Distilling Value: Turning Unmerchantable Timber into Premium Spirits

The Case for Residue-Based Liquor to Revive Forests and Revitalize Rural Economies

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Proposal Summary

Distilled spirits can be made from various ingredients such as corn, rice, grapes, barley, and potatoes; now, trees are joining the list. Research from The Forestry and Forest Products Research Institute (FFPRI) of Japan has developed a world-first technology allowing access to the sugars trapped in wood to produce high-value alcoholic beverages from cellulose. The mechanical process enables direct saccharification, fermentation, and distillation of wood without chemicals and heat treatment. The distilled alcohols made from cedar, cherry, and birch in pilot studies all have distinct flavor characteristics, suggesting that every wood species can produce alcohol with a unique character.

Washington State is rich in forest resources, with millions of acres in active management across public and private ownerships. Yet within this abundance lies a persistent challenge: small-diameter stems generated during pre-commercial thinning (PCT) are too small for traditional markets and too costly to extract for low-value uses like chips or hog fuel. These residues—often left to decompose on site—represent an untapped feedstock with biochemical potential. Similar-sized material accumulates in Eastside forests, where dense regeneration and limited market access create persistent fire hazards in dry mixed-conifer stands.

Pre-commercial thinning (PCT) is a proven silvicultural tool for improving forest health, reducing wildfire risk, and enhancing long-term timber value. Application involves thinning suppressed trees and allowing remaining dominant trees to capture more resources; the thinned trees remain on the forest floor as residues. Yet despite its ecological benefits, PCT remains financially and administratively difficult to implement at scale. Costs typically range from \$150 to \$300 per acre, and must be paid upfront—often a decade after planting—without amortization. Monitoring stand conditions for species-specific trigger points further complicate adoption. Equipment mismatches add to the challenge: most cable yarding systems are designed for merchantable logs, not the small-diameter stems typical of PCT operations. In difficult terrain, extraction costs far exceed the \$33/ton average delivered chip price in Washington State.

This proposal offers a novel solution: converting PCT residues into consumable alcohol. Drawing on recent Japanese research, where 1000 kilograms of Japanese cedar yielded 453 (750 ml) bottles of 35% alcohol. We find that Pacific Northwest species—Douglas-fir, western hemlock, Pacific silver fir, Sitka spruce, lodgepole pine—offer equal or better yields. One ton of PCT residues could yield \$4,004 in wholesale liquor revenue. If residues account for just 2% of wholesale revenue, their implied value jumps to \$681 per thousand board feet (MBF), making them comparable to #2 sawlogs, greater than #3 and #4/chip-saw, and well above utility-grade pulp.

The use of PCT residues for liquor production represents a strategic elevation in land use—akin to the transformation seen on Washington's eastside, where growers shifted from commodity crops like wheat to high-value viticulture (i.e. wine). Where wine unlocked a new tier of economic and cultural value for agricultural landscapes, distilling from forest residues offers a step-change in how we value and manage restoration-scale forestry. It reframes low-margin biomass as a premium input while establishing a uniquely Washington industry. This would remove financial barriers to thinning operations, leading to standardized PCT operations.

Prior to 2008, Washington operated under a strict version of the three-tiered system of liquor distribution - separating producers, distributors, and retailers. The 2008 craft distillery law eliminated this system, allowing craft distilleries to act as all three. The subsequent 2012 privatization further expanded market access while imposing a volume tax of $3.7708 per liter and a combined sales tax of 37.5% when distillers sell directly to the public. The Legislature could further incentivize PCT operations by reducing taxes on liquor produced from residues. A reduction of the combined sales tax from 37.5% to 27.5% and the liter tax from $3.7708 to $2.7708, would increase wholesale revenue by 12%; in turn, increasing the per-ton value of residues to $80.08, equivalent to $762 per MBF. This would make PCT residues as valuable as most sawlogs delivered over the past 36 months.

This level of value creation would justify investments in research and development towards equipment infrastructure tailored to meet PCT operational requirements. An analogous collaboration between the US Forest Service, the University of Washington's College of Forest Resources, and UW's Applied Physics Laboratory in the 1970s produced the PeeWee yarder, a small, mobile cable yarding system designed to access timber that was then considered too small, and are now graded as #2 and #3 sawlogs. With lower capital costs, it becomes feasible for small independent contractors to occupy this niche market, absorbing the costs of PCT application in exchange for the residues, then processing and selling the product to distillers. Such a market for logging residues currently exists on the Olympic Peninsula; a PCT residue market would unlock ecological and economic returns rooted in restoration, innovation, and rural revitalization.

1. Benefits of, and Barriers to Thinning Small Diameter Trees

The development of forests of various species and across a range of population densities is understood generally[1]: At wider initial inter-tree distances, the average tree develops a larger diameter and maintains a full live crown; conversely, as spacing narrows, individual trees present with smaller diameters and shorter live crowns. Ultimately, maximum individual tree size is limited by population density[2] [3] [4]. Early thinning may be required in order to achieve management objectives at older ages that require large diameters[5]; failure to thin stands may be detrimental to future stand integrity [6].

1.1 Westside Forests: Stand Improvement

A precommercial thinning (PCT) is a forest management operation that promotes future growth by reducing the number of live trees, usually by about half; less-vigorous individuals are removed, providing the more-vigorous trees that remain better access to water, soil nutrients, and light. Across Westside forests dominated by Douglas-fir and western hemlock, PCTs are associated with early stand development. The timing and intensity (i.e. how many trees are removed) of a PCT depend strongly on the desired size of trees at harvest. A PCT benefits the stand in several ways: the financial performance of the investment improves with time as the remaining trees develop into higher-value log grades faster than in comparable stands without a PCT; the fire resistance of the stand is improved; and for stands that are managed for benefits other than financial performance, habitats for several regional species are promoted.

The majority of timberland investment costs are expended within the first three years covering site preparation, cost of seedlings, planting, and subsequent brush control. While costs vary by landowner and region, the total cost may be expected to average $1500 per acre. For stands expected to be PCT candidates, more trees may be planted with the expectation of a future PCT, increasing the costs of both seedlings and planting. The cost of a PCT may be expected to average $300 per acre, likely to increase with increasing need for treatment. This (~20%) cost premium cannot be amortized, but must be paid in full at the time of application. There is an additional, hidden cost of continuous monitoring by managers to track stands as they develop to an indeterminate trigger point (which will differ by species at the same location, and differ by location for the same species). This monitoring period is likely to be more than a decade after the stand was planted. While the benefits of a PCT are known, the financial and administrative costs prevent its widespread adoption.

General guidelines on timing and intensity exist[7] based on desired outcomes at the time of harvest, but not *when* the stand will achieve those outcomes. Recently, more precise models have been developed for westside forests that specify yield by age as a function of species, site productivity, treatment method, and treatment intensity[8]. A PCT should be applied before density-induced competition reduces live-crown length below 30%, in order to maintain stand vigor. As live crown is affected by density at a given height, and stand height is affected by density[9] [10], it is possible to establish a more uniform management guide on when to initiate a PCT based on *relative spacing*[11], a metric combining stand height and density. Figure 1 below illustrates the relationship between relative spacing and live crown, and relative spacing at combinations of stand height and density.

[1] Oliver C.D. and B.C. Larson. 1996. Forest stand dynamics update edition. New York: John Wiley & Sons, Inc. 398 p.

[2] Reineke, L.H. 1933. Perfecting a stand-density index for even-aged forests. Journal of Agricultural Research 46:627-638

[3] Yoda, K., T. Kira, H. Ogawa, and K. Hozumi. 1957. Intraspecific competition among higher plants IX. Further analysis of the competitive interaction between adjacent individuals. Journal of the Institute of Polytechnics (Osaka City University). 8: 161-178.

[4] Drew, T.J. and J.W. Flewelling. 1979. Stand density management: An alternative approach and its application to Douglas-fir plantations. Forest Science. 25(3): 518-532.

[5] Poage, N.J., Tappeiner, J.C. 2002. Long-term patterns of diameter and basal area growth of old-growth Douglas-fir trees in western Oregon. Can. J. For. Res. 32:1232-1243.

[6] Wilson, J.S. and C.D. Oliver. 2000. Stability and density management in Douglas-fir plantations. Canadian Journal of Forest Research. 30:910-920.

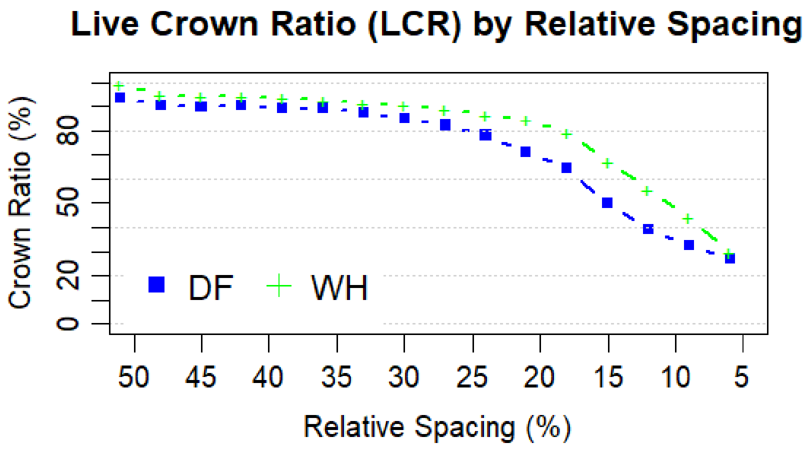
[7] Reukema, D.L. 1975. Guidelines for precommercial thinning of Douglas-fir. USDA-FS General Tech. Report. 30, 10 p.

[8] Cross, J. 2020. Yield Models for Douglas-fir and western hemlock plot thinned precommercially: ages 35-60. Stand Management Cooperative Working Paper No. 7.

[9] Scott, W.R., Meade, R., and R. Leon. 1993. Observations from 9 to 19-year-old Douglas-fir variable density plantation test beds. Forestry Research Field Notes, Weyerhaeuser Company, Timberlands Forest Resources R&D, Silviculture-West, Paper #92-2.

[10] Scott, W., Meade, R., Leon, R., Hyink, D., and R. Miller. 1998. Planting density and tree-size relations in coast Douglas-fir. Can. J. For. Res. 28: 74–78.

[11] $RS\% = \{[\sqrt{(43560/TPA)}]/HT40\} * 100$
where TPA = density in trees per acre; HT40 is the average height of the 40 largest trees by diameter per acre.



Relative Spacing by top height and density

Color-coded for crown ratio retention after PCT

Stand Density (tpa) \ Top Height (ft’)	20	25	30	35	40
550	45	36	30	25	22
525	46	36	30	26	23
500	47	37	31	27	23
475	48	38	32	27	24
450	49	39	33	28	25
425	51	41	34	29	25
400	52	42	35	30	26
375	54	43	36	31	27
350	56	45	37	32	28

Figure 1: *Left:* Average live crown ratio by percent relative spacing. Douglas-fir = blue; western hemlock = green .
Right: Percent relative spacing by density and top-height. Color codes indicate risk to residual potential growth.

At relative spacings above 50%, there is no effect on LCR. There are early signs of crown-reduction at spacings between 50% and 40%, whether caused by inter-tree abrasion, shading, or both. Once relative spacing falls below 30%, there is a rapid and dramatic reduction in LCR; as spacing approaches 10%, crown ratios fall below 33%, endangering future growth and increasing the risk of stagnation. Adopting a standard of 30% relative spacing as the trigger for PCT applications would make timing more predictable and reduce administrative costs. Yields can then be predicted more accurately using the models mentioned above. Standardized practices will lead to more uniform products in terms of PCT residues, increasing efficiency and reducing operational costs.

1.2 Eastside Forests: Fuel Reduction

Across Eastside forests, particularly those dominated by stands of lodgepole pine, ponderosa pine and Douglas-fir, structures have been altered profoundly by a century of fire-suppression policies, disrupting natural disturbance regimes. Historically, these forests experienced frequent, low- to moderate-intensity surface fires every 6 to 13 years, ignited by lightning and Indigenous burning practices[12]. These fires maintained open, park-like conditions by consuming fire fuels and suppressing shade-tolerant regeneration. In the absence of regular fire, shade-tolerant species such as Douglas-fir and grand fir have proliferated, forming dense understories beneath mature overstory trees[13]. These young cohorts create a continuous vertical canopy and function as *ladder fuels*, enabling surface fires to transition into crown fires.

In this context, precommercial thinning serves dual objectives: it improves overstory vigor by reducing competition from the understory cohort, and it reduces wildfire hazard by disrupting vertical fuel continuity[14]. Unlike Westside PCT candidates, which are typically uniform plantations in early development, Eastside candidates are more likely to be mature stands with a developing understory, or plantations that are much older as they reach PCT triggers due to lower regional site productivity. While conditions differ, resulting PCT material is structurally analogous to Westside stands and equally suitable for thinning.

While Eastside PCT application and residue extraction costs may be lower than for Westside forests due to terrain and stand structure, they still exceed the current value of the residual material; therefore, residues remain in the forest to decompose and may increase the fuel load and risk that any fire will severely damage or destroy the stand[15]. These concerns have traditionally been reserved for Eastside forests; however, the risk of catastrophic

[12] USDA Forest Service Fire Regime Synthesis: Northern Rocky Mountain Ponderosa Pine. <Web link>

[13] Fiedler, C.E., Arno, S.F., Harrington, M.G. 1998. Reintroducing fire in ponderosa pine-fir forests after a century of fire exclusion. In: Fire in ecosystem management: shifting the paradigm from suppression to prescription. Tall Timbers Fire Ecology Conference Proceedings No. 20.

[14] Cram, D.; Baker, T.; Boren, J. 2006. Wildland fire effects in silviculturally treated vs. untreated stands of New Mexico and Arizona. Research Paper RMRS-RP-55. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 28 p.

[15] Alexander, M.E. and R.F. Yancik. 1977. The effect of precommercial thinning on fire potential in a lodgepole pine stand. Fire Management Notes. 38(3):7-10.

wildfire has reached even the wettest regions of the Pacific Northwest. The result is administrative hesitancy towards widespread PCT adoption.

Whatever the financial benefits to landowners are, the most compelling economic argument may be the avoided fire suppression costs. Federal wildfire response in Washington and Oregon (i.e. Region 6) routinely exceeds $100 million per major incident[16]; Washington landowners pay annual fire protection assessments of $0.27 per acre plus flat fees[17]. By reducing ladder fuels, thinning operations may yield measurable public savings (decreased fire intensity and related costs) and justify infrastructure investment through avoided suppression expenditures.

1.3 Cost: The Fundamental Barrier

As long as PCT residues are too small to be merchandized and operational/extraction costs exceed their value as chips and pulpwood, a financial disincentive towards widespread adoption will exist. Historically, the price of delivered chips has remained relatively flat near $33 per ton[18], as illustrated in the time-series for Douglas-fir and western hemlock shown in Figure 2 below. Given the price stability, there can be little expectation of change in the current dynamic.

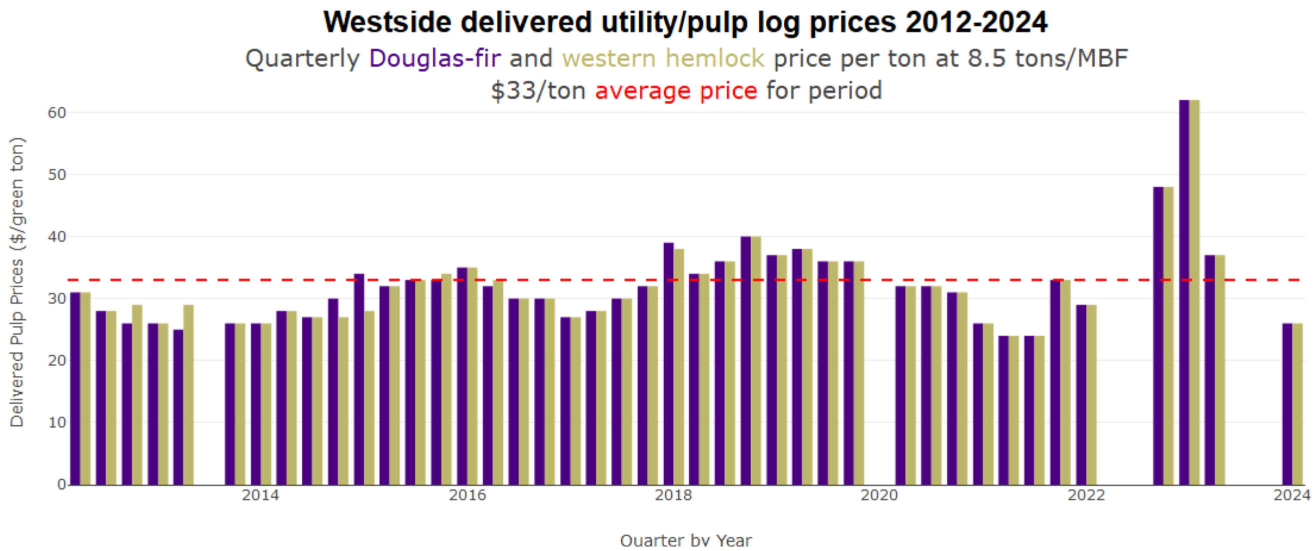


Figure 2: *Quarterly delivered chip prices for Douglas-fir and western hemlock in Western Washington for the period 2012-2024; dotted line indicates period average value of $33 per ton.*
Source: Washington State Department of Natural Resources.

Precommercial thinning (PCT) operations on the Westside typically cost between $150 and $300 per acre, depending on stand density, terrain, and treatment intensity[19]. Without yield estimates for PCT residues, it is difficult to translate this cost to a *per ton* basis. When residues are extracted for off-site use, cable yarding adds a significant cost layer—ranging from $90 to $150 per thousand board feet (MBF) [$10.50 - $17.65/ton[20]] in standard conditions, and up to $234 per MBF [$27.53/ton] in steep terrain or low-yield scenarios requiring careful crop tree protection[21].

However, a change in residue utilization that increases the value of the material sufficiently, coupled with new extraction technology that is scaled for this particular application, can remove the financial and administrative barriers to adopting PCT as a standard practice. That result would improve economic and ecologic outcomes.

16 USDA Forest Service. FY 2022 Wildfire Disaster Funding Adjustment Report. <Web link>
17 Washington Department of Natural Resources. Forest Fire Protection Assessment. <Web link>
18 Washington State Department of Natural Resources
19 Stand Management Cooperative internal cost estimates, 2023
20 Ton:MBF conversion rate = 8.5 (source: Washington State Department of Natural Resources).
21 University of Washington Forest Engineering Cost Analysis. <Web link>

2. Transforming Woody Residues into Alcohol

2.1 Residues as Biofuel

For decades, wood-to-alcohol conversion has been dominated by industrial-scale biofuel initiatives, most notably the Northwest Advanced Renewables Alliance (NARA), led by Washington State University. NARA's goal has been to convert forest residuals into aviation biofuel using a multi-step process: mild bisulfite pretreatment, enzymatic hydrolysis, and fermentation to produce ethanol or isobutanol. The project explored feedstocks ranging from logging slash to construction and demolition waste, with a focus on maximizing biomass yield and minimizing transport costs. Despite technical success, the economic viability of these systems has proven elusive; as noted by NARA researchers[22], "Biomass residues are often left on site and are the lowest value products in the forest". The bioconversion plant in Eastern Washington never reached commercial scale, largely due to the high cost of feedstock collection and preprocessing, and the limited market value of fuel-grade alcohols.

2.2 Residues As Consumable Alcohol

New research originating from the Forestry and Forest Products Research Institute (FFPRI) of Japan has demonstrated a process for accessing the sugars in wood cellulose to produce a distilled alcohol safe for human consumption[23]. In contrast to NARA's efforts, FFPRI's patented process (Japanese Patent No. 6846811) represents a fundamentally different approach: mechanically disrupting cell walls using wet-type bead milling to grind wood into a fine powder with grains less than 2 microns in diameter. This exposes the cellulose and enables enzymatic saccharification and fermentation using food-grade yeast. This process is similar to that used in food-processing[24], and yields safe, consumable liquors with distinct flavor profiles depending on the wood species (e.g., cedar, cherry, birch). A video describing the technology is available[25] with english subtitles; a less-technical overview aimed at the public is also available[26].

The FFPRI system is designed to be distributed among rural mountainous communities, creating new business opportunities in forestry (specifically), and revitalizing rural, mountainous communities. In contrast, the NARA effort is to build centralized operations producing producing aviation fuels. The differences in objectives and scale lead naturally to process distinctions, detailed in Table 1 below.

Table 1: Comparison of Wood-to-Alcohol Conversion Processes Between FFPRI and NARA Systems.

Process Element	FFPRI method	NARA method
Pretreatment	Mechanical	Chemical
Temperature	Ambient	∼145°C
Fermentation	Food-grade yeast	Industrial yeast (GIFT® process)
Feedstock	PCT residues	Logging slash, C&D waste, pulp mill residues
Byproducts	Aromatic liquors	Lignosulfonates, industrial alcohols
Scale	Benchtop, distributed	Industrial, centralized

Note: FFPRI - Forestry and Forest Products Research Institute [of Japan]. <Web link>
NARA - Northwest Advanced Renewables Alliance. <Web link>

2.3 Scaling Equipment for Residue Extraction

In the 1970s, Pacific Northwest forestry was still dominated by large-scale industrial logging, with high-lead systems and tower yarders extracting massive old-growth timber—often with diameters exceeding 4 feet and log weights measured in tons. But as accessible big timber dwindled and environmental regulations tightened, the industry faced a shift: second-growth stands, steeper terrain, and smaller-diameter logs began to define the new

22 <Web link>
23 Otsuka, Y., Nojiri, M., Kusumoto, N., Navarro, R.R., Hashida, K., and N. Matsui. 2020. Production of flavorful alcohols from woods and possible applications for wood brews and liquors. RSC Adv., 10:39753–39762. DOI: 10.1039/d0ra06807a
24 <Article link>
25 <Video link>
26 <Video link> (begins at 20:52)

harvest profile. Many of these younger trees were under 20 inches in diameter, and traditional yarding systems proved inefficient or uneconomical for such lighter material. This transition created a demand for more agile, cost-effective equipment, captured in the following statement:

> Today, with the high cost of lumber and increased emphasis on more complete tree utilization, small logs command much higher prices. In the Pacific Northwest, as in many other regions of the country, there is a need for equipment that can harvest these small logs, often from very steep slopes, scattered ownerships, and areas of low yield and fragile soils. *— USDA Forest Service, 1978*

This recognition led directly to the development of the PeeWee yarder; a compact, mobile yarder designed for smaller crews, offering a nimble solution for thinning operations and selective harvests in constrained settings. Its name comes from the 'peewee' logs that were too small (economically) to be harvested using the standard cable-based systems. The design and construction of the PeeWee was a joint partnership between the US Forest Service, the University of Washington's College of Forest Resources (CFR), and the UW Applied Physics Laboratory (APL)[27] [28].

The conditions and rationale for the original peewee yarder are just as applicable today, only for material an order of magnitude smaller: PCT residues and understory wildfire fuels are at the extreme end of utilization. These residues are to today's sawlogs what today's sawlogs were to old growth some 45 years ago. While they cannnot be merchandized for lumber, opportunities for complete-tree utilization remain. Advances in technology and equipment may further increase the value of PCT residues by reducing the cost of extraction, if the same design objectives for the peewee are applied: moderate selling price; small crew size; highway mobility and accessibility on narrow forest roads; reduced set-up time; minimum ground compaction and site disturbance; ability to operate on on both gentle and steep slopes.

Enter the Pee-Wee Junior, a low-cost, low-impact, modular extraction system that enables cost-effective recovery of forest residues. It is designed to support PCT thinning operations on the Westside, and reduce wildfire fuel loading on the Eastside; while in both cases maintaining the economic value of the extracted residues. Figure 3 below present an image of the original PeeWee yarder and the author's conceptual sketch of the PeeWee Junior, intended to demonstrate the expected reduction in scale and increase in mobility compared to the original PeeWee.

The original PeeWee yarder was based on a running skyline system of rigging[29] [30]. In a proper running skyline, a continuous loop of cable circulates through a tail block and returns to the carriage, allowing logs to be transported with minimal ground disturbance and without a separate haulback line. Scaling down to the PeeWee Jr., may provide an opportunity to implement a single circulating cable yarding system[31]; a simplified variant of the PeeWee's running skyline system, adapted for small-scale, low-impact timber harvesting. The single circulating system retains this core principle—using one cable for both skyline support and carriage movement—but modifies it for portability, cost-efficiency, and ease of setup. It typically involves lighter equipment, manual or semi-mechanical carriage return, and simplified rigging suited to small-diameter trees and sensitive terrain. While the conceptual sketch suggest an original design, a prototype may utilize off-the-shelf technology[32] [33] to implement such a system.

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27 USDA Forest Service. 1978. The peewee yarder a new concept in running skyline yarders [brochure]. US Dept. of Agriculture. <Document link>

28 Mann, C.N., and R.W. Mifflin. 1979. Operational test of the prototype peewee yarder. USDA-FS General Tech. Report PNW-92. 7p.

29 Studier, D. D., & Binkley, V. W. (1974). Cable logging systems. U.S. Department of Agriculture, Forest Service, Pacific Northwest Region. <Document Link>

30 https://www.fs.usda.gov/forestmanagement/equipment-catalog/cable.shtml<Web link>

31 Wang, L. (1999). Environmentally sound timber extracting techniques for small tree harvesting (Paper No. 995053). ASAE Annual International Meeting. American Society of Agricultural Engineers. <Web link>

32 <Document link>

33 <Web link>

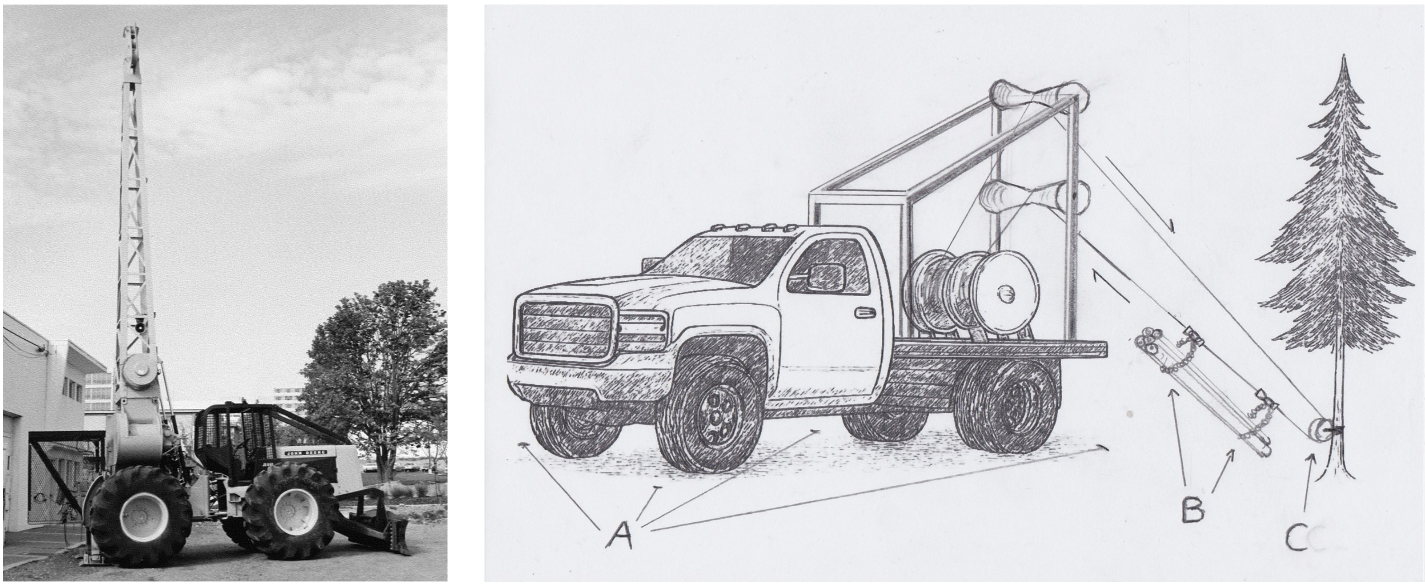

Figure 3: *Left-* Profile image of original PeeWee yarder (source: USDA Forest Service).
Right- Author's conceptual image of PeeWee Jr. yarder with labeled elements A, B, C.
A: locations for anchor points or outriggers for stability and increasing load capacity.
B: Simplified, carriage-less butt rigging such as a chain sling or grabinski.
C: Light loads and higher-gauge wire (e.g. 3/16") may facilitate use of a snatch block for fast setup.

3. Making Consumable Alcohol from Wood in Washington

3.1 Regulatory Environment

Washington State formally recognized craft distilleries in 2008 with the passage of House Bill 2959; this legislation created a new craft distillery license, allowing small producers—defined as those making 20,000 gallons or less annually—to operate with significantly lower fees and expanded privileges. To qualify, at least half of the raw materials used in production had to be grown in Washington. The law permitted craft distilleries to offer limited free samples on-site and enabled direct-to-consumer sales of up to two liters per person per day for off-premises consumption. Specific language in the bill framed distilling as an agricultural activity. Specifically, the bill required that at least 51% of the raw materials used by a licensed craft distillery be grown in Washington, and it introduced the idea that distilling is an agricultural practice.

Prior to 2012, Washington State operated a government-controlled liquor system in which the state managed all wholesale and retail sales of spirits through state-run or contracted stores, with no private retail or distribution allowed. Initiative 1183, enacted in June 2012, dismantled this monopoly and privatized liquor sales. It allowed grocery stores and large retailers to sell spirits, introduced private distribution, and replaced state markups with three new taxes: a 17% sales tax paid by the retailer, a 20.5% sales tax paid by the consumer, and a $3.7708 per liter spirits liter tax paid by the consumer. When craft distillers sell directly to the public, they act as a retailer and pay the 17% tax. The Washington State Liquor Control Board transitioned from seller to regulator, overseeing licensing and compliance rather than direct sales.

Together, Washington's 2008 craft distillery law and the 2012 privatization initiative created a uniquely favorable environment for small spirits producers. By recognizing distilling as an agricultural activity and requiring that over half of raw materials be Washington-grown, House Bill 2959 strategically positioned craft distillers as part of the state's farming economy—qualifying them for lower fees and local sourcing incentives. Then, Initiative 1183 dismantled the state's liquor monopoly, allowing private distribution and retail sales. As a result, licensed craft distillers could act as both wholesaler and retailer, selling directly to consumers from their own facilities while bypassing traditional three-tier constraints. This dual role empowered small producers to build local brand identity and contribute to rural economic development.

3.2 Economic Analysis

Wood has three primary components: cellulose, lignin, and water. In the construction of a tree, it is reasonable to think of the cellulose as the scaffolding, lignin as the cement, and water as a variable that changes with size and age. When harvested, the amounts of cellulose and lignin remain constant, while water dissipates over time. The amount of alcohol that can be produced from a volume of wood depends on the cellulose content that varies by species within known ranges; calculating that content depends on the moisture content of the wood. Japanese researchers indicated that an input of 1000 kilograms of Japanese cedar (*Cryptomeria japonica*) air-dryed for 2 months yielded 453 750ml bottles of 35% alcohol. The cellulose content of selected Pacific Northwest softwood species (also air-dryed for 2 months) is compared to Japanese cedar in Table 2 below.

Table 2: Properties per 1,000 kg Air-Dried Wood for Selected Pacific Northwest Softwood Species. Japanese Cedar Included for Baseline Conversion Reference.

Wood Species	Green Mass *(Kg)*	Moisture *(%)*	Dry Mass *(kg)*	Cellulose *(% dry)*	Cellulose *(kg)*	Proportion *(to CRJA)*
Japanese Cedar (CRJA)	1,282	22	780	42.5	331.5	1.00
Douglas-fir	1,250	20	800	45.5	364.0	1.10
Sitka Spruce	1,282	22	780	45.0	351.0	1.06
Lodgepole Pine	1,266	21	790	43.5	343.4	1.04
Western Hemlock	1,282	22	780	43.5	339.3	1.02
Pacific Silver Fir	1,299	23	770	43.0	331.1	1.00
Western Redcedar	1,316	24	760	41.0	311.6	0.94
PNW Species' Average	1,283	22	780	43.6	340.5	1.03

Source: Forest Products Laboratory. 2021. Wood handbook—wood as an engineering material. General Technical Report FPL-GTR-282. Madison, WI: U.S. Department of Agriculture, Forest Service, Forest Products Laboratory. 543 p.

Cellulose yields for PNW species compare favorably to Japanese Cedar. For analysis purposes, the metrics for PNW species and Japanese cedar can be treated as equal: 1.41 green tons yielded 453 bottles at 35% alcohol; this is equal to 323 bottles per-ton of green mass. US federal law [34] requires a minimum alcohol content of 40% for vodka, whisky, bourbon, and rum; given that, 323 bottles at 35% is equivalent to 282 bottles at 40%.

The average wholesale (pre-tax) price of a 750ml bottle of liquor has risen from $11.15 in 2012 (when privatization occured) to $14.20 in 2025[35]; the rate of increase in price is $0.23 per year. With one ton of green mass yielding 282 bottles, the wholesale revenue generated by cellulose-liquor would have been $3,145 in 2012 and $4,005 per ton in 2025. The implied value of a ton of residues will vary with its percentage of the wholesale revenue. For comparison purposes, per-ton values can be converted to per MBF values using the conversion rate of 8.5 tons per MBF[36]. Using the 2025 wholesale liquor price, the implied per-ton and per-MBF values of PCT residues are presented in Table 3 below at different percentages of wholesale revenue.

Table 3: Implied Value ($) of Woody Residue by Metric and Percentage of Wholesale Revenue.

Value Basis	1%	2%	3%	5%	7%	10%
Per Ton	$40.05	$80.09	$120.14	$200.23	$280.32	$400.45
Per MBF	$340.39	$680.77	$1,021.16	$1,701.93	$2,382.70	$3,403.85

Notes: 1. Based on 2025 wholesale price of $14.20 per 750ml bottle of 40% alcohol (80 proof).
2. Wholesale price = retail price less sales tax (20.5%) and volume tax ($3.8281 per 750ml).
3. Wholesale price further reduced by retail fee (17%) assuming distillers act as retailers.
4. Conversion rate: 8.5 tons per MBF.

34 27 CFR (§5.141) <Web link>

35 Washington State Department of Revenue. This data includes the 17% retailer sales tax that is excluded in this analysis. <Web link>

36 Washington State Department of Natural Resources' monthly delivered log price survey. <Web link>

3.3 Value-Added Comparison

The per-ton values in Table 3 suggest an increase of 21% in the value of a ton of PCT residues if thinning, extraction, and processing costs account for only 1% of wholesale revenue for a 750ml bottle of liquor sold at the 2025 price of $14.20; a 243% increase at 2% of wholesale; and 364% increase at 3%. Without accurate yield estimates of PCT residuals, it is difficult to identify a breakeven per-ton price given that thinning and extraction vary by location, but are expected to be high due to the low yield and the need to protect remaining trees from damage. By converting per-ton values to per-MBF values, a more direct comparison of PCT residues to sawlog values is possible. The values for various grades of sawlogs drive timber harvest decisions; where PCT residue values compare well to sawlog values, that provides insight into the economic feasibility of operations even when operational costs are unkown. Figure 4 below provides time-series distributions of delivered log prices by grade, with references for the implied value of PCT residues at 1%, 2%, and 3% of wholesale revenue.

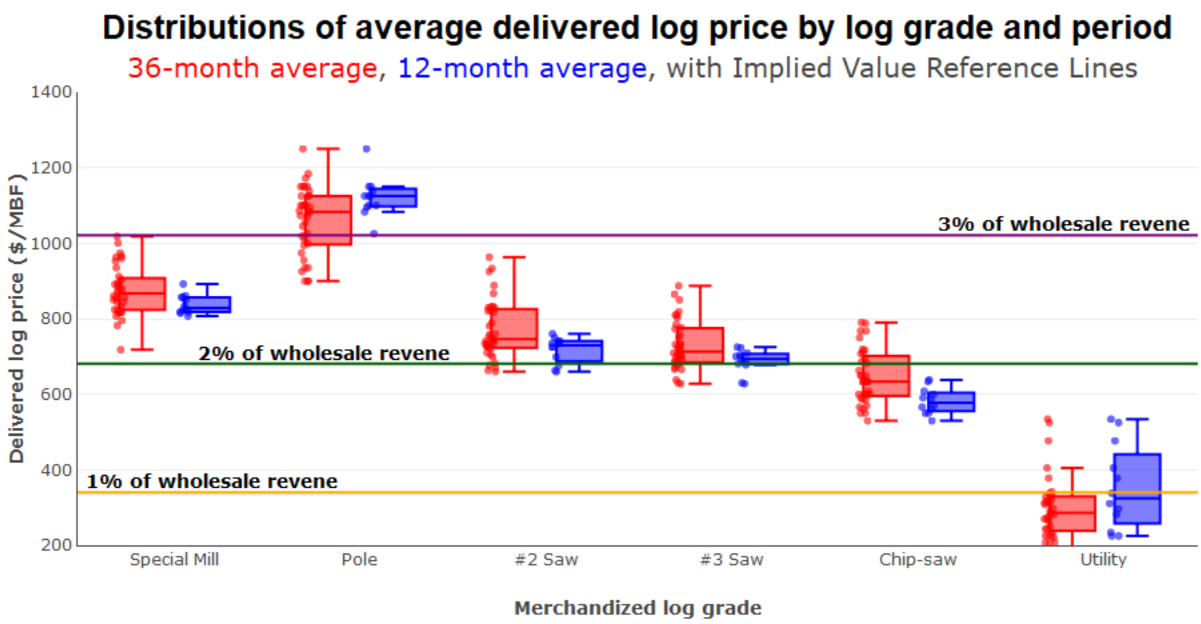

Figure 4: Average delivered log prices by grade and period (36 Mo., 24 Mo) for Westside Douglas-fir. Orange reference line indicates implied value of $340 per MBF when residues account for 1% of wholesale revenue; green reference line indicates implied value of $681 per MBF when residues account for 2% of wholesale; purple reference line indicates implied value of $1,021 per MBF when residues account for 3% of wholesale. Assumes 8.5 tons per MBF conversion rate.

Sources: Washington State Department of Natural Resources (prices).
Washington State Department of Revenue (implied values).

Comparing residues to sawlogs using Figure 4, at 1% of Wholesale with a value of $340 per MBF, PCT residues compares to the median delivered price of the past 12 months' distribution for utility logs, slightly above the 75th percentile over the past 36 months, and well below the lowest-value sawlog (#4/chip-saw) price. However, At 2% of wholesale, a value of $681 per MBF compares favorably to #4/chip-saw prices over the past 36 months; and is near the 25th percentile of #2 #3 sawlog prices over the past 12 months. At 2% of wholesale revenue, it is reasonable to assume that the value of residues would be greater than thinning, extraction, and processing costs. At 3% of wholesale revenue, the implied value is $1,021 per MBF, making residues comparable to poles (the most valuable grade of sawlog) over the past 36 months.

3.4 Tax Incentivization

The Washington State Legislature, seeking a strategic incentive to catalyze forest restoration and economic innovation, might offer a tax break on *liquor produced from wood residues*. The conversion of residues into high-value products like liquor clearly enhances their market worth, and the public benefits are well-established: reduced fire fuel loads (and lower emergency firefighting costs), improved forest health, and stronger returns at the time of harvest. A targeted tax incentive could therefore serve multiple purposes: to add value to the material and ensure economic feasibility for landowners and producers; to establish a novel, place-based industry that leverages Washington's forestry and distilling strengths; or simply to accelerate the realization of these public benefits. In essence, it's a policy lever to align private action with public good, using tax relief to unlock fiscal, ecological, and economic returns.

Specifically, the Legislature may reduce the effect of the combined sales tax rate, the volume tax, or some combination of both. Assuming that the post-tax sale price remains constant (i.e. determined by markets), a reduction in either tax has the effect of increasing the wholesale price of a bottle of liquor, and with it the implied value of woody residue inputs, enhancing futher the benefits of PCT applications. A matrix detailing the percent increase in pre-tax price of a bottle of liquor based on differential reductions in the sales and liter taxes is presented in Table 4 below.

Table 4: Percent increase in the pre-tax price of a 750ml bottle of liquor given a constant post-tax price of $22.35; combined sales tax rate of 0.375; current liter tax rate of $3.7708 per liter, and a resulting pre-tax price of $14.20. Columns from left to right represent liter tax reductions of $0.00, $0.10, $0.20, $0.30, $0.50, $0.70, and $1.00. Rows from top to bottom represent sales tax reductions at 0%, 1%, 2%, 3%, 5%, 7%, 10%. based on the sale price (not the sales tax rate).

Sales \ Litre	2.8281	2.7531	2.6781	2.6031	2.4531	2.3031	2.0781
0.375	0.00%	0.38%	0.77%	1.15%	1.92%	2.69%	3.84%
0.365	0.73%	1.12%	1.51%	1.89%	2.67%	3.44%	4.60%
0.355	1.48%	1.87%	2.26%	2.65%	3.43%	4.20%	5.37%
0.345	2.23%	2.62%	3.02%	3.41%	4.19%	4.98%	6.16%
0.325	3.77%	4.17%	4.57%	4.97%	5.77%	6.56%	7.76%
0.305	5.36%	5.77%	6.17%	6.58%	7.39%	8.20%	9.41%
0.275	7.84%	8.26%	8.67%	9.09%	9.91%	10.74%	11.99%

As an example, if the Legislature lowered the combined sales tax rate from 37.5% to 27.5% and the volume tax from $2.8281 to $2.0781 per 750ml bottle, the effect would be to increase the wholesale price from $14.20 to $15.90, a 12% increase. Using the same conversions as in the previous section, this would increase the value of a green ton of PCT residues from $80.09 to $89.67 at 2% of wholesale revenue, equivalent to $762 per MBF. This would value residues equally with #2 sawlogs for most of the past 36 months.

4. Implementation Plan

4.1 Residue Volume Quantification

4.1.1 Reconnaissance

1. Define Objective and Population
   (a) Objective: Estimate total volume per hectare of felled stems (residues) left on the ground after pre-commercial thinning.
   (b) Population: Stratified by ownership type and primary species;
      - Ownerships: Private, State & Tribal, Federal
      - Possible Partners: Quinault Indian Nation, Jamestown S'Klallam Tribe, Makah Nation, Confederated tribes of the Colville Reservation, Yakama Nation, Rayonier, Nuveen Capital, Merrill & Ring, WADNR, USFS, BLM
      - Primary Species: western hemlock, Douglas-fir, Sitka spruce, lodgepole pine, Pacific silver fir, ponderosa Pine, grand fir
2. For all candidate sites:
   (a) Record metrics of interest:location; primary species; planting density; PCT intensity; quadratic mean diameter (before, after); stand age & height at PCT

4.1.2 Fieldwork

1. For selected sites within Each Strata
   (a) Lay Out Line Intersect Transects the unit: random or systematic
   (b) Transect length: typically 20–50 meters.
   (c) Orientation: random azimuth or perpendicular to slope.
   (d) Record transect length precisely.
2. Measure Each Stem That Tntersects the Transect Line
   (a) Basal diameter (at butt end)
   (b) Length from base to point of intersection
   (c) Diameter at point of intersection
   (d) Total stem length

4.1.3 Analysis & Products

1. Calculate Piece-Specific Taper Rate
   (a) Taper rate = $\frac{Basaldiameter - Diameteratintersection}{Distancefrombasetointersection}$
   (b) Units: inches per foot or cm per meter
2. Estimate Volume
   (a) Estimate tip diameter using taper rate and total length
   (b) Volume of Truncated Cone = $\frac{\pi \times Length}{12} \times (Basal^2 + Basal \times Tip + Tip^2)$
3. Aggregate by Transect
   (a) Sum volumes of all intersected stems
   (b) Divide by transect length to get volume per meter of transect
   (c) Scale to volume per hectare using Gregoire and Valentine's LIS methods:
   Volume per hectare = $(\frac{\pi^2}{8 \times transectlength}) \times sumofstemvolumes$
4. Stratify and Estimate Totals
   (a) Group stems by ownership $\times$ species strata
   (b) Calculate mean volume per stratum
   (c) Use stratified estimators to combine across strata
5. Estimate Variance
   (a) Use design-based variance formulas or bootstrap resampling
   (b) Account for variation in taper, stem size, and orientation

6. Report Results
    (a) Express volume in cubic meters per hectare or tons per acre
    (b) Include:
        - Mean volume per stratum
        - Standard errors and confidence intervals
        - Notes on taper variability and thinning intensity
7. Draft Paper for Peer Review

4.2 Research and Development on PeeWee Jr.

1. Follow similar path laid out by Original PeeWee Yarder.
    (a) Identify appropriate cable yarding system
        - See if Japanese researchers have already figured this out
    (b) Decide if off-the-shelf equipment meets requirements; otherwise purpose-built
    (c) Field Tests.
2. Partners: US Forest Service, School of Environmental and Forest Sciences, Applied Physics Lab, Port of Port Angeles

4.3 License Technology From FFPRI

1. Make contact with Researchers
2. Send representative to train in methods and gather equipment requirements

4.4 Regulatory Changes

1. Federal legislation and/or rule-making required to allow liquor to be made from wood
    (a) Vodka must be distilled from a starch; rum from sugar; bourbon from corn
        - There is currently no mechanism to label and cell liquor distilled from cellulose
2. Approach state legislators to explore sales/volume tax incentivizes.