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Forecasting the demand for Cross Laminated Timber (CLT) in the Pacific Northwest

By: Indroneil Ganguly[1], Todd Beyreuther[2], Matt Hoffman[3], Skip Swenson[4], and Ivan Eastin[1]

1. University of Washington, 2. Washington State University, 3. Heartland Construction, 4. FORTERRA

With the establishment of multiple manufacturing facilities in the Pacific Northwest (PNW) for cross-laminated timber (CLT), it is clear that this region leads the country in CLT manufacturing. It is important to understand the potential demand for CLT in the PNW (broadly defined as including Washington, Oregon, Idaho and Montana) as interest in CLT construction increases. Using an analysis grounded in the risks associated with the adoption of CLT and the projected construction of mid to tall buildings in the Pacific Northwest, this study provides an estimate of the volume of CLT demand in the region through 2035. Also explored are the hybrid uses of CLT and concrete, referred to as 'CLT composite concrete'. The architectural scope of the study targets mid- and high-rise buildings (4+ stories). The conservative demand estimates developed in this study indicate that by 2035 overall demand for CLT panels in 4+ story buildings in the PNW could be 6.6 million cubic feet annually. The cumulative demand for CLT panels in the PNW is estimated to be 56 million cubic feet between 2016 and 2035. Our study results suggest that a significant component of the projected demand for CLT panels in the PNW will be for 4-7 story multifamily residential and commercial buildings.

Installation of CLT panels. *Photo credit: LEVER Architecture*

Background

Mass timber, a collective term for a family of engineered wood products, is an emerging building system in North America that offers a variety of benefits. Cross-laminated timber (CLT), an innovative mass timber product, has been gaining popularity in mid to high-rise residential and non-residential construction in several countries, including Europe and Canada. CLT panels are typically comprised of an odd number of layers of kiln-dried boards (in general three, five, seven or more), with adjacent layers oriented perpendicular to each other and quasi rigidly connected by adhesive bonding, Figure 1.

Relatively new in the US, CLT is a cost competitive wood-based building system that substitutes for concrete, masonry and steel in many end-use applications. The flexibility of CLT allows for its use in walls, floors and other large-sized load-bearing structural components. Construction applications of CLT include vertical walls, horizontal floors and roof diaphragms. However, the combination of building code restrictions and limited commercial production capacity makes it difficult for architects, designers and builders to specify CLT over more readily available building materials.

Originally developed in Europe in the 1990s and used increasingly around the world, CLT production has been slow to gain traction in the US. Currently there are only two CLT mills operating in the US, both in the PNW region. Nonetheless, growing interest in CLT among construction professionals (especially architects and designers), along with the approval of CLT construction in the 2015 International Building Code, should help to encourage the expanded use of CLT panels.

Study Objectives

The objectives of this project were to: 1) develop an end-use specific demand forecast model for CLT panels in the PNW region and 2) provide an estimate of the volume of CLT that could be used in medium/tall buildings in the PNW region. The demand forecast model was designed to factor in the 'risk/hurdles' to CLT adoption within specific end-use applications and estimate the market demand for various thicknesses of CLT panels (3, 5, 7 and 9 ply panels) based on building loads and end-use applications. The specific end-use applications considered in this paper included vertical walls, horizontal floors and roof diaphragm systems.

Study Methodology and Parameters

To estimate the demand for CLT in the PNW region, this study utilized a combination of three models, (i) a construction projection model, (ii) a CLT utilization model, and (iii) a CLT innovation diffusion model (each model is discussed in more detail below). The 'construction projection model' utilized two established databases, CoStar and the Northwest Power and Conservation Council's (NWPCC) 7th Power Plan, to develop a regional forecast of relevant building construction projects through 2035.

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Director's Notes

University of Washington
School of Environmental & Forest Sciences
Box 352100
Seattle, Washington
98195-2100
Phone: 206-543-8684
Fax: 206-685-0790
www.cintrafor.org

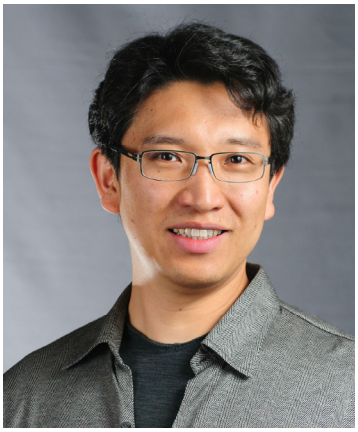
The Center for International Trade in Forest Products addresses opportunities and problems related to the international trade of wood and fiber products. Emphasizing forest economics and policy impacts, international marketing, technology developments, and value-added forest products, CINTRAFOR's work results in a variety of publications, professional gatherings, and consultations with public policy makers, industry representatives, and community members.

Located in the Pacific Northwest, CINTRAFOR is administered through the School of Environmental & Forest Sciences at the University of Washington under the guidance of an Executive Board representing both large and small companies, agencies, and academics. It is supported by state, federal, and private grants. The Center's interdisciplinary research is carried out by university faculty and graduate students, internal staff, and through cooperative arrangements with professional groups and individuals.

An interesting thing happened in the first half of 2017, despite the current Administration's continued assaults on free trade. For the first time in three years, US exports of wood products showed positive growth over the first half of the year (+5.8%). It seems that the forest products industry is paying little attention to all the anti-trade rhetoric issuing forth from Washington DC, preferring to move forward with finding new markets and expanding existing markets for their products overseas. Recent trade data show that export growth was strong across all of the major wood product categories in the first half of 2017, with lumber exports up by 12.6%, log exports up by 10.9%, exports of builder's joinery up by 1% and plywood exports up by 21%. US exporters enjoyed their greatest success in China where exports jumped by 25.5% in the first half of 2017. This success was largely due to a government policy that eliminated all commercial logging activities within state-owned forests in China. US wood exports to Vietnam also surged in the first half of 2017, partly in response to raw material shortages, as well as efforts by Vietnamese furniture and flooring manufacturers to comply with timber legality regulations that have been adopted in the US, the EU and Australia. Finally, a joint collaboration between CINTRAFOR and the Softwood Export Council, with funding support from the USDA Foreign Agricultural Service's Emerging Markets Program, has been looking at identifying export opportunities in new, emerging markets, including Vietnam, Thailand, Indonesia, Malaysia, India, Pakistan and the Philippines. The results of these efforts should help to support expanded exports of US wood products into these new markets and provide new opportunities for US wood exporters in the future.

Transitions

Dr. Daisuke Sasatani left CINTRAFOR in August to take a position as an Agricultural Specialist with the US Department of Agriculture Foreign Agricultural Service in the US Embassy in Tokyo. Daisuke joined CINTRAFOR as a doctoral student in 2004. Following his graduation, he left Seattle to take a positon at Auburn University in Alabama as a post-doctoral research fellow focused on international trade and competitiveness issues. After a year at AU, we successfully recruited Daisuke back to CINTRAFOR where he has been working to help implement CINTRAFOR's Japan research program. Most notably, Daisuke was instrumental in gaining the acceptance of US Douglas-fir as a "domestic wood species" in Japan under the Wood Use Points Program. While we are sorry to see Daisuke leave CINTRAFOR, we are excited to continue working with him in his new role as an advocate for US wood products in Japan.



Dr. Ivan Eastin also left CINTRAFOR at the end of August to take up a faculty position as a Research Professor in the School of Environment and Sustainability at the University of Michigan. Ivan began his affiliation with CINTRAFOR in 1987 as a doctoral student. Upon graduation in 1992, he joined CINTRAFOR as an assistant professor in forest products marketing and trade. In 1997 he was appointed the Associate Director of CINTRAFOR and he has been the Director of CINTRAFOR since 2004. As Director of CINTRAFOR, Ivan has worked with forest products companies in the PNW region to support the development of innovative new wood products, including bio-jet fuel from woody biomass and forest residuals, the thermal modification of low value timber species such as western hemlock and the introduction and diffusion of cross laminated timber in commercial construction. In recognition of his innovation research, Ivan was appointed a UW Presidential Innovation Fellow in 2015. Ivan has also served as the Associate Dean for Research in the College of the Environment since 2015.

Trade Trends

US total wood exports grew by almost 6% over the first half of 2016 and are projected to reach $9.2 billion by the end of 2017, Table 1. US wood exports experienced their largest increases to China (+25.8%) and Vietnam (+20%) where supply constraints in both countries helped drive demand for US exports. In contrast, US wood exports declined substantially to Canada (-6%), the UK (-3.6%) and Japan (-5.1%). The majority of US wood exports were lumber (37.1%) and logs (24%), both of which showed strong growth in the first half of 2017 (up 12.6% and 10.9%, respectively). Plywood also displayed strong growth in the first half of 2017 (+21%), while chips and pellets exports were down by 1.8%, Table 2. Washington state remained the largest exporter of wood products (with 14.5% of total US wood exports), followed by Pennsylvania, California, and Oregon, Table 3. Taken together, the three west coast states represented 26.6% of US wood exports in the first half of 2017. However, it should be noted that the PNW region has seen its share of US wood exports decline substantially between 2011 and 2017, falling from 35.9% to 26%, respectively. Most of this decline occurred in Washington State where the export share declined from 21.7% to 14.5%. Softwood lumber exports increased by 7.4% in the first half of 2017, with large increases to China (+10.1%) and Mexico (+10.9%), while exports to Japan dropped by 13.7%, Table 4. Finally, softwood log exports increased by 7.3% in the first half of 2017 and were up by 16.4% to China and by 45% to S. Korea. In contrast, softwood log exports were down to Japan (-6.8%) and Canada (-2.4%), Table 5.

Trade Trends is a new service for our readers where we provide a summary of the most up-to-date trade data. Please let us know if this information has been useful or if there is other trade data that you would be interested in seeing.

Table 1. Value of US Total Wood Exports, by Destination, 2010-2017 (thru June) *Source: Global Trade Atlas*

	2010	2011	2012	2013	2014	2015	2016	June 2017
World total	***$6,785,568,573***	***$7,593,359,285***	***$7,608,457,938***	***$8,680,347,195***	***$9,463,814,275***	***$8,667,622,338***	***$8,752,070,932***	***5.58%***
China	$1,162,660,922	$1,915,350,285	$1,640,263,620	$2,344,302,708	$2,660,090,631	$2,065,670,969	$2,543,278,986	25.48%
Canada	$2,101,831,525	$2,117,371,307	$2,186,601,990	$2,227,215,045	$2,270,658,571	$2,100,439,586	$1,987,885,854	-5.92%
UK	$212,034,509	$211,649,981	$306,343,200	$431,013,355	$638,043,700	$839,867,038	$749,428,664	-3.57%
Japan	$633,666,682	$734,240,780	$729,583,491	$850,194,163	$813,359,290	$725,719,269	$694,526,151	-5.12%
Mexico	$481,728,646	$513,768,108	$582,340,481	$604,176,008	$656,015,575	$694,648,808	$692,359,399	1.98%
Vietnam	$156,023,712	$150,000,582	$187,340,989	$210,987,031	$254,832,918	$221,369,361	$215,591,785	19.95%
Australia	$86,847,808	$111,185,282	$110,239,584	$98,475,532	$112,542,444	$112,307,236	$116,531,028	6.42%
Korea South	$202,760,908	$206,307,255	$163,788,176	$193,635,537	$191,093,367	$129,555,052	$111,215,857	10.39%
Italy	$187,857,949	$161,183,822	$112,891,018	$159,852,256	$168,538,224	$152,236,733	$97,741,252	-24.71%
Germany	$148,663,777	$134,603,657	$123,163,320	$105,967,325	$110,242,363	$98,057,422	$95,336,300	-11.14%
Turkey	$53,722,320	$72,205,420	$100,667,226	$77,981,182	$99,546,013	$124,871,564	$94,316,487	-25.55%
Spain	$87,226,118	$72,503,848	$54,564,623	$52,818,038	$71,417,837	$90,524,943	$91,864,693	-10.69%
Dominican Rep.	$54,788,022	$49,095,176	$49,988,580	$67,353,887	$73,181,711	$77,087,625	$80,979,600	-7.33%
Bahamas	$42,116,934	$42,472,599	$51,516,776	$61,329,716	$58,381,731	$54,781,525	$62,864,012	31.36%
Taiwan	$70,043,062	$73,279,372	$75,531,296	$83,971,127	$85,524,729	$65,414,050	$61,591,230	-2.13%
Belgium	$52,117,345	$36,427,060	$84,363,933	$79,955,101	$75,463,159	$106,726,935	$60,616,988	15.56%
Pakistan	$11,711,235	$17,109,880	$24,722,793	$30,251,207	$37,739,878	$48,560,223	$51,872,395	18.09%
Hong Kong	$70,625,791	$40,326,210	$38,740,941	$39,592,334	$40,253,009	$36,607,381	$50,771,802	-13.17%
Indonesia	$50,155,223	$52,973,620	$51,693,309	$50,631,753	$49,003,512	$46,214,245	$50,093,677	-6.35%
Ireland	$17,951,234	$15,229,232	$18,248,274	$19,549,605	$26,396,954	$34,363,333	$44,584,834	2.97%
France	$33,877,417	$28,658,698	$24,974,316	$28,555,557	$28,611,310	$38,326,996	$41,414,923	-26.89%

Table 2. Value of Total US Wood Exports by Commodity, 2010-2017 (thru June) *Source: Global Trade Atlas*

	2010	2011	2012	2013	2014	2015	2016	June 2017
Total	***$6,785,568,573***	***$7,593,359,285***	***$7,608,457,938***	***$8,680,347,195***	***$9,463,814,275***	***$8,667,622,338***	***$8,752,070,932***	***5.58%***
Lumber	$2,165,485,033	$2,480,049,110	$2,556,420,960	$3,012,709,159	$3,462,004,183	$3,043,408,527	$3,242,750,386	12.63%
Logs	$1,873,611,190	$2,230,656,256	$1,986,667,141	$2,432,204,552	$2,515,732,140	$2,030,137,598	$2,097,010,178	10.86%
Chips/Pellets	$351,212,639	$366,710,200	$525,799,984	$644,079,328	$831,253,768	$1,028,748,820	$895,395,997	-1.82%
Builders' Joinery	$417,081,080	$430,891,936	$432,453,365	$446,645,711	$461,048,132	$412,231,982	$372,684,709	0.77%
Plywood	$351,538,726	$347,237,486	$379,997,078	$398,941,431	$377,642,573	$317,942,199	$316,303,714	20.98%
Veneer Sheets	$316,571,659	$305,640,394	$304,448,068	$309,607,107	$315,378,145	$304,254,790	$299,273,769	-5.00%
Moulding/Millwork	$243,644,622	$281,961,982	$298,125,688	$298,634,039	$301,324,798	$294,511,465	$296,717,190	-21.21%
Casks/Barrels	$113,185,542	$109,759,549	$123,609,898	$139,908,266	$184,353,417	$223,274,838	$202,740,523	8.69%
Fiberboard	$242,570,626	$243,617,289	$261,020,225	$245,326,269	$227,103,639	$202,482,137	$193,580,257	-3.72%
Other Wood, Nesoi	$200,212,972	$249,452,891	$194,471,537	$189,415,349	$195,001,454	$173,207,590	$159,526,839	-16.19%
Particle Board	$150,196,548	$159,082,362	$166,268,133	$183,964,079	$189,407,784	$171,752,446	$159,008,248	-9.58%
Railway Sleepers	$88,990,579	$130,396,972	$123,820,969	$115,410,467	$142,741,450	$168,779,926	$156,339,810	-17.29%
Pallets, Etc	$134,580,684	$137,499,706	$128,860,645	$138,806,811	$131,613,709	$133,064,970	$132,140,849	-19.03%
Wood Marquetry	$28,084,823	$30,137,826	$32,266,227	$30,695,242	$30,058,821	$48,595,323	$111,266,635	-15.31%
Tools/Tool Handles	$49,175,360	$27,436,402	$32,761,101	$29,135,416	$27,390,211	$39,344,899	$43,866,673	11.88%
Table/Kitchenware	$11,710,919	$13,700,498	$14,374,736	$18,161,709	$21,034,802	$23,409,665	$24,336,348	-26.76%
Wooden Frames	$18,449,824	$20,009,468	$18,562,664	$17,520,874	$18,684,949	$22,932,891	$16,238,020	-4.20%
Wood Charcoal	$9,755,214	$10,867,527	$11,325,025	$14,957,977	$15,606,653	$11,500,195	$12,882,037	-14.41%
Wood Wool	$9,894,964	$10,008,428	$8,276,352	$7,216,845	$7,736,570	$8,576,558	$8,651,399	-28.01%
Densified Wd Blocks	$4,829,808	$4,258,016	$5,383,089	$4,103,018	$3,198,175	$4,722,847	$8,244,101	9.38%
Split Poles/Stakes	$4,785,761	$3,984,987	$3,545,053	$2,903,546	$5,498,902	$4,742,672	$3,113,250	-57.23%

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Table 3. Value of Total US Wood Exports, By State, 2010-2016. *Source: Global Trade Atlas*

	2010	2011	2012	2013	2014	2015	2016	June 2017	Share
Total	***$7,076,308,910***	***$7,914,476,070***	***$7,890,641,014***	***$8,963,166,683***	***$9,744,606,733***	***$8,927,937,190***	***9,018,769,304***	***5.07%***	
WA	$1,302,386,562	$1,716,824,587	$1,427,800,271	$1,918,919,661	$1,800,607,201	$1,314,431,907	$1,311,586,995	-3.24%	14.5%
PA	$350,302,250	$335,470,568	$361,582,608	$427,108,415	$515,637,739	$525,222,895	$618,651,915	7.88%	6.9%
GA	$222,347,403	$270,894,757	$381,422,742	$403,557,594	$505,888,167	$554,820,094	$434,082,408	19.96%	4.8%
CA	$353,151,744	$452,662,325	$439,371,483	$507,965,475	$554,662,255	$560,967,360	$562,440,952	-9.42%	6.2%
NC	$365,382,157	$407,873,468	$395,878,371	$414,808,765	$508,820,421	$425,010,573	$404,090,880	15.33%	4.5%
OR	$493,354,339	$671,406,467	$621,474,094	$659,194,979	$635,920,537	$511,067,880	$470,542,251	0.59%	5.2%
NY	$325,870,378	$290,836,475	$308,748,908	$381,050,330	$414,207,158	$362,985,018	$399,883,261	2.78%	4.4%
VA	$251,002,337	$247,933,066	$289,233,202	$343,885,160	$439,923,539	$426,931,184	$394,605,540	3.48%	4.4%
FL	$293,606,934	$234,765,729	$271,815,789	$324,381,035	$334,522,656	$326,466,879	$365,420,924	23.62%	4.1%
OH	$242,655,672	$252,858,140	$245,789,359	$251,294,198	$313,900,083	$284,894,731	$308,408,677	10.58%	3.4%
TX	$186,991,599	$207,141,976	$200,179,691	$206,890,150	$240,557,983	$266,948,126	$349,581,270	23.26%	3.9%
KY	$116,563,521	$115,911,220	$137,468,478	$170,342,802	$234,899,682	$263,471,399	$254,583,879	29.24%	2.8%
AL	$219,036,778	$216,415,041	$208,945,258	$282,527,058	$329,362,015	$311,083,827	$314,519,916	-3.59%	3.5%
TN	$174,928,475	$224,458,073	$225,194,317	$240,381,209	$301,521,049	$245,679,718	$261,739,533	6.49%	2.9%
WI	$184,203,645	$208,833,474	$200,678,297	$209,467,548	$208,290,334	$207,018,173	$224,981,742	8.80%	2.5%
MO	$102,631,671	$121,384,787	$122,293,170	$128,635,841	$169,687,813	$175,620,011	$169,967,076	14.22%	1.9%
WV	$85,709,125	$76,367,952	$89,756,770	$86,667,342	$134,865,022	$133,384,175	$159,273,586	28.23%	1.8%
ME	$221,465,059	$206,045,710	$235,454,925	$278,836,531	$276,605,702	$278,360,867	$209,743,116	-17.87%	2.3%
IN	$160,160,451	$150,116,499	$154,664,285	$169,475,111	$194,299,885	$180,919,300	$190,634,921	-3.61%	2.1%
MI	$147,053,409	$138,288,981	$154,239,403	$159,933,506	$174,960,040	$175,126,128	$173,583,720	3.70%	1.9%

Table 4. Value of US Softwood Lumber Exports, by Destination, 2010-2017 (thru June). *Source: Global Trade Atlas*

	2010	2011	2012	2013	2014	2015	2016	June 2017
Total Lumber	***$2,165,485,033***	***$2,480,049,110***	***$2,556,420,960***	***$3,012,709,159***	***$3,462,004,183***	***$3,043,408,527***	***$3,242,750,386***	12.63%
HW Lumber	*$1,322,010,118*	*$1,443,468,767*	*$1,593,369,005*	*$1,858,639,452*	*$2,335,897,156*	*$2,059,583,898*	*$2,262,255,223*	16.88%
SW Lumber	*$843,474,915*	*$1,036,580,343*	*$963,051,955*	*$1,154,069,707*	*$1,126,107,027*	*$983,824,629*	*$980,495,163*	7.37%
China	$100,556,884	$246,214,829	$140,419,748	$222,021,146	$203,679,501	$157,472,033	$188,133,426	10.09%
Canada	$188,639,971	$183,433,646	$202,828,432	$219,721,746	$212,556,891	$178,835,984	$177,987,238	2.34%
Mexico	$112,184,869	$127,118,094	$152,210,907	$162,729,063	$169,753,612	$173,262,781	$177,561,811	10.93%
Japan	$136,023,091	$156,368,019	$146,200,007	$178,654,256	$129,118,852	$114,073,147	$94,679,129	-13.68%
Dominican Rep.	$37,514,399	$31,159,257	$31,990,139	$43,627,134	$44,990,410	$51,163,641	$54,151,988	0.46%
Pakistan	$5,340,794	$10,308,584	$12,150,132	$17,198,512	$22,947,757	$30,971,573	$31,181,720	22.75%
Jamaica	$18,782,060	$21,183,967	$19,915,943	$27,492,264	$25,478,906	$21,384,502	$25,547,500	-6.13%
Taiwan	$31,194,287	$36,967,858	$33,001,704	$45,121,120	$46,736,841	$29,186,542	$20,885,915	-11.60%
Bahamas	$7,818,211	$6,442,592	$10,642,362	$13,766,330	$16,523,055	$16,274,152	$19,697,823	37.33%
Haiti	$22,633,952	$19,942,633	$11,226,690	$16,850,720	$12,761,359	$14,716,297	$18,736,287	63.22%
Indonesia	$13,384,273	$16,174,910	$14,699,016	$18,088,598	$14,953,518	$8,811,933	$12,384,365	-28.27%
India	$2,513,753	$15,126,283	$12,076,712	$7,329,142	$12,391,234	$12,477,819	$9,465,482	92.75%
Philippines	$24,883,269	$19,980,685	$19,687,550	$23,371,943	$21,511,386	$10,522,723	$8,223,095	147.53%
Vietnam	$6,696,825	$4,238,770	$6,246,380	$7,757,531	$8,805,751	$6,540,482	$5,898,891	82.34%
SW Lumber Ratio	**38.95%**	**41.80%**	**37.67%**	**38.31%**	**32.53%**	**32.33%**	**30.24%**	

Table 5. Value of US Softwood Log Exports, by Destination, 2010-2017 (thru June) *Source: Global Trade Atlas*

	2010	2011	2012	2013	2014	2015	2016	June 2017
Total Logs	***$1,873,611,190***	***$2,230,656,256***	***$1,986,667,141***	***$2,432,204,552***	***$2,515,732,140***	***$2,030,137,598***	***$2,097,010,178***	**10.86%**
HW Logs	*$769,898,246*	*$689,513,884*	*$678,937,603*	*$671,065,077*	*$801,182,912*	*$772,129,179*	*$830,104,609*	11.50%
SW Logs	*$1,103,712,944*	*$1,541,142,372*	*$1,307,729,538*	*$1,761,139,475*	*$1,714,549,228*	*$1,258,008,419*	*$1,266,905,569*	7.30%
China	$414,823,625	$824,049,827	$568,160,969	$858,010,392	$865,741,721	$521,973,638	$618,088,301	16.45%
Japan	$296,479,827	$336,992,180	$350,100,171	$454,755,151	$424,129,319	$360,837,289	$359,546,505	-6.79%
Canada	$182,421,320	$180,536,472	$188,803,530	$209,925,317	$187,845,232	$202,682,925	$167,731,780	-2.41%
S. Korea	$146,073,830	$147,180,385	$109,255,692	$127,038,662	$100,042,746	$55,505,482	$53,064,787	45.37%
Italy	$3,692,415	$1,891,350	$4,145,491	$28,642,031	$34,625,096	$52,521,318	$11,685,028	-98.84%
India	$1,784,022	$4,738,670	$11,624,920	$23,520,148	$27,979,523	$11,448,518	$8,477,044	27.78%
Pakistan	$890,478	$209,319	$922,839	$1,966,669	$2,471,277	$3,127,982	$6,029,923	11.09%
Vietnam	$3,846,927	$2,853,609	$3,477,813	$5,656,022	$6,409,710	$4,463,624	$5,522,475	300.43%
Taiwan	$307,031	$14,127	$647,580	$438,964	$751,525	$1,087,111	$5,309,071	-16.32%
Bangladesh	$307,031	$14,127	$647,580	$438,964	$751,525	$1,087,111	$5,309,071	31.33%
Mexico	$2,824,526	$3,946,327	$7,428,901	$3,217,269	$3,606,711	$5,161,001	$2,128,583	-32.64%
SW Log Ratio	**58.91%**	**69.09%**	**65.83%**	**72.41%**	**68.15%**	**61.97%**	**60.41%**	

CLT in PNW continued from page 1

The 'CLT utilization model' estimated the volume of CLT that could be used in various end-use applications in the different types of construction, assuming no constraints (e.g., CLT use was accepted by local building codes). Finally, the 'CLT innovation diffusion model' estimated the volume of CLT used in the new construction, after factoring in the characteristics of the market and the relative market constraints. The construction types modeled in the study included mid-high rise multifamily residential buildings (4+ stories) and mid-high rise commercial buildings (4+ stories and at least 50,000 sq. ft.). The demand estimation considered a twenty year timeframe (2016-2035).

The construction projection for the PNW region was modeled using two databases, (i) CoStar and (ii) the Northwest Power and Conservation Council's' (NWPCC) 7th Power Plan. CoStar is a privately held, subscription-based third party data provider that captures over 4.5 million commercial properties, including office, industrial, retail, mixed-use, hospitality, and multifamily. The CoStar dataset includes the age of construction, building height, and total unit count for multi-family and total rentable square footage for all commercial buildings. The Northwest Power and Conservation Council (NWPCC) was established to coordinate between the regional power generation goals and ecological conservation objectives to develop 'Power Plans'. These Power Plans are developed every five years and the 7th Power Plan was adopted in February, 2016. Using historic development cycle trends, the floor area of new construction of multi-family buildings, by building height, was estimated using the CoStar data and historic demographic and construction trends.

The ***CLT utilization model*** estimates the potential CLT demand (in volume) based on the floor area estimates derived from the construction projection model. The project team established baseline structures for two building types (i.e., multifamily and office) and applied applicable building codes and zoning regulations for low-, mid-, and high-rise buildings (4+ stories) in the PNW region. Using secondary data and expert opinion, the model developed CLT baseline building (utilization) models for 4+ stories buildings types (multi-family and commercial) based on the following considerations: 1) the structural, acoustic, and fire performance of CLT; 2) the speed and cost of CLT construction; and 3) the potential of CLT to enter underserved markets.

The ***CLT innovation diffusion model*** is based on a repeat purchase diffusion model for structural wood products within each specific end-use market. The CLT applications for this study were divided into two major applications, diaphragms (horizontal floor and roof applications) and walls (vertical applications). For floor/roof applications, CLT use was divided into bare section (3 or 5 ply) and composite concrete section (5-ply). For wall applications, CLT use was divided into bare sections (3, 5, 7 and 9-ply), and wood composite section (6 and 10-ply). To estimate application/material specific market penetration levels, adoption risks associated with (1) building codes and standards adoption and jurisdiction acceptance, (2) technical design and engineering, and the (3) manufacturing and construction cost of adoption, were considered.

Results

Pacific Northwest Multifamily Building Projections

Over the past 20 years, multifamily development has seen strong growth in the PNW region. Between 1996 and 2015 a total of 122.8 million square feet of new multifamily construction was completed at a compound annual growth rate (CAGR) of 6.5%. In 1996 approximately 62% of the total multifamily building area was in buildings between 4 and 5 stories, 13% was in buildings between 6 and 7 stories, 20% was in buildings between 8 and 16 stories, and 5% were in buildings over 16 stories. By 2015 this distribution had shifted and only 48% of the square footage was in buildings between 4 and 5 stories and 26%, 14% and 12% in 6-7, 8-16, and 17+ story buildings, respectively.

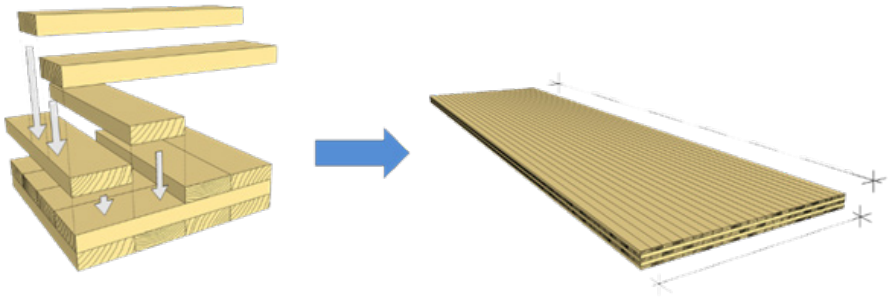

Figure 1. CLT Panels (Source: Gavin White, Ramboll UK, 2015)

Based on the 20-year moderate growth outlook derived from the construction projection, we estimate that a total of approximately 193 million sq. ft. of new multi-family construction will be built between 2016 and 2035 across the PNW region, Figure 2. The model results show that there is substantial variability in the amount of floor area built annually and within the four different building height categories. However, the model results suggest that there appears to be a trend towards taller buildings overall, particularly in the 17+ story category. Over the 20 year period, the largest share (42%) of new construction floor area will be from tall buildings (+17 stories) followed by 6-7 story buildings (29%), 8-16 story buildings (21%) and 4-5 story buildings (9%). This is a significant change from the distribution observed in 1996.

Pacific Northwest Office Building Projections

The construction estimates for the number and size of new office buildings that could be built between 2016 and 2035 were based on the NWPCC 7th Power Plan for the PNW region. The focus for the office building estimates were "large" office buildings that are at least 50,000 square feet in area. The construction estimates in this sector show much less variability in both height and the total amount of floor area that could be built relative to the multi-family sector. Figure 3 shows the forecasted growth estimates through 2035 based on the moderate growth scenario.

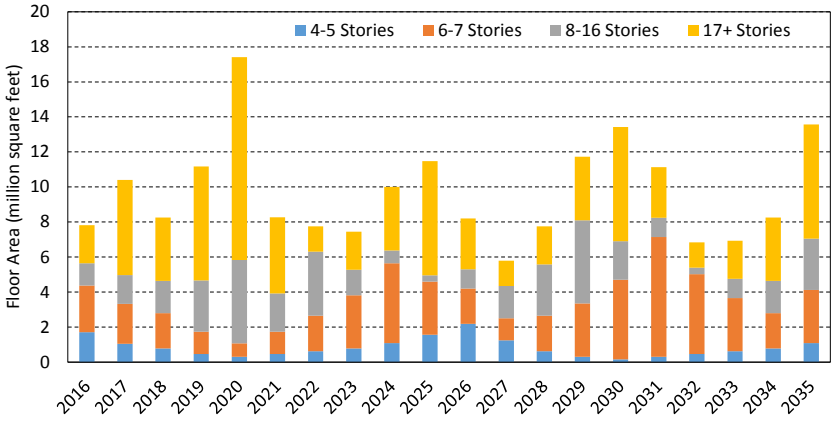

Figure 2: Annual projections of multi-family building floor area by building height.

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CLT in PNW continued from page 5

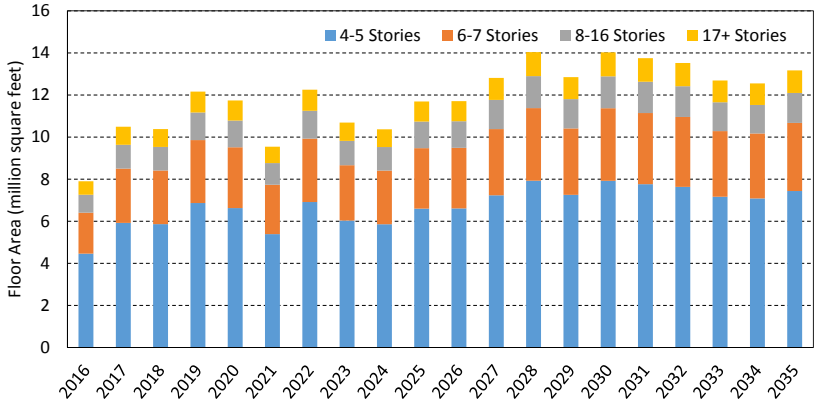

Figure 3: Annual projections of large office building floor area by building height.

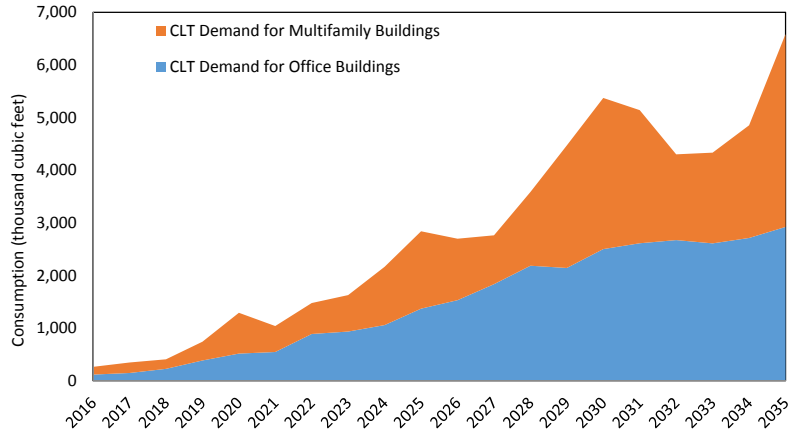

Figure 4: CLT adoption diffusion forecast by building type.

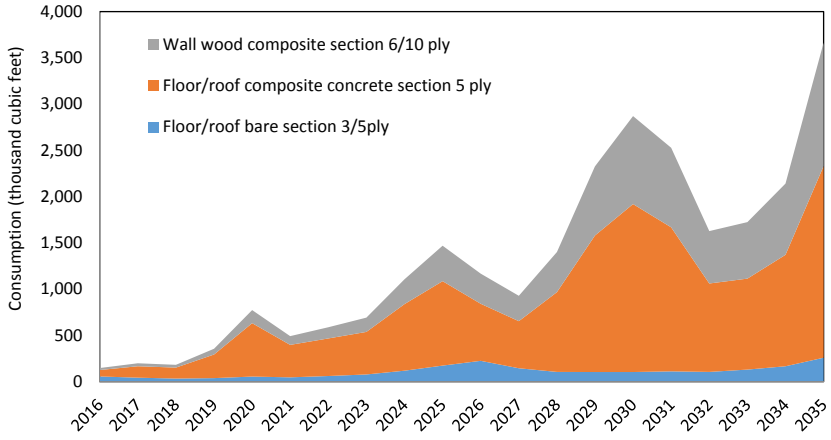

Figure 5: CLT adoption diffusion forecast, by end-use application, in multi-family buildings.

Between 1996 and 2015 the supply of office buildings over 50,000 square feet in area that were built in the PNW region increased by 216%, from 2.3 million to 7.2 million sq. ft. The construction projection model results estimate that the supply of office buildings will increase by 3.4% annually under the moderate growth scenario between 2016 and 2035. The rate of growth in this sector is slower than in the multi-family sector and is based on a larger office building footprint than in 2016. During this period, we estimate that a total of approximately 238 million square feet of new office space will be built under the moderate growth scenario. The majority of the new office space will be in shorter (4-5 story) buildings (56%), followed by 6-7 story buildings (25%) and 8-16 story buildings (11%). Only a small share of the office market will be in very tall (+17 story) buildings (8%).

Market Diffusion of CLT in the Pacific Northwest Region

Market diffusion refers to the speed with which a new product is adopted within a market. In contrast to consumer products, where rapid market adoption often occurs, building regulations and building codes can slow down the adoption of new construction materials and technologies substantially. In addition, the rate of adoption and diffusion for a new product can be influenced by previous generations of similar products. For example, while the adoption and diffusion of plywood within the US construction industry took several decades, it set the stage for the much more rapid adoption of oriented strandboard based on the similar performance and end-use applications of these two structural panel products.

When developing an innovation diffusion model, the first year of the introduction of the product into the market, generally termed 'Year 0', is of critical importance. Though CLT was first introduced in the early 1990s in Austria and Germany, its introduction in the U.S. is much more recent. While the first CLT construction project in the U.S. was in 2011, the first CLT use in a major metropolitan jurisdiction in the PNW region occurred in 2014. As a result, we designate 2014 as 'Year 0' for the CLT diffusion model and the twenty year time period specified within the CLT diffusion model estimations extends from 2016 through 2035.

In this study, we defined the following six end-use applications and developed specific diffusion trajectories for each case using the CLT innovation diffusion model:

(i) bare section* (3 or 5 ply CLT) for floor/roof applications, in multifamily buildings,
(ii) bare section (3, 5, 7 or 9 ply CLT) for floor/roof applications, in office buildings,
(iii) composite concrete section** (5-ply CLT) for floor/roof applications, in multifamily buildings,
(iv) composite concrete section (5-ply CLT) for floor/roof applications, in office buildings,
(v) wood composite section (6 and 10-ply CLT) for wall applications, in multifamily buildings,
(vi) bare sections (3, 5, 7 and 9-ply) for wall applications, in office buildings.

* *Bare section - bare floor and wall applications,*
** *Composite concrete section - CLT panels with a concrete layer (CLT concrete hybrid) floor/roof applications,*
*** *Wood composite section - use of two adjacent CLT panels with a space in the middle, for wall applications.*

Diffusion trajectories for each of these end-use categories were then developed using a range of adoption risk parameters, including regional building codes and building standards, engineering risk and uncertainty, and various manufacturing and cost of adoption factors. These end-use specific diffusion trajectories were then layered over the potential CLT use applications in multi-family and office buildings. The diffusion results of the end-use and building type CLT demand forecasts are presented in Figures 4-7.

Diffusion Modeling Results by building type

As can be observed from Figure 4, both multifamily and office buildings are likely to contribute equally to the overall CLT demand. During the first half of the projection period, between 2016 and 2025, the cumulative CLT demand from office and multifamily building constructions is projected to be 6.2 and 6.0 million cubic feet, respectively. Cumulative demand for CLT is projected to be 3.6 times greater during the second half of the projection period, with demand from office and multifamily building projects estimated to be 23.4 and 20.4 million cubic feet, respectively.

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CLT in PNW continued from page 6

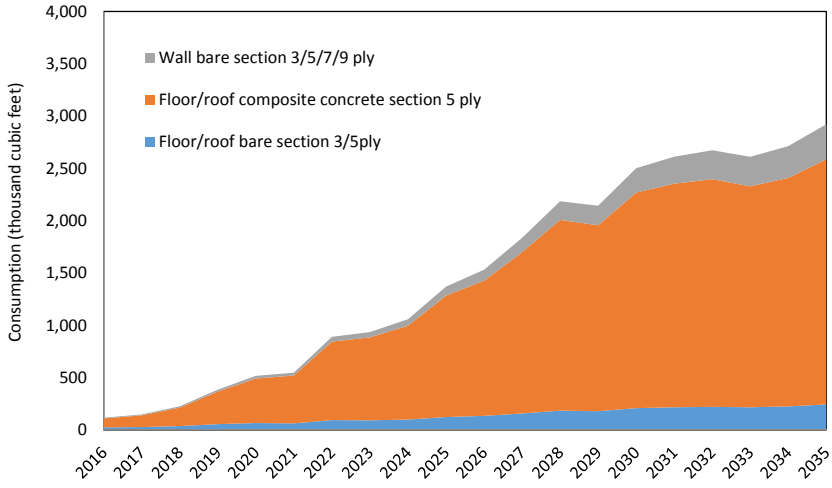

Figure 6: CLT adoption diffusion forecast, by end-use application, in office buildings.

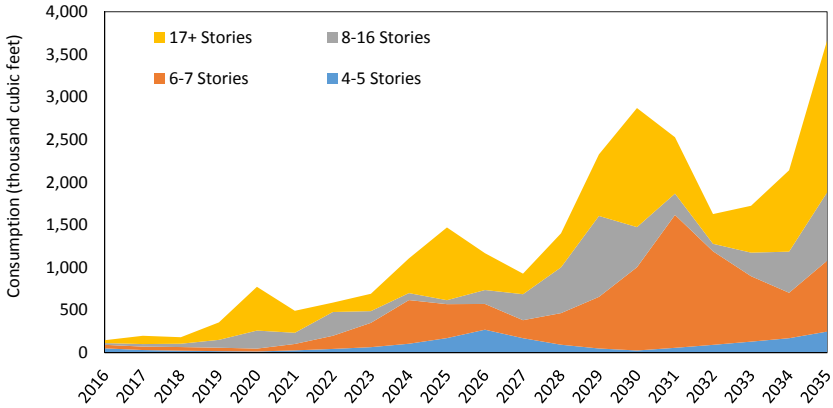

Figure 7: CLT adoption diffusion forecast, by building height, in multi-family buildings.

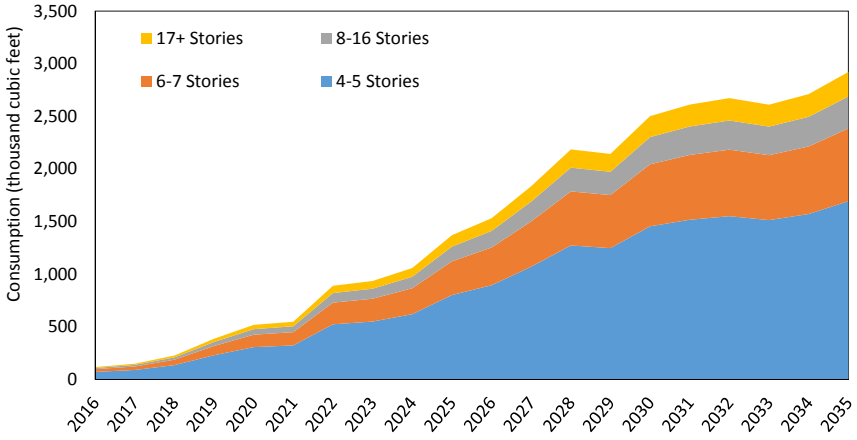

Figure 8: CLT adoption diffusion forecast, by building height, in office buildings.

Diffusion Modeling Results by end-use application

In terms of end-use applications, Figures 5 and 6 show that the floor/roof concrete composite sections (5-ply CLT) are projected to generate the vast majority of demand for CLT panels in both the multifamily and office building construction sectors. In the medium to long term projection, the demand for CLT panels within the multifamily sector will begin to increase following a slow start during the first half of the projection period. The modeling results clearly show that the use of CLT panels for bare section floor/roof applications are not expected to significantly contribute to the overall demand for CLT panels in multi-family buildings during the projection period. In fact, the proportion of overall CLT demand derived from bare section floor/roof 3/5 ply CLT panels is projected to decline from 21% of the overall CLT demand in 2017 to just 7% by 2035, Figure 5.

Similar to the multifamily buildings, in office buildings the use of CLT panels for bare section floor/roof applications is not expected to significantly contribute to the overall demand for CLT panels in the long run. The proportion of overall CLT demand derived from bare section floor/roof 3/5 ply CLT panels is projected to decline from 21% of the overall CLT demand in 2017 to just 8% by 2035 (Figure 6). The floor/roof concrete composite application will dominate the overall demand for CLT panels in office buildings because of its ease of use and competitive cost relative to steel and concrete. CLT use in wall applications will likely play a minor role in the overall demand of CLT for office constructions, especially in the initial years, due to greater regulatory constraints around using CLT for structural walls, and the perception of higher perceived risks and challenges of using CLT for structural walls on the part of architects and engineers. The study projects that with improved understanding of the product the proportion of overall CLT demand derived from structural wall applications in office buildings will increase from 5% of the overall CLT demand in the initial years to over 10% by 2030.

Diffusion Modeling Results by building height

Within the multifamily building construction sector, 4-5 story buildings are projected to play a minor role in the cumulative demand for CLT panels (less than 10%) during the projection period (Figure 7). In contrast, tall buildings (+17 stories) are expected to be the major driver of CLT demand over the 20 year projection period, representing 39% of the cumulative CLT demand, followed by 6-7 story buildings (30% of cumulative CLT demand). The average annual increase in CLT demand in the multi-family building sector will exceed 25% per annum. The growth in demand will be slightly higher in the first half of the projection period (+36% per annum) than in the second half (+26% per annum).

Within the office building sector, 4-5 story buildings are expected to provide the majority (60%) of the cumulative demand for CLT panels during the projection period (Figure 8). Over the medium to long term period, the market share of CLT use within 6-7 story office buildings will begin to grow and is projected to reach 24% of total demand by 2035. Over the entire projection period, the average annual growth in CLT demand within the office building sector will be approximately 21% per annum. Similar to the trend observed within the multi-family sector, the annual growth in demand will be higher in the first half of the projection period (34% annual growth) before slowing in the second half of the projection period (8% annual growth).

Combining both building types, commercial office and multi-family, our results suggest that the 4-5 and 6-7 story building categories will represent the largest markets for CLT panels, Figures 7 and 8. Our modeling results indicate that by 2020, the overall demand for CLT panels in the PNW region could reach 1.2 million cubic feet annually. Given these modeling results, it is also likely that from 2020 onwards the demand for CLT panels will double every 5 years within the building construction market. This demand estimation may be somewhat conservative, given that revised building code/jurisdiction approvals would no longer impose any significant constraints on the use of CLT panels in multi-family or office buildings after 2020.

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CLT in PNW continued from page 7

Overall CLT demand for building construction: moderate vs best case scenario

Finally, we ran the diffusion models for the moderate case (green area) and best case scenarios (green and yellow area combined, Figure 9). In the best case scenario, all the building types and material end-uses follow a 'no risk' and 'no restriction' innovation diffusion trajectory which essentially assumes that there will be no regulatory or building code restrictions to slow down the adoption and diffusion of CLT panels in either the multi-family or office building sectors. Because of this assumption of no regulatory constraints, the largest difference between the moderate scenario and the best case scenario occurs during the first half of the projection period (2016-2025). For example, in 2016 the projected demand for CLT panels in the best case scenario is 10 times higher than in the moderate scenario. The difference between the two scenarios declines over the forecast period, and by 2035 the CLT demand in the best case scenario is approximately double to that in the moderate scenario.

Conclusions

This project used a combination of models to develop a forecast of the potential demand for CLT panels in the PNW region. The model results for the moderate case scenario suggest that the overall demand for CLT panels in the PNW region could reach approximately 6.6 million cubic annually. However, if over this period (i) the perceptions of architects, engineers and designers improve faster than projected, (ii) the construction cost efficiencies of using CLT relative to traditional building materials are recognized, or (iii) the regulatory regime towards the use of CLT in building construction were to substantially improve, then the total annual demand for CLT panels in the PNW region could almost double to 12 million cubic feet by 2035.

Using the diffusion model with the moderate market parameters, the cumulative demand for CLT panels in the PNW region could total 56 million cubic feet over the twenty year period. It is important to note that the modeling results reflect a market diffusion process that grows over time based on the predicted (and positive) trial and adoption of the CLT construction technology. A typical characteristic of all 'new product diffusion models' is a slow initial adoption (trial) phase followed by an increasing rate of adoption based on positive customer experiences. Our results substantiate this observation, with demand for CLT panels in the trial phase (2016-2018) being approximately 300,000 cubic feet per year while demand by the end of the growth period (2030-2035) averages over 5 million cubic feet per year.

Based on the projected annual demand of 6.6 million cubic feet (or 187,000 cubic meters) of CLT panels by 2035, we estimate that demand in the PNW region could support approximately four medium-sized CLT manufacturing plants (with each plant producing 40,000 cubic meters of CLT per year). It should be noted that this demand estimate is limited to 4+ story buildings located within the PNW region. Total demand for CLT panels would be significantly higher if other building types were included in the analysis (e.g. warehouses, school buildings, etc.) as well as exports of CLT panels into nearby regions of the country.

This study was undertaken in conjunction with FORTERRA, Washington State University (WSU) and Heartland Construction. An unabridged version of this report is available through FORTERRA's website.

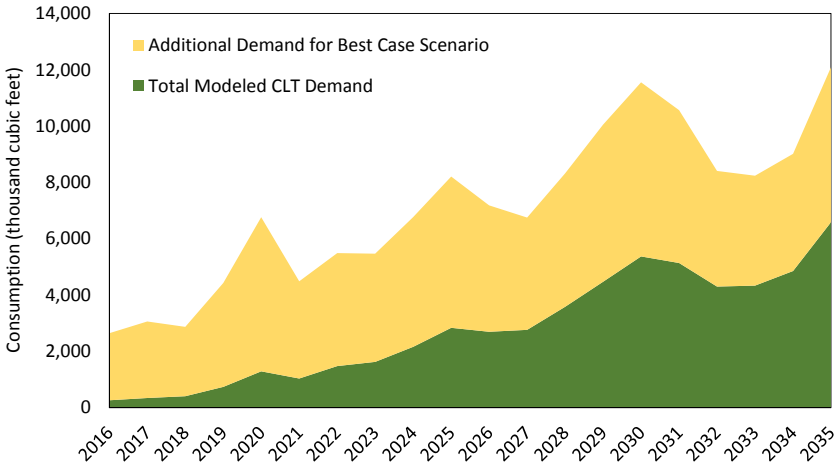

Figure 9: CLT adoption diffusion forecast for the moderate vs best case scenarios.

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