Morally Imagining Implications Induced on Forests by Mass Timber Construction

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Michael Peyton Rice

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Technical Project Team Members: Aleyna Bedir, Indigo Breza, Hannah Herrmann, and Lindsey Maxwell

On my honor as a University Student, I have neither given nor received unauthorized aid on this assignment as defined by the Honor Guidelines for Thesis-Related Assignments

Signature Michael Peyton Rice Date 5/2/2020
Michael Peyton Rice

Approved ____________________ Date ________
Michael Gorman, Department of Engineering and Society

## Reviews and Comments

Throughout the duration of this course and in preparation of my STS research paper, I received helpful feedback from Professor Gorman and my peers. Without their input, I would have been unable to cultivate my research into an appropriate thesis topic. This section is dedicated to my gratitude for their assistance.

I failed to accurately identify and apply any one STS framework to my thesis topic. Professor Gorman was vital in suggesting one that would best highlight the issues I was hoping to cover. He also recommended that I write about existing building practices and how they harm the environment in order to emphasize the strengths and novelty behind engineered wood products. Jared Tufts was generous enough to provide feedback on some of the other frameworks I was considering. While he though the consequentialist ethics framework fit my topic, I found it too difficult to connect each ethical scenario to mass timber in a succinct manner. Additionally, he suggested that I bring anticipatory governance into my research paper. I wish I had implemented this idea in retrospect, as it would have validated the power of policy in forestry and mass timber industry. I do think my application of moral imagination and mental models overlapped with the application of anticipatory governance to some degree. Professor Gorman also aided in the development of my framework discussion through his work with Matt Mehalik and Patricia Werhane in *Ethical & Environmental Challenges to Engineering*.

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**The Rise of Mass Timber Construction**

Under the ever-evolving burden of climate change, the world faces stresses and subsequent decisions that hold the potential to alter the trajectory of human and environmental health. Statistically speaking, the built environment is responsible for a large portion of these issues. In 2009, 5.7 billion tons of CO2, equivalent to 23% of global CO2 output, were emitted by construction practices alone (Huang et al., 2017). Furthermore, buildings consume 40% of the world's energy every year (*Buildings*, 2013). In analyzing what components of the building construction industry contribute most to greenhouse gas (GHG) emission, the most problematic elements of the system are apparent. Pollutant production during building construction can be broken down into four stages: resource extraction and processing, material manufacturing and transportation, construction equipment energy usage, and waste disposal. Up to 87% of total GHG emissions originate in building materials themselves, around 94% of which are derived from the carbon intensive procedures needed to create concrete and reinforced steel. The remaining portion of emissions are evenly split between transportation processes and construction equipment practices (Yan et al., n.d.). While these metrics may project a bleak future for the planet, recent innovation in the industry may be the catalyst in inverting the built environment's role towards climate change.

During the 19$^{th}$ and 20$^{th}$ centuries, the push for industrialization and urbanization brushed wood aside as the predominant building material in favor for concrete and steel (Team, 2018). These more modern products hosted many advantages. From strength characteristics to fire rating, concrete and steel were far superior to timber based on society's needs at the time. Almost cyclically as a response, increased concerns regarding environmental destruction throughout the latter part of the 20$^{th}$ century led to the development of cross-laminated timber

(CLT) in Austria and Germany (*History of CLT | CLT Panels USA*, n.d.). CLT is considered an engineered wood product, a family of timber-based materials defined by various cuts of wood that are pressed and adhered together. Designed as a replacement for concrete slabs, CLT is constructed through the layering of dry-pressed timber boards with alternating grain directions. These boards are laminated together and can be built to a desired thickness given the material's modular nature. Contrary to its solid wood counterpart, CLT matches the performance of concrete and steel in strength to weight ratios as well as surpassing both materials in burn tests (EST, 2016).

Other engineered wood products also offer comparable performance results in different applications. Glue-laminated timber, most commonly known as glulam, is a material consisting of long thin boards with parallel grains that can offer comparable structural support to that of steel I-beams (Rodriguez, n.d.). Constructed similarly to glulam but with far denser layers, laminated veneer lumber (LVL) serves as a great material for edgework and detailing ("Laminated Veneer Lumber," 2015). Beyond their structural capabilities, engineered wood products' largest draw is their agreeability with the green building movement. Wood is completely renewable if treated correctly throughout its life cycle (*Why Mass Timber?*, n.d.). The implications of that statement will be discussed in the following section. Since timber is naturally created and biodegradable, its production and disposal put far less strain on the environment than the energy intensive, high temperature, and linear processes for concrete and steel (Shams et al., 2011). Furthermore, wood possesses inherent carbon sequestering properties. While a tree is living, the organism holds carbon dioxide from the atmosphere. This ability continues, to a lesser extent, while wood is obtained from the tree and used for building. A timber building has the capacity to sequester the same amount of GHGs as a comparably sized concrete and steel building would emit, effectively offsetting most of the existing environmental impacts of current building practices (Robbins, 2019).

Mass timber construction is the utilization of engineered wood products to structurally frame a building. It differentiates itself from traditional timber building styles, such as box framing and post and beam framing, largely because of the scale at which wood structures can be built. Mjostarnet, finished in spring of 2019, is an 18-story tall building in Brumunddal, Norway constructed almost exclusively with mass timber. Not only is it the world's tallest timber structure but the third tallest building in the country, a feat no structural engineer or architect would have deemed possible before the invention of engineered wood products (*Mjøstårnet in Norway becomes world's tallest timber tower*, 2019).

Mass timber provides several other advantages which architects, contractors, and clients desire. Given the fact that CLT and other engineered wood products can be built from wood parts rather than solid timber sections as well as the ubiquity of forests globally, worksites can take advantage of local forests by eliminating the need for a single lumber type and decrease transportation costs for their construction materials. Additionally, the modular nature of engineered wood products allows for prefabrication of building parts. Prefabrication processes lower worksite labor costs, ensure less mistakes on the jobsite, and increase safety during construction. In some projects, these savings can add up to approximately 20% cost reductions (Laguarda-Mallo & Espinoza, 2016).

Not to be neglected, the aesthetic properties of timber in construction greatly contribute to the social role of a building. In turn, materiality can contribute to the project's success economically through visual appeal that pays measurable dividends. An article by Australian not-for-profit organization, PlanetArk, found that the presence of wood in place of artificial materials, such as steel or concrete, induced positive psychological benefits for a building's inhabitants. Blood pressure decreased across various subpopulations when they occupied buildings with timber interiors. Additionally, students were found to be more productive in classrooms adorned with timber, walls while studies in Canada and New Zealand found that subjects were more likely to interact with each other and found work spaces more appealing when exposed to wood buildings (*Doc-1253-wood—Housing—Health—Humanity-report-2015-04-00-final.pdf*, n.d.). Furthermore, a study from the University of British Columbia concluded that the visual appeal of wood in the built environment reduced stress and helped compensate for the benefits of time sacrificed in nature to be in the office (Fell, 2010). These experiments indicate that the use of mass timber construction improves the health, happiness, and attractiveness of a building for tenants. As a result, architects and engineers design mass timber buildings to reveal the structural frame to inhabitants rather than hide it behind drywall panels or similar facades. This practice helps reduces construction costs and encourages interdisciplinary interaction in the design stage of a project.

**Forestry Bears the Load**

Mass timber is an appealing product for many stakeholders in North America's built environment. Architects can design healthier and more customizable buildings. Engineers garner a larger role in the visual appearance of a project. Contractors make a larger profit and run a safer worksite. Clients own greener buildings for their tenants. For all these reasons, American firms are attempting to replicate the use of mass timber that many European companies have been undergoing the past two decades. Canadian and American building codes are slowly adopting the supplementary material needed to legalize the construction of timber buildings larger than six floors ("North America's Mass Timber Industry, and Its Ascent To The Global Stage," 2019). American mass timber manufacturing companies, such as SmartLam and LignaTerra, are in the midst of expanding their reach through the addition of new plants in areas of the country lacking mass timber production such as the Southeast ("The U.S. mass timber industry is maturing while it branches out," 2019). In 2018, The Beck Group, a sustainably driven design and real estate firm based out of Dallas, Texas, calculated that the number of annual mass timber projects in the US had grown from 20 to over 200 since 2014 (*Beck-mass-timber-market-analysis-report.pdf*, n.d.). As the North American market for mass timber continues to grow, so will the demand for timber resources.

The green potential of mass timber construction may never be fully realized if engineered wood products are not analyzed holistically. Harvesting wood from forests is a vital component of the life cycle of mass timber. Fortunately for North America, approximately a quarter of American and Canadian land is forested (*North America1,2*, n.d.). Despite the abundance of timber as a resource, the vast majority of existing American mass timber projects sourced engineered wood products from Europe (*Will the skyscrapers of the future be made out of wood?*, 2020). This is not to say that the United States is incapable of using its forests to produce materials like CLT, LVL, or glulam but indicative of a lacking mass timber market. As of 2017, only two mass timber manufacturing facilities operated on American land (*Northwest companies take major role in CLT - Washington Forest Protection Association*, n.d.). While efforts to grow domestically are apparent, timber harvesting for as consistently demanding of an industry as construction requires more forethought than clearcutting existing forests. One of the most prominent and efficient mass timber manufacturers in Europe, an Austrian company Binderholz, boasts 13 factories, none of which hold more than 10 days' worth of engineered wood products.

Evidently, this is an uncomfortably low amount of stock for such a large company. An increase in material extraction could prove shortsighted in alleviating this issue because trees take decades to grow. As Binderholz attempts to maintain production and negotiate harvesting challenges, it is forcibly dependent on a delicate natural resource. With the emergence of other green technologies such as biofuels or bioplastics, forests are pulled in several directions. Binderholz is one of many companies applying strain on a limited, yet renewable resource (*Will the skyscrapers of the future be made out of wood?*, 2020).

Therefore, mass timber markets necessitate sustainable forest management. Struggling to balance conservation and material extraction, foresters face several issues in regards to planning successful forests. Although many parcels of wooded land were planted in Austria with the means of harvesting them for uses not yet known at the time (some were planted as early as the late 18$^{th}$ century), the country still struggles to meet demand for two reasons. First, land is difficult to acquire for forestry due to encroaching development. Second, increasing volatility of the climate hinders the health of Austrian tree species and ecosystems (*Will the skyscrapers of the future be made out of wood?*, 2020). The United States is less susceptible to the former issue because of the amount of available forested land, a good portion of which is privatized for harvesting. The latter indicates a global obstacle that an American forest would also face. In conclusion, while the United States possesses the financial and physical assets to fully pursue mass timber construction, it lacks the market infrastructure in both widespread demand and operable domestic mass timber factories to manufacture enough engineered wood product to support the entirety of its domestic projects. This not only overexerts the current capacity of American forests and factories but does the same for European ones as well.

This is not to say that the unpredictability of the climate is negligible when considering the growth of mass timber in North America. In fact, harvesting practices are critical in combating climate change; the harvesting cycle determines both whether or not America can grow enough trees to bolster mass timber construction and whether or not America can do so in a manner that benefits the environment, as this is timber's greatest draw in industry.

An important note, forestry was not framed with an ecological approach until the 1980s (Bell & Apostol, n.d.). Traditional forest harvesting around the world before that time was largely unregulated and few countries enforced annual allowable cuts (AAC). AACs are federally permissible volumes of forested land that can be cut down in a given year. Most countries also lacked restrictions on the shapes that parcels could be cut and how reserves were to be maintained. Ecological forest planning introduced analyses and justification behind the management of these issues. Yet, it was not until the past 15-20 years that forest planning pushed beyond governmental policy and into green market demands under the name "sustainable forestry" (Bell & Apostol, n.d.). This movement differs from prior eras of forestry in that it focuses on protecting forests' ability to provide goods and services for both the present and the future. For the purpose of harvesting wood for mass timber, this is best done through recognizing differences between natural forests and plantation forests.

A plantation forest is one in which a singular fast-growing tree species is planted and harvested in order to obtain the most volume of wood per area of land. Natural forests are managed so that they can be harvested as well, although there is a much larger priority placed on the conservation of these lands (Bell & Apostol, n.d.). In the United States today, the Pacific Northwest holds vast amounts of conifer plantation forests whereas the South expects large growth rates of planted wooded land to combat amplified timber demands (*Plantations forests in* *the United States of America: Past, present and future*, n.d.). In essence, plantation forests, which are most frequently privatized land, act as a buffer for natural forests, which are most commonly public land. Plantation forests undergo clearcutting on short harvesting cycles, so under prolonged increases in demand they are easily exhausted. Oftentimes, plantation forests are implemented as reactionary efforts to compensate for losses in natural forest volume (Pirard et al., 2016). Unfortunately, the answer to sustainably managing American forests may not be as easy as balancing total forested volume and is an issue that must be treated more ethically.

**Moral Imagination: Mapping Solutions**

Werhane, Mehalik, and Gorman's STS framework, Moral Imagination, is ideal for analyzing forest management's challenges regarding mass timber industry today (Gorman, Michael E. et al., 2000). The underlying principles of the framework are that every individual molds their own "mental model", a frame in which one views the world around them. It can be treated as a perspective cultivated through experience. While each mental model will be unique based on the assumption that every individual's experiences are singular, there will undoubtedly occur parallels within mental models across individuals who share similar lives, whether that be through economic background, geographic upbringing or profession to name a few. These mental model resemblances help an individual operate in a familiar environment. For example, almost any scuba instructor on a dive would most likely be prepared to react to unforeseen circumstances underwater. Through experience, the instructor created a mental model that prioritizes information that a novice diver might consider unessential, such as the direction of the current relative to nearby coral reefs. Conversely, a mental model filters through information deemed important to a specific perspective, so it will inevitably cause lapses in judgement that another mental model may have been more likely to gather. To continue with the example, ecological studies show that scuba diving around coral reefs harms reef health over time, a notion that many scuba instructors may not realize (Lonne, 2015).

In understanding that the rules drafted by one's mental model determine one's perception of the goals behind mass timber construction, the current proponents of the technology, such as architects, engineers, policy makers, and contractors, begin to acknowledge that they operate under vastly different mental models than foresters do. It is then important for each party to contemplate other mental models that may exist throughout the life-cycle of engineered wood products, such as those owned by foresters. Moral imagination is the process of allowing oneself to perceive others' mental models in order to evaluate all realistic alternatives to and byproducts of a situation (Gorman, Michael E. et al., 2000). The goal of moral imagination lies in achieving a moral solution by aligning one's mental model with ethical considerations. Under the interpretation that "morality [is] something that's personal or normative, whereas ethics is the standards of 'good and bad' distinguished by a certain community or social setting", moral imagination performs as a tool to not only create a moral decision but to help make the decision more ethical as well (*What's the Difference Between Morality and Ethics?*, n.d.).

If the construction industry utilizes moral imagination and understands the implications that exist in supporting mass timber, it would realize that plantation forests cannot directly replace natural forests. They are largely unsustainable. This assertion, made by foresters, emanates from a five-part sustainability analysis (Bell & Apostol, n.d.). First, plantation forests often fail to assimilate to landscape context. As they frequently consist of one tree species, a monoculture, they cannot provide the ecological services of natural forests. American forests alone sequester 14% of the country's carbon emissions (Melillo et al., 2014). Native and natural forests are more efficient in storing carbon emissions than planted forests ("Leaving trees alone might be better than planting new ones," 2019). Next, plantation forests harm site productivity. As plantation forests undergo intensive, frequent, and repetitive harvesting cycles, the topsoil they rely on to grow become susceptible to erosion and loss of nutrients. These effects reduce the land's ability to support natural or plantation forests in the future. Further, a lack of biodiversity in planted forests increases disease risk for the trees, potentially decimating forest crops. Additionally, plantation forests lack the capacity to carry natural habitats. This is for two reasons. Monoculture lacks the ecological complexity biodiversity needs to survive, and persistent clearcutting destroys long-term habitat capability. Penultimately, the chemical and physical control within plantation forests harms water quality in aquifers underneath these forests and in runoff along their topsoil. Lastly, the incongruent aesthetics of plantation forests can prompt social and economic drawbacks to those living near them. A study from the Canadian Forest Service found that natural looking forests were far more appealing (*Perceptions of forests*, n.d.). It can be concluded from the study that residential land near natural forests is of higher value than comparable land near plantation forests.

These considerations, all paramount in implementing and accommodating for the widespread use of mass timber construction are grossly underrepresented in policymaking. On December 21st, 2018, President Trump issued a declaration calling for increased logging of natural forests to meet increased timber sales (Fears et al., n.d.). The large-scale harvesting of these lands could potentially offset many of the desired benefits of using engineered wood products. The narrative often communicated to the public with regards to forestation practices in the United States revolves around the growth-to-drain ratio. A number comparing the area of land grown per year to the area harvested and lost due to wildfires and disease, a value greater than one indicates net positive growth. This number has been above one since the 1970s (*Is mass timber construction really renewable and sustainable?*, n.d.). Misleading and misrepresentative, the majority of growth in the United States is put into plantation forests rather than the reforestation of natural woodlands. The tradeoff is not equal and dangerously creates a false sense of security regarding the current status of forestry in America.

There lies a disconnect between mass timber industry and forestry. While the United States reports that forests are growing, mass timber is only environmentally effective when natural forests are maintained appropriately. Although mass timber can be supported entirely through plantation forests due to the fact engineered wood products can be manufactured from small, young trees, even a marginal conversion of the world's ecological landscapes, from natural forests to plantation forests, would incur adverse environmental effects. Despite the dangers of this issue, as mentioned before mass timber construction is already in the process of growing popular in the United States.

Not to neglect the efforts to combat this lapse in judgement from those unfamiliar with forestry, moral imagination is pushing its way into industry. To ameliorate the challenges of sustainable forestry, the USDA Forest Service and other conservation organizations have been heavily involved in several of the most recent annual International Mass Timber Conferences (*Dispatch from the 2019 International Mass Timber Conference*, n.d.). Representatives of sustainable forest planning, they educate architects, engineers, and manufacturers on green practices. Even entities outside of industry are calling mass timber manufacturers and policymakers to consider external mental models. In 2018, Oregon based environmental organizations, Oregon Wild, Oregon PSR, and the Sierra Club, wrote a letter to Mayor Wheeler of Portland addressing their concerns regarding the city's mass timber development plans (*Can* *mass timber reform construction's carbon footprint?*, n.d.). Because the city vowed to use mass timber construction for affordable housing units without certification from the Forest Stewardship Council, a certification committee that ensures mass timber manufacturers use moral imagination to consider harvesting practices, Portland residents feared the environmental effects "determined by where the wood used to fabricate CLT components came from, how it was harvested, and the carbon impacts of that harvest and of the product throughout its lifecycle" (*Can mass timber reform construction's carbon footprint?*, n.d.). While the letter points out weaknesses in the City's plans, it also helps industry acknowledge its mental models so that it can improve.

Building codes have not yet fully adapted to the demand for mass timber construction, and arguably, this is for the best. In the time it takes for engineered wood products to make their way fully into the market, there are indications that forestry is merging into mass timber industry and policy through moral imagination from architects, engineers, contractors, building owners, and many others. Adjunct Professor in Environmental Studies at Dartmouth College, Donella H. Meadows, claims that "vision is the most vital step in the policy process. If we don't know where we want to go, it makes little difference that we make great progress" (Meadows, 2014). This notion encapsulates the spirit of mass timber construction in both its strengths and flaws. If humankind does not envision what it wants the future to look like, whether it be high rise towers constructed from renewable material or beautiful forest landscapes that are managed sustainably, any technologies that will propel humankind in the right direction will eventually fail to do so.

Works Cited

*Beck-mass-timber-market-analysis-report.pdf*. (n.d.). Retrieved April 5, 2020, from https://www.oregon.gov/ODF/Documents/ForestBenefits/Beck-mass-timber-market-analysis-report.pdf

Bell, S., & Apostol, D. (n.d.). *Designing Sustainable Forest Landscapes*.

*Buildings*. (2013, July 22). Alliance to Save Energy. https://www.ase.org/initiatives/buildings

*Can mass timber reform construction's carbon footprint?* (n.d.). Retrieved April 6, 2020, from https://inhabitat.com/can-mass-timber-reform-constructions-carbon-footprint/

*Dispatch from the 2019 International Mass Timber Conference*. (n.d.). Hacker. Retrieved April 6, 2020, from https://www.hackerarchitects.com/notes/2019-international-mass-timber-conference

*Doc-1253-wood—Housing—Health—Humanity-report-2015-04-00-final.pdf*. (n.d.). Retrieved April 5, 2020, from https://makeitwood.org/documents/doc-1253-wood--housing--health--humanity-report-2015-04-00-final.pdf

EST, M. B. O. 02/20/16 at 1:02 P. (2016, February 20). *The tallest wooden-framed buildings in the country are under construction in Portland*. Newsweek. https://www.newsweek.com/carbon-sequestering-construction-oregon-428745

Fears, D., Bay, closeDarryl F. focusing on the C., policy, issues affecting wildlifeEmailEmailBioBioFollowFollowJuliet E. closeJuliet E. covering domestic, & affairsEmailEmailBioBioFollowFollow, national. (n.d.). *Trump's executive order will aggressively cut more forest trees*. Washington Post. Retrieved April 6, 2020, from https://www.washingtonpost.com/energy-environment/2019/01/14/trumps-executive-order-will-cut-more-forest-trees-some-publics-tools-stop-it/

Fell, D. R. (2010). *Wood in the human environment: Restorative properties of wood in the built indoor environment* [University of British Columbia]. https://doi.org/10.14288/1.0071305

Gorman, Michael E., Mehalik, Matthew M., & Werhane, Patricia H. (2000). *Ethical and Environmental Challenges to Engineering*. Prentice Hall.

*History of CLT | CLT Panels USA*. (n.d.). Retrieved April 4, 2020, from https://research.cnr.ncsu.edu/blogs/clt-panels/history-of-cross-laminated-timber/

Huang, L., Krigsvoll, G., Johansen, F., Liu, Y., & Zhang, X. (2017). Carbon emission of global construction sector. *Renewable and Sustainable Energy Reviews*, *81*. https://doi.org/10.1016/j.rser.2017.06.001

*Is mass timber construction really renewable and sustainable?* (n.d.). TreeHugger. Retrieved April 5, 2020, from https://www.treehugger.com/sustainable-product-design/mass-timber-construction-really-renewable-and-sustainable.html

Laguarda-Mallo, M., & Espinoza, O. (2016, August 1). *CROSS-LAMINATED TIMBER VS. CONCRETE/STEEL: COST COMPARISON USING A CASE STUDY*.

Laminated Veneer Lumber. (2015, August 19). *MJB Wood Group, LLC*. https://www.mjbwood.com/laminated-veneer-lumber/

Leaving trees alone might be better than planting new ones. (2019, October 20). *Grist*. https://grist.org/article/leaving-trees-standing-might-be-more-important-than-planting-new-ones/

Lonne, T. (2015, May 8). A Scuba Diver's Impact on a Coral Reef: Learning to be sustainable. *DIVEIN.Com*. https://www.divein.com/articles/a-scuba-divers-impact-on-a-coral-reef/

Meadows, D. (2014). Envisioning a Sustainable World. In R. Costanza & I. Kubiszewski, *Creating a Sustainable and Desirable Future* (pp. 9–14). WORLD SCIENTIFIC. https://doi.org/10.1142/9789814546898_0002

Melillo, J. M., Richmond, T. (T. C. ), & Yohe, G. W. (2014). *Climate Change Impacts in the United States: The Third National Climate Assessment*. U.S. Global Change Research Program. https://doi.org/10.7930/J0Z31WJ2

*Mjøstårnet in Norway becomes world's tallest timber tower*. (2019, March 19). Dezeen. https://www.dezeen.com/2019/03/19/mjostarne-worlds-tallest-timber-tower-voll-arkitekter-norway/

*North America1,2*. (n.d.). Retrieved April 5, 2020, from http://www.fao.org/3/w4345e/w4345e0i.htm

North America's Mass Timber Industry, and Its Ascent To The Global Stage. (2019, August 30). *Structurlam*. https://www.structurlam.com/whats-new/news/north-americas-mass-timber-industry-and-its-ascent-to-the-global-stage/

*Northwest companies take major role in CLT - Washington Forest Protection Association*. (n.d.). Retrieved April 5, 2020, from http://www.wfpa.org/news-resources/blog/northwest-companies-take-major-role-in-clt/

*Perceptions of forests*. (n.d.). Retrieved April 6, 2020, from http://www.fao.org/3/y9882e/y9882e06.htm

Pirard, R., Dal Secco, L., & Warman, R. (2016). Do timber plantations contribute to forest conservation? *Environmental Science & Policy*, *57*, 122–130. https://doi.org/10.1016/j.envsci.2015.12.010

*Plantations forests in the United States of America: Past, present and future*. (n.d.). Retrieved April 6, 2020, from http://www.fao.org/3/xii/0325-b1.htm

Robbins, J. (2019, May 21). *As mass timber takes off, how green is this new building material?* [Text]. GreenBiz. https://www.greenbiz.com/article/mass-timber-takes-how-green-new-building-material

Rodriguez. (n.d.). *Glulams Are Laminated Wood Beams That Are Stronger Than Steel*. The Balance Small Business. Retrieved April 4, 2020, from https://www.thebalancesmb.com/what-is-glulam-applications-and-advantages-of-glulam-845106

Shams, S., Mahmud, K., & Al-Amin, M. (2011). A comparative analysis of building materials for sustainable construction with emphasis on CO2 reduction. *Int. J. of Environment and Sustainable Development*, *10*, 364–374. https://doi.org/10.1504/IJESD.2011.047767

Team, W. (2018, September 26). *History of Mass Timber Construction | Seagate Structures Blog*. Seagate Structures - Mass Timber Construction, Prefab. https://seagatestructures.com/a-brief-history-of-mass-timber-construction/

The U.S. mass timber industry is maturing while it branches out. (2019, January 14). *Archpaper.Com*. https://archpaper.com/2019/01/u-s-mass-timber-industry-maturing/

*What's the Difference Between Morality and Ethics?* (n.d.). Encyclopedia Britannica. Retrieved April 6, 2020, from https://www.britannica.com/story/whats-the-difference-between-morality-and-ethics

*Why Mass Timber?* (n.d.). HDR. Retrieved April 4, 2020, from https://www.hdrinc.com/insights/why-mass-timber

*Will the skyscrapers of the future be made out of wood?* (2020, January 13). Science. https://www.nationalgeographic.com/science/2020/01/skyscrapers-of-the-future-will-be-made-out-of-wood/

Yan, H., Shen, Q., Fan, L. C. H., Wang, Y., & Zhang, L. (n.d.). Greenhouse gas emissions in building construction: A case study of One Peking in Hong Kong. *Building and Environment*, *45*(4), 949–955.