Supplementary 7 – Mass Timber Construction

The Mass Timber Construction analysis estimates the potential carbon benefits of an increase in Mass Timber Construction in New England within both the multifamily and non-residential commercial building sectors. Carbon benefits are estimated as carbon avoided from concrete and steel construction when Mass Timber Construction is used instead (embodied carbon), and long-term storage of carbon in the buildings themselves. Embodied carbon resulting from substituting concrete and steel construction with Mass Timber Construction includes the carbon avoided from the life cycle of the materials (e.g., manufacturing, production, transport) but does not include operational carbon, which is the carbon load from building operations to heat and power a building.

Potential carbon benefit of Mass Timber Construction (C) in New England = (C_b) x (B_d) x (MT_B)

Where:

(C_b) = Carbon benefit/building = (reduced emissions from substitution of concrete/steel design with wood design + carbon storage in Mass Timber Construction buildings)

(B_d) = Projected multi-family and non-residential commercial building demand (new construction, 2020-2050)

(MT_B) = % of projected multi-family and commercial building demand (new construction, 2020-2050) built with Mass Timber Construction

The study uses LCA data on carbon avoided and stored for an 8-story and a 12-story Mass Timber Construction design developed by Oliphant and Generate Technologies in Boston, MA. In May 2019, Oliphant was awarded a two-year Wood Innovations Grant from the US Forest Service to seek early adopter policy and financial incentives to encourage developers to use Mass Timber Construction for its carbon storage benefits. The Mass Timber Construction building designs were developed by John Klein (MIT and now Generate) and Buro Happold Engineering was contracted to develop LCAs for the designs. The Mass Timber Construction buildings designed and leveraged for the current study take a whole-building approach: the building designs reflect Mass Timber Construction design realities and therefore the LCAs do not only represent a substitution of wood for the concrete and steel structural elements of a building, but rather are carbon profiles of using Mass Timber Construction designs relative to concrete and steel counterfactuals.

Multiple design options were assessed in the LCAs for both the 8-story and 12-story building designs; each design option had a different carbon profile (See Figure 1 for carbon profiles associated with 8-story Mass Timber Construction designs). For example, the 8-story LCA study found that the Mass Timber Construction designs ranged between a 14-52% reduction in whole building embodied carbon and a 31-73% reduction when considering only the structural systems. (Jensen et al 2020)

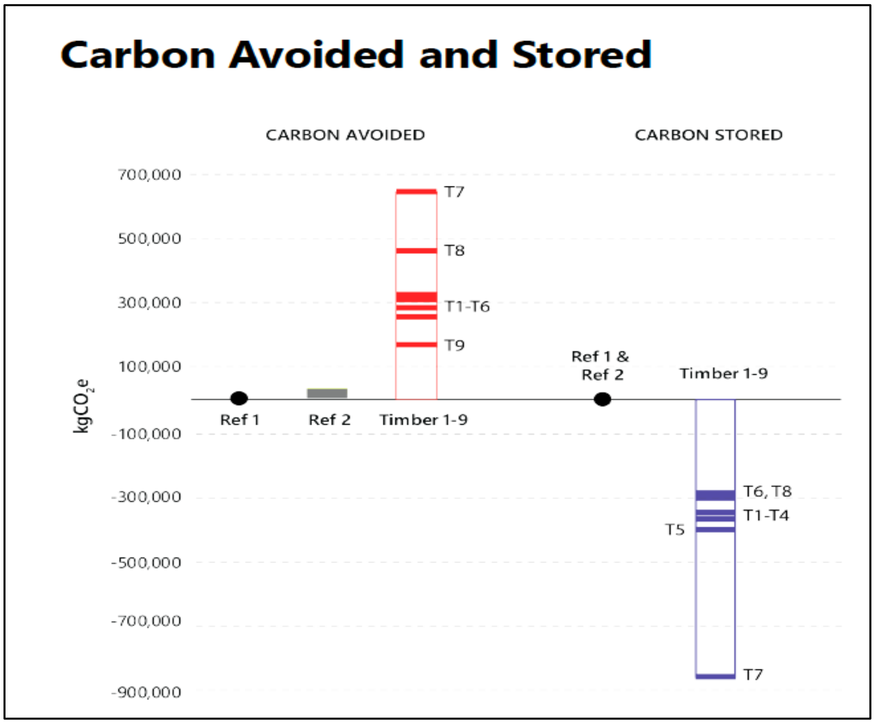

Figure 1: Carbon Profile of 8-story Mass Timber Construction Designs

Source: Jensen et al 2020

One design was selected for both the 8- and 12-story models in consultation with Oliphant and Buro Happold Engineering through consideration of which design was most likely to be adopted by developers based on design and cost. The average of the carbon stored and carbon avoided for the 8- and 12-story buildings selected was estimated to represent the average carbon stored and carbon avoided values for a representative Mass Timber Construction building considered in our analysis as shown in Figure 2.

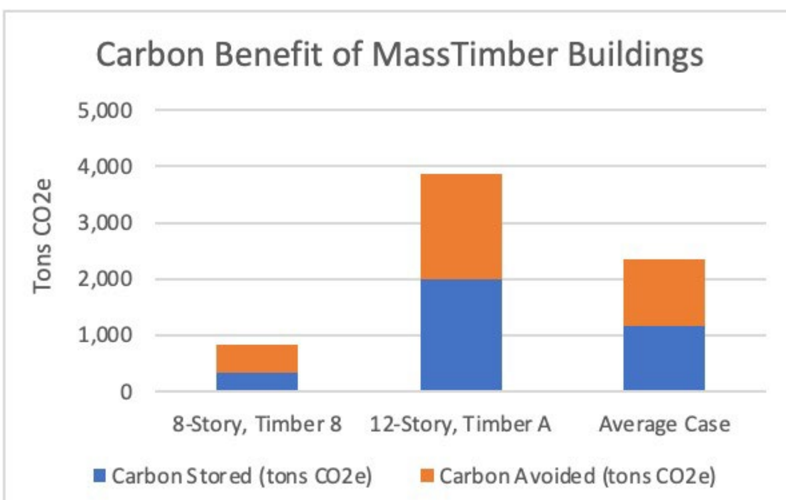

Figure 2: Carbon Benefits of Mass Timber Construction Buildings

The average case estimate reflects 2,350 tons of CO2e benefit per building - just over 1,000 tons CO2e stored in each building and 1,000 tons of CO2e avoided in the LCA of each building as compared to a steel and concrete reference case. This average may be an underestimate of carbon benefit both because the 12-story Mass Timber Construction building may be more likely to be adopted (the 8-story building is very narrow) and because carbon benefits between these buildings are not linear: the 12-story building utilizes more wood as it is not only taller but wider and has a much larger carbon benefit.

The average case estimate for carbon benefits associated with Mass Timber Construction is applied to assumptions about the percentage of the multifamily and nonresidential commercial building markets that Mass Timber Construction may capture in the 30-year time period of the analysis. For both markets, we provide estimates for a 20%, 50% and 100% market capture.

For the **multifamily market analysis**, data from the US Census Building Permits Survey from 1980-2020 (https://www.census.gov/construction/bps/pdf/annualhistorybystate.pdf) is used for new 5+ unit buildings authorized by building permit under the study's assumption that apartment buildings have 5+ units (assumption from Moody's at https://www.economy.com/united-states/housing-starts-multi-family). The average annual number of new 5+ unit buildings over this time period is used given the variability across years and is multiplied by 30 years to arrive at the total multifamily market for 2020-2050. To estimate the number of taller buildings of this total market that would be appropriate for a Mass Timber Construction building, the total is divided in half based on an estimate derived from the U.S. Census that showed roughly 50% of multifamily units are in buildings greater than 4 stories (https://www.census.gov/construction/chars/highlights.html). Table 1 below shows the number of buildings that may be built from Mass Timber Construction at different levels of capture of this multifamily market.

Table 1: Estimated number of MT buildings in the multifamily building market

Number of MT Buildings (2020-2050)	CT	ME	MA	NH	RI	VT	New England Total
Total Potential Multifamily Market [1]	2,215	787	4,049	1,025	443	593	9,112
MT Buildings @20%	443	157	810	205	89	119	1,822
MT Buildings @50%	1,108	393	2,024	513	222	296	4,556
MT Buildings @100%	2,215	787	4,049	1,025	443	593	9,112

Notes:
[1] The total potential multifamily market for Mass Timber reflects half of the average number of new 5+ unit buildings from the US Census Building Permits Survey 1980-2020.

For the **nonresidential commercial market analysis**, the study uses 2020 to 2022 building trends data on Mass Timber Construction buildings in New England from WoodWorks (https://www.woodworks.org/resources/u-s-mass-timber-projects/). As of March 2022, WoodWorks reported that 1,384 Mass Timber Construction buildings had been constructed or were in design at that time in the U.S. In New England, 129 buildings had been constructed or were in design at that time, representing nearly 10% of all Mass Timber Construction activity in the U.S. A review of the WoodWorks database on details on the buildings constructed showed that they are mostly institutional buildings (e.g., Common Ground High School in New Haven, CT; Beverly Municipal Airport in Beverly, MA; a base lodge at Mount Snow in VT; the North Hall at the Rhode Island School of Design in Providence, RI; the Boston Marriott Long Wharf in Boston, MA; and an insurance building in Portland, ME).

To estimate the total potential number of nonresidential commercial Mass Timber Construction buildings built per year the study first calculates the average number of Mass Timber Construction buildings built per year between 2020 and 2022 in New England, and then multiples by 30 to estimate the total average number of potential buildings over the 30-year period of analysis. The study then applies the tier percentages (20%, 50% and 100%) above this average to estimate the potential number of Mass Timber Construction buildings in New England over the 30-year period of analysis.

Table 2: Mass Timber Construction Building in New England

US Data by State as of Sept 2020 (Built & In Design)	**CT**	**ME**	**MA**	**NH**	**RI**	**VT**	**New England Total**
Construction started/built	6	4	21	1	2	2	36
In Design	4	13	31	2	2	9	61
Total	**10**	**17**	**52**	**3**	**4**	**11**	**97**
US Data by State as of March 2022 (Built & In Design)	**CT**	**ME**	**MA**	**NH**	**RI**	**VT**	**New England Total**
Construction started/built	11	7	25	1	4	2	50
In Design	5	9	50	3	1	11	79
Total	**16**	**16**	**75**	**4**	**5**	**13**	**129**
Average MT built per year (2020/2022)	8.5	5.5	23	1	3	2	43
Assuming same number increase for 30 years	255	165	690	30	30	60	1,230
Assuming same number increase + 20%	306	198	828	36	36	72	1,476
Assuming same number increase + 50%	382.5	247.5	1035	45	45	90	1,845
Assuming same number increase + 100%	510	330	1380	60	60	120	2,460
Average MT built per year (2020/2022)	8.5	5.5	23	1	3	2	43
Assuming same number increase for 30 years	255	165	690	30	30	60	1,230
Source: Woodworks Mass Timber Construction Project Data: https://www.woodworks.org/resources/u-s-mass-timber-projects/							

Applying the total carbon benefit of the average Mass Timber Construction building case to both the potential multifamily and nonresidential commercial building markets yields total carbon benefits over 30 years in the current study.

An important caveat to the analysis is that it does not consider forest-level impacts**.** A detailed treatment of harvested wood product pools and impacts of an increase in Mass Timber Construction production on the forest was beyond the scope of this study. Given the researchers' understanding that engineered wood manufactured for Mass Timber Construction will be drawn from the same dimensional lumber pool of products used for building construction, and the assumption that the percentage of building construction displaced by Mass Timber Construction will not be higher relative to overall building construction numbers, the researchers do not expect that the Mass Timber Construction scenario would have a significant impact on wood removed from the forest, or on storage in wood products. Further, growth vs harvest data for New England states show capacity for increased harvest in the region (Table 3).

Table 3: Growth and removals data for New England states

Trees 1 inch d.b.h Dry tons on timberland	CT	ME	MA	NH	RI	VT	New England Total
Net growth	2,002,363	15,241,173	2,358,190	4,392,947	174,467	3,975,642	28,144,783
Harvest	338,523	13,482,441	604,571	2,282,067	94,335	1,630,577	18,432,514
Harvest/net growth	17%	88%	26%	52%	54%	41%	65%
Source: FIA Evalidator							

Other comparisons

Other studies have previously estimated the climate benefits of building with wood, and of Mass Timber Construction more globally. A recent paper exploring the global carbon benefits of replacing steel and concrete with Mass Timber Construction found potential carbon benefits of storing an additional 10 million to 700 million tons of carbon per year over the period 2020-2050, based on a range of 10% to 90% of new buildings constructed with Mass Timber Construction instead of concrete and steel (Cherkinya et al 2020). Other studies have estimated that wood substitutes for construction materials such as steel, concrete, brick and aluminum could reduce global emissions of CO2 by 14% to 31%, and 12% to 19% of global fossil fuel consumption through use of 35% to 100% of sustainable wood growth globally (Oliver et al 2014). The New England Forestry Foundation has estimated that substituting common wood framing for steel and concrete in low-rise (one to 6 stories) non-residential construction and in floors and walls of residential buildings throughout New England could yield GHG emissions reductions of roughly 3.5 million metric tons of CO2e, equivalent to taking 750,000 cars off the road (Gosline 2014).

Recent research has supported the viability of Mass Timber Construction in New England. A 2017 study concluded that there was a market for engineered wood products in New England for the mid- and high-rise construction market, and that New England was home to tree species (e.g., spruce, fir, pine, hemlock) appropriate for manufacturing engineered wood products, including the CLT used in Mass Timber Construction. (NEFF Poyry 2017). The Poyry report also concluded that New England could support one or two mills for CLT construction. Recent research has also indicated that Eastern Hemlock, an otherwise low-value species abundant in Southern New England, may be used for CLT manufacture (Kaboli et al 2020).

The researchers also reviewed other work on Mass Timber Construction and building with wood that has been completed recently in New England. Chapter 7 of NEFF's Path to Sustainability Report, Grow More Wood (NEFF 2014) includes an assessment of carbon benefits of using wood-framed construction for 1 to 6 story nonresidential buildings in New England where carbon benefits are estimated based on the quantity of wood that could be used to replace concrete and steel construction; and the carbon benefits of using wood to replace concrete slabs and in walls for residential construction for single-family homes and low-rise residential construction. This study relies on data available from Adair et al 2013. Carbon benefits estimated in this report are based on an estimated additional 64,750,000 board feet equivalent (bfe) in residential construction in floors and walls and an additional 338,190,000 bfe in walls, floors, roofs and siding of low-rise nonresidential construction. The study uses a displacement factor from Sathre and O'Connor 2010 for its estimate of 3.9 t CO2eq emission reduction per oven–dry t of wood product. The displacement factor is applied to the sum of 338,190,000 bfe in low-rise nonresidential construction and 64,750,000 bfe in residential construction to yield an annual CO_2e savings of nearly 3.5 million metric tons of CO_2e, equivalent to the annual emissions from almost ¾ of a million cars.