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Forest Biomass Utilization in the Pacific Northwest: Innovative Research Facilitates Business Success

Proceedings of a Workshop

Technical Editors

David L. Nicholls is a research forest products technologist, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 11175 Auke Lake Way, Juneau, AK 99801; **Rachel White** (retired) was a science writer, U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station, 1220 SW 3rd Avenue, Suite 1400, Portland, OR 97204.

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Abstract

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The U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station hosted a 2-day regional biomass workshop in May 2022, with the objective of reviewing recent developments, trends, and opportunities in biomass utilization. Day 1 focused on recent research, and Day 2 focused on biomass success stories from practitioners and business owners. About 120 attendees participated in this virtual event.

Effective biomass utilization—from forest residues, wood products residues, and thinned or sustainably harvested stands—is one tool that managers have to help mitigate wildfire risk. Biomass supplies, transportation chains, processing, and product marketing are gaining importance, while more efficient utilization of logging and wood products residues is becoming an imperative as smaller diameter logs receive greater utilization. Although the geographic focus of this workshop was the Pacific Northwest, many topics had relevance nationally, such as biochar production and use, biohub formation, wood residue utilization, and successful small business management. Presentations identified current barriers to commercial utilization so that businesses could use this information to achieve greater success, while also enabling sustainable forest stewardship and serving rural communities.

KEYWORDS:

Biochar

Biomass utilization

Mass timber

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Wood products

Foreword

David L. Nicholls

A virtual, 2-day Pacific Northwest regional biomass workshop was held in May 2022, with the objective of reviewing recent developments, trends, and opportunities in biomass utilization. Day 1 focused on recent research, and Day 2 focused on biomass success stories from practitioners and business owners. About 120 attendees participated in this virtual event.

The biomass landscape is changing rapidly in this region of the country, with new products like biochar, torrefied wood, pellets, and sustainable aviation fuels currently being developed and on the horizon. Biomass supplies, transportation chains, processing, and marketing are of interest to practitioners in this field.

At the same time, more efficient utilization of logging and wood products residues is becoming an imperative as smaller diameter logs receive increased attention with greater utilization. Additionally, the U.S. Department of Agriculture, Forest Service's wildfire crisis strategy includes mechanical thinnings aimed at reducing wildfire risk to vulnerable communities, which creates additional regional biomass supplies.

Although the geographic focus was the Pacific Northwest, many topics had relevance nationally. Included were biochar, biohub formation, wood residue utilization, and successful small business management. A common theme of the presentations was to identify current barriers to commercial utilization in an effort to help startup businesses, as well as established operators, identify strategies for greater business success, while helping with sustainable forest stewardship, serving rural communities, and recognizing and enabling underserved populations.

Western forests and landscapes are undergoing unprecedented shifts as climate change results in ever-increasing wildfire magnitude, size, and severity. Effective biomass utilization—from forest residues, wood products residues, and thinned or sustainably harvested stands—is one tool that managers have for mitigating these trends. Responsible and cost-effective biomass use can provide an array of societal benefits from energy, innovative wood products, and other ecosystem services. Many of the topics presented in this summary are closely intertwined with the Forest Service's wildfire crisis strategy and are expected to gain importance over the coming decades.

Following the workshop, science delivery specialist Rachel White worked with authors to summarize the information in their presentations, and these summaries, are what we report in this proceedings. Information, such as company names and addresses, were accurate at the time of the workshop but may not be current at the time of publication.

We acknowledge Dr. Carlos Rodriguez Franco and Dr. Thomas Schuler (both of the Forest Service) for their help, insights, and guidance in planning this workshop.

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Biomass Utilization Issues, Challenges, and Successes

Carlos Rodriguez-Franco[1]

Introduction

Forest management activities combined with natural disturbances generate abundant quantities of forest biomass that are often underutilized. This is especially true in Western U.S. states where inherently high wildfire risks mean that there is a compelling need to utilize hazard fuels. Forests can sustainably provide substantial forest biomass as a renewable source for biobased products and bioenergy that are critical to maintaining and enhancing environmental conditions, economic stability, and energy security. Forest management activities can generate biomass, including branches, tops, leaves, bark, and other unmerchantable components, that are frequently left in the form of slash piles, which are either burned or left in place on the forest floor, increasing wildfire risk. In other cases, biomass is redistributed back to the forest floor to enhance the site quality and avoid soil erosion. In still other instances, biomass is removed from harvest sites to facilitate access and site preparation for replanting operations, decreasing the risk of insect and disease outbreaks. Thus, there are numerous options available to managers for processing biomass from forest restoration activities, yet few of these generate merchantable products.

However, this is changing. The industrial use of forest biomass and the need to decrease carbon emissions to mitigate climate change have created incentives to increase the use of forest biomass in bioenergy production and related products. The expanded use of forest biomass for value-added products and energy is one strategy for decreasing hazardous fuel volumes while also decreasing the potential atmospheric carbon emissions. Forest management practices and utilization technologies that are currently in place to harvest, recover, and process forest biomass facilitate its use as a bioenergy feedstock and a source of innovative biobased products. Specific benefits of increased biomass utilization include (1) more robust energy supply chains and bioproducts, (2) decreased impacts of climate change, and (3) decreased risk of catastrophic fires.

The objective of this paper is to examine the main issues surrounding forest biomass utilization, challenges, and successes in the United States including sustainability, industry location, transportation costs, and current policy.

[1] Senior leader, U.S. Department of Agriculture, Forest Service, Washington Office, Research and Development, 201 14th Street SW, Washington, DC 20250; carlos.rodriguez-franco@usda.gov.

Defining Biomass

In practical terms, forest biomass includes all standing vegetation (live and dead trees), vegetation on the forest floor, and other plant residues. However, for industrial purposes, biomass becomes the sum of all parts of trees available for utilization. This includes saw logs; veneer logs; and bark, branches, leaves, needles, shavings, chips, and tips of the tree. Forest biomass also includes residues remaining after harvesting forest products, fuelwood from forestlands, residues from forest products processing mills, and forest residues from silvicultural treatments or restoration actions included in a forest management plan (Greene 2020).

Summary of Key Biomass Legislation

- **Energy Security Act of 1980**—defined biomass as "any organic matter which is available on a renewable basis, including agricultural crops and agricultural wastes and residues, wood and wood wastes and residues, animal wastes, municipal wastes, and aquatic plants."
- **National Energy Policy Act of 1992**—comprised of several provisions that encourage the use of renewable energy sources.
- **Executive Order 13134 (1999)**—issued to encourage the development and promotion of biobased products and bioenergy.
- **Energy Policy Act of 2005**—established the use of cellulosic materials for biofuels production and established the Renewable Fuels Standard that imposed an upper limit on forest biomass use for biofuels.
- **Energy Independence and Security Act of 2007**—defined renewable biomass in such a way that the Renewable Fuels Standard imposed restrictions on the use of raw material from federal and tribal lands.
- **Food, Conservation, and Energy Act of 2008 (also known as the 2008 Farm Bill)**—included biomass from federal lands as a biofuel feedstock but limited the use of forest biomass as a feedstock for biofuels imposed since 2007.
- **Agriculture Improvement Act of 2018 (also known as the 2018 Farm Bill)**—included provisions on forestry, farming, and renewable energy. The Forest Service was granted permanent authority to conduct stewardship contracting. This bill also established Energy Title programs for rural energy, biomass crop assistance, markets, biofuels, and community wood energy.
- **Inflation Reduction Act of 2022**—indicated uses for biomass to be consistent with the definition of biomass provided by Internal Revenue Code (1986): any organic material other than—(A) oil and natural gas or any product thereof, and (B) coal (including lignite) or any product thereof.

A key benefit of this forest biomass legislation is to provide definitions of which feedstocks can be used under various programs and for which bioenergy applications. These definitions also have important implications for research and development and technology transfer and can reduce technology costs for landowners and businesses.

States have also enacted their own forest biomass legislation. Ebers et al. (2016) reported 494 state laws to support using forest biomass for heat and electricity (of which 83 percent applied broadly to all renewable energy, 8 percent addressed biomass energy, and 9 percent were related to forest bioenergy). Financial incentives (including tax incentives, subsidies, and grants) are the most widely accepted policy instruments used by states to overcome the challenge of producing a sustainable feedstock.

Social Issues Associated With Biomass Use

Environmental and community groups have expressed concern about the use of forest biomass for bioenergy. Key issues include noise and traffic near processing mills; human health concerns related to pollution; and the location of the mills in, and potential impacts on, underserved communities. Other topics of concern stem from climate change, in particular the debate regarding carbon neutrality and carbon debt. Carbon neutrality refers to forest biomass use for energy production that releases the same amount of carbon sequestered by the trees (biogenic cycle), based on carbon stocks accounted for at the landscape level. The carbon removed from harvesting one stand is offset by the carbon uptake of the remaining stands. Alternatively, a carbon debt model assumes that when forest biomass is removed, that there is a lag time before it regenerates (i.e., the time to recover the amount of carbon removed assuming the same plot will regenerate). Forest managers must weigh these tradeoffs as they consider how sustainability issues balance with responsible use of forest resources.

Climate Change

The effects of climate change have been shown to increase wildland fire risk not only in summer months but throughout the year. The persistent drought in the Western United States combined with overstocked forest stands creates forest ecosystem imbalances, promoting high competition for nutrients, water, light, and other resources. This creates conditions for insect attacks and diseases, which in turn enhance conditions for wildland fires.

California has been at the forefront of forest wildfire risk because of climate change. There, an estimated 150 million trees have died over the past 10 years. The Forest Service manages close to 583 thousand acres of California forests, with fires occurring on more than 20 million acres and prescribed burns on close to 2 million acres (NIFC 2022, USDA FS 2018). However, the total area of forest land managed in California per year is relatively low, producing close to 440 million m^3 of wood; 70 percent of which is related to biomass for pulp, woodchips, and wood fuels (Greene 2020). When considering all Forest Service lands, forest growth outpaces harvests (Oswalt et al. 2019), and innovative opportunities to use forest biomass and timber can still be seized within the realm of sustainable management.

Biomass Related Employment (and Federal Support)

According to the U.S. Bureau of Labor and Statistics (2022), nationally, about 33,000 employees work as timber fallers, logging equipment operators, logging truck drivers, and wood sawing machine operators. Despite this, an estimated 7,000 additional loggers will be needed by 2026. Potential barriers are related to employee demographics and the trend for younger workers to seek urban (rather than rural) jobs as well as a reluctance to work in what they perceive as "low-tech" industries. Thus, companies are having difficulty replacing tradesmen as they retire and are losing institutional knowledge and expertise. This is especially evident in the logging and wood processing-related industries.

In response to the coronavirus pandemic of 2019 (COVID-19), Congress provided $200 million in assistance to specified timber harvesters and haulers through the Consolidated Appropriations Act of 2021. Other timber-related businesses may have received assistance under the provisions of other laws, such as the Coronavirus Aid, Relief, and Economic Security Act of 2020 (CARES Act), which provided loans, advances, supplements to state unemployment benefits, tax relief, and paid leave. The Forest Service also authorized additional time to harvest timber on federal lands for specified timber contracts (Riddle 2021). All these provisions were designed to facilitate biomass removals from federal lands while also stimulating rural employment.

Opportunities, Successes, and Challenges

The opportunities to use low-value or low-quality biomass are abundant. This is supported by reporting from the U.S. Department of Energy, which indicated high-yield potential scenarios of up to 483 million dry metric tons by 2022 and up to 1.15 billion dry metric tons by 2040 of sustainably produced forest residues each year in the United States (US DOE 2016). The Biomass Research and Development Board coordinates research and development activities for biobased fuels, products, and power across federal agencies and aims to maximize the benefits of federal programs and bring coherence to federal strategic planning. The Forest Service was part of the interagency woody biomass utilization group, integrated by staff members from the U.S. Departments of the Interior, Agriculture, and Energy that had an interest in coordinating biomass efforts, recommending policies, and coordinating on technical issues to promote biomass utilization.

The development of new technologies and innovation will provide more uses for biomass, such as greater production of biochar as a soil amendment and new advanced applications of biochar for batteries, superconductors, and concrete amendments. The development of new plastics from biomass is also underway. Innovative partnerships to find biomass opportunities and solutions also warrant consideration, including the following efforts within west coast states:

- The Northern Blues Forest Collaborative partners with Wallowa Resources and other organizations to restore forestland in northeast Oregon and southeast Washington.
- The Sierra Institute for Community and Environment’s Indian Valley Wood Utilization Campus in Plumas County, California will consist of businesses and partnerships that generate high-value products from low-value woody biomass.
- In August 2020, the Washington Forest Protection Association announced plans to develop the Darrington Wood Innovation Center in Washington (WFPA 2020).
- In February 2021, the U.S. Department of Commerce announced a $6 million investment to establish the Darrington Wood Innovation Center in Washington (US EDA 2021).
- The Forest Service is working with partners to develop biomass utilization campuses located near national forests where local communities and governments provide incentives to establish biomass utilization industries.

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Synthesis of Challenges and Innovations in Forest Biomass Logistics

Nathaniel Anderson[1]

The Objectives of Forest Biomass Utilization

Using woody biomass to produce energy, fuel, and products is an important opportunity for foresters. Although it can be grown in agricultural settings using short-rotation species, like willow and poplar, in this context, "woody biomass" refers to the tops, limbs, small trees, and unmerchantable logs that are a byproduct of forest management.

Forest management objectives often include harvesting timber, restoring ecological conditions, improving forest health, and reducing wildfire risk. Looking at the big picture, forest managers also work to protect site productivity and deliver a sustainable flow of ecosystem services, including timber and nontimber forest products, water, biodiversity and wildlife, recreation, carbon sequestration, and other benefits, especially on public lands. The silvicultural treatments implemented to achieve these objectives and benefits can produce a lot of waste woody biomass. For example, fuel treatments used to reduce wildfire risk generally remove smaller, subdominant trees, dead and dying trees, and understory vegetation that has low or no market value. This biomass is often piled and burned for disposal to reduce wildfire risk (fig. 1).

[1] Research forester, U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 800 East Beckwith Avenue, Missoula, MT 59801; nathaniel.m.anderson@usda.gov.

Figure 1—A fuel treatment with biomass removal. Forest Service photos.

Depending on the situation, we may be able to remove biomass from the site, along with logs used for lumber, pulpwood, firewood, and other products. In this case, one of our objectives is to meet the needs of our customers downstream. Woody biomass can be used as fuel for heat and power, or as raw material for producing biofuels and bioproducts, including biochar, as well as other uses of wood fiber. The downstream use informs how we handle, process, and deliver the biomass from the forest to the user, with consideration of quality, size, consistency, ash content, moisture content, and other characteristics.

Using biomass rather than burning it for disposal might generate some revenues to help offset the cost of treatment, depending on logistics and market conditions. But even if revenues do not cover the full cost of biomass harvest, processing, and transportation, there may be significant nonmarket benefits that make removal preferable to burning. Compared to open burning, removing and using biomass reduces smoke and the negative health effects associated with it, helps protect soils from burn scars that invasive species can colonize, reduces the risk of escaped fire, and is not subject to the same restrictions as pile burning, so removal can be conducted year round. Use can also reduce greenhouse gas emissions. On federal public lands, utilization must follow appropriate policies and laws, including retention of some biomass onsite for ecological benefits, and generally must serve the public interest, such as supporting local economies and jobs. This helps ensure that biomass use is environmentally, economically, and socially sustainable.

Advantages and Challenges of Forest Biomass

Advantages of Forest Biomass

- Large stocks available as waste or byproduct of management
- Many options for material type, cost, and quality
- Low purchase cost
- Colocated with existing industry and infrastructure
- Generally good carbon balance and sustainability
- Tied to nonmarket benefits and diverse ecosystem services

Woody biomass has several important competitive advantages over other types of biomass. It is plentiful and widely available. Even in landscapes that may not be considered forest, such as urban areas and woodlands, vegetation management can produce a lot of waste biomass. Across the landscape, there are many different options for material cost and quality ranging from clean, dry chips to wet, ground hog fuel with relatively high ash content. As a waste or byproduct of forest management, woody biomass often has a low, zero, or negative purchase cost (i.e., stumpage cost), sometimes as little as $0.25 per ton from national forests, for example. Active forest management is generally colocated with existing forest industry, such as sawmills, which means the equipment and infrastructure for biomass harvest and delivery is available. Woody biomass generally has good carbon balance and sustainability, depending on land use, compared to things like growing corn for ethanol. And unlike agricultural biomass crops, forest biomass does not compete with food crops for land use, and its harvest is tied directly to enhancing forest ecosystem services and nonmarket benefits, like improving forest health, reducing wildfire risk, lessening smoke effects, and improving greenhouse gas emissions.

Even though it has a low purchase cost, woody biomass also has some significant challenges and constraints:

- Associated with a high cost of production
- Dispersed across the landscape
- Bulky and difficult to transport efficiently, even after processing (e.g., chipping or grinding)

Many treated sites are distant from customers on difficult terrain with poor road access, further increasing transportation costs (fig. 2). Compared to harvesting and loading long logs, biomass can have high harvest, handling, processing, and loading costs. These high logistics costs are met with low market value, which is reflected in low delivered prices that are often less than the cost of logistics, making it financially infeasible to harvest in many places. Certain types of woody biomass feedstocks are also episodic in nature, with highly variable characteristics and uncertain long-term flow related to future land management needs and associated treatments. For example, beetle epidemics may result in a short-term surge of biomass associated with salvaging dead timber, which is unlikely to continue reliably into the future.

Innovations in Operations Research and Logistics

Over the past decade, these challenges have catalyzed a considerable amount of research, development, and innovation to help reduce biomass costs and increase value, with the goal of improving biomass supply chains and generating both market and nonmarket benefits from increased biomass utilization. This work has helped derisk investment in new enterprises and businesses that use biomass. Furthermore, recent developments cut across forest planning, operations, logistics, designer feedstocks, and densification, and research has quantified nonmarket values and benefits of biomass utilization.

Figure 2—Harvesting woody biomass from a fuel treatment to fuel a powerplant. USDA Forest Service photo.

In planning, researchers have developed new analytical techniques to link traditional forest operations research with spatial analysis to map the economic favorability of harvesting methods and optimize biomass harvest to reduce costs. For procurement planning, geographic information system tools have also been developed to map aboveground biomass, link forest characteristics to specific types of treatments, and optimize harvest logistics and transportation to a specific facility location (Hogland et al. 2018). Using lidar and other remotely sensed data, forest managers can map optimal harvesting systems over large landscapes based on terrain and forest conditions and then determine where biomass is most likely to be concentrated for removal versus left on the treatment unit (Becker et al. 2018). Inventory control methods have been applied to biomass supply chains to optimize material flows and storage for facilities like pellet mills and powerplants (Helal et al. 2023).

To help reduce costs, recent forest operations research has focused on developing accurate cost models for fuel treatment and biomass harvest, using both empirical cost models (Townsend et al. 2019) and simulation-based approaches (She et al. 2018). Researchers and industry innovators have also developed new and modified equipment for biomass harvesting, including trucks and machines that can increase load density and access difficult sites including steep slopes and places with poor road access. To improve value, researchers have focused on production of designer feedstocks close to the forest and densifying biomass products to improve transportation efficiency, energy density, material handling, and storage (Han et al. 2018a, 2018b). Slash sorting, value handling, precision grinding, and production screening can be used to separate slash into various components and process it to meet specifications for different end uses. Small-scale systems also have been developed to produce sawdust, wood crumbles, wood straw, and other biomass products closer to the biomass source. Densification options now include slash bails, slash bundles, briquettes, pellets, torrefied wood, and biochar, all of which can be made either onsite or at a concentration yard or facility.

Finally, to help inform effective public policy, researchers have blended technoeconomic analysis with nonmarket valuation to quantify the various market and nonmarket costs and benefits of using biomass for energy, fuels, and products. For example, one study in Colorado showed that fuel treatments are likely to be undervalued when evaluated strictly on a financial basis and that the public has a significant willingness to pay for nonmarket values associated with renewable energy, less smoke from wildfire and pile burning, improved forest health, and lower likelihood of severe wildfire (Campbell and Anderson 2019). Harvesting biomass can help meet diverse management objectives, but forest biomass logistics are costly and challenging, and favorable economics often hinge on nonmarket values associated with treatment. As we continue to make improvements that reduce costs and increase value, many of these innovations in logistics, forest operations, and economics must be implemented at scale to realize the full potential of biomass as a renewable resource for the expanding bioeconomy.

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Woody Biomass Potential for Energy Feedstocks in the Pacific Northwest

Burton English[1] and Lixia H. Lambert[2]

Burton English, professor of agricultural and resource economics at the University of Tennessee, is leading a project to analyze the technology and markets required to develop sustainable aviation fuel in the Pacific Northwest using privately owned forest residues.

Addressing Feasibility and Sustainability

Made from renewable biomass or waste, sustainable aviation fuel has the potential to shrink the airline industry's carbon footprint.

Using programming models, English's team addressed the following questions:

- How much woody biomass can be sustainably supplied from private forests while also meeting demand for conventional wood products?
- How do different sources compare?
- How much would this cost?

The team analyzed potential site locations for a biorefinery in three states—Washington, Oregon, and Idaho. They broke the analysis into two different scenarios: one in which feedstock demand is 545,000 dry tons per year, and one with a demand of 724,000 dry tons per year.

To find out what level of biomass feedstock is sustainable in the United States, the team ran the ForSEAM model over a 20-year period. Given the constraints, the model found that over 20 years, 50 million dry tons per year was feasible. Constraints included the assumption that the forest residue biomass is within 1 mile of a road and that only private lands are supplying the forest residue. They then used the spatial model BioFLAME to estimate the cost of feedstocks in the Pacific Northwest and conducted a suitability analysis for siting a biorefinery at prespecified potential locations.

Results for the 545,000 Dry Tons Per Year Facility

A biomass facility with the demand for 545,000 dry tons per year will require 3.4 million green tons of biomass hauled from forest landings in chipped form. The analysis located four potential sites for a biorefinery under this scenario: one in Spokane County, eastern Washington; two near Seattle (King County and Lewis County); and one in Douglas County, southwestern Oregon (see tables 1 and 2).

Results for the 724,000 Dry Tons Per Year Facility

The analysis determined there is sufficient residue for two potential biorefinery locations in the Pacific Northwest under the 724,000 dry tons per year scenario: one in Lewis County, Washington and one in Douglas County, Oregon (see tables 3 and 4).

[1] Professor, University of Tennessee, Department of Agricultural and Resource Economics, Morgan Hall, 2621 Morgan Circle Drive, Knoxville, TN 37996; benglish@utk.edu.

[2] Assistant professor, Oklahoma State University, Department of Agricultural Economics, 215 Agricultural Hall, Stillwater, OK 74078.

Table 1—Four potential biorefinery locations and costs under the 545,000 dry tons per year scenario, 2019

Potential plant location	Quantity	Average transportation distance	Transportation cost	Total cost	Per ton cost
	DRY TONS	MILES	U.S. DOLLARS		
Lewis County, Washington	545,001	77	12,952,281	32,645,187	59.90
Douglas County, Oregon	545,019	73	12,321,907	33,194,496	60.91
Spokane County, Washington	545,127	82	13,824,646	41,004,643	75.22
King County, Washington	545,022	103	17,399,604	44,798,777	82.20

Table 2—Composition of the four sites under the 545,000 dry tons per year scenario, 2019

Potential plant location	Hardwood logging residues	Hardwood pulpwood	Softwood logging residues	Softwood pulpwood
	PERCENT			
Lewis County, Washington	11	0	68	21
Douglas County, Oregon	6	2	66	26
Spokane County, Washington	0	0	24	76
King County, Washington	3	1	20	76

Table 3—Two potential biorefinery locations and costs under the 724,000 dry tons per year scenario, 2019

Potential plant location	Quantity	Average transportation distance	Transportation cost	Total cost	Per ton cost
	DRY TONS	MILES	U.S. DOLLARS		
Lewis County, Washington	724,038	80	18,037,908	46,748,076	64.57
Douglas County, Oregon	724,012	76	48,228,366	48,228,366	66.61

Table 4—Composition of the two sites under the 724,000 dry tons per year scenario, 2019

Potential plant location	Hardwood logging residues	Hardwood pulpwood	Softwood logging residues	Softwood pulpwood
	PERCENT			
Lewis County, Washington	9	0	56	35
Douglas County, Oregon	4	6	49	41

Summary

The locations of potential sites for a biorefinery are mostly near urban centers. Some sites are not located near a forest. Perhaps sources of feedstock other than forest residues might be used at those locations. Forest residues consist of logging residues, pulpwood, and unmerchantable or small-sized wood. Sawtimber was not included as an energy feedstock except for residues from logging. Only wood from private land was considered in the analysis.

Programming Models Used in This Project

ForSEAM is a linear programming model that estimates forest land production. It calculates the quantity and types of woody biomass that can be available as energy feedstock with respect to certain marginal costs. The model can be divided into three major sections: supply, demand, and sustainability. Dynamic tracking of forest growth is incorporated into the analysis, so once an area is harvested or thinned, it is taken out of production until it reaches harvestable quantities.

Biofuels Facility Location Analysis Modeling Endeavor (BioFLAME) is a spatial model that allows users to examine any combination of counties within the conterminous United States given parameters, such as biorefinery capacity, crop prices, transport cost rate, feedstock yield adjustments, hay land availability, driving distance limit, required profit, and more.

Innovative Mass Timber Development Opportunities

Marcus Kauffman[1]

Marcus Kauffman, biomass resource specialist at the Oregon Department of Forestry, is a member of the Oregon Mass Timber Coalition.

Oregon Mass Timber Coalition Goals

- Scale up housing production.
- Create good urban and rural jobs.
- Address race-based disparities.
- Provide equitable job training in forestry, construction, and advanced manufacturing.
- Support forest restoration and climate adaptation.

Oregon Mass Timber Coalition

This project aims to expand the use of highly engineered wood products for uses that would be impossible with regular lumber. The project has received $500,000 from the U.S. Economic Development Administration and is a finalist competing for $1 billion in economic development grants. If selected, the coalition will receive up to $50 million to build and supply mass timber panels for modular homes (table 1), which will be shipped to communities in need around Oregon.

A Transformational Project

The Oregon Mass Timber Coalition is a transformational project that connects rural and urban economies in a way that has never been attempted. “We’re looking at mass timber and digital fabrication as ways to address some of the deepest challenges in our state,” said Kauffman.

Wildfire and a changing climate are of major concern across Oregon and so is income inequality, lack of housing options for all income levels, and the economic struggles of rural communities. The project is designed to address some of these equity issues by including underrepresented communities in the suite of benefits.

The project will take advantage of existing technology. For example, the mass timber panels that will be used to construct homes are a commercial product. What’s new about this project is the prototyping—putting the mass timber panels into multifamily housing units and showing that they can compete well against stick frame houses. Others are developing modular mass timber but not necessarily trying to create affordable housing with it. Another innovation with this project is that it will attempt to tap into a restoration fiber supply.

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[1] Biomass resource specialist, Oregon Department of Forestry, Eugene, OR; marcus.kauffman@odf.oregon.gov.

Table 1—How do modular homes compete against site-built homes?

Site-built house	Modular house
Higher cost of construction	Reduced construction costs
Higher cost to meet energy standards for funding and code requirements	Lower energy design and less construction expertise needed
Low supply of labor and contractors—cannot meet affordable housing needs	50 to 100 percent faster time to market (lower holding costs—higher capacity)
High utility costs as a percentage of housing costs or operation expenses	Lower energy reduces utility costs (high revenues), improving debt capacity
Limited financing	Improved tax credit competitiveness and other sources of capital

Connecting to Forest Restoration

The project has the potential to support forest restoration and wildfire management by sourcing from lands that are being managed for conservation goals. The idea is to connect the forest restoration supply chain to the existing market for cross-laminated timber and mass plywood. Building on the success of Oregon's Federal Forest Restoration Program—a partnership between the State of Oregon, federal forest managers, and public land stakeholders—this project would demonstrate what is possible if that partnership could be scaled up. Because it is working on federal lands, the coalition is developing a robust track and trace program to bring transparency and accountability to the wood supply chain. The plan is to add administrative capacity and contracting capacity, through the Federal Forest Restoration Program, to do the work in partnership with the Willamette National Forest. The goal is to support up to 10 million board feet of small-diameter Douglas-fir over 4 years, connecting market growth with sustainable forest management.

An Integrated Package of Work

The coalition is building an integrated program that addresses forest restoration, jobs, and affordable housing. One key piece of this is a **flagship building innovation hub**, which will be built at Terminal 2 in the Port of Portland. The site will be home to a mass timber manufacturing facility and a 53-acre research and development campus. Once running, the factory will build modular mass timber, including 3D panels that can be flatpacked on a truck, and seismic and energy retrofits.

Other key aspects of this program will be workforce development that will address training across all aspects of the supply chain as well as research and prototyping. To further these efforts, the coalition has partnered with Hacienda, a Latino-owned, nonprofit housing developer that delivers low-income housing. The Port of Portland will be leasing an existing warehouse at Terminal 2 for Hacienda's fabrication and manufacturing of housing prototypes. Hacienda is going to produce 30 units in urban and rural communities around the state. In addition to positioning Hacienda as an industry leader, these prototypes will show what is possible.

The Code Aspect—Making Mass Timber Easier to Build

Modular homes are often confused with mobile homes, and therefore the coalition is looking at land-use code as well as building code. Many small, rural communities in Oregon don't have the planning capacity or code-writing capability to make these changes themselves. The coalition partnered with the Oregon Department of Land Conservation and Development to create model code that we will pilot in 10 communities around the state to ensure that once we have a product, it can quickly hit the ground in the communities that need it the most.

Done right, mass timber can provide affordable housing, create jobs, and address climate change. Lack of housing is a huge crisis in the region. Oregon needs to produce 30,000 to 40,000 new housing units a year to meet demand, and cost competitiveness is important. There are already 18 modular housing factories that ship within the region, but none of them focus on a broad mass timber market, and none are dedicated to affordable housing. We think our digital automated approach will contribute to lower prices. That is what this work is all about—bringing together partners, technology, and innovation, to create affordable and long-lasting homes, while also improving forest management, creating well-paying jobs, and making communities more resilient by meeting housing needs.

Forest Service Timber Contract Changes to Facilitate Biomass Use

Kraig Kidwell[1]

Three Contract Types for Disposing of Forest Products

Sale of property contracts—standard timber sale contracts in which we are selling a product that has value (even if that value is negative by the time the product gets to a mill).

Service contracts—for services, such as fuels reduction, that are funded with appropriated dollars. No revenues are generated; we are simply procuring a service or item.

Stewardship contract—a blend of the above, used for services, such as fuels reduction, in which the value of the material removed might offset some of the costs.

It might come as a surprise to learn where federal land management agencies get the authority to harvest forest products from federal lands—the U.S. Constitution, Article IV, §3. The government owns trees on federal land, and this article of the Constitution deals with the authority to dispose of government property. "This is why we sometimes feel very restricted in our capacity to do timber sales," said Kraig Kidwell, the timber contracting officer for the Pacific Northwest Region of the Forest Service. "We have difficulty managing it because it is public property, which means we have a responsibility to dispose of forest products in the best interest of taxpayers and the government."

Timber Contracting Authorities

Timber contracting has been around for a long time. A lot of case law, statutes, and regulations have developed around it, starting with the Organic Administration Act of 1897 and including major environmental legislation in the 1960s and 1970s, such as the Multiple-Use Sustained-Yield Act of 1960. The National Forest Management Act of 1976 had a major impact on timber sales because it stipulates that we cannot sell any forest product at less than its appraised value. "We get hung up on this because we think of appraised value as 'ending at zero.' But when we're dealing with certain forest products, we can actually have a negative appraised value and a negative economic value," explained Kidwell.

Other authorities include stewardship agreements, the Tribal Forest Protection Act of 2004, and the Good Neighbor Authority (Agricultural Act of 2014)—all of which have their own regulations. To help navigate this confusing array of options, a flowchart has been added to the Forest Service Manual (USDA FS 2021).

[1] Timber contracting officer, U.S. Department of Agriculture, Forest Service; 1220 SW 3rd Ave., Ste. G015, Portland, OR 97204; kraig.kidwell@usda.gov.

Forest Products Contract Options

"We have all sorts of different options. The big thing to remember about these contracts is that these are simply forms. We call them contracts, but they are just forms authorizing those activities," said Kidwell.

Refer to USDA FS (n.d.b) for more information about contracts and permits and to download forms.

Standard Contract Forms

- FS-2400-2: Contract for Sale of Decked Timber
- FS-2400-3S: Timber Sale Contract, Scaled (for simple, small sales)
- FS-2400-3T, Timber Sale Contract, Premeasured (for simple, small sales)
- FS-2400-3P: Timber Sale Contract, Forest Products (for simple, small sales)
- FS-2400-4: Forest Products Contract and Cash Receipt (for simple, low-value sales)
- FS-2400-6: Timber Sale Contract, Sales to Be Scaled After Felling (for complex, large sales)
- FS-2400-6T: Timber Sale Contract, Sales to Be Measured Before Felling (for complex, large sales)

Permit Forms

- FS-2400-2: Contract for Sale of Decked Timber
- FS-2400-3S: Timber Sale Contract, Scaled (for simple, small sales)
- FS-2400-3T, Timber Sale Contract, Premeasured (for simple, small sales)

Stewardship Contract Options

"We have options to blend restoration services with timber value, depending on what we're trading—the goods for the services. At the very simplistic level, trading goods for services could be trading 1 cubic foot of timber nonsaw biomass for whatever services we want to pay for. So, we have a lot of options within these contract types, especially when we're dealing with low-value material and trying to work through paying for service but also needing to dispose of product," explained Kidwell.

Refer to USDA FS (n.d.a) for more information about stewardship contracts options and to download forms.

Stewardship Contract Forms

When **service work exceeds the timber value**, use an Integrated Resource Service Contract (IRSC) form:

- SF-33 or SF-33T: Construction
- SF-1449 or SF-1449T: Commercial Services

When **timber value exceeds the service value**, use an Integrated Resource Timber Contract (IRTC) form:

- FS-2400-13: Scaled, Contracts with Measurement After Harvest
- FS-2400-13T: Tree Measurement, Contracts with Measurement Before Harvest

Putting It All Together

The need to provide rationalization for dealing with low-value material was not a consideration when the legislation and regulations for disposal of forest products were crafted. But Kidwell argues that there are still ways we could reach that goal. "We need to start with doing a better job right at the beginning of the process, with the analysis and NEPA," he said, referring to the assessment and reporting requirements defined by the National Environmental Policy Act of 1969 (NEPA). "In our NEPA assessment, we need to analyze for the disposal of biomass. That would open the door to all those contract options we have that we can implement to get the work accomplished. We also need to analyze all different aspects and systems for product removal. We are way behind on tethered logging systems—that's no-one's fault, but we need to be proactive instead of reactive."

Kidwell suggests that planners and project designers consider the full scope of service options from a restoration standpoint. "We need a more thorough analysis of the benefits of removing this material, plus all the opportunities presented by technological advances. For example, in my opinion, we need to do a better job of analyzing the option of creating biochar on the landing instead of burning our piles. Why is that not part of our air quality analysis? We need to then choose the best tool and stop focusing on the need to meet timber targets. Or if you are talking about timber targets, that's fine as long as we don't give it away for free. If it's going to industry, we can figure out how to do it."

All Forest Service timber contracts allow the opportunity to opt into disposal of biomass. "We can write in 'timber subject to agreement' and that could mean tops and limbs," said Kidwell. "As a regional contracting officer, I need to do a better job teaching other contracting officers and sale administrative staff what authorities and abilities they have to opt into other disposal methods. We need to update our regional slash provisions to better accommodate the disposal of slash as biomass, versus burning piles on the landing and paying that cost. Negative economic value really opens up the door."

As an example of this kind of creative problem-solving, in 2017, the Pacific Northwest Region of the Forest Service updated their slash disposal provision to say that the agency may waive specific slash treatment requirements or substitute disposal methods if it will give satisfactory results.

Summary: Rules of Thumb

1. Begin with the analysis.
2. Use NEPA to fully address the desired end results.
3. Analyze all avenues and systems for product removal.
4. Analyze all restoration service options.
5. Choose the best tool, whether it's a straight service contract, an Integrated Resource Service Contract (IRSC), an Integrated Resource Timber Contract (IRTC), or a regular timber sale.

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U.S. Department of Agriculture, Forest Service [USDA FS]. 2021. Forest Service manual, Chapter 2430—Commercial timber sales, Section 2432.32—Tasks, Exhibit 01—Best Tool Decision Tree and Exhibit 02—Decision Considerations. Washington, DC.

Innovative Production of Post/Pole and Firewood Products

Matt King[1]

Wallowa County in northeast Oregon was once one of Oregon's major timber producers. When federal forest management policy changes in the 1990s sparked a transition away from the extractive timber industry, mill closures left local communities struggling. Matt King has been working to address this issue for the last decade. He is the vice president of sales and innovation for Heartwood Biomass, LLC (hereafter, Heartwood), a small company that specializes in taking wood products that are underutilized by traditional logging and turning them into higher value products like clean energy.

Heartwood partners with Wallowa Resources, a community-based nonprofit that supports rural livelihoods and the natural resource economy. King explained how the partnership came about. "We started with Wallowa Resources back in 2000, seeking ways to help facilitate forest restoration. We wanted to try to reinvigorate the rural economy and get back to natural resource utilization but with a focus on stewardship to create rural community vitality," he said.

A Restoration Economy Supporting Communities and the Climate

As wildfires continue to increase in frequency and intensity across the West, many have tried to link and solve the parallel problems of excess biomass in forests with the economic struggles of rural communities. "There's a real need to utilize biomass, and several parties have made it work in different ways. But nobody has a silver bullet to pay for biomass to come out of the woods and facilitate that forest restoration. There has been so much thought on this—so much need for that work, particularly in light of all these wildfires that are happening and the degradation of forest health. We know that it's going to continue to be a problem. We will continue to need to remove that biomass for the sake of the forests and the communities in proximity."

Sorting and Zero Waste

"Our core competency is sorting," said King. Unlike traditional sawmills, the Heartwood facility can process small-diameter trees, which they use to create wood products such as bundled firewood sold in grocery stores. Heartwood sells its products within a 400-mile radius of the facility; both Fred Meyer and Walmart are customers.

"We can take unsorted loads of logs from restoration projects. There is way less sorting at the landing. You don't have to separate out piles for firewood, or for post and pole. If there are traditional saw logs, they can go straight to a traditional sawmill," said King. "We have worked with the U.S. Forest Service as a supplier for the last 11 years and the vast majority of the projects we've worked on have had a saw log component. It helps support the restoration work."

[1] Vice president of sales and innovation, Heartwood Biomass, LLC, 75100 Lower Diamond Lane, Wallowa, OR 97885; matt@heartwoodbiomass.com.

At Heartwood's facility, the only sorting that happens on the landing is saw logs. The rest of the logs come into the facility where they are decked or put onto a merchandizing line, which sorts each log and puts it toward its best use to maximize value, with zero waste. Besides their primary product of firewood for residential and recreational use, Heartwood also sells posts and poles, which they sell to agricultural producers, including hop farms, vineyards, and orchards.

"We also make a variety of grades of fiber. We make and sell a small amount of chips, and we make hog fuel that we use in a biomass boiler onsite that heats a couple of kilns," said King. "We even use the leftover bark in a boiler to generate the heat that kiln-dries our firewood and heats our facility. We squeeze every penny out of every log."

Heartwood's zero-waste model maximizes the value of every tree. In contrast, without a market, small-diameter logs often burn, contributing to wildfires, carbon emissions, loss of habitat, and the degradation of public and private lands. Heartwood monetizes all parts of those low-value logs and turns them into higher value consumer products.

What About Supply?

Most of Heartwood's logs come from national forest land within a 100-mile radius. Additional logs come from privately owned timberlands, often small, family-owned parcels. "We have five active U.S. Forest Service harvest contracts stretching through 2023 to remove 27,725 tons of biomass from the Wallowa-Whitman and Umatilla National Forests," said King. Meanwhile, the U.S. Department of Agriculture (which administers the Forest Service) has allocated $60 million in federal forestry investments over the next 10 years for the Northern Blue Mountains in Oregon and Washington (where Heartwood is based).

"It's been interesting over the last decade. In communities across the West, people focus on some sort of feedstock agreement that's going to last 10 years," said King. "Without that, they think it's impossible to build a sustainable facility. But we have never had one of those agreements; we just work with the Forest Service and private landowners. The Forest Service, in particular, has stepped up. For 20 years, there was no stewardship sale, but in the last 9 years, there have been 11. We really trusted the Wallowa-Whitman and Umatilla National Forests, that they would play ball, and they really stepped up to the plate."

Revitalizing Rural Wallowa County

Heartwood plays an important role in revitalizing rural Wallowa County. Their facility provides more than 20 direct, permanent, entry- and mid-level jobs. This would be the equivalent of adding 10,000 jobs in greater San Francisco. An additional 30 or more third-party jobs have been created in related businesses. Heartwood has contributed more than $15 million to the local economy via wages alone, while facilitating more than 30,000 acres of forest restoration.

"We see this sort of facility—which we have proven effective here in Wallowa County—as promoting the idea of the stewardship economy. We are maintaining that North Star of forest restoration but also revitalizing communities by creating jobs, educational opportunities, and direct contributions to the local economy, to people's livelihoods, and even in how people interact with the forest. You can really see on an individual and personal basis the impacts these businesses can have for people. We are really proud of that," said King.

Scaling Up

With a stable source of raw material and growing demand, Heartwood has an opportunity to scale up its facility across the West. "We are pretty excited after 10 years of doing this model, because we have worked out the kinks and found ways to do things more efficiently to get higher through-put and higher quality products. And we understand there is a need for these sorts of facilities across the West—facilities that are regional in terms of markets and local in terms of supply," said King. "Heartwood has shown you can be successful in creating a restoration-based economy in the rural West and bring benefits to the communities that really need the help."

Restoration Fuels Update and the Role of Torrefied Products

Matt Krumenauer[1]

The U.S. Endowment for Forestry and Communities is a nonprofit, public charity that was established in 2006 at the request of the U.S. and Canadian governments. The endowment is committed to promoting forest retention and forest health, while revitalizing forest-rich communities. Matt Krumenauer, vice president of special products for the endowment, is currently working on a program focused on forest carbon.

"We believe people value what they use. Using forest services and products—wood, paper, water, carbon, recreation—incentivizes forest retention and health," said Krumenauer. "We are seeking to make a number of investments in both capacity building for the sector and in projects and mission-related investments to help advance opportunities for forest carbon and biochar."

The Restoration Fuels Project

Krumenauer also serves as chief executive officer of Restoration Fuels, LLC (hereafter, Restoration Fuels), which launched in 2018 when the endowment and the U.S. Department of Agriculture, Forest Service decided to invest in a commercial demonstration facility to prove viability at scale. This multiyear project is developing a market for small-diameter, low-value biomass that can ultimately help support the economics of forest health restoration and reduce the risk of catastrophic wildfire.

Working with the Forest Service's Forest Products Lab, the project team formed a consortium of academic institutes, technology providers, landowners, and utilities to collaborate on accelerated commercialization needs in a noncompetitive way. That work culminated in a large-scale test in Oregon, where a large amount of torrefied fuel was delivered to the Boardman powerplant. The powerplant ran for about a 12-hour shift on 100 percent woody biomass that had been turned into a torrefied fuel product.

A First-of-Its-Kind Facility

Following the proof of concept at the Boardman powerplant, work began on a demonstration and development facility capable of producing torrefied wood, biochar, and other carbon-based products. The result is the first commercial-scale torrefaction facility in North America, located in John Day, Oregon. Construction was completed in late 2020.

The plant is designed for a production capacity of 100,000 tons of torrefied fuel annually. A critical aspect of this demonstration facility is the fact that it is colocated with an existing mill—the Malheur Lumber Company. The source for the biomass is nearby restoration treatments on the Ochoco and Malheur National Forests.

"We wanted a low-cost opportunity to deploy this type of system and establish a new suite of product lines but also to take advantage of existing infrastructure. Not only physical infrastructure, such as log yards, scales, chipping facilities, and utilities, but also the human resource infrastructure that's in place," explained Krumenauer.

[1] Vice president of special products, U.S. Endowment for Forestry and Communities, 908 E North Street, Greenville, SC 29601; matt@usendowment.org.

"It made sense for us to incorporate those existing skillsets and expertise to help take advantage of the opportunity that the mill has to provide new markets for their residuals, help provide some additional diversification, help with the overall financial picture for some of the timber sales and stewardship contracts, and just try to strengthen the infrastructure in some of these areas that are lacking in a lot of the traditional infrastructure that we see in other places."

Challenges

External events and circumstances—for example, the COVID pandemic, supply chain issues, and the remote rural community—caused a few of the early challenges. "A lot of our lessons learned are not just technical but also social- and community-based," said Krumenauer. "Small businesses and others within this sector face these same challenges, and we hope our learning will help the endowment to design programs and investments to best support those needs."

The two biggest remaining challenges are **workforce** and **fiber supply**. It has been difficult to find people available to operate the plant, so the team is continuing to look at labor rates and recruitment strategies and has automated certain parts of the system to reduce staffing requirements. In terms of biomass supply, the plan was to rely on the existing supply chain in the region, but there have been a few stretches of time when the facility could not run because of a lack of fiber.

Lesser issues include technical challenges, such as startup and shutdown, creosote, and condensation of gases. "As we begin to approach full production and operations, we will need to engage in evaluation with the Department of Environmental Quality in Oregon on some of the regulatory requirements that we may face with the different product mix and the final configuration of the plan," said Krumenauer.

Products

Restoration Fuels can produce a torrefied fuel product designed to meet the customer's desired specification and plant design. They can provide test volumes to customers' plants to allow for evaluation and refinement of the final contract specification.

"Right now, we're beginning to send product samples out. We've got some material that's gone down to California for some biochar demonstrations for biomass energy, carbon capture and storage, gasification, and oxycombustion into geologic sequestration. Metallurgical coal is a big one—there is lots of interest in that," added Krumenauer. "We are working with researchers on opportunities to add this material to concrete and other built environment applications, as well as the original torrefied fuel market that we have been initially focused on."

Next Steps

Restoration Fuels is working on final commissioning, operational testing, and preparing initial product samples. They have been able to get the plant up to 3 tons per hour of production, which is about a third more than the overall design capacity of the plant. Next, they want to start pivoting to see how the project can support broader market opportunities.

"We are really interested in biochar, either through Restoration Fuels, or through investments by the endowment. We are beginning to collaborate with a number of other companies seeking to develop similar types of facilities. We are very eager to share our information, our cost structures, the lessons we have learned, and other ways we may be able to help. Along those lines, we are always seeking help. We have learned to be quite humble in operating a big thermal system like this. Ultimately, the endowment is seeking to engage in strategic partnerships to help advance our mission and bring the right parties into collaboration to help this opportunity grow even further. Our mission is to focus on the original intent, which was to provide markets where needed to grow this opportunity to support forest health restoration."

New Opportunities for Biochar From Biomass Energy in the Pacific Northwest

Tom Miles[1]

The U.S. Biochar Initiative is a nonprofit organization that promotes sustainable biochar production and use through research, networking, policy, and demonstration. The initiative provides a learning database on their website and offers conferences, workshops, newsletters, and other educational material. Executive director Tom Miles has 50 years of experience in wood products and biomass energy. "Biochar markets and uses continue to grow," he said. "Biochar applies to a wide variety of markets. All of them apply here in the Pacific Northwest, particularly in agriculture and retail garden applications."

What Is Biochar?

Biochar is a fine-grained charcoal that can be used as a soil amendment or in building products. It is created through pyrolysis, a process that involves heating biomass (e.g., wood, manure, crop residues, solid waste) with limited to no oxygen in a specially designed furnace that captures all emissions for reuse as energy. It has proven very successful as a soil amendment because it boosts water-holding capacity and soil productivity.

Biochar is Climate Smart

As a replacement for burning fossil fuels, burning biomass through pyrolysis to produce biochar plus heat and power is a carbon-neutral process. Biochar retains about 50 percent of the carbon from raw biomass. Based on U.S. Department of Energy reporting, the United States has the future potential to produce at least 1 billion dry tons of biomass resources annually (US DOE 2016). Carbonizing that billion tons of biomass, which contains about 500 million tons of carbon, could result in a couple of products. Through biochar, the carbon could be returned to the soil, where it would be sequestered for centuries, reducing atmospheric CO_2 and enhancing plant growth. The rest of the carbon could be channeled through green carbon markets.

Green carbon markets include the transportation sector, which can utilize liquid fuels, sustainable aviation fuels (see "Woody Biomass Potential for Energy Feedstocks in the Pacific Northwest"), and hydrogen; energy uses (heat and steam, power); chemical applications, such as oils, cosmetics, and wood vinegar; and industry (through resins and bioplastics). The technologies for increasing overall value recovery from carbon continue to evolve.

Challenges and Opportunities

Biochar does have marketing challenges in terms of delivered cost versus perceived benefits. "We find that people who buy and use biochar get addicted; they love it. But they would like to see it at a lower cost. Cost is a challenge, especially with hauling in forest residues," said Miles. Communicating the value of biochar and the various ways it can be applied could take additional awareness and education campaigns.

One opportunity that U.S. Biochar Initiative is focusing on is developing a classification

[1] T.R. Miles Technical Consultants, Inc., 1470 SW Woodward Way, Portland, OR 97225; tmiles@trmiles.com.

of biochars for specific uses. "People call them standards. It means matching the appropriate biochars according to their different qualities, which lend to different applications, which is not appreciated in the market today," explained Miles. Another need is specifications that would allow the addition of biochar to existing practices in soil improvement, stormwater filtration, remediation, building products, and septic systems. "We need specifications that an engineer could use to specify the use of biochar for particular applications. It's a long-term process," said Miles.

Reducing wildfire risk presents other opportunities, especially with the passage of the Infrastructure Investment and Jobs Act of 2021. Specifically, the bill set aside $200 million to remove flammable vegetation "for the creation of biochar or innovative wood products." The U.S. Biochar Initiative has demonstrated various techniques for converting forest residues to biochar in the woods. They hosted a webinar and workshop in January 2022 demonstrating some of these mobile techniques (USBI 2022).

Biochar Applications

Soil health (agriculture, retail garden, landscape, turf, trees, orchards, vineyards)

- Compost, composted biochar (5 to 20 percent biochar)
- Animal bedding, litter, feed trials
- Biochar-based fertilizer (15 to 25 percent biochar)
- Biotic soil amendments (biochar plus organics plus minerals and biologicals)
- Granulated and liquid products for seeding, foliar sprays (extracts)
- Micro/nano carbons, nanofertilizers

Environment

- Remediation
- Erosion control (growing market)
- Revegetation
- Biosolids
- Urban soils
- Wetlands
- Odor control
- Waste
- Remediation-persistent herbicides
- Perfluorinated chemicals

Water quality

- Stormwater filtration
- Water treatment
- Functionalized chars
- 3-D aerogels
- Antibiotics

Forestry

- Wildfire fuel reduction
- Reforestation
- Range improvement
- Growing media for nursery and outplanting
- Revegetation
- Reclamation of mines and degraded land

Quick Reference Guide for Biochar Resources

Practitioners

- Brett Kencairn, policy advisor, City of Boulder, CO (Urban Drawdown Initiative).
- Jim Doten, environmental services supervisor, City .of Minneapolis, MN (Biochar in the City).
- Mark Highland, president, Organic Mechanics Soil Company, LLC, Kennett Square, PA.
- Bartlett Tree Experts, Portland, OR (uses biochar in a media with biologicals).
- EcoRemedy. Wastewater treatment plant. City of Edmonds, WA.
- Missouri Organic Recycling, Kansas City, MO, has a Food Residual Environmental Diversion program that can incorporate a large quantity of food waste.

Producers

- Ag Energy Solutions, Spokane, WA (small outfit doing product development).
- Wakefield Biochar, Valdosta, GA.
- American Biochar Company, Niles, MI (carries VITAL Blend soil amendment).
- Rexius, Eugene, OR.
- Pacific Biochar, Santa Rosa, CA.
- Oregon Biochar Solutions, White City, OR (offers carbon dioxide removal credits).
- LESCO, Roswell, GA (biotic soil amendment).

Technologies

- VOW project, Tønsberg, Norway (valorization of organic waste into sustainable products for cleanup of contaminated water, soil, and air).
- PYREG systems , Portland, ME (convert biosolids to biochar).
- Modular pyrolysis systems (being developed by ARTi, Des Moines, IA).
- KDS Windsor systems, Hendersonville, NC (green sawdust gasifier, dry kilns).

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Optimizing Transportation Networks for Biomass Utilization

John Sessions[1]

An estimated 7.5 million bone dry tons of logging residues are produced annually in the four-state region of Oregon, Washington, Idaho, and Montana (Berg et al. 2016). Accumulation of logging residues on steep slopes at roadsides can result from whole-tree yarding using cable systems. On flatter terrain, the residues are distributed in the field either as a result of shovel logging or cut-to-length operations and require secondary collection to roadside (Zamora-Cristales and Sessions 2016). Comminution is usually done at or near roadside to increase density of the forest residues before transport. Moisture management is essential to optimize the cost-effective transportation and utilization of logging residues.

Zamora-Cristales et al. (2015) approached the optimization of the logistics for processing and transporting residues as a network problem. Truck transport optimization issues include trailer volume, load density, moisture content, and access for large trucks and trailers to the forest site. Access is a function of necessary road width and gradeability (Sessions et al. 2010). Logging roads have been built for the piggy-back truck and trailer to climb steep grades and the stinger-steered pole trailer to negotiate narrow forest roads. The necessary road width is a function of trailer configurations where configurations can be classified as nonstinger-steered, stinger-steered, or steerable trailer axles. Unloaded chip vans have particularly low gradeability due to the small load on the drive axles of the truck tractor. Four-wheel-drive truck tractors increase the gradeability for unloaded chip vans.

Recent interest in battery-electric log trucks (Sessions and Lyons 2019) could contribute to improved access through improved traction, reduced operating costs from regenerative braking, and possibly reduced off-tracking from electric-powered steerable trailers. Three major truck manufacturers (Kenworth, Peterbilt, and Freightliner) offer battery-electric log trucks that could operate in mountainous terrain. Issues of truck cost, battery weight, and charging station availability remain.

Temporary improvements can be made to improve large truck and chip trailer access to forest sites. These include widening curves, filling in ditches with chips, and removing or reversing superelevation of roads around curves (Beck and Sessions 2013). Beck and Sessions (2013) developed a mathematical formulation to optimize the selection of truck-trailer combination and route modifications to minimize transport costs.

Other approaches to reducing transportation costs have been the use of intermediate processing sites (depots) and mobile facilities. Studies have evaluated intermediate depots, and a few have examined mobile or transportable biomass facility design. Recent studies by Martinkus et al. (2018), Berry et al. (2018), Mirkouei et al. (2016) and Sessions et al. (2019) illustrate the ideas.

Martinkus et al. (2018) developed a quantitative facility siting tool to identify the least-cost, regional, biorefinery supply chain from an array of potential depot and biorefinery locations. A total transportation cost model is used to quantify the feedstock procurement

[1] Distinguished professor emeritus, Oregon State University, College of Forestry, Department of Forest Engineering Resources and Management, 140 Peavy Forest Science Center, 3100 SW Jefferson Way, Corvallis, OR 97331; john.sessions@oregonstate.edu.

and processing costs at each linkage of the supply chain. An optimization routine validated the results of the decision matrices in the selection of depots for each biorefinery and for selecting the least-cost, depot-and-biorefinery supply chain. Martinkus et al. (2018) considered rail as well as truck routes.

Berry et al. (2018) considered higher value wood products in the context of transportable facilities, including regional variability (market, cost, logistic constraints, energy and fuel prices), and their impact on the potential viability of a proposed marketplace. They analyzed the relative advantage and disadvantage of transportable depots when compared to stationary modular plants within the context of energy costs and transportation distances to determine which design may be more desirable in the regions reviewed.

Mirkouei et al. (2016) investigated reducing the cost and environmental impact of integrated fixed and mobile bio-oil refinery supply chains. Mobile pyrolysis units could chip and process logging residues and the bio-oil taken to a fixed refinery, or chipped residues could be transported directly to a fixed biorefinery.

Sessions et al. (2019) evaluated joint optimization of wildfire hazard reduction treatments, biochar facility locations, and agricultural field applications to promote forest restoration, forest-related employment, increased agricultural competitiveness, and carbon sequestration.

Using steep-slope tethered harvesters and forwarders for wildfire hazard reduction treatments, Petitmermet et al. (2019) developed a biomass collection and transportation model using field data from the Fremont-Winema National Forest. This was coupled with an engineering design for a 50,000 dry ton per year biochar production unit with the biochar destined for regional agricultural applications in the upper Klamath Basin. The model was applied under varying assumptions of agricultural productivity increases and carbon sequestration credits to identify the level of a hazard reduction program whose direct costs could be offset by receipts from carbon credits and agricultural productivity increases.

Recently there has been increasing interest in rail for moving biomass, particularly in the Western United States. Rail has a lower carbon footprint and lower variable cost and could reduce road congestion. Demand for shipping containers from Asia has created low shipping costs from containers moving east to west across the United States. Coupled with declining or absent infrastructure in the Southwestern United States, there is the potential opportunity to move biomass from areas without infrastructure to areas with infrastructure in the Western United States as well as Asia.

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New Markets and Products for Low-Value Forest Biomass

J.Y. Zhu[1]

Current Wood Utilization and Market

We use wood in many aspects of our lives—from shelter, heating, and furniture to paper. With growing concerns regarding CO_2 emissions from using nonrenewable resources, increasing wood utilization is a good strategy for decarbonization. In 2019, U.S. wood utilization was 341 million m^3, of which about 54 percent was used for pulp and paper production (fig. 1). The next largest wood use category was sawn wood (27 percent was softwood, and 4 percent was hardwood) (fig. 1).

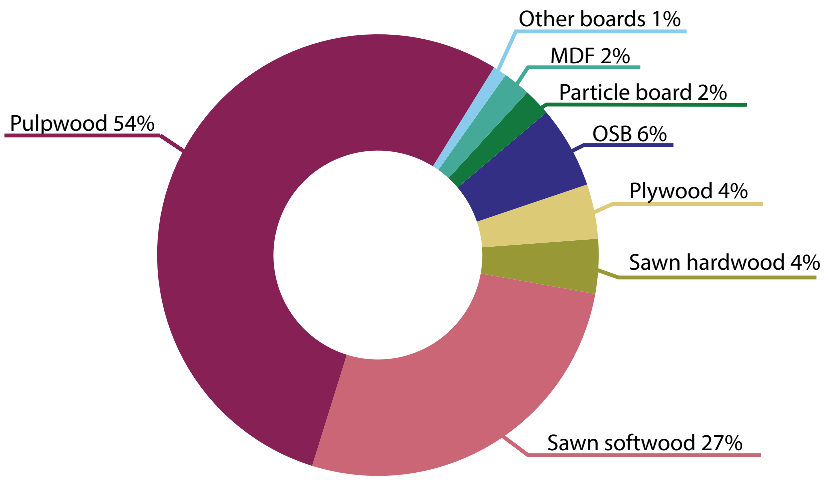

Figure 1—Wood utilization in different sectors in the United States with a total of 341 million m^3, including oriented strand board (OSB) and medium density fiberboard (MDF), 2019.

Emerging Market for Wood Utilization

In addition to the existing markets, two emerging markets are worth consideration. The first is wood pellets as bioenergy. In 2018, the United States produced about 8 million tons of wood pellets, equivalent to 16 million m^3 of wood per year or about 5 percent of U.S. wood utilization. It is a relatively small market but has some potential for growth. Based on U.S. Department of Energy's 2016 estimates, there were about 93.1 million tons of forest residues biomass from clearcutting and thinning operations available (US DOE 2016). Wood torrefaction to produce biochar has attracted great interest recently to utilize these forest residues. Torrefaction can improve wood energy density to reduce transportation cost versus untorrefied wood. Biochar can be used to cofire with coal or completely replace coal in powerplants. This is equivalent to 1.6 million tons of wood or about 3.2 million m^3 of wood per year; still a very small market. Another emerging market is cross-laminated timber. Although the current market is very small and is estimated at U.S. $125 million in 2020, it is growing at an estimated 14 percent per year.

[1] Research general engineer, U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, 1 Gifford Pinchot Drive, Madison, WI 53726; junyong.zhu@usda.gov.

Biojet From Forest Residue

With the rapid development of electrical cars, the focus of the renewable liquid transportation fuel market has shifted to sustainable aviation fuel. In 2019, jet fuel demand was 26 billion gallons in the United States alone, or 5.2 billion gallons of isoparaffinic kerosene, assuming 20 percent blending with petroleum jet fuel and also assuming that isoparaffinic kerosene yields of 45 gallons per ton of wood. This would be the equivalent of 100 million tons of wood, or about 200 million m^3 of wood per year, a very significant market.

At the U.S. Department of Agriculture, Forest Service, Forest Products Laboratory, we developed a process using sulfite pretreatment to overcome recalcitrance of lignocellulose that can efficiently preprocess forest residue, including those from softwoods, to produce sugars at a high yield (Gu et al. 2016). The Northwest Alliance for Advanced Renewal (NARA) used this process to produce 1,000 gallon of isoparaffinic kerosene from harvested softwood forest residue. On November 14, 2016, the biofuel that they produced was used for the world's first successful wood-based fuel powered commercial flight by Alaska Airlines from Seattle to Washington, DC (Alaska Airlines 2016).

Advanced Wood Utilizations

Recently, the concept of wood cell wall engineering has emerged as a groundbreaking concept to process wood for transformative applications as a structural material. Specifically, a process has been developed that transforms wood into a super-strong material through densification after delignification; the wood's well-aligned fiber structure is used as a template. In another example, cell wall engineering has enabled wood veneer to be super flexible; also called origami wood, this veneer can be molded into various shaped structures. Yet another example involves wood being made fully transparent as glass. These new markets are yet to be determined.

Cellulose nanomaterials are another new area of wood utilization. The cellulose nanomaterial market size was estimated at U.S. $346 million in 2021 and could reach U.S. $963 million in 2026; however, in terms of the volume of wood, it is still not substantial.

Summary

Technology innovations can significantly increase wood utilization. Converting low-value wood to bioenergy and biofuels, such as sustainable aviation fuel, remains the main large-volume outlet. Conversion barriers need to be removed to make wood-based biofuel economically competitive. Wood cell wall engineering provides a great opportunity for transformative utilization of wood as a sustainable structural material.

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U.S. Standard Equivalents

When you know:	Multiply by:	To find:
Cubic meters (m^3)	35.3	Cubic feet

Metric Equivalents

When you know:	Multiply by:	To find:
Feet	.305	Meters
Miles	1.609	Kilometers
Acres	.405	Hectares
Cubic feet (ft^3)	28.3	Liters
Gallons	3.78	Liters
Tons (ton)	.907	Tonnes or megagrams

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