Clallam County log supply by species, size, and source.

Implications for mass-timber production on the Olympic Peninsula.

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Executive Summary

Wood product manufacturers consumed 3.1 billion board-feet (MMMBF) of timber in 2016, of which 85% was harvested within the state. The remainder was sourced primarily from Oregon, with contributions from Idaho, British Columbia, and other states. Of the 2.7 MMMBF harvested in Washington, two-thirds were sourced from private timberlands, with one third coming from state, federal, and other public lands. Private timber supply is split evenly between non-industrial and industrial owners. A large majority of public timber is supplied by the Washington State Department of Natural Resources (WADNR). These rankings of supply by ownership type have remained consistent for the period 2004 through 2016.

More than 98% of the timber consumed within Clallam County in 2016 was harvested in Washington. Harvest within the county totalled 187 MMBF, of which 58.3 MMBF was removed to other counties for further use; at the same time, one million board-feet were imported from British Columbia and 49.8 MMBF were added from other counties. Jefferson County supplied more than 20% of the timber consumed in Clallam County in 2016. The result is that, in 2016, Clallam County was a net exporter of timber. This condition is not unique to 2016, but has been the case a majority of years dating back to 2004. Table ES1 below details the log movements into and out of the county, as well as overall supply.

Table ES1. Net timber consumed in Clallam County by source and selected years.
Volumes reported in millions of board-feed (MMBF).

Year	Supply	Clallam (Removed)	Jefferson	Grays	Kitsap	Mason	Skagit	Other	Total
2004	244.0	(116.7)	26.0	1.8	0.0	0.0	2.5	8.5	166.1
2006	259.2	(119.1)	35.5	1.3	1.4	0.3	0.9	42.0	221.8
2008	162.2	(44.3)	27.5	0.6	3.5	2.7	0.0	0.7	155.6
2010	169.3	(49.8)	40.9	3.5	5.2	4.9	0.4	0.2	179.5
2012	187.5	12.3	36.4	4.8	2.9	0.0	2.6	16.9	263.4
2014	241.8	(90.7)	32.0	2.6	2.4	0.0	0.2	2.4	190.7
2016	187.0	(58.3)	41.5	3.4	2.1	0.0	0.9	1.9	178.5

Data sources: WADNR Mill Surveys, Timber Harvest Reports; WA Dept. of Revenue (WADOR).

Note: Category 'Supply' includes within-county harvest and timber harvested in other counties, plus imports. Category 'Other' includes sources such as Native American tribes which are not reported to WADOR and are not assessed excise tax.

If Clallam County's log consumption by size class and species (i.e. *sort*) is reflective of the Olympic Region - consisting of Clallam, Jefferson, Mason, Grays Harbor, Thurston, Lewis, and Pacific counties - then sawmilling drives the demand for logs, followed by chipping and export sectors. Sawmilling and export consumption in Clallam County is highly concentrated on a few sorts, chipping log demand is spread more uniformly across size and species classes. However, the magnitude of demand is important to note: aggregate chipping log consumption is equal roughly to half of sawmills' consumption within a single size class (11"-

20"). Consumption of Douglas-fir and western hemlock account for 85% of all consumption by species; three-quarters of logs consumed come from four sorts: Douglas-fir 5" to 10" logs (25%); Douglas-fir logs 11" to 20" (15%); western hemlock 5" to 10" logs (21%); and western hemlock logs 11" to 20" (13%). The joint distribution of demand by size and species is detailed in Table ES2.

Table ES2. Joint distribution of Clallam County log consumption by size class and species.
Average distribution for period 2004-2016.
Volumes reported in millions of board-feet (MMBF).

Species		Douglas-fir	Western hemlock	Red alder	Other	Total
Size class	Proportion	0.453	0.386	0.075	0.086	1.00
< 5"	0.055	4.8	4.1	0.8	0.9	10.7
5" - 10"	0.555	48.7	41.5	8.1	9.2	107.5
11" - 20"	0.342	30	25.6	5	5.7	66.2
>= 21"	0.048	4.2	3.6	0.7	0.8	9.3
TOTAL	1.00	87.7	74.8	14.5	16.7	193.7

Note: Size and species distributions are reflective of region-wide proportions.

The volume of Douglas-fir logs consumed has increased and surpassed that of western hemlock over time. However, harvest volumes within the county have not reflected this trend: the proportion of hemlock produced to all species was 23% higher in 2016 than its proportion of all species consumed; for Douglas-fir the proportion produced was 45% lower than for consumption. The log movements described in Table ES1 describe removals consisting mostly of hemlock, and additions consisting of mostly Douglas-fir. Nearly half the volume of logs consumed coming from Douglas-fir and western hemlock in the 5" to 10" size class; consequently, significant price competition should be expected to fetch these sorts for other uses.

Mass-timber production on the Olympic Peninsula may be feasible if a product (or range of products) can be produced cost-effectively within the universe of biomass supply described (partially) in this report. Alternatives identified and discussed in this report includ wood composite panels, re-capitalizing paper mills as bio-refineries, cross laminated timber, structural composite lumber, glulam production, wood-plastic composites, dowel laminated timber, nail laminated timber, and wood pellet production. Feedstock requirements ranged from process waste streams (e.g. hog fuel) to manufactured goods (e.g. lumber). Some alternatives appear naturally competitive for log sorts, while others are more complimentary to existing industry sectors. The major distinction within the group is the cost of capitalization: there is a high cost to capitalize pellet mills, nail laminated timber production, and dowel-laminated timber production; while there is expected to be a much higher cost to capitalize wood composite panels, re-capitalizing paper mills as bio-refineries, cross laminated timber, structural composite lumber, glulam production, wood-plastic composites, due mostly to equipment requirements.

Some alternatives may be feasible only if one or more of local, state, and federal policy changes result in an increased overall log supply. In this case, additional research will be required on the potential for and impact of changes in policy regarding access to timber on state (WADNR) and federal (USFS) lands. While it is beyond the scope of this report to speculate on the nature of those changes, data suggest there are surplus suplies of timber: the average acre within Olympic National Forest grows 600 BF/acre/year, yet harvests only 10 BF/acre year. Other alternatives may require additional research to explore, develop, and test methods for utilizing potential biomass supplies (i.e. supplies that heretofore have not been marketed). This, in turn, may require subsequent policy changes for markets to develop. While the products identified and discussed in this paper have a significant amount of research and development already associated with each of them, there may exist a new or hybrid product with a high potential for success that requires similar fundamental research and development.

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Introduction and Scope

Wood products manufacturing is an important economic sector in Washington State in general and Clallam County in particular. In 2016, 401 businesses statewide supported 11,805 employees, with an aggregate payroll of $149.4 million dollars. Demand for timber by manufacturers equates directly to jobs in logging, timber management, and transportation: In 2016, 648 businesses statewide in these sectors employed 15,317 people with a total payroll of $127.5 million dollars.

All timber harvests in Washington generate excise tax revenue equal to five percent of gross sales of which, 80% is remitted to the counties where the timber was harvested, supporting local institutions (e.g. schools, hospitals, libraries, and fire departments). In 2016 this totalled $33.3 million, In addition, harvest from WADNR lands generated revenue for State institutions (e.g. K-12 schools, universities, hospitals, prisons); the 2016 trust revenue generated by timber harvest was approximately $144.1 million[1].

Mass timber wood products are naturally sustainable construction material engineered with strength and stability properties allowing their substitution for concrete, masonry and steel in both residential and non-residential applications. Used in Canada, Europe, and Australia to rapidly construct multi-story wood buildings, there is increasing interest in the U.S. in utilizing the technology in residential and commercial buildings due to its appeal as a potential locally-sourced and sustainable building material. The manufacturing process is similar to that of plywood: layers of wood, veneer, or long fibers adhered together to form a panel, where layers are oriented crosswise to each other. As thickness increases with layering, so does a panel's strength and stability across multiple dimensions. Dimension lumber is the most common substrate for the most widely known mass-timber product: cross-laminated timber (CLT). However, different wood products are also employed in making panels of laminated veneer lumber (LVL), laminated strand lumber (LSL), or oriented strand lumber (OSL).

Widespread adoption of mass timber in construction will sequester large amounts of carbon in the form of wood. If an average wood-framed house contains 40 thousand board-feet (MBF), then the equivalent house built with mass timber contains 240 MBF. As one cubic foot of CLT sequesters 42.3 pounds of carbon dioxide (CO2), the average CLT house sequesters approximately 425 tons of atmospheric carbon. By contrast, production of one cubic foot of concrete emits 23.3 pounds of CO2 (some of which is recaptured over decades as concrete calcifies). Steel and cement account for half of carbon dioxide emissions in Canada (ARUP workshop). At the time of production, each cubic foot of CLT substituted for concrete removes over 65 pounds of CO2 from the atmosphere. Additionally, wood offers more

[1] This estimate is based on a transformation of excise tax into gross revenue, and taking 75% of that figure; 25% of revenue is removed by DNR for management and administration costs. There may have been land exchanges or other, non-timber sources of revenue to the Trusts, and the exact amount charged by DNR for management and administration varies by Trust account. This figure would also include Forest Board Transfer and Purchase lands, which are county-level Trust lands.

product for less input energy: one ton of cement requires 5 times more energy to create than a ton of wood. The contrast is more dramatic for other materials: 14 times more energy for one ton of glass; 24 times for steel; and 126 times for aluminum.

As a manager of resources for long term sustainability, the Port of Port Angeles recognizes the economic opportunity of mass timber manufacturing in terms of living-wage job creation and tax revenue generation that benefits local and state institutions. The Port also recognizes the ecologic and forest-health benefits of mass-timber to displace other materials whose manufacture has negative environmental consequences.

The Port requested this report to be prepared to quantify the demand for logs in Clallam County and identify underutilized and possibly undervalued log sorts that are available for mass timber applications. Further, this report will explore manufacturing requirements for selected mass timber products whose input requirements best match available supply.

Washington State

Washington State consumed 3.1 billion board-feet (MMMBF) of timber in 2016; of which 2.7 MMMBF (85%) was harvested within the state. The balance was supplied by Oregon, Idaho, Montana, other states, and British Columbia. For the period 2004 through 2016, total log consumption has declined along with intrastate supply, as well as supplies from Idaho and British Columbia. Log supplies from Oregon have remained consistent over the same period. A summary of timber supply by source is presented in Table 1 below.

Table 1: Washington State timber supply by source for selected years.
Volumes reported in millions of board-feed (MMBF).

Year	Oregon	Idaho	Montana	British Columbia	Other States	Washington	Total Supply
2004	353.4	102.6	6.8	242.5	51.4	3,787.5	4,544.2
2006	335.2	116.4	5.3	238.7	12.5	3,319.1	4,027.2
2008	408.9	107.0	2.1	97.0	9.1	2,363.1	2,987.2
2010	400.9	77.5	2.0	76.2	15.6	2,702.7	3,274.9
2012	443.2	48.0	0.0	72.3	3.2	2,766.5	3,333.2
2014	408.5	66.6	0.0	68.2	3.2	3,052.6	3,599.1
2016	388.2	44.4	0.0	26.5	4.8	2,719.9	3,183.8

Data source: WADNR Mill Survey

Two-thirds of the timber harvested within Washington State in 2016 was sourced from private ownerships. Among private ownerships, the volume was split evenly between industrial, and non-industrial private owners. A small, but not insignificant, portion is sourced from owners for whom timber excise taxes do not apply (e.g. Native American timberlands). A majority of the public timber is supplied by Washington Department of Nautral Resources (WADNR). Federal sources of timber include United States Forest Service (USFS) and Bureau of Land Management (BLM). Slightly more than 10% of all timber consumed in Wasihngton is supplied by other public entities, which may include county and local governments. A summary of public and private timber suppliers over time is presented below in Table 2.

Table 2: Washington State timber harvest by ownership for selected years.
Volumes reported in millions of board-feed (MMBF).

	Public			Private				
Year	State	Federal	Other	Small	Large	Industrial	Unknown	Total
2004	589.4	94.7	51.6	891.1	1,011.1	930.9	218.7	3,787.5
2006	399.6	76.5	58.4	602.2	1,131.5	1,000.2	50.7	3,319.1
2008	489.7	104.1	15.9	320.3	622.5	542.1	268.5	2,363.1
2010	724.6	117.7	27.5	359.4	766.1	658.4	49.0	2,702.7
2012	442.1	82.1	33.2	684.2	470.6	760.6	293.7	2,766.5
2014	434.4	117.2	44.6	572.9	678.6	1,146.6	58.3	3,052.6
2016	534.2	120.6	34.3	605.9	315.3	1,070.5	39.1	2,719.9

Data source: WADNR Timber Harvest Report

Aggregate log demand is the sum of demands from manufacturing sectors: sawmills; veneer and plywood; pole, post, and piling; pulp and board; shake and shingle; chips; and log exports. Sawmills account for half or more of total log consumption over the period 2004 through 2016. Demand for chips has varied over time but accounts for around 10% of demand. Export demand has varied over the period, as has veneer. Pulp log demand has decreased over time. The distribution of log consumption among industry sectors is summarized below in Table 3.

Table 3: Washington State log consumption by industry sector for selected years.
Volumes reported in millions of board-feed (MMBF).

Year	Sawmills	Veneer	Chipping	Exports	Other	Total
2004	3,080.3	0.0	280.6	897.9	322.3	4581.1
2006	2,401.9	0.0	286.6	541.0	337.1	3566.6
2008	1,913.0	473.7	361.7	661.7	79.3	3489.4
2010	2,049.8	196.1	402.6	916.7	109.4	3674.6
2012	1,764.5	171.5	339.1	1,010.9	44.9	3330.9
2014	1,894.9	262.1	228.3	1,139.3	88.7	3613.3
2016	1,636.9	226.0	309.5	882.3	80.1	3134.8

Data source: WADNR Mill Survey.

Note: Category 'Other' includes pole and pulp operations.

Log consumption is distributed among size classes (Table 4) and species groupings (Table 5). Demand for logs between 5" and 10" accounts for approximately 45% of total log consumption; demand for 11" to 20" logs accounts for another 40%. The remainder is split nearly even between small logs (< 5") and large logs (>= 21"). Given equal volumes, the ratio of the number of small to large logs is *at least* 16:1. The number of large logs consumed in Washington is quite small relatvie to smaller logs.

Table 4: Washington State log consumption by size class for selected years.
Volumes reported in millions of board-feed (MMBF).

Year	Under 5"	5" - 10"	10" - 20"	Above 20"	Total
2004	194.4	2,237.8	1,749.8	399.1	4,581.1
2006	220.8	1,547.1	1,490.1	308.7	3,566.6
2008	182.6	1,571.3	1,492.2	243.3	3,489.4
2010	174.2	1,725.4	1,515.8	259.2	3,674.6
2012	123.3	1,471.7	1,516.7	219.3	3,330.9
2014	118.4	1,765.4	1,519.1	210.4	3,613.3
2016	173.2	1,487.2	1,238.1	207.8	3,134.8

Data source: WADNR Mill Survey.

Douglas-fir and western hemlock accounted for eighty-five percent of aggregate log demand in 2016; with the demand for Douglas-fir 2.5 times greater than for hemlock. These proportions are consistent for the period dating back to 2004; however, the absolute amounts have declined as described previously. All other softwoods combined account for 10-15% of aggregate demand; red alder and other hardwoods account for 3-5% of demand.

Table 5: Washington State log consumption by species for selected years.
Volumes reported in millions of board-feed (MMBF).

Year	PSME	TSHE	ABIES	PISI	PIPO	PICO	THPL	OTCON	ALRU	OTHRD	TOTAL
2004	2,206.1	1,124.9	394.9	64.9	221.4	112.0	192.8	11.6	207.7	44.7	4,581.1
2006	1,744.1	913.1	194.9	49.9	196.8	60.7	141.6	0.6	223.3	41.7	3,566.6
2008	1,971.0	852.6	111.5	34.9	212.0	35.9	114.0	0.2	145.9	11.6	3,489.4
2010	2,201.1	851.9	139.2	43.0	115.2	39.7	105.4	0.8	165.0	13.3	3,674.6
2012	1,958.2	866.0	119.8	43.6	93.7	18.1	75.9	7.0	140.7	14.5	3,330.9
2014	2,158.0	886.3	137.2	34.6	112.2	33.1	101.0	5.5	128.6	16.8	3,613.3
2016	1,855.1	772.9	74.5	40.9	107.7	22.9	87.0	14.8	128.5	16.8	3,134.8

Data source: WADNR Mill Survey.

Species key: PSME = Douglas-fir; TSHE = western hemlock; ABIES = true firs (e.g. silver fir); PISI = Sitka spruce; PIPO = ponderosa pine; PICO = lodgepole pine; THPL = western redcedar; OTCON = other conifers; ALRU = red alder; OTHRD = other hardwoods.

Clallam County

Log demand in Clallam County is met primarily by local timber harvest. In 2016, 185.9 MMBF of timber was harvested in Clallam County; proportions of timber harvest by ownership in Clallam County are comparable to statewide figures. However, harvest rates vary significantly by ownership: USFS owns 199,000 acres[2], producing 10 BF/acre; DNR manages 178,000 acres[3] producing 247 BF/acre; there are 347,800 acres of private timberland[4] producing 400 BF/acre. A summary of timber harvest by ownership is presented below in Table 6.

Table 6: Clallam County timber harvest by ownership for selected years. Volumes reported in millions of board-feed (MMBF).

	Public			Private				County
Year	State	Federal	Other	Small	Large	Industrial	Unknown	Total
2004	18.6	4.3	0.0	67.4	118.9	3.4	27.3	239.9
2006	17.4	5.6	0.0	47.9	114.1	19.3	5.9	210.2
2008	63.0	3.4	0.0	27.5	44.9	0.5	20.8	160.1
2010	51.5	6.1	0.0	24.8	61.8	0.0	19.1	163.3
2012	39.5	1.7	0.0	36.7	21.1	11.8	71.3	182.1
2014	60.1	1.7	0.0	28.2	56.8	56.3	25.1	228.2
2016	44.1	2.0	0.5	7.5	93.2	37.5	1.1	185.9

Data source: WADNR Timber harvest reports.

Note: No quantitative criteria provided for ownership classifications.

Additional logs may be sourced from other states and British Columbia. However, the average volume of wood from these sources over the period 2004 - 2016 accounted for only 5.9% of the volume produced locally. A summary of timber supplied to Clallam County from other states and British Columbia is presented in Table 7, below.

[2] Data Source: USFS (https://www.fs.fed.us/land/staff/lar/LAR07/TABLE_6.htm)

[3] Data Source: WADNR (https://data-wadnr.opendata.arcgis.com/datasets/wa-dnr-managed-land-parcels), Timber Trusts 1-13.

[4] Data source: Washington State forestland database (http://www.ruraltech.org/projects/wrl/fldb/pdf/The_2007_Washington_State_Forestland_Database.pdf)

Table 7: Clallam County timber consumption by source for selected years. Volumes reported in millions of board-feed (MMBF)

Year	Clallam County	Oregon	Idaho	Montana	British Columbia	Other State	Total Supply
2004	239.9	0.0	0	0	3.1	1.0	244.0
2006	210.2	3.5	0	0	44.8	0.7	259.2
2008	160.1	0.0	0	0	2.1	0.0	162.2
2010	163.3	0.7	0	0	0.2	5.1	169.3
2012	182.1	2.4	0	0	3.0	0.0	187.5
2014	228.2	10.6	0	0	3.0	0.0	241.8
2016	185.9	0.0	0	0	1.1	0.0	187.0

Data source: WADNR Timber harvest reports.

In the same manner that wood moves into Clallam County from out of the area, some of the timber harvested in the County is removed for use elsewhere. More often than not, the amount removed is greater that the amount brought in - suggesting that Clallam County is a net exporter of its timber. A review of the number of sawmill, veneer, chipping, and export operations on the Olympic Peninsula and in the broader Olympic Region supports this, as the total capacity in Grays Harbor, Pacific, and Lewis counties is much greater than in Clallam and Jefferson counties. There is much more competition for logs. A summary of timber production in Clallam county with additions from other sources, less timber removed to other counties, is presented in Table 8. The total in Table 8 is the net volume of timber utilized in Clallam County, accounting for all imports and exports, foreign and domestic.

Table 8: Net timber consumed in Clallam County by source for selected years. Volumes reported in millions of board-feed (MMBF).

Year	Supply	Clallam (Removed)	Jefferson	Grays	Kitsap	Mason	Skagit	Other	Total
2004	244.0	(116.7)	26.0	1.8	0.0	0.0	2.5	8.5	166.1
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2008	162.2	(44.3)	27.5	0.6	3.5	2.7	0.0	0.7	155.6
2010	169.3	(49.8)	40.9	3.5	5.2	4.9	0.4	0.2	179.5
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2016	187.0	(58.3)	41.5	3.4	2.1	0.0	0.9	1.9	178.5

Data sources: WADNR Mill Surveys, Timber Harvest Reports; WA Dept. of Revenue (WADOR).

Note: Category 'Other' includes sources such as Native American tribes which are not reported to WADOR and are not assessed excise tax. The large amount of 'Other' in 2012 coincides with influx of timber in Timber Harvest Reports' 'Unknown' category for 2012 (see Tables 2, 6).

Industry Sectors

The total timber volume consumed across the Olympic Region in general and Clallam County

specifically will have a separate distribution for size classes and species. A particular combination of size and species of timber is a *sort*. Sawmills, veneer and plywood mills, chipping operations, shake and shingle mills, export operations, pole and post mills, and pulp mills each have preferred sorts. Where different industry sectors' sorts overlap, the demand for available supply increases; if industry sectors are absent or sorts are unique then demand decreases. The level of demand for a sort relative to its supply is the *saturation* of a given sort. For Clallam County, the shape of size class and species distributions are determined by the industry sectors operating in the County. The number of operations by industry sector for both Olympic Region and Clallam County are presented in Figure 1.

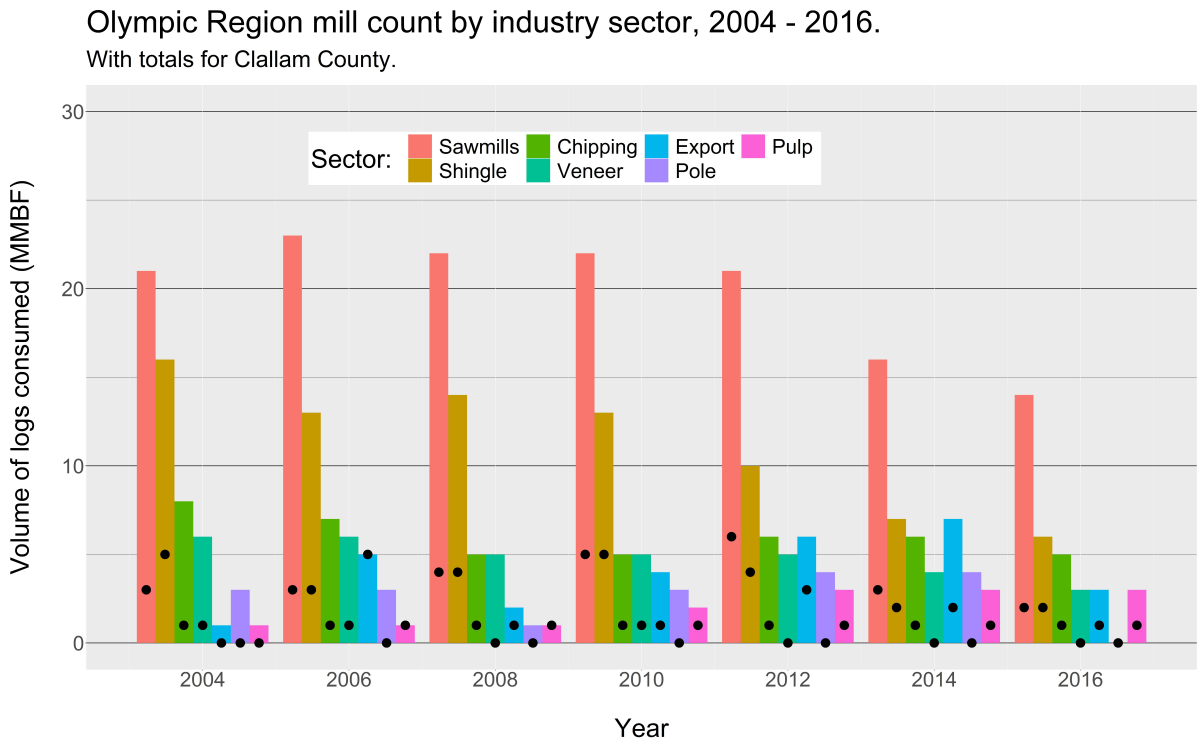

Figure 1: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

Overall mill count has declined both across the Region and in Clallam County. Sawmilling is the dominant industry sector, followed by shake and shingle, and then chipping operations. Clallam County has not had any post and pole operations, and veneer has been absent for five to seven years.

Log demand within the county is driven by the size and species distributions for the three largest industry sectors in Clallam County: sawmills, chipping, and exports. Those distributions of timber consumption for the Olympic Region are detailed in the following figures. Data for Clallam County's share of the volume is not available and is computed as a ratio of the number of operations within a sector to the region-wide total in that sector. Figure 2 illustrates the degree to which regional demand is driven by sawmilling. Forest management decisions such as initial planting density, whether (and when) to thin pre-commercially (PCT), and whether or not to fertilize will be influenced by the expected price a sawmill would pay for the delivered sorts, and whether that return justifies a particular investment. Once a stand has reached maturity for commercial purposes, however, harvest decisions may be influenced by demand on sorts from other sectors.

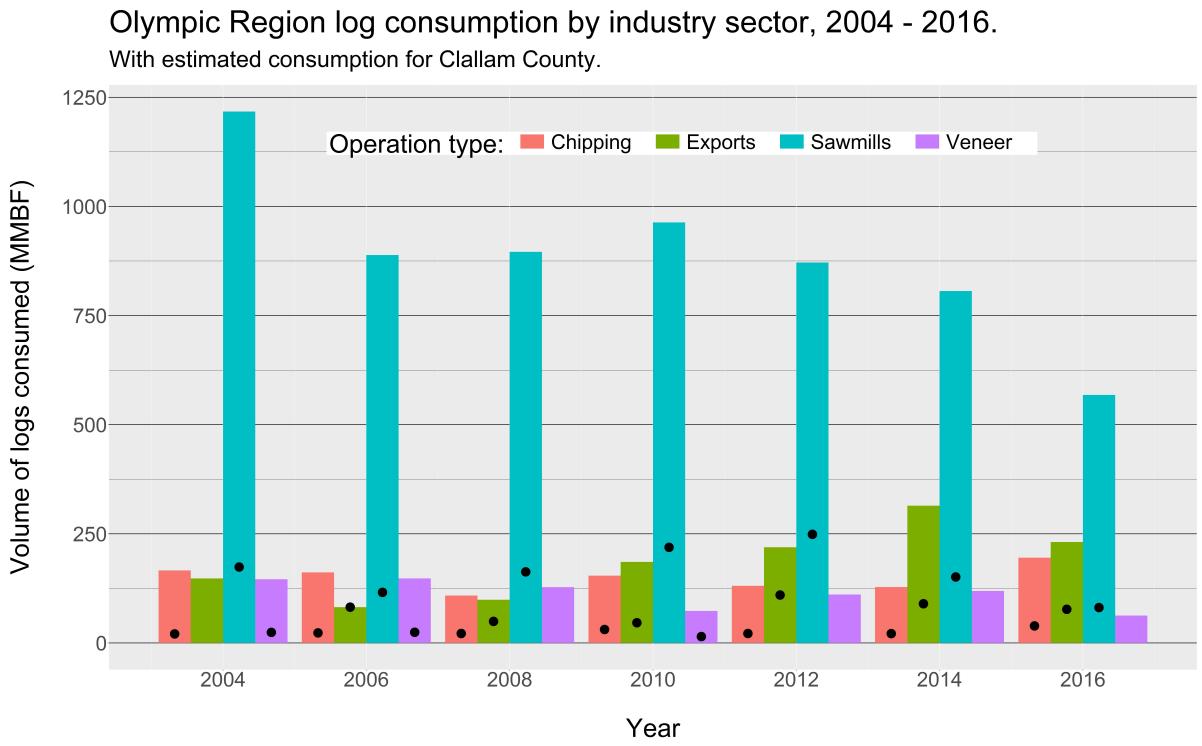

Figure 2: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

Size

Average log consumption across all sectors in the region was 745.3 MMBF in the 5"- 10" class for the period 2004 - 2016, equal to the other three size classes combined. The dominance of this class is not quite as pronounced in Clallam County. Region-wide, 1,203.9 out of 1,341.8 million board-feet are in the 5"-10" and 11"-20" classes.

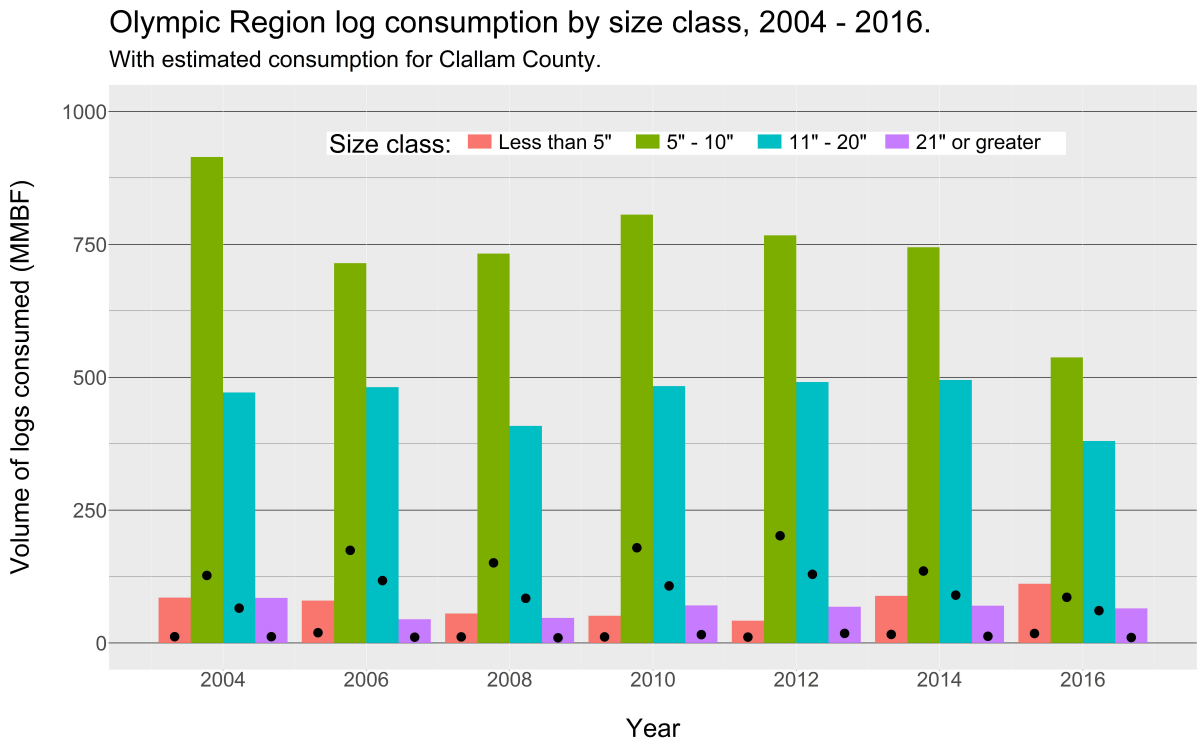

Figure 3: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

Sawmilling follows a pattern of usage that is similar in proportions to industry aggregate. The demand for logs in the 5"-10" class is more pronounced, and Clallam's estimated demand is in proportion to the region, illustrated in Figure 4. Chipping log demand (Figure 5) is much more uniform across size classes. However, it is the magnitude of demand that is most important to note - total chipping log demand is about half that of sawmills' demand for the 11"-20" logs, and comparable to the total export demand for 11"-20" logs. The majority of export demand (Figure 6) is for logs in the 11"-20", with a minority but not insignificant component of 5"-10" logs. While aggregate export demand has risen over time, it is still very small in comparison to sawmill demand.

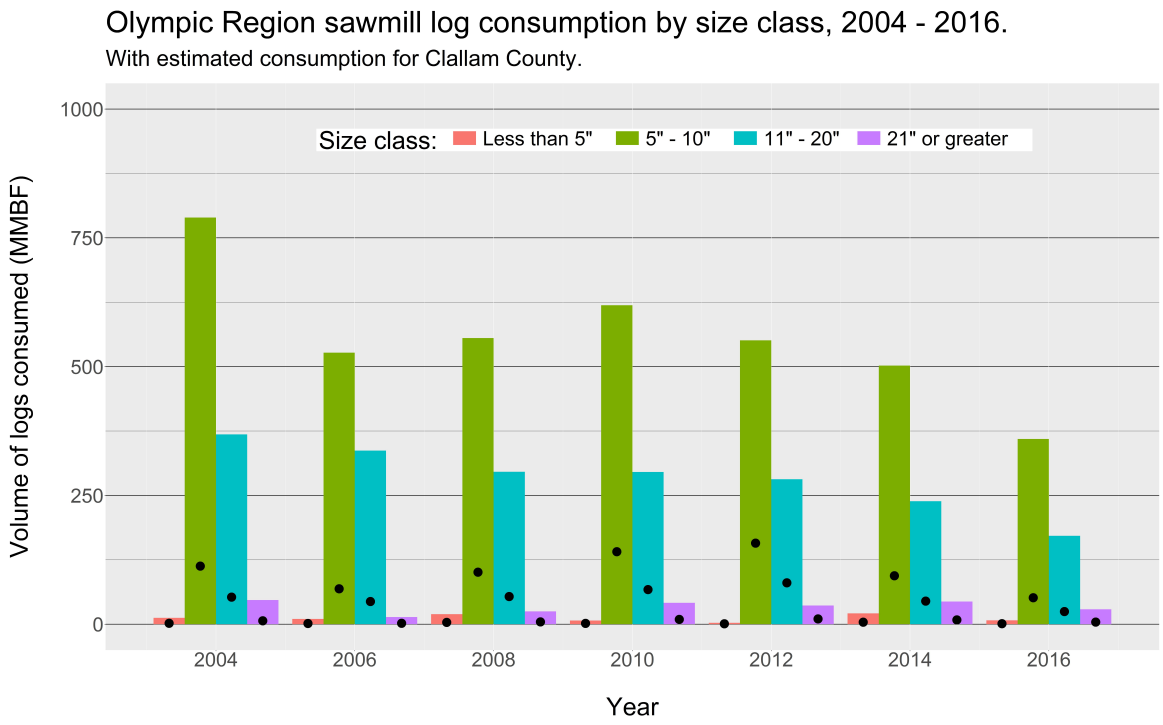

Figure 4: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

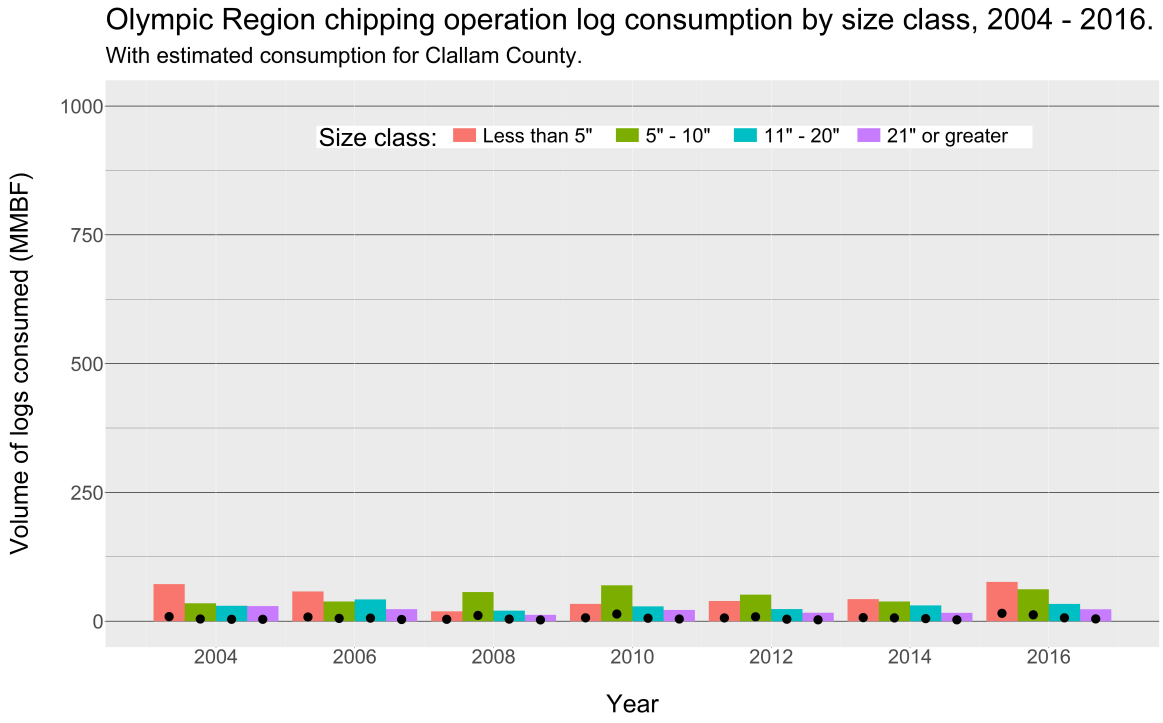

Figure 5: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

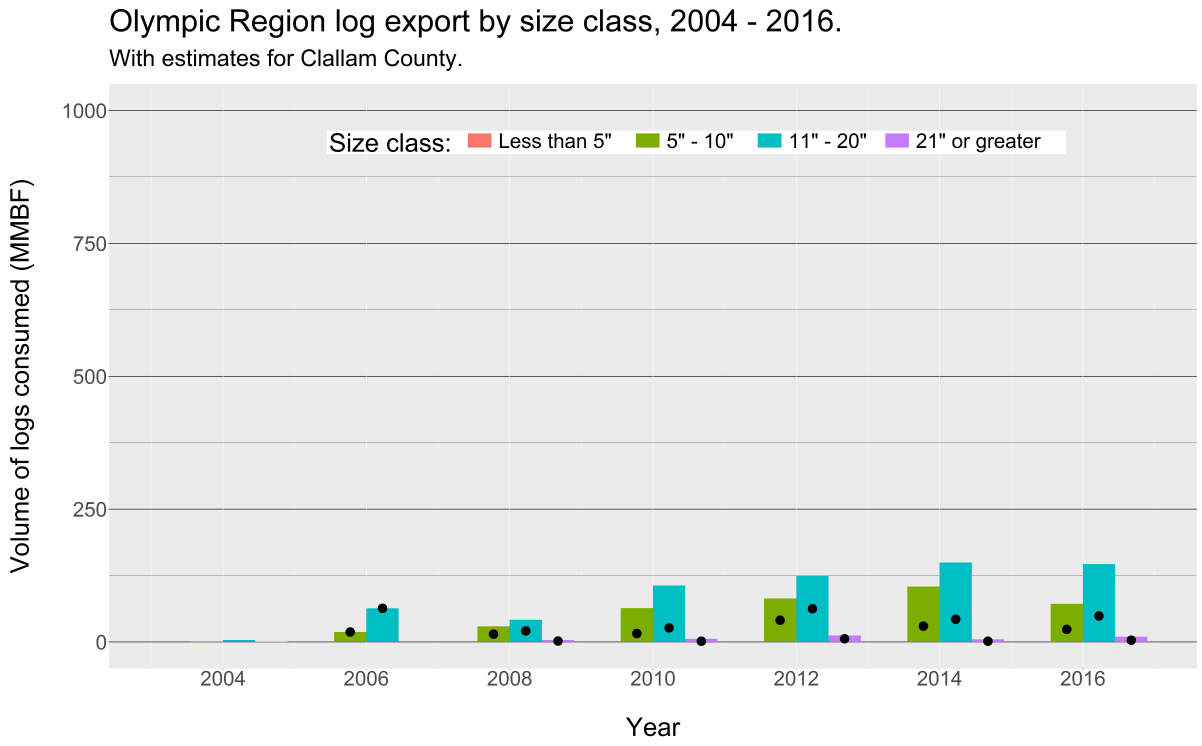

Figure 6: Industry sectors represented by bars, Clallam County estimates by points. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

Species

Region-wide species demand is dominated by Douglas-fir and western hemlock. For the period 2004 through 2016, the relative demand for Douglas-fir has increased and overtaken demand for western hemlock, with the aggregate demand remaining relatively constant. The average demand for both species account for % of total demand over the same period; aggregate demand by species is illustrated in Figure 7. Demand across the region for red alder is equal to that for all remaining species groups combined and both have remained constant over time, as has the estimated demand within Clallam County. Species demand by industry sector and year are presented in Figure 8 (sawmilling), Figure 9 (chipping), and Figure 10 (exports).

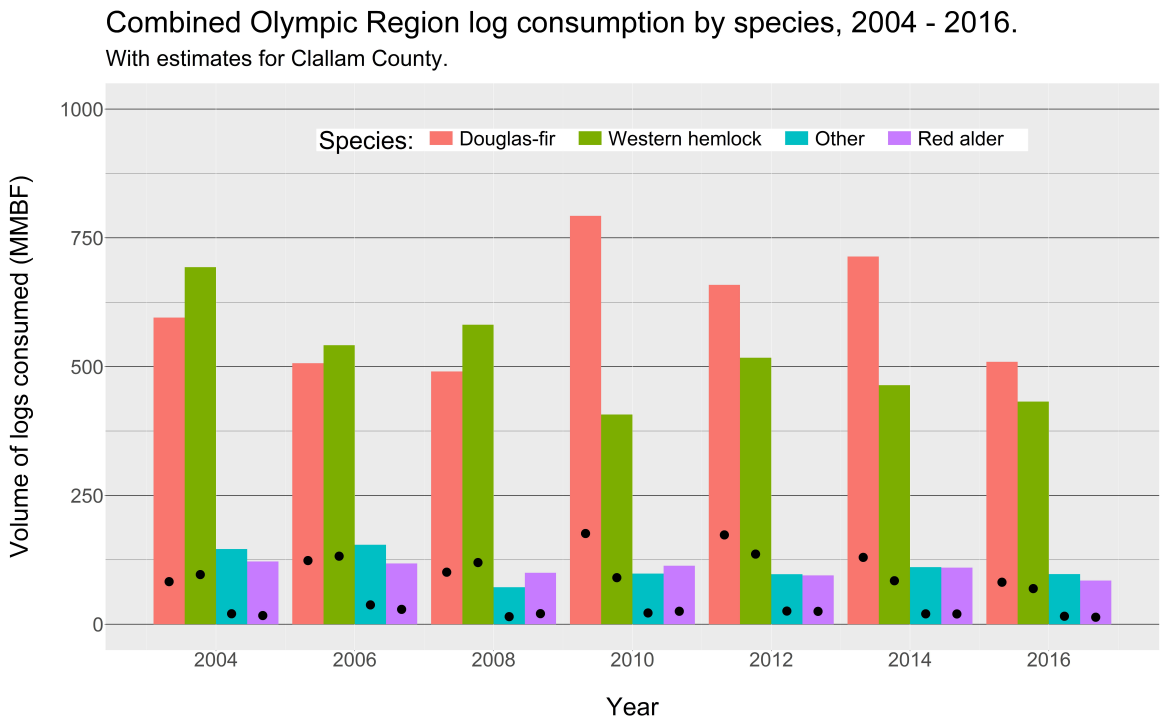

Figure 7: Species represented by bars, Clallam County estimates by points. Category 'Other' includes true firs, spruce, pines, western red-cedar, and other conifers. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

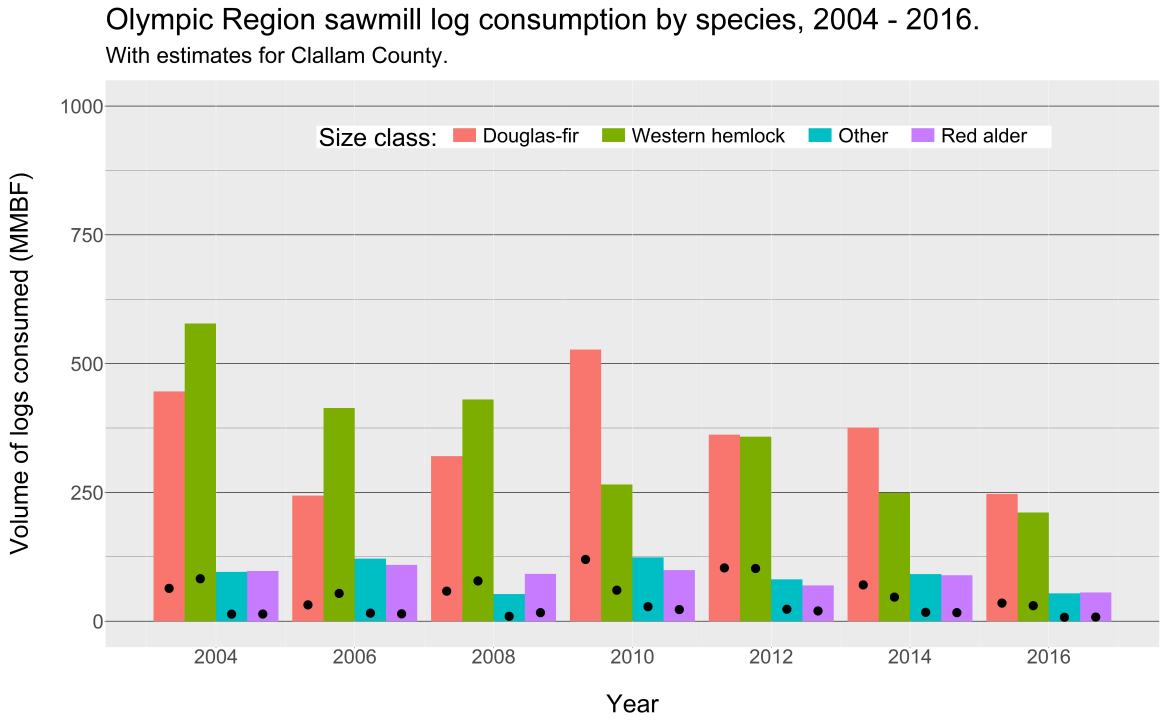

Figure 8: Species represented by bars, Clallam County estimates by points. Category 'Other' includes true firs, spruce, pines, western red-cedar, and other conifers. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

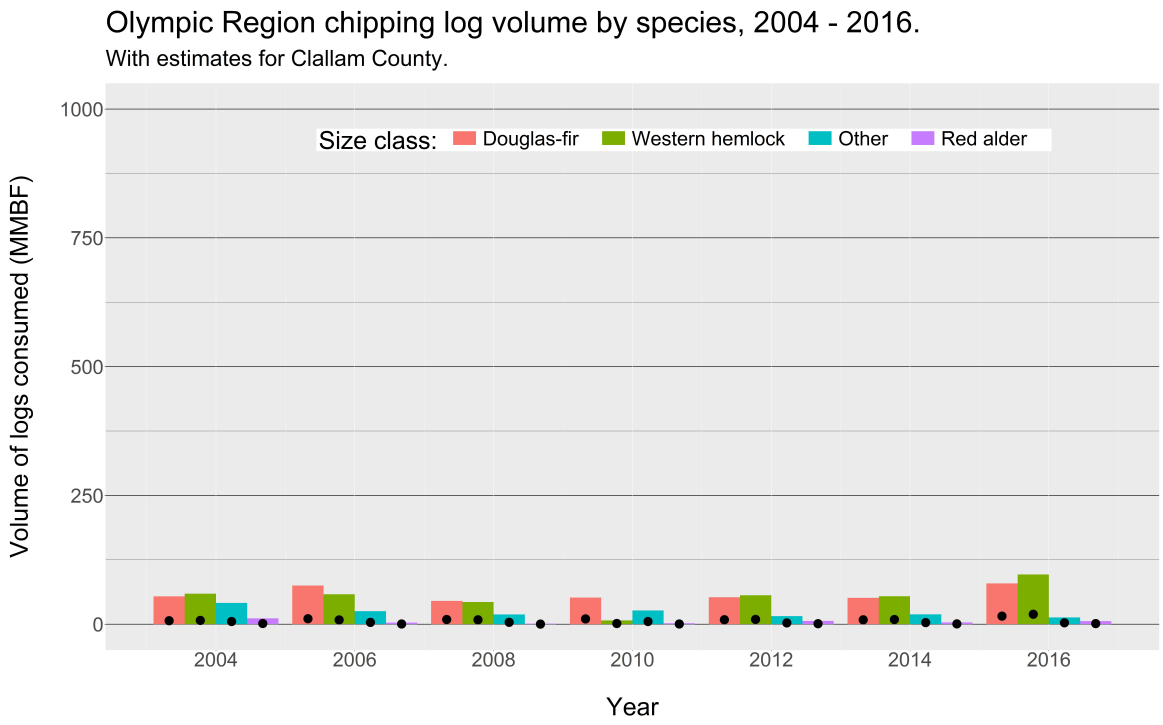

Figure 9: Species represented by bars, Clallam County estimates by points. Category 'Other' includes true firs, spruce, pines, western red-cedar, and other conifers. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

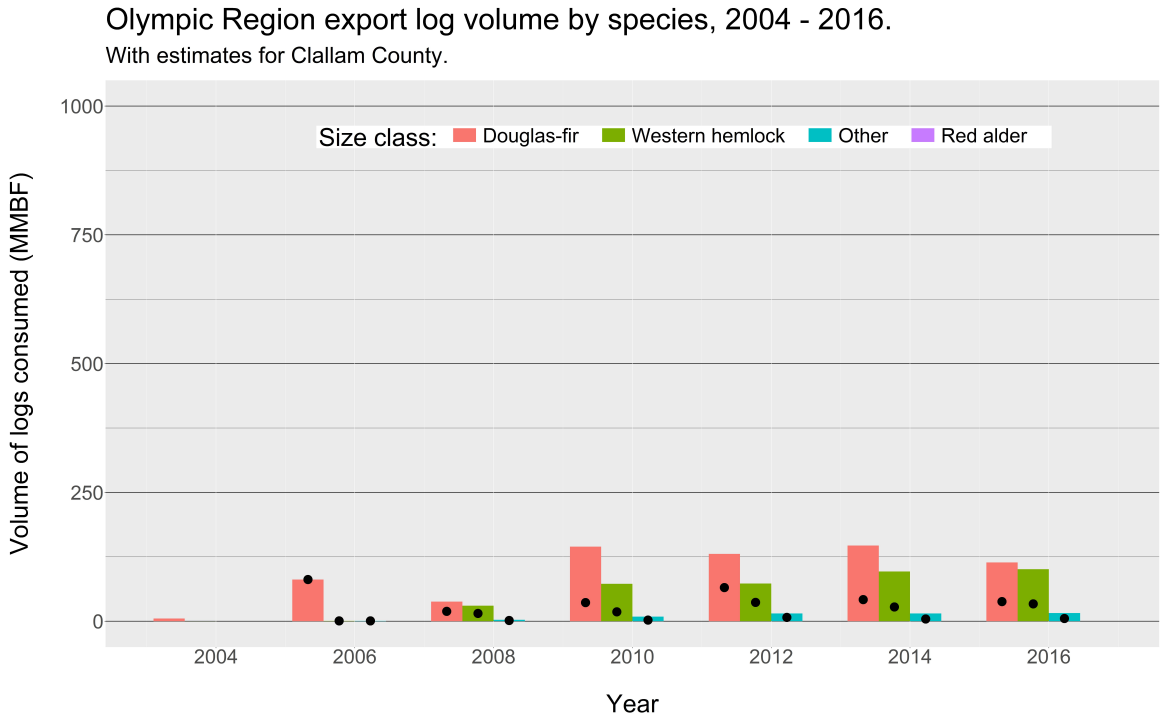

Figure 10: Species represented by bars, Clallam County estimates by points. Category 'Other' includes true firs, spruce, pines, western red-cedar, and other conifers. Data Source: WADNR mill survey; Olympic Region consists of Clallam, Jefferson, Grays Harbor, Mason, Thurston, Lewis, and Pacific counties.

Sort Analysis

Given independent, region-wide demand distributions for both size class and species[5], we can calculate the joint distribution of size and species by industry sector as the product of the two distributions. That is, the demand for a specific size class of a specific species is the sector-specific proportion of that species multiplied by the sector-specific proportion of the size class; the product is then evaluated against the aggregate sector demand.

Primary data for Clallam County's demand by industry sector was not available (and was estimated). However, if the number of operations in Clallam County (for which primary data exists) is proportional to the region - a reasonable assertion given Figure 1, then the joint distribution can be evaluated against aggregate demand in Clallam County that was detailed in Table 8. Below, Table 9 describes the joint distribution of log consumption in Clallam County by sort.

Table 9: Joint distribution of Clallam County log consumption by size class and species.
Average distribution for period 2004-2016.
Volumes reported in millions of board-feet (MMBF).

Species		Douglas-fir	Western hemlock	Red alder	Other	Total
Size class	Proportion	0.453	0.386	0.075	0.086	1.00
< 5"	0.055	4.8	4.1	0.8	0.9	10.7
5" - 10"	0.555	48.7	41.5	8.1	9.2	107.5
11" - 20"	0.342	30	25.6	5	5.7	66.2
>= 21"	0.048	4.2	3.6	0.7	0.8	9.3
TOTAL	1.00	87.7	74.8	14.5	16.7	193.7

Note: Size and species distributions are reflective of region-wide proportions.

Assuming that the consumption patterns in Clallam County are reflective of the Olympic Region, three-quarters of logs consumed come from four sorts: Douglas-fir 5" to 10" logs (25%); Douglas-fir logs 11" to 20" (15%); western hemlock 5" to 10" logs (21%); and western hemlock logs 11" to 20" (13%). Over half the volume of logs consumed is from the 5" to 10" size class.

The disparity of volumes consumed from the four sorts mentioned above suggest significant price competition if these sorts are to be fetched for other uses. We can inform on this further by examining the consumption relative to the total supply in Clallam County. The total volume of logs consumed in Table 8 is the sum of local production, imports from other states, imports from British Columbia, and imports from other counties, less the volumes removed to other counties. It is reasonable to expect that the volumes removed could be fetched at reasonable prices for use locally. Adding back in the volumes removed provide an estimate of the total available log supply.

[5] Independence means that a tree of any particular size may fall equally among any species, with the converse true as well.

Another difference that can be accounted for is that of species distribution for logs consumed versus the species distribution of logs produced. Data is available on the species distribution for timber harvested in Clallam (and Jefferson) counties, which make up most of the supply. Size class distribution data is not available at county-level resolution.

If we express the *saturation* of demand for a particular log sort as as the ratio of consumption to supply, in particular, $Consumption_{\text{size class,species}}/Supply_{\text{size class,species}}$ where the size class distributions for consumption and supply in Clallam County are the same as for the Olympic Region; however, species class distributions for consumption are the same as for Olympic Region, but the supply distributions are informed by harvest in Clallam and Jefferson Counties. The saturation of demand across size classes by species class is presented in Table 10.

Table 10: Saturation of log sort demand - Clallam County consumption as a fraction of available log supply (production plus imports) by size class and species. Average distribution for period 2004-2016.

Species		Douglas-fir	Western hemlock	Red alder	Other	Total
Size class	Proportion	0.247	0.475	0.043	0.235	1.00
< 5"	0.055	1.37	0.61	1.31	0.27	0.75
5" - 10"	0.555	1.38	0.61	1.32	0.27	0.75
11" - 20"	0.342	1.38	0.61	1.32	0.27	0.75
>= 21"	0.048	1.37	0.61	1.31	0.27	0.75
TOTAL	1.00	1.38	0.61	1.31	0.28	0.75

Note: Size class proportions are the same for both consumption and available supply (this is why ratios are the same across size classes within a species group); both reflect region-wide values. However, species distribution is informed by county-level harvest data.

Note the disparity between the proportions of Douglas-fir and western hemlock produced and consumed in Clallam County: the proportion of Douglas-fir is 80% higher than the proportion produced, and the proportion of hemlock consumed is 20% lower than proportion produced. This suggests that much of the volume removed from the county (detailed in Table 8) is hemlock, and most of the volume imported from other counties (or states and British Columbia) is Douglas-fir. Consequently, the demand for Douglas-fir across all size classes in Clallam County is over-saturated, while the demand for western hemlock is under-saturated. Also, the production of other species is nearly triple than the rate of consumption (i.e. under-saturated); this group includes true firs, western redcedar, and lodgepole pine. Demand for the smallest species group, red alder, is fully-saturated relative to rates of production.

Mass Timber Products

The sort-supply analysis suggests that the most abundant supplies of timber are found in small (<5") and large (>21") diameter logs; mid-size log sorts are saturated by demand from sawmilling and export sectors. The expected recovery (by volume) for each sort differs significantly: a conifer sawlog less than 7" will yield less than half its volume in the form of finished lumber, with a third as chips, and the remainder split roughly even between bark, saw dust, and dry shavings[6]; while a log greater than 20" will yield more than 80% of its volume as lumber. Combined with the 16:1 ratio in the quantity of small to large logs, there are barriers to operating efficiently while utilizing dissimilar sorts.

A basic economic truth for manufacturing wood products is that logs' harvest, transportation, and processing costs are underwritten by the value-added products they yield. Timber harvest activities create a supply of residual biomass (i.e. slash) that may remain scattered about the harvest unit or concentrated in piles; both represent an opportunity for consistent supply of low-cost feedstock[7]. Sawmilling also creates a supply of both green and dry residues, including bark, chips, hog fuel, and planer shavings. With of these materials, the sorts identified above, and other inputs (e.g. lumber), there are several manufacturing applications to consider.

The following sections describe manufacturing alternatives presented in order of expected cost of capitalization from highest to lowest[8].

Wood Composite Panels

Wood strands, fibers, and small wood particles are pressed together with glue under extreme heat and pressure to create a composite solid panel[9]. Products may include oriented strand boards (OSB), medium density fiberboard (MDF), and engineered wood siding and trim (EWST). These advanced composites are designed for dimensional stability, protection against decay, and moisture resistance. These properties translate into durability over decades of service life. Within the sorts described in Table 9, feedstock requirements are likely to be met by Douglas-fir, western hemlock, and Other species in the < 5" size class; other feedstock sources may include biomass residuals from manufacturing operations. While

[6] Source: Mason, C.L., Gustafson, R., Calhoun, J., Lippke, B.R., and Raffaeli, N. 2009. Wood to Energy in Washington: Imperatives, Opportunities, and Obstacles to Progress. University of Washington, Seattle. 210p.

[7] for further detail on supply, see: Cross, J.C., E.C. Turnblom, and G.J. Ettl. 2013. Biomass production on the Olympic and Kitsap Peninsulas, Washington: updated logging residue ratios, slash pile volume-to-weight ratios, and supply curves for selected locations. USDA For. Serv. Gen. Tech. Rep. PNW-GTR-872. 30 p.

[8] Personal communications: Don Bender, Weyerhaeuser Professor and Director, Composite Materials & Engineering Center, Washington State University (9 March 2018); Vikram Yadama, Associate Professor, Dept. of Civil & Environmental Engineering, Composite Materials & Engineering Center (11 March 2018).

[9] Personal communications: Don Bender, Weyerhaeuser Professor and Director, Composite Materials & Engineering Center, Washington State University (9 March 2018)

biomass costs are expected to be low, capital costs are expected to be very high due to the need for a hydraulic press system.

Re-capitalizing paper mill to bio-refinery

Bio-refineries convert biomass into fuels, power, heat, process steam, and chemicals. Instantaneous heating of biomass to extreme temperatures may transform up to 80 percent (by weight) of the biomass into bio-oil[10], 10 percent to biochar, and the rest to gasses. By taking advantage of differences in biomass components and intermediates, a bio-refinery might yield one or several low-volume, but high-value, chemical products and a low-value, but high-volume liquid transportation fuel, while generating electricity and process heat for its own use and possibly for sale. Similar to WPC, feedstock requirements are likely to be met by most any species in the < 5" size class; other feedstock sources may include biomass residuals from manufacturing operations. However, due to the number and complexity of chemical processes, capitalization costs are expected to be very high.

Cross laminated timber

Cross laminated timber is an engineered wood product with a manufacturing process similar to plywood: three or more layers of wood adhered together using glue and hydraulic pressure to form a panel, where layers are oriented crosswise to their neighbor(s). Layering, combined with thickness, gives CLT panels strength and stability in multiple dimensions, allowing substitution for concrete, masonry or steel in floor, roof, and wall applications. Where layers of plywood are composed of thin veneers, layers of CLT are composed of planks. Notably, the Engineered Wood Association's (APA) species specification for CLT does not include western hemlock. Panel thickness may range from 3 to 15 inches, width from 12 to 120 inches, and length up to 60 feet. Transportation regulations, rather than manufacturing limitations, may limit CLT panel sizes. Feedstock requirements are likely to be met with Douglas-fir and western hemlock (pending specification) in the 5"-10", 11"-20", and >21" size classes if the facility manufactures lumber; if the facility purchases lumber, expect the usage across these sorts to increase.

There are three phases to the CLT manufacturing process: preparation, remanufacturing, and assembly. Each phase consists of several steps and sub-processes. A manufacturer may or may not be involved in end-user project design and construction: a mill may simply produce CLT panels of varying width, length, and thickness; mills with computer numeric control (CNC) technology can cut panels to precise specifications; and mills may engage in sub-assembly of components and/or volumetric pre-construction of structural elements in

[10] Bio-oil is a brown, free-flowing liquid fuel resulting from the condensation of volatiles during pyrolysis; also known as pyrolysis oil, wood oil, wood distillate, or liquid wood.

coordination with architects and engineers. Capital costs are expected to be high due to the hydraulic press system; engaging in additional phases increases capital requirements.

Structural composite lumber

Structural composite lumber (SCL) is a subset within the family of mass timber products, which includes laminated veneer lumber (LVL), parallel strand lumber (PSL), laminated strand lumber (LSL) and oriented strand lumber (OSL). These products are created by layering dried and graded wood veneers, strands or flakes with moisture resistant adhesive into large blanks that are subsequently resawn into specified sizes. SCL is a solid, highly predictable, and uniform engineered wood product that is sawn to consistent sizes and is virtually free from warping and splitting. Typical uses for SCL include rafters, headers, beams, joists, studs, and columns. Feedstock requirements are likely to be met by conifer species groups in the < 5" size class; depending on the particular application, it may be feasible to utilize pre-commercial thinning residues as a feedstock. SCL requires a hydraulic press system and therefore high capital costs.

Glulam operation

Glulam[11] is composed of individual wood laminations (dimension lumber), selected and positioned based on their performance characteristics, and then bonded together with durable, moisture-resistant adhesives. Where CLT alternates grain direction with each layer, the grain of all glulam layers run parallel with the length of the member. While typically used as beams and columns, designers can use glulam in the plank orientation for floor or roof decking. With the flexibility of glulam manufacturing, glulam 'panels' can be used to create complex curvature and unique geometry. The International Building Code (IBC) recognizes glulam products manufactured in conformance with ANSI Standard A190.1-2012: Standard for Wood Products-Structural Glued Laminated Timber. Similar to CLT, feedstock requirements are likely to be met with Douglas-fir and western hemlock in the 5"-10", 11"-20", and >21" size classes if the facility manufactures lumber; if purchasing lumber, usage across these sorts is likely to increase.

Wood–plastic composites

Wood plastic composites[12] (WPCs, also 'composite lumber') are roughly 50:50 mixtures of thermoplastic polymers and small wood particles. WPC can be manufactured in a variety of colors, shapes and sizes, and with different surface textures. Depending on the processing

[11] Source: http://thinkwood.com
[12] Source: https://ag.tennessee.edu/fwf/Documents/ATaylor/Wood-plastic-composites-primer_PB1779.pdf

method, WPCs can be formed into almost any shape and thus are used for a wide variety of applications, including windows, door frames, interior panels in cars, railings, fences, landscaping timbers, cladding and siding, park benches, molding and furniture. Wood used in WPC manufacturing is in the form of dry particles with a powdery consistency, often called wood flour. In general, the wood waste raw material is in the form of sawdust and/or planer shavings. Wood flour can also be obtained from wood products operations such as sawmills, mill work or window and door manufacturers that produce sawdust as a byproduct. A study conducted by WSU has shown that sawmill residues, including bark, can be successfully utilized to extrude WPCs; additionally, moisture resistance properties were shown to improve with inclusion of bark. In practice, wood species has not been considered to be an important variable; any fiber source that is readily available and inexpensive is generally preferred. Feedstock requirements are likely to be met by most any species in the < 5" size class and residuals from manufacturing operations. This product is extruded rather than being pressed, so capital requirements are not as high, but equipment requirements remain substantial.

Dowel laminated timber

Dowel-laminated timber[13] panels are a next-generation mass timber product commonly used in Europe. Panels are made from softwood lumber boards (2-by-4, 2-by-6, 2-by-8, etc.) stacked like the boards of nail laminated timber (NLT) and friction-fit together with dowels. Typically made from hardwood lumber, the dowels hold each board side-by-side, similar to how nails work in an NLT panel, and the friction fit lends some dimensional stability to the panel. There isn't a prescriptive code path for the use of DLT under the current IBC, and the National Design Specification (NDS) doesn't provide published design values or equations for calculating capacities of wood dowel joints. Consequently, the use of DLT would require approval by a regulating authority on a case-by-case basis. Further research may identify an opportunity to incorporate composite technologies in the dowel manufacturing process. Feedstock requirements are likely to be met with Douglas-fir and western hemlock in the 5"-10", 11"-20", and >21" size classes if the facility manufactures lumber; if the facility purchases lumber, expect the usage across these sorts to increase. With no complex equipment or pressing system requirement, capital expenditures are expected to be lower.

Nail laminated timber

Nail laminated timber[14] is created from individual dimension lumber members (2-by-4, 2-by-6, 2-by-8, etc.), stacked on edge, and fastened with nails or screws to create a larger

[13] Source: http://thinkwood.com
[14] Source: http://thinkwood.com

structural element. NLT has been used for more than a century: most commonly in floors, decks, and roofs. It offers the potential for a variety of textured appearances in exposed applications, and wood structural panels can be added to provide a structural diaphragm. Other applications include elevator and stair shafts in midrise wood-frame buildings. Because panels are comprised of individual boards spanning in a single direction, both singly curved and freeform panels can be created by slightly offsetting and rotating each board relative to the others. Complex geometries of curved roof and canopy structures can be achieved within a simple system.

While an NLT system can be created through on-site carpentry, suppliers may choose to offer prefabrication that has benefits of scale and design complexity. Prefabricated NLT panels typically come in sizes up to 10 feet wide and 60 feet long, and may include preinstalled sheathing. When detailing NLT systems, designers need to account for moisture movement. The IBC recognises NLT and provides guidance for structural and fire design. No product-specific ANSI standard is required, as the structural design of each element is covered by the NDS and applicable grading rules. NLT can be used in all types of combustible construction. Feedstock requirements are likely to be met with Douglas-fir and western hemlock in the 5"-10", 11"-20", and >21" size classes if the facility manufactures lumber; if the facility purchases lumber, expect the usage across these sorts to increase. Neither specialized equipment nor a pressing system is required, lowering capital expenditures.

Wood pellet mill

Pellet mills collect and process biomass into a commoditized solid fuel; applications range from residential and commercial users to large-scale utilities, both foreign and domestic. Feedstocks include nearly all species groups and materials in the <5" size class. Sources include unmerchantable tree branches and tops (i.e. textitslash) that remain in the field after timber harvest operation; bark and hog fuel created by primary processing of logs in a sawmill; to planer shavings created as dried, rough lumber is processed further. Pre-commercial thinning residues may represent a feedstock source if a cost-effective removal method exists. If fed solely by slash, a pellet mill that yields 400,000 bone-dry tons of pellets is expected to require 550 MMBF of timber harvest annually; for context, the 2016 combined timber harvest for all ownerships in Clallam and Grays Harbor counties 525 MMBF MMMBF. Cost of capilatlization are expected to be lower relative to other alternatives.

Recommendations

It may be advantageous to view timber in the Olympic Region generally and in Clallam County specifically as a system; where the major forces acting on that system include access, supply, and demand. In 2016, these forces acted on the system such that the net effect is to reduce the overall supply of logs in Clallam County (Table 8) while redistributing the supplies of Douglas-fir (increasing) and western hemlock (decreasing) relative to their harvest levels (Tables 9, 10).

Consider each manufacturing alternative in terms of its impact on these forces: production facilities with feedstock requirements that may compete with existing industry sectors (e.g. CLT, SCL, DLT, NLT) may be less desireable than those with disjoint feedstock requirements (e.g. WCP, bio-refineries, WPC, pellets). A facility whose inputs may be another's products (e.g. CLT, DLT, NLT) may increase the overall resilence of the system. The supply and demand forces may create an opportunity for creativity and specialization in production. Systems thinking also suggests that more than one alternative may be feasible. A plant that utilizes lumber as its input while yielding a stream of residual biomass increases the supply of feedstock that might be utilized by a facility that scavenges for low-cost biomass (e.g. bio-refinery, WPC, pellets).

All alternatives are impacted by changes in access, which includes public policy and is influenced by forces outside the system. Diversification among products is likely to make the system robust relative to changes in access. Diversity among industry sectors is also likely to have its own influence on access. Per-acre productivity comparisons between ownership types in Clallam County suggest that there are under-utilized resources: USFS produces 10 BF/acre/year (on a base of 199,000 acres); WADNR produces 247 BF/acre/year (on a base of 178,000 acres), and private timberlands yield 400 BF/acre/year (on a base of 347,800 acres). All of these may be compared against a growth benchmark of 600 BF/ac/year.

Additional research may be required to explore, develop, and test products that utilize available and/or potential log supplies in particular manufacturing applications; which, in turn, may require changes in access. Every manufacturing option (along with existing sectors) can benefit from time-series research of Forest Inventory and Analysis (FIA) and/or other permanent-plot forest data to compare current yields across required sorts with expected future yields in the same sorts. That is, to ensure future timber supplies across ownerships align with feedstock requirements, and how any changes might affect location selection today for any given facility.