Oregon Biofuels And Biomass

Woody Biomass in Oregon - Current Uses, Barriers and Opportunities for Increased Utilization, and Research Needs

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Preface

The Oregon University System, working in partnership with the Oregon Economic & Community Development Department, commissioned a bio-fuels industry readiness survey for Oregon. This report serves as one component of the readiness survey. The report has three primary sections:

- An overview of the current forest products industry in Oregon combined with estimates of regional biomass supply;
- A review of literature related to use of woody biomass in Oregon for biofuels and bio-based products; and
- Interviews with key stakeholders - private landowners and manufacturers that use wood products residues (including wood-based composites and pulp & paper).

Information from the three sections is used to determine implications for research needs related to woody biomass utilization in Oregon. Findings of the report are intended to assist decision makers determine how best to focus efforts in this area.

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Executive Summary

There is currently a great deal of interest in Oregon, and around the nation, in woody biomass utilization. Biomass utilization has the potential to simultaneously address 3 seemingly unrelated goals – 1) reduced incidence of forest fires; 2) economic development; and 3) renewable energy. While a number of recent reports have addressed utilization of biomass for renewable energy, lesser emphasis has been given to bio-based products or bio-chemicals.

Woody biomass is defined here to include logging residues (tree tops, limbs, and non-merchantable logs) from conventional timber harvesting activities and from forest restoration work; residues from existing wood products manufacturing facilities (mill residues); and urban wood waste. Oregon has significant existing industry infrastructure utilizing woody biomass (e.g., wood-based composites and pulp & paper). This fact combined with reports indicating marginal economic feasibility of bioenergy in the absence of value-added markets (OFRI, 2006) suggests the need to consider a wider array of potential products from woody biomass.

The Oregon Innovation Council's plans to form the Bio-Economy and Sustainable Technologies (BEST) Signature Research Center present an opportunity for Oregon to lead the nation in developing renewable and sustainable energy and materials from woody biomass and as a result, realize the three goals described above. However, research is needed all along the value chain – from forest restoration science to biomass harvesting and transportation systems; processing and conversion technologies; bio-based product development and marketing; and understanding consumer demand for end products.

This report assesses barriers and opportunities to utilization of woody biomass and implications for research via an overview of Oregon's current primary forest products manufacturing industry combined with estimates of regional biomass supply, review of recent reports related to use of woody biomass for biofuels and bio-based products, and interviews with private landowners and forest industry personnel.

Findings demonstrate that Oregon's primary forest products manufacturing industry is highly interconnected and interdependent. Biomass users such as pulp and board mills are critically dependent on production from sawmills and veneer mills. Sawmills and veneer mills in turn rely on pulp and board mills as markets for the substantial volume of residues generated in sawmilling and veneer production. Nearly all of the existing mill residues are used. By contrast, markets for logging slash and non-merchantable (i.e., small diameter) timber are currently very limited.

The majority of timber supply in Oregon currently comes from private forestlands. The ratio of public/ private forestlands varies significantly county to county. Hence, when discussing potential for increased utilization of woody biomass, it is critical to examine supply and existing markets within a narrowly-defined region (e.g., county or radius around a community).

There are substantial inventories of merchantable logs and net biomass on public as well as private lands in southern Oregon. In addition, there is significant existing processing infrastructure. This region appears to have very strong potential for increased biomass utilization.

Economic development is needed in most rural areas of the state and in eastern Oregon in particular. Grant County has significant volumes of woody biomass and some processing infrastructure for logs is still in place. However, markets for mill residues such as chips, sawdust/ shavings, and hog fuel are extremely limited. Further, net biomass supply in this area is heavily dependent on the availability of publicly-owned timber.

Northwest Oregon has the greatest diversity of both processing infrastructure (sawmills, veneer mills, <u>and</u> pulp & paper) and the most balanced mix of public and private ownership of both merchantable logs and net biomass. Little attention has been given to this area for biomass utilization potential thus far. However, as the only area of the state with existing pulp & paper mills, northwest Oregon is likely to play a role as a

biomass 'test case' for other areas of the state in that fewer hurdles exist such as dependency on publicly-owned timber and requirements for investing in construction of new processing facilities.

Existing primary processing infrastructure in central Oregon is likely to be a limiting factor in near-term utilization of woody biomass. Both infrastructure and available merchantable log volume and net biomass volume are modest. However, central Oregon appears to hold the best potential for western juniper utilization; the greatest concentrations of juniper in the state are in Crook County.

Recent reports related to biomass utilization provided significant information related to potential biomass supply, barriers and opportunities related to increased biomass utilization, stakeholder perspectives, and policy and technical recommendations. Stakeholder interviews confirmed the interdependent nature of the industry and that demand for mill residues is currently quite high while supplies are limited. However markets are needed for logging slash; the majority of slash is currently piled and burned on site. Economics drive most landowner decisions with respect to harvesting – if biomass pays its way out of the woods, many landowners will be 'players' in the marketplace. Although some landowners also see benefits to thinning overstocked forests beyond pure cost recovery. Discussions of the economic feasibility of harvesting and transporting biomass should consider costs currently incurred by landowners for slash disposal (piling and burning).

The literature review and interviews indicate that the three goals described above (renewable energy, economic development, and forest restoration) also represent individual paradigms on biomass utilization. That is, how one defines biomass and its utilization depends on the specific goal. For example, when focusing on renewable energy, biomass is often seen as forest residues and the primary research need might be cellulosic ethanol conversion technology. On the other hand, when focusing on economic development, biomass might be viewed as small diameter timber and thus value-added product development would be emphasized. Achieving the 3 goals requires simultaneously addressing all 3 paradigms. *As a collaborative and multidisciplinary effort, the Bio-Economy and Sustainable Technology (BEST) Signature Research Center will fulfill a critical role as the entity that links the 3 paradigms together via collaborative research.*

The review of recent reports on biomass utilization and stakeholder interviews revealed several specific barriers and opportunities related to woody biomass utilization in Oregon as well as specific areas of research. These recommendations may be categorized broadly as simply related to supply and demand.

Adequate supply of biomass was stated as perhaps <u>the</u> critical need to enhanced utilization of woody biomass in Oregon. For firms to invest in biomass processing infrastructure for <u>any</u> end use, some assurance is needed that there will be an affordable and reliable supply of raw materials. Challenges are primarily two-fold: 1) supply from federal lands is dependent on federal forest management policy and subject to litigation that can effectively prevent harvesting from occurring and 2) for both public and private lands, costs to harvest, gather, and transport woody biomass (in the absence of merchantable logs) typically exceed the market value of the material.

Specific supply-oriented research recommendations are:

1. <u>Forest restoration science</u> – For many regions of the state, supply of woody biomass will depend heavily on material obtained via <u>restoration</u> of public forestlands. Hence, for public support of such restoration treatments, it is critical that the treatments be based on sound science. This science is still in the developmental stages.
2. <u>Public perceptions</u> – Research is needed on how the public views forest restoration, biomass utilization, and bio-energy, to identify practices and technologies that are most broadly acceptable. Demonstrations/ pilot projects can play a key role in helping stakeholders to see first-hand the results of restoration projects, how biomass facilities function, etc. Public perceptions also include research related to consumer acceptance of new bio-based products.
3. <u>Forest inventory data</u> – The primary input for biomass supply estimates are forest inventory data, the most recent of which are 10-15 years old and often at a scale such that they are only accurate across large geographic areas. To determine if a specific biomass facility is economically feasible, detailed and accurate local inventory data are needed.

4. Harvesting, processing and transportation – Costs associated with harvesting and transporting biomass result in delivered prices that typically exceed current market value. Systems are needed to reduce costs of biomass harvesting, processing, and transportation. Costs per delivered ton could be reduced by technology capable of densifying biomass at the harvest site. For biomass to be used in existing products that require clean (free of bark and foliage) raw materials, technology is needed that can segregate materials cost-effectively. Lastly, research is needed to develop systems uniquely suited to western juniper.

The above recommendations emphasize research directed to enhancing available biomass supply. It is also imperative to pursue research focused on the 'demand side' – development of technology, products and markets that improve the market value of the material.

Specific demand-oriented research recommendations are:

1. Product and market feasibility - Computer modeling and simulation can help assess feasibility of various approaches (e.g., integrated biorefineries, integrated small log processing facilities; and log sort yards) to biomass utilization. There has been significant federally-sponsored R&D work on small diameter timber utilization. There is a need for technology transfer of results as well as to identify opportunities specifically suited to Oregon resources and infrastructure. With respect to biorefineries, research is needed to understand existing products and markets. And there is a need for research to identify barriers (technical and market-based) to production of industrial grade pellets in Oregon.
2. New product development - Several specific areas of opportunity for new product development in Oregon include: advanced wood composites such as wood-plastic, wood-rubber, and wood-nylon; specialty chemicals derived from various tree species and biomass 'fractions' (wood, bark, and foliage); value-added products from small diameter timber and western juniper; and industrial/ commercial-grade pellets.
3. Technology development/ refinement - Lastly, research is needed in a broad array of topics related to development or refinement of technology for biomass utilization. Specific examples include: cellulosic ethanol research specific to the softwood resources of Oregon; research to explore ethanol fermentation organisms tolerant to fermentation inhibitors in bark; alternative separation technologies such as nanocomposite membranes for separating ethanol and water; conversion processes to produce ethanol from pulp mill sludge; and removal of hemicellulose prior to pulping for conversion to ethanol and other products. There are also a number of research recommendations related to other forms of renewable energy such as portable pyrolysis units to produce bio-oil for use as a fuel oil or for chemical feedstocks; gasification of pulp mill black liquor to produce syngas; and a woody biomass-powered microbial fuel cell.

Introduction

There is currently a great deal of interest in Oregon, and around the nation, in woody biomass utilization. Seemingly unrelated subjects – producing renewable energy and improving forest health are coming together in what some have described as the 'stars being aligned.' In a presentation to the Oregon Business Council, Allyn Ford, CEO of Roseburg Forest Products, discussed the biomass 'triple win' for Oregon – reducing wildfire hazard by reducing fuel loads in forests, creating economic prosperity in rural Oregon, and producing renewable energy.

In addition to renewable energy (e.g., burning biomass for heat and/or electricity or conversion to liquid fuels such as ethanol), other potential uses for woody biomass include bio-based products such as wood-based composites, cellulose nanocrystal composites, chemical feedstocks (e.g., resins and dyes) and specialty chemicals (e.g., aromatic compounds for fragrances or natural insect repellents), just to name a few. Several recent reports have addressed biomass utilization in Oregon. Examples include:

- the *State of the Oregon Forest Biomass Working Group: report to the Governor's Renewable Energy Working Group* (Oregon Forest Biomass Working Group, 2007);
- *Biomass Energy and Biofuels from Oregon's Forests* (Oregon Forest Resources Institute, 2006);
- *Southwest Oregon Interagency Biomass Utilization Strategy* (Medford District Bureau of Land Management and Rogue River – Siskiyou National Forest, 2006); and
- *Biomass Task Force Report* (Western Governors' Association, 2006).

The focus has been primarily on barriers and opportunities related to using biomass for renewable energy; lesser emphasis has been given to bio-based products or bio-chemicals.

Oregon has significant existing industry infrastructure utilizing woody biomass (e.g., pulp & paper and wood-based composites). This fact combined with reports indicating marginal economic feasibility of woody biomass-to-energy in the absence of value-added markets (OFRI, 2006) suggests the need to consider a wider array of potential products from woody biomass.

The Oregon Innovation Council's plans to form the Bio-Economy and Sustainable Technologies (BEST) Signature Research Center present an opportunity for Oregon to lead the nation in developing renewable and sustainable energy and materials from woody biomass and as a result, realize the triple win described above. Oregon has a significant competitive advantage in this area given the state's well-established forestry sector and more acres of forests in need of thinning than any other western state (OFRI, 2006). However, research is needed to capitalize on these advantages. Research is needed all along the value chain – from forest restoration science to biomass harvesting and transportation systems; processing and conversion technologies; bio-based product development and marketing; and understanding consumer demand for end products.

Reaping economic development benefits from research requires commercialization of the results. Commercialization can occur via a number of pathways including formation of new companies, spin-offs of existing firms, or product line extensions for existing firms. Regardless of the pathway, commercial partners are key links in any R&D effort. For this reason, an understanding of the existing network of businesses that currently use woody biomass and their interest and capabilities to partner in research and capitalize on results is critical.

This report assesses barriers and opportunities to utilization of woody biomass and implications for research via three steps:

1. Current industry overview – A description of Oregon's existing primary forest products manufacturing industry is presented including discussion of the different feedstocks, regional distribution of facilities, and flow of various types of raw materials.
2. Review of recent reports – As stated previously, a number of reports relevant to forest biomass utilization in Oregon have been developed recently. Five reports are summarized with particular attention given to recommendations for research.
3. Industry perceptions – Given the importance of commercial partners in developing a viable biomass-using industry, interviews were conducted with key stakeholders including private forest landowners (industrial and non-industrial), wood products manufacturers, and pulp & paper firms. The interviews focused on understanding the views of industry personnel on barriers and opportunities to expanded utilization of woody biomass and their opinions as to strategies the state can pursue to grow this industry.

The report concludes with a summary of the findings and recommendations for research investments that will help move a woody biomass industry forward in Oregon.

1. Oregon's Existing Wood Products Industry – An Overview

When discussing markets for woody biomass, it is critical to understand the types of raw materials used by existing firms, geographical distribution of the firms, and market dynamics (e.g., one firm's residues and/or outputs are another firm's inputs). Further, new facilities are likely to compete with existing firms for raw materials. Location of firms relative to potential supply is crucial as well since costs of transporting materials can add significantly to the delivered cost of materials; this is particularly the case with respect to low-value residual materials (OFRI, 2006).

Increasing sustainable timber supply from public forestlands is one of the three components of the Oregon Business Plan's Forestry Cluster Initiative (Oregon Business Plan, 2006). Given the industry's keen interest in raw material supply, there is likely to be significant competition for woody biomass if and when more volume becomes available – provided the material meets the quality requirements (e.g., particle size and purity) of existing mills.

Biomass Defined

Prior to discussing Oregon's existing wood products industry, some definitions of terms are required. Specifically, is there a difference between biomass, forest biomass and woody biomass? Is a log used for producing lumber (a.k.a. a sawlog) considered biomass? The report *Biomass Energy and Biofuels from Oregon's Forests* addresses this question (OFRI, 2006). **Biomass** is defined as "…the sum total of all organic material in trees, agricultural crops and other living plant material. **Woody biomass**, then, is any biomass that is composed of wood." Woody biomass thus includes sawlogs, residues from existing wood products firms, **forest biomass** (logs and logging residues, also known as slash – tree tops, limbs, and non-merchantable material from logging operations), and urban wood waste (e.g., discarded wood and yard debris).

Oregon Senate Bill 1072[1] defines woody biomass more narrowly as "material from trees grown in a forest, woodland, farm, rangeland or wildland-urban interface environment that is the by-product of forest management, ecosystem restoration or hazardous fuel reduction treatment." Hence, this definition excludes mill residues and urban wood waste. It is not clear if the term 'by-product' suggests that only non-merchantable (defined below) logs are considered or if a mixture of merchantable (sawlogs) and non-merchantable logs is applicable.

While there is no single definition of what makes a log 'merchantable', log diameter is the most common criterion. As sawmills and veneer mills have invested in processing innovations, they are able to use smaller and smaller logs. Thus, the definition of

[1] Oregon Senate Bill 1072 was signed into law by Governor Kulongoski in 2005 and took effect January 1, 2006. SB 1072 directs state government to take a greater role in federal forest planning and management and encourages greater use of forest residues for bio-energy facilities on federal and state lands and development of other forest products.

merchantability will vary from mill to mill depending on processing and handling machinery and target market for the end product. In general, logs less than 5 to 7 inches in diameter are typically considered non-merchantable. Such logs are also variously referred to as sub-merchantable or simply ‘small diameter timber.’

For purposes of discussing Oregon’s broad wood-using industry, the broader definition of woody biomass is more applicable. Hence, in this report, the term ‘log’ without a qualifier refers to merchantable or larger diameter material and woody biomass refers to non-merchantable logs, mill residues (i.e., the ‘waste’ or byproducts from wood products firms), and urban wood waste.

Thus, woody biomass originates from four primary sources:

1. Logging residues (a.k.a., slash - tree tops, limbs, and non-merchantable logs) from conventional timber harvesting activities (i.e., harvesting conducted primarily to produce merchantable timber);
2. Logging residues from forest restoration or timber stand improvement work (i.e., harvesting conducted primarily to reduce fire danger and improve forest health in general);
3. Residues from existing wood products manufacturing facilities (mill residues); and
4. Urban wood waste, e.g., demolition waste, pallets, and yard debris.

Sources 1 and 2 may come from public as well as privately-owned forests. Given the challenges and resistance to timber harvesting on public lands in recent years and dramatic reductions in federal timber harvests, many in Oregon’s forest industry question the reliability of supply of woody biomass from public lands (Oregon Business Plan, 2006; OFRI, 2006). Therefore, many feel near-term supply for source 1 is most likely to come from private lands. By contrast, harvests from public lands, assuming there is any significant harvesting conducted, will primarily result in source 2.

Forest restoration harvesting, also often referred to as forest thinnings or in some cases ‘fuels reduction treatments’, does not preclude the possibility for the generation of merchantable timber. However, some in the conservation community have stated that their organizations only support harvesting on public lands if the harvesting is genuinely about restoration and not commercial timber harvest (OFRI, 2006); absence of larger (i.e., merchantable) timber in the harvest plan is a proxy for evidence of the legitimacy of the intent. A simple method to achieve this goal is simply to set a diameter limit on the harvesting, e.g., “no trees larger than 6 inches in diameter will be cut.”

Therefore, the primary difference between sources 1 and 2 is the mix of merchantable and non-merchantable material and hence the delivered cost per unit of input (often board feet or ton) to a processing facility. As source 1 is generated from conventional timber harvesting, merchantable logs are included in the mix. Source 2 may or may not include merchantable logs, however, in that the objectives are forest restoration, reducing fire danger, etc. and not timber production. Delivered costs are much higher, and often exceed market value, when the dominant output is non-merchantable logs.

In summary, when discussing available volumes of woody biomass (broadly defined), one must define the source (public or private) as well as the nature of the material (merchantable logs, non-merchantable logs, residues, etc.).

Forest Products Manufacturing – An Overview

The forest industry can be categorized via a number of different schemes. One common classification system defines firms essentially by stage in the production process, e.g., primary (essentially firms that buy logs) and secondary/ value-added (firms that buy lumber and panel products). Pulp & paper is often considered as separate and distinct. However, some industry analysts define primary to include firms that buy logs as well firms that buy the residual materials from these operations. Thus, sawmills, plywood plants, (and other firms that buy logs such as log home builders and utility pole producers), as well as pulp & paper and 'board' (particleboard, hardboard, and medium density fiberboard – MDF) manufacturers would all be considered primary

Another approach is to list firms by products produced, e.g., lumber, plywood, particleboard, cabinets, etc. The U.S. Census Bureau's North American Industry Classification System (NAICS) categorizes firms following this approach and contains various levels of hierarchy (NAICS, 2002). For example, NAICS 321 is the broad category for wood products manufacturing. NAICS 3211 is for sawmills and wood preservation; 321113 is for sawmills. As another example, NAICS 3212 is for veneer, plywood, and engineered wood product manufacturing while 321211 is for <u>hardwood</u> veneer and plywood manufacturing.

For purposes of understanding markets for woody biomass, a system that segregates firms by raw materials used such as logs, veneer, lumber, bark, sawdust, urban wood waste, etc., would be most useful. The following is an overview of such materials and their end uses.

Logs are naturally what most people think about when talking about the forest industry. Trees are felled in the forest, delimbed, bucked (cut) to length, and the resulting logs are sold for a wide variety of markets. The most common uses for logs include:

- <u>Lumber</u> – Logs destined for this market are often termed sawlogs. Sawmills remove bark and saw logs to produce lumber for varying end uses including dimension lumber for construction, boards that are typically appearance grade lumber for applications such as soffit/ fascia, fencing or shelving, or to be remanufactured into other products such as door jambs, flooring, cabinets, etc.
- <u>Veneer</u> – Veneer mills remove bark and peel logs into thin, wide sheets for plywood and laminated veneer lumber (LVL). The 'peeler core' (center of the log that is too small to be peeled into usable veneer) is sold for landscape timbers, agricultural posts, or chipped.

- Chips - Chipping contractors remove bark and produce chips from low-grade logs for markets including pulp and paper, hardboard, medium density fiberboard (MDF), and animal bedding.
- Utility poles (a.k.a. telephone poles) are produced from long, straight, high-quality logs. Pole plants remove bark and apply chemicals to logs to provide insect and decay resistance.
- Post & pole firms peel small logs for fence posts and rails, as well as poles for various agricultural applications such as grape stakes for vineyards. Most products are treated to provide decay and insect resistance.
- Log home builders use long, straight logs with a minimum amount of taper for building log homes. Logs are usually debarked.
- Firewood producers often purchase otherwise non-merchantable logs following a timber harvest or wildfire. Logs are bucked (cut to length), split, and then stacked to dry ('season').
- Oriented strand board (OSB, a.k.a., waferboard, flakeboard, or even chipboard) is often thought of as a product produced from chips (hence the name 'chipboard') or other sawmill residues. However, OSB is produced from logs. OSB is now the dominant product used for wall, floor, and roof sheathing in home construction as well as for wood I-beams. There are currently no OSB mills in the western U.S.

Within the broad classification of log markets described above there are also sub-categories based on species. For example, in western Oregon, Douglas-fir is the dominant species for dimension lumber for construction and plywood whereas western redcedar is used for fencing, decking and siding. In eastern Oregon, ponderosa pine and radiata pine, with the latter being imported from southern hemisphere plantations, is used for moulding & millwork. Hardwoods such as red alder, are used for cabinets and furniture; markets are far more limited for other Oregon hardwoods such as bigleaf maple, Oregon white oak, and Pacific madrone.

Veneer is mentioned here as a separate category of raw materials because in addition to veneer mills (firms that purchase logs to produce veneer, described above) there are also mills that purchase veneer to produce plywood and LVL.

Within the veneer-based products sector of the forest industry, there are also companies that manufacture wood I-beams (similar in shape to a steel I-beam). These engineered wood products are increasingly being used as replacements for solid wood (e.g., 2x10 or 2x12) in floor joists. Companies that produce wood I-beams purchase LVL for use as the flange (horizontal components) of the I-beam and either plywood or OSB as the web (vertical component of the I-beam). These firms thus machine and assemble the components to produce the I-beam.

Lumber markets include a wide array of end uses. Of course, lumber is often simply used 'as is', such as for framing lumber for construction or other applications such as fencing, decking, shelving, fascia, etc. Glued-laminated beam (glulam) producers laminate lumber to produce large beams for residential and commercial construction. Secondary wood products firms purchase lumber and remanufacture it into 'value-added' products such as doors, windows, furniture, cabinets, flooring, and a multitude of other products.

The above provides a brief overview of markets for logs, lumber, and veneer. There are also a wide variety of markets for the residues produced from lumber and veneer production as well as from non-merchantable or low-grade logs.

Bark is used for mulch or fuel. As described above, most firms that purchase logs remove the bark prior to producing lumber, veneer, utility poles, etc. Bark that is relatively free of wood can be ground to various sizes and sold as bark rock or bark mulch for landscaping. Residues that are a mixture of bark and wood are usually ground in a machine called a hammer hog and used as a boiler fuel known as hog (or hogged) fuel. Hog fuel is typically the lowest value market for the material and thus firms strive to segregate material as much as possible to divert residues to higher-value markets.

Hog fuel is often used internally as boiler fuel by mills that produce it, as well as sold to other firms with wood-fired boilers. Several mills have the capacity to produce combined heat and electrical power (CHP, or cogeneration) as well. In fact, over one half of all energy used in the U.S. primary forest products industry is self-generated (EIA, 1998). The pulp & paper industry is particularly self-reliant for energy. Expansion of electrical generation capacity, however, often requires sourcing outside material. This is one potential use for forest biomass and many see this as the use with the greatest near-term potential (OFRI, 2006, WGA, 2006).

Sawdust is another byproduct of any operation that saws wood. For decades, the material was simply burned as a means of disposal. However, there are now well-established and competitive markets for sawdust to manufacture particleboard and fuel pellets.

Shavings are a byproduct of lumber planing operations. Planing is the process by which rough lumber is machined to produce a smooth surface. Markets for shavings include particleboard and animal bedding.

Sawdust and shavings are often combined in estimates of residues and termed ‘fines.’

Chips come from a two primary sources: 1) ‘Coarse’ residues from sawmills and veneer mills, i.e., slabs (outer, rounded portion of logs), edgings (material removed when cutting boards to standard widths), trim ends (material removed when trimming boards to standard lengths) and pieces of veneer; and 2) low-quality logs that have been debarked and chipped without any additional processing. Common markets for chips include medium density fiberboard (MDF, commonly used in millwork, furniture, and cabinetry), hardboard (used for applications such as exterior siding, ‘skins’ for hollow-core doors, and pegboard), and of course, pulp & paper.

Any of the products discussed above that involve creating a larger piece of wood from smaller components (LVL, MDF, particleboard, and hardboard) are generically known as wood composites.

Logging slash as discussed above, is a broad term for the waste/ non-merchantable material resulting from a timber harvesting operation. Slash includes tree tops, limbs, foliage, and non-merchantable logs (perhaps due to being too short, containing rot, etc.). There are limited markets for some small diameter timber for firewood, post & poles, and chips. However, the vast majority of logging slash is simply piled and burnt on-site.

Slash, as well as timber deemed non-merchantable due to being smaller in diameter than desired by existing sawmills, figures prominently in discussion of biomass markets. Key challenges are costs to gather, load, haul, and process the material as well as issues with segregating the various fractions – wood, bark, and foliage. Segregation is key as mills such as pulp, MDF, hardboard, and particleboard, have specifications for the amount of bark or other non-wood material they will accept in their furnish (raw materials).

Urban wood waste includes demolition waste, yard debris, pallets, etc. This material is often simply discarded at the landfill, however there are limited markets for stand-alone (i.e., not directly affiliated with a wood products firm) facilities that grind and burn the material for combined heat and power (CHP or cogeneration).

As can be seen from the description of the various raw materials used and end uses described above, the forestry cluster has developed around the log market. Entire industries exist based on the primary products and residues of firms that use logs. Thus, the industries are intricately linked as well since, for example, declining production from sawmills leads to declines in the supply of feedstocks for the pulp and paper industry, particleboard mills, and other sectors.

The above describes raw materials used for traditional wood products, or wood products currently on the market. However, bio-based products and biochemicals are not addressed. While any of the materials discussed above could be considered a bio-based product given the source is biomass of one form or another. At the same time, there are opportunities to develop advanced and/or engineered bio-based composite products engineered for specific end uses and adapted to specific types of input raw materials. Such advanced bio-based composites might include wood and non-wood composites such as wood-cement, wood-plastic, wood-agricultural residues, and a host of other materials. Many wood-non-wood composites such as wood-plastic decking and wood-cement siding are currently on the market; however there are no manufacturing facilities for such products in Oregon.

With respect to biochemicals, there are a multitude of by-products produced from pulp & paper facilities. For example, terpenes for production of turpentine and other solvents, is a common byproduct of resinous species such as pines. However, information on production and markets for specific chemicals is not readily available in standard forest industry sources. In Oregon in particular, the small number of pulp mills compared to sawmills leads to concerns for sharing of proprietary data on markets for byproducts. Kelkar et al. (2006) discuss the potential for distilling essential oils and resins from small ponderosa pine trees as a means to improve the economics of forest restoration treatments. Such distillation may or may not be directly affiliated with a pulp mill. In fact, distillation may occur prior to pulping rather than as a byproduct of pulping. While price information on pine oils was not readily available, the authors cite prices ranging from $5 to $8.66 per 10 ml in 1999 as the retail sales price for comparable oils from other softwoods.

Oregon's Forest Products Industry – An Overview

With the preceding as a general overview of markets for the different forms of woody biomass, attention now shifts to markets in various regions of Oregon. Prior to that discussion however, some mention must first be made of the global nature of the industry.

It is difficult to view the forest products industry in Oregon in isolation. On a daily basis, forest products, in the form of logs, finished and semi-finished products and wood residues move not only in regional markets, but also in global markets. While the export focus of Oregon's industry has shifted from logs to more value added products in recent decades, the focus on exports has remained steady. This movement of material across the state's borders makes it difficult to assess the total volume of wood raw material available in the state and has forced companies to compete in a global market.

Oregon, and the US in general, do not import large quantities of logs. However, Oregon manufacturers do receive large quantities of raw materials from outside of the state. Logs are purchased from Oregon, Washington, Idaho, California, and British Columbia. While log export volume has dropped significantly from the peak volumes of the 1980s, there continues to be an active export market in Oregon with Japan, China and Korea serving as the most important markets. Residual materials, in the form of chips, sawdust, planer shavings, etc., are also purchased from Oregon, Washington, Idaho, California, and British Columbia. Residual materials are also exported to provide raw materials to paper and board mills in several international locations. While furniture and cabinet manufacturers utilize some local hardwoods, they source a large percentage of their material from the eastern US, with smaller volumes of material coming from South America, Asia and Africa. Raw materials originating in the state of Oregon also move outside of the state's borders into Washington, Idaho, and California. The movement of raw materials both inside and outside the state is dependent on markets for those products. When markets are up, products can be moved longer distances.

It is also important to consider that one of the largest economies in the world, the state of California, is located just to the south. Oregon's wood products manufacturers provide a substantial proportion of the wood products used in California, creating a very large market for Oregon firms. However, this market is reaching saturation, which will impact the industry.

With the preceding information on the global nature of the industry as a caveat, focus is now shifted on the flow of materials within the state and locations of specific types of firms.

Brandt et al. provide a detailed analysis of the Oregon forest products industry for 2003 (Brandt et al., 2006). The information was collected via a 2003 statewide census of the industry and focuses on primary timber processing. The authors define primary quite broadly as shown in the list below. Secondary processing (e.g., doors, windows, cabinets, furniture, flooring, etc.) is not discussed.

Based on their statewide census, in 2003, there were a total of 249 primary forest products firms in Oregon distributed by product produced as follows:

- 126 sawmills
- 33 plywood and veneer plants
- 25 house log manufacturers
- 23 pulp and board (i.e., reconstituted or composite products like particleboard, hardboard, and MDF) facilities
- 18 chipping, bark products, fuel pellets, and energy plants
- 12 log furniture, cedar products (shakes & shingles), export, and engineered wood products manufacturers
- 12 post, pole, piling, and utility pole manufacturers

Of the $6.7 billion in sales generated from these facilities in 2003, 37% was from pulp and board mills and 33% from lumber. With respect to volumes products, **Oregon is consistently the leading producer of softwood lumber and structural panel products in the nation.**

Brandt et al. (2006) also discuss the flow of materials in primary wood processing firms. Values are reported in cubic feet as a means to standardize across the different units used for measuring logs, lumber, and residues. In 2003, timber harvest in Oregon totaled 997 MMCF (million cubic feet). Seventy-one percent (706 MMCF) of this volume went to sawmills, 20% (201 MMCF) to veneer mills and plywood plants, 7% (73 MMCF) was chipped and sent to pulp and board mills, and 2% (17 MMCF) went to other facilities.

Of the 706 MMCF delivered to sawmills, approximately 50% (354 MMCF) was converted to lumber and 49% (343 MMCF) became mill residues. The remaining 1% was lost due to shrinkage of green lumber. About 96% (331 MMCF) of the residues were sold to pulp and board plants and 2% (6 MMCF) were used for energy; approximately 30% of the residues were used for energy in-house whereas 70% were sold to other facilities. About 1.5% (5 MMCF) of the residues were used for other purposes such as animal bedding. Less than 0.3% (1 MMCF) went unused.

Of the 201 MMCF delivered to veneer mills, 57% (115 MMCF) was converted to veneer and 43% (86 MMCF) became mill residues. Of the residues, 77% (66 MCF) were sold to pulp and board plants and 13% (11 MMCF) were used for energy; as with residue use in sawmills, a little under 30% of veneer mill residues were used for energy in-house and 70% were sold to other facilities. Approximately 10% (9 MMCF) of the residues were used for other purposes such as animal bedding.

Pulp and board mills received only about 15% (73 MMCF) of their raw materials from chipping facilities (i.e., where non-merchantable, low-grade logs are chipped whole). The remaining 85% (400 MMCF) came from sawmill and veneer mill residues. This is a key difference between Oregon's pulp and paper industry and that of other regions in the country that grow and harvest trees as 'pulpwood'; i.e., for the sole purpose of papermaking. Oregon's pulp & paper sector is the primary consumer of mill residues in the state. Over 70% of the residues generated from sawmills and veneer/ plywood mills were processed by the pulp & paper industry in 2003.

For the 2003 industry census, sawmills and veneer/ plywood mill reported residue factors as a percentage of total lumber output in MBF (thousand board feet). Residues are reported as percent residue in Bone Dry Units (BDU – 2400 lbs. of ovendry wood) per MBF lumber tally (total lumber produced). For example, a factor of 0.25 would indicate that 0.25 BDUs (or 600 lbs) of residues were produced for every 1 MBF of lumber produced.

The sawmill sector had a coarse residue (large material that is chipped) of 0.37 BDU per MBF lumber tally. For sawdust, planer shavings, and bark, the factors were 0.13, 0.08, and 0.17, respectively.

For veneer/ plywood mills, the factors for residues were 0.21, 0.01, and 0.07 for coarse, fines, and bark, respectively.

In 2003, coarse (chippable) residues totaled 3.4 million BDUs (54% of the total) and thus were the dominant fraction of mill residues. Production and use of mill residues from Oregon sawmills and veneer/ plywood mills is shown in Table 1. Figure 1 shows the volumes and flow of material within Oregon's primary wood processing industry in 2003.

Table 1. Production and disposition of wood residues from Oregon sawmills and veneer/ plywood plants, 2003

Type of residue	Total utilized	Pulp and board	Fuel	Other uses[a]	Unutilized	Total
Bone dry units[b]						
Coarse[c]	3,366,703	3,138,714	120,971	107,018	10	3,366,713
Sawdust	889,961	782,752	64,623	42,586	5,875	895,836
Planer shavings	563,914	531,101	9,851	22,962	1,590	565,504
Bark	1,416,435	51,179	1,087,684	277,572	6,085	1,422,520
All residues	6,237,013	4,503,746	1,283,129	450,138	13,560	6,250,573

[a] Other uses primarily include animal bedding and landscape material.
[b] Bone dry unit (BDU) = 2,400 lbs of oven dry wood.
[c] Peeler cores (from veneer production) are included in coarse residue.
Source: Brandt et al., 2006

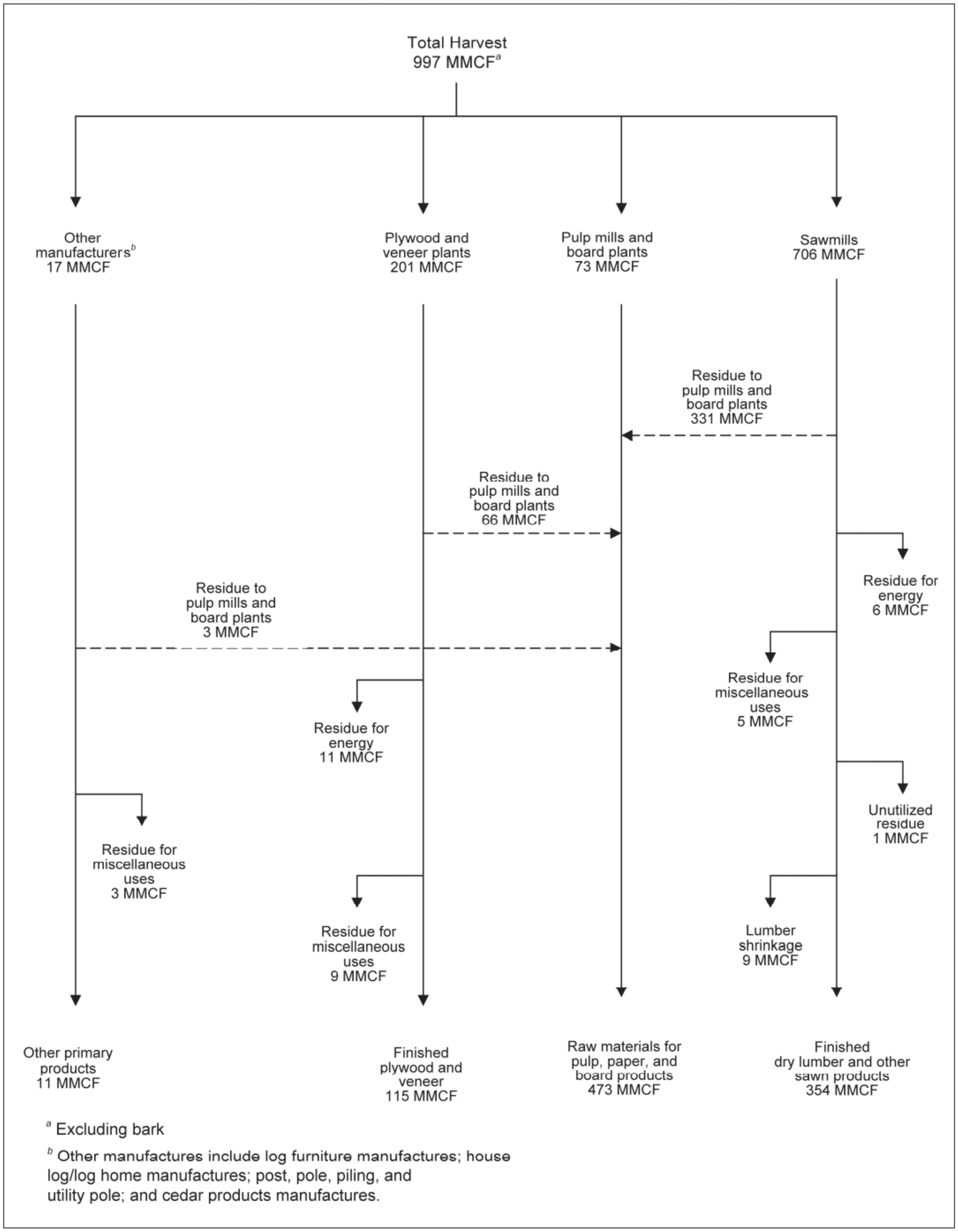

Figure 1. Oregon's timber harvest and flow 2003. Source: Brandt et al. (2006)

The preceding served as an overview of volumes and flows of the various forms of woody biomass in Oregon. Given the low value of some forms of biomass, hog fuel and mill residues in particular, transportation costs limit the distance the materials can be hauled and still remain economically viable. Thus, there are typically clusters of logs and woody biomass-using facilities is specific regions of the state.

To examine regional distribution of the primary forest products processing industry in Oregon, 4 regions are defined as follows, and as shown in Figure 2 below:

Regions:

- <u>Northwest Oregon</u> – Benton, Clackamas, Clatsop, Columbia, Hood River, Lane, Lincoln, Linn, Marion, Multnomah, Polk, Tillamook, Washington, and Yamhill Counties
- <u>Southern Oregon</u> – Coos, Curry, Douglas, Jackson, Josephine, Klamath, and Lake Counties
- <u>Eastern Oregon</u> – Baker, Gilliam, Grant, Harney, Malheur, Morrow, Umatilla, Union, and Wallowa Counties
- <u>Central Oregon</u> – Crook, Deschutes, Jefferson, Sherman, Wasco, and Wheeler Counties.

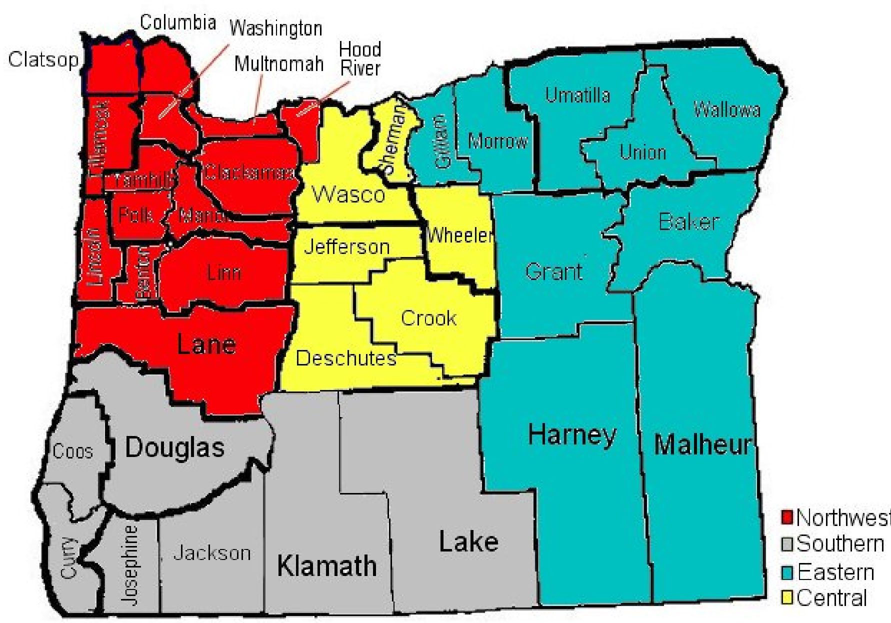

Figure 2. Map of Oregon regions

There are numerous approaches to defining regions or clusters of counties within Oregon. The approach selected here was chosen primarily for compatibility with the regions defined for the biomass supply assessment conducted for the OFRI report *Biomass Energy and Biofuels from Oregon's Forests* (OFRI, 2006) discussed in Chapter 2 below.

The OFRI report focused on 20 counties of eastern and southern Oregon. The counties are those represented here by the southern, central, and eastern regions, with the exception that Coos and Curry Counties on Oregon's south coast were not considered in the OFRI report. These counties were selected due to the predominance of drier forests thus greater need for fuels reductions treatments to reduce wildfire risk. Other definitions of forest/ forest industry regions in Oregon typically consider Klamath and Lake Counties as part of the Central Oregon 'corridor' rather than as southern Oregon as done here. However, as these counties are described as southern Oregon in the OFRI report as well as other regional biomass supply assessments for Oregon, that convention is followed here as well.

Tables 2 through 5 below list the major facilities in each region that use various forms of woody biomass. Fuel consumption per year is listed for firms with wood- or pulping liquor-fired combustion facilities and/or cogeneration. Information in the tables was derived from the Oregon Forest Industry Directory (OFID, 2007) and the Oregon Biomass Energy Facility Directory (ODOE, 2005). As the report by Brandt et al. (2006) described above does not identify individual mills by name[2], it was not possible to cross-reference the firms listed in the tables with the totals for firm types (i.e., sawmills, veneer mills, etc.) in each region.

Table 2. Northwest Oregon facilities that utilize merchantable logs and woody biomass (partial list)

Mill Name	Mill type	County	City	Fuel Consumption BDT/Year
Diamond West Lumber	Sawmill	Benton	Philomath	
Georgia Pacific	Sawmill	Benton	Philomath	
Hull-Oakes Lumber Co.	Sawmill	Benton	Monroe	1,668
Mary's River Lumber Company	Sawmill	Benton	Corvallis	
Mary's River Lumber Company	Sawmill	Benton	Philomath	
TTT Timber	Log sort yard	Benton	Philomath	
Blue Heron Paper Co.	Paper	Clackamas	Oregon City	594
Grimms Fuel Company	Firewood	Clackamas	Lake Oswego	
Interfor	Sawmill	Clackamas	Molalla	
Mark Fritch Log Homes	Log homes	Clackamas	Sandy	
Natural Wood Tek	Log homes	Clackamas	Mulino	
Pacific Timber Products	Poles	Clackamas	Molalla	
RSG	Sawmill	Clackamas	Estacada	
RSG	Sawmill	Clackamas	Molalla	
West Linn Paper Company	Paper	Clackamas	West Linn	
Woodwinds Log Homes	Log homes	Clackamas	Colton	
Olney Mill	Sawmill	Clatsop	Astoria	
Weyerhaeuser Co.	Sawmill	Clatsop	Warrenton	18,935
Boise Cascade	Paper	Columbia	St. Helens	577,500
Boise Cascade	Veneer	Columbia	St. Helens	
Georgia Pacific: Wauna Mill	Paper	Columbia	Clatskanie	65,097 wood; 491,597 pulp liquor
McCormick Piling and Lumber	Utility poles	Columbia	St. Helens	
RSG	Sawmill	Columbia	Mist	
Stimson Lumber Company	Sawmill	Columbia	Clatskanie	
Stimson Lumber Company	Sawmill	Columbia	St. Helens	
West Oregon Wood Products	Pellet mill	Columbia	Columbia City	32,000 tons/yr produced
Bear Mountain Forest Products	Pellet mill	Hood River	Cascade Locks	82,168 tons/yr produced
Billy's Firewood & HMH Logging	Firewood	Hood River	Hood River	
Bald Knob Land & Timber	Veneer	Lane	Creswell	
Bear Mountain Forest Products	Pellet mill	Lane	Brownsville	
Elk River Enterprises	Sawmill	Lane	Swisshome	1,680
Goshen Forest Products	Chipmill	Lane	Creswell	
Kingsford Manufacturing Co.	Charcoal	Lane	Springfield	125,000 tons/ yr produced

[2] Oregon forest industry data collected by Brandt et al. (2006) are confidential with respect to individual company names.

McFarland Cascade	Utility poles	Lane	Eugene	
McKenzie Forest Products, LLC	Plywood	Lane	Springfield	21,150
Murphy Plywood	Plywood	Lane	Eugene	
Northwest Hardwoods	Sawmill	Lane	Eugene	
Northwest Fir Products	Post & pole	Lane	Creswell	
Oregon Industrial Lumber Products	Sawmill	Lane	Springfield	3,400
Pacific Cascade Log Homes	Log homes	Lane	Eugene	
Rosboro Lumber Company	Plywood	Lane	Springfield	No data
Rosboro Lumber Company	Sawmill	Lane	Springfield	
Seneca Sawmill	Sawmill	Lane	Eugene	
SierraPine Ltd.	Particleboard	Lane	Springfield	5,749
Starfire Lumber Co. Inc.	Sawmill	Lane	Cottage Grove	
States Industries	Plywood	Lane	Eugene	
Sundance Lumber Company	Sawmill	Lane	Springfield	
Swanson Brothers Lumber Co.	Sawmill	Lane	Noti	
Swanson Group	Sawmill	Lane	Noti	
Tinkertoy Fencing	Post & pole	Lane	Junction City	
Westwood Lumber Company	Chipmill	Lane	Saginaw	
Weyerhaeuser Co.	Sawmill	Lane	Coburg	56,938
Weyerhaeuser Co.	Sawmill	Lane	Cottage Grove	
Weyerhaeuser Co.	Plywood	Lane	Springfield	12,290
Weyerhaeuser Co.	Paper	Lane	Springfield	469,148
Zip-O-Lumber Company	Sawmill	Lane	Eugene	
Georgia-Pacific West, Inc.	Paper	Lincoln	Toledo	71,668 wood; 470,721 pulp liquor
Eagle Veneer	Veneer	Linn	Harrisburg	
Frank Lumber Co., Inc.	Sawmill	Linn	Mill City	9,130
Freres Lumber Co.	Sawmill	Linn	Lyons	33,881
Georgia Pacific	Paper	Linn	Halsey	
Lincoln Log Homes	Log homes	Linn	Sweet Home	
Pope & Talbot	Paper	Linn	Halsey	400,428
Triple T Studs	Sawmill	Linn	Sweet Home	
Weyerhaeuser Co.	Plywood	Linn	Sweet Home	11,579
Weyerhaeuser Co.	Sawmill	Linn	Lebanon	
Weyerhaeuser Co.	Paper	Linn	Albany	287,635
Wilson Operations	Chipmill	Linn	Lyons	
Hardwood Components	Sawmill	Marion	Mehama	
Thomas Creek Lumber and Log Co.	Chipmill	Marion	Stayton	
Treehouse Log Homes	Log homes	Marion	Salem	
Alder Creek Lumber	Sawmill	Multnomah	Portland	
Boise Cascade	Veneer	Polk	Willamina	8,639
Coastal Fiber	Chipmill	Polk	Willamina	
Diamond West Lumber	Sawmill	Polk	Willamina	
Hampton: Willamina	Sawmill	Polk	Willamina	
Hampton: Fort Hill	Sawmill	Polk	Grande Ronde	1,188
Weyerhaeuser Co.	Sawmill	Polk	Dallas	
Hampton: Tillamook	Sawmill	Tillamook	Tillamook	29,398
Northwest Hardwoods	Sawmill	Tillamook	Garibaldi	
Stimson Lumber Company	Sawmill	Tillamook	Tillamook	
Banks Lumber Company	Sawmill	Washington	Banks	
Pacific Fiber Products	Chipmill	Washington	North Plains	
Stimson Lumber Co.	Sawmill	Washington	Forest Grove	63,826
Stimson Lumber Co.	Hardboard	Washington	Forest Grove	
Dye-Hard Timber	Firewood	Yamhill	McMinnville	
Monroe Oak	Sawmill	Yamhill	Sheridan	
Oregon Fuel & Firewood	Firewood	Yamhill	Sheridan	
Pacific Wood Preserving	Utility poles	Yamhill	Sheridan	
Sheridan Forest Products	Chipmill	Yamhill	Sheridan	
SP Newsprint Corp.	Paper	Yamhill	Newberg	119,880

Table 3. Southern Oregon facilities that utilize merchantable logs and woody biomass (partial list)

Mill Name	Mill type	County	City	Fuel Consumption BDT/Year
East Fork Lumber Company	Sawmill	Coos	Myrtle Point	
Georgia Pacific	Sawmill	Coos	Coos Bay	
Northwest Hardwoods	Sawmill	Coos	Coos Bay	
Roseburg Forest Products	Plywood	Coos	Coquille	34,576
Southport Forest Products	Sawmill	Coos	Coos Bay	
W&L Contractors	Sawmill	Coos	Myrtle Point	
Wilson Operations	Chipmill	Coos	Coos Bay	
Pacific Wood Laminates	LVL	Curry	Brookings	26,132
South Coast Lumber Co.	Chipmill	Curry	Brookings	4,680
South Coast Lumber Company	Sawmill	Curry	Brookings	
All Native Hardwoods	Sawmill	Douglas	Roseburg	
C&D Lumber Company	Sawmill	Douglas	Riddle	
CoGen II	Sawmill	Douglas	Riddle	82,752
D.R. Johnson Lumber Company	Sawmill	Douglas	Riddle	
Douglas County Forest Products	Sawmill	Douglas	Winchester	
Glide Lumber Products Co.	Sawmill	Douglas	Glide	6,220
Herbert Lumber Company	Sawmill	Douglas	Riddle	
Keller Lumber Company	Sawmill	Douglas	Roseburg	
Murphy Plywood Co.	Plywood	Douglas	Sutherlin	9,700
Nordic Veneer	Veneer	Douglas	Roseburg	
Roseburg Forest Products	Sawmill	Douglas	Dillard	
Roseburg Forest Products	Particleboard	Douglas	Dillard	
Roseburg Forest Products	LVL/ I-Joists	Douglas	Riddle	
Roseburg Forest Products	Plywood	Douglas	Riddle	87,966
Roseburg Forest Products	Plywood	Douglas	Dillard	137,577
Sun Studs LLC	Sawmill	Douglas	Roseburg	13,641
Superior Lumber Co.	Sawmill	Douglas	Glendale	27,777
Swanson Group	Sawmill	Douglas	Roseburg	
Swanson Group	Sawmill	Douglas	Glendale	
Umpqua Lumber Co.	Sawmill	Douglas	Dillard	7,135
Weyerhaeuser	Utility poles	Douglas	Wilbur	
Biomass One, L.P.	Power Plant	Jackson	White City	111,895
Boise Cascade	LVL	Jackson	White City	20,042
Boise Cascade	Plywood	Jackson	Medford	101,768
Boise Cascade	Sawmill	Jackson	White City	
Boise Cascade	Plywood	Jackson	White City	
Homestead Log Homes	Log homes	Jackson	Medford	
Murphy Veneer	Veneer	Jackson	White City	
Panel Products LLC	Veneer	Jackson	Rogue River	6,648
SierraPine Ltd.	MDF	Jackson	Medford	
Timber Products Co.	Plywood	Jackson	Medford	
Timber Products Co.	Plywood	Jackson	White City	
Timber Products Co.	Particleboard	Jackson	Medford	
Rough & Ready Lumber Co.	Sawmill	Josephine	Cave Junction	3,250
Timber Products Co.	Plywood	Josephine	Grants Pass	
Collins Products	Particleboard	Klamath	Klamath Falls	
Collins Products	Hardboard	Klamath	Klamath Falls	
Columbia Plywood	Plywood	Klamath	Klamath Falls	15,791
Interfor Pacific Inc.	Sawmill	Klamath	Gilchrist	79,180
JELD-WEN Fiber of Oregon	Door skins	Klamath	Klamath Falls	
JELD-WEN Inc.: Thomas Lumber Co.	Sawmill	Klamath	Klamath Falls	19,431
Fremont Sawmill	Sawmill	Lake	Lakeview	7,655

Table 4. Eastern Oregon facilities that utilize merchantable logs and woody biomass (partial list)

Mill Name	Mill type	County	City	Fuel Consumption BDT/Year
Bear Creek Timber Products	Post & pole	Grant	Seneca	
CoGen Co.: Prairie Wood Products	Sawmill	Grant	Prairie City	96,695
Grant Western Lumber	Sawmill	Grant	John Day	7,695
Malheur Lumber Company	Sawmill	Grant	John Day	4,026
Storm Carpenter Log Homes	Log homes	Grant	John Day	
Louisiana Pacific Corp	LVL	Harney	Hines	
Boardman Chip Company		Morrow	Boardman	
Port of Morrow: Heppner Power Plant	Power Plant	Morrow	Boardman	12,981
Blue Mountain Lumber Products	Sawmill	Umatilla	Pendleton	3,702
Blue Mountain Lumber Products	Pellet mill	Umatilla	Pendleton	N/A
Boardman Pulp Company	Chipmill	Umatilla	Pendleton	
Boise Cascade	Chipmill	Umatilla	Umatilla	
Kinzua Resources	Sawmill	Umatilla	Pilot Rock	
Blue Mountain Log Homes	Log homes	Union	Elgin	
Boise Cascade	Plywood	Union	Elgin	83,055
Boise Cascade	Sawmill	Union	La Grande	24,400
Boise Cascade	Particleboard	Union	La Grande	
Community Smallwood Solutions	Post & pole	Wallowa	Enterprise	
JayZee Lumber	Sawmill	Wallowa	Joseph	
Joseph Timber Company	Sawmill	Wallowa	Joseph	
Wallowa Forest Products	Sawmill	Wallowa	Wallowa	7,143

Table 5. Central Oregon facilities that utilize merchantable logs and woody biomass (partial list)

Mill Name	Mill type	County	City	Fuel Consumption BDT/Year
Line Shack Log Structures	Log homes	Crook	Prineville	
All American Timber Company	Post & pole	Deschutes	La Pine	
High Country Builders Log Homes	Log homes	Deschutes	Redmond	
Northwest Custom Log Homes	Log homes	Deschutes	Bend	
Stanley Custom Log Homes	Log homes	Deschutes	Bend	
Trails End Log Homes	Log homes	Deschutes	Sisters	
Wilderness Log Homes	Log homes	Deschutes	La Pine	
Warm Springs Forest Products Ind.	Sawmill	Jefferson	Warm Springs	35,344
Oregon Log Home Company	Log homes	Wasco	Maupin	
Juniper Log Homes	Log homes	Wheeler	Mitchell	

As can be seen from the tables, primary wood processing infrastructure is not evenly distributed throughout the state. Forty of the 75 sawmills listed are in northwest Oregon and 25 are in southern Oregon. Thus, there are only 10 sawmills in the central and eastern region of Oregon. The 28 veneer/ plywood/ LVL mills are distributed between the northwest (10) and southern (16) regions with only 2 facilities in the eastern region and none in central Oregon. Pulp mills are even more narrowly concentrated – all of the state's pulp & paper facilities are in the northwest region.

Additional details that would be useful for purposes of identifying firms with potential to use specific forms of biomass (e.g., chips, hog fuel, small diameter timber), include wood species used, volumes of raw materials purchased, log sizes preferred (e.g., ability and interest in using small diameter timber), volumes and types of residues produced, and production capacity. Such information is not currently available in published sources. An in-depth census of the industry would be required to obtain the data and it is unlikely that firms would provide detailed information if the data were to be disclosed on an individual mill basis. The data collected by Brandt et al. (2006), for example, are confidential on an individual mill basis.

The tables also list numerous facilities in Oregon that use wood fiber (typically hog fuel) to produce heat and/ or power. Within the last 12-24 months, several mills in Oregon have announced plans to add to existing facilities or work with an industrial partner to expand their current generation capacity. Some examples of projects include:

- Freres Lumber in Lyons,
- Warm Springs Forest Products Industries in Warm Springs,
- Collins Products' Fremont Sawmill in Lakeview,
- Rough & Ready Lumber in Cave Junction, and
- Wallowa Resources has explored small log processing and cogeneration in northeast Oregon. (OFRI, 2006)

Vulcan Power is seeking to develop a stand-alone biomass-powered cogeneration facility in La Pine. The company is seeking a firm to co-locate a small log processing facility with their plant to help reduce fuel shipping costs (OFRI, 2006). Thus, should each of the projects above prove to be successful, markets for woody biomass for power generation are likely to improve in all 4 regions of the state.

The preceding information in this section has discussed the existing infrastructure utilizing various forms of woody biomass by region of Oregon. This does not address the issue of the availability of various forms of biomass in the state. The existing infrastructure combined with potential availability of raw materials in each region are critical pieces of information to assess potential for increased utilization of woody biomass.

Volumes Available

The question, "How much woody biomass is available in Oregon?" is far more challenging to answer than one might imagine. A key term embedded in the question is 'available.' Availability of standing timber varies by ownership, i.e., public (federal, state, county, and municipalities) and private (industrial, non-industrial, and tribal). Certain percentages of lands within both ownerships are 'reserved' or set-aside from commercial timber harvesting, designated for multiple uses, or available for wood production. The 'big picture view' of Oregon's forests is as follows:

- Of the 61 million acres in Oregon, approximately 28 million acres (46%) are forested. Of this, approximately 18 million acres (64%) are publicly owned and 10 million acres (34%) are privately owned.

- Approximately 8.8 million acres (31%) are considered *reserved* in that they are closed to commercial timber harvest by law, regulation, or forest plan requirement. Such acreage includes riparian reserves, late-successional (i.e., old growth) reserves, parks and wilderness areas.

- Approximately 9.2 million acres (33%) are in what may be considered *multi-resource* use, e.g., where timber harvest is balanced with non-wood production goals by state regulations, forest plans, policies, or owner objectives. Such lands include matrix and federal adaptive management areas[3] and national scenic areas, state forests, and portions of private forestland.

- The remaining roughly 9.9 million acres (36%) may be considered '*wood production*' forests, i.e., forests managed at varying levels of intensity for the purpose of producing wood products. This currently includes private and tribal-owned forestlands and a small percentage of federal lands.

(Source: OFRI 2003)

One way to determine volume of biomass potentially available from forestlands is to examine recent and past timber harvest statistics with the expectation that future harvests may be within the range of historic harvest levels.

Just over 4 billion board feet of timber were harvested in Oregon in 2003. Over 84% of this harvest came from private and tribal lands and the remaining 16% from public lands. Figure 3 shows the shift in harvest percentage based on ownership that has occurred within the past 10 to 15 years. In this time period, the share of total annual timber harvest from federal forests declined from representing an average of 50% of the total harvest to representing just 5%.

Private landowners have thus 'picked up the slack' in timber supply due to reductions in federal timber harvesting. As a result, more than 80% of timber harvested in the state is coming from less than 40% of the state's non-reserved (i.e., available for commercial timber harvest) timberlands.

With respect to volume potentially available, one approach is to list standing inventory data from non-reserved public and private lands. This is essentially the multi-resource and wood production forests described above. A more conservative estimate would be to simply look at the wood production forests, however that would exclude large volumes of biomass that are potentially available from forest restoration treatments.

Tables 6 through 9 below show the volumes of merchantable biomass and net woody biomass by county and ownership in Oregon. Public lands include federal, state, county, and municipal forests. Private include industrial, non-industrial, and tribal forests.

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[3] Federal matrix lands and Adaptive Management Areas are designated in the Northwest Forest Plan as open to harvest.

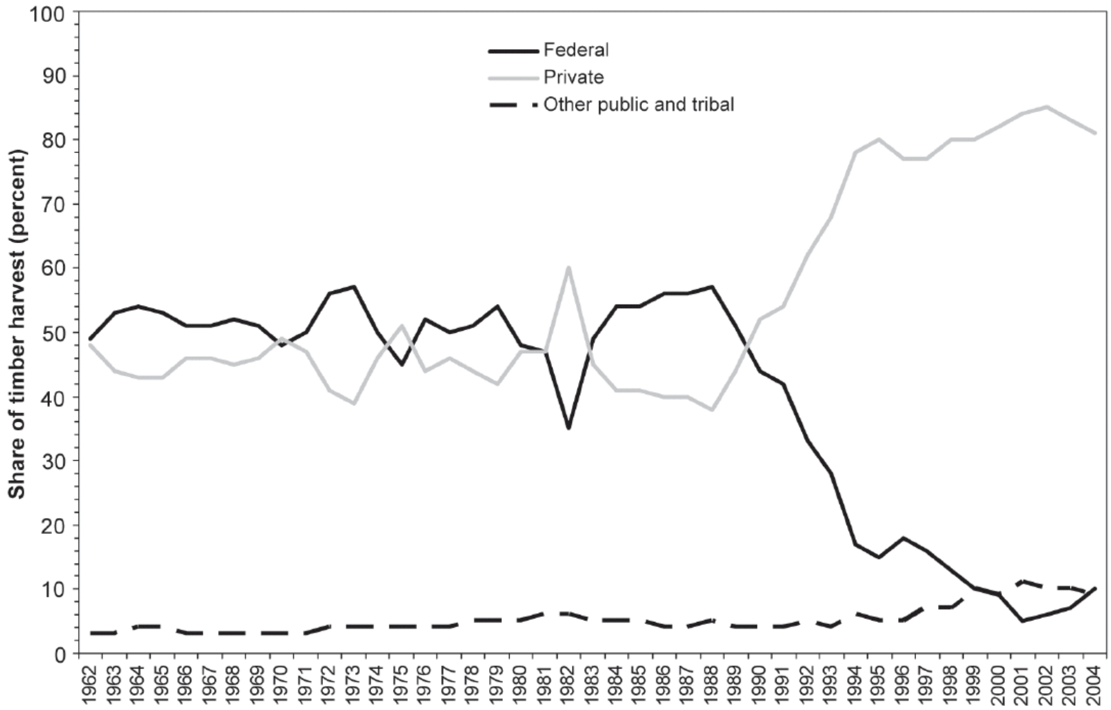

Figure 3. Changing shares of Oregon timber harvest 1962-2004. Source: Andrews and Kutara 2005.

The data reported are from the most recent[4] U.S. Forest Service Forest Inventory and Analysis (FIA) information (USDA, 2002a). Volume of merchantable logs includes the volume contained in all trees (hardwood and softwoods, excluding juniper) up to a 5-inch top. Net biomass is defined as material from bark, branches, tops (i.e., the remaining portion of the merchantable log), and whole trees less than 5 inches in diameter. Note: It would be more common to report merchantable logs in units of MBF rather than tons. However, for purposes of comparison, bone dry tons (BDT) are used for both.

Biomass volumes for western juniper are also provided based on data reported by Azuma et al. (2005). These values consider all juniper stems as biomass, regardless of stem diameter. This assumption is invalid to the extent that local markets exist for juniper sawlogs.

[4] Plot sampling dates for the data vary from 1993-1999.

Table 6. Merchantable logs and net biomass in northwest Oregon

County	Public		Private		Total	
	Merchantable Logs	**Net Biomass**	**Merchantable Logs**	**Net Biomass**	**Merchantable Logs**	**Net Biomass**
Millions of Bone Dry Tons (BDT)						
Benton	5.5	1.9	10.7	4.4	16.2	6.3
Clackamas	23.2	9.9	14.2	6.5	37.3	16.4
Clatsop	10.9	4.5	13.3	7.0	24.2	11.5
Columbia	1.4	0.6	14.2	5.5	15.6	6.1
Hood River	6.0	2.7	1.8	0.9	7.8	3.6
Lane	64.8	24.0	32.6	14.4	97.4	38.4
Lincoln	4.2	1.6	16.8	8.2	21.2	9.8
Linn	20.4	8.3	22.2	9.3	42.6	17.6
Marion	13.9	5.3	8.5	3.2	22.4	8.5
Multnomah	1.8	0.7	2.2	1.1	4.0	1.9
Polk	0.3	0.1	15.2	5.6	15.5	5.7
Tillamook	20.9	9.3	7.4	3.9	28.4	13.2
Washington	8.7	3.2	7.2	2.9	15.8	6.1
Yamhill	0.7	0.4	11.3	4.5	11.9	4.8
Total	182.6	72.5	177.5	77.5	360.1	150.0

Table 7. Merchantable logs and net biomass in southern Oregon

County	Public		Private		Total	
	Merchantable Logs	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass**
Millions of Bone Dry Tons (BDT)						
Coos	19.2	7.6	22.5	11.6	41.7	19.1
Curry	11.0	7.3	12.1	9.4	23.1	16.7
Douglas	64.6	28.1	44.4	21.9	109.0	50.0
Jackson	27.1	13.7	16.5	10.2	43.6	23.9
Josephine	21.1	10.4	9.0	5.0	30.2	15.4
Klamath	26.0	19.7 *0.8*	8.6	7.5 *0.7*	34.6	28.7
Lake	15.8	11.9 *1.3*	5.6	5.8 *0.6*	21.4	19.6
Total	185.0	100.8	118.7	72.6	303.6	173.4

Table 8. Merchantable logs and net biomass in eastern Oregon

County	Public		Private		Total	
	Merchantable Logs	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass**
Millions of Bone Dry Tons (BDT)						
Baker	9.2	5.7 *0.3*	1.5	1.1 *0.1*	10.7	7.2
Gilliam	--	--	--	-- *0.1*	--	--
Grant	25.0	15.2 *0.6*	4.1	2.9 *0.9*	29.1	19.6
Harney	6.6	4.3 *1.7*	0.6	0.5 *0.1*	7.2	6.6
Malheur	0.03	0.01 *0.3*	0.04	0.03 *0.2*	0.1	0.5
Morrow	2.7	1.5	1.1	0.6	3.8	2.2
Umatilla	5.8	3.0	3.8	2.3	9.6	5.4
Union	10.2	5.9	4.9	2.8	15.0	8.6
Wallowa	6.4	3.9	5.8	3.8	12.3	7.7
Total	66.0	42.4	21.7	15.5	87.7	57.8

Table 9. Merchantable logs and net biomass in central Oregon

County	Public		Private		Total	
	Merchantable Logs	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass/ *Juniper***	**Merchantable Logs**	**Net Biomass**
Millions of Bone Dry Tons (BDT)						
Crook	7.6	4.2 *1.5*	1.3	1.0 *1.4*	8.8	8.1
Deschutes	9.8	7.6 *0.7*	1.0	0.7 *0.03*	10.8	9.1
Jefferson	1.1	0.7 *0.1*	5.2	3.3 *0.4*	6.4	4.6
Sherman	--	--	--	--	--	--
Wasco	6.6	3.7	8.6	4.7 *0.1*	15.2	8.5
Wheeler	3.9	2.1 *0.3*	1.4	1.1 *0.7*	5.3	4.2
Total	29.0	21.0	17.5	13.4	46.5	34.5

Certain counties appear to be ‘biomass hot spots’ with respect to large concentrations of net biomass. Douglas County leads the pack with 50 million BDT of net biomass and the neighboring county to the north, Lane County, is second with 38.4 million BDT. The next largest concentrations of net biomass are Klamath County at 28.7 BDT (including juniper) followed by Jackson County with 23.9 million BDT. There is thus a cluster of counties in southwest Oregon – from Lane County south through Douglas County and Jackson County and east to Klamath County where the majority of net biomass concentration is found in the state.

In eastern Oregon, Grant County stands out with 19.6 million BDT - significantly more net biomass than any other county in central or eastern Oregon. This is more than double the volume found in the next highest county – Deschutes with 9.1 million BDT.

With regards to western juniper volumes, Crook County is a juniper biomass 'hotspot' with 2.9 million BDT. This is substantially more than the next two highest counties; Lake and Harney Counties contain 1.9 and 1.8 million BDT, respectively. Klamath and Grant Counties are next highest in juniper volumes at approximately 1.5 million BDT each.

When considering land ownership, Douglas County is unique in that the net biomass volume is nearly evenly split between public and private ownership – 56% and 44%, respectively. Net biomass volumes in Lane County are shifted more towards public ownership at 62% public, 38% private. By contrast, net biomass volume in counties east of the Cascades is slanted towards public ownership. In Klamath County, 71% of the volume is on public lands while in Grant County, 80% of the net biomass volume is on public lands.

Again, while the above tables report estimates of volume standing on public and private lands, the volume that <u>might</u> be available for either commercial timber production or resulting from forest restoration treatments is likely to be substantially less than the values reported in the tables. Filters such as need for restoration treatment (e.g., based on risk of catastrophic wildfire) and steepness of slope (harvest costs increase considerably for steep slopes) must be applied to reach a more reliable estimate of potential volumes available in each region. Such an assessment is provided for 20 Oregon counties (those in greatest need of forest restoration based on fire conditions) in the report *Biomass Energy and Biofuels from Oregon's Forests* (OFRI, 2006). This report is reviewed in the following chapter.

Implications & Gaps

To assess the potential for biomass utilization (for any end product), one must consider a variety of factors including existing forest products processing infrastructure, timber ownership (public/ private), timber volume, and forest conditions (e.g., fuels accumulation and resultant needs for timber harvesting to reduce fire hazard) for each region of the state. The above discussion attempted to provide some information on what and where logs and biomass are currently being used and potential regional volumes of merchantable logs and biomass inventory.

Some key implications and gaps from the above discussion include:

Recent timber harvest statistics reveal that the vast majority of timber supply in Oregon is currently coming from private forestlands. Thus, when considering <u>near-term</u> supply of biomass for any product, it is reasonable to assume this trend will continue. While 64% of Oregon's forests are publicly held, this percentage varies widely county to county. For example, publicly owned forests represent a low of 1.6% of the total volume (log and net biomass) in Polk County. By comparison, nearly 91% of the total volume in Harney and Deschutes Counties is publicly owned. Thus, it is critical to approach biomass utilization from a consideration of conditions unique to each locality.

When considering implications of existing processing (log and woody biomass) infrastructure combined with timber volumes, it is clear that the majority of the infrastructure in Oregon lies west of the Cascades. Southern Oregon contains both vast amounts of merchantable logs as well as net biomass and processing infrastructure. Further, significant volumes of material are on private lands and thus less dependent on federal forest management policy and personnel capacity to plan and oversee timber harvest plans and operations. For these reasons, southern Oregon is worthy of further attention with respect to woody biomass utilization.

At the same time, economic development is critical in most rural areas of the state and eastern Oregon in particular. Grant County stands out as an area with significant volumes of woody biomass and processing infrastructure for logs is still in place. However, markets for mill residues such as chips, sawdust/ shavings, and hog fuel are extremely limited. Further, net biomass supply in this area is heavily dependent on the availability of publicly-owned timber.

Northwest Oregon appears to have the greatest diversity of both processing infrastructure (sawmills, veneer mills, AND pulp & paper) and the most balanced mix of public and private ownership of both merchantable logs and net biomass. Little attention has been given to this area for biomass utilization potential given the strong existing industry in the region. However, as the only region of the state with existing pulp & paper mills, the northwest region is likely to play a role as a 'testing ground' for other regions of the state in that fewer hurdles exist such as dependency on publicly-owned timber and needs to build new processing facilities.

Existing primary processing infrastructure in central Oregon is likely to be a limiting factor in near-term utilization of woody biomass. Again, part of this limitation is an artifact of how regions have been defined here. In short, using county boundaries is convenient for such high-level assessments, however a more realistic assessment would consider hauling radius, given existing roads, to a specific facility. The OFRI biomass report (OFRI, 2006) did just that for a 75-mile radius around both Klamath Falls and La Grande. Regardless, for the central Oregon region, both infrastructure and available merchantable log volume and net biomass volume are modest. As a region for potential western juniper utilization, however, this region has the greatest concentrations of juniper volumes in the state (Crook County in particular).

Dynamics in the industry are complex. For example, increased federal harvest if not accompanied by additional milling capacity could result in oversupply and low prices. This underscores the importance of focusing on developing products for high-value uses as well as for commodity energy products.

And finally, this overview has shown clearly that the mills are interdependent. Biomass users such as pulp and board mills are critically dependent on production from sawmills and veneer mills. Sawmills and veneer mills in turn rely on these residue users as markets for the substantial volume of residues they generate. One cannot exist without the other.

With respect to mill residues as potential sources of wood biomass, it seems unlikely that existing markets can be disrupted in the absence of new, higher-valued markets. For example, a cellulose-to-ethanol facility would have to pay at least as much for its raw materials as a pulp mill or existing particleboard mill in order to compete in the existing residues market. Very little of existing residues go unused. Hence, emphasis on supply potential for woody biomass must focus on net biomass – logging slash and non-merchantable timber.

Limitations

While the above discussion has emphasized log and biomass processing infrastructure, what has not been addressed here is logging and hauling infrastructure. Logging contractors are linked to the mill infrastructure in the area. That is, as mills close, logging must close too. An assessment of supply potential in a region of the state where processing infrastructure is lacking must also consider if the logging and hauling workforce is adequate to provide the proposed supply. Similarly, in areas where expansion of existing firms is contemplated, there will be concerns for sufficient workforce personnel in terms of numbers and skills to enable existing firms to expand.

Again, there is bias in the assessment due to definition of regions and large size of some eastern Oregon counties. For example, Interfor in Gilchrist is closer to Bend than Klamath Falls and thus is as likely to source logs from the central as from the southern region.

Tables 2 through 5 are attempt to list the existing log and biomass using infrastructure in the regions, however many mills are not listed, particularly very small firms. Further, the information does not include details on specific raw materials used (though this can typically be inferred), species, and raw material requirements. With respect to the latter, it is known that for fuel pellets, ‘clean’ (bark and other contaminant-free) sawdust is required, or at least preferred. However, what is the potential for (and interest of) existing firms to use material that might contain higher levels of bark and foliage, perhaps of mixed wood species, for new applications?

Also, the tables provide little indication of markets for small diameter timber. Post & pole facilities are the one exception where one might assume buyers will prefer small diameter timber. However, the capacity of sawmills to use small diameter timber must be addressed on an individual mill basis. In short, a simple listing of existing firms cannot address the level of detail required to fully understand markets for merchantable logs, small logs, and woody biomass.

Estimates of total timber inventory data are, of course, subject to sampling error. In addition, the data are many years old. In the period between when the last inventories were taken and the present, substantial changes have occurred with respect to harvesting on public lands. As discussed above, as a result, private lands have ‘picked up the slack.’ Thus, it is highly likely that inventories have accumulated on public lands and declined on private lands.

Also, the information presented does not include data on secondary wood products facilities. While these firms use primarily lumber and panel products, rather than logs and biomass, these firms also produce significant volumes of residues. There is a need for an assessment of the volumes of flows of materials in this sector of Oregon’s forest industry.

Lastly, no information is presented on the bio-chemicals industry. As mentioned previously, it is known that there are markets for chemicals and chemical feedstocks that are byproducts of pulp & paper production. However, the small number of pulp mills in the state makes it difficult to obtain such information as market data would be relatively easy to trace to an individual mill site, or at least company.

2. Review of Recent Reports on Woody Biomass Utilization

Numerous reports related to biomass utilization have been developed in the past several years. A wealth of information is contained in these reports related to feedstock availability, technology, markets, barriers, opportunities, and recommendations for research. In this chapter, five recent reports relevant to Oregon are reviewed. These reports include:

- *Biomass Energy and Biofuels from Oregon's Forests*, Oregon Forest Resources Institute. June 30, 2006.

- *Forest Biomass Utilization Research Program,* Oregon State University College of Forestry. Working paper. 2006.

- *State of Oregon Forest Biomass Working Group:* report to the Governor's Renewable Energy Working Group: Research and Development Subgroup. January 5, 2007.

- *Biomass Task Force Report,* Western Governors' Association, Clean and Diversified Energy Initiative. January 2006.

- *Forest Products Industry Technology Roadmap:* June 2006. Final Draft. Sponsored by Agenda 2020 Technology Alliance, American Forest & Paper Association, and the U.S. Department of Energy.

Note: Initial plans were to provide a review of the report, *A Cost-Benefit Assessment of Gasification-Based Biorefining in the Kraft Pulp and Paper Industry*, (Larson et al., 2006). However, a key assumption for the report was that technology for black liquor gasification was developed such that a cost-benefit assessment could be conducted. Therefore, there were no discussions of research needs from which implications could be drawn for the BEST Center. Further, the assessment was primarily focused on the U.S. Southeast where 2/3 of kraft pulp mill capacity is located rather than the west coast. For these reasons, a study that did directly present R&D recommendations for biorefining - the *Forest Products Industry Technology Roadmap* - was substituted for the Larson study.

Relevant information from these reports is summarized in the following pages and synthesized to present a synopsis of the barriers, opportunities, and needed research related to forest biomass utilization in Oregon. Particular emphasis is placed on the OFRI report given its comprehensive coverage of the topic of biomass utilization in Oregon including a detailed review of other similar studies, current efforts, barriers and opportunities, and a detailed assessment of potential biomass supply in the state.

Biomass Energy and Biofuels from Oregon's Forests

The most recent and comprehensive report related to woody biomass utilization in Oregon is the Oregon Forest Resources Institute's (OFRI) report *Biomass Energy and Biofuels from Oregon's Forests* (June 2006). OFRI commissioned the study with the objectives to:

1. "Review existing research on potential for production of biomass energy and biofuels from Oregon's forests.
2. Assess the potential for production of electricity and biofuels from woody biomass, including available wood supply and environmental, energy, forest health, and economic effects.
3. Review and summarize efforts underway to promote electric energy and biofuels from wood biomass, and identify gaps in existing efforts.
4. Conduct interviews with Oregon biomass stakeholders to document the diverse perspectives of various groups concerning the opportunities for forest biomass-derived energy production, its potential benefits, and challenges or barriers to development.
5. Assess constraints and challenges to development of biomass energy and biofuels from Oregon forests, including economic, environmental, legal, policy, infrastructure, and other barriers.
6. Develop recommendations on how Oregon can best overcome the barriers to production of wood-based bio-energy."

The primary focus of the report was on identification of short-term opportunities for bio-energy (combustion, cogeneration, and cellulose to ethanol) production in Oregon. As the emphasis was on woody biomass for energy production, the report did not focus on opportunities and barriers for bio-based products or biochemicals; however, the authors frequently acknowledge the importance of value-added products such as can be made from small diameter timber and biochemicals as well. For example, with respect to the latter the authors state, "Production of biochemicals to replace petroleum-based chemicals is also an opportunity that deserves increased attention."

The biomass source of primary interest was forest biomass – logging slash and other non-merchantable logs. Mill residues received secondary attention given that current markets are strong and end products (paper, wood composites, etc.) are higher value. As the authors state, "…it seems unlikely that prices for fuel chips would reach the price of residuals currently used for pulp production. Recent market price for conifer pulp chips average $62 per bone dry ton (BDT) versus $36 per BDT for energy biomass in competitive markets in California." Supply assessments included both public and private land and were examined from national, regional, state, and sub-state levels.

This review will discuss findings for each of the six objectives listed above and conclude with implications for research. As the report was quite detailed and comprehensive (in excess of 400 pages), this reviews is also quite lengthy.

Background - Review of Existing Research

The authors conducted an extensive review of literature on seven broad topic areas relevant to biomass-to-energy production:

A. Current energy trends and emergence of bio-energy alternatives
B. Biomass and biofuels technology
C. Market conditions for woody biomass in Oregon
D. Forest biomass supply
E. Biomass harvesting and transportation technology
F. Environmental impacts of harvesting and use for energy
G. Public perceptions on woody biomass utilization in Oregon

<u>A. Current Energy Trends</u>
This review discusses the impacts of peak oil production and enormous potential for biomass to contribute to domestic energy production. In 2003, biomass represented about 10% of the total energy value of non-transportation fuels used in Oregon in 2003. Of this amount, approximately 37% came from wood wastes and 46% from combustion of pulping liquor. Accelerated thinning of Oregon's forests could greatly increase the amount of material available for bioenergy production in the state. In the U.S. as a whole, over one half the energy used in the forest products industry is self-generated – more than any other sector.

The potential for deriving chemicals and industrial feedstocks from woody biomass is also discussed. The author states, "…the prospect for a petroleum peak within the relatively near term provides both a need and an opportunity for production of industrial chemicals and chemical feedstocks from biomass." Further, the author references the U.S. Department of Energy's forecast for 10% of industrial chemicals and materials to be produced from renewable resources by 2020 and approaching 50 percent by 2050. At a 10% share, the annual value of these chemicals (in 1999 dollars) would be about $400 billion. This is approximately twice the value of all forest products produced in the U.S. in that year. In short, the potential for industrial chemicals appears very strong.

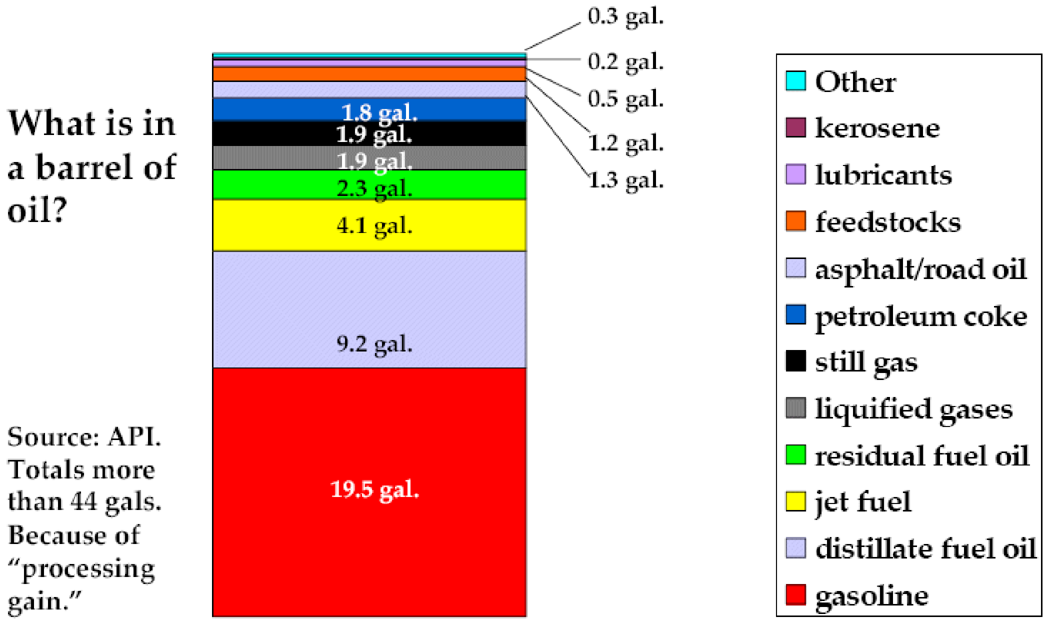

Figure 4. Industrial chemicals derived from petroleum

As indication of the potential, Figure 4 shows the myriad of industrial chemicals derived from petroleum.

With respect to existing energy markets in Oregon, the author reports that currently 3% of the state's electricity is generated from biomass and municipal solid wastes. The dominant source of electricity in Oregon is hydroelectric (44%), followed closely by coal (42%). Wood wastes are currently burned for steam and process heat at 49 sites (see Tables 2 – 5); 10 of these sites also generate power. Pulping liquor is burned at 6 pulp mills and 2 of these sites also generate power. Four of the facilities (Biomass One, Georgia Pacific's Wauna Mill, Port of Morrow: Heppner Power Plant, and Weyerhaeuser's Springfield Containerboard Plant) sell power back to the grid.

The author concluded the review by saying the greatest near-term opportunity for bio-energy in Oregon is biomass-derived electricity generation. Longer term, the state is "…in a strong position to exploit cellulosic ethanol markets…" The greatest potential benefit to the state would result from pursuing a liquid fuels industry that also produced a range of industrial chemicals and advanced composite materials. And finally, the review provides strong support for partnering with existing wood products firms in that, "A major risk is that without the active participation of the state's wood products industry, decisions may be made that do not maximize potential returns or that lead to whole new industries that are exclusive of the current wood using sector."

B. Biomass and Biofuels Technology

This section discusses the "sugar platform" route to produce fuel ethanol from forest residues and combined heat and power (CHP, a.k.a. cogeneration) technology. A significant portion of the discussion focuses on feedstock preconditioning, i.e., steps taken to reduce particle size and prepare feedstocks for pretreatment. Preconditioning involves:

1. harvesting/ collection
2. debarking/ peeling
3. coarse chipping
4. coarse screening
5. drying and storage (optional)
6. fine-milling (most costly step)
7. delivering to main pretreatment processing

Particle size is particularly important as it influences the mass and energy transfer properties of biomass as well as reactivity; particle size optimization is integral to chemical, thermochemical, biochemical, and microbiological processes. Put simply, it is critical to understand that 'raw logging slash' (i.e., small stems, limbs, foliage, etc.) is not a suitable feedstock for cellulose to ethanol processing. Significant effort (and thus cost) is required to properly prepare the material for ethanol production. Further, there is a gap in publicly available information on "…state-of-the-art milling options applied to specific biomass feedstocks…" Also, much of the research in cellulosic ethanol to date has focused on hardwoods. Thus, for Oregon feedstocks, there is a need for research focused on softwoods.

There is also mention of the need for technology to efficiently remove water in ethanol recovery, particularly with respect to smaller scale ethanol production facilities.

The section on cellulosic ethanol concludes with the comment "…a better understanding of the chemical nature of the non-carbohydrate components, along with improvements in applicable separation technologies, will undoubtedly reveal constituents that have potential as value added products."

The review of CHP discusses that the technology is well established. Generating power from biomass is dictated by having access to very low cost biomass supplies. The Department of Energy reported that, under economic conditions in 2000, cost of transporting biomass fuels beyond 20 miles was significant and prohibitive for distances greater than 100-200 miles.

Particle size is also discussed as important for CHP as is design for multiple fuels. With respect to efficiency, the author states that cogeneration dramatically increases the efficiency of net energy capture.

The review concludes by discussing the feedstocks and capacity for four Oregon biomass facilities including the Warm Springs Forest Products Industries, Biomass One, Douglas County Forest Products, and Collins Companies (Fremont Sawmill). These facilities are listed in tables 2-5 above.

<u>C. Market Conditions for Woody Biomass in Oregon</u>

Current market conditions and trends for hog fuel, chips (mill residues), and woody biomass from logging operations (slash) are discussed. Results indicate that the market for logging waste (slash) is limited due to high recovery and transport costs. For these reasons, nearly all of this material is currently left in the woods following timber harvesting operations. Most of the material is piled and burned (at the expense of the logging contractor).

According to the US Forest Service, in 2002, $222.6 million worth of mill residues were produced in Oregon. The volumes were distributed as shown in Table 10 below. This information is quite similar to that presented by Brandt et al. (2006) and shown in Table 1 above.

Table 10 - Volume of mill residues (bone dry tons - BDT) produced in Oregon and end use in 2002.

Primary Mill residues	Total Residue Product	Secondary End Use			
		Fiber Byproducts	Fuel Byproducts	Misc. Byproducts	Un-used Mill Residues
Bark	1,443,828	499	1,188,002	249,744	5,583
Coarse wood	3,398,509	2,869,026	196,046	330,274	3,163
Fine wood	1,992,489	1,490,387	344,378	156,557	1,166
Total	6,834,826	4,359,912	1,728,427	736,575	9,912

Source: USDA Forest Service (2002)

The majority of residues (64%) were used in secondary fiber products, primarily for pulp and paper; 25% were used as fuel. Less than 1% of the 6.8 million BDTs generated in 2002 in Oregon were unused. While some have speculated that some of these residuals could be redirected to energy production, this is unlikely given the relatively high prices paid for chips in the pulp & paper market. Prices for pulpwood chips have reached as high as $120 per BDT in late 2006 whereas energy biomass prices were around $35 per BDT.

The potential supply from logging slash and material from precommercial thinnings (i.e., logs too small to be merchantable) is much larger than for mill residues. However, high transportation costs and lack of reliable long-term supply have resulted in limited markets for these materials.

A table listing the 49 facilities in Oregon that burn wood fiber solids for steam and process heat is provided including the mill type, location, fuel consumption, and energy of fuel consumed. As described above, this table was used to create Tables 2-5 above (however, numerous additional wood products manufacturing facilities that do not burn wood fiber were added).

The best potential for new forest biomass-based biomass facilities appears to be in eastern Oregon due to proximity to the resource, drier fuel supply, and the need for thinning. However, the authors report that the information they reviewed suggests, "…limited market potential in the near- to mid-term for the use of forest biomass in energy production." The caveat for this statement, however, is the fact that several recent efforts in eastern Oregon (LaGrande, Wallowa, and Warm Spring in particular) may serve to prove that the potential is better than it appears.

As further support for the notion of partnering with existing industry, the authors state, that the economics of ethanol production could be improved by the coproduction of biochemicals from lignin as well as using pulp and paper mill sludge as a potential feedstock. Thus, an ethanol facility could benefit from locating in proximity to a paper mill.

D. Forest Biomass Supply

Biomass supply estimates are provided based on reports estimating national, regional, statewide, and sub-state volumes. Table 11 presents a summary of 3 studies estimating regional volumes.

Table 11. Summary of results from three regional forest biomass studies.

Study	Region Included	Trees Removed	Million Acres Treated	Removal Per Acre (BDT)	Total Volume (MBDT)	Biomass Volume (MBDT)	Merch. Volume (MBDT)
Sampson et al. (2001)	11 Western States	Variable percentage of trees in 5-11" dbh classes	28.7	15.0	400	n/a	n/a
USDA Forest Service (2005)	15 Western States	All diameter classes from 2" dbh but generally from small to medium sized trees	96.9 (All treatable)	22.3	2,154	617	1,537
			66.9 FRCC2+3	22.3	1,493	433	1,060
			28.5 (FRCC 3)	20.2	576	167	409
			17.1 (FRCC3*0.60)	20.2	346	101	245
Western Governors' Association Biomass Task Force (2006)	12 Western States	Thin from below on 50%; thin across all diameters on 50% of area	10.6 (treatable, providing 300 ft^3/acre of merchantable wood)	25.5	270	135	135

dbh = tree diameter at breast height (4.5 feet)
MBDT = Million Bone Dry Tons
FRCC = Fire Regime Current Condition Class:

- Class 1 includes forested acreage where fires are within an historical range and risk of losing key ecosystem components is low; areas can be maintained by treatments such as fire use.
- Class 2 includes forested acreage that has been altered moderately from the historical range. Risk of losing key ecosystem components is moderate; fire frequencies have departed from historical values; these areas may need moderate level of restoration treatments such as by mechanical (timber removal) means.
- Class 3 includes forested acreage that is significantly altered from the historical range; risk of losing key ecosystem components is high; these areas may need high levels of mechanical treatments to be restored to the historical fire regime.

As can be seen from the table, volumes vary widely depending on assumptions made and definitions of treatments. For example, the US Forest Service study demonstrated how volume would vary if all acres were treated, or if only those in various 'risk classes' (Fire

Regime Condition Class – FRCC) were treated. The Western Governors' Association Study focused on 'thinning from below' (i.e., removing trees starting with the smallest trees first for ½ the area and across all tree diameters on ½ the area).

Four reports providing statewide estimates for Oregon biomass were reviewed as well. Table 12 below presents the results of these studies.

Table 12 - Summary of statewide reports on forest biomass supply in Oregon.

Study	Harvest Residues	Mill Residues	Forest health thinnings	Comments
		Million BDT/yr		
Walsh et al. (1999)	1.3-2.5	0.0-6.8		Based on current harvest levels
CH2MHill (2005)	1.8	0.06	2.5	Assumptions for thinnings not provided
Graf and Koehler (2000)			2.9	Thin 140,000 ac/yr for 50 years
			7.3	Thin 350,000 ac/yr for 20 years
			14.5	Thin 700,000 ac/yr for 10 years
USDA Forest Service (2005)			0.8-6.4	Depending on landbase available for treatment if treated in 20 years
			1.6-12.7	Depending on landbase available for treatment, if treated in 10 years

The US Forest Service study showed that Oregon is first among western states for acres of forest in need of treatment and for acres in FRCC 2 and 3 (moderate to high risk of losing key ecosystem components) as well as FRCC 3 acres. There are 16.9 million treatable acres of timberland in Oregon, 12.2 million acres of FRCC 2 and 3, and 5.6 million acres of FRCC 3. Treating only FRCC class 3 lands would result in 91 million BDT removed whereas treating all acres would result in 437 million BDT. The authors assume that 29% of this volume would be non-merchantable and thus available for energy production. Thus, volumes available would vary from 16 to 127 million BDT. These values were used to derive the volume per year estimates shown in the 'Forest health thinnings' column in Table 12.

Finally, 3 reports were reviewed that provided sub-state estimates for biomass supply in Oregon – 2 studies were conducted for northeast Oregon (Grant-Wallowa Counties and Baker-Wallowa-Union Counties) and one for the east Cascades and southwest Oregon/ northern California region.

For the Grant & Wallowa Counties study, estimates varied from 5.55 to 8.28 million BDT in Grant County; the vast majority (82%) of which would come from National Forests. For Wallowa County, estimated supply was 3.95 to 5.93 million BDT; by contrast with Grant County, over 70% of this volume would come from private forestlands. Such a significant difference in public/private mix of available timber volumes demonstrates the importance of examining markets on a local level. Note: These volume estimates are for total biomass (i.e., merchantable as well as non-merchantable material). Other studies report biomass volume to be 25-29% of the total volume removed. Thus, to arrive at non-merchantable biomass volumes (i.e., material available for energy production), the values for Grant and Wallowa Counties should be multiplied by 0.25- 0.29.

The study conducted for Baker, Wallowa, and Union Counties was more comprehensive than other studies in Oregon to date. Potential sources of biomass examined included forest biomass (material from forest restoration, precommercial thinning, timber stand improvement, and logging residues), mill residues, and agricultural residues. One potential limitation of the study was that the volumes estimated were based on current levels of timber harvest rather than accelerated harvesting that might result from increased efforts to improve forest health and reduce fire danger. The estimates are thus likely to be quite conservative.

Volume available from forest biomass varied from 231,000 to 318,000 BDT/yr in the three-county area. Fifty-three percent of this volume would come from private land and 46% from federal (with the remaining 1% from state, county, and municipal ownerships). Assuming these volumes would need to be reduced to accommodate technical barriers such as steep slopes and ecological concerns such as the requirement to leave some biomass on-site to reduce soil erosion and provide wildlife habitat, the estimated volume of biomass available would be 179,000 to 246,500 BDT/yr.

Mill residues in the three-county region are estimated at 357,500 BDT/yr. All are currently utilized either by mills in the region such as a particleboard mill in La Grande or pulp mills outside the region. The authors assumed approximately 20% of this volume might be available for energy (particularly the volume currently sold outside the region).

For the east Cascades and southwestern Oregon regional estimate, US Forest Service Forest Inventory and Analysis (FIA) data were combined with simulations of alternative fuels reductions treatments, and estimates of harvest and haul costs to identify biomass 'hot spots.' Hot spots were defined are areas with the best potential for accumulation of biomass, merchantable volume, net revenue, and acres treated assuming 4 biomass processing facilities capable of generating 50 MW each.

The study focused on a 28 million-acre region. After excluding Wilderness areas, parks, preserves, and roadless areas, and steep slopes more than 2000 feet from roads, the remaining study area included 8.2 million acres of federal land and 2.2 million acres of private.

The 4 sites chosen were Bend, Klamath Falls, and Grants Pass in Oregon, and Burney, California. Seven treatment scenarios were examined: 1. maximum revenue; 2. maximum improvement in Torching Index[5]; 3. minimizes merchantable timber removed; 4. maximizes improvement in Crowning Index[5]; the three additional scenarios were variations of scenarios 1-3 (titled 1A, 2A, 3A) that only treated plots that broke even or generated positive revenue. Biomass had an assumed value of $18/green ton (equivalent to $36/BDT).

[5] Torching Index is the estimate of the wind speed at which a fire could be expected to move from surface fuels into tree crowns (upper portion of the forest); Crowning Index is the wind speed at which a crown fire could be expected to be sustained. For both indices, a higher value indicates lower risk of catastrophic forest fire.

Table 13 shows volume of biomass delivered to the various sites by treatment scenario.

Table 13. Volume of biomass delivered to hypothetical processing sites by fuel treatment policy scenario (Fried et al. 2005)

Processing Site	Biomass Delivered by Scenario (millions of green tons)					
	1	**2**	**3**	**1A**	**2A**	**3A**
Burney (CA)	24	30	21	11	12	12
Klamath Falls	14	15	12	7	7	7
Bend	12	11	9	8	8	8
Grants Pass	30	37	34	16	17	21
Total	**79**	**94**	**75**	**42**	**44**	**47**

Note: The authors do not state why scenario 4 is not listed in the table.

The study concluded that 75% of the material removed would be merchantable. Although biomass represented 25% of the total volume removed it only represented 10% of the total value recovered. The authors conclude that "Biomass rarely pays its way out of the woods. Haul cost alone averaged $8.53 per green ton ($17.06/BDT), nearly half the delivered market value. Harvest costs exceeded the remaining $9 per green ton of value by a significant margin."

Lastly, with respect to potential biomass supply in Oregon, two additional sources of supply are examined – hybrid poplar plantations and western juniper. There are more than 34,000 acres of hybrid poplar plantations in Oregon. The plantations were established primarily to supply chips to pulp & paper mills. However, the companies that own the plantations shifted focus to longer harvest rotations (period between planting and harvest) to grow larger timber destined for solid wood markets. The authors state therefore that, "higher values for lumber and wood chips are likely to preclude use of much of the volume produced in these plantations for energy production." However, harvest residues may be available. Such residues are estimated to be 7 to 15 BDT/acre. Assuming a rate of harvest of 3,400 acres per year (11-year rotation), this would produce 23,800-51,000 BDT/yr. This is a relatively small volume and would thus likely be a supplemental, rather than sole source, for an energy facility.

With respect to western juniper, the authors review the significant expansion of the species (considered invasive) and resulting degradation of rangeland (loss of grasses and forbs for forage, erosion, etc.). There is, therefore, significant interest in thinning juniper stands to restore rangeland function. In eastern Oregon, juniper acreage increased from 420,000 acres in 1936 to 3.6 million acres in 1999. The mixture of public to private is nearly evenly split with 1.5 million acres on federal land and 1.6 acres on private land (with the balance in tribal, county, state, and municipality). Total biomass of juniper is estimated to be 12.6 million BDT (excluding foliage). Fifty-six percent of the volume is on federal lands and 41% is on private. Counties with significant juniper volumes include Crook (2.7 million BDT), Lake (1.7 million BDT), Harney (1.6 million BDT), Klamath (1.5 million BDT), and Grant (1.4 million BDT). Other counties with moderate (by comparison) juniper volumes include Wheeler, Deschutes, Jefferson, Malheur, and Baker Counties.

The primary challenge with juniper harvesting is high harvesting costs due to low volumes per acre (averaging 3.3 BDT/acre) and poor stem form – highly-tapered large trees with limbs often all the way to ground level. Despite the expense, juniper biomass has been shipped to the Honey Lake power plant in Wendell, CA since 2000. Thus, there are some lessons to be gleaned from experiences in a neighboring state. As with any of the woody biomass discussed here, the significant need to thin stands for rangeland improvement combined with interest in renewable energy provides strong incentives to seek value-added markets for this raw material.

E. Biomass Harvesting and Transportation Technology

In this section, a summary is presented of literature related to forest biomass harvesting and transportation costs. The information here is critical as one of the primary barriers to biomass utilization for energy is harvesting and transportation costs. As the author states, "Biomass energy has the potential to become more cost competitive with other forms of energy if the delivery of woody material was a more dependable and affordable option for facility managers."

Studies are examined from both domestic as well as international settings in an effort to identify technologies and methodologies that might be adapted for use in Oregon. Systems examined included basic harvesting technology (e.g., manual timber felling and either manual extraction or with animals or ATVs), conventional logging operations (e.g., feller-bunchers, single-grip harvesters, forwarders, skidders, and small skyline systems), and modified or purpose-built equipment (e.g., modified farm tractors, specialized equipment for extracting small diameter stems). The latter category has been particularly prevalent in Europe and Scandinavia where biomass has been used on a larger scale than in the U.S.

Currently, most forest restoration/ fuels reduction harvesting that occurs is essentially a commercial harvest with biomass as a by-product. Thus, it is difficult to know biomass harvesting costs because they are essentially 'mixed' with the costs of an integrated harvest. Were the costs to be segregated by merchantable and non-merchantable material, the costs for the non-merchantable material would increase considerably.

Harvesting costs vary with technology utilized, piece size, distance to landings (areas in a timber harvest where logs are stored and trucks loaded), and volumes per acre. In general, research has shown that 8 inches is the 'magic number' for tree diameter in timber harvesting operations; profitability rapidly declines as average log diameter drops below 8 inches.

In Nordic countries, biomass is typically transported in chip form. Chips are either generated in the forest as trees are felled or produced at the landing; increasingly, logs are chipped at the landing. Chipping at the landing is also common in the U.S. as it is more economical to transport densified, rather than loose, material. Nordic countries have also experimented with slash bundlers – machines that accumulate slash in densified and 'packaged' bundles for transport. For these machines to operate efficiently, slash must be concentrated. There has been limited use of this technology in the U.S. The author also states that what is being hauled is energy rather than tons of biomass; as such, he recommends research on other approaches to 'maximize energy per load.'

Non-traditional forms of transport may hold some promise. For example, roll-off bin containers can be used to haul chips or loose residue. While not cost competitive with chip vans, these bins can be hauled on conventional trucks that are able to navigate roads impassable for chip vans. The author recommends more research on the applicability of roll-off bin containers and other transport systems for biomass.

With respect to western juniper harvesting, one study reported harvest costs at a very high $150/BDT. However, these costs included slash piling which could be more appropriately allocated to management rather than harvesting. If that were the case, costs would drop to $91.50/BDT – which are still extremely high given that hog fuel is often valued at around $35/BDT delivered. In short, if juniper is to be used for biomass for any end use (energy, biochemicals, value-added products), research is needed to significantly lower harvest costs.

While Scandinavia is often touted as the example of a region whose systems should be emulated, there are some caveats that make direct imitation unlikely. For example, in Nordic countries, biomass harvesting from small stems decreased in the 1990s due in part to competitiveness of forest residues for energy conversion. In Sweden and Finland, biomass is currently collected from harvest residues from a final (i.e., merchantable) harvest rather than from thinnings. Denmark's high energy tax on fossil fuels and lack of a pulpwood market also aid in the feasibility of biomass markets.

The author concludes that, in the Pacific Northwest, biomass for fuels typically range in value from $25-$40/ BDT delivered to the facility. Given the literature reviewed, there is no system (felling, extraction, and transport) that would result in positive net values. Integrated harvesting, i.e., inclusion of some component of merchantable timber, is currently the only way for the treatments to be economically feasible. However, if the mindset of the landowner is such that markets for biomass are seen as merely subsidizing (rather than fully funding) forest restoration work, then the potential volume available will be far greater than if forest restoration is only conducted in situations where the material 'pays it way.'

F. Environmental Impacts of Harvesting and Use for Energy

This section examines the literature for important positive and negative environmental impacts of forest biomass harvesting and woody biomass use for energy. A report for the Western Governors' Association (WGA, 2006) presented a framework for exploring social and environmental impacts. Biomass is either 1) used for energy production or 2) burned in the open, spread/ composted, landfilled, etc. The impacts of each option on air pollution, greenhouse gases, water use, land impacts, and groundwater contamination are considered. Further, the impacts are compared to those resulting from the energy alternative of fossil fuels (coal and natural gas).

The science indicates that use of forest biomass for energy production provides benefits from reducing the risk of catastrophic wildfire and restoring overcrowded forests to more natural conditions, and from replacing non-renewable energy with renewable energy. Benefits include air quality improvement, reduction in greenhouse gases, conservation of soil and water, and protection of wildlife habitat. Benefits result from forest restoration as well as from replacement of fossil fuels.

Air quality improves due to reduced pollution from wildfires and reduced emissions from energy generation via fossil fuels. Estimated environmental benefits of biomass energy are 11.4¢/kWh. The value of avoided forest overgrowth is estimated as 20.2¢/kWh. The estimated net benefit of fuel reduction treatments is $606 - $1,402+ per acre. Results suggest that the environmental benefits of forest biomass use for energy exceed the market value of electricity produced.

G. Public Perceptions on Woody Biomass Use in Oregon

Understanding public perceptions on woody biomass use is critical to the development of management strategies given that much of the material of interest is found on public lands. Converting biomass to energy in Oregon is not a new concept. What is new, however, is the both the larger scale of the efforts (perhaps statewide) and the fact that biomass removal will be conducted specifically for the production of energy. Few studies have been conducted on public perceptions of woody biomass use for energy in Oregon. Therefore, reports and interest group position papers on topics such as forest health, forestry, biomass utilization, and renewable energy were used as indicators of public perceptions on the topic at-hand.

Viewpoints of specific groups vary, as would be expected. For example, the policy statement of the Rural Voices for Conservation recommends "…development of a wide range of value-added products made from small-diameter timber, and small-scale bioenergy facilities that serve the local community (1-10MW)."

The Oregon Natural Resources Council sees biomass removal for forest restoration as being short term. Hence there is risk of the 'tail wagging the dog' in that energy facilities, once built, could lead to harvesting in excess of what is needed for restoration.

Many organizations feel that demonstration projects are essential to show stakeholders the results of forest restoration work, bioenergy facility impacts, etc.

Results suggest that public support for woody biomass utilization is contingent on projects being driven by forest restoration goals rather than economic interests. This point is key in that it significantly impacts the nature of the raw materials to be obtained from the forests (i.e., predominantly material with little current market value).

Assessment of Potential

The estimate of potential supply of woody biomass available in Oregon from the preceding section of the OFRI report was based on a review of studies on the topic. In this section of the OFRI report, the authors report on the results of their own assessment. The assessment provides a conservative estimate of potential woody biomass available from thinning forestlands in Oregon that are most in need of forest restoration. These 'at risk' acres are defined as a 20-county area of southern and eastern Oregon. On a statewide basis, other sources of biomass are discussed as well including western juniper, hybrid poplar, and mill residues. Additionally, assessments are conducted for 2 locales – La Grande in northeast Oregon and Klamath Falls in south-central Oregon.

The authors used the US Forest Service's Fuels Treatment Evaluator (FTE) for the assessment. FTE includes public and private timber inventory data from the Forest Service's FIA program. Two forest types were considered: those that tend towards surface or mixed fires and those for which high-intensity fires naturally occur.

The assessments (20-county and 2 regional) involved three primary steps:

1. Filters were used to identify the eligible landbase (based on Fire Regime Condition Class and other factors relevant to fire risk and roadless areas) and 2 conditions for sensitivity analysis - steepness of slope (due to high harvesting and extraction costs), and plots for which merchantable harvest would generate less than 300 ft^3/ acre of timber.
2. Alternative thinning regimes were simulated; the regimes varied by how trees were selected for removal (essentially by size) and impact on Crowning Index and Torching Index (i.e., resulting reduction in fire risk); and
3. Merchantable and non-merchantable volumes resulting from treatments were estimated as were harvest and transport costs to 8 theoretical sites - Bend, Grants Pass, John Day, Klamath Falls, La Grande, Roseburg, Warm Springs, and Wallowa.

<u>Twenty-County Area</u>
The 20-county study area included 14.9 million acres of timberland (i.e., not including parks and wilderness areas) of which 69% was publicly owned and 30% privately owned. Of the 14.9 million-acre area, 12.4 million acres are in FRCC 2 and 3, that is, the vast majority of the forests in the region are at moderate to high risk of losing key ecosystem components due to forest fire. This is a key strength of the study in that the region selected for the assessment is predicated on those forests for which forest restoration is a documented need. Referring to the public perceptions review presented above, these are the forestlands for which public acceptance of treatments is most likely. The treatment scenarios chosen further address some groups' concerns for removal of larger timber.

Different assumptions were applied for harvesting treatments on public vs. private land. In essence, treatments for private land emphasized economic viability whereas for public lands, treatments emphasized social acceptability.

Following application of the 'fire hazard filter' and removal of roadless areas, a conservative 4.25 million acres were deemed eligible for treatment and defined as the 'Base Case.' Eliminating slopes steeper than 30% reduced eligible acreage to 2.9 million acres; application of the ‘<300 ft^3 merchantable timber’ filter resulted in 1.5 million acres eligible for treatment. Certain counties are ‘hotspots’ in the sense of eligible acres. Douglas and Klamath Counties each had over 500,000 eligible acres. Grant, Jackson, and Lake Counties each had over 400,000 acres. Douglas and Jackson counties in southwest Oregon alone represented 55% of the total volume available.

For the Base Case, as defined above, treatments would result in 45.5 million BDT of total biomass of which 22.4 million BDT would be ‘net biomass’ (non-merchantable timber, branches, and tops). Removing steep slopes would reduce volume by about ½. Approximately ¼ of the volume is found in treatments with less than 300 ft^3 per acre (i.e., insufficient merchantable volume to cover costs). By region, southern Oregon (excluding Coos & Curry Counties on the south coast) represent 16.8 million BDT of net biomass. Northeast Oregon would net 3.2 million BDT and central Oregon 1.8 million BDT.

With respect to harvesting costs, 54% of the volume can be brought to roadside for less than $40/BDT and 68% for less than $60/BDT. Note: These costs are for ‘integrated’ harvesting, in other words, where costs for harvest and extraction are spread over both merchantable and non-merchantable material.

Transportation costs to the closest facility (of 8 hypothetical locations) showed that 64% of the volume could be hauled for less than $20/BDT and 85% for less than $28/BDT. Average haul costs were $19.20/BDT.

Assuming delivered prices for merchantable timber of $400/ MBF (thousand board feet) and $36/BDT for biomass, net revenues varied by treatment scenario as shown in Table 14 below.

Table 14. Net revenues per acre by treatment

Treatment	Net revenue ($/ acre)	Merchantable timber (MBF/ acre)	Net Biomass (BDT/ acre)	Comments on Treatment
1A	$1270	6,400 MBF	9.6	Thins across all tree diameters; leaves relatively more small trees and removes more larger trees than 2A
2A	$484	3,700 MBF	7.7	Thins across all tree diameters; leaves less structural diversity than 1A; removes more small trees and leaves more larger trees
3A	($93)	<1 MBF	5	Thins from below – removes trees beginning with smallest and proceeding to larger trees until fire reduction goals are met.

Over a 20-year period, 212,500 acres would be treated per year (151,000 public and 61,000 private) to result in 410 MMBF (million board feet) of merchantable timber per year and 1.1 million BDT of net biomass.

The authors discuss what they refer to as the ‘sawtimber subsidy.’ In short, “The cost of harvesting and transporting the biomass material is nearly always subsidized by the sale of more valuable merchantable products.” In this regard, treatment decisions are likely to vary for public vs. private landowners. Specifically, the authors propose the following:

> “The concept of using sawtimber revenues to cover, or subsidize, the costs of fuel reduction treatments may make sense from the standpoint of a public land management agency charged with reducing fire hazard over large acreages with minimal outside funding. However, an economically rational, profit-maximizing private landowner would likely make a different calculation. He/she is likely to view biomass removal cost at the marginal or incremental cost. They would compare the harvest cost per acre with and without biomass recovery and attribute all of the additional cost to the biomass rather than spreading it over the merchantable volume. For example, if a planned logging job would cost $500/acre for merchantable volume and $900/acre including biomass removal, the incremental $400/acre (plus haul cost) would be compared against the market value of the biomass. Unless the landowner can at least break even on the biomass, or there are other objectives attained through biomass removal (e.g. timber stand improvement or fire risk reduction), the landowner would not be motivated to incur the loss of profit from biomass harvest.”

Given uncertainties for supply of biomass from public lands, it will be critical to determine if this statement above accurately reflects the sentiments of private landowners. The following chapter in the present report attempts to do this via interviews with private landowners.

The statewide assessment is summarized as follows: 1.0 million BDT per year could be available for 20 years at an average delivered cost of $59/BDT. This would enable generation of 146 MW of electricity or approximately 18 MW at each of the 8 hypothetical locations. To produce electricity in the 6.5¢ to 7.5¢/ kWh range, delivered costs for biomass need to be reduced to $45/BDT. Alternatively, for ethanol production, an annual volume of 1 million BDT of biomass would enable 61-66 million gallons of ethanol at an average cost of $0.97/ gallon for the feedstock.

Several caveats are provided, among these are that the FIA data for inventory are old (2002 for national timber assessment and 1992 for non-federal lands). Further, the volume estimates depend heavily on actions of private landowners (29% of the acreage). Further, northwest forests were excluded as these forests do not have the same level of need for treatment to reduce fire hazard. However, research is needed to identify the restoration needs of these forests and further, the potential volume of logging slash available given that the majority of commercial timber harvest in Oregon today occurs on private lands in northwest Oregon (Brandt et al., 2006). Thus, a significant volume of woody biomass is being generated in the part of the state not covered by the OFRI assessment. CH2M Hill (2005) estimated that, statewide, 1.8 million BDT of material is left in the forests after logging operations. Given that only 19% of the state’s timber harvest during 1990-2004 was in eastside counties, the volume of woody biomass in western Oregon is likely to be quite substantial.

Additional potential sources of biomass are also addressed including western juniper, hybrid poplar, slash from commercial timber harvests (as distinct from the forest restoration harvests discussed here) and mill residues.

It is important to note that western juniper is not taken into account in the assessment above because juniper forests do not meet the technical definition for 'timberlands' – lands capable of producing at least 20 ft^3/acre/year and not administratively withdrawn from timber harvest. There is an estimated 11.8 million BDT of juniper biomass available for stems greater than 5 inches (Azuma, 2005). Over a 20 year-period, treating 178,000 acres per year would result in 600,000 BDT/yr. However, the delivered cost is unknown.

Estimates of potential volume of woody biomass generated from hybrid poplar plantations were discussed in a previous section. The authors report that juniper, poplar, and slash from existing commercial timber harvests could provide an additional 1 million BDT/year above and beyond the volume generated from forest restoration treatments.

Lastly, with respect to potential biomass volumes from a statewide perspective, there is the issue for additional mill residues. In the Base Case discussed above, an additional 410 MMBF of sawtimber would be generated each year. This would represent a 31% increase in harvest level in the 20-county study area compared to 2004 harvest levels (9% for the state as a whole). Such increases in log supply would undoubtedly impact the industry, though it is difficult to determine the specific impact. If mill capacity increases, markets will be strong. Otherwise, log prices will decline and private landowners will have little incentive to harvest. Further driving the point home of needing to consider local circumstances, for ponderosa pine in particular, markets in eastern Oregon have shrunk considerably due to imports of radiata pine from the southern hemisphere plantations. Hence, for the market to absorb an increased volume of pine sawtimber, new markets may need to be developed in eastern Oregon.

Regional Assessments – Klamath Falls and La Grande

Volume and delivered cost estimates were also conducted for biomass obtained from forests within a 75-mile radius of both Klamath Falls (including counties in northern California) and La Grande (including counties in southeastern Washington).

For both locations the mix of public and private forestlands were approximately 50:50 for two of the treatment scenarios and approximately 75-80% public for a third scenario. Results for the Base Case are shown in Table 15 below.

Table 15. Regional volume and cost estimates for Klamath Falls and La Grande

City	Merchantable Timber (Total BDT, BDT/acre)	Net Biomass (Total BDT, BDT/acre)	Avg. Delivered Cost ($/BDT)
Klamath Falls	11.4 mill., 10.3	9.4 mill., 8.4	$76
La Grande	1.6 mill., 5.1	0.965 mill., 3.7	$73

The authors state that very little volume can be delivered for less than $45/BDT in either location. Significant volumes from California are obtained in the Klamath Falls case; however, volumes from Washington are not significant for La Grande. Accounting for harvest systems adapted to steeper terrain is more significant in La Grande.

Current Efforts

This chapter of the OFRI report reviews state, federal and private efforts related to biomass utilization for energy, discusses projects underway, and relevant efforts in other states. The purpose is to document these efforts, assess their effectiveness, and identify gaps and opportunities. Detailed discussion of these efforts is beyond what is needed for the present review, however interesting statements from the summary include:

There is a bewildering array of grant and incentive programs and no single source of information for stakeholders. For this reason, many programs such as the Federal Joint Biomass Research and Development Initiative (a multi-agency effort), Fuels Utilization and Marketing Program (US Forest Service/ Department of Interior collaboration), USDA Rural Development Section 9006 (Renewable Energy and Energy Efficiency/ Rural Development) program, and Section 6401 (Value-Added Agricultural Product Market Development Grants) program have received limited, if any, use in Oregon.

Conversely, there are numerous projects underway such as the Confederated Tribes of Warm Springs, La Pine, and Lakeview, as well as past grant projects from which lessons can be learned. It is unclear how and whom will gather and disseminate this information, however.

A recent Government Accountability Office report (GAO, 2006) suggested "…government efforts must focus on finding uses specifically for… small diameter trees. Otherwise, efforts to stimulate biomass use may simply increase the use of other woody biomass, such as mill residues, rather than biomass from thinning." The same report also included the comment, "Government efforts may be more effective if they take into account the extent to which a logging and milling infrastructure is in place in potential user's locations."

Lastly, specific recommendations for R&D include mention of the need to support the US Forest Products Laboratory's research in harvesting technologies, alternative small diameter timber products, economics and supply modeling as well as the Sun Grant Center and Wood Innovation Center at Oregon State University. With respect to the former, significant research has been conducted. However, as is often the case with national efforts where staffing is limited (and shrinking), communicating results and transferring the technology at the local level are always a challenge.

Stakeholder Opinions

As with the chapter on assessment of potential supply, this chapter on stakeholder opinions differs from the earlier material presented previously in that new information (rather than from a review of the literature) was obtained. Forty stakeholders were interviewed for the purposes of understanding their views on converting forest biomass to energy in Oregon and to identify, from stakeholders' perspectives, the barriers and opportunities for converting biomass to energy, strategies to overcome the barriers (including perhaps research), and guidelines required to move forward.

Stakeholders represented a wide variety of perspectives. The various organizations and a summary of their comments is found in Table 15 below.

Table 16. Summary of stakeholders and select comments

Group	Summary of select comments
Community organizations	• Creating markets for small diameter timber (energy or otherwise) is critical • One participant commented that "…energy production should be the very last use of forest biomass as communities would benefit more from value added wood products" • There is likely not enough supply for energy, but what about value-added forest products? • There is strong support to develop new businesses and use local materials • Rural communities need a manufacturing sector which value added production would develop, whereas straight energy product will not • There are less jobs related to biomass energy production than when biomass is used to make value added products
Conservation community	• There was concern for (and opposition to) the need to build new roads • Some biomass (post-harvest) needs to stay on the site for ecological reasons • National Forests should not bear the brunt of needs for energy and wood products • Focus should also be on conserving energy and energy efficiency • Federal agencies should only guarantee 1/3 to ½ of the supply required for an energy facility • Lack of trust between players (conservation, agency, forest industry) leads to inaction; adding large logs to "pay for the project" would cause issues with trust • Perhaps a diameter limit (i.e., remove only trees x inches and smaller) is what is needed
Elected officials	• Supply needs to be close to minimize haul costs and guaranteed so investors can get loans • Demonstrations/ pilots are needed to show people how these projects work • Agencies should avoid old growth or other contentious areas
Energy utilities	• Biomass energy would result in base load power as opposed to wind • How deep is the support? • Incentives should be on the forestry, rather than the energy, side if the goal is to thin the forest • Challenges with power transmission (e.g., new infrastructure) is less of an issue if power is sold locally
Federal agencies	• Primary focus for agency personnel is on forest restoration; rural economic development is a side benefit • More research with models such as CROP (Coordinated Resource Offering Protocol from Federal forestlands) as it focuses on where infrastructure exists • There is a sentiment that "removing biomass is more expensive than burning it on site" – is this true? • Competition for material – would biomass take away from the firewood program? • Concerns for loss of infrastructure (who will harvest and process the material given the decline in the industry?)

	• Need to focus on educating stakeholders via demonstrations and pilot projects • Forest Service could deliver material to a non-profit organization, and the non-profit organization could distribute to local businesses (e.g., a cooperative-owned log sort yard[6]) • Focus where infrastructure still exists
Forest Industry	• An opportunity might be to improve the pulpwood market • Barriers include that material must be gathered in large, clean piles; not all fuels are the same (we need to characterize materials to understand potential end uses); need large landings in a harvest operation to merchandise logs and/or chip biomass; Capital – given limited funds for a business, would they perceive this as the best place to invest? • Harvesting must include merchantable logs • Strategies – pilot projects with supply from state and private sources • Link biomass facilities with existing mills
Informed energy participants	• Be cautious about energy industry being able to solve forest restoration problems • Not much R&D needed for cogeneration • Oregon has lots of old (vacant) mill sites in good locations • Energy density of forest biomass is low • Competing uses – energy vs. value added forest products • Siting facility is crucial – where there are multiple revenue streams • Issues with supply and infrastructure require focusing on local level
State agencies	• Biomass is currently Oregon's largest renewable source of energy • Must include sawlogs to improve transport costs
Tribal organizations	• With respect to ongoing project, by building new small log sawmill, will create 60 jobs • Agencies expect new markets to pay <u>all</u> restoration costs – this is unrealistic • Facilities must be scaled so that 'tail doesn't wag the dog'

Recurrent themes in these perceptions included the need for pilot projects/ demonstrations[7] to enable all stakeholders to see how these projects work 'on the ground.' There was also significant discussion of competing markets and the need to focus on existing facilities and/or improving markets for value added forest products. A key point of conflict surrounded issues with including merchantable logs in forest restoration projects – this was seen as critical to the economics from the forest industry's perspective, whereas it would serve to violate the trust (that the primary mission was about forest restoration) for conservation organizations.

Constraints & Challenges

The authors summarize the report by listing 6 key areas of constraints and challenges:

Public acceptance

- "Without a social license from the public, development of a woody biomass industry will not proceed very far."

[6] Log sort yards are facilities that accumulate logs of a wide variety of species, sizes, quality, lengths, etc., sort and sell them to end users with specific requirements (e.g., low-grade logs to a chipping contractor, high-grade Douglas-fir to a veneer mill, etc.)

[7] Note: Several interview respondents (Chapter 3) expressed concern about such pilot projects. In essence, their concern was with investing in unproven technologies when proven technologies are being used by existing firms. Further, 'proving' the new technology may only come at the expense of existing firms if they compete for raw materials.

- The public is concerned with environmental impacts of timber harvesting and biomass energy.

Biomass supply

- A reliable long-term supply of woody biomass is a critical, perhaps the top, concern, particularly from public lands.
- There is a lack of infrastructure to harvest and deliver biomass.
- Markets for mill residuals are mature; among participants in the market, prices are well-established and known; biomass markets, by contrast, are currently small and not well understood – this makes it difficult to coordinate large scale supplies
- There is likely to be competition for raw materials such as from existing small log facilities and pulp mills; if a liquid fuels industry develops, there will be further competition
- Markets for small diameter log products have been limited by supply; the challenge will be to develop value-added products that can be made from a large volume supply of logs
- Pulp markets have potential, however the industry has relied on low-cost residuals for raw materials; use of whole-tree chips (as would be obtained from woody biomass) has been limited; as a high-cost producer, it is unlikely pulp mills would use higher-cost raw materials if lower-cost materials are still available; the same can be said for particleboard
- We must work to balance short-term needs for highest value use with potential for liquid fuels industry.

Markets

- Concerns include competitiveness of biomass energy and barriers to start ups and energy markets
- The distributed nature of biomass supply lends itself to small scale but economics suggest large scale
- Liquid fuels or chemical feedstocks may be more attractive long term

Public policies

- On the plus side, the state and federal governments are moving ahead with policies supportive of renewable energy; however challenges remain
- There is an overwhelming array of incentive programs
- There are lessons to be learned from California – the state is home to 40% of current US biomass capacity; this is due largely to the 30-year terms following the enactment of PURPA (Public Utility Regulatory Policies Act, 1978)

Institutional issues

- Much of the potential woody biomass supply (~70%) is on public lands; BLM and Forest Service policies are thus crucial

- Biomass is not a budgeted program in the agencies

Technical issues

- Research is needed on:
    - Scientific agreement on forest restoration – e.g., ability of mechanical treatments to replace the role of fire; is biomass removal good for the forest?
    - Harvesting and transportation technology – equipment design; systems suitable for juniper; technologies to remove bark from whole tree chips; methods of recovering and transporting slash
    - Energy technologies – the sugar platform and syngas in particular; ethanol research specific to softwood species is needed
    - Alternative uses for small diameter logs – stronger value-added market for small diameter logs will improve economics of fuels reduction; research in engineered and composite wood products is needed; markets for ponderosa pine in particular
    - Biomass supply estimates – Forest Service inventory data rely on data from the early 1990s; harvest cost analysis is based on integrated (combined merchantable and non-merchantable) rather than marginal costs of either; other sources such as juniper and logging slash have not been studied; estimates are required for specific processing locations

Recommendations

The final chapter of the report presents conclusions and recommendations. The conclusions are:

> **"An opportunity exists in Oregon to combine a need for forest restoration treatments on large areas of forest land with goals of reducing reliance on fossil fuel energy and strengthening the state's rural economy."**
>
> Opportunities lie in power generation, biofuels such as ethanol, and biochemicals. With respect to the latter, biorefineries offer the potential to replace many fossil-fuel derived chemical. This opportunity deserves consideration from the state's pulp and paper industry.
>
> **"The magnitude of this opportunity hinges on the question of to what extent forest restoration treatments are needed and how much biomass material would be removed to support restoration goals."**
>
> Most potential supply will be derived from forest thinnings on public lands. Western juniper and logging slash are other potential sources.
>
> **"Evidence supports the conclusion that forest restoration needs, not the need for renewable energy or rural development, is the key driver of this**

issue."

In parts of southern and eastern Oregon, biomass can be competitive if cost of harvesting and transporting biomass are offset by including merchantable timber in the mix and if steam and waste heat are used (e.g., the energy facility is located at an existing mill).

"At the same time, tapping Oregon's excess of forest biomass as a renewable energy source can help meet Oregon's need for renewable energy."

The 1 million BDT per year of biomass that could be obtained in the study area would produce about 150 MW of energy.

"If forest restoration goals can be identified and agreed upon, energy needs can provide a market for the biomass that is removed and at the same time provide for economic revitalization of Oregon's rural areas."

Energy and small diameter log markets can help reduce costs of forest restoration.

"Oregonians want action to address severe wildfire. However, there does not seem to be agreement over the specifics regarding where and how treatments should occur and whether or not the biomass material should be removed from the site and used for energy production."

This underscores the need for research in the science of forest restoration.

"Recent collaborative efforts around the state involving land management agencies, tribes, local communities, conservation organizations, and other stakeholders have been successful in breaking down barriers, rebuilding trust and building public support for forest restoration projects."

Thus, demonstrations and pilot projects are critical from which to glean lessons learned.

"Increasing our scientific understanding of the ecological underpinnings of forest restoration treatments, along with demonstrated success of on-the-ground treatments, is essential to gaining public confidence in the need for forest restoration."

Growth of a biomass energy industry will not occur until the public reaches a consensus on appropriate management strategies for public lands.

"At the same time, it must be remembered that scientific certainty, especially regarding natural resource questions, is seldom if ever possible.

Some uncertainty and risk unavoidably accompanies natural resource decisions."

Inaction might lead to consequences more severe than those of the proposed action.

"If forest restoration is to drive the development of a biomass energy industry, and not the other way around, policymakers must first resolve the issues surrounding forest restoration."

"Once forest restoration issues are resolved, if forest biomass removal is part of the forest health solution, there are other challenges to be addressed by policymakers."

Based on these conclusions, 22 specific recommendations are provided. Those recommendations that appear to have particular relevance and implications for the BEST Signature Research Center are in bold and include additional commentary.

<u>Recommendations to Promote Forest Restoration</u>

1. **"Build forest restoration program on scientific understanding of restoration needs and treatments, and increase knowledge through research, monitoring and adaptive management."**

    A bio-based product economy will not develop in Oregon without a reliable, cost-effective supply of raw materials. Findings in this report clearly indicate that supply will depend heavily on material obtained via <u>restoration</u> of public forestlands. Hence, for public support of such restoration treatments, it is critical that the treatments be based on sound science.

2. "Encourage community collaboration and multi-party monitoring."

3. "Initiate an outreach effort to build awareness of forest restoration needs, science-informed treatments and bio-energy opportunities among the Oregon public."

4. "Where consistent with management objectives, encourage integrated forest management across all diameter classes of trees."

5. "Build federal land management agency capacity."

6. "Develop larger scale, long term, fully-funded forest stewardship contracts and restoration programs."

7. **“Promote long-term research efforts into the methods and effects of forest restoration and juniper control.”**

   Research is required to reduce biomass harvest and transportation costs and improve data regarding potential supply of biomass and focused on Oregon. Harvest methods and costs specific to western juniper and improvements to the estimates of available supply are needed.

<u>Recommendations to Promote Biomass Energy Development</u>

8. “Explore development of a Renewable Portfolio Standard for Oregon that creates a market for woody biomass and resolves concerns about unintended adverse consequences to rate payers.”

9. “Explore development of a Renewable Fuels Standard for Oregon that creates a market for woody biomass energy and resolves concerns about unintended consequence to the Oregon economy.”

10. “Level the playing field vs. other renewables and non-renewables.”

11. “Adopt a comprehensive state policy on renewable energy.”

12. “Promote the goals of sustainable biomass energy development.”

13. “Promote increased use of incentives and grants programs.”

14. **“Look for synergies that make biomass energy economically sustainable.”**

    Efforts should be focused on opportunities with existing wood products facilities. Research is needed to develop a better understanding of Oregon’s existing forest industry - raw materials used, species preferences, capacities, etc. Such information is crucial in identifying the appropriate partner for commercialization.

    Biochemicals are closely linked with bio-energy. Research is needed for specific chemical feedstocks that may be obtained from Oregon species, economics of conversion processes, and market potential. This has been described as one aspect of “resource characterization”, i.e., cataloguing the chemical constituents found in the wood, bark, and foliage of key Oregon tree species.

15. “Build community and workforce capacity.”

16. **“Promote establishment of a pilot cellulose-to-ethanol plant.”**

    Recommendation #20 discusses locating this facility at OSU.

17. "Promote small-scale uses of biomass where appropriate."

Given uncertainties for large-scale supply, particularly in some parts of the state, it will be important to develop bio-energy technology suited to the scale of the region of interest. Research is needed in this area and should be focused on specific locales. Additionally, research and technology transfer are needed for value-added markets for small diameter timber. Research into production and markets for wood pellets and compressed fire logs produced from woody biomass (that is of lesser purity than they use now) is also needed.

18. "Encourage involvement of existing bio-energy producers."

Given the fact that economic development success is far more likely when focused on expansion of existing businesses, efforts must be made to better understand the needs and challenges of existing firms. In-depth interviews should be conducted with the state's existing wood-fired combustion boiler facilities and pulping liquor facilities to see what it would take to create interest in expansion of the bio-energy and bio-refinery aspects of their existing businesses.

19. "Engage the state pulp and paper industry in examining the potential for co-production of biochemicals and biochemical feedstocks."

Similar to #18. In addition, other facilities that use chips such as MDF manufacturing, and finer particles such as shavings/ sawdust, should be contacted as well.

20. "Promote needed research and development efforts."

The report recommends establishment of a cellulosic ethanol pilot research laboratory at Oregon State University that focuses on conversion technologies focused on Oregon softwoods and production of bio-chemicals and feedstocks. Research into portable production facilities is also recommended in order to lower production costs by operating closer to the harvest site.

21. "Recognize the role of woody biomass in achieving the Governor's 2025 carbon emission goal."

22. "Encourage local governments to adopt the ODOE model land use standards for small-scale energy development."

The full OFRI report states that results show adequate potential supply of forest biomass for renewable energy production even with very conservative estimates of supply potential. For forests in 20 counties in southern and eastern Oregon (those forests at greatest risk of catastrophic fire and in need of restoration) there are 4.25 million acres of eligible forest from which thinning would produce 1 million BDT of biomass (in addition to substantial volumes of merchantable logs) each year for 20 years. This volume would enable production of about 150 MW of electrical power[8] (based on 8 generation facilities at 18 MW each) or 61-66 million gallons of ethanol. However, economics were marginal for electricity in stand-alone facilities; the best option appears to be to focus on existing wood products firms to add or increase capacity for electricity generation, with cogeneration to provide process steam in addition to power, being optimal. Harvest costs for biomass alone are too high given current markets; hence in the absence of subsidies, forest restoration harvests must include some fraction of merchantable timber to be economically feasible.

The technology is not yet available for ethanol production, although this appears to be a better opportunity in the medium to long-term than electricity

OSU Forest Biomass Utilization Research Program

In the spring of 2006, an ad hoc team of four faculty in the College of Forestry at Oregon State University were tasked with developing a white paper addressing barriers and opportunities related to biomass utilization and to catalog ongoing research by faculty in the College, as well as gaps in the research. Each team member interviewed research faculty in their respective discipline. As of this writing, the work is in-progress; however a draft of a white paper presenting the perspectives of faculty in the Department of Wood Science & Engineering is provided here.

<u>Barriers</u>

The key barriers to achieving greater utilization of forest biomass are related to information gaps with respect to economic feasibility, resource inventory/ supply, infrastructure, and policy. The faculty members interviewed were less familiar with the latter topic and thus it is not addressed here. Naturally, there are overlaps in these topic areas, however specific issues related to each area are discussed below.

- *Economic Feasibility* - The basic steps involved in converting forest biomass to a usable product involve harvesting, transporting, processing/ conversion (e.g., grinding to chips, sawing to lumber, peeling posts, pyrolysis to produce chemical feedstocks for liquid fuels, combustion for heat and electricity, etc.), and distribution of the finished products. The technology is in the developmental stages for many of these steps (the harvesting, transportation and conversion steps in particular). Thus, the economic feasibility is very much uncertain for forest biomass enterprises. Further, the markets and channels (distribution systems) are not yet fully developed for some of the products such as ethanol.

[8] Note: One interview respondent (Chapter 3) stated he felt this estimate of power generation was high. His experience showed that it takes 1.2-1.3 tons per MW not 0.9 as stated in the OFRI report.

- *Resource Inventory/ Supply* - Closely related to economic feasibility are issues surrounding the resource inventory/ supply. An adequate supply (in terms of both volume and quality) of affordable raw materials is crucial for an industry utilizing forest biomass to develop in Oregon. We do not yet have detailed information on the resource with respect to potential volume available in a given locale, quality of material (e.g., size, stem form, species), and accessibility (access for harvesting equipment, proximity to roads, environmental or legal restrictions for harvesting). Further, it is not yet clear what species/ quality/ volume combinations would be required to derive value-added products and/ or chemical feedstocks.

- *Infrastructure* - Thinning overcrowded forests to reduce wildfire hazard and improve forest health are the primary drivers for discovering economical means to utilize forest biomass. In Oregon, the greatest risk of wildfire and forest insect and disease epidemics are east of the Cascades. However, there is very little existing infrastructure in eastern Oregon to harvest, transport, and process the materials. Further, haul distances (and distribution systems) to major markets for end products will likely drive up costs. As often happens, there is a 'chicken-and-egg' scenario at play with respect to uncertain supplies and development of infrastructure and markets; investors are looking for assurances of supply whereas land management agencies are concerned there are no (or limited) contractors/ buyers for raw material.

Opportunities

Several key outcomes will serve to address the barriers listed above:

Research and pilot projects for conversion/ processing technology

- Conversion technology, for example, to convert cellulose to ethanol needs further refinement to be economically viable. While national research labs are working on this issue, it is not clear if the results will be broadly applicable to Oregon feedstocks. Further, it is not clear of the scale being targeted by such research. Given the unique challenges of rural Oregon, a specific focus on small-scale or portable technology is needed.

- A tool is needed to assist with evaluating economic feasibility that accounts for the complex dynamics and interactions inherent to forest biomass utilization. One approach might be a simulation model that addresses merchandising raw materials to appropriate end uses. For example, for any given locale there will be a specific mix of species/ diameters/ volume, harvest and transportation costs, and markets (e.g., for sawlogs, hog fuel, chips, etc.). Given these variables, what is the optimal allocation of materials to markets? A number of 'what if' scenarios could be examined such as how the presence or absence of a market (i.e., processing infrastructure), longer or shorter haul distances, etc. impact the feasibility of biomass utilization in the region as a whole.

- Laboratory equipment and pilot-scale facilities are needed for research and development of small-scale conversion technology and in general (regardless of scale) for products such as biofuels and specialty chemicals to determine actual production costs for feasibility studies.

Resource inventory

- A detailed inventory of biomass is needed on a county/ regional level that includes volume by species, indicators of quality (e.g., diameter classes), and accessibility.

- Research is needed to 'characterize' the resource to develop a portfolio of potential products - solid, fiber-based, and chemical - that may be derived from the various feedstocks.

- The underlying assumption here is that 'commodity' biomass products such as liquid fuels or cogeneration will not be economically viable as a primary product, but only as a residue. Higher value, specialty products are likely needed to offset the high costs of harvesting, transportation, and processing (i.e., to convert logging slash to an appropriate feedstock for ethanol).

Environmental impact

- In addition to research related to the science of forest restoration, research is needed to document the energy and carbon balance from 'cradle to grave' for extraction, transport, processing, utilization, and disposal of products produced from forest biomass. Such research could compare and contrast alternatives such as 'do nothing', wildfires, prescribed fire, thin and burn slash piles, thin and convert to various end products, etc.

<u>On-going Research</u>

Wood Science & Engineering faculty have extensive experience and expertise with the conversion technology for wood products, composite products, and specialty chemicals. Many faculty have expressed interest in expanding their research programs into various aspects related to forest biomass utilization. The table below describes the interests and expertise of select faculty.

Faculty Member	**On-going Research; Expertise and Interests**
Dr. Mike Milota	Interests - Management of fuel moisture to make feedstock breakdown more efficient; developing portable pyrolysis units for producing oil to be transported to a biorefinery.
Dr. Kaichang Li	Ongoing - development of exterior grade adhesives from biomass; development of a microbial fuel cell using wood waste

	Past - development of biodiesel from tree bark in collaboration with faculty in the department of Chemical Engineering at OSU Interests - Using catalytic pyrolysis of wood for ‘biorefining’ (developing feedstocks for fuels and other chemicals); understanding how enzymes & chemicals penetrate woody cell wall to improve conversion to ethanol; development of pressure-sensitive adhesives from biomass
Dr. Barb Lachenbruch	Ongoing – Characterization of plant parts (branches, roots, etc.) Interests - determination of time limits for use (e.g., from salvage)
Dr. John Simonsen	Ongoing – wood-plastic composites Interests - Pervaporation membranes containing cellulose nanocrystals (in collaboration with Jovanovic in Chem Eng. and Atre in IME) to separate ethanol – a key requirement for small-scale/ distributed production
Dr. Jim Wilson and Dr. Maureen Puettmann	Ongoing - Life cycle analysis to evaluate carbon and energy balance; harvesting efficiency, emissions, output of raw materials by type and volume, economics, and distance to market; modeling of manufacturing practices to compare biomass and fossil fuel use
Joe Karchesy	Ongoing – natural insecticides and repellents from forest resources Interest - Resource characterization for production of specialty chemicals (in particular, extraction of such compounds <u>prior</u> to other uses such as pulping rather than as byproducts); methods of chemical processing to give uniform fuel (given mix of bark, leaves, species, and location); heterogeneous catalysis to convert bark and foliage to fuels
Composites Group (Drs. Kamke, Nairn, Muszynski, and Li)	Ongoing - Research and development of wood- and wood-nonwood (plastic, nylon, rubber) composites Interests – utilizing forest biomass as feedstock for composites
Computer-Aided Manufacturing Group (Drs. Funck, Reeb, and Brunner)	Ongoing - Computer modeling and simulation of manufacturing systems Past - developing value-added products from small diameter timber; determining quantities, locations, costs and alternative products to make biomass economically viable Interests - examining value-added markets for sawmill residues (slabs and edgings); simulation of integrated biomass utilization facility

<u>Gaps in Current Research</u>

The expertise and experience to address the breadth and depth of the key barriers described above are available at OSU and other OUS institutions. The primary gaps at this point are related to targeting research to specifically focus on forest biomass (as opposed to wood materials from conventional sources) and funding for laboratory equipment and targeted research.

As an example with respect to the former issue of research focus, faculty conducting research in composites are currently not specifically focused on the use of forest biomass but rather conventional raw materials such as residues from other wood products manufacturing operations. However, there are unique challenges with respect to biomass as feedstock for composites. For instance, for composites, forest biomass would require adapting product or process variables to accommodate non-wood (i.e., bark and foliage) in the composites without sacrificing product performance.

With respect to the latter issues of equipment and funding, several faculty have expressed specific needs to be able to continue ongoing or reinitiate prior projects. For example, Dr. Kaichang Li ceased his work with biofuels development due to high costs associated with testing fuels.

Oregon Forest Biomass Working Group

The Oregon Departments of Forestry and Energy formed the Forest Biomass Working Group Oregon in response to Oregon Senate Bill 1072. SB 1072 was signed into law by Governor Kulongoski in 2005 and took effect January 1, 2006. The bill directs state government to take a greater role in federal forest planning and management and encourages greater use of forest residues for bio-energy facilities on federal and state lands and development of other forest products. The working group is a team of more than 35 people representing diverse interests related to biomass utilization. The working group sought to identify existing barriers to utilizing biomass in Oregon and to present approaches to overcome these barriers. The group is organized into six sub-groups. Key recommendations from each sub-group are presented below, with particular emphasis on the recommendations of the R&D sub-group. It must be noted, however, that as with the OFRI report, the primary emphases are bioenergy and biofuels and not specifically bio-based products.

Shared Vision and Public Support – this group is developing a communication plan regarding the role of biomass use in healthy forests. A website, template for discussing biomass in community meetings, and speaker's bureau have resulted.

- The group recommends holding a dialogue with communities and the general public on how biomass utilization can address issues related to forest health. A person, with staff support from other agencies, is needed to coordinate such meetings and draw in other experts.

Predictable Supply – "A consistent and level amount of biomass supply is essential for there to be a reliable, competitive, and sustainable biomass market." Including a mixture of merchantable timber, small diameter value added production, and biomass is essential to moving biomass waste out of the woods.

- A better understanding of small-diameter timber supply potential is needed for high opportunity areas. Data layers for levelized supply, as are created by the Coordinated Resource Offering Protocol (CROP) pilot projects are needed for market information.
- Adequate staffing is needed for federal agencies to offer long-term stewardship contracts for increased acreage, provide monitoring, and collaborate with others to ensure efficient and effective National Environmental Policy Act (NEPA) processes.

Harvesting and Transportation – harvesting workforce and infrastructure are rapidly being lost in regions of Oregon where forest restoration needs are greatest. Harvesting and transportation costs are significant barriers to utilization.

- Use the OFRI study and Associated Oregon Logger's study to design an education program and to understand existing infrastructure and interest in forest restoration on federal lands. Hold an educational program highlighting operators skilled in biomass removal.
- Build on existing harvesting technology studies and fill in research gaps. Develop transportation system guidelines.

Biofuels – "Oregon is well-positioned to play a major role in the development of cellulosic ethanol in this country." Cellulosic ethanol can generate 6 to 7 times as much income as using biomass as a fuel for power.

- The state should adopt cellulosic ethanol goals as state benchmarks such as 5 million gallons by 2008, 25 million gallons by 2010, and 65 million gallons by 2012.
- Build a commercial cellulose to ethanol demonstration facility using public/ private funds within the next 2½ years.

Supportive Regulatory Environment – a number of uncertainties exist regarding using biomass as an energy supply such as lengthy interconnection agreements with utilities, non-negotiable avoided costs based contracts, and variability in the familiarity of local jurisdictions in siting energy facilities.

- Address the inequity in federal production tax credits (i.e., disparities between open-loop[9] biomass and other renewable energy sources).
- Provide Oregon production/ consumption credit for renewable resources; provide state incentives for forest biomass projects.
- Extend the public purpose charge to further renewable energy development.

Research and Development

[9] Open-loop biomass is easiest to define by contrasting with closed-loop biomass – closed-loop biomass is biomass derived from crops grown specifically to produce energy. Thus, by contrast, open-loop biomass is derived from sources as described in this report – mill and forest residues and thus <u>not</u> specifically intended for producing energy.

This group was tasked with identifying barriers to biomass power and fuels that exist due to a need for research, current research efforts, and gaps where further research is needed. The group identified 4 primary categories of barriers. These categories and accompanying research needs include:

1. Resource Supply, Forest Health, and Environmental Tradeoffs

- A landscape-scale assessment of forest inventory and conditions is needed to determine supply, availability, cost, and impacts, and to assess forest health impacts of biomass harvesting activities. The Interagency Mapping and Assessment Project (IMAP) of the Oregon Department of Forestry and US Forest Service PNW Research Station may provide this information; IMAP is targeted for completion in 2010. This information can be used to refine estimates of potentially available biomass volume as were reported in the OFRI report and from the Western Governors' Association report.
- Regarding forest health, the report simply echoes the findings of the OFRI report with regards to the need for research on the effects of forest restoration treatments on environmental values. In short, additional research is needed in the science underlying forest restoration.
- Consequences of forest health restoration need to be compared with the consequences of inaction.

2. Technology and Infrastructure

- New research is needed in biofuels and biochemicals including product potential of different species; i.e., what is the potential for specialty chemicals and value-added products from hardwoods, juniper, pine, Douglas-fir, etc.
- Hydrolysis/ fermentation processes for softwoods need refinement, such as "enzyme cocktails" to convert cellulose to ethanol. Decreased costs and increased efficiencies will make these products more economically feasible.
- Research is needed into the potential for pyrolysis to produce bioproducts.
- While cogeneration is a mature technology, advances can be made in preprocessing of feedstocks (a topic applicable to nearly all end uses), higher steam temperatures, and turbine efficiencies.

3. Markets and Economics

- More emphasis needs to be placed on federal R&D funding for biomass energy; funding is currently biased towards nuclear and fossil fuels.
- Research should be conducted to explore opportunities to co-locate bioproducts plants with pulp & paper facilities vs. stand-alone facilities.
- The US Forest Service's FIA Biosum model should be used to: identify best locations for siting cogeneration or wood-processing facilities (based on material availability and local markets); assess likely impact of fuel treatments on plot-level wildfire hazard; estimate volumes of biomass removed; and explore tradeoffs among costs, area treated, and treatment effectiveness.
- A financial analysis toolbox should be developed for project analysis such as to model conditions necessary for profitability of a 15- to 30-megawatt plant.

- Research should be conducted on the marginal effect of different types and levels of subsidies to achieve outcomes; e.g., does an $x per green ton transportation subsidy achieve the desired results in different regions?
- Investigate alternative uses for small-diameter trees for others products to increase financial returns.

4. Social Acceptance (public license)

- A collaborative, science-based approach must be used to overcome public concerns related to forest biomass-based energy projects. Research is needed to determine the parameters of socially acceptable biomass harvesting.
- Pilot projects should be conducted in the Wildland Urban Interface (WUI) to gauge public acceptance.

The R&D subgroup concluded their report with a list of key actions needed including:

- The Oregon Department of Forestry should continue working with the PNW Research Station to develop the IMAP project.
- The Oregon Departments of Forestry and Energy, and the Oregon Wood Innovation Center at OSU should develop a matrix of existing and potential research funding sources.
- Long-term research into forest restoration and juniper control should be promoted; opportunities for market incentives such as carbon credits should be explored.
- Establish a cellulose-to-ethanol pilot plant.
- Research public perceptions of BLM stewardship contracts in the WUI
- Support actions to coordinate R&D advances with commercial technology development such as through the BEST Center proposed by the Oregon Innovation Council.
- Capitalize on OSU's status as a regional Sun Grant Center – support research on alcohol fuels such as by developing a pilot cellulosic ethanol research lab at OSU via a partnership between the Oregon Wood Innovation Center, College of Agricultural Sciences, and Chemical Engineering.
- The Oregon Wood Innovation Center at OSU should engage the pulp & paper industry in research efforts exploring the potential for co-production of biofuels and biochemicals.
- The Oregon Department of Forestry should convene a committee on biomass energy, biofuels and bio-products R&D to develop a strategy to address research needs.

Western Governors' Association

The Western Governors' Association's (WGA[10]) Clean and Diversified Energy Advisory Committee commissioned a report on biomass in February of 2005. The report outlines the benefits of biomass, provides a biomass supply assessment for the western U.S., and

[10] The WGA represents 12 western states – Arizona, California, Colorado, Idaho, Montana, Nevada, New Mexico, Oregon, South Dakota, Utah, Washington, and Wyoming.

presents policy barriers and policy recommendations. Given that the objectives of the report were to provide policy recommendations to state governors related to biomass energy, discussions of research needs in the report are limited.

The analysis considered biomass solely for the production of electricity as opposed to a broader suite of products (e.g., biochemical or bio-products). However, the authors acknowledge the significant contributions these other products can provide and in fact, state that biomass should only be directed to energy in the absence of higher-valued markets. Further, the authors state that biomass conversion to heat, fuels, and chemicals each have a major role to play in the full utilization of biomass in the western U.S. States will, "…benefit most from a set of policies that encourage development of all end uses for Bioenergy making this resource as ubiquitous as natural gas is today."

Biomass feedstocks considered included forest resources, agricultural residues and products, and resources from the municipal waste stream including solid wastes, biosolids, sewage, and waste buried in landfills. Forest-based biomass residues were identified as the largest supply component when all the sources (mill residues, harvesting residues, and fuels treatments materials) are considered.

As with reports discussed previously, "economic availability of the feedstocks" (i.e., biomass supply) was a key concern and for this reason, the authors conducted a biomass supply assessment for western states. This assessment was one of the studies reviewed in the OFRI report. Supply was considered from the standpoint of the amount of volume that would be available at the electricity production cost of 8¢/ kWh. The volume estimate for the western region (not specific to Oregon) was discussed in the OFRI report section and is presented in Table 11 above.

'Forest resources' in the supply estimate included mill residues, timber harvest (logging) residues, and forest fire treatment materials. Mill residues and timber harvest residues were obtained from the US Forest Service's Timber Products Output (TPO) database (USDA, 2002b). As with the OFRI report, the WGA supply estimate used the US Forest Service's Fuels Treatment Evaluator (FTE) to derive estimates of biomass volume from fuel harvests. And again, as with the OFRI report, the assessment does not consider 'wet climate' regions (those areas not in need of treatment to reduce fire danger), i.e., the northwest region and coast of Oregon.

The authors acknowledge that supply of forest biomass (as opposed to mill residues or urban waste) in the U.S. west will be obtained principally from treatment of forests to reduce fuels and hence fire risk. However, they state removal of a limited number of trees is needed in treatments for economic viability. Citing a U.S. Forest Service report (USDA, 2005), the authors state that fuels treatments with no higher value products can cost from $600-$1000/acre, whereas also removing larger trees (in accordance with meeting ecological goals) can result in netting $400-$600/acre.

Advantages of the distributed nature of the biomass resource itself are frequently mentioned in the report. Supply, production, and use are all conducted at the local level. Hence, there is a need for assessments unique to each locale.

The report concludes with 10 policy recommendations. Where applicable, implications for research are highlighted. The recommendations include:

1. Achieve tax parity among renewable technologies – specifically with respect to the federal Production Tax Credit for open loop biomass (Section 45 of IRS Regulations).

2. Strengthen federal land management policies to allow larger, longer restoration projects.
    - Only long term (20-year minimum), large-scale (150,000+) activities will attract infrastructure investment.
    - **Contracts should be based on forest restoration and should be science-based. Thus, as suggested in the OFRI report, research in forest restoration science is needed.**
    - Artificial constraints such as material use or tree diameter size limits should not be pre-determined.

3. Environmental benefits of biomass should be paid for by beneficiaries.

4. Demonstrate government leadership by purchasing power/ REC's from biomass projects and by supporing biomass R&D.
    - State and federal governments should purchase biomass power or an equivalent amount of RECs to meet renewable purchase requirements.
    - **Governors should support R&D in partnership with the private sector to demonstrate the use of new biomass technologies and conduct engineering development research leading to near-term commercialization of improved conversion and harvesting technology. "By evaluating and publicizing the performance and benefits of new technologies in an objective assessment the state greatly reduces the risk for the next user."**

5. Recognize the value of firm capacity in renewable purchase programs.

6. Renewable energy credits should not include ancillary environmental benefits.

7. Establish a single definition for biomass.

8. Revise utility interconnection policies.

9. Provide long-term certainty for biomass programs.

10. Consider fuel-based emissions when issuing air quality permits.

In addition to the 10 recommendations above, the task force recommended follow-up effort on supply assessments. Specifically, the authors recommend, "The crux of this analysis is to set forth the sequence for developing each of [sic] primary resources (with key improvements in resource estimates) in tandem with the conversion technologies and in response to the proposed policy measures. This analysis would directly consider the question of what is the likely mix of end uses by among heat, power, transportation fuels, and Bio-based chemicals/ products. Answering these key questions will provide the basis for crafting the implementation details of policy changes recommended by the Task Force." Further, assessments should consider the mix of end uses (power and liquid fuels production) such that a framework can be built for an integrated biomass policy rather than a competitive set of policies varying by end use.

Forest Products Industry Technology Roadmap

The technology roadmap was developed by the Agenda 2020 Technology Alliance with the support of the American Forest & Paper Association and the U.S. Department of Energy to provide the research community and funding organizations with information on the technical challenges and research needs considered priorities by the U.S. forest products industry. The roadmap focuses on "…reinvigorating the industry through technological innovations in processes, materials, and markets." One of the 4 cornerstones of the strategy is "A stream of new biomass-derived products and materials, including electric power, liquid transportation fuels, polymers and composites, and industrial chemicals."

While 7 technology strategies are presented, the Forest Biorefinery strategy is most directly applicable to a discussion of woody biomass utilization. Thus, this review focuses on this specific strategy.

The strategy focuses on existing mills evolving into biorefineries that are self-sufficient in their energy needs and that produce traditional wood and paper products, electricity, fuels, and chemicals. Such facilities will use raw materials already collected and provide markets for additional, locally produced or harvested biomass resources.

The 2 key strategies for the Forest Biorefinery are:

1. New values from residuals and spent liquor
2. Extracting value prior to pulping

Each strategy and recommended R&D needs is described below.

1. New values from residuals and spent liquor

This approach involves gasification of biomass and black liquor to produce additional electric generation capacity (for use at the mill or for export) or liquid fuel. The authors state a key advantage of this pathway is that it takes advantage of existing biomass collection and manufacturing infrastructure.

This strategy addresses the need for replacement of Tomlinson boilers and other biomass- or fossil-fuels based boilers currently used by pulp mills for energy production and chemical recovery. Gasification of black liquor and biomass would provide combined heat and power and/ or recover chemicals for re-use as well as produce a syngas composed primarily of hydrogen and carbon monoxide. Economics would dictate if the syngas should be burned to produce steam and power, used to replace fossil fuels, or converted into transportation fuels.

A downside to the technology is that such a process would produce more electricity and less heat and thus could result in a steam deficit for pulp mill operations. Also, if the syngas were converted to liquid fuels, a source of energy would no longer be available to the mill. The authors propose that one solution to this situation would be to increase collection of locally-produced biomass and process these materials in a conventional boiler or biomass gasifier. Thus, there is a synergy here for this technology that would result in increased demand for biomass in many forms.

Several technical barriers are presented including:

- Lack of understanding on optimal mix of bioproducts that can be economically produced from syngas
- Lack of understanding on how feedstock variability and hemicellulose extraction prior to pulping (see below) impact syngas composition and bioproducts

Other specific technical barriers are also presented such as lack of fully developed autocausticizing technology, lack of understanding of and modeling capabilities for the chemistry and kinetics, etc.

The top priority research needs included a number of specific technical needs as well as more general needs such as:

- Identify commercially valuable, renewable transportation fuels and chemicals that can be produced from syngas and develop cost-effective technologies to produce them on a pulp mill scale
- Develop cost-effective pyrolysis process to convert wood or wood components to value-added products (e.g., resins, kiln fuel).
- Determine how feedstock variability and removal of hemicellulose prior to pulping affects syngas composition and bioproducts

2. Extracting value prior to pulping

The focus for this recommendation is essentially on hemicellulose extraction and conversion to products such as ethanol or acetic acid; key in the strategy is the phrase prior to pulping. The essence is to "…glean greater value from the wood after it is delivered to the mill but before it is pulped."

Of the 3 primary components of wood (cellulose, ligning, and hemicellulose), hemicellulose is currently underutilized in pulp mills as it either remains with the cellulose in the paper (and is inferior to cellulose for papermaking) or is dissolved in the spent pulping liquor and burned. Better utilization of hemicellulose will increase revenue streams for pulp mills. Further, removal of the hemicellolose prior to pulping could lead to the development of alternative, sulfur-free pulping chemistries. Potential hemicellulose products include ethanol, acetic acid, as well as alternatives to petrochemicals such as polymers, adhesives, dyes, etc.

Several key barriers are listed including:

- Insufficient understanding of optimal lignin products that can be derived from hemicellulose and lignin
- Inadequate understanding of feedstock variability on process performance

The three top priority research needs recommended were:

- Determine the optimum process for and level of hemicellulose extraction, including impacts on pulping, bleaching, and chemical recovery processes
- Determine optimum use of hemicellulose as biomaterial feedstock and develop robust, cost-effective enzymes and fermentation processes
- Investigate opportunities for integrating hemicellulose extraction and conversion technologies into existing pulp manufacturing processes

Nearer-term opportunities not addressed in the technology roadmap include production of specialty chemicals from bark and the manufacture of biodiesel from tall oil (a by-product of softwood pulp mills). As the authors state, these "…pathways are close to commercialization and offer mills lower-capital, lower-risk opportunities to initiate biorefinery applications and test the value proposition."

Summary of Research Recommendations

The five reports reviewed here provide several recommendations for research to address challenges related to woody biomass utilization. These recommendations can be categorized according to the barriers they are intended to address. Specifically, recommendations are related to improving the economic feasibility of biomass supply and improving the value of the end products produced from woody biomass. Of course, these two barriers are interrelated. A brief overview of the recommendations is presented here. More detailed discussion of the recommendations is presented in Chapter 3.

Improving the supply and economics of woody biomass

Adequate supply of biomass was stated repeatedly as a critical need to improve the utilization of woody biomass in Oregon. For firms to invest in infrastructure to process woody biomass for <u>any</u> end use, some assurance is needed that there will be an affordable supply of raw materials. Put simply, the challenges can be summarized as utilization depends on sufficient quantities of supply at the right price. ‘Sufficient quantities’ of woody biomass, particularly east of the Cascades, is largely contingent on federal forestlands. Public support for forest restoration and timber harvesting is critical to shape federal forest management policy as litigation from conservation groups can effectively prevent harvesting from occurring (or at least greatly delay the process). ‘The right price’ involves both public and private lands and includes costs to harvest, gather, and transport woody biomass. In the absence of an ‘integrated harvest’ (i.e., where merchantable logs and woody biomass are removed in one treatment), delivered costs typically exceed the market value of the material.

Specific research recommendations are related to:

- Forest restoration science
- Understanding public perceptions of forest restoration and biomass utilization
- Quantifying environmental impacts of biomass harvesting and utilization
- Improving estimates of available biomass volume in specific locales
- Biomass harvesting and transportation systems for all species
    - Harvesting systems and costs specific to western juniper
- In-woods biomass processing systems to prepare materials for downstream users

Improving the value of biomass-derived products

As stated above, delivered costs often exceed market value of woody biomass. Thus, one approach to improving utilization is to reduce the delivered costs. Conversely, one can focus on improving the value of the materials derived from biomass.

Specific research recommendations are related to:

- Characterization of biomass materials – understanding the variety of potential end uses for both species and ‘class’ of material (e.g., bark, wood, foliage)
- Development of new products such as:
    - advanced wood composites,
    - high value specialty chemicals, and
    - value-added products from small diameter timber
    - fuel pellets produced from ‘mixed’ (bark, foliage, and wood) biomass
- Development/ refinement of technology to:
    - convert softwood cellulose to ethanol
    - remove hemicellulose prior to pulping and convert to ethanol and other products
    - gasify pulp mill black liquor for syngas and cogeneration
    - use woody biomass in a microbial fuel cell
- Explore business models for various approaches to woody biomass utilization such as:
    - a cooperative-owned log sort yard

- an integrated biomass utilization facility (e.g., post & poles, chips, sawlogs, etc.)
- an integrated biorefinery at an existing pulp mill

The above recommendations are based on reviews of reports related to woody biomass utilization and interviews with research faculty. However, to date, input from key stakeholders - private forest landowners and forest industry personnel - has been quite limited. Private forest landowners have a crucial role to play as suppliers of woody biomass; as users of woody biomass, the forest industry is critical as well. Thus, it is imperative to understand the viewpoints of these stakeholders, the challenges surrounding biomass utilization, and their thoughts on technology gaps that, if filled, would help improve the overall economics of woody biomass utilization. Further, several of the reports reviewed above discussed the importance of focusing on existing industry or directly recommended engaging the industry in conversation (e.g., the pulp & paper industry).

3. Stakeholder Interviews

As stated in the previous chapter, input from key stakeholders in woody biomass utilization - private forest landowners and forest industry personnel - has been quite limited in the existing reports on the topic. Private forest landowners have a crucial role to play as suppliers of woody biomass and the existing forest industry is of course, critical as users of woody biomass. The viewpoints of these stakeholders were sought with regards to the challenges surrounding biomass utilization and their thoughts on technology gaps that, if filled, would help improve the overall economics of woody biomass utilization. Interviews were conducted with 23 stakeholders. Sectors represented included:

- Landowners
    - Industrial Private
    - Non-Industrial Private
- Forest Industry – board mills (i.e. firms currently using mill residues) and other biomass users
- Pulp & Paper

Given the time limitations for the study, it was not possible to conduct a large, statistically representative sample of these stakeholders. Rather, a 'convenience sample' was chosen for each group as follows: a representative sample of the major industrial landowners in Oregon were chosen, Oregon Small Woodlands Association members, and a representative sample of the major biomass-using forest industry firms and pulp & paper producers. Responses are presented so as to maintain the confidentiality of interviewees.

Interview questions varied by sector and will be presented in the appropriate section. Responses are summarized for each sector followed by an overall summary with implications for research.

Landowners

Private forest landowners include industrial (e.g., large corporations and timber investment management organizations) and non-industrial (a.k.a. family forestland owners or small woodland owners). Both sets of landowners were asked 5 questions; however the first two questions varied for industrial and non-industrial landowners. The first two questions for industrial landowners were developed with the assumption that these personnel are already players in the market and thus, the objectives were to learn what they currently do with non-merchantable material and their interests in increased utilization of the material.

For non-industrial landowners, initial assumptions were that small landowners may or may not see themselves as players in biomass markets; these markets are typically high volume and many non-industrial landowners own relatively small acreages. Question 2 for non-industrial private forestland owners was targeted specifically to determine if economics of biomass utilization dictates these landowners' involvement in biomass markets or if their perspectives are also significantly influenced by other objectives such as forest restoration (as is assumed for public land managers).

Specific questions were as shown in Table 17 below.

Table 17. Questions asked of forest landowners.

Question	Industrial	Non-industrial
1	What do you currently do with non-merchantable logs (thinnings and slash)?	Do you see yourself being a player in biomass markets?
2	Do you see a need to do more with this material?	Does the quote from the 2006 OFRI biomass report[a] (below) accurately represent how you view biomass markets?
3	What sort of price point would it take to divert slash to a higher value use?	
4	What technology would help this to be more technically and economically feasible?	
5	What policy changes do you feel are needed to make biomass markets more economically feasible for the private landowner?	

[a] "The concept of using sawtimber revenues to cover, or subsidize, the costs of fuel reduction treatments may make sense from the standpoint of a public land management agency charged with reducing fire hazard over large acreages with minimal outside funding. However, an economically rational, profit-maximizing private landowner would likely make a different calculation. He/she is likely to view biomass removal cost at the marginal or incremental cost. They would compare the harvest cost per acre with and without biomass recovery and attribute all of the additional cost to the biomass rather than spreading it over the merchantable volume. For example, if a planned logging job would cost $500/acre for merchantable volume and $900/acre including biomass removal, the incremental $400/acre (plus haul cost) would be compared against the market value of the biomass. Unless the landowner can at least break even on the biomass, or there are other objectives attained through biomass removal (e.g. timber stand improvement or fire risk reduction), the landowner would not be motivated to incur the loss of profit from biomass harvest." (OFRI, 2006 pg. 2-27)

Summaries of responses to each question are presented separately for each group (industrial and non-industrial) below.

Industrial Private Landowners

1. What do you currently do with non-merchantable material?

As suspected, most of the material is currently being piled and burnt. However, most respondents were clear that every bit of value is squeezed out of the material. One respondent had a buyer for Douglas-fir logs as small as 3 to 3.5 inches on the small end. Another said, "if it goes on a log truck, it gets used." Further, if it is too short to go on a log truck, it gets sent to a chipping facility in a container.

One person stated that forest thinning was conducted even if it doesn't make money, if forest health was improved (though it can't lose too much money either…).

2. Do you see a need to do more with this material?

Most respondents said yes; one added "anything but burn." Interestingly, several respondents discussed the fact that it costs to pile, cover with plastic (to wait for the burn season), and burn slash piles. Thus, there are costs that must be accounted for even when the slash is not used. Hence, a "non-burning use is a win-win."

Whole-tree logging (vs. felling trees and removing tops and limbs where the tree falls) has resulted in a more slash being brought to the landing. As a result, one respondent commented that handling costs were already covered for this material (at least to the landing). Thus, utilization of this material is the 'low-hanging fruit.'

One person discussed OSB manufacturing to underscore the importance of economics. OSB is a proven product that now has the majority of the market share for sheathing. There are no OSB mills in the Pacific Northwest due to our higher costs of labor, production, materials, and transportation. In short, "If OSB [a product with proven markets] doesn't work here, how will biomass?"

3. What price point is needed to divert this material to higher uses?

Most respondents stated a range of $40-$50/ BDT. One respondent stated that their break-even cost was in the high $30s per ton. Another respondent stated the question was not relevant given current demand from pulp mills is leading to the need for more sources for chips; pulp mills are now using chipped urban wood waste to meet demand.

4. What technology is needed to improve biomass economics?

Responses varied most widely for this question. One person simply said, "we need a customer who wants to pay for it."

Another person felt that the harvesting technology is there; when supply is tight for fuel pellets and biofuels, biomass could work on its own. Others felt harvesting technology developments are needed. For example, "need to get it out of the woods and minimize handling." Specific recommendations were made for slash bailers for efficient handling and packaging of biomass.

One respondent specifically addressed the need for cellulose to ethanol. They felt this technology will lead to new markets for a number of different kinds of products and overall, will be good for the industry. A cellulose-to-ethanol facility will be most feasible if run in conjunction with another mill such as a paper mill. That way, materials can be diverted to different facilities as markets fluctuate.

5. What policy changes are needed to improve biomass economics?

One respondent suggested a tax incentive or subsidy to "jumpstart" businesses and lower risk and another mentioned a road fee exclusion/ reduction for biomass.

One person provided a 3-phase approach: 1) invest in pure R&D for cellulosic ethanol, chemicals, energy, etc.; 2) determine best locations for plants – where there is supply and markets; and 3) focus on the economics - understand the break-even point.

"The market develops on its own without government interference." Where the state can take a role, however, is to "…incubate products/ ideas on a small scale and provide incentives." This respondent also stated that Oregon must invest in the university system.

The importance of the state's pulp and paper industry came through again and again from this group. One person stated they would really like to see biomass markets develop given their concerns for the long-term viability of the region's paper industry. Without chip markets, some sawmills will close. "Biomass could pick up the slack for mill residues."

Non-Industrial Private Forestland Owners

1. Do you see yourself as a player in biomass markets?

Responses to this question were about evenly split. Those that said no provided various reasons such as the fact that they do not have a problem with fuels build-up in their forest and decomposing wood is good for the soil. Another stated that they would need to be part of a larger group to be a player in the market. Two others stated that current markets/ prices and technology precluded them from being involved in biomass markets.

Respondents that said yes also provided various reasons such as the fact that one landowner had a relatively large amount of acreage and was close to markets. Another person simply said they were becoming more active in biomass markets as they became involved in developing biofuels initiatives. One respondent echoed the comments of the industrial landowners by saying that they could avoid the costs (and smoke) of burning slash piles. Along these same lines, another person stated that it made better environmental sense to use biomass in some manner than to add CO_2 to the atmosphere.

2. Does the quote from the OFRI report (see the footnote to Table 17 above) accurately represent how you view biomass markets?

The majority of respondents simply said yes, "…biomass removal needs to make economic sense." There were 2 dissenting opinions, however. One person discussed broadening their consideration of costs. There are direct costs (harvesting and transport) and costs avoided such as firefighting, hiring a burn crew, managing brush with herbicides, losing timber to fire, liability costs for fire that starts on their land

and moves to a neighbor's, etc. While these costs may be difficult to estimate, they must also be taken into account.

Another person stated that the comment took a simple view of harvest analysis. There are large differences in harvest costs based on wood quality, species, volume per acre, etc. Further, discussions of biomass utilization seem to lack the recognition that removing biomass removes nutrients that are put back in the forest. A few dollars made in the short-term may be at the cost of loss of long-term productivity. Further, there are animals, insects, fungi, etc. that depend on the biomass and they may also be more important than a few dollars.

3. What price point is needed to divert this material to higher uses?

As expected, few respondents were able to provide a specific dollar figure, although one person stated $60 per ton, and then only if haul costs made it feasible.

The comment "has to pay its way out of the woods" was stated quite frequently and several respondents added a margin such as costs plus $10 per ton. Another person stated they would want to cover their costs less the avoided costs of piling and burning.

The pulpwood market was also a frequent reference in that there is a perception that biomass and pulpwood markets should be the same.

One person reiterated their concern for removing excessive nutrients from the site in stating their price point was the "price at which the forest is not adversely affected by the mining of all vegetation."

4. What technology is needed to improve biomass economics?

Several respondents focused on the need for forestry-related equipment such as in-woods chipping, portable grinding machinery, forwarders, or pulpwood technology such as self-loading log trucks designed to move 8-foot logs. One respondent stated that logging systems would need to change to get slash to landing[11].

In conjunction with statements about equipment needs, these respondents also highlighted the importance of the economics of the process and unique challenges of small landowners. For example, small landowners have the additional challenge of the need to capture thinnings and other biomass and aggregate it across multiple ownerships. Perhaps a chipping facility connected to a landowner-owned and operated log sort yard would help improve the economics. Similarly, one landowner discussed the need for technology to produce multiple products (e.g., chips, hog fuel,

[11] One industrial forestland owner stated this was already the trend for their firm due to whole-tree harvesting.

cellulose to ethanol, fuel pellets, kitty litter, special forest products, and niche products like flooring) on-site.

One landowner discussed the need for technology that worked ‘on site’ to power, for example, steam-powered chippers or for distillation. In other words, technology could be developed to use biomass to produce energy for other biomass operations.

Two respondents emphasized the need for technology related to cellulose to ethanol production. One person stated the importance of locating these facilities in rural areas to sustain local communities. Another suggested the need to understand the chemical structure of biomass and develop efficient conversion processes for liquid fuels. They also felt, however, that if biomass is burned directly (e.g., CHP), research is needed to reduce emissions.

Lastly, there was a suggestion for the need to consider what is done in parts of Europe with respect to local ‘fuel wood forests.’ That is, focus on developing close local connections for private landowners to supply fuel for local facilities heated with woody-biomass fuels. This respondent felt that direct, local options make more sense than the large-scale approaches that appear to be developing.

5. What policy changes are needed to improve biomass economics?

Many private woodland owners suggested the need to directly compensate landowners for benefits society receives from carbon retention in well-managed forests. There should also be recognition of the benefits of avoiding carbon emissions the result from using the biomass.

Tax credits were also frequently mentioned with the intent of making biomass energy more cost-competitive with existing sources, giving loggers and other entrepreneurs financial incentives for equipment upgrades so they can change logging practices or incentives to purchasers such as power companies to buy biomass. However, one landowner felt that it would be a mistake to legislate or subsidize the industry to make it feasible – “it’s more a question of economics and productivity analysis than policy.”

One respondent focused on policies related to public land management. They felt that efforts needed to be made to rebuild trust in public forest managers so that we can move ahead with thinning overstocked federal forests. At the same time, the concerns that demand of biomass-using facilities will drive forest practices (i.e., scale the facilities appropriately to available and sustainable local supply) must also be addressed.

Two landowners discussed the need to invest in research to test and demonstrate alternative forest management strategies, test mobile processing technology, and estimate markets for alternative forest products. Public subsidies should be shifted from subsidization of petroleum-based fuels to locally processed fuels.

From the interviews it is clear that private forestland owners do not perceive biomass equally. For example, with respect to prices, some referred to biomass as equivalent to pulpwood (which in fact, is a merchantable product) while many others referred to logging slash – a byproduct of commercial timber harvesting. Few respondents specifically discussed 'forest thinnings', i.e., material derived from harvests specifically conducted to remove non-merchantable material. It was also clear that demand is currently high and supply is tight; every effort is made to find markets for materials (e.g., hauling shorter and smaller diameter logs).

With respect to economics, many landowners felt they would only be participants in biomass markets if the biomass 'paid its way out of the woods.' In general, industrial landowners reported a lower price point than non-industrial forestland owners for biomass to be economically feasible - $40-$50/ BDT vs. $60/ BDT, respectively. However a few landowners stated that there were other motivations for thinning forests such as forest health and reducing risk of potential firefighting costs. One interesting point was that whole-tree logging systems result in logging slash being accumulated at the landing. Hence, the extraction costs are already covered for these systems.

Further, a key point revealed in these interviews is that <u>not</u> using biomass (at least with respect to logging slash) does not equate to zero costs. A valid comparison of costs associated with the current system (piling and burning logging slash) vs. processing and hauling biomass to a facility must take into account costs to pile and burn. In addition, there are environmental costs such as CO_2 release associated with burning that are not currently being taken into account. An additional environmental cost was mentioned related to long-term impacts on forest productivity due to 'mining the forest.'

Recommendations for technology needed to improve biomass utilization varied from specific recommendations for harvesting, processing (including on-site value-added processing), and transportation technology to cellulose-to-ethanol conversion technology. Specific mention was made of linking cellulosic ethanol production with pulp & paper mills. Non-industrial landowners also saw a need for systems such as log sort yards (perhaps with chipping capacity) to enable accumulation of material from smaller acreages. Further, there was mention of the importance of scaling biomass utilization facilities with local supply and demand.

With respect to policy, several landowners mentioned the need for tax incentives to spur investment. Other specific recommendations included a road fee exclusion or reduction for hauling biomass and carbon credits for well-managed forests. Lastly, one respondent felt the state needs to invest in the university system and foster biomass utilization via incubating technology on a small-scale.

Forest Industry

Forest industry personnel were interviewed to obtain their perspectives on woody biomass utilization. Firms were selected that currently use woody biomass such as producers of particleboard, medium density fiberboard (MDF), hardboard, and fuel pellets. As with private forestland owners, respondents were asked about their views on the required price point needed to divert biomass to higher uses as well as technology and policy changes they felt were needed to improve biomass economics (questions 3 – 5 in table 17 above). However, the other questions were adapted to reflect the fact that these respondents are currently biomass users. Specifically, respondents were asked to describe their raw material requirements (e.g., size, species, and level of purity required) and presented an opportunity to pose questions or comments about research related to woody biomass utilization in general. The latter question was developed due to the authors' awareness that some personnel in this sector see efforts to improve markets for woody biomass as promoting competition for the raw materials they currently struggle to obtain. Thus, the opportunity to voice this concern was provided, albeit without explicitly asking respondents "do you view this as new competition for materials?"

Summaries of responses to each question are presented below.

1. What are your raw material requirements?

Of course, material requirements varied by product produced. With the exception of a 'true biomass' facility (biomass-powered cogeneration), respondents expressed the need for materials free of contaminants such as bark, foliage, and debris.

For fuel pellets, residential pellets must produce less than 1% ash. However, one respondent stated that remaining competitive in the west requires even less ash content – ¼ - ½%. Hence the need for clean sawdust. Pellet mills surveyed buy hogged or chipped materials and not solid wood. For pellet production, the most important factors are cleanliness, particle size, and moisture content. Material is usually processed to the proper particle size and dried. Douglas-fir is the species of choice for pellets, although many other species can and are used including hardwood residues from cabinetmakers. However, given that ash content varies by species, it is important to have the right species mix. Economics of pellet production require sourcing material locally. Further, as one respondent stated, "I probably couldn't make pellets cost effectively from a tree stump even if you gave it to me." Similarly, if coarser material were available, it would probably be chipped and sold to pulp mills given current prices.

Other mills such as hardboard and MDF facilities essentially compete with pulp mills for the same materials. They can also use residual materials from millwork producers and some from chipped pallets, however clean chips are a must.

One person simply stated, "Raw material supply is the biggest challenge and unknown."

2. What sort of price point would it take to divert biomass materials to a higher value use?

Two respondents stated that good quality material that has been chipped or hogged is worth $50-$60/BDT delivered. Others were either uncertain of price due to their position in the company or simply stated "not much more than is currently being paid." One person suggested that shared facilities (with a sawmill) can pay more for hog fuel. Historically, prices for hog fuel have been around $20-$23/BDT, although facilities have paid as much as $38-$40/BDT. For one respondent's facility, $45 is break even.

One respondent reported their hauling and processing costs to explain the challenging economics underlying biomass utilization. Haul costs for biomass are $1.80-$2.00 per mile and a truck can haul about 15 BDT per load. Thus, it costs about $13/BDT for a 100-mile round trip (i.e., assuming a processing facility is 50 miles from the source). Grinding (pre-processing) costs are about $15/ BDT. Thus, for unprocessed materials, $28/BDT must be added to the harvest costs simply to break even.

3. What technology is needed to improve biomass economics?

One firm is looking at more efficient boilers. They also reported needs for assistance with distribution systems, bulk delivery systems (similar to Europe), non fossil-fuel based packaging and whole house heating systems.

As with many interviewees, several firms expressed the need for technology to "get fiber out of the woods" in the most cost efficient manner and that provides raw materials without contaminants.

Challenges with infrastructure were also mentioned. Specifically, one person stated that the state has lost much of its processing infrastructure. As a result, "we have 4.5 million acres in need of immediate treatment but there is no infrastructure available to do the work." They felt that stewardship contracts are needed with federal forestland managers, that is, a contractor must be paid to remove the material.

One person felt that utilization of biomass has the potential to add to the existing supply such that other sources could be freed up. As a result, overall costs for residues will go down.

4. What policy changes are needed to improve biomass economics?

Subsidies for start-ups would be unfair unless existing firms also had the opportunity to compete for the funds. One respondent stated that they are currently profitable without subsidies. "Subsidizing an inefficient business (cellulose to ethanol) to put a viable business out of business does not make any sense."

As with other groups, several respondents mentioned the potential for tax incentives such as to end users to increase use of renewable sources of energy or to replace fossil fuels with renewable sources. Tax incentives were reported to "…always help businesses and encourage new investment." R&D credits were also seen as useful, although the person suggesting this was not sure if such credits still exist.

At the same time, two respondents stated that incentives given to biofuels or bioproducts will allow these producers to pay more for residues and/or get residues existing mills cannot afford. This will result in driving up costs for existing mills that will have to be passed along to consumers. One respondent stated that "…particleboard producers and the Kingsford charcoal plant are struggling now."

One mill manager simply stated, "I currently employ 140 employees. If state government gave me enough money, I'd build another plant and employ another 140 employees." In short, new markets for biomass are not needed – we have existing facilities that can't get supply or keep up with demand.

Lastly, there was a suggestion to reduce road use fees for hauling biomass. Given that a load of biomass may only be worth $200, it isn't feasible to pay a high fee (or really any fee) to use the road.

5. General views on biomass utilization.

Many of these comments merely echoed the policy concerns stated above. One respondent expressed concern over the Department of Energy subsidizing cellulose to ethanol. They stated that this will cause competition for existing mills and could result in putting existing firms out of business. Alternatively, subsidies could be directed to existing mills with proven business models and track records.

One respondent addressed challenges related to the dependencies of these firms on sawmills as suppliers of raw materials. For example, recent reduction in lumber demand due to declining housing starts resulted in reduction of supply. This was one of the contributing factors to recent pellet fuels shortages (other factors included increased demand due to stove sales and increased sales from west coast producers to the east coast). Similarly, closures of secondary wood products mills has left less residues available and further, sawmills are becoming more efficient and producing less residues. One particleboard mill is running 6 days a week, but said they would run 7 if they could find more supply.

One firm stated that they are currently developing a new product that is able to use materials with more contaminants. Research is needed to understand how to overcome current market barriers to acceptance of this product.

One respondent stated that he felt much of the talk in the state right now is not well grounded. Logging contractors have not been asked to provide input. Instead, most discussions are from agency personnel and academics that do not know how to run a business. He felt there were many errors in recent reports related to the true costs to get biomass out of the woods. For example, BTU value per ton of material has been overestimated (experience has shown it takes 1.2-1.3 tons per MW not 0.9 as stated in one recent report).

In summary, many forest industry respondents stated emphasized their need for clean (free of bark, foliage, and other debris) raw materials. Of course, this was not the case for facilities able to use hog fuel. Hence, for existing firms to use biomass, research is needed in systems that can remove contaminants. At the same time, new product development is needed for products able to use a higher level of contaminants; one firm reported that they are currently developing such a product. For clean materials, one respondent stated that new products are not needed – given increased supply, they would build another facility and hire more workers now.

With regards to size of material, markets vary by particle size – fine (sawdust and shavings), coarse (chips), and hog fuel. Fuel pellet mills prefer fine material, and though they are able to use chips, one respondent reported that current chip prices would lead them to sell chips to pulp & paper mills rather than use the material in-house. Pulp & paper, MDF, and hardboard mills all prefer clean chips and hence compete for materials.

With respect to price, respondents stated that 'good quality' (i.e., clean and processed) material is worth up to $50-$60/BDT delivered; one firm reported $45/BDT as the break-even point. Hog fuel is of course, of lower value; one respondent stated that hauling and processing (grinding) added $28/BDT to their costs. Thus, the delivered cost will be at least $28 plus harvesting costs.

Recommendations for technology varied by specific industry type (pellets, MDF, cogen, etc.). For pellet producers, there is a need for bulk delivery systems. As with private landowners, there were recommendations for harvesting technology to get material out of the woods economically; however the added caveat for this audience is the need for <u>clean</u> material. Further, given the decline in harvesting infrastructure in some parts of the state, there were concerns for sufficient capacity to provide supply; public land management agencies should use stewardship contracts to pay operators to harvest this material.

Demand is currently high and supply is tight for raw materials. As such, industry personnel are concerned for any subsidies or incentives given to new firms that may lead to unfair competition for materials; existing firms should be allowed to compete for subsidies. However, one respondent saw potential for new biomass markets to 'free up' other residues for existing firms. That is, if overall supply were to increase, perhaps existing firms may have access to more material.

Lastly, forest industry personnel discussed the complex dynamics of residues markets. For example, as housing starts decline, sawmills curtail production. This results in fewer raw materials for pellet fuels, pulp & paper, and board mills. This situation was one component of the recent pellet fuels shortage. Further, as sawmill efficiency increases, residues decrease. These dynamics have combined to make raw materials supply increasingly challenging for the industry.

Pulp & Paper Industry

Several pulp & paper industry personnel were interviewed to obtain their perspectives on woody biomass utilization, biorefining, and how, or if, they see their industry being involved in an expanded biomass using industry in Oregon. Given the small number of pulp mills in Oregon only a handful of respondents were reached.

In addition, a paper industry expert (not affiliated with an Oregon pulp mill) was interviewed. He expressed doubts that firms would be willing to discuss the subject in any detail given the small number of mills in the state and concerns for confidentiality. Further, he felt that personnel at the multi-site mills' corporate headquarters (all of which are out of state) would be better able to address the questions, rather than contacts at local mills. For single-site, i.e., smaller company mills, there was skepticism as to whether these firms would have interests in research. This person's viewpoints were accurate in that it was difficult to reach personnel in Oregon pulp & paper mills.

As with other interviewees, pulp & paper industry personnel were asked the required price point needed to divert biomass to higher uses as well as technology and policy changes they felt were needed to improve biomass economics (i.e., questions 3 – 5 in table 17 above). However, as with the other forest industry personnel, the other 2 questions were adapted to better suit this audience. Specifically, respondents were asked to describe their raw material requirements (e.g., size, species, and level of purity required) and presented an open-ended question regarding their views about research related to woody biomass utilization in general.

Summaries of responses to each question are presented below.

1. What are your raw material requirements?

   One respondent used only clean chips and sawdust. They stated that supply has been tight. Another firm echoed this sentiment by stating they are currently in a scramble for material. A third reported using clean chips and recycled fiber.

   With regards to hog fuel, one mill uses about 7000 BDT per month. Most is bark but some is urban wood waste or agricultural wastes. This mill is currently working to increase hog fuel usage by 30% to replace natural gas; this is purely an economic tradeoff.

2. What sort of price point would it take to divert biomass materials to a higher value use?

   One respondent stated that $60/BDT is too high for hog fuel; natural gas is the benchmark for energy costs.

3. What technology is needed to improve biomass economics?

As with other respondents, the need for technology to reduce harvesting and transportation costs were mentioned frequently.

One mill reported that all their sludge is currently land applied. Technology to convert sludge to ethanol appears to have good potential.

4. What policy changes are needed to improve biomass economics?

One person reported that black liquor should be classified as renewable energy. Another stated that, with big enough incentives, their mill might invest in hog fuel-fired cogeneration. However, they would need to document that local supply was sufficient.

5. General views on biomass utilization.

One respondent echoed the viewpoint of the paper industry expert by saying he felt it was unlikely personnel at Oregon mills would provide many insights on this topic. He further suggested the need to talk to corporate folks for the larger firms; several Oregon mills are too small to do R&D. Time constraints did not allow for interviews with corporate personnel.

One person reported that Georgia Pacific tried making ethanol from spent pulping liquor at their mill in Bellingham, Washington. The project failed due to challenges with storage capacity for spent liquor and finished product in required quantities for market. This facility is also discussed by Graf and Koehler (2000).

With regards to biorefining and potential for specialty chemicals, one respondent stated that several Oregon mills currently sell crude terpenes as essentially ‘scrap’; the product is refined elsewhere. Another respondent wasn’t sure of the infrastructure required for a biorefinery. Further, they had not heard any discussions of it at their company. He felt this might be due to the fact that paper prices are good now and perhaps discussions will come up in the next downturn.

Further, one person emphasized the importance of understanding that there are 3 basic kinds of mills in the industry: 1) pulp mills; 2) pulp and paper mills, and 3) paper mills. Within these categories there are further distinctions based on process (e.g., how the pulp is produced). Some mills simply purchase and ‘repulp’ recycled paper, whereas others grind (refine) wood chips to produce pulp for newsprint. Neither of these types of mills have need for chemical processes or recovery systems. By comparison, kraft mills use chemicals to ‘dissolve’ (digest) wood chips to produce pulp; some of these mills sell the pulp to paper mills, others produce pulp <u>and</u> paper. Kraft mills are most likely to be candidates for biorefining given their existing chemical processes.

Energy costs were reported to be very high for one mill - worse than for mills with large hog fuel boilers. This mill has a small hog fuel boiler but currently has to burn clean, dry shavings because the material is delivered pneumatically (i.e., sawdust is too fine, mulch is too stringy). The mill's future energy plans are focused on natural gas rather than wood. Although they would like to use wood for energy, they have space constraints for a wood yard. Similarly, with respect to energy costs, another person stated that bioenergy has always been more expensive than traditional sources (at least locally); thus, they have not pursued it at all. Another mill reported having 3 boilers: 2 use natural gas, 1 uses black liquor.

In support of the notion of using more biomass for generation of electricity, one person stated, "anything that can be done to use biomass to generate electricity will help because it will reduce demand for natural gas."

As with other firms in the forest industry, pulp and paper firms require clean raw materials (primarily chips and sawdust) for producing their finished products. Several mills also use recycled fiber. Hog fuel is used by a few of the mills to fuel recovery boilers. With respect to the economics, the decision to increase use of hog fuel is largely driven by comparison to natural gas costs, and of course, local availability of hog fuel material. Each mill would likely require a detailed local assessment of potential biomass supply before committing to convert natural gas-fired boilers to hog fuel.

A key point from the discussions is that pulp & paper is not a homogeneous industry. When considering existing firms' abilities to use biomass, the distinction between different types of mills and their processes must be taken into account. For example, for biorefining, chemical pulp mills such as kraft mills are more likely to be candidates than mills that use purely recycled fiber or mechanically refine wood chips to produce pulp. However, at least from the mills interviewed, there was little current discussion of biorefining at the mill level.

As with prior interviewees, there was mention of a need for harvesting technology development. Technology development for converting pulp mill sludge to ethanol was also suggested.

Finally, with respect to pulp & paper firms, there appear to be significant opportunities for lessons learned from the experience of Georgia Pacific in producing ethanol at their Bellingham, Washington facility.

Interview Summary

In general, stakeholders reported that raw material supplies are constrained at the present time; for the most part, woody biomass is currently being directed to the highest and best use possible. However, markets are needed for logging slash in that the majority of slash is being piled and burned. Research is needed to develop products that can use 'mixed' biomass (wood, bark, and foliage) and/or systems to segregate residues to produce clean materials desired by the vast majority of existing firms. Research was also recommended related to harvesting, processing, and transportation technology as well as cellulosic ethanol.

Economics drive most landowner decisions with respect to harvesting – if biomass pays its way out of the woods, many landowners will be 'players' in the marketplace. Price points cited by landowners and industry personnel overlapped - landowners felt they needed to receive between $40 and $60 per BDT at the landing; at least one industry member stated that $45/BDT delivered is their break-even purchase price. Given that hauling costs are not being covered at these prices, there is a significant gap in meeting the price points of suppliers and users. Further, more discussions are needed here to ensure the two groups are talking about the same material (hog fuel vs. clean chips).

Also with respect to economics, some landowners see benefits to thinning overstocked forests beyond pure cost recovery. Further, several landowners stated that the current approach to handling logging slash – piling and burning – is not free. Thus, discussions of the economic feasibility of harvesting and hauling should take into account the costs currently incurred by landowners for slash disposal.

Stakeholder views on incentives and subsidies were mixed. Some felt incentives are needed to spur investment. Others were concerned that such incentives will lead to creating unfair advantages for new firms such that they out-compete existing firms for raw materials.

Lastly, though it did not come up in the interviews, the recently (4/12/07) announced formation of a 'biofuels alliance' between Weyerhaeuser and Chevron[12] is strong evidence of interest within the forest industry in biofuels.

[12] See the press release at http://www.chevron.com/news/press/2007/2007-04-12.asp

4. Conclusions & Recommendations

The preceding chapters provided an overview of Oregon's existing primary forest products manufacturing industry and estimates of potential biomass supply by region, a review of recent reports related to woody biomass utilization, and stakeholder perceptions on biomass utilization barriers and opportunities. A recap of the contents of each chapter is presented below followed by key conclusions and recommendations.

Conclusions

Supply and Demand – Biomass Inventory and Existing Industry

Chapter 1 presented a discussion of the various forms of woody biomass (logs, veneer, bark, chips, shavings, sawdust, hogfuel, etc.) used in the forest industry. To assess regional demand for various forms of woody biomass, geographical distribution of Oregon's primary wood products firms was presented. Total timber harvest and product (logs and residues) flows within Oregon's primary wood products industry were discussed as well. Volumes of merchantable and non-merchantable standing timber inventory were presented for each county in the state as an indication of potential supply. Implications for enhanced biomass utilization in each region were presented based on existing infrastructure and potential supply.

In looking at Oregon's existing primary wood products industry it is clear that the firms are highly interconnected and interdependent. Biomass users such as pulp and board mills are critically dependent on production from sawmills and veneer mills. Sawmills and veneer mills in turn rely on pulp and board mills as markets for the substantial volume of residues generated in sawmilling and veneer production. Nearly all of the existing mill residues are used. In considering mill residues as potential sources of woody biomass, it seems unlikely that existing markets can be disrupted in the absence of new, higher-valued markets. For example, a cellulose-to-ethanol facility would have to be able to pay at least as much for its raw materials as a pulp mill or existing particleboard mill in order to compete in the existing mill residues market. By contrast, markets for logging slash and non-merchantable (i.e., small diameter) timber are currently very limited.

In examining existing forest industry primary processing infrastructure in conjunction with potential biomass supply, the key conclusions for the state as a whole, and by region are:

- Statewide – The majority of timber supply in Oregon currently comes from private forestlands. The ratio of public/ private forestlands varies significantly county to county. Hence, when discussing potential for increased utilization of woody biomass, it is critical to examine supply and existing markets within a narrowly-defined region (e.g., county or radius around a community).

- Southern Oregon – There are substantial inventories of merchantable logs and net biomass on public as well as private lands in southern Oregon. In addition, there is significant existing processing infrastructure. This region appears to have very strong potential for increased biomass utilization.

- Eastern Oregon - Economic development is needed in most rural areas of the state and in eastern Oregon in particular. Grant County has significant volumes of woody biomass and some processing infrastructure for logs is still in place. However, markets for mill residues such as chips, sawdust/ shavings, and hog fuel are extremely limited. Further, net biomass supply in this area is heavily dependent on the availability of publicly-owned timber.

- Northwest Oregon – This region has the greatest diversity of both processing infrastructure (sawmills, veneer mills, and pulp & paper) and the most balanced mix of public and private ownership of both merchantable logs and net biomass. Little attention has been given to this area for biomass utilization potential thus far given the strong existing industry in the region and the low risk of catastrophic wildfire in the region's forests. However, as the only area of the state with existing pulp & paper mills, northwest Oregon is likely to play a role as a biomass 'test case' for other areas of the state in that fewer hurdles exist such as dependency on publicly-owned timber and requirements for investing in construction of new processing facilities.

- Central Oregon - Existing primary processing infrastructure in central Oregon is likely to be a limiting factor in near-term utilization of woody biomass. However again, this assessment is partly due to how regions have been defined here (e.g., Klamath County could be considered part of the 'central Oregon corridor' rather than southern Oregon). Both infrastructure and available merchantable log volume and net biomass volume are modest. However, this region appears to hold the best potential for western juniper utilization; the greatest concentrations of juniper in the state are in Crook County.

Review of Recent Reports on Biomass Utilization

Chapter 2 presented a review of five recent reports related to biomass utilization in Oregon. Reports included the Oregon Forest Resource Institute's comprehensive assessment of the potential for biomass energy and biofuels in Oregon, a report on the research capabilities and opportunities at Oregon State University's College of Forestry, biomass working group/ task group reports to the Governor of Oregon's Renewable Energy Working Group and the Western Governors' Association, and a technology roadmap developed by the American Forest & Paper Association. Specific focus for the reviews was on recommendations for research to help overcome current barriers to biomass utilization.

The reports provided significant information related to potential biomass supply, barriers and opportunities related to increased biomass utilization, stakeholder perspectives, and policy and technical recommendations. As the primary objective of the reviews was to summarize research recommendations, conclusions from this portion of the report are addressed in the section on Recommendations below.

Stakeholder Interviews

Chapter 3 presented the results of interviews with several private forest landowners and forest industry personnel. Stakeholders were asked how they currently use woody biomass, their raw material requirements, interests in increasing biomass utilization, price point to divert biomass to other uses, technology- and policy-related recommendations for increasing biomass utilization, and general views on biomass utilization.

Stakeholders confirmed the information presented in the forest industry overview above with respect to the interdependent nature of the industry. Raw material supply is currently quite limited, however markets are needed for logging slash in that the majority of slash is currently piled and burned on site. Research is needed to develop products that can use 'mixed' biomass (wood, bark, and foliage) and/or systems to segregate residues to produce clean materials desired by the vast majority of existing firms. Research was also recommended related to harvesting, processing, and transportation technology as well as cellulosic ethanol.

Economics drive most landowner decisions with respect to harvesting – if biomass pays its way out of the woods, many landowners will be 'players' in the marketplace. Although some landowners also see benefits to thinning overstocked forests beyond pure cost recovery. Further, discussions of the economic feasibility of harvesting and hauling should take into account the costs currently incurred by landowners for slash disposal (piling and burning).

General Observations

Based on the data collected, it became clear that there are distinct paradigms that influence how individuals define biomass and view its utilization. The primary paradigms are the components of the 'triple win' as described in the Introduction: renewable energy, economic development, and forest restoration:

- *Renewable energy* – In this paradigm, the primary focus for biomass utilization is reducing fossil fuel use through increased production of biomass energy (cogeneration) or biofuels. As such, biomass is defined primarily as non-merchantable timber, logging residues and perhaps urban wood waste. To have an impact on fossil fuel use, scale and/ or number of facilities must be large; thus large volumes of biomass are required. Primary barriers are related to public land management and energy policy as well as harvesting and transportation costs for non-merchantable timber. Key players in the existing energy are sawmills (given existing capabilities to use hog fuel) and pulp & paper firms. The latter are existing markets for hog fuel and may have potential to serve as biorefineries producing liquid fuels. Key technology needs are related to improving the economics of biomass harvesting and transportation systems and liquid fuels conversion processes.

- *Economic development* – For those concerned primarily with economic development, the focus is on creation of local jobs via utilization of local raw materials. Small diameter timber utilization is the top priority, and thus biomass is defined primarily as small timber. Key barriers are federal timber supply and gaps in local infrastructure (harvesting as well as processing). The principal players in the existing industry are small log sawmills, post & pole mills, and log home builders and new firms and/ or markets are needed for small timber and non-merchantable timber. Technology needs are related to reduced harvest and transport costs for small timber as well as value-added products and markets.

- *Forest restoration* – For individuals and organizations focused on forest restoration, the primary goals are improving forest health in general and reducing wildfire hazard (i.e., harvesting to reduce fuel loading) in particular. Hence, federal forest management is the primary concern. Biomass is viewed primarily as non-merchantable timber, although there is recognition by some (but not all stakeholders) that merchantable timber will likely result from restoration work as well. Industry (existing or new) is considered primarily from the viewpoint of a means to reduce treatment costs. Key needs are related to the science underlying forest restoration, public perceptions of forest management, and more accurate inventory data and harvesting technology for non-merchantable timber.

Of course, the 3 paradigms are not mutually exclusive; there are significant areas of overlap and many individuals will hold more than one paradigm. The main point is that these appear to be the dominant viewpoints. As a result, people with differing paradigms may use the same terms, but mean different things and will emphasize different 'solutions' to the problem (or perhaps not see that there is a problem needing a solution). Realizing the 'triple win', however, requires the ability to simultaneously address all 3 paradigms. *As a collaborative and multidisciplinary effort, the Bio-Economy and Sustainable Technology (BEST) Signature Research Center will fulfill a critical role as the entity that links the 3 paradigms together via collaborative research*. Without an entity like the BEST Center, it is likely that research and development will be narrowly-focused rather than taking a systems view.

Recommendations

The review of recent reports on biomass utilization (Chapter 2) and stakeholder interviews (Chapter 3) revealed several specific barriers and opportunities related to woody biomass utilization in Oregon as well as specific areas of research that can help address the barriers and capitalize on the opportunities. These recommendations may be categorized according to the basic principles of supply and demand. Specifically, increasing woody biomass utilization in Oregon requires addressing:

- *Supply* - Research is needed that will enable increasing the volume of available supply and reducing delivered costs;
- *Demand* - At the same time, research is needed to improve the value potential of woody biomass and hence the ability of users to pay for the material. This can be accomplished through development of new technologies and products.

Improving the economics and assurances of woody biomass supply

Adequate supply of biomass was stated repeatedly as a critical need to improve the utilization of woody biomass in Oregon. For firms to invest in infrastructure to process woody biomass for <u>any</u> end use, some assurance is needed that there will be an affordable and reliable supply of raw materials. Challenges are primarily two-fold: 1) supply from federal lands is dependent on federal forest management policy and subject to litigation that can effectively prevent harvesting from occurring (or at least greatly delay the process) and 2) for both public and private lands, costs to harvest, gather, and transport woody biomass (in the absence of merchantable logs) typically exceed the market value of the material.

Specific research recommendations are related to:

<u>1. Forest restoration science</u> – The OFRI study's first recommendation was to "Build forest restoration program on scientific understanding of restoration needs and treatments, and increase knowledge through research, monitoring and adaptive management" (OFRI, 2006). A bio-based economy will not develop in Oregon without a reliable, cost-effective supply of raw materials. It is clear that, for many regions of the state, supply of woody biomass will depend heavily on material obtained via <u>restoration</u> of public forestlands. Hence, for public support of such restoration treatments, it is critical that the treatments be based on sound science. This is a relatively young area within the discipline of forestry.

<u>2. Public perceptions</u>
As discussed in recommendation 1 above, public support is critical to gaining the 'license to operate' on public lands. Basing restoration treatments on sound science is one path towards gaining public support. However, it is also important to simply gain a better understanding of public perceptions on issues related to biomass utilization in general. More research is needed on how the public views forest restoration, biomass utilization, bio-energy, and what sorts of practices and technologies are most broadly acceptable.

In this regard, many of the reports and interviewees suggested that demonstrations/ pilot projects play a key role in helping stakeholders to see results of restoration projects, how biomass facilities function, etc., first-hand. Thus, demonstrations/ pilot projects and research to understand public perceptions should go hand in hand.

Lastly, public perceptions can be extended to include research related to consumer acceptance of new bio-based products. As a specific example, it took years to grow the market and consumer acceptance for Oriented Strand Board (OSB). It is likely that other new bio-based products will also face resistance from consumers. Research can help to smooth the process so that acceptance of new products in the marketplace is streamlined as much as possible.

3. Forest inventory data

There have been a number of studies estimating potential biomass supply at varying scales (nationwide, regional, state and sub-state). The most realistic estimates begin with an understanding of timber inventory data within an economical haul distance (e.g., 50 or 75-mile radius) of a specific community and then filter the information to remove forestlands withdrawn from commercial timber harvest (e.g., Wilderness Areas), roadless areas, etc. to result in an estimate of potential local biomass supply. However, these estimates are only as good as the primary input – the timber inventory data. Even in the comprehensive assessment for 20 counties of Oregon conducted as part of the recent OFRI study (OFRI, 2006), a key limitation is that the inventory data are 10-15 years old and often at a scale such that they are only accurate across a large geographic area. For individual communities to determine if a biomass facility is economically feasible, detailed and accurate inventory data are needed on a case-by-case basis.

Further, there has been little biomass supply information developed for northwest Oregon. The OFRI report addressed fire-prone areas of southern and eastern Oregon but not northwest Oregon. Given that a substantial portion of the existing forest industry infrastructure and harvest activity is currently occurring in northwest Oregon, a supply assessment (including standing timber inventory and logging slash from ongoing commercial timber harvesting activity) is warranted in this region of the state.

Lastly, there is a need for additional CROP (Coordinated Resource Offering Protocol) projects in Oregon. To date, the only CROP project in the state has been in Central Oregon. These projects work to identify planned local timber harvesting/ forest restoration projects in specific US Forest Service Ranger Districts. The projects then work to schedule harvests such that volume of biomass supply is reasonably consistent in a region and hence the forest industry and investors have some reasonable assurance of long-term supply. At a minimum, new CROP projects are needed in northeast Oregon and southwest Oregon. The research emphasis related to this topic is to explore past and ongoing projects and seek lessons learned and opportunities for new projects.

4. Harvesting, processing and transportation

Availability of public timber is often cited as a key (or the key) barrier to increased utilization of biomass. However, even from private forestlands, the high costs associated with harvesting and transporting biomass result in a delivered price that typically exceeds current market value of the material. Thus, systems are needed to reduce costs of biomass harvesting, processing, and transportation.

Research is needed to develop and test new harvesting systems and to test and refine existing technology used in other regions. ‘One size fits all’ systems will not be effective as harvest systems must be matched to specific forests and topography (e.g., mix of tree species and diameters, steepness of slopes, proximity to residences, etc.).

One key hurdle related to transportation is the low density of biomass; costs per delivered ton could be greatly reduced by technology that densified biomass at the harvest site. Slash balers are one example. Additional processing conducted at the harvest location may further reduce costs per ton. Examples of processing technology include machinery to grind material to a particle size usable in cellulosic ethanol conversion, portable pyrolysis units that convert logging slash to bio-oil, distillation systems for removing high-value volatile oils, etc.

For biomass to be used in existing products that require clean raw materials, technology is needed that can segregate bark, foliage, and wood in a cost-effective manner. Approaches used today involve leaving limbs (and hence foliage) in the forest and debarking logs at the mill. It is far more challenging, however, to segregate wood, bark, and foliage from logging slash given the size and shape of the material.

While the above recommendations on harvesting, processing, and transportation are applicable to most tree species in Oregon, the situation for western juniper is unique. The dramatic expansion of juniper into eastern Oregon rangeland and resulting detrimental impacts on water availability, erosion, and reduction in forage for wildlife and livestock have led to increased interest by public and private land managers to pursue juniper control programs. However, juniper harvesting is difficult and expensive. The trees are short, highly-tapered, often large diameter at the base, and have numerous large limbs that often extend to ground level (making felling difficult). Further, there are often few stems per acre. Thus, research is needed to develop systems uniquely suited to western juniper.

Improving the value of biomass-derived products

The preceding recommendations emphasize research directed to enhancing available biomass supply in Oregon. It is also imperative to pursue research focused on development of biomass utilization technology, products and markets to improve the market value of the material.

<u>1. Product and market feasibility</u>

Research is needed related to a number of topics that can help assess the market feasibility of various approaches to biomass utilization. Variability in quantity and quality of supply and complex interactions and interdependencies in the forestry sector make it difficult to assess the feasibility of a proposed new facility as well as impacts on existing enterprises. Computer modeling and simulation are well-suited to such assessments and enable testing numerous ‘what if’ scenarios without incurring the high costs and risks inherent in new ventures. Specific examples of facilities that could benefit from simulation models include:

- Integrated biorefineries – facilities that use biomass to produce liquid fuels, specialty chemicals, and chemical feedstocks; scale could vary from facilities similar to existing chemical pulp mills to portable facilities for in-woods use;
- Integrated small log processing facilities – for example, co-located but independently-owned and operated small log sawmills, post & pole processors, pellet mills, and whole-log chipping contractors; and
- Log sort yards – various scenarios could be examined such as cooperative-owned, with and without value-adding capacity, etc.

From the 'economic development paradigm' discussed above, there is considerable interest in developing value-added uses for small diameter timber. Much R&D work has been done in this area. The USDA Forest Products Laboratory (FPL) in Madison, WI has been particularly active in small diameter timber R&D. The research needs here are to review current literature and identify additional needs with a specific focus on Oregon resources and infrastructure. Of course, where opportunities exist, technology transfer is needed to establish a commercial enterprise capable of capitalizing on products and technologies already developed by the FPL and others.

With respect to biorefineries, research is needed simply to understand existing products and markets. One interviewee at an Oregon pulp mill stated that chemical pulp mills currently produce crude terpenes that are essentially sold as 'scrap' and refined into higher valued chemicals and chemical feedstocks outside the state. Assessing the potential for integrated biorefining requires greater understanding of existing products and markets.

One specific research need related to markets is to identify barriers to development of industrial grade pellets in Oregon. As described by existing pellet producers, current markets are primarily bagged 'premium' grade pellets that require clean raw materials such that the pellets have very low ash content. What are the barriers to development of a bulk pellet industry that is capable of using biomass that contains higher concentrations of impurities such as bark and foliage (and hence, pellets with higher ash content)? Are there significant market opportunities beyond fuel (e.g., animal bedding) for which ash content is not important?

2. New product development

Closely linked to the above recommendations for research to assess market and new venture feasibility is of course the necessary research to develop the new products themselves. Several specific areas of opportunity for Oregon include:

- Advanced wood composites – Wood and non-wood composites such as wood-plastic, wood-rubber, and wood-nylon composites are examples of products engineered for specific end uses. Research is ongoing at OSU in these areas, however expanded support would help to speed the development and ensure the commercial success of these products. In particular, though markets for wood-plastic composites have been increasing steadily for over a decade, there are no wood-plastic manufacturing facilities in Oregon.

- High value specialty chemicals – basic research is needed to characterize various forms of biomass for potential biochemicals and bio-products. That is, what suite of chemicals and chemical feedstocks might be derived from various tree species[13] and biomass 'fractions' – wood, bark, and foliage? Following such characterization, research is needed to determine potential end uses for compounds such as chemical feedstocks, natural insecticides and their efficacy, flavorings and fragrances, etc.
- Value-added products from small diameter timber and western juniper – research was recommended above for biomass/ juniper harvesting systems and review of small diameter timber product development. Additional research is needed to develop high-value products from these resources. For example, given that juniper is highly durable and aromatic, what potential products might be derived from this species?
- Industrial/ commercial-grade pellets – As stated above, research is needed to identify market barriers to pellets that may be produced from biomass. Research is also needed to determine the mix of biomass fractions and species for which pellets can feasibly be produced (e.g., without plugging equipment or failing to pelletize) and the properties of these pellets for uses such as bulk fuel, animal bedding and perhaps other uses.

<u>3. Technology development/ refinement</u>

Lastly, research is needed in a broad array of topics related to development or refinement of technology for biomass utilization. Specific examples include technology for converting cellulose to ethanol as well as other forms of renewable energy.

With respect to cellulosic ethanol, while research is ongoing around the nation on this technology, there were several recommendations to focus on systems applicable to the softwood resources of Oregon; a pilot cellulose-to-ethanol facility at OSU was recommended as a means to achieving this goal. Chemical Engineering faculty at OSU recently presented research[14] to explore robust ethanol fermentation organisms that are tolerant to fermentation inhibitors like oxalic acid in bark. And as described in Chapter 2, faculty in Wood Science & Engineering at OSU have proposed research on alternative separation technologies such as nanocomposite membranes for separating ethanol and water following distillation.

Also with respect to ethanol, one interview respondent discussed the need for research in conversion processes to produce ethanol from pulp mill sludge. And a recommended technology road map for the pulp & paper industry suggested research into removing hemicellulose prior to pulping for conversion to ethanol and other products.

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[13] There are at least 10 commonly-used commercial species (e.g., Douglas-fir, western larch, ponderosa pine, sugar pine, lodgepole pine, western hemlock, white fir, grand fir, western redcedar, and red alder) in Oregon and numerous 'lesser-known' species (e.g., Pacific madrone, golden chinkapin, bigleaf maple, western juniper, myrtlewood, Oregon white oak, tanoak, black oak, Port-Orford-cedar, etc.).

[14] Note: These research recommendations were not presented in Chapter 2 as the information was presented at a symposium following data collection for this report.

There are also a number of research recommendations related to other forms of renewable energy. For example, the need to 'densify' woody biomass to reduce transportation cost per ton was mentioned in the section above on harvesting and transportation research. Portable pyrolysis units are one potential approach to densification. These units use logging slash (or other woody biomass) to produce a bio-oil that may be used as a fuel oil or for chemical feedstocks. Research is needed to develop and refine portable technology such that the equipment can operate at the harvest site.

A pulp & paper industry technology road map recommended gasification of pulp mill black liquor to produce syngas. Economics will dictate if the best use of this syngas is for production of liquid fuels or for cogeneration.

Lastly, faculty in Wood Science & Engineering and Biological and Ecological Engineering at OSU have proposed research into using woody biomass in a microbial fuel cell. A small-scale working prototype has been developed to produce enough electricity to power a small fan. Research investments are needed to refine the processes and to enable scaling-up this technology for larger-scale use.

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