turns chunks of woody slash into hog fuel that can be combusted in a boiler, is perhaps the essential piece of equipment owned by processing contractors, and all but two processors interviewed retained that capacity in-house. Most processors also owned excavators or other heavy equipment to help collect and pile the biomass dispersed in a unit, although many

contractors also sometimes relied on independent logging contractors to have previously collected and piled the biomass for them.

One positive attribute of most biomass harvesting equipment is that it can be used for multiple types of forest-product processing activities. To take a couple of examples, excavators can be used to salvage wood chunks for pulp and paper production rather than energy production, while grinders can grind biomass for composting. Processors tended to report that this equipment versatility provided flexibility allowing them to rely upon alternative revenue streams during weak hog fuel markets or during seasonal periods when it is difficult to harvest forest biomass.

Partially because biomass harvesting operations have not been a significant or long-standing component of the forest products industry, many types of biomass-specific equipment are not necessarily available in mass production. In order to better achieve their biomass collection, grinding, and transportation needs, 4 of 13 processing firms mentioned inventing or substantially modifying new harvesting equipment. As one impressed landowner observed,

these guys are really kind of true entrepreneurs, as they try... to figure out how to get this really low cost material from point a to point b, and make a shekel on it.

Several firms mentioned that the steerable rear-axle chip trailer had been a particularly important equipment innovation developed by a Washington processing contractor. Respondents reported that these vehicles allow in-woods grinding to take place far up forest roads with tight turns, and help the contractor haul hog fuel from any roads that logging trucks can also navigate.

Expensiveness of Equipment and Operations

The equipment required in order to harvest biomass is not cheap: depending on design, respondents reported that new grinders cost in the range of \$1 million apiece, and previously-

used grinders still might cost hundreds of thousands of dollars. A grinder may just be the tip of the iceberg, too, in terms of equipment costs, as one contractor recounted:

The tub grinder I quickly found out is the very cheapest part of your whole operation. Because the tub grinder is nothing without the support equipment you need- two excavators, a dozer, you need a huge big front end loader, you got to have a minimum of two chip vans, two semis... you start adding all that stuff up, the tub grinder it really is the cheapest part of the whole investment.

Several contractors estimated the total equipment costs associated with a single grinding site as at least a couple million dollars.

In addition to the baseline costs of biomass equipment, specialized biomass equipment may be more expensive if is being prototyped and designed in conjunction with a manufacturer, and is not mass-produced. Even if a firm is willing to accept the expense of owning equipment, a few respondents noted that it can be difficult to obtain bank financing to buy equipment, particularly difficult in light of recent hog fuel market fluctuations and the uncertain economic viability of the biomass harvesting industry.

Firms responded to the capital-intensiveness of biomass harvesting equipment in a couple of ways. Some firms pursued a strategy of buying used equipment, and three processors indicated that their decision to purchase used equipment had helped them to weather the current hog fuel market downturn. A second strategy processors employed was to forego new purchases entirely, or at least to hold off purchases until absolutely necessary. A few respondents also speculated that high equipment costs may also be keeping firms out of the industry, and one landowner explicitly cited the capital required to purchase harvesting equipment as a “barrier to entry” to the biomass harvesting industry.

In addition to being expensive to purchase, biomass harvesting equipment is expensive to operate. A few respondents noted that the high cost of diesel fuel was an important cost driver in

their business's harvesting operations. In addition, a couple of respondents noted that operational and maintenance costs for this equipment would be substantial if firms did not have the internal capacity to repair vehicles. Interview respondents viewed having this internal repair capacity as essential for businesses to participate in the industry, and one landowner explicitly viewed obtaining that repair capacity as a prerequisite before he would be willing for his firm to invest in biomass harvesting equipment:

If you are going to take the risk of going out from going out and buying...a used Peterson horizontal grinder, and cobble together some used trucks. You better have a mechanic that knows what the hell he is doing because they are going to be working on that thing several hours a week, trucks and whatever else.

However, many firms are able to minimize their vehicle maintenance costs by maintaining in-house vehicle repair capacity, and one landowner even described the processing contractors' job as being "*half-mechanic, half-lumberjack.*"

Grinders and other essential heavy biomass harvesting equipment are a capital-intensive investment that often cannot be used at full theoretical capacity. Most respondents indicated that their grinders were frequently idled for hours at a time due to the logistical requirements of the harvesting process. Firms idled their grinders while moving equipment between nearby slash piles, while readying slash piles with excavators or other equipment, and while repairing jammed or broken down machines. Even the more active biomass harvesting companies still idle their grinder most of the day, as well as for weeks or months between harvesting jobs. However, at least one processor noted that his grinder had still definitely proved a profitable investment, even though it was idled for all but an hour or two each day. In addition, the capital-intensiveness of biomass harvesting equipment means that firms may not have a sufficiently diverse fleet to allow deployment of optimal size equipment to every site. One respondent noted,

There are times when we could use a smaller machine, it would be more cost effective running it, and it would be good to have that.

Summary of Key Findings

For processing contractors, biomass harvesting served as one component of a diverse stream of revenue-generating services. Processing contractors, rather than landowners, tend to own the majority of biomass processing equipment. Firms used equipment with a variety of functions to harvest biomass, and contractors have innovated substantially in equipment design. Equipment is costly to purchase and difficult to maintain. Equipment costs may present a barrier to entry in the harvesting industry for firms that might otherwise consider becoming more actively or directly involved in biomass harvesting.

2. Drivers of Forest Biomass Businesses' Short and Long-Term Decision-Making

The results in this section describe (1) firms' motivations for entering the biomass harvesting industry, (2) the factors that firms consider when deciding whether to harvest biomass from a particular unit of land, and (3) how firms make long-term strategic decisions, including how they make investment decisions and respond to perceived risks.

2.1 Decisions to Enter the Biomass Harvesting Industry

This section (1) reviews the business activities of biomass harvesting firms previous to entering the biomass industry, and the timing with which they entered the biomass industry, (2) contrasts the industry entrance motivations of landowners and contractors, and (3) notes other motivations that inspired firms to enter the biomass industry.

Biomass Industry Entrance Backstory & Entrance Context

None of the firms interviewed was wholly new to the forest products, land development, or wood waste handling industries when they decided to enter the biomass-to-energy supply chain. The vast majority of firms had entered the biomass harvesting industry as a result of being forest landowners or logging contractors. However, two firms entered the biomass-to-energy supply chain from a background of organic waste management (including urban wood waste). In addition, several firms had experience in construction and real estate development activities, in addition to a background in logging or other forest products services.

While most landowners and in-woods contractors had been in business in some form or another for decades, the largest class of firms (9 of 21 interview respondents) became active in harvesting biomass during the 2004-2009 time period, when the market price of biomass was increasing, and biomass-centric policies were starting to be enacted. However, a few contractors, including some of the more currently-successful firms, have been involved in the use of woody biomass for energy for decades. Notably, even these industry veterans tended to report that until the early-to-mid 2000s, in-woods grinding was only sporadically requested by the mills or landowners. These contractors with a longer, more-established history of handling wood waste or grinding slash piles perceived themselves as benefitting from certain advantages over the wave of newer entrants into the market: one processing contractor partially explained his firm's success at dominating the local processing industry by noting that he had been in the logging and pulpwood business since long before biomass-for-energy became a true industry. With this head start, the processor noted that he had an easier time obtaining financing than a new entrant would have. A local landowner who contracted with this processor also speculated that the firm's large size explained its local dominance: Since this firm had a built-in diversified revenue stream that

benefited from equipment and transportation synergies, it could more efficiently process biomass and thereby win a pricing war against potential competitors.

Different Motivations for Landowners and Contractors

Most landowners indicated that they had started engaging in biomass harvesting operations in order to reduce costs associated with alternative biomass disposal options. In the view of many of these landowners, biomass is a waste product, and disposing of biomass in ways other than harvesting it for energy production imposes costs and risks associated with burn management and lost land area for re-planting. In particular, seven of nine landowners mentioned that reducing their slash burning management costs and meeting burn-related regulatory responsibilities was an important entry motivation.

Several landowners mentioned that rather than being motivated by any substantial immediate profit from biomass harvesting, they had been motivated by the long-term prospect that biomass would become profitable once harvesting operations and technology had matured. As one landowner operating in the relatively-strong North Peninsula market explained,

(We saw that biomass) was going to be a valuable product very soon. At first it was a quarter a ton, and you made a truck load run to town, you made five dollars and twenty five cents. That didn't amount to a whole bunch, but... I think the foresight that we had seven or eight years ago is now bearing fruition, and we are going to make some money off of this program.

In comparison to landowners, short-term profit provided processing contractors with a more immediate motivation to enter biomass-to-energy industry. Four processing contractors, all of whom entered the market in the relative heyday of 2004-2009, mentioned that they joined the industry because they perceived that they would be able to profit from providing that service. In

several instances landowners had approached contractors without prior biomass experience and asked them to consider providing that service, after which the contractor began doing so.

Other Non-Economic Motivations

Both processing contractors and landowners mentioned a variety of industry entrance motivations other than short or long-term profitability. A few firms mentioned that part of the reason they began biomass harvesting because they viewed it as the right thing to do from a resource-utilization perspective. Some landowners mentioned that they were motivated by the desire to be neighborly, and had responded to public pressure to reduce slash burns in certain areas. However, these additional motivations were not usually described as being the driving factor underlying the firm's decisions to enter the industry.

In a divergence from the findings of the Washington Forest Biomass Supply Assessment, which found that BCAP was a major incentive for many contractors to enter the industry, only one firm mentioned that BCAP had played into their biomass industry entrance decision. By contrast, most processing contractors interviewed in this study entered the industry in the years immediately prior to the initiation of the BCAP program. Survivorship bias offers one possible explanation for this discrepancy; several contractors in the industry explained that many of the firms enticed to enter the Washington biomass-harvesting industry as a result of BCAP have since folded and exited the industry. Besides BCAP, firms did not mention other government programs as providing incentive or as a disincentive to enter the biomass industry.

Summary of Key Findings

Most firms began actively harvesting biomass in the last ten years, although certain landowners and contractors date their operations much earlier than that, and may have experienced certain

competitive advantages as a result of their early market entrance. Landowners tended to be motivated to begin biomass harvesting to avoid other costs associated with managing residuals, and with the hope that if the industry develops, the material will ultimately become profitable. Processing contractors tended to be comparatively more motivated by perceived opportunities to realize short-term profits. Both landowners and contractors also cited non-financial motivations for entering the industry, but these were largely seen as secondary in importance. Firms did not cite government programs as an important motivation to enter the biomass harvesting industry.

2.2 Description of Harvesting Decision-Making Process

This section examines the factors that interview respondents reported to be important in their decisional processes to harvest biomass from specific forest parcels. The factors important to firms' harvest decisions include (1) calculations of overall revenue and costs associated with harvesting transactions, (2) specific logistical and cost considerations, including the feasibility of burning biomass or transporting it to an energy facility, and (3) other factors which influence decisions whether to harvest biomass.

As contextual background, firms have three basic options for managing their residual biomass from logging operations at a site:

- Pile and burn it
- Grind it and transport it for use in energy production
- Leave it to decompose on site

All else being equal, many landowners indicated a preference for biomass harvesting:

We end up with this 2 to 3 week window... to burn, and it's just a hassle, it costs money, you assume risk, and so in a perfect world, I'd have every landing ground up for biomass, because you are reclaiming those acres.

However, the likelihood of a landowner choosing to burn, harvest, or decompose residual biomass at a given site depends on many of the factors that influenced firms' initial decisions to

enter the biomass industry, including calculations of biomass harvesting costs, the price paid by energy producers for hog fuel, the cost of burning slash, the ability to obtain a slash burning permit for the site. In general, interview respondents reported that the basics of supply and demand are central to their decisions whether or not to harvest biomass: Harvests depend on whether there is local market demand, and whether the firm can profitably supply hog fuel after taking into account the costs associated with collecting, grinding, and transporting it.

Overall Revenue and Cost Calculations

Most landowners and contractors discussed their decision-making process in terms of supply and demand, and generally indicated a strong financial orientation to their decision-making process.

One typical harvesting contractor explained,

Every job that we bid, we go into it with- is it going to cost us to get rid of the biomass- are we going to break even? Are we going to make money?

Most firms (14) indicated that their goal is to meet or exceed a “breakeven” point on the actual biomass harvesting operations from a particular site; in other words, the value paid for the biomass by the energy producer must exceed the landowner and/or contractor’s costs in collecting, grinding, and transporting it. Many respondents noted that profit margins are typically thin on biomass harvesting operations, although several firms were notably hesitant during interviews to share their hoped-for profit margin on each activity. Among firms willing to discuss the profit margin they sought, the amount depended on the relative strength of the hog fuel market: as one landowner explained,

When it’s going good, people are making good money on it, then we expect a fair share back. If things are borderline, then the pendulum swings the other way, and if that means that we don’t get any stumpage and we just get the tax credit, and (the contractor) walks away with the slash for free then that’s what we do. If the price per ton is up there skyrocketed, and we can make 3 or 4 or 5 bucks a ton, then we’re going to take that as well, and the credit. It is all market driven just like anything else.

Only two respondents reported that short-term profit from a biomass harvesting transaction was not a consistent factor in their harvesting decision-making: One development-focused landowner intent on short-term property resale, and one vertically integrated landowner and processor who viewed industry participants as largely

sharing in the loss to try to get (the biomass industry) off the ground.

Short-Term Revenue vs. Long-Term Avoided Cost Motivations. As previously noted, landowners mentioned the aversion of short-term or long-term costs as an important motivation for their initial entry into the industry. Landowners interviewed also widely reported that they consider avoided costs when they make location-specific harvesting decisions:

- 7 of 9 landowner respondents were motivated harvest from sites to reduce risk of burns escaping from contained slash piles and damaging timber or neighboring properties;
- 8 of 9 landowner respondents were motivated to harvest from sites to avoid losses associated with buying a burn permit and paying an employee or contractor to conduct and monitor the burn; and
- All 9 landowner respondents indicated that they were motivated to harvest from sites in order to increase future timber revenues by increasing the land available for re-planting after slash pile removal.

However, in contrast to the frequency with which these avoided costs were mentioned as by relevant to harvest decisions, many landowners also indicated that these avoided costs are not valued equivalently to upfront stumpage revenue generated at the time of the harvesting operation. Landowners tended to expect to at least break even on the biomass harvest transaction itself, even if the gains from the avoided costs should have theoretically exceeded the value of

stumpage. One landowner acknowledged that their accounting for avoided costs wasn't necessarily financially rational:

We should be willing to pay (to remove biomass) because, if I am admitting or we are accepting of losing acres to slash-occupying plantable ground, that would imply that we are willing to pay. (But) We haven't gotten that far yet.

Similar landowners tended to think of avoided costs separately from the profit-loss calculation on the harvesting activity itself. Seven of nine landowners reported (or at least implied) that they did not go through a thorough calculation of avoided costs; instead, as one firm explained,

The avoided cost a lot of times would be costs that may happen in the future... so they get to be kind of a little bit more subjective... depending on who you talk to and what the skills of the various operators are, it's a little bit harder to quantify... you tend to make the decision basically based on the revenue you're going to generate less the costs, and you're going to try to get a breakeven and knowing that there are some avoided costs that will allow you to justify that activity.

One of the two outliers in terms of how landowners thought about the value of avoided costs associated with biomass harvesting was, not coincidentally, the landowner that self-described as being the State's biggest biomass harvester by volume. This firm valued the avoided costs in the same manner as the revenue received from the immediate transaction:

we actually signed a contract that we would pay... to get the biomass off the ground, because last year DNR decided to triple the rates for burn permits, and it would have cost us \$6,500 to burn the piles out there, and we figured the transportation costs would be about \$5,000, so we reduced the risk for lighting a match... So we added all those things up with then the return that we are able to get the B&O tax credit, and figured out that thanks to the credit, we were able to actually able to subsidize the hauling for the harvest and at worst break even to what all of our other costs would have been, and at best, come out a little bit ahead... It wouldn't have a made a heck of a lot of money either way, but it saves an expense.

In sum, whether landowners quantify avoided costs as a part of their revenue calculations appears to be an important factor underlying those landowners' decisions whether or not to harvest biomass from a particular site.

Size of Harvesting Jobs. Several grinding contractors reported that they were most likely to harvest from large harvest sites with larger volumes of slash, units close to mills, and units that are close to other harvesting sites in order to minimize equipment re-location costs. Respondents reported that they were less likely to harvest from small and geographically dispersed units. One contractor explained his harvesting decision-making calculations:

There's mobilization costs and you've got economy of scale- you have to have a certain amount of material just to be able to afford to move the equipment in, because you have to be able to move in a grinder in, you've got to move in an excavator- at least one or two shovels to put the material in, and of course you've got to have your trucks lined up... I mean nobody's going to go back just for one pile, unless it is a gigantic pile with enough material to cover the costs, plus you know make some money.

Such mobilization costs help explain why industrial tree farms with large, geographically contiguous ownerships are reported to be more important to the statewide biomass industry than small private forest landowners. Small-acreage grinding is less likely to be a breakeven endeavor after mobilization costs have been factored in, and might only take place on developments where landowners find it necessary to grind regardless of stumpage revenue from the operation.

Specific Logistical Considerations

In addition basic calculations of profitability weighing into firms' decision-making, respondents reported that harvesting logistics factored into their decision-making. The type of land ownership may also influence the volume of biomass that is harvested from a particular piece of land. Tree farms reported limiting on-site harvest levels out of precaution to ensure the maintenance of soil health for future tree growth. By contrast, real estate developers reported preferring to clear sites of all biomass in order to proceed with their other management goals for the site, including the facilitation of property sales.

Road Distance. 14 of 21 respondents considered transportation costs and the distances from prospective harvest units to the mill in their harvest decision-making. Many respondents perceived the existence of a freight-logical limit for biomass harvesting, beyond which harvesting could not take place without losing money. This freight-logical geographical region surrounding each local energy producer is, as thoroughly described by the Washington Forest Biomass Supply Assessment, a function of both the current market price for hog fuel at the mills, and the costs of fuel to transport the biomass (Perez-Garcia et al. 2012).

Burning Feasibility. 8 of 21 respondents indicated that anticipated or actual difficulty in obtaining slash burning permits influenced their decision-making process in favor of harvesting biomass. Several respondents had decided to harvest biomass from a site only after the State Department of Natural Resources had rejected their burn permit application. Other respondents mentioned that they generally anticipated in advance the counties or areas in which they were unlikely obtain burn permits, and began planning for a biomass harvest in those locations before even filing burn permit applications. Several landowners mentioned that even if they expected to successfully obtain burn permits, the short window of time when weather allows for slash burning prevents the landowner from getting to all of the slash piles on their ownership, and forces them to leave biomass piles to rot or to pay for the piles to be harvested.

Other Seasonal Considerations. In addition to seasonal and weather considerations factoring into the feasibility of burning on a site, 9 of 21 respondents also reported that the optimal time to pile and grind slash, use forest roads, and sell hog fuel are all also seasonally dependent. The overall impact of the seasonality of the logistical considerations, detailed further in Appendix H, is that biomass harvesting is not reported to take place at a consistent pace, but instead may be subject to short-term price and volume fluctuations throughout the year.

Other Factors Important to Biomass Harvesting Decisions

This section explains how biomass harvesting decisions may integrate with other land management decisions, how the time at which the decision to harvest biomass is made can affect the economic viability of conducting that harvesting operation, how communication between landowners and contractors can have important implications for harvesting viability, and how harvest method innovations can facilitate the cost-effective delivery of hog fuel to markets.

Biomass Harvesting Integration with other Land Management Activities. Respondents perceived the value of hog fuel to be negligible, and consequently disregarded biomass when developing their overall tree-growing strategies. However, biomass harvest did factor into land management decisions to the extent that firms considered it in the context of higher-value log-harvest plans.

Once firms have decided to harvest logs at a site, some firms may devote special forethought to biomass harvest when laying out roads on a site and instructing logging contractors on where to locate landings and slash piles. This special accommodation of biomass harvest can take two basic forms. First, piling of slash for burning can double as piling for biomass harvest. However, many contractors indicated that in order to optimize the logistical efficiency of biomass harvesting, they size and shape slash piles slightly differently than if they were going to burn them, and in a different spatial arrangement across the site. Second, several respondents reported that unless using steerable-rear axle chip trailers, roads built specifically to accommodate biomass harvested must include wider turns, wider culverts, or other special design features. A few respondents indicated that building roads to accommodate both logs and biomass can be accomplished without additional cost so long as the planning is integrated into road design at the outset; however, others indicated that roads built to accommodate biomass are more expensive and difficult to build.

Timing of Harvest Decision-Making. Because piling and forest road layout can sometimes be designed to facilitate biomass harvesting, the timing of when a landowner or contractor decides to proceed with biomass harvesting can have implications for the feasibility and efficiency of the biomass harvest. However, the majority of contractors and landowners indicated that the final decision to do biomass harvesting on a unit tends to be an afterthought, and take place after logging, log road-building, and piling have been completed.

A few firms implied that instability in the hog fuel market undercuts their ability to make efficiency-increasing upfront planning decisions for harvesting biomass, since the effort and costs that go into planning roads and piles to accommodate biomass in advance of a log harvest may not be worthwhile if there is uncertainty about the market for that biomass. The conundrum faced by firms is this: if a decision is made upfront to grind, and then the mills decide they don't need the hog fuel, the contractor has already spent time and money on the site preparation that will be wasted if biomass is not harvested. On the other hand, if the landowner and contractor wait until after logging, piling, and road building have taken place before making a decision to harvest biomass, there may be parts of the site that are inaccessible or prohibitively expensive to harvest due to need to re-shape piles or add turning radius to roads.

Landowner-Processor Communication in Harvesting. The particular dynamics of the relationships between landowners and logging and biomass harvesting contractors may also be important to the cost-effective and consistent harvest of biomass. A few of the landowners who were most active in harvesting biomass reported having close working relationships with their biomass harvesters, and kept in frequent communication with them about their upcoming harvesting locations and prospective biomass removal needs. On the other hand, since many landowners separately contract out for logging and biomass harvesting on a site and may use a

number of different contractors, there is not always direct communication between landowners and logging contractors. Even if the landowner has it in mind to harvest from a particular site, the logging contractor will not necessarily know to take the pains to set up roads and piles so as to facilitate subsequent biomass harvest; at least one landowner noted that his biomass processing contractor had requested better lines of communication with the logging contractor so as to make his biomass harvesting job easier.

Innovations in Harvesting Methods. Six firms perceived that there had been a notable learning curve after entering the biomass industry, and that it had taken their company months or years to develop their harvesting practices and systems. As this section has previously detailed, firms may need to consider a number of complex logistical factors in making harvest decisions. Since there is not a uniform, agreed-upon harvesting system suitable for the variety of site conditions statewide, many respondents reported innovating and adapting to discover the biomass harvest techniques that worked best for them. As one contractor explained,

Until you see it, there is many things hidden behind the scenes that people don't see or understand in the biomass industry that have to happen in a certain sequence in order to make the whole thing work.

Specifically, several respondents developed important knowledge and harvesting innovations regarding road layout, seasonal timing of harvesting, the timing, siting, and shaping of slash piles, and the need to exclude materials like roots, dirt, rocks, and vine maple from the grinder.

Summary of Key Findings

Firms factored in a variety of financial and logistical considerations when making decisions whether to harvest biomass from a particular site. Revenue and profitability from harvesting operations motivated many harvesting firms. The avoidance of other land management costs was also important to site-specific harvest decisions, although firms varied in the degree to which

they considered and quantified the value of those avoided costs. The size of the harvesting job, road distances, the feasibility of obtaining a slash burning permit, the season of the harvesting operation, and landowners' post-harvest plans for their land all impacted the likelihood of biomass harvesting taking place, and the amount of slash that was removed from sites. Up-front planning for biomass harvest offers certain cost-minimizing advantages as compared to decisions made after logging had taken place.

2.3 Long-Term Strategic Decision-Making: Business Risk-Taking and Investments

This section (1) reviews how firms in the industry perceive risk, uncertainty, and instability in their industry, (2) describes how landowners and contractors adopt divergent strategic approaches to taking on risk, and (3) notes the how strategic approaches to risk interplay with firms' equipment ownership decisions.

Perceptions of Risk, Uncertainty & Instability

Firms tended to view the forest biomass industry as an uncertain business arena, characterized by the risks posed by hog fuel market price fluctuations, uncertain economic viability of many hog fuel consuming energy production facilities, large equipment investments, changing technologies, and a shifting policy environment. Most (11) firms characterized the hog fuel market as unstable and subject to substantial price fluctuations:

this business that you're interviewing on, is so volatile, and changes so many times, it goes through many many depressions, recessions, booms. It's a crazy industry.

Sources of Uncertainty in the Forest Biomass Market. Four firms explained the instability in the market price of hog fuel as being most closely tied to instability in the price and availability of superior substitutes like natural gas and mill residuals. Several also perceived that the tough

economic climate for pulp and paper mills (the largest energy-producing consumer of hog fuel), added uncertainty to the hog fuel market. Risk and instability from hog fuel market fluctuations was compounded by a distrust of many of the mills, which processors saw as having taken advantage of market instability to increase their negotiating power.

Firms also perceived uncertainty regarding the future viability of new biomass-utilizing fuel and energy technologies. The uncertainty related to questions of if and when new technologies might increase the value of hog fuel left landowners reticent to enter into long-term biomass supply contracts at pre-set prices. The vast majority of respondents also perceived uncertainty in the biomass market stemming from questions about the future direction of regulatory and economic policies at all levels of government.

Biomass as a Risk Reducer. Although respondents tend to perceive biomass as an industry infused with uncertainty and risk, many respondents also viewed biomass as a mechanism for offloading other business sector risks by diversifying the firm's revenue streams. Several contractors saw biomass as a means of diversifying their business away from an exclusive reliance on other forest products, waste, and construction services. In addition, firms that had invested in biomass-specific equipment, such as grinders, often also used those grinders for purposes other than biomass-to-energy in order to balance out hog fuel market fluctuations.

Landowners sometimes thought of biomass harvesting as a means of hedging against downturns in housing and pulp and paper markets. Several landowners also saw biomass harvesting as a mechanism for mitigating the risks associated with in-woods slash burning: the risks associated with market instability might sometimes be outweighed by the quickly-expensive risks of sparks escaping the burn area and damaging trees or neighboring property.

Trends in Risk Tolerance

Chart 3 displays respondents' attitudes toward risk-taking. As discussed in the methodology chapter, self-reports by interview respondents form the basis for these assessments of risk tolerance, and risk tolerance was not formally experimentally determined. Most firms did not distinguish between their willingness to take risks in general, and their willingness to take risks specifically with respect to biomass. However, a few respondents indicated that they were more willing to take risks on biomass activities than were in other aspects of their business. This relative willingness to take risks in biomass could reflect the fact that many firms viewed biomass as an auxiliary component of their firm's business, and that firms had less to lose by experimenting with biomass.

Chart 3: Summary of Firms' Attitudes With Respect to Taking Risks

Attitude Toward Risk	Number of Firms Interviewed
Risk Loving	6
Risk Neutral	7
Risk Averse	8

Risk-Avoiding Landowners and Risk-Loving Contractors.

There was a sharp distinction between how landowners and contracting processors approached risk, with contracting processors being much more tolerant of risk, shown in chart 4. Note that charts 3 and 4 ostensibly appear to sum inconsistently because certain firms were coded as both landowners and processing contractors.

Chart 4: Summary of Risk Tolerance Trends for Landowners and Contractors

Type of Firm	Number of Risk-Loving Firms Interviewed	Number of Risk-Neutral Firms Interviewed	Number of Risk-Avoiding Firms Interviewed
Landowners	0	2	7
Processing Contractors	6	6	1

A typical landowner explained the long-term thinking and risk avoiding tendencies that characterized their segment of the biomass-to-energy supply chain:

Timber companies are generally not guys that take a lot of risk. They are somewhat risk averse, very long-term in their thinking, and not incredibly high margins and returns but they are somewhat consistent. So jumping into a new market, with a product that's never been around before, it's kind of a stretch. We typically want to see it done first before we get in there.

The several “landowners” interviewed who partly or exclusively managed land on behalf of financial entities cited the desire to produce stable, consistent financial returns as a driving goal underlying their decision-making. Several landowners noted that their firms had made a strategic choice to offload risks associated with both log and biomass harvesting onto contractors. One landowner also suggested that the risks borne by their biomass contractors are a fair tradeoff for their disproportionate share of potential financial upside from biomass harvest.

By contrast, contractors tended to be much more tolerant of risk than landowners. Several mentioned that they perceived risk-taking as a business advantage:

If you want to play big, you've got to bet big.

Other contractors viewed living with risk as a necessity in their industry, and tried to make bearing that risk tenable through strategies like revenue stream diversification:

You know these mills, they don't always need hog fuel. For instance, they'll call you up and say hey we don't need hog fuel for three weeks. Well if you don't have something else to do with that material, you're literally out of business...until that mill decides to start taking material again. So as far as risk goes...the way that I try to stabilize that risk is to try to find

as many outside sources as aren't affiliated with the mill to take that wood from us. So that way if we are in the middle of a project, the mill calls us up, then we have another outlet.

Risk and Equipment Investments

Both landowners and contractors tended to view investing in biomass equipment as risky, due to its cost and the uncertainty posed by market fluctuations. In many instances, participants viewed and discussed their willingness to take risks interchangeably with their willingness to make investments, particularly in new equipment. One noted,

every time you buy a piece of equipment you've taken a risk.

Another contractor recounted,

I've thought about buying a tub grinder and going that route, but they are so expensive and the market is so iffy... I could sure use some new (trucks), but I'm not going to stick my neck out until need be.

Firms viewed the instability in the hog fuel market, and the uncertainty it engendered in the contracts between firms, as a hindrance to new investments in biomass harvesting infrastructure:

The uncertainty is the biggest part of it. There is nobody around here that will give you a commitment. If a guy was to come in here and make me a guarantee that he was going to take my material for five years; Yeah, I'd go for (a new) piece of equipment to do it. But there's nobody here that will make that commitment.

Where firms perceive less risk in the biomass market, some evidence from interviews suggested that firms may be more likely to invest in equipment: One contractor noted that the firm's longer-term contracts to supply hog fuel to local mills had convinced it to buy expensive pieces of harvesting equipment. However, firms in all sectors of the industry tended to indicate a high degree of reticence to make large financial commitments to developing forest biomass supply chain capacity.

The prospect of not finding a re-sale market for equipment compounded the risks associated with equipment purchase. One contractor noted that a weak equipment re-sale market led the firm to

offload equipment at a substantial loss. A second contractor noted that his technologically innovative piece of equipment had little re-sale potential:

Other than the oil fields in North Dakota, there's probably not a lot of people that really need something like (our equipment).

Nevertheless, several respondents did note that their biomass harvesting equipment had generated acceptable returns that had exceeded their initial investments.

Firms responded to the risks posed by equipment investment in several ways. Several risk-avoiding firms made strategic decisions to explicitly avoid taking on debt in order to buy equipment, and instead leased their equipment or purchased used equipment. Other contractors had sufficient capital to avoid reliance on bank financing for equipment purchases, and therefore had less exposure to risk:

when the market turns like it did, I just park the grinders in the back yard and they just sit here. But if I had to make payments on anything...I'd probably be in a tent underneath the bridge.

A few of the respondents whose firms had entered the biomass industry with similarly strong financial positions also expressed a greater willingness to take risks unrelated to biomass (in attempting to enter a new business niche, for example) because business could survive if a risky bet didn't immediately pay off. As one explained,

I do own my equipment so I have a bigger risk threshold...so I have a little bit bigger threshold for saying 'hey that didn't work let's not do that again'.

A few landowners were pursuing a different strategy to reduce the risk of prospective equipment investment: They were actively trying to recruit new local energy-production facilities (including those employing novel bioenergy technologies) which would provide a stable, certain future local hog fuel market. Several firms mentioned that successful facility recruitment might make their firms more likely invest in biomass equipment. In some cases, this recruitment effort reflected a bit of a chicken-or-the-egg problem: Landowners were hesitant to commit to the

long-term biomass supply from their lands sought by prospective biomass facilities who might otherwise be hesitant to invest in facility infrastructure, but they were also hesitant to invest in biomass harvesting equipment without the surety afforded by a local facility siting. This dilemma suggests that if landowners ever take the leap of investing directly in biomass harvest equipment, it will only be part of a package deal in conjunction with the siting of a local energy production facility, and a long-term contract for the supply of forest biomass to that facility.

Even if the barriers to entry posed by biomass equipment cost and market instability were to disappear, landowners that are not directly collecting and grinding biomass might still opt not to become biomass processors because it does not align with their basic business model. For example, one landowner that wanted to increase biomass harvest levels from the firm's lands indicated that he had looked into investing in biomass harvesting equipment, but was concerned about the scale of company expansion that such an investment would entail; this landowner did not currently do its own logging, and adding a biomass harvest operation would represent a fundamental strategic change for the business.

Summary of Key Findings

Industry participants perceived uncertainty and risk in the forest biomass industry that stemmed from a variety of contributing factors. Landowners tended to be less willing than processing contractors to bear risks such as investing in new equipment. Processing contractors tended to view the acceptance of certain risks as an inherent part of their business model, and had adopted several types of strategies to temper those risks. Although biomass harvesting tended to be viewed as an unstable industry and a risky market to invest in, firms also perceived risk in business strategies which attempted to entirely avoid the practice of biomass harvesting.

3. Economic and Policy Barriers to the Viability of Using Forest Biomass for Energy Production

Firms tended to see the biomass-to-energy industry as having a bleak future, or at least a bleak immediate future. Among the eight firms that reported being pessimistic about the industry's future, several were contractors who had already ceased biomass harvesting operations, or were in the process of trying to exit the industry. By contrast, only four firms had favorable short-term outlooks on the market, including three operating solely in the North Olympic Peninsula's relatively strong market. Six firms thought that the biomass-to-energy industry would eventually rebound, but was likely to be bleak for at least the next handful of years.

Even firms that are relatively optimistic about the industry's future are not necessarily counting on it becoming a major revenue driver: One typical landowner volunteered that

no one is going to get rich off of this stuff in terms of private timber companies... it's still going to remain a really small percentage of what their overall profit and revenue would be.

Instead, landowners primarily hoped that in-woods biomass will eventually generate enough operational revenue to facilitate it taking place more frequently, so that landowners could benefit from the costs that harvesting biomass averts.

Firms perceived a variety of economic and policy changes that might help secure a brighter future for the biomass-to-energy industry. The results in this section describe (1) firms' perceptions of what general barriers to the success of biomass-to-energy exist in both the economic and policy environments, (2) how firms' experiences with the BCAP program and the state B&O tax credit might indicate the existence of economic policy barriers to industry viability, and (3) firms' perceptions of existing regulatory barriers to industry viability.

3.1 Perceptions of Broad Barriers in the Economic and Policy Environment

Interview respondents identified three categories of factors that were important to the future of their industry: economic and regulatory policy certainty (15 of 21 respondents), new biomass technology (12 of 21 respondents), and public opinion (9 of 21 respondents).

Economic and Regulatory Policy Certainty

In general, firms viewed the government and policy makers as attempting to be supportive of the biomass to energy industry. One contractor, while pessimistic about the current state of the industry, noted that

it's not like they haven't tried.

Firms' perception that the government wanted to support the biomass industry seemed to apply to both the federal and state governments, and to certain government agencies. Firms perceived the State Department of Natural Resources as being particularly supportive of the biomass to energy industry, while they viewed the State Department of Ecology as less supportive.

In contrast to the fact that firms generally viewed government as supportive in intent, they also viewed government activities as tending to be meddlesome, interruptive, or distortionary in their impacts on the industry. This negative feeling towards government intervention in their industry held true regardless of whether the policy being implemented was intended to alternatively help or restrict the industry, and whether the policy was economic or regulatory in nature. Several referenced their conservative political or ideological leanings in explaining their perspective on the appropriate role of government in the industry, while others linked their opinions on the proper role of government to specific experiences that they had had with particular government policies or agencies (See sections 3.2 and 3.3). None of the firms expressed a desire for new or

additional government subsidies, although some suggested that the establishment of subsidies might help the market.

In general, firms tended to view the policy environment in which they operated as uncertain and unstable. As one interview subject noted,

I don't think of anything in Olympia as being permanent.

Firms viewed economic and regulatory policy certainty as especially important to processing contractors:

Because of the short term time-frame, (economic subsidies) cause like schizophrenic activity... it's not so much on the owners of the biomass who are just sitting back.... It's those guys that have to respond to the short term opportunities to try to make something out of this stuff are the ones that are just getting jerked around... They would benefit the most by having more longer-term, stable, energy policy...that's going to be in place for the long term to get this up and running.

On the regulatory policy side of things, firms' views of the predictability of government policies depended on the agency administering them. Forest practices rules, including rules for biomass harvest, were mentioned as being stable and well-understood by industry participants. Firms saw unpredictability in other aspects of government policy-making, especially regulatory standards set by the Department of Ecology or the U.S. Environmental Protection Agency.

By contrast, economic policies and incentives were widely viewed as uncertain and lacking permanence. As one firm put it,

there's no such thing as a long term subsidy.

To the extent that economic policies are viewed as unstable or uncertain, some of the effectiveness of those incentives at spurring business investment may be lost: As one landowner explained,

private industry doesn't typically make investments that are solely based on and made feasible on subsidies, because those come up every year or two years... and you don't know if you are going to end up getting 'em- without the subsidy if everything goes upside down, then you're in a tough situation.

Firms also saw uncertainty with respect to how certain economic and tax policies were being implemented, and who was eligible to participate in them.

Firms expressed a variety of thoughts about the future direction of government biomass policy, but a couple of common themes emerged. First, firms did not anticipate that policymakers would agree on a comprehensive carbon policy like cap and trade anytime in the near future. Second, many respondents expected government support for the biomass-to-energy industry to continue to be financially restrained as a result of lingering state budget difficulties.

New Biomass Technology

Although biofuels and new biomass technologies have not yet been commercially deployed, most (12) firms viewed the introduction of new biomass technologies as likely to improve the long-term landscape of the industry. Firms mentioned a variety of specific biomass technologies that they were most excited about, including ethanol, jet fuel, pyrolysis, bio-gas, bio-diesel, pellets, and coal-facilitation. Each respondent seemed to have a particular technology that he was most excited about, although several respondents noted that their firms were indifferent to the specific end uses of the biomass so long the new technology improved the local hog fuel market. A couple of landowners also reported that the anticipation of new technology had made them hesitant to commit to long-term supply contracts in anticipation of new technology triggering a consequent hog fuel price increase. However, a few respondents indicated that their optimism over new biomass technology had tempered due to the long duration that firms have waited in vain with high hopes:

How much money has our state spent on trying to get that stuff going? A lot of people have tried, a lot of smarter people than you and me with big-time government backing have tried, and it hasn't happened yet. You would think that if they were going to figure it out- it is 2012, they have been working on it for what, ten years?

Public Opinion

Firms perceived broad but weak public support for the use of forest biomass as a fuel source.

Many saw this broad public support as overshadowed in practice by the strong opinions of a vocal minority of environmental or community stakeholder groups. One landowner explained,

I think there's a push for (biomass-based fuel technology), but I also don't think that there's a lot of backbone to use forest products for that... my opinion is that the environmental community will get too involved, and forest products will not be favored. I don't think there's a lot of political and environmental will... people are still attached to trees, and don't think that forests should be utilized... You get into an issue like this, and biomass is a divisive issue that way.

Firms saw the influence of these groups on policy decisions as a source of uncertainty in industry activities, particularly with respect to point-source air emission policies and to the siting of new, biomass-utilizing energy production facilities.

Eight firms viewed addressing the concerns of biomass-to-energy critics, or at least mitigating the impact of critical opinions, as a key to the industry's future success. Several respondents noted a catch-22 in public opinion: several felt that public opinion against in-woods slash burning would lead to continual tightening of burn regulations, but also expected that public opinion would prevent the siting of new facilities, leaving landowners with few slash disposal options.

Summary of Key Findings

Respondents viewed the development of new biomass technologies, the shaping of public opinion, and the amendment of biomass policies as important to setting the course of the future of the industry. Respondents generally viewed the state and federal government as supportive in

intent with respect to the biomass-to energy industry, but as meddlesome and counterproductive with respect to the implementation of specific policies. Respondents characterized government policies, and particular economic and tax policies, as temporary and uncertain in application. Respondents also saw public opinion, and the strong opinions of certain stakeholder groups, as introducing uncertainty into policy and permitting decisions affecting industry activity.

3.2 Economic Policy Barriers to Industry Viability

This section reviews respondents' views on the impact of two biomass economic incentive programs that have impacted forest biomass harvesting in Washington: the USDA's Biomass Crop Assistance Program (BCAP), & the State B&O tax credit. Almost all industry participants indicated familiarity with both programs, and many expressed strong feelings about the programs' effectiveness.

The Biomass Crop Assistance Program (BCAP)

Interview respondents provided mixed indications as to whether the BCAP program affected overall forest biomass harvest levels in Washington. During the period of time that the BCAP matching payments program was active, about half of respondents indicated their firms had harvested from geographically dispersed or difficult-to-access forestlands that wouldn't otherwise have been financially viable for harvesting. In local markets where the new economic landscape under BCAP induced energy producers to combust biomass instead of natural gas or other fuels, the program may have led to increased biomass harvesting for energy production.

However, one firm which did report expanding the geographic dispersion of its harvesting activities simultaneously noted that

we have so much (biomass) available that we would have been grinding about the same amount either way.

Another added that under BCAP,

I didn't do anything different, only (thing) different was instead of getting paid every two weeks from the mill I got half of it from the government.

To the extent that BCAP failed to induce existing or new energy producers from increasing their overall demand for biomass, the program may not have increased the amount of woody biomass used in energy production. However, taken as a whole, firms' responses do indicate that BCAP succeeded at increasing overall harvest levels in the state, even though that conclusion may not apply to all contractors that participated in BCAP.

However, to conclude that BCAP may have succeeded at increasing forest biomass harvest levels is not to conclude that BCAP was a successful program overall. The vast majority of respondents who had actively participated in BCAP had unfavorable things to say about the program. The criticisms most frequently mentioned by respondents are described in the subsections below.

Temporary Windfall. Five respondents mentioned that their firms had briefly made substantial profits from biomass while the program was in place. However, regardless of whether they had personally profited from the program, 10 of the 13 contractors interviewed perceived that the program had existed so briefly that no lasting positive effects, such as the siting of a new energy production facility, could be traced to the program.

Market Distortion. Six respondents perceived that BCAP had generally upset market dynamics by leading to changes in the price mills were willing to pay for biomass. Several firms also viewed the program as hurting well-established firms, who had developed business plans based on market conditions that were upended by the program.

Unfair or Unintended Beneficiaries. Seven participants in the BCAP program indicated that they felt that companies with political or personal connections to BCAP program organizers or mills

were able to benefit disproportionately. Several also thought that paper mills and other unintended beneficiaries had reaped large financial rewards, and perhaps precipitated the BCAP's downfall by overwhelming the program's financing.

Forced Participation. Four processing contractors noted that even though BCAP was designed to theoretically help their margins, they had thought the program was a bad idea from the start and had been hesitant to participate in it. However, these firms had ultimately felt forced to participate in BCAP so as to not be at a competitive disadvantage against firms that were receiving the matching government payments (and thus able to increase their profits while simultaneously reducing the price charged to mills for hog fuel).

Lasting Damage. Five respondents reported that BCAP had done lasting damage to the forest biomass industry that is only now beginning to sort itself out. These respondents noted several facets of BCAP's impact.

First, by incentivizing the entrance of new businesses into the supply chain and an over-investment in biomass equipment, three respondents reported that the capacity of the biomass harvesting supply chain expanded dramatically.⁴ While the program was in place, hog fuel flooded the market, diluting the market price and reducing the revenue gains that contractors could derive from the program. After the matching payments ceased, the three contractors reported that hog fuel supply was far beyond what could be supported by market, which led to a steep drop in the price of hog fuel that hurt all processing firms, including those who had not

⁴ None of the firms interviewed admitted making equipment investments based solely on BCAP, but many believed that other firms in the industry had done so. One possible explanation why no firms admitted changing their own behavior, but perceived a fundamental shift in market conditions indicating that other firms had changed their behavior, is that firms may have been reticent to admit making investments based on government subsidies, or having made a strategic mistake in having invested based on a since-terminated program. A second plausible explanation was offered by one firm that noted that many of the entrants who had made investment decisions based on BCAP had subsequently gone out of business, and thus would have been among the firms that were unable to be contacted for interviews during this research.

over-invested in equipment. These three contractors reported that the inflated harvesting capacity triggered by BCAP was only now beginning to dissipate after enough firms had gone bankrupt or sold their equipment over the past few years.

Second, several contractors mentioned that BCAP had left landowners with an unreasonable expectation of the stumpage price for biomass, and made landowners less willing to harvest biomass when that stumpage narrowed or evaporated entirely.

Third, several contractors mentioned that the overnight cessation of BCAP and consequent drop in the price of hog fuel had led the contractors to back out of harvesting contracts with landowners, many of whom had already incurred costs or opportunity costs in accommodating the planned-for biomass harvest. A few contractors mentioned that the lingering disaffection attributable to BCAP had made landowners less likely thereafter to harvest biomass, and had also left logging contractors less willing to accommodate future biomass harvest.

B&O Tax Credit

This section examines the B&O tax credit's effectiveness at incentivizing biomass harvesting by entering into firms' harvest decision-making calculations. The section also explores the following drawbacks in the credit's design and implantation that interview respondents identified as mitigating the tax credit's power as a behavioral incentive:

- Lack of consideration of tax credit in harvesting decision-making
- Lack of familiarity with the tax credit's value or provisions
- Lack of tax liability that can be offset by tax credit
- Uncertainty about eligibility for the tax credit
- Tax credit not considered equivalent to the value of cash-in-hand
- Tax credit not incorporated into long-term strategic planning

B&O Credit's Role in Biomass Harvest Decisions. Firms which are eligible for the tax credit

fall into three primary camps with respect to the credit's power to incentivize their behavior: The

credit incentives harvest behavior (4 firms), the credit never incentives harvest behavior (4 firms), or the credit incentivizes harvest behavior only under strong market conditions (10 firms).

The first group, comprised of four firms operating in locally-strong hog fuel markets, said that they do currently consider the B&O credit in their harvesting decision-making processes, and that the credit sometimes entices them to harvest biomass in instances where they otherwise might not. As one landowner explained,

it has allowed us to essentially subsidize the biomass hauling. But when we are way out there a long distance... it does matter, and it enables us to harvest more than we otherwise would be harvesting. So I think from that standpoint, it is meeting the purposes.

The responses of this landowner and others with a similar outlook suggest that the removal of the tax credit might substantially curtail their harvesting program.

The second group, comprised of four landowners primarily motivated by land management goals other than short-term harvest profits, reported that the tax credit is not a factor that they consider in biomass harvest decisions. As one landowner explained, the B&O tax credit is

incentive for some people, but it wasn't for us, especially at (site name)... We had a real estate land development goal in mind, and just getting rid of the material was a biggie. On the timberlands side, we did I think apply for that money, I don't know whether we actually got it, I just handed all that over to our tax guy. But that wasn't our motivation for grinding.

Note that for this particular landowner, the B&O credit was not only an ineffective harvesting motivation, but the landowner was also unsure whether his firm had received the B&O credit, and therefore the credit does not appear to factor into his calculations of harvesting profit.

For the third group, the B&O credit was cited as a factor they normally considered in their harvest decision-making. However, for these 10 firms, the credit been rendered moot by current market conditions where hog fuel market prices are substantially lower than the costs of

harvesting, grinding and transporting it. Although the tax credit can reduce harvest losses where firms plan to harvest regardless of profit to achieve other goals, the credit is not a decisive factor at increasing harvest volumes. Even though the tax credit increased in value from \$3 a green ton \$5 on July 1, 2013 per the schedule laid out in the authorizing statute (RCW 82.04.4494), respondents suggested that the increase in the B&O credit's value is unlikely to surmount the gap between harvesting costs and hog fuel market prices. Several firms mentioned that for harvesting to become economically viable, the tax credit would need to be substantially larger, with one firm estimating that a credit value as high as \$15 a ton might be needed for harvesting to resume economically viability.

Familiarity with the B&O Tax Credit. An anecdotal account by one landowner suggests that businesses' lack of awareness of the credit could present one barrier to its effectiveness at incentivizing harvest decision-making:

When we talked to the guy who wrote the rule and got it through the legislature, and he said... everybody else isn't paying any attention to it, or else it was there's a few pitfalls in it so they didn't qualify. But...he said it's crazy because there's this incentive out there but nobody's using it.

Of those who were aware of the credit, most still indicated only passing familiarity with the specifics of the tax credit mechanism. Several respondents misstated the value of the tax credit (\$3 per ton at the time of interviews), when the credit was due to increase in value (July 1, 2013), when the credit is scheduled to expire (June 30, 2015), or what types of companies and activities might be eligible for the credit. At several businesses which Department of Revenue records verify had in fact claimed the B&O credit, interview respondents indicated that they weren't even sure if their firm was eligible for it. These responses suggest a potential lack of internal communication between persons that handle tax preparations and those that make biomass

harvest decisions. In general, this lack of familiarity with the financial details of the B&O credit may indicate that the credit is not of preeminent importance to firms' harvesting decisions.

Tax Credits in the Context of Tax Liability and Credit Eligibility. Beyond firms' basic lack of familiarity with the tax credit's mechanics, aspects of firms' tax liabilities and eligibility may also limit the tax credit's power as a behavioral incentive.

First, in order to claim the tax credit, the firm must qualify as a "harvester" under the definition written into statute.⁵ While most landowners and processing contractors believed that they were eligible for the credit, not all contracting processors active in the supply chain thought that they were eligible to claim the credit. Several respondents reported that the law, as it has been interpreted by the Department of Revenue, allows contracts to be structured between the landowner and processor so as to allow one entity to be designated as the "harvester." This arrangement offers the benefit of allowing the B&O credit be earned by whichever party in the biomass harvest process has greater need to reduce outstanding B&O tax liability. However, five firms also indicated that they were confused as to whether the law did contain this flexibility in assigning tax credit ownership. To the extent that firms are confused about their eligibility for the B&O credit, or are rendered technically ineligible for the B&O credit, the credit probably fails to influence firm decisions and incentivize additional harvesting.

⁵ RCW 84.33.035, which is cross-referenced in the statute authorizing the tax credit, defines a "harvester" as "every person who from the person's own land or from the land of another under a right or license granted by lease or contract, either directly or by contracting with others for the necessary labor or mechanical services, fells, cuts, or takes timber for sale or for commercial or industrial use. When the United States or any instrumentality thereof, the state, including its departments and institutions and political subdivisions, or any municipal corporation therein so fells, cuts, or takes timber for sale or for commercial or industrial use, the harvester is the first person other than the United States or any instrumentality thereof, the state, including its departments and institutions and political subdivisions, or any municipal corporation therein, who acquires title to or a possessory interest in the timber. The term 'harvester' does not include persons performing under contract the necessary labor or mechanical services for a harvester."

Second, only entities which are required to pay B&O taxes benefit from the tax credit. Public and unincorporated private landowners do not pay B&O taxes, and would not be motivated by the credit. However, some contracting processors that operate on non-eligible ownerships thought they might still be able to claim the B&O credit, depending on how their harvesting contract was written.

Third, for firms that do pay the B&O tax, the tax credit is only effective at incentivizing up to amount of the company's B&O tax liability. Firms with small B&O tax liabilities might only perceive a very limited incentive in the tax credit; as one landowner explained,

It is almost like it doesn't exist, because... our B&O tax liability ... is \$12,000 bucks. So we have to grind 3,000 bds (bone dry tons). It's not unusual to get 3,000 bds on one big unit. ... So we have no B&O tax liability after we do one unit. So why do any more? ... It stops being an incentive after one unit.

Likewise, a second firm that characterized itself as highly motivated by the tax credit, noted that their credits earned exceeded their B&O tax liabilities, and that since the start of the credit,

we have not had to pull out the checkbook and write a B&O check yet.

Firms' Valuation of the B&O Credit. Finally, related to questions of firms' tax liability and credit eligibility is the question of whether firms' discount in practice the value of the \$3 tax credit. Three respondents indicated that they viewed a \$3 tax credit as less valuable than \$3 cash in hand because the firm had insufficient or uncertain B&O tax liability to apply the full value of the tax credits against, or because they perceived uncertainty in whether they would qualify for the credit. The fact that these prospective tax credit recipients did not perceive the \$3 tax credit to be worth its nominal value confirms that the tax credit might under-perform as a motivator of biomass harvesting.

One firm, by contrast, indicated that tax credits might actually be more motivating at incentivizing biomass harvest than would be the cash-in-hand of stumpage profit. This land manager explained that to the institutional and family investors that formed his client base:

It's much more of in human nature, I think, and in business, people see that as a bigger advantage of saving \$3,000 than making \$3,000. Because whenever you tell someone that we can save you \$3,000 on your taxes, it's just kind of human nature that what I've noticed is that people are more willing to do it. Suddenly it's worth the time and expense to do it. Whereas the time and expense to make \$3,000 is harder to justify... A lot of clients, [the tax credit] was the selling point.

While this perspective was the outlier among interview respondents, it does indicate a subset of land managers may be a particularly effectively stimulated by tax credit incentives.

Incentive Duration. Many firms perceived that there was some uncertainty as to whether the B&O tax credit would be extended:

I think there is a risk there with the tax credit, just because of legislative and state budget issues, any kind of tax credit or tax break that is given for any particular industry that doesn't apply to the entire state population is always at risk.

Several firms noted that uncertainty about the tax credit's renewal made them less likely consider the tax credit in making long-term plans, including investment decisions which may not be paid off until years after the credit is scheduled to expire.

Summary of Key Findings

Firms had a much more positive view of the state B&O tax credit than they did of BCAP. Firms perceived that BCAP had distorted the market, benefitted unintended businesses, and caused lasting damage to the industry. By contrast, the impacts of the B&O tax credit have been much more muted, as firms tended to view it as inadequate to make harvesting economically viable under current hog fuel market conditions. Firms' interview responses indicate that several aspects of the tax credit's structure may also mitigate its value as an incentive for businesses,

including confusion over eligibility for the credit, the credit's limited utility to entities with low or no B&O tax liabilities, and uncertainty about the future availability of the credit.

3.3 Regulatory Policy Barriers to Industry Viability

All 21 respondents interviewed mentioned at least one regulatory policy (or set of policies) that they viewed as important to the biomass-to-energy market. This section reviews the policies whose importance were most frequently noted by respondents: facility siting processes (5 respondents), point source air emission rules (12 respondents), silvicultural burning rules (8 respondents), electricity market policies (7 firms), and stormwater regulations (3 firms).

A few respondents noted that while government regulations generally affected how they did business, they did not believe that regulations were “deal breakers” for the viability of their operations. Others, by contrast, viewed certain regulations as representing major impediments to the current or future viability of the biomass harvesting industry. Firms did not view the all of the regulations reviewed in this section as barriers to industry viability; rather, firms thought that the industry might benefit if certain regulatory policies were to be amended, or even strengthened in the case of silvicultural burning rules.

Facility Siting and Point-Source Air Emission Policies

Five firms mentioned that the difficulty of siting prospective facilities that would burn hog fuel has held back market development, and that the siting of new local bioenergy producers would be important to the industry's future viability. Several firms believed that the siting of new facilities was the most important change that could improve the biomass industry. One landowner even noted that the siting of a new local energy producer would be beneficial regardless of the ultimate economic viability of that facility:

As a timberland owner, if you just put your own greedy goggles on, you want them to come put an investment on the ground that chews up biomass and converts it into something, you want that there, because even if that thing goes bankrupt with the first guy, someone else is going to come in and buy it cheaper and be in a better position to make money, and you've got some sort of place for your material to go.

Respondents tended to see point source air emission regulations as the most problematic portion of the new facility review process, and as important in shaping ongoing hog fuel use at existing facilities. Many firms also perceived that vocally-opposed sectors of the public could disrupt the facility siting processes. One firm summarized the intersection of facility siting impediments:

There hasn't been...a political will to see those (biomass-utilizing) projects all the way through... I think that everyone talks about it, but then no one supports it when it gets down to the project... If you want someone to build a 200 million or 300 million dollar plant as a business, they have got to have some certainty somewhere that they are going to be shielded from certain things, and lawsuits or whatnot, that the laws are going to be there and be supportive.

Several other firms pointed out that they thought it was illogical and unfair that it was so difficult to site new biomass facilities, when the alternative means of biomass disposal would likely result in the uninhibited burning of slash piles in the woods. As one landowner explained,

you know it's crazy that we have people even like in (town name), people went bananas over the proposed (...) plant because it had a smokestack in it. Well and they had all sorts of pollution control devices on that smokestack, yet we burn those piles uncontrolled in the woods, it's the same material that comes in and goes through a controlled burning process and generates something that's good, versus being just torched up in the woods and all of that material going up in the air.

Silvicultural Burning Policies

Eight firms mentioned the importance of silvicultural burning rules in determining their biomass-harvesting behavior. Several viewed state and local governments as having purposefully made slash burning permits increasingly difficult to obtain. These firms noted that they had made long-term strategic decisions as a result of the expectation that slash burn permits would continue to

become more difficult to obtain. Firms viewed both the costliness of burn permits and temporal restrictions attached to the permits as being important facets of burning policy.

Electricity Market Policies

A total of seven firms noted the importance of policies such as the Energy Independence Act (aka Initiative 937) which provide mandates for utilities to use alternative energy sources. A couple of firms mentioned that they preferred policies that target the alternative energy and alternative fuels markets, rather than direct subsidies like BCAP or the B&O tax credit:

what we really need if there are subsidies, would be the RECs- the renewable energy credits- and those things that are associated with green power, green fuels, helping those producers of the end product get those things off the ground. Those things all filter back to the biomass producer because now they can afford to spend a little more to get your biomass out of the woods.

A couple of other firms mentioned that the Energy Independence Act does not provide utilities with a universal incentive to purchase biomass-derived electricity, and felt that the limitations⁶ on when biomass energy could be credited under the Act were counter to the state's goal of incentivizing biomass-based energy production.

Stormwater

Three firms that owned properties used in facilitating forest biomass processing (similar to log yards) identified stormwater regulations as imposing significant costs and restrictions on their activities. Two of these processors mentioned having gotten permits and built out their stormwater systems years ago, and believed that they would have faced prohibitively high costs if they had entered the industry later. One surmised,

Because of all of the environmental concerns I've always wanted to be one step ahead of the curve, we went ahead and designed a state of the art stormwater system... At today's

⁶ In order for biomass-derived energy to count as contributing to meeting utilities' alternative energy mandates, it must be combusted at facilities which meet certain temporal and combustion efficiency qualifications.

values, and to do what we're doing: it couldn't be done... We're very lucky that we built this and designed the stormwater when we did."

To the extent that some biomass harvesting firms may rely on intermediate biomass handling locations between the harvest unit and the mill, restrictively expensive stormwater requirements may pose a barrier to entry for firms wishing to join the industry.

Summary of Key Findings

All respondents perceived that at least one government regulatory policy was important to the biomass-to-energy industry. The most frequently mentioned regulatory policies were point source air emission policies, especially in conjunction with new energy production facility siting procedures. Firms tended to view these regulatory policies as a barrier to biomass industry viability. Many firms also viewed alternative energy mandates, silvicultural burning policies, and stormwater regulations as affecting aspects of biomass-to-energy industry operations.

Chapter V. Discussion & Conclusions

The 21 interviews with representatives from biomass firms elicited a wide range of findings, including several topics that were not anticipated to arise at the outset of the interview process. The findings related to research question one helped to characterize the organizational structure of the forest biomass industry and to understand the activities of businesses in the industry. The findings related to research question two provided insight into how businesses in the industry make short-term harvesting decisions, as well as how they make longer-term strategic decisions to enter the industry and respond to perceived risks to their businesses. Lastly, the findings related to research question three reviewed the perceived barriers to the future viability of the industry, and indicated how aspects of existing economic and regulatory policies might impede the development of the forest biomass industry.

This chapter is organized into three sections. First is a discussion of how the findings from all three research questions relate to the academic literature reviewed at the outset. The next section discusses how changes in industry economics and in the policy environment might increase the viability of using forest biomass in energy production. Finally, the third section contains suggestions for areas of future research.

1. Study Findings in the Context of Previous Research

This section reviews how this study's findings about the forest biomass-to-energy industry compare to previous findings of academic studies of biomass firms or other types of businesses. This section reviews whether this study's results reflect the findings and theoretical predictions of previous literature on (1) the organization of industry and the existence of barriers to entry for new market entrants, (2) the factors that weigh into businesses' decision-making processes, (3) the extent to which economic supply curves constructed in perfect competition models can accurately predict on-the-ground behavior, and (4) the response of businesses to tax incentives.

1.1 Industrial Organization

This study's findings on industrial organization bear relevance to previous academic literature on both contracting structures and barriers to business entry and exit from industry.

Contracting Structures

The geographic dispersion of biomass firms aligns with Coasian theory's predictions that firms will exist if it increases production efficiency and decreases transactional costs. The state's biomass market features harvesting activities oriented around local energy-production sources, with difficult to move equipment, and a variety of logistical harvesting conditions benefitting firms with specialized local knowledge and experience. These characteristics of the state's

biomass industry would tend require high internal organizational costs for a widely-dispersed firm, which can probably be met more efficiently with separate firms operating in each region.

The contracting arrangements between landowners and harvesting processors observed in the state can also be partially explained by Coasian transaction cost economic theory, although landowners' attempts to avoid or off-load risks may also contribute to contractor dominance of biomass processing. Due to the high capital cost of biomass harvest equipment and the relatively high asset specificity of certain biomass equipment like chip trucks modified to navigate forest roads, revenue generation ability from biomass harvesting activities is highly dependent on the efficient deployment of that equipment (Bidwell 2012). Individual landowners, who may only harvest biomass sporadically and from certain locations within their ownership, experience lower transactional costs in contracting out for biomass harvesting, rather than carrying out the operations internally. Likewise, because of the greater availability of harvesting opportunities afforded by working on multiple ownerships, processing contractors within a region are able to deploy their equipment more consistently than would a landowner only harvesting biomass from land it owned. Contractors, therefore, can provide biomass harvesting services for landowners at a lower cost than if the landowners were to harvest it themselves in most cases (Conner 1991).

Finally, mirroring reports on the structure of the logging contracting industry in Idaho (Coulter 2009), this study found that most landowners in Washington worked closely with preferred biomass contractors whom they had grown to trust through experience. Likewise, biomass contractors, like logging contractors in Idaho (Coulter 2009) hold little pricing power relative to the mills, although there were indications that larger firms, such as the successful processing contractor on the North Olympic Peninsula, may hold more power over their contractual terms.

Businesses' Entrance and Exit from Industry

In general, the structure of the forest biomass industry and firms' patterns of industry entry, exit, success and failure reflect many of the literature's previous findings (Caves 1998).

First, previous studies have noted that new firms to an industry experience higher industry exit and failure rates as compared to established firms or firms with industry-specific work experience, and also might experience more difficulty in receiving financing (Caves 1998). This study of the forest biomass industry reflected similar findings, where several of the most successful biomass processing firms have relatively long histories of involvement in biomass harvesting and the forest product industry, and many recent market entrants encouraged by the introduction of BCAP have already exited the industry. In addition, prospective new market entrants perceived the difficulty of obtaining financing without a proven biomass harvest business model as a barrier to entering the industry.

Second, industrial organization literature suggests that existing firms may benefit from surmounting a "learning curve" that allows them to operate with comparatively lower costs than potential competitors (Caves 1998). Biomass contractors in Maine also benefitted from innovations (Stone et al. 2011). This study replicated those findings on the importance of experience and innovation to the organizational structure of the industry: several respondents indicated that the cost-effectiveness of biomass harvest operations had improved as they gained working experience. Likewise, Washington biomass contractors experimented with new processing technologies and harvest techniques in a bid to lower production costs and increase efficiency, and several firms attributed their success to systemic or technological innovations.

Third, previous industrial organization literature suggests that, taken as a whole, industries which are more capital intensive or feature high rates of firm entrance may also feature high rates of

firm exit (Caves 1998). This study found that the biomass-to-energy industry featured all three of these characteristics: capital intensiveness, high entrance rates, and high exit rates.

Narrowing down from generalized findings on industrial organization, this research indicates that biomass harvesting is characterized by several types of barriers to entry. First, well-established firms may benefit from barriers to entry in the form of capital requirements, especially the high cost of equipment, and incumbent firms' superior ability to obtain financing for that equipment. Second, economies of scale also appear to exist, as a few established biomass processors were reportedly able offer lower prices than potential new market entrants because their diverse equipment fleets can accommodate a variety of harvesting circumstances, and can be applied to multiple revenue streams. Third, firms may also benefit from product differentiation and cost advantages owing to experience: this study contained multiple examples of businesses developing specialized harvest systems and technologies that allowed otherwise inaccessible or infeasible harvests. Finally, respondents described certain government policies as presenting a barrier to entry, such as stormwater regulations that make new biomass-handling facilities prohibitively expensive. While none of the above observations contain groundbreaking implications for firm market entrance and exit theories, these findings do confirm the literature's recognition of the prevalence and variety of barriers to entry characterizing most types of markets.

1.2 Biomass Industry Decision-Making Processes

This study reached findings similar to those from several previous examinations of biomass industry contractors in other states. The findings of this study supported the conventional wisdom identified by Becker and colleagues (2011) that biomass harvesting largely occurs in conjunction with other log or woody material harvesting activities. Mirroring the findings of

Stone and colleagues in Maine (2011), Washington biomass contractors indicated a strong financial orientation in their decision-making thought process, especially toward the availability of local markets and the current market prices. Notably, most landowners did not express a similarly strong financial motivation in explaining their decision-making processes and biomass market entry motivations, which were more heavily oriented to long-term cost avoidances associated with achieving their complementary land management goals. Matching the findings of Dirkswager (2011), interview respondents were largely optimistic about the future of biomass-to-energy, but for many the optimism showed signs of tempering in light of the recent hog fuel market instability and weakness. Paula and colleagues' (2011) findings indicating that larger acreage landowners are more likely to harvest biomass were only partially supported by this study's findings: While firms preferred to harvest from large, high-biomass parcels of land to overcome equipment mobilization costs, there was not an obvious correlation between the self-reported size of firms' landholdings and their biomass harvesting activity. This finding could indicate that economic factors other than ownership size were more important in determining harvesting viability from a landownership, and could also indicate that the harvest units of most landowners generate sufficient biomass volumes to overcome mobilization costs.

1.3 Lessons Learned for Supply Curve Modeling

As a whole, the results suggest that supply chain models do provide accurate approximations of the activities of businesses aggregated across an industry. Most firms explained their actions in terms of costs and prices, indicated that they consistently contemplate transactional profitability in their decision-making, and generally try to make the profit-maximizing decisions that perfect competition economic models predict them to.

However, certain aspects of firms' decision-making processes are not fully reflected in basic calculations of supply, demand, price and quantity. These observations tend to confirm the behavioral economic literature's analysis of the limitations of basic supply and demand estimations of real-world economic behaviors. First, respondents indicated numerous instances in which their firms did not operate within a "perfect information" scenario upon which perfect competition economic models are predicated. For instance, not all respondents were aware of or responding to the B&O tax credits that perfect competition economic theory would predict to increase business production levels and shift industry supply curves. Second, respondents indicated that even if they were aware of the B&O tax incentive, they might respond to tax credits in a manner that wouldn't necessarily be reflected in a simplified economic modeling of the tax credit's value, and that they might not value a \$3 tax savings equivalently to a \$3 profit from a market transaction. Third, respondents indicated a similar, mostly-qualitative thought process in their evaluation of the benefits of avoided costs attributable to biomass harvesting's reduction of burn risk, burn costs, and area lost to re-planting on tree farms. Fourth, some respondents indicated that profit maximization (as viewed narrowly from a lens focused solely on the biomass harvesting transaction itself) is not necessarily the primary motivation driving firm decision-making; this observation was especially true of landowners. Fifth, firms' tendency to perceive risk and uncertainty in the biomass market reduced some firms' willingness to invest in biomass-specific equipment, and therefore might contribute to lower-than-predicted levels of forest biomass production. Finally, simple supply curve estimations might not account for the barriers to entry and exit associated with capital investments by firms. These barriers to entry and exist may at least delay industry-wide return to a long-run equilibrium in supply and demand following exogenous shocks such as the recent steep decline in the price of hog fuel.

1.4 Response to Government Policies

Respondents' belief that biomass policy interventions by the government had not strengthened their industry mirrored the findings from surveys of the broader business community. As in the broader business community, biomass businesses reacted negatively to uncertainty and instability associated with government policy-making. During interviews, negative opinions about government intervention in the biomass market were especially elicited in the context of discussions of specific policies characterized by that uncertainty and instability, such as BCAP.

Tax policy uncertainty may inadvertently reduce the tax credit's power to incentivize business behavior. Interview respondents' processes of considering the B&O tax incentive in making harvest decisions indicated that firms largely do not value tax credits equivalently to cash.

Respondents indicated that tax credit eligibility uncertainty undercuts their willingness to make harvesting decisions based on the credit. Likewise, uncertainty surrounding the longevity of the tax policy undercut respondents' willingness to make long-term investment decisions predicated on the existence of those tax policies. In light of these factors, the power of the B&O tax credit to incentivize behavior may be less than the magnitude that would be anticipated by a cash-in-hand payment of equal size.

2. Application of Findings to Washington's Forest Biomass Industry

One goal of this study was to uncover opportunities for Washington policymakers to better achieve the State's announced goal of improving the viability of the biomass-to-energy industry.

In order to diagnose why the biomass-to-energy industry has underperformed the hopes and expectations of its supporters, this section explores (1) possible changes in the organization of the industry or economic circumstances that might improve the viability of biomass-to-energy, and (2) policy amendments that might improve the viability of the industry.

Two of the most notable industry trends that surfaced during interviews are the different market conditions observed in the different geographic regions of the state and the divergent perspectives on the industry held by different sectors of the supply chain. As chart 5 notes, the regional biomass market strength was related to firms' activities (equipment ownership) and perceptions (outlook on industry future). Likewise, chart 6 shows how landowners and biomass processing contractors differed in their activities and strategic decision-making processes. These two tables illustrate trends that suggest means by which the biomass industry might improve organically or with the help of policy reforms, as is discussed in the following subsections.

Chart 5: Geographic Trends in Biomass-to-Energy

Geographic Region	Current Economic Strength of Biomass Market	Biomass Equipment Ownership	Outlook on Biomass Industry Future
North Olympic Peninsula	Medium-high	High	Positive
Southwest Washington	Low	Low and Declining	Negative in short-term, positive in long-term
Northern Cascades	Very Low	Low	Negative in short-term, positive in long-term
Eastern Washington	Low	Low	Negative in short-term, positive in long-term

Chart 6: Trends in Biomass-to-Energy by Supply Chain Role

Supply Chain Role	Biomass Equipment Ownership	Entrance Motivation	Propensity to take Risks
Landowner	Low	Long-Term Profit, Cost Avoidances	Low
Processing Contractor (Grinders, Harvesters, Transporters)	High	Short-Term Profit, Landowner Expectations	High

2.1 Important Economic Factors to Industry Viability

In general, in order for the forest biomass-to-energy industry to become more viable, the price of hog fuel will need to increase, either as a result of fundamental changes in market dynamics, or as a result of policy interventions. However, apart from whether the market price of hog fuel eventually increases, this study's findings suggest that the industry may retain the potential for additional growth if certain existing barriers in the industry's organizational structure and the decision-making processes of firms could be addressed. To explore these organizational and strategic circumstances that might hold the opportunity for marginal improvement in the industry, this subsection reviews (1) the lessons that can be learned about forest biomass industry economics from the region of the state in which it is comparatively thriving, (2) what the implications of the recent hog fuel market downturn might portend for the future viability of the industry should the price of hog fuel recover, (3) why the recent instability in the economic and policy environment might reduce the efficiency of forest biomass harvest planning, and (4) why the low esteem in which many forest biomass contractors are held by industry colleagues could impede the future development of the industry.

Lessons from Biomass Market Bright Spots

The biomass-to-energy market is stronger in the North Olympic Peninsula than it is in the rest of the state. Several partial explanations suggested by interview respondents may help account for this observation. First, the area is relatively geographically isolated from other parts of the state. Due to the high costs of transporting biomass, geographic isolation has insulated the market from the hog fuel market weakness in the rest of the state. Second, the area has a relatively geographically contiguous and pervasive group of actively-harvesting tree farms. The abundance

and geographic density of potential slash piles close to energy-producing mills enables comparatively cost-effective harvesting. As one Cascades-based contractor noted,

we've got to go 20 or 30 40 miles to hit the woods; up (in the North Olympic Peninsula), they live in the woods.

Finally, and potentially most importantly, the area is not serviced by natural gas pipelines (Appendix G). Mills must instead use oil as an alternative fuel source to power their boilers. One firm on the peninsula explained

if these mills had to run oil, and no hog fuel, they wouldn't exist... They will tell you...oh boy we had to use 17 barrels of oil last month, like it was a big deal. Well, compared to hog fuel, it was a big deal... But then there's always something that's cheaper- if they could get to natural gas, that'd burn that, because that's even cheaper yet, and it's clean too, a lot easier to handle.

These favorable factors have conspired to allow the persistence of two large local consumers of biomass. Interview respondents reported that these two mills are currently dependent on their access to biomass to profitably conduct their industrial processes, which creates a locally stable demand for biomass. The mills, probably as a result of their geographic isolation from other hog fuel sources and natural gas, were also reportedly willing to enter into long-term supply contracts to purchase forest-derived hog fuel, which has provided some market stability. The local forest biomass market also is in the midst of receiving a boost from a local mill's decision to increase their biomass consumption capacity by installing a new boiler. Finally, the North Olympic Peninsula market features the contracting processor most recognized by its peers for biomass harvesting innovation and efficiency.

The success of this particular contractor is also worth separately exploring. While the peer-recognized contractor is obviously helped by the strength of the local market in which the business operates, their success cannot be entirely explained by geography. One partial explanation could be that the firm is simply abnormally competent and innovative at driving their

production costs down; an argument against this theory is that respondents also identified other contractors as active innovators of harvest equipment or techniques, which has not equated to the same degree of business successes. A second partial explanation was the contractor's long-term supply contracts with the local mills (on a scale of years, rather than days), which may provide the successful contractor with enough market certainty to justify their investments and innovation. A third partial explanation could be that the contractor's long-term local experience in forestry and biomass harvesting not only provides them with the acquired knowledge needed to do their job well, but also buffers their business by forming a barrier to entry. The firm's heavy investments in a fleet of advanced harvesting equipment may also serve as a barrier to industry entry by potential competitors.

In sum, the relative success of the North Olympic Peninsula's market appears to reside with a number of factors, none of which offer obvious prospects for organic improvement. The availability of natural gas, geographic isolation, and proximity of biomass harvesting sites to mills are circumstantial drivers of market success, and can't be artificially recreated in other regions of the state.

The Implications of Recent Market History

The drastic drop in the price of hog fuel over the past three years, combined with important changes in policies like BCAP, have left biomass firms in varied positions of strength going forward. If new technology or changing market conditions were to make forest biomass more economically viable again, many landowners will likely be well-positioned to take advantage when the market returns. A few processing contractors that have survived the downturn by relying on diversified revenue streams may also be well positioned to exploit business opportunities if the market rebounds. On the other hand, many of the smaller, less-experienced

biomass contractors whose operations had been more heavily concentrated around forest biomass tend to be more embittered about the future of the industry, and are in the process of exiting the industry, often with large losses on their equipment investments. The state's goal of improving the long-term viability of the forest biomass industry may be impeded if these contractors with in-woods experience do exit the biomass-to-energy sector: Even if the forest biomass market improves and new firms enter, there will be a loss of institutional knowledge that may be difficult to replace, and it could conceivably delay a return to peak systemic harvesting efficiency across the industry. In the case of some individual firms, the harvesting method and equipment innovations that firms had developed may be lost entirely with the exit of the firms.

On a brighter note, the findings on market entry and exit reviewed by Caves (1998) indicate that the loss of institutional knowledge from firms' industry exit tends to be offset by other gains to the industry from the innovation and replenishment of capital investment offered by new market entrants during industry turnover. With this in mind, the loss of institutional knowledge may not be an insurmountable impediment to the biomass-to-energy market if it were to be reinvigorated.

The Implications of Market Instability

The instability and uncertainty that has characterized the price of hog fuel in recent years may have various implications for the efficiency of future harvesting operations. In regions of the state (excluding the North Olympic Peninsula) which have featured recent hog fuel market instability, contractors and landowners were less willing to make investments or spare the forethought to design roads or piling locations to accommodate biomass harvesting. Those potential road and pile planning synergies are irreversibly lost if they are not incorporated into pre-harvest planning. Without the integration of biomass into harvest layouts, biomass harvest is ultimately more expensive and less likely to occur. By contrast, on the North Peninsula, the

advance knowledge that biomass harvest has a good chance of taking place allowed landowners and logging contractors to perform more of the upfront harvest-facilitating preparatory work.

Uncertainty in the hog fuel market also undermined the industry's viability in other ways.

Respondents viewed market uncertainty as adding risk to equipment investments, and could limit the industry's harvest capacity. Hog fuel market uncertainty was also an important explanation for why contractual relationships were uniformly short term in the industry, which may also contribute to underinvestment in harvesting infrastructure.

Implications of Forest Product Industry Perceptions of Biomass Contractors

The generally unfavorable perceptions of biomass contractors by landowners and others in the forest products industry could present an obstacle to the state's goal of improving the viability of the forest biomass-to-energy industry. Distrust of contractors by landowners could conceivably hold back the future development of the biomass-to-energy industry, in the event that landowners become reticent to commit to supplying biomass or committing to energy production ventures for fear of being forced to rely on overmatched contractors. Second, the low social status of biomass harvesters relative to others in the forest products industry could discourage logging outfits or others who might be top-notch biomass contractors from entering the industry, which could cap the biomass industry's capacity to innovate. However, the two aforementioned social obstacles to scaling up biomass harvesting are probably not insurmountable. Respondents' descriptions of their initial market entrance decision-making processes indicate that financial considerations are likely to outweigh social stigma in dictating the entrance and exit of firms. Therefore, if the biomass industry shows promise for improvement on its small, uncertain profit margins, new and innovative contractors may once again be drawn to return to the industry, and landowner distrust of their contractors may wane as more reputable firms reenter the industry.

2.2 Important Policy Factors to Industry Viability

This study raises a variety of potential avenues for amending existing policies so as to better achieve the State's proclaimed goal of improving the viability of the forest biomass-to-energy sector. The evaluation of state energy and carbon policy are well beyond the scope of this study, but one policy suggestion raised by others, including Yoder and colleagues (2008), would be to adopt a state carbon policy which would make forest biomass more price-competitive with carbon-intensive fuel sources. Changes to other aspects of state energy policy, such as an amendment to the State's Energy Independence Act, could also be applied in order to bolster biomass-to-energy. Absent such a fundamental change that would restructure the market dynamics for boiler fuels and have myriad implications on other industries, this study offers a variety of clues for how to improve the ability of existing policies to support the viability of biomass-to-energy.

Overall Government Goals

Even where government policies are successful at incentivizing biomass harvest, they may not be achieving some of the state's stated environmental objectives. Some of the biomass harvest in current market conditions is not in self-perpetuating forestry operations, but results from developers clearing land for housing developments (though this research did not quantify the relative supply from each biomass source). This land conversion-driven biomass harvesting does not necessarily fit the sustainable model of bioenergy production that that biomass-harvesting supporters might have in mind. Arguably, utilizing the biomass resource made available by land development, where it displaces petroleum-based fuel sources, is better for the environment than letting the slash go unused. As a consequence, should the hog fuel market remain weak over the coming years, and harvesting activity remain dominated by clearings from land development,

state policymakers may wish to reevaluate incentives like the B&O credit if the incentives do not solely benefit firms engaged in self-perpetuating forestry operations, but also indirectly subsidize the conversion of forestland for development.

Slash Burning Policy

The application of tighter slash burning and smoke management regulations could be a tool to incentivize biomass harvesting. In general, if landowners are restricted from burning their slash, they may grind it rather than incur the long-term costs associated with leaving areas covered by piles of woody debris that render it difficult to replant. If the state were to increase burn permit costs, and generally continue its reported trend of tightening burn permit restrictions, firms might be more likely to harvest biomass, and may also grow accustomed to pre-planning biomass harvests as it becomes a status-quo means of slash disposal.

This is not to suggest that the costs of employing burn regulations as a means of encouraging biomass would not have other problems associated with it, or that the social benefits from the increased biomass harvesting and reduced smoke emissions are worth those costs. First, in many areas far from biomass-consuming energy producers, biomass harvesting would remain prohibitively expensive even if burn restrictions were heightened, and the biomass would be left to decompose in the forest. In addition, mills have a limited biomass combustion capacity in their boilers. In the short-term, to the extent that increasing burn restrictions increases hog fuel supply without a concordant increase in mill demand, it could counterproductively further weaken the hog fuel market. However, stringent enforcement of slash burn regulations does present a potential tool available to policymakers worth mentioning, whether applying that tool is a wise choice for policymakers or not.

Biomass Energy Facility Siting

Interview respondents widely saw the introduction of new biomass-utilizing energy production facilities in the state as a key to improving the hog fuel market. However, respondents also thought that efforts to site potential new facilities were likely to encounter insurmountable obstacles during various regulatory review processes, particularly for point-source air emission permits. One avenue to facilitate siting of biomass-to-energy facilities would be to allow environmental impact statements for new facilities to consider the impacts of avoided slash burning on ambient air quality, and not just the additional point-source emissions that would be generated by the siting of the new facility. This practice was followed in the environmental impact statement submitted for one new biomass boiler that recently successfully navigated the facility siting and air emissions permitting processes, and could be adopted as standard practice for future permitting endeavors (CH2M Hill 2010). Policymakers could also consider other favorable streamlining of the site development application process for bioenergy producers.

Lessons from BCAP

The USDA suspended the BCAP matching payments program due to lack of funding several years ago, and interview respondents foresaw little likelihood of its resurrection. Nevertheless, the experiences related by respondents do offer a few lessons to policymakers interested in supporting biomass-to-energy. First, for all programs that target biomass-to-energy, careful attention should be paid in drafting the statute and administrative regulations in order to ensure only intended recipients are eligible for the program. Second, if policymakers decide to offer similar economic incentive programs for biomass, they should realistically assess anticipated program costs prior to finalization of the program's structure, so as to ensure that there is a sustainable funding source for the program, and that it will be a stable presence in the market that

firms will be able to rely on. Third, policymakers should remain cognizant that the introduction and elimination of programs can impact an industry long beyond the program's cessation, and should therefore be cautious in experimenting with untested policy ideas. Finally, policymakers should be aware that many firms in Washington's biomass-harvesting industry bear a recent history of having been harmed by BCAP, and may keep that past experience in mind as they strategically respond to future biomass policies.

B&O Credit Size

One potential remedy to the fact that harvesting costs are currently much higher than the price offered for hog fuel at most mills would be to substantially increase the value of the tax credit, so as to bridge the gap for processors between costs and revenue. Most firms that consider the B&O tax credit in their decision-making indicated that the tax credit would need to increase much more than the \$2 it jumped in 2013 in order to motivate widespread harvesting.

The hypothetical prospect of a dramatically larger tax credit raises an interesting point about how its effects would likely be dispersed. Because the woody biomass market is locally-driven, with substantially different market prices being offered in different segments of the state, any tax credit increase sufficient to motivate harvesting decisions in most of the state would likely lead to a profit windfall for operators in the North Olympic Peninsula where harvest is already financially viable under current market conditions. This local windfall would not necessarily trigger a concordant increase in harvesting volumes in those areas, since demand is locally capped by mills' hog fuel consumption capacity, and transport to other portions of the state is prohibitively expensive. The prospect of such a windfall accruing to one region of the state--in conjunction with the fact that the tax credit would need to increase substantially to incentivize harvesting for most firms and would be costly to the state in foregone revenue-- indicates that

increasing the size of the tax credit would be a rather unsharpened, non-cost-effective tool to increase biomass harvest. This conclusion is also supported by the fact that many respondents reported that they perceived the tax credit to be an appropriate size, even if they also acknowledged that it was not large enough to overcome the currently-weak hog fuel market.

On the other hand, eliminating the tax credit entirely or letting it expire might also have undesirable repercussions. This course of action might further weaken the biomass harvesting industry, which has already suffered greatly in the past two years. In addition, to the extent that firms might view a lapsing of the tax credit as a withdrawal of state policy support for their industry, removing the tax credit could prove to be the final straw for firms who have been attempting to weather the weak hog fuel market, and cause them to exit the industry entirely. Therefore, even though this study has identified several aspects of the implementation of the tax credit that are functioning sub-optimally and mitigating its value as a behavioral incentive, the most prudent course of action might be to leave the size of the credit unchanged.

Tax Policy Stability

Once state policymakers have decided whether to retain the B&O tax credit, one critical improvement to the credit's incentivizing power would be to extend it at a stable price far into the future. Such an extension would provide some certainty to those in the industry, who largely tend to view the credit as temporary. As one respondent explained,

I would say from the accountant's point of view, and the ability to forecast things in the future, I would very much like to see the credit become permanent. You know, I hate things that expire.

Without some enhanced stability for the credit, respondents indicated that they are unwilling to plan strategic decisions around the credit; in introducing the uncertainty of an expiring subsidy, the state mitigates the potential of that subsidy to incentivize behavior. Note too that a long-term

extension of the tax credit might be politically feasible in today's policy environment: During the 2013 Washington legislative session, a hog fuel sales tax exemption was extended for a ten-year period, and passed both houses nearly unanimously (WA Legislature, 2013a).

B&O Tax Credit Clarity & Eligibility

A second means of bolstering the incentivizing power of the B&O tax credit would be to clarify firm eligibility for the credit, and to ensure that the law contains the flexibility to allocate the credit to anyone in the supply chain by contractual arrangement. The confusion over firm eligibility for the tax credit appears to derive from the authorizing statute. The authorizing statute cross-references another statute which is housed within the code governing timber and forestland operations, and creates a timber-centric definition of biomass harvester. Since in-woods biomass harvesting was almost certainly not contemplated as a forestry activity at the time that this older, timber-centric "harvester" definition was written into law, respondents in the industry were confused whether the statute allowed a biomass processing contractor acting as the biomass collector, piler, or grinder to receive the credit, if not also acting as the timber harvesting contractor. Certainly, several respondents indicated that contractors believe that they are eligible for the credit (or can be eligible for the credit depending on the language assigning slash ownership in the contract), and many biomass contracting firms have successfully filed for the tax credit with the Department of Revenue. However, even if the statute does as a matter of law contain the flexibility necessary for the biomass contractor to receive the credit, because the tax credit eligibility remains an open question in the mind of many respondents interviewed, it is a deterrent to efficient biomass harvesting planning behavior and to the full utilization of the credit. Landowner confusion regarding the credit is likely detrimental to their biomass harvesting

levels, since firms will not want to base harvest management changes upon assumptions of tax benefits that may or may not accrue to them.

Policy-makers that intend to incentivize biomass harvesting should ensure that the B&O tax credit can be flexibly allocated to multiple types of firms involved in biomass harvesting, for two reasons. First, since many firms only have limited B&O tax liabilities capable of being offset by a tax credit, ensuring that the credit's value can be flexibly allocated among all firms involved in a harvesting operation could significantly increase the total potential incentive value of the credit.⁷ This flexibility should be especially important in leveraging the tax credit's incentivizing power to apply to biomass harvesting on non-incorporated types of land ownerships: If the tax credit cannot be flexibly allocated to the biomass contractor in harvests from those ownerships, the tax credit fails to incentivize behavior, since none of the entities involved in the biomass harvest would be both eligible for the tax credit and possess B&O tax liabilities to be offset. Second, contractors were more likely than landowners to view short-term transactional profits from harvesting operations as important to the harvesting decision-making process; therefore it would seem to be sensible to ensure that financial incentives are directed to the firms most likely to be motivated by short-term financial considerations.

Two policy recommendations could address the existing confusion over tax credit eligibility.

One recommendation would be to amend the existing statute: A presumably non-controversial amendment to the definition of "harvester" might significantly improve the credit's effectiveness

⁷ For example, take a hypothetical landowner harvesting 50,000 tons of biomass a year, and that only possesses \$5,000 in B&O tax liabilities. With a \$5 per ton tax credit, the tax credit incentive should only be relevant to the first 25,000 tons of biomass harvested; however, if the landowner can also assign "ownership" of the slash and the tax credit for 25,000 tons of slash to his grinding contractor (who also has \$5,000 in B&O tax liabilities), then the full value of the credit would be able to be used.

as an incentive. A second, possibly easier recommendation would be for the Department of Revenue to issue more explicit guidance regarding who is eligible for the tax credit under current law; the Department could also more proactively conduct educational outreach to past and prospective tax credit applicants. The recommendation for increased educational outreach efforts is also supported by the observation that at least one tax credit recipient admitted not being aware of the existence of the credit until after the second year that the credit had been in effect. Several other potentially-eligible biomass harvesters, who had participated in BCAP but who had not claimed the B&O credit, also appeared unfamiliar with the credit. After hearing about it the credit during this research's interviews, several respondents indicated that they planned to look into their eligibility for the credit.

Reducing Public Opposition to Biomass-to-Energy

Finally, interview respondents identified the general uneasiness about biomass harvesting amongst certain members of the public as an impediment to the future progress of biomass-to-energy. One landowner recounted the importance of outreach in advance of the successful siting of a new local biomass facility:

a lot of time and energy was spent... having to do with groups around here in just really, really focusing on educating and bringing them out and showing, kicking the tires, so people at least could make informed decisions.

To the extent that firms in the industry are able and willing to continue to conduct such outreach to the public, it may pay dividends in the form of future public support, which in turn can facilitate the siting of new biomass-reliant energy production facilities.

3. Areas of Future Research

Several potential areas remain for future research into the activities, thought-processes, and policy responses of participants in the biomass-to-energy industry.

First, this study did not probe the activities and perspectives of biomass-consuming energy production facilities. A complementary study of those facilities would lend a more comprehensive picture of the industry. In particular, since landowners and contractors viewed the siting of new biomass-consuming facilities as a key to the future of the industry, additional research could explore the technological, economic, and policy barriers perceived by businesses contemplating the development of new facilities in Washington.

Second, although this study probed the role of the B&O tax credit in firm decision-making, the tax credit's success at incentivizing harvest behavior could be more quantitatively analyzed if access to firms' specific harvest volumes and tax claims were released from confidentiality. In addition, future research could examine the volume of harvested forest biomass that qualified for the B&O tax credit that derives from self-perpetuating forestry operations as compared to land clearing for real estate development. This information would be useful to policymakers interested in evaluating whether the B&O tax credit is achieving the state's environmental goal of incentivizing sustainable, renewable energy production. One additional aspect of the state's biomass incentive policy scheme that is ripe for research would be to explore the harvest decision-making processes of small private landowners. Research into the harvest decision-making of small private landowners could help determine whether a similar incentive scheme, such as a per-ton tax credit applied against property taxes, might stimulate forest biomass harvest from landownerships that are not eligible for the B&O tax credit.

Third, because this research identified market and policy uncertainty as an important factor weighing on firms' decision-making, future research could explore how policy-makers might best reduce businesses' perceptions of uncertainty.

Finally, because the findings in this research reflect a period of time in the industry characterized by low hog fuel prices and recent market turbulence, future study of industry behavior under different market conditions may be warranted, especially as new technologies come online.

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Appendices

Appendix A. Interview Script

Appendix B. Consent Form

Appendix C. Codes Used in Data Analysis

Appendix D. Context Helpful to Understanding the Biomass Industry

Appendix E. Factors Seen as Contributing to a Weak Hog Fuel Market

Appendix F. Map of Biomass Consuming Facilities in Washington (2011)

Appendix G. Map of Natural Gas Pipelines in Washington (2012)

Appendix H. Seasonal Influences on Biomass Harvesting Logistics

Appendix A. Interview Script

Company Name:	Date:
Respondent Name & Title:	

Introduction: So just to formally introduce myself again, my name is Jacob Lipson, and I am a graduate student at the University of Washington's School of Forestry. I am here to interview you today for my research on the perspectives and activities of people involved in harvesting, processing and transporting biomass for use in energy production. I am hoping to get a better sense of your thoughts on the current status, and future potential of, the biomass-to-energy sector. I really appreciate your taking the time today to speak with me.

Instructions: In this interview, please answer these questions to the best of your ability, and ask me for clarification if the question is unclear, or if you forget the original question after you begin answering. Many of the questions I ask will be open-ended, and after your initial response I may ask you follow up questions on specific aspects of the broader questions.

Information that you share with me will be kept confidential, and any quotes that I use will not be attributed to you specifically. If I ask you any questions that you don't feel comfortable answering or which you don't feel comfortable estimating an answer to, you are free to decline to answer, and to ask me to skip to the next question.

I am hoping to tape-record this interview in order to take accurate notes on your responses. After this interview, I will transcribe the interview, and then delete the audio recording. Do you give me permission to tape record our conversation?

Definitions: I'll supply you with some definitions for words I use in the interview to make sure that we are on the same page in terms of what we are talking about. Please let me know if you would define any of these terms in a substantially different way.

A. When I say biomass in this interview I am specifically referring to forest residual biomass such as tree limbs, tops, needles, leaves, and other woody debris that are residues from such activities as timber harvesting, forest thinning, fire suppression, or forest health, not including chipwood or other scalable timber products.

B. Harvest refers to the processing (e.g. chipping or grinding) and transport of forest biomass to an energy production facility.

C. Energy production includes electricity, steam, heat, or biofuels.

To give you a brief outline of this interview, I'm first going to ask you some questions about your company's biomass harvesting activities, followed by some questions about your company's investments in biomass harvesting equipment, and then concluding with some questions about your company's perceptions of the importance of policies and the market environment. Do you have any questions for me at the outset? (Ok, let's begin.)

Activities Questions *First, I'm going to ask you a few questions about your company's biomass harvesting activities or operations.*

1. So, to start, tell me about your company's current biomass operations.

Follow up probes:

- A. What type of biomass operations does your company engage in- for example, do you grow biomass, harvest it, collect it, process it, and/or transport it?
- B. How integrated is your firm? Do you contract out operations, or own your own harvesting equipment?
- C. (For contractors) Whose land do you usually harvest and haul biomass from?
- D. For approximately how many years has your firm been harvesting and/or transporting biomass for energy production?
- E. Does biomass harvesting ever play a role in timber harvesting decisions?
- F. Are you entered into long-term sales contracts with energy producers who purchase your company's biomass, or do sell biomass on a per-load or short-term basis to energy producers?
- G. Where do you usually haul to?
- H. What parts of the state do you operate in?
- I. Besides, biomass for energy, what else does your business do, if anything? How important, relatively, is biomass-for-energy harvesting in what you do?

2. Do you know approximately how much biomass your company harvests annually, in green tons?

Follow up probes: How has this amount changed over the years?

3. How did you decide to get into the biomass harvesting business?

4. What factors do you consider in your decision whether to harvest biomass from a particular area?

Can you walk me through your decision-making process, or the decisionmaking process for how you and/or the landowners decide whether biomass can be harvested from a stand?

Follow up probes:

- A. How do you make decisions about whether to harvest biomass from an individual stand? Do you even make biomass harvesting decisions on an individual stand basis?
- B. How important is your company's ability to profit - Do you make per-stand profit calculations?
- C. Is any competitive advantage gained by your company relative to other forest products companies important?
- D. Is any public goodwill generated as a result of harvesting biomass from that stand important?
- E. Do you consider impacts on soil health or the long-term productivity of the stand?
- F. Is just disposing of the biomass (to avoid burning or piling that takes up lands that could be re-planted) a major harvest motivation?

Investments Questions *Now I'm going to ask you a few questions about the investments in biomass infrastructure that your company has made.*

What type of equipment do you use? What parts of business are contracted out?

1. Approximately how many _____ does your company currently own or lease?
 - A. "Excavators" or similar vehicles which collect and compile logging slash
 - B. Vehicles to transport chips, hog fuel, or other forest biomass used for energy production
 - C. Machines like "chippers" or "grinders" that can turn tree tops, branches, and other biomass into a form that can be easily transported for use in energy production

Follow up: Do you have useful/recent versions of equipment needed to optimally harvest biomass?

2. Does your company have plans to invest in new or additional equipment which would increase your company's biomass harvesting and hauling capacity? (*Follow up:* If so, can you explain the thought process behind the investments// If not, can you explain why not?)

3. How willing is your company to take risks with its biomass business? (An example of risk taking would be to make an investment that has large potential payoffs, but also large potential downsides).

Policy & Market Environment Questions *In this third section of the interview, I'm going to ask you a few questions about the importance of government policies and the market environment on your decisions.*

1. Is your company aware of the Washington State tax incentive which provides a business and occupation-or B&O- tax credit of \$3 per green ton of harvested forest-derived biomass?

(If no, skip to question 3)

Follow up Probes:

- A. Do you think that the \$3 B&O tax credit contributed to your company's biomass harvesting decision-making processes, and if so, how?
 - B. To use a hypothetical scenario, how much of an increase in the B&O tax credit do you think it would take to increase your company's biomass harvest by a substantial amount-say at least a 5% increase over current harvest levels?
 - C. In your business decision-making, do you treat the \$3 B&O tax credit the same way as you would a \$3 increase in biomass market price? (*Follow up:* How is the tax credit different to you than an equivalent increase in cash price? Can you utilize B&O credits?)
 - D. What is your tax status- are you incorporated, a TIMO, a REIT, etc? Do you pay B&O taxes?
2. How permanent do you think of the tax credits as being?
 3. Besides the B&O tax credit, are there other tax incentives or economic and financial policies that you think are important to your biomass harvesting decisions?

Follow up:

- A. *How does the prospect of carbon policies (tax or cap and trade) influence your outlook?*
 - B. Has your firm been involved in helping or influencing any biomass policies?
4. What do you think of the future of the biomass hog fuel industry?

A. Are there major impediments in the way the market or supply chain for biomass is set up that prohibit you from harvesting as much biomass as you might otherwise?

5. How, if at all, does the potential emergence of a wood-based ethanol or other wood-based fuels industry affect your company's biomass harvest activities, investments, or plans?

Concluding Questions: *So, to wrap up,*

1. Is there anything else you would like to tell me about biomass harvesting?

2. Is there anyone else you would recommend that I talk to?

Appendix B. Consent Form

Key Informant Interview Consent Form

(Sign 2 copies; keep one for your records)

Business Perceptions and Activities Associated with Forest-Residual Biomass Harvesting in Washington State

You are invited to be in a research study that will explore business perspectives on biomass harvesting in Washington State. You have been selected as a potential participant because of the insight that you may be able to provide on this particular subject. We ask that you read this form and ask any questions you may have before agreeing to be in the study. When we have answered all your questions, you can decide if you want to be in the study or not. This process is called “informed consent.” We will give you a copy of this form for your records.

This study is being conducted by: **Clare Ryan, Professor, and Jacob Lipson, graduate student**, both of the **School of Environmental and Forest Sciences at the University of Washington**.

Background Information

The purpose of this study is to enhance understandings about the businesses participating in the collection, processing and transportation of forest residual biomass for use in energy (electricity, steam, heat, fuel) production. The study will cover three main areas: (1) the extent and nature of businesses’ biomass harvesting activities (2) businesses’ investments in equipment and infrastructure to support biomass harvesting (3) businesses’ perceptions of government biomass policies and biomass market conditions, and how businesses make decisions in light of the policy and market environment within which they operate.

Procedures:

By agreeing to participate in this study, we will ask you to do the following things:

- In a one-on-one interview, you will be asked questions regarding the activities, perceptions, and decision-making processes of your business, with respect to biomass harvesting for energy production. In the interview, you will be free to refuse to answer any question if you so choose.

The entire session is anticipated to take roughly one hour.

Risks and Benefits of being in the Study

Your participation will help enhance the understanding of businesses in the biomass to energy industry sector.

Confidentiality:

The records of this study will be kept private. Information that would make it possible to identify you will not be included in any report or publication that may result from this study and the

audio-records will be destroyed as soon as they are transcribed. Information will be stored securely and only researchers will have access to the records.

Voluntary Nature of the Study:

Participation in this study is voluntary. Your decision whether or not to participate will not affect your current or future relations with the University of Washington. If you decide to participate, you are free to not answer any question or withdraw at any time without affecting those relationships.

Contacts and Questions:

The researchers conducting this study are: Jacob Lipson and Professor Clare Ryan. You may ask any questions you have now. If you have questions later, you are encouraged to contact them in Seattle at (206) 660-9720; jacobl@u.washington.edu ; cmryan@u.washington.edu

Printed name of study staff obtaining consent

Signature

Date

Subject's statement

This study has been explained to me. I volunteer to take part in this research. I have had a chance to ask questions. If I have questions later about the research, I can ask one of the researchers listed above. If I have questions about my rights as a research subject, I can call the Human Subjects Division, of the University of Washington, at (206) 543-0098. I will receive a copy of this consent form.

Printed name of subject

Signature of subject

Date

Appendix C. Codes Used in Data Analysis

Category of Code	Code	Sub-Codes
Activities	Business	Grinders, Brokers, HarvesterLogs, Landowner, Mill, Piling, Transport
Activities	Company Size	Biomass1, Biomass2, Biomass3, Overall1, Overall2, Overall3
Activities	Contract	Long Energy, Long Harvest, Short Energy, Short Harvest
Activities	Harvest Decision	Burn Cost, Burn Permit, Burn Risk, No Volition, Replanting, Roads, Supply & Demand, Season, Soil Health, Transportation
Activities	Energy	Canada, Greys Harbor Paper, Importance, Kimberly Clark, Mill Residuals, Natural Gas, Oil, Other Mills
Activities	Geography	East, North Cascades, North Peninsula, South Cascades, South Peninsula
Activities	Land	Harvest Changes, No Harvest Changes, Piles, Roads, Timing
Activities	Market	Competition, Destroyed, Fluctuations, Product Quality, Stable, Unload, Monopoly
Activities	Market Entry Mode	Construction, Forest Experience, Newbie, Waste
Activities	Market Entry Motivation	Accidental, Burning, Diversification, Non-Economic, Quick Profit, Strategic
Activities	Market Entry Year	BCAP, Mid-2000s, Prior to 2004
Activities	Material- End Use	Composting, Energy Use, Erosion Control, Landscape/ Construction, Livestock
Activities	Material- Supply Source	Agriculture, Development, Mill Residuals, Smallholders, Tree Farms, Urban, Waste
Activities	Ownership	Development, Federal, Individual Private, Industrial Private, State, Tribal
Activities	Relationship to other Firms	None, Bi-Lateral, Multi-Lateral
Activities	Revenue	Chip Hauling, Construction or Development, Hog Fuel Hauling, Logging, Waste Management
Activities	Timing	Forethought, Post-Log, Post-Pile
Investments	Equipment	Bulldozer, Chip Vans, Excavator, Grinder, Log Trucks, Outsourced, Semis
Investments	Expenses	Forgone Purchase, Purchase Pays off, Purchase Used
Investments	Innovation	Biomass Technology, Demoed, Harvesting System, Market Consistency, New, Repair
Investments	Plans	Contracts, Downscale, Exit Industry, Financing, Hold the

		Course, Passive, Reliability, Scale Up, Uncertainty, Just Right
Investments	Risk	Risk Avoider, Risk Lover, Risk Neutral
Investments	Versatility	Multi Use, No Resale, Resale
Policy & Market Environment	B&O	Better Than Cash, Confusion, Decisions, Eligible, Familiar, Flexibility, Limited Tax Liability, No Internal Communication, Rendered Moot, Size Appropriate, Temporary, Worse Than Cash
Policy & Market Environment	BCAP	Distortion, Ephemeral, Harvest Increase, Inflated Expectations, Lasting Damage, Required Participation, Skeptical, Unintended Beneficiaries, Windfall
Policy & Market Environment	Future	Bleak, Carbon, Critical Public Opinion, New Local, Policies, Rosy Long-Term, Rosy Short-Term, Supportive Public Opinion, Technology
Policy & Market Environment	Government	Distortion, Facility Red Tape, Favoritism, Fickle, Inflation, Secondary, Supportive
Policy & Market Environment	Participants	Distrust, (Firm Name), Innovation, Networking, Unsophisticated
Policy & Market Environment	Perceptions of Uncertainty	Economic & Tax Policy, Energy Producer Viability, Government Lands, Market Price, New Biomass Technology, Regulatory Policy, Substitute Goods
Policy & Market Environment	Policy	Air, B&O Credit, BCAP, Carbon, Development & Urban Growth, Energy Facility Siting, General, Government Grants, Hazmat and Waste, I-937, Silviculture Burn Rules, Harvest Rules, Stormwater, Vehicle Emissions
Quotables		
Spring 2013 Interview		
Winter or Fall 2012 Interview		

Appendix D. Context Helpful to Understanding the Biomass Industry

This appendix briefly reviews several aspects of the biomass industry that help explain businesses' activities, decision-making processes, and perceptions of economic and policy barriers to industry viability.

Waste or Resource?

Biomass can be either “*your best friend or your worst enemy*,” as one interview respondent noted. Though respondents acknowledged forest-derived biomass’s potential value as a resource, they also viewed it as a waste product in contexts where mills, logging, or land-clearing operations are generating residual biomass without an energy-producing market that it can cost-effectively go to. Without a viable energy market for hog fuel, firms which produce residual biomass from logging, land-clearing, or milling operations incur costs in managing their biomass waste streams, as they would with any other type of waste product. In the case of landowners, unmarketable biomass imposes costs either related to slash burning, or as replanting opportunity costs if left to rot in the forestlands. Likewise, in the case of mills, unmarketable biomass requires payment to a waste handler to remove the biomass from the site of business operations.

Biomass Quality

Not all biomass that can be burned by an energy producer is created equal. Biomass with a higher moisture content, or with impurities such as dirt and rocks (in the case of forest biomass) or plastics and metals (in the case of wood residuals coming from urban waste streams) is less efficient when combusted for energy in a boiler, and increase the burden of cleaning and maintaining the boiler. As a result, forest-derived biomass usually tends to fetch a lower price from biomass-sourcing energy producers than do residuals from forest product processing, which have low percentages of impurities and low-moisture content owing to the kiln-drying of the

lumber prior to processing at the mill. In the currently-weak biomass market, where unutilized woody biomass is burned or left in the woods, and market prices are low, mills are reported to have the leeway to be picky as to the moisture content and purity of the biomass they purchase.

In the case of forest-derived biomass, many biomass processors mentioned the need to screen biomass after it had gone through a grinder in order to separate dirt and impurities. Even after screening, the biomass can vary in value as a fuel source. One biomass processor noted that his inability to meet energy producer specifications for biomass fuel quality (in spite of the screening system he used in an attempt to improve product quality) resulted in the mill dropping his contracts, and the end of his direct involvement in biomass harvesting.

Apart from reasons related to boiler operational efficiencies, biomass product quality was also noted as particularly important to certain biomass energy producers with newer boilers who are required to meet more stringent air quality standards. By contrast, certain older mills and energy producers are reported to have been grandfathered into less stringent emissions permits, and can burn lower-quality biomass while still meeting permit requirements.

Transportation

This study did not probe interview respondents about their specific cost structures associated with biomass collection, processing, and transportation, which have been thoroughly evaluated the Washington Forest Biomass Supply Assessment. However, it is worth noting that all nearly all respondents mentioned the high costs and logistical difficulties associated with transporting biomass over forest roads and across long distances to their energy production destination. Firm responses regarding the importance of transportation costs closely echo the findings of the Washington Forest Biomass Supply Assessment (Perez-Garcia et al. 2012).

Appendix E. Factors Seen as Contributing to a Weak Hog Fuel Market

Interview respondents widely reported that several recent developments in the forest biomass market had conspired to weaken the current market for forest biomass: The elimination of the Biomass Crop Assistance Program (BCAP), the decrease in the market price of natural gas and biomass residuals from mills (substitute goods), and the closure of two of Washington's biomass-consuming mills.

Biomass Crop Assistance Program (BCAP)

By the start of 2011, the funding for BCAP's matching payment program had been depleted (USDA 2012), and the program's effects on the market price of hog fuel and the volumes of biomass harvesting in Washington essentially ceased. However, for a window of time lasting less than two years (depending on when individual firms and energy producers got certified to participate in the program), the biomass industry participants interviewed in this research reported that the BCAP program was an important factor underlying the influx of harvesting during that time period.

Substitute Good Price Fluctuations

Interview respondents reported that the forest-derived biomass industry has recently seen substantial decreases in the price of two critical substitute goods: hog fuel sourced from mill residuals, and natural gas.

Mill Residuals. Several interview respondents noted that the recent relative abundance of mill-derived biomass residues has diminished market demand and price for forest-derived biomass. In general, two dynamics favor the use of mill residuals over forest biomass as a source of hog fuel.

First, as noted in Appendix D, mill-derived residuals tend to have a lower moisture and impurity content than forest-derived biomass. Second, because forest-product processing mills are generating residuals as a waste byproduct of their other business activities, the mills may be primarily concerned with avoiding costs associated with disposing of the material. In the current market environment, interview respondents reported that mills are willing to dispose of their residuals for free in some instances, with the energy-producing consumer simply paying any costs of transportation from the mill to the energy source. In any case, firms possessing mill residuals may be willing to sell the material for less than the break-even costs associated with transporting forest-derived biomass, which can be substantial due to the dispersed geographic locations of the source materials.

So long as mill-derived hog fuel is insufficient to satisfy energy producer demand, there remains potential market space for forest-derived hog fuel. However, interview respondents reported that beginning around 2011, the national economic recovery and resumption of housing starts instigated an overall uptick in Washington forest product mill activity, and a concurrent increase in the volume of residual material generated, displacing forest-derived hog fuel.

The uptick in mill residual production in Washington has been compounded by an uptick in imports of residual materials from Canadian forest-product mills. The British Columbian government reports that sawmill activity has increased as a result of an increase in logging activity authorized by the provincial government response to infestations by mountain pine beetle (British Columbia, 2013). The importation of Canadian mill residuals was reported by many interview respondents as recently providing tough price competition in comparison to locally-sourced hog fuel.

Natural Gas. The proliferation of cheap natural gas is reported by industry participants to be a second critical factor in undercutting the market for forest-derived hog fuel. Commercial natural gas prices are currently about half of the 2008 peak price (US EIA 2013). Several energy producers that currently use biomass in the production of heat, steam, and/or electricity also have parallel boiler systems capable of firing natural gas or fuel oil, which can be used to partially or wholly displace the use of biomass as a fuel source. However, commercial use of natural gas as a fuel source also generally requires pipeline delivery infrastructure that is not currently in place statewide, including on the Olympic Peninsula (WSU Extension Energy Program). While the price of natural gas has plummeted in recent years, the price of heating oil has not, and facilities limited by natural gas infrastructure to choosing between running hog fuel and fuel oil in their boilers were not reported to have shifted away from the use of hog fuel.

In addition to being cheaper than forest-derived biomass, natural gas is reported to be comparatively logistically simple as well- rather than having to coordinate biomass load delivery, take steps to ensure product quality, and set aside adequate storage space on the property, energy producers which have moved to rely on natural gas may now, in interview subject's words, *“go over and hit the switch and not have to deal with the mass and volume of materials- it's all right there at the end of a pipe.”*

Mill Closures

Beyond the changes in the market wrought by BCAP and the shifting prices of mill-derived hog fuel and natural gas, the state's overall demand for hog fuel has also declined sharply since 2011 as a result of the closure of two paper mills which had been major consumers of biomass in Washington: Kimberly-Clark in Everett, and Greys Harbor Paper in Aberdeen. Although these closures were attributable to broader market forces acting upon the pulp and paper industry

generally, the closures also remade the dynamics of the local hog fuel markets in the state. 10 of 21 interview respondents, including 7 of 9 interviewees operating in the Cascades north of Seattle, mentioned Kimberly Clark's closure as having affected the hog fuel markets that they participate in; likewise, four interviewees mentioned that the cessation of Greys Harbor Paper operations had affected their local hog fuel market.

Appendix F. Map of Biomass Consuming Facilities in Washington (2011)

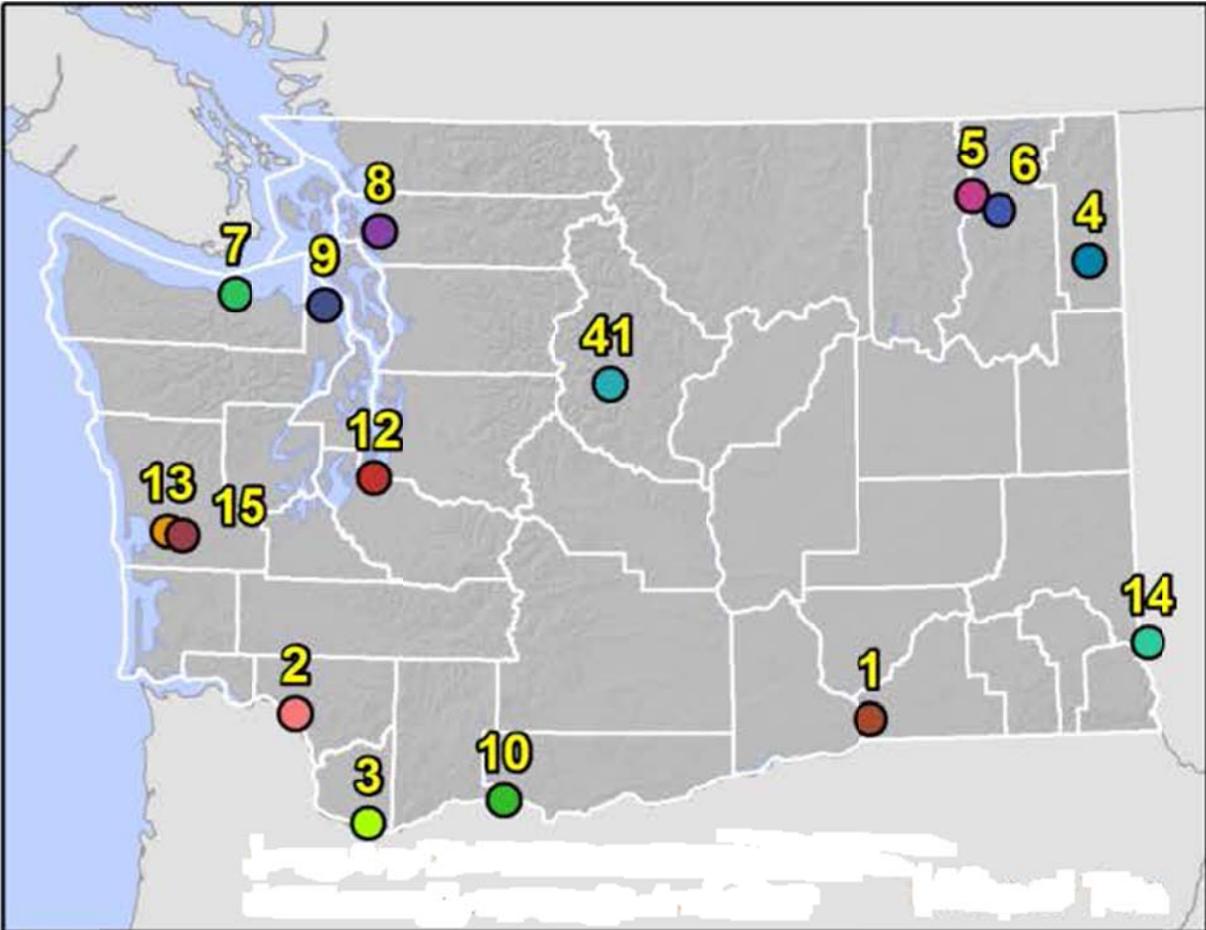


Image reproduced from Perez-Garcia et al. (2012). Note that at least one of the facilities (#13) on this map had suspended operations and was no longer an active consumer of biomass during the time that the interviews in research were conducted.

Appendix G. Map of Natural Gas Pipelines in Washington (2012)



Image reproduced from WSU Energy Extension Program (2012). The Map in Appendix G shows the distribution of natural gas pipelines in Washington as of 2012 (the map also shows the location of wood pellet mills, which are currently of limited relevance to the forest biomass-to-energy industry because of pellet mills' nearly exclusive reliance on sawmill-derived feedstock).

Appendix H. Seasonal Influences on Biomass Harvesting Logistics

Interview respondents indicated that seasonality of several aspects of the biomass-to-energy supply chain influence firms' harvesting decision-making processes. First, as detailed in Section 2.2 of the results, the ability to burn slash piles is a seasonally-dependent activity.

Second, many forest roads in Washington may not be accessible to either log trailers or chip and hog fuel trailers during certain months of the year, due to snow, mud, or washouts. Rainy, muddy time periods also were reported to present a logistical difficulty for in-woods grinding, as grinders must operate on the firm and stable ground found in either dry or frozen conditions. Depending on the harvesting site and the ownership's road maintenance practices, biomass harvest may only be feasible during portions of the spring, summer, and fall, when road conditions are more favorable. The optimal biomass harvesting season varied widely depending on geographic location. One successful contractor reported that his firm found it important to have access a variety of ownerships, including some whose lands and roads are accessible during the winter months. Local access to ownerships in different microclimates and elevations reportedly allowed this contractor to spread out its harvesting activities throughout most of the year, giving it a steadier revenue stream.

Third, several contractors reported that they tried to time the harvest of biomass slash piles to minimize the moisture content of the wood, so as to fetch a higher price from the mills and lower their transportation costs. Optimal piling and harvest-timing strategies mentioned by contractors depended on harvest site topography, road layout, and tree species present, and sometimes involved purposefully leaving biomass piled for months after log harvest, before returning to grind and transport it to an energy producer.

Finally, energy-producer demand for forest-derived hog fuel is reported to fluctuate over the year, depending on the availability of processing mill residuals, and ambient air temperature (colder months tend to require more feedstock to achieve the same power output). Fall and winter are generally reported to feature the greatest demand for forest-derived hog fuel, although more specific seasonal trends in the hog fuel market are difficult to generalize, as interview respondents' reports varied depending on the geographic locations of the firm's operations, and the specific weather patterns and log harvesting activities that had taken place in the area that particular year.