Forest-Driven Futures:

A Center for the Advancement of Sustainable Forestry

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Abstract

Forest-Driven Futures: a Center for the Advancement of Sustainable Forestry

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Forests across the world are in a state of remission. Healthy forest ecosystems play a critical role in maintaining stable environmental conditions; if today's climate change problems are caused by too much carbon dioxide in the air and trees turn carbon dioxide into wood and oxygen, then there must be a solution in planting more trees. This research aims to identify and promote systems for planting trees on an industrial scale and to design an architectural intervention to put these systems in place. Technological advancements are proving that intelligent forest management can benefit the economy and the ecology at the same time. A 'restoration economy' is emerging, a holistic business approach that can solve many problems simultaneously. Artificial intelligence and automation are showing promise in greatly improving efficiencies in planning, planting, and harvesting. Innovative forestry businesses are finding ways to turn carbon dioxide into cash. These developments hold great potential for reversing environmental degradation, but they are still in their infancy and are generally inaccessible to the majority of forest owners. The Center for the Advancement of Sustainable Forestry will help to teach the values of sustainable forest management to a diverse set of stakeholders in order to provide a healthy future for our children and the planet.

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First of all I'd like to acknowledge Professor Gundula Proksch for her excellence in academic research and deep knowledge of living architectural systems, my architectural hero Professor David Miller FAIA for his expertise in the practice of sustainable design development and 'systems architecture', and Associate Professor Tyler Sprague for opening doors for me in academic research and sparking my enthusiasm for the incredible potential of wood fiber.

I also acknowledge UW Architecture alumni who have refined the Northwest Regionalism by which I am so inspired, particularly Paul Hayden Kirk for his mastery of expression in wood. I acknowledge the entire Department of Architecture for cultivating the importance of bringing the natural environment into the built environment, and for fostering a sensitivity toward bigger-picture issues such as ecology and humanity. I also recognize and applaud the work of UW's School of Environmental and Forestry Sciences and Pack Forest Executive Director Greg Ettl whom has been very helpful in grounding this project in reality.

Finally, I thank my parents Laura and Ben Nicholson for encouraging me to pursue this fulfilling career in Architecture; in face of its many challenges, I have found this to be the medium by which I can do the most good for humanity. All of these people and institutions have contributed to this research in some way and to the person I am today. Thank you all!

DEDICATION

This research is dedicated to the life-giving forests of the world and their well-being, and to the warriors who make it their life's work to restore and protect this incredibly valuable resource.

CHAPTER 1. INTRODUCTION

"Forest-driven futures" is the premise of planting trees to ensure a sustainable tomorrow. This thesis proposes an architectural interface for the exploration of mass forestry operations to ensure a healthy building environment for the future as a means to empower landowners to manage their forests to achieve ecological and business objectives.

This thesis begins with establishing an understanding of the forest's ecological function, a consideration of issues facing forests in the 21st century, and a survey of contemporary forest management practices. After analyzing the scenario from an ecological, economic, and political perspective, an architectural solution is formulated.

The primary goal of this research is to examine how a modern forest industry can help to address 21st Century challenges such as housing security, job security, and resilience to natural & economic disaster; and to facilitate intervention on a landscape scale with an architectural system of mitigation to make restoration and conservation efforts more economical. Assuming self-responsibility and action at an individual level is essential to overcoming such large-scale problems.

The thesis investigates a means for the forest industry to achieve self-sufficiency, resiliency toward climate change, financial stability, and sustainable development. With smart forestry management tools designed to capitalize on 21st century revenue opportunities, private property owners and government agencies alike can be empowered by economic drivers to make climate change intervention happen at a faster pace.

Advanced forest management practices can help simultaneously achieve multiple goals, which generally fall into two categories: ecological/conservation goals, and economic goals i.e. harvesting forest products for profit. The ecological benefits of managing forest land include environmental restoration for cleaner air & water, fertile soil, prevention of wildfires & erosion, and sustaining wildlife by improving biodiversity. The financial opportunities presented include selling carbon credits, sale of timbers for lumber, and conversion of biomass for paper, composites, biofuel, and other industrial products. Green technology from trees, i.e. wood products, can safely and cost-effectively sustain housing and energy needs for the expanding population. Forest management, it seems, offers a sweeping solution to the many of the 21st century's most serious challenges, though many markets remain untapped due to challenges like scale, access to equipment, and knowledge of appropriate forestry methods.

Housing demand is driving timber sales, incentivizing forest management, and well-managed forests can improve ecological and environmental conditions. With this combination of knowledge, it can be deduced that cultivating forests to manage atmospheric CO_2 levels is an effective measure for mitigation of global warming and the damage it is projected to cause. Add into it the factor of construction-related carbon footprints and the economies of new forest products & building technologies, and a viable solution begins to emerge. This research draws connections between the fields of restoration initiatives, timber technology, and sustainable development, with the premise that overlapping spheres of influence can inform a sweeping, cohesive solution which benefits each sector in a symbiotic manner (Figure 1). Each component of the relationship illustrated below will be analyzed before a response is proposed in the form of a design project.

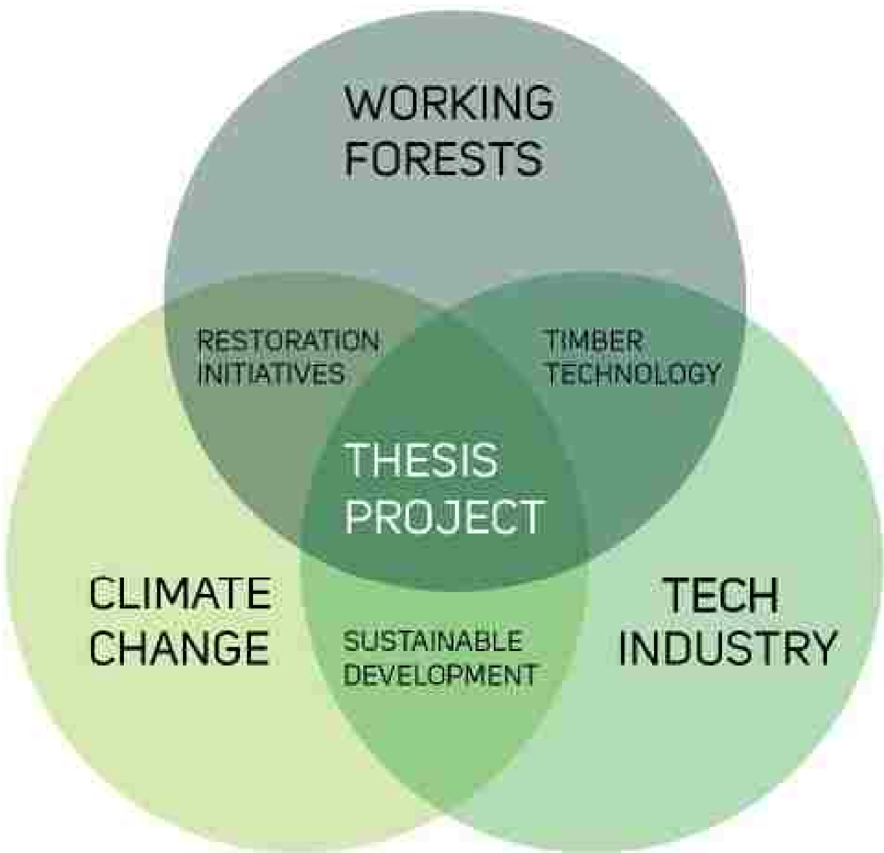

Figure 1. Intersection of Interests

CHAPTER 2. RESEARCH AND ANALYSIS

2.1 Problem: Climate Change

The most pressing issue of the 21st century is climate change, cause and effect. Climate change is defined as anthropogenic global warming, referring to long-term temperature changes to the Earth's surface & all associated effects, as caused by human activity[1]. Besides surface temperature increase, the quantifiable, documented effects include: warming and acidification of oceans, glacial retreat, decreased snow cover, sea level rise, extreme weather events, and dangerous levels of atmospheric carbon dioxide[2]. Environmental problems in the 21st century affecting both climate and society include harmful agricultural practices, temperature increases, increased severity of storms and natural disasters, deforestation, desertification, wildfires, drought, flooding, erosion, and loss of biodiversity. These issues, compounded by economic and socio-political factors, are driving up the cost of living and the cost of housing.

Weather pattern modifications linked to human activity have begun to cause widespread environmental damage in many forms, quantifiably affecting global food and housing security, and are projected to ramp up unless large-scale action is taken to reduce human-induced stress on the ecosphere. The evident way to address environmental degradation is environmental *restoration*. We all know trees naturally and effectively take carbon dioxide from the air and replace it with life-breathing oxygen, but the services offered by our woody green friends go far beyond fresh air. Wood products i.e. agroforestry is actually the least important function of forests from an environmentalist stand-point, but as we will see it is the strongest motivator for enacting change.

[1] *What's in a Name? Global Warming vs. Climate Change* (NASA, 2011), https://pmm.nasa.gov/education/articles/whats-name-global-warming-vs-climate-change

[2] *Climate change: How do we know?* (NASA), https://climate.nasa.gov/evidence/

2.1.1 The Carbon Cycle

The National Aeronautics and Space Administration is one of the leading authorities on atmospheric science and one of their principal interests is the study of carbon dioxide (CO_2) concentration. "A minor but very important component of the atmosphere, carbon dioxide is released through natural processes such as respiration and volcano eruptions and through human activities such as deforestation, land use changes, and burning fossil fuels. Humans have increased atmospheric CO_2 concentration by more than a third since the Industrial Revolution began (Figure 2). This is the most important long-lived 'forcing' of climate change."[3] The natural ability of trees to transform carbon dioxide molecules into carbon (in the form of wood fiber and foliage), and life-giving oxygen, proves to be an invaluable tool for balancing atmospheric conditions.

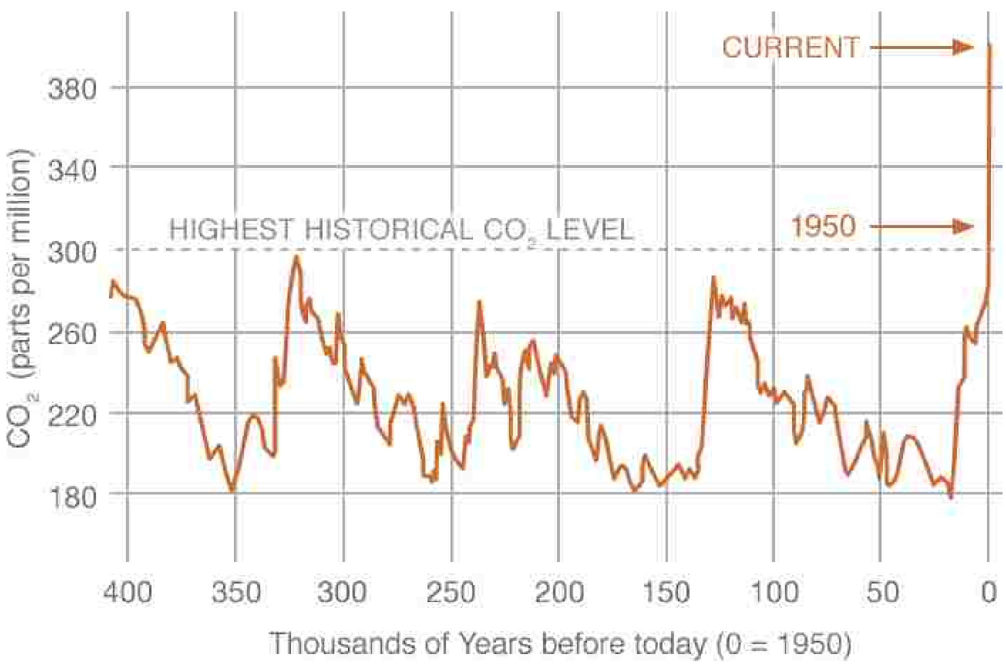

Figure 2. Historical Atmospheric CO2 Levels[4]

[3] *A Blanket Around the Earth* (NASA), https://climate.nasa.gov/causes/
[4] *Facts: Carbon Dioxide* (NASA), https://climate.nasa.gov/vital-signs/carbon-dioxide/

A general technical report entitled *Carbon Storage Accumulation in the United States Forest Ecosystems* by the National Forest Service, a subdivision of the United States Department of Agriculture, offers a succinct summary of the forest's role in combating climate change:

> "Analysis of forestry opportunities requires knowledge of carbon storage and accumulation in forest ecosystems. […] Forest ecosystems are capable of storing large quantities of carbon in solid wood and other organic matter. Forests may add to the pool of carbon dioxide in the atmosphere through burning of forest lands, deforestation, or decomposition of wood products and byproducts. Forests may also reduce the amount of [CO2] through increases in biomass and organic matter accumulation. Young, growing forests take up carbon at high rates, while carbon uptake in mature forests is balanced by carbon release from decaying vegetation. The end use of timber harvested from forests is an important factor in evaluating the contributions of forestry to the global carbon cycle. If the end uses of forest products are in long-term durable goods such as furniture or timber bridges, the carbon is stored in those materials. If the end use is for paper products that are rapidly used and discarded to decay, then the carbon is released to the atmosphere. Carbon in waste from the manufacturing process may be sequestered in landfills for long periods of time. When forest biomass is burned for energy it may be substituted for fossil fuels, which is an effective way to reduce the depletion of nonrenewable fossil carbon. **Because of the relation between forests and carbon dioxide, there are opportunities to manage forests in ways that would result in storage of additional carbon and thus reduce atmospheric carbon dioxide** [editor's emphasis]. Major forestry opportunities include increasing forest area, increasing the productivity of existing forest lands, reducing forest burning and deforestation, planting trees in urban environments, and increasing use of wood in durable products."[5]

[5] *Carbon Storage and Accumulation in United States Forest Ecosystems* (USDA Forest Service, General Technical Report WO-59, 1992)

2.1.2 Deforestation

Deforestation is a global threat, affecting each biome across the planet. In order to determine what can be done about it, a survey of the world's forests will be conducted to define the problem and a point of entry for a solution. After analyzing existing conditions, identifying threats to forest ecology, and assessing contemporary forest management practices, a solution can be formulated. Said solution may then be scaled up and modified to tackle the problem on a more regional basis.

In the 21st century, it is a widely-believed and scientifically demonstrated fact that "forests are essential to economic development and maintenance of all forms of life."[6] In 1992, the United Nations held a major conference on environment and development (UNCED), also known as the Earth Summit, in Rio de Janeiro, Brazil. It produced several important documents defining the imperative of conservation and responsible land management; the most significant one being Agenda 21: an extensive action plan for addressing the issues presented at the conference. University of Washington research done by Joyce Chen in 2009 summarizes the globally-defined relationship between forest ecology and climate change:

> "Chapter 11 of Agenda 21[7] [calls] to all nations for their 'urgent and consistent action for conserving and sustaining forests resources[8]' because 'forests world wide have been and are being threatened by uncontrolled degradation and conversion to other types of land uses, influenced by increasing human needs; agricultural expansion; and environmentally harmful mismanagement…[9]' In fact, global deforestation is occurring at about 13 millions hectares annually and contributes to 20 percent of all greenhouse gas emissions[10]. Agenda 21 recognizes 'the role of forests as national carbon reservoirs and sinks[11]' and encourages 'enhancing the protection, sustainable management and conservation of all forests, and the greening of degraded areas, through forest rehabilitation, afforestation, restoration and other

6 *Report of the United Nations Conference on Environment and Development* (United Nations General Assembly. A/CONF.151/26 (Vol. III). Preamble: (g) 1992)

7 *Agenda 21* (United Nations Conference on Environmental and Development (the Earth Summit), 1992)

8 *Agenda 21* (United Nations Conference on Environmental and Development (the Earth Summit), 1992), 11.12

9 *Agenda 21* (United Nations Conference on Environmental and Development (the Earth Summit), 1992), 11.11

10 Katia Karousakis, *Incentives to Reduce GHG Emissions from Deforestation: Lessons Learned From Costa Rica and Mexico*. (Organization for Economic Co-operations and Development (OECD), Paris, France: OECD/IEA, 2007), p8

11 *Agenda 21* (United Nations Conference on Environmental and Development (the Earth Summit), 1992), 11.14

rehabilitative means.[12]' […] The need to reduce deforestation by encouraging sustainable forest management practices and research programs to combat climate change is recognized and established."[13]

Deforestation is occurring worldwide, but each region faces a unique set of challenges. There are three basic types of forests, each corresponding to the planet's major climate zones. In the extreme northern (and southern) regions there is the Boreal Forest, characterized by very cold temperatures, primary precipitation being snow, acidic and nutrient-poor soil, dense evergreen conifers and limited understory. Higher temperatures are causing drought in Boreal forests, leading to forest fires. Thawing of the tundra is causing the carbon sink to become a carbon source. In temperate climate zones there are Temperate forests, which are characterized by well-defined seasons with a distinct winter, even annual distribution of precipitation, fertile soil due to decomposing plant litter, and a moderately dense canopy of deciduous and/or conifer trees permitting a diverse understory. Temperate forests are suffering tree deaths due to drought and water stress causing pests and disease, which in turn increase risk of wildfires. In regions closer to the Equator are found Tropical forests. Tropical forests are comprised of a great diversity of species and having only a wet and dry season with no winter. They are consistently hot with lots of rain, acidic and nutrient-poor soil, rapid decomposition, and a multilayered, continuous canopy. Threats to tropical forests include uncontrolled logging, slash and burn deforestation for agriculture, clear cutting for firewood, and resulting extinction of species both flora and fauna.[14]

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[12] *Agenda 21 (*United Nations Conference on Environmental and Development (the Earth Summit). 1992) 11.10.B.
[13]Joyce Chen, *Discovering and Developing Carbon Forest Indicators: Combatting Climate Change at the International Level (*University of Washington, 2009), 2
[14]Herbert Eldin, *The Illustrated Encyclopedia of Trees: Timbers and Forests of the World* (Harmony Books, 1978)

2.1.3 Drought

The principal threats to today's forests across the world are twofold. On one hand we have man-made deforestation such as clear cutting for agriculture or unsustainable logging. On the other hand, we have "natural" disasters causing destruction and widespread tree deaths by wildfire, disease, and/or pests. Technically, these environmental stresses are usually caused by drought, which, in turn, has been linked to human activity. Research by Birmingham University's Water Science Research Groups indicates that human activity has direct impact on drought. *WasteWater Treatment*, an online publication for water engineering, reports: "Direct effects of people on drought are water abstraction, reservoir building and water transfer. Indirect effects are changes to the land surface made by people that can affect the development of drought by altering hydrological processes. These can include evaporation from land to air (evapotranspiration) and the rate at which water penetrates the soil (infiltration), as well as surface runoff and storage of water. These direct and indirect influences can be long-term (big engineering projects for reservoirs or gradual urbanization) and short-term (more efficient irrigation methods, different crops). Short term adaptation to drought can decrease the severity of the next drought or even cause within drought changes influencing the drought end."[15]

Just as forests are linked to atmospheric carbon levels, they also play a major role in balancing environmental water, moisture, and precipitation levels. It all relates the biological function of evapotranspiration, i.e. the transformation of carbon dioxide into oxygen during the process of photosynthesis. The sun's energy catalyzes the conversion of CO2 into carbon-based cells (i.e. wood fiber), and oxygen is released from the leaves as a byproduct. Sunlight hitting the leaves causes evaporation of water in the leaves as well, inducing a stack-effect-like syphon drawing groundwater up through the stalk structure. The evaporation, on the landscape-level of a forest, eventually condenses to begin a precipitation cycle. Trees also play a role in water retention and drought prevention: their roots help maintain soil integrity on a nutrient level while providing the structural support of the root network resisting runoff and erosion.

[15] Maureen Gaines, *Human Activity Contributes to Severe Drought, Says University,* (Water & Wastewater Treatment News, 2016), http://wwtonline.co.uk/news/human-activity-contributes-to-severe-drought-says-university#.WuZ88Zch0uU

2.1.4 Wildfire

Forest fires are a natural phenomenon necessary for balancing ecosystems. However, today's fires are anthropogenic, and have much different effects. The Camp Fire of 2018 in Northern California was one of the most destructive fires in recorded history, and one of thousands burning across the PNW. The increasing severity of these fires is alarming, causing tens of thousands of people to be evacuated from their homes, hundreds of deaths, smog cover as far away as Seattle, and billions of dollars' worth of property damage. These fires are raising political controversy in the forestry community, calling attention to ineffective federal forest management regulations and ripe burn conditions they have resulted in. Mainstream news attributes these fires to the change in climate, but the data tells a different story: forest fire occurrences are significantly down from rates recorded toward the beginning of the twentieth century (Figure 4).

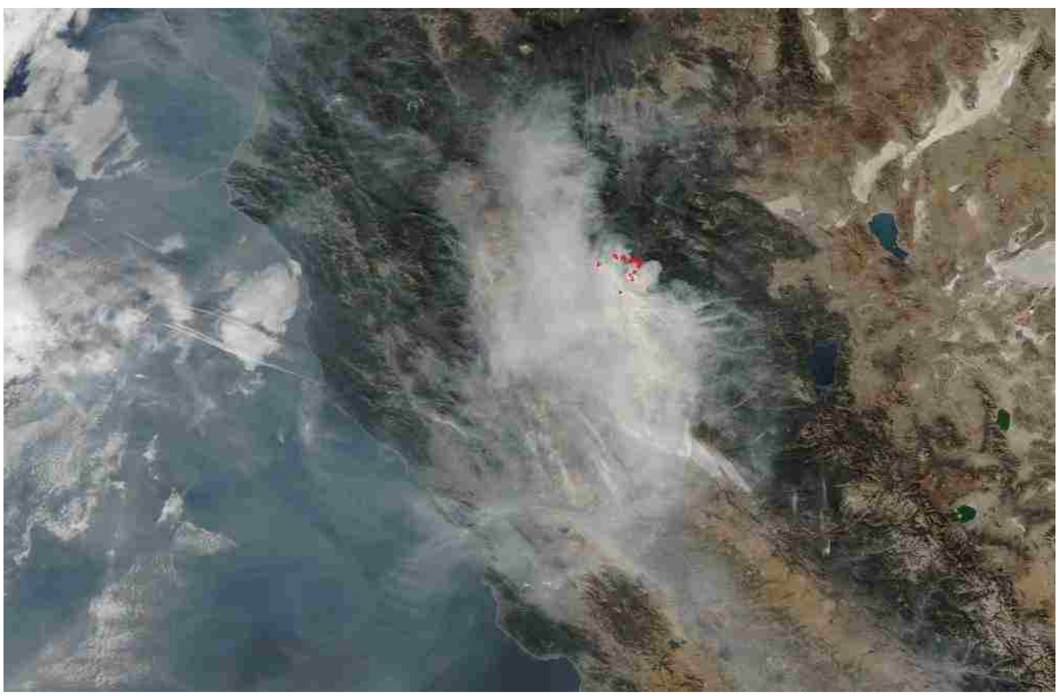

Figure 3. Camp Fire of 2018, Northern California[16]

[16]*California Shrouded in Smoke from the Ongoing Camp Fire* (NASA, 2018), https://www.nasa.gov/image-feature/goddard/2018/california-shrouded-in-smoke-from-the-ongoing-camp-fire

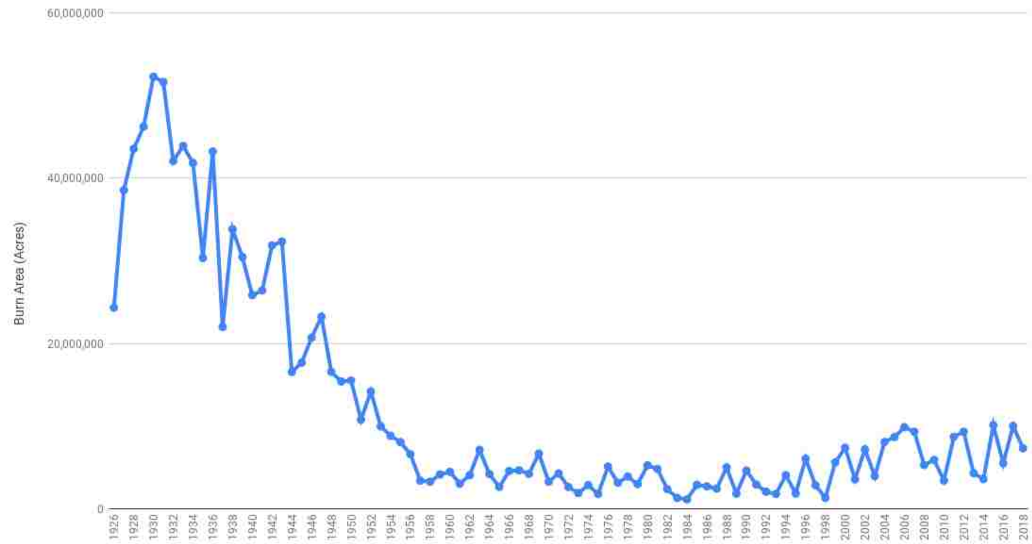

Figure 4. US Forest Fire Burn Acreage per year.[17]

Urban development over the last hundred years has fragmented and domesticated natural ecosystems. Human presence in timberlands has prevented naturally-occurring fires which cleanse the ecosystem of smaller vegetation competing for resources and re-fertilize the land. Radical environmental policies have severely restricted forest service on federal lands as a conservation effort. These factors have left forests across America in a state of decay, as natural processes are being interrupted, and they are overstocked with dead trees and over-populated leading to slow growth. When fires do start under these conditions, they tend to burn much hotter and deeper, causing damage to root and soil systems which should normally withstand wildfires. This deep damage disrupts natural regeneration mechanisms such as rhizomes, roots, and mycelium networks. Of course, they become harder to contain and tend to spread farther than they should.

Across the world, deforestation has resulted from destructive yet profitable agricultural practices including monoculture, chemical fertilizer & pesticide pollution, clear cutting, slash and burn, etc. The lack of trees can lead to erosion, poor air quality, desiccation/compaction of soil, and decimation of wildlife populations. Deforestation is a significant factor driving climate change, given its direct connection to atmospheric gas levels.

[17] *Criteria & Indicators for Forest Sustainability,* (USDA Forest Service, 2010), https://web.archive.org/web/20140913135647/http://www.fs.fed.us:80/research/sustain/criteria-indicators/indicators/indicator-316.php

Forests have a direct impact on environmental welfare, and demand for forest maintenance is outpacing land management capacity, leaving major opportunities for innovation and enterprise. For investors, there is the promise of a rich, tangible reward: fresh air, forested land, and salable timber. Advanced forestry practices have the potential to simultaneously purify contaminated soil, foster plant & animal life, cool & fertilize the ground, absorb & deflect UV rays, improve soil stability. Most importantly, because money makes the world go around, careful forest management can generate a continual supply of wood products and offer many other value-added services like public recreation, water system restoration, and salable carbon credits for offsetting industrial CO_2 emissions. With engineered wood products quickly becoming the most economical building material, planting new working forests and managing existing forest lands with a reinvigorated approach is bound to be profitable and have the bonus effect of double carbon sinkage: the embodied energy of mass timber construction and its associated forest biomass. Demand for rapid forest growth, as this paper will demonstrate, is growing faster than the trees.

2.2 Solution: Working Forests

2.2.1 Economic Incentives For Managing Forests

The ecological imperative to plant forests is evident; less evident are the social and economic implications of planting forests. Healthy Forests, Health Communities, a forest policy advocacy group, claims in its mission statement that "active and sustainable forest management on federal lands will create jobs in rural communities. It will help create economic opportunities for our struggling rural counties while protecting federal forests for the future." Expanding sustainable forest management programs is an effective way to restore not only the environment, but depressed rural economies as well. "Reliable data and the experience with state management of public forest land suggests that relatively modest timber harvest levels could generate county payments significantly higher than current federal subsidies while also providing tens of thousands of new jobs in rural communities."[18] With the U.S. population continually expanding and concentrating in metropolitan areas, supporting forestry activity in rural communities has many benefits. It is good for the environment and the economy, supports local economies, and the products of sustainable forest management have far-reaching impacts.

According to a 2003 study by the Forest Service's Pacific Northwest Research Station *An Analysis of the Timber Situation in the United States: 1952 to 2050*, "The [projected] 126-million-person increase in U.S. population by 2050 is accompanied by a 76-million increase in the number of households. In the past, each additional household consumed about 1 acre of land. These projections lead to about 40 million acres of total rural land being converted to urban/developed uses by 2050. If historical trends continue, 15 to 20 million acres of this land could come from forests. Population growth is projected to be strongest in the South and West, regions that contain the Nation's key timber supply areas" [19] This information indicates a deeper correlation of forests and housing beyond the basic relationship of wood to house. Forests are being torn down to make room for housing. It suggests yet another a demand for afforestation, perhaps even calling for implementation of new forestry practices to offset housing development. The housing aspect therefore offers a direct connection between forest conservation &

[18] *Issues* (Healthy Forests, Healthy Communities), healthyforests.org/issues/
[19] Richard W. Haynes, *An Analysis of the Timber Situation in the United States: 1952 to 2050* (U.S. Department of Agriculture, Forest Service. Pacific Northwest Research Station, 2003) 151

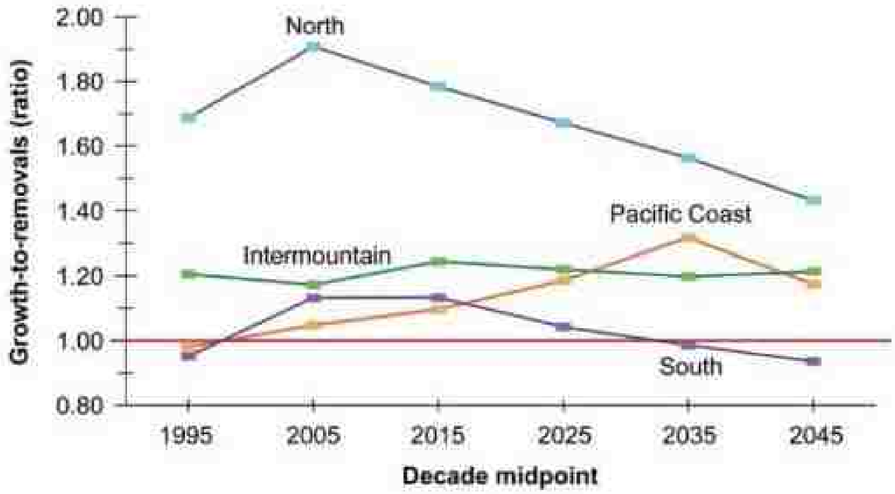

Figure 5. Growth-to-Removals Projection in U.S. Forests[20]

restoration imperatives, carbon sequestration, logging jobs, and timber demand. The *Analysis* projects a 40% increase in consumption of forest products by 2050, and US timber harvest is projected to increase 24%. The tree growth-to-removal ratio remains above 1.0 until 2050, but the ratio is getting worse every year (Figure 5).

Though the study offers calculated data for a variety of possible futures based on variable factors of market or policy influence, the *Analysis* makes its base projections on the predominant yet outdated housing model, i.e. single-family homes. Current economic trends and urbanist theory places people in higher density metropolitan situations. The closer together people live, the more efficient their lives can be. Efficiency drives affordability, the biggest concern for anyone seeking housing. Early modernist principles have long idealized cities comprised of high-density housing towers scattered among naturalistic surroundings. Modernist and New Urbanist principles perhaps lend themselves well to a housing typology of semi-rural, high-density communities based in a forest economy which directly satisfies the more universal needs for healthy natural habitat while sustaining economical needs for goods, services, and shelter. From a contemporary developer's standpoint, the economy of scale in high-density housing makes wood construction very attractive now that new developments have been made in fire ratings and building codes for mass timber structures.

[20] Richard W. Haynes, *An Analysis of the Timber Situation in the United States: 1952 to 2050* (U.S. Department of Agriculture, Forest Service. Pacific Northwest Research Station. 2003)

2.2.2 Innovation in Wood Building Systems

Of particular interest to the restoration economy is a new wood construction product called cross-laminated timber (CLT) or simply *mass timber*. CLT is a solid wood product made by laminating small dimensional lumber in alternating directions, resulting in a structural panel which can resist loads in two directions. Because of its bulk, CLT is naturally fire-resistant: fire can only into burn the first inch of solid wood. The charred outer layer can no longer burn, and forms a layer of char which protects the member's structural integrity. CLT is also praised for its high performance in earthquakes: because wood is lighter than concrete and more flexible, seismic forces are effectively reduced. The panelized nature of this product allows for improved efficiencies as it is prefabricated off-site in a controlled factory environment to reduce waste and improve efficiencies. The tectonics of a structural panel system allows CLT buildings to be erected very quickly, saving significant amounts of time and labor during construction.

Perhaps the most interesting aspect is CLT's carbon sequestration potential. Because wood fiber stores the carbon absorbed during photosynthesis, the more wood used the more carbon stored. This makes CLT a very effective driver for planting of new trees. Furthermore, because it is a composite material, dead and thin-diameter trees can be used to make it. CLT production can therefore motivate restoration by turning wood fiber removed in forest thinning operations into a valuable commodity. Fast-grown plantation lumber tends to be softer (less dense) and structurally weaker than old growth lumber, but this is overcome when pressing the lumber into panels with glue. Short rotations yield fast returns on investment.

As good as it sounds, it should be mentioned that CLT can only help if the lumber used to produce it is harvested sustainably. Forest Stewardship Council is the current industry-scale certification best practice, which mandates that two or more trees are planted for every tree cut, and is a good measure to ensure sustainability of wood products. Without sustainable management practices like this, CLT runs the risk of causing more ecological harm than good: the fastest return on investment in business-as-usual is plantation of monocultures which are clear-cut as fast as possible. This is why development and implementation of better forest management practices is crucial. Luckily, as we have seen, there are a multitude of incentives, including financial, to maintain a symbiotic relationship between business and ecology.

Figure 6. Brock Commons Tallwood House by Acton Ostry Architects[21]

As proof of concept, The University of British Columbia has recently completed a ground-breaking eighteen-story timber tower to house new dormitories (Figure 6). The building is significant because it stores 1750 metric tons of carbon in its walls and saved another 650 metric tons of carbon by streamlining construction process: the structure was erected in only 66 days![22]

Timber towers, a new building typology enabled by mass timber, are popping up across the world in any place that can work around the politics of the international building code which has until recently prohibited tall wood buildings due to fire safety. In the Society of Wood Science & Technology's study entitled Insights into the Global Cross Laminated Timber Industry, building codes were identified as the primary barrier to construction of mass timber buildings (Figure 7). Fortunately in 2018 the International Building Code was amended to allow wood structures up to 18 stories, a major breakthrough with huge implications for the construction industry[23].

[21] Acton Ostry Architects, (https://www.actonostry.ca/type/brock-commons/, 2017)
[22] Acton Ostry Architects, (https://www.actonostry.ca/type/brock-commons/, 2017)
[23] *Code Officials Move to Update IBC For Tall Mass Timber Buildings* (https://csengineermag.com/code-officials-move-update-ibc-tall-mass-timber-buildings/, 2018)

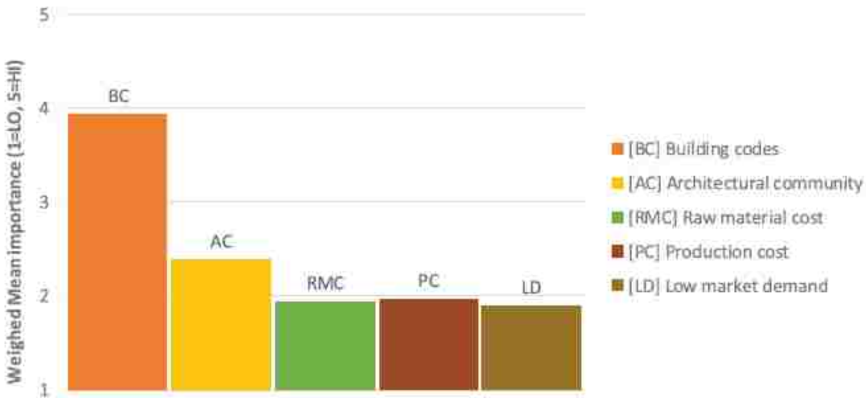

Figure 7. Barriers to CLT Market Growth[24]

These new trends in building construction are directly impacting the CLT market. An online publication by an organization of resources for the advancement of the Oregon CLT industry reports, "What's clear is that the hurdles to using wood in tall buildings are beginning to be removed. Access to certified material at a competitive price, modernizing of building codes, and technical capacity in the industry are all improving daily. So, it's easy to see why analysts predict the market for Cross-laminated timbers (CLT) in the U.S. With an abundance of renewable raw material to supply the market, tall wood buildings will be a growing presence in the market."[25]

2.2.3 The Building Industry

There are many legitimate and pressing reasons to proliferate forests, but the basic function of wood as a building material is ultimately the forest's most valuable asset and thus the most influential driver for forest management initiatives. Forests supply the essential building blocks of life on earth but also the material building blocks of human dwelling, even in the 21st century. Wood is an age-old material with thousands of years of building tradition and accumulated knowledge, but modern technology consistently improves upon its usefulness. Though contemporary buildings are typically made of concrete, masonry, or steel, there is a reemergent interest in wood building systems. Popular Science magazine made the declaration in a 2014 article titled *The World's Most*

[24] Lech Muszynski, Eric Hanse, Shanuka Fernando, Gabriel Schwarzmann, Jasmin Rainier, *Insights into the Global Cross Laminated Timber Industry* (Society of Wood Science & Technology, 2017)

[25] Oregon CLT, *The Market for Tall Buildings Heats Up* (https://oregonclt.com/the-market-for-tall-wood-buildings-heats-up/, 2015)

Advanced Building Material is… Wood. The article showcases projects already on the boards, singing praise for timber towers of cross-laminated timber which can be designed for up to forty floors. The author recounts, 'Even in the world's largest cities, only a handful of buildings are taller than 40 floors. 'A huge chunk of the market is viable. New York is a high-rise city, but it's not that tall,' says William F. Baker, who oversaw the Skidmore [CLT] study with project engineer Benton Johnson. 'We could handle most of Manhattan.' […] 'Wood is the new concrete,' says de Rijke, of dRMM. 'Concrete is a 20th-century material. Steel is a 19th-century material. Wood is a 21st-century material.'[26]

The timber industry became self-aware in the first half of the twentieth century upon the realization that cutting down trees was perhaps unsustainable when old-growth timber stock in the North-West started to dwindle as a result of the post-war housing boom. Since then the US government has implemented regulation to protect remaining forest resources by overseeing responsible timber harvest. In response, new methods of forestry have been developed and mandated to make sure there was always a plentiful supply of timber. But because old growth wood was becoming less widely available come mid-century, the industry adapted to using new-growth timber and began developing new products to economize on underutilized forest resources. Now known as engineered wood products, these include plywood, oriented strand board, laminate flooring, truss-joists, glue-laminated beams, parallel strand and laminated veneer lumber, medium-density fiberboard moldings, particleboard, lignin-based adhesives, not to mention cross-laminated timber (CLT)… the list is exhaustive. Thin-diameter trees are now used ubiquitously for dimensional framing lumber, sheet goods, siding, trim, etc. With such an array of standardized wood products available, there is plenty of opportunity to replace expensive, carbon-intensive building materials with the renewable option.

Wood remains the most economical building material in most markets, and contemporary technology is continually making wood products more durable and finding new ways to use every part of the tree. Wood can be engineered to be stronger than expected, but the more significant strength is that the timber required to manufacture most engineered wood products can be of grade and species not typically acceptable for construction-grade wood products. This means that young, fast-growing trees, damaged or dead trees, and otherwise unusable tree waste for particulate composites, biofuels, etc. have all been commodified, which is a boon for wildfire prevention efforts

[26] Clay Risen, *The World's Most Advanced Building Material is… Wood,* (Popular Science, 2014), https://www.popsci.com/article/technology/world%E2%80%99s-most-advanced-building-material-wood

because it creates a profit incentive to remove flammable biomass from federal lands. The other major appeal is that expedited pre-fab construction granted by panelized wood technology holds promise for minimizing on-site construction time and labor costs while being structurally, financially, and safety-wise competitive to concrete or steel. Cross-Laminated Timber (CLT), aka "Mass Timber" has the added benefit of carbon sequestration, being a carbon-negative material by nature. Figure 8 shows that new wooden buildings between 7-15 stories tall are projected to require 1.6-2.4 billion board feet per year, but will save 7-10 millions of metric tons of CO2. The carbon savings here per-year is equivalent to almost 3 coal-fired power plants being shut down for a year. A series of case study projects are presented by architect Susan Jones, professor at the University of Washington and activist in mass timber building code policy, documented in her book *MASS TIMBER: Design and Research*. Her research quantifies the potential of CLT buildings to sequester carbon and save construction costs across several types buildings, and the findings demonstrate that CLT can indeed live up to its various expectations in each type of building studied.[27]

	Approximate additional wood volume annually (billion board feet)	Additional annual carbon benefit [b/] (million metric tons CO_2e)	Equivalent number of passenger vehicles off the road for a year	Equivalent number of coal fired power plants shut down for a year
Low-rise nonresidential [a/]	4.5	19	4,100,000	5
Multifamily [a/]	0.7	3	700.000	1
U.S. buildings 7 to 15-stories	1.6-2.4	7-10	1,500,000 - 2,200,000	2-3
Aggregate	6.8-7.6	29-33	6,300,000 - 7,000,000	8-9

Figure 8. Carbon Implications of Increased Use of Wood in US Construction[28]

[27]Susan Jones, *Mass Timber: Design and Research* (ORO Editions, 2017)

[28] Jim Bower, *Modern Tall Wood Buildings: Opportunities for Innovation* (Dovetail Partners Inc., 2016), 9

2.2.4 Sustainable Development

Established forestry practices have maintained a sufficient supply of timber, enough even to support the exponential increase in CLT production volume. Despite the ongoing need to be planting trees to combat environmental threats demonstrated earlier, industrial timber harvest is generally sustainable in the united states. Dovetail Partners, a source of environmental information, released study that again finds the ratio of growth to removals to currently be around two to one (Figure 9).

The report affirms the link between mass timber construction and the greater ecological economy, stating "Tall wood buildings offer an opportunity to connect rural resources with urban communities in a manner that has the potential to support forest restoration, drive green building, and address carbon emission reduction objectives. Wood is also renewable, further enhancing it as a 21st century building material."[29] To elaborate on the concept of connecting urban communities with rural resources, which in this case refers chiefly to supplying the housing

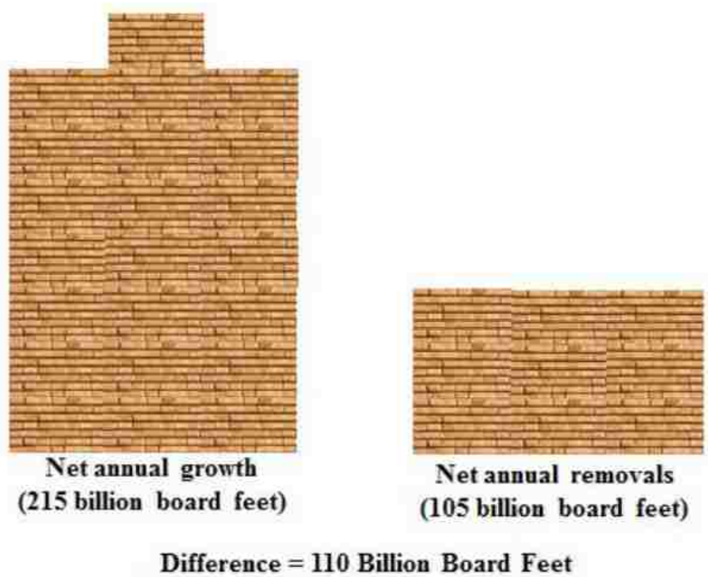

Figure 9. US Forest Growth-to-Removal Ratio in 2012[32]

[29] Jim Bower, *Modern Tall Wood Buildings: Opportunities for Innovation* (Dovetail Partners Inc., 2016), 8

market with lumber but also to the bigger picture of supplying the general population with clean air and water, the *Timber Situation* analysis, again, offers direction:

> "Markets have played and can be expected to continue to play a central role in shaping the forested landscape of the United States. Markets for timber and forest products are, therefore, an integral component of forest management. Opportunities to sell a variety of goods and services can be one of the most powerful incentives to use management practices that sustain a diversity of forest conditions and outputs."[30]

In particular, the market for CLT holds huge potential for growth. A recent study by Hancock Timber Resource Group cites a tripling of CLT production from 2008 until 2016 (Figure 11). Based on timberland market indicators, the study forecasts that the CLT market will boost US softwood lumber demand by 12 percent *per year*.[31] The CLT industry is expected to make $4 billion annually.

[30] Richard W. Haynes, *An Analysis of the Timber Situation in the United States: 1952 to 2050* (U.S. Department of Agriculture, Forest Service. Pacific Northwest Research Station. 2003), 188
[31] *A Potential New Source of Demand for U.S. Timber: CLT* (Hancock Timber Resource Group, 2017), 4.

	Approximate additional wood volume needed	
	Billion board feet (Bbf)	Million cubic meters (m³)
Low-rise nonresidential [a/]	4.5	10.6
Multifamily [b/]	0.7	1.7
U.S. buildings 7-15 stories	1.6-2.4	3.8-5.7
Aggregate	6.8-7.6	16.0-17.9

Figure 10. Potential Increase in Annual Use of Wood in US Construction[32]

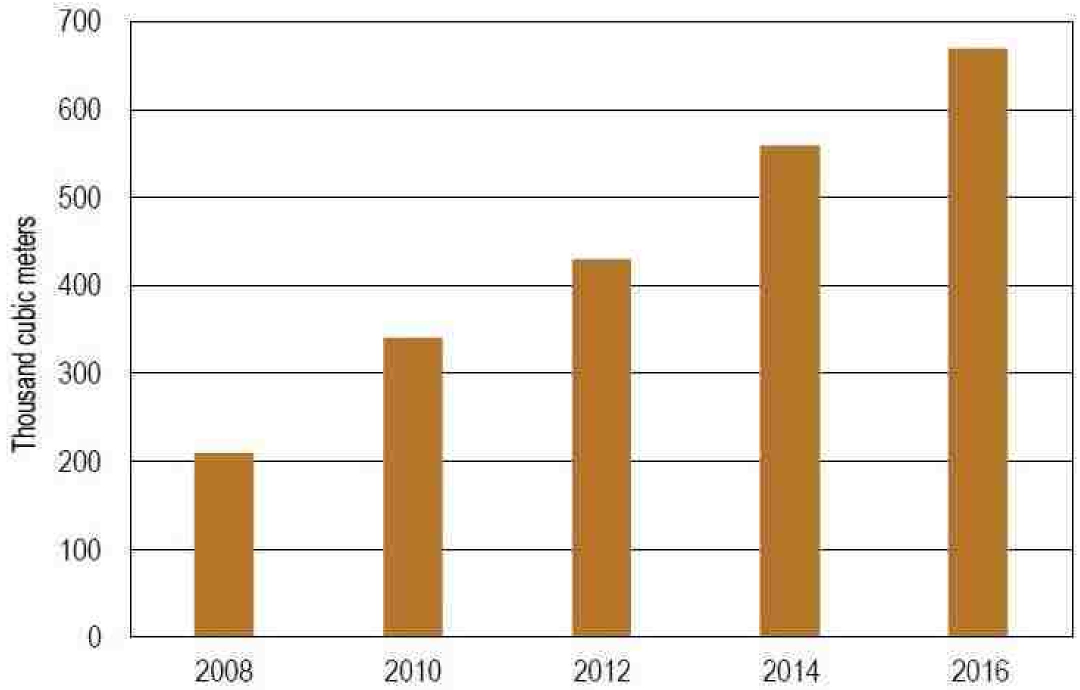

Figure 11. Global CLT Production Tripled in Last Eight Years[33]

[32] Jim Bower, *Modern Tall Wood Buildings: Opportunities for Innovation* (Dovetail Partners Inc., 2016), 9
[33] Jim Bower, *Modern Tall Wood Buildings: Opportunities for Innovation* (Dovetail Partners Inc., 2016), 8

2.2.5 Economic Implication of New Forest Products

Recent reports indicate a trend of lumber mills closures across the United States **(figure 12)**[34] However, new production plants have been popping up to supply the growing CLT market. IN 2015 Dr. Johnson Lumber Co. has opened a CLT and glue-lam facility in Oregon called Riddle Laminators. Treehugger.com's article on the company reports that "Many industry leaders and Oregon policymakers view the development of CLT as serving two important objectives: advancing sustainable building design and promoting rural economic development. The product creates a new market for struggling Oregon sawmills and a new technology for developers who are eager to further reduce carbon emissions tied to buildings. Until now, however, the U.S. market has been slow to materialize. 'The market for CLT is growing,' said [President Valerie] Johnson. 'We are either under contract or in design conversations with over a dozen projects along the West Coast. Demand is there, and we expect other manufacturers may enter the market soon.'"[35] A 2017 press release by a successful construction tech start-up called Katerra announced plans to open a large CLT facility in Spokane, Washington, which will create more than 150 construction-related manufacturing jobs in the region[36] and additional local forestry jobs of all kinds. Projections for manufacturing jobs created by Oregon's CLT market range from 2000 to 6000 new jobs. (Figure 13)[37]

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[34] *Washington Mill Survey 2016* (Washington State Department of Natural Resources, 2017)
[35] Lloyd Alter, *Cross Laminated Timber Now Made in the USA,* (treehugger.com, 2015), https://www.treehugger.com/green-architecture/cross-laminated-timber-now-made-usa.html
[36] *Katerra Announces New Mass Timber Facility (*Katerra, 2017) https://katerra.com/en/who-is-talking/press/2017/press-releases/CLT-Factory.html/
[37] *Advanced Wood Product Manufacturing Study for CLT Acceleration in Oregon and SW Washington* (Pacific Northwest Manufacturing Partnership, 2017)

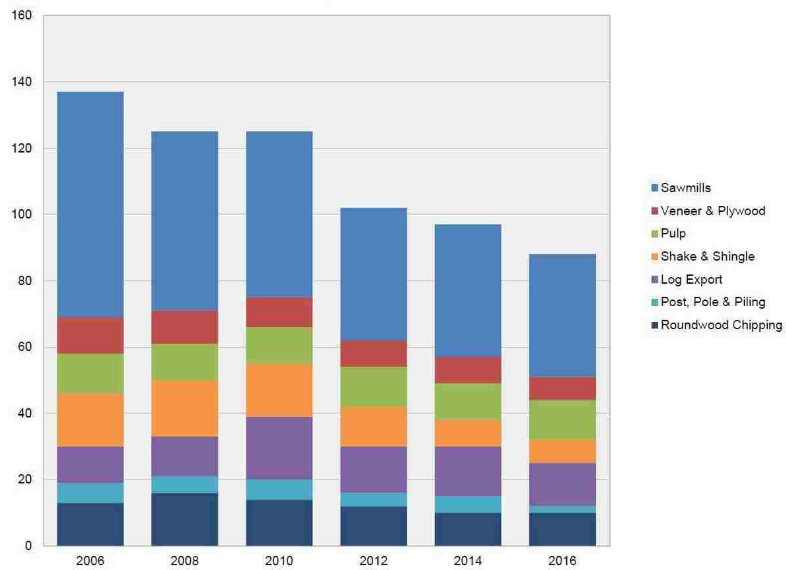

Figure 12. Decline in WA Forest Product Facilities: Mill Count Per Sector[38]

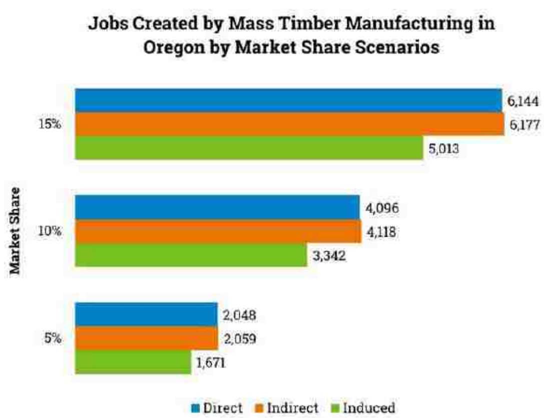

Figure 13. CLT Job Potential in Oregon[39]

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38 *Washington Mill Survey 2016* (Washington State Department of Natural Resources, 2017) 2

39 *Advanced Wood Product Manufacturing Study for CLT Acceleration in Oregon and SW Washington* (Pacific Northwest Manufacturing Partnership, 2017)

From a business standpoint, the beauty of a forest ecology is that a wide variety of products are available to sustain the forest economy. CLT is the biggest buzzword in wood construction, but it doesn't work in every application. Stick frame construction is still more efficient for single family homes and low rise housing, maintaining a steady demand for conventional dimensional lumber. There are many other very efficient engineered wood products on the market today. Glu-laminated beams are made in a similar fashion with young timber, working into traditional wood framing systems where old-growth heavy timber beams would have been. Truss-joists, with fir chords and plywood or pipe metal webbing, make very economical and efficient floors. Plywood is of course infinitely useful, and it's made from veneers peeled off thin trees. Parallel strand lumber, oriented strand board, medium density fiberboard, etc…. All these products have been engineered to best serve their respective uses while making use of every scrap, chip, and sawdust from the tree.

These engineered wood products are good for the job market by reinvigorating small rural economies by providing high tech forest-products sector jobs in land management, manufacturing, sawmilling, logging, forestry, IT, and even robotics. Emerging technologies are responding to increasing demand with GPS and GIS based data analysis for planning and management, drone-assisted surveillance and planting, and automated logging robots for harvesting operations. These principals shall be described in chapter 3.

Housing demand is driving timber sales, incentivizing forest management, and forests improve ecological and environmental conditions. With this combination of knowledge, it can be deduced that sequestering carbon is the first thing we can do to mitigate global warming and the damage it is projected to cause. Add into it the factor of construction-related carbon footprints & the economies of new forest products & building technologies, and a viable solution begins to emerge. This research draws connections between the fields of restoration initiatives, timber technology, and sustainable developments, with the premise that overlapping spheres of influence can inform a sweeping, cohesive solution which benefits each sector in a symbiotic manner (figure _). As a result, environmental restoration becomes more attractive than fast money.

2.2.6 Enter the Restoration Economy

The inter-dealings of forest product companies, conservation groups, land trusts, government agencies, private landowners constitute what has become known at the *restoration economy*. Opening remarks in a 2018 journal from the World Resources Institute states "We are optimistic that the restoration economy will continue to expand, simultaneously creating financial, social, and environmental value."[40] Report after official reports cite the need for public-private partnerships and other measures of improving efficiency in contemporary forest management practices: The *Proposed Strategic Plan for Washington State Forest Products Sector 2017-2019* declares it's program's mission to preparing a 21st century workforce to meet new industry needs, to foster public/private partnerships, and to grow & diversity Washington's wood industry. It explicitly calls for entrepreneurship and networking[41]. *The Advanced Wood Product Manufacturing Study for CLT Acceleration in Oregon and Southwest Washington* concludes that changes in production capacities and dominant technologies are necessary for global CLT production and emphasizes the role of innovation systems in implementation strategies. The study concludes that more research is needed regarding businesses positioned within existing or potential value chains of the CLT industries in various regions. [42] *The Nationals Action Plan: National Cohesive Wildland Fire Management Strategy* likewise calls for strengthening of national mobilizations capabilities by seeking means to assist private landowners manage forest fuels, and it recognizes the economic opportunities in forest thinning.[43] Forest fuels include dead mature trees (such as killed by invasive beetles or drought), and general thinning of tree limbs (which can be used for engineered lumber) improves forest growth by improving light penetration to younger trees. Reducing fire by planting and maintaining healthy, productive working forests is a triple bottom line pathway to a greener future. In other words, forest management achieves economic, humanist, and ecological objectives.

The literature all points to the profitability and ecological imperative of managing lands public and private for forest products. The strive for cooperation and efficiency is a recurring theme. With an architectural intervention at systems-level, connections can be made to update American forestry practice to the latest and most effective methods. The result of introducing a real-estate incentive to unite forest management with the building industry is a proactive countermeasure to the biggest issues facing people in the 21st century. The inter-dealings of forest product companies, conservation groups, land trusts, government agencies, private landowners constitute what has become known at the restoration economy. Opening remarks in a 2018 journal from the World Resources Institute declares

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[40] *The Business of Planting Trees: A Growing Investment Opportunity* (World Resources Institute, The Nature Conservancy, 2018), 6

[41] *Proposed Strategic Plan for Washington State Forest Products Sector 2017-2019* (State of Washington Department of Commerce, 2018), 5

[42] *Advanced Wood Product Manufacturing Study for CLT Acceleration in Oregon and SW Washington* (Pacific Northwest Manufacturing Partnership, 2017)

[43] *The National Action Plan: National Cohesive Wildland Fire Management Strategy* (US Department of the Interior, Environment, and Related Agencies, 2014)

“We are optimistic that the restoration economy will continue to expand, simultaneously creating financial, social, and environmental value.”

Figure 14. Various Studies Calling For Industry-Driven Restoration Initiatives

Of all the various forest products available, from paper to carbon offset credits, CTL is probably the most promising in terms of partnering up community of interests and industries. CLT is entering the market the end of the post-industrial era entering the digital age, and correspondingly, its manufacture requires companies to update from conventional lumber business models to 21st century project management technology. The current best practice in architectural design is building information modelling (BIM), digital data management tools to facilitate integrated design processes (IDP) and integrated project delivery (IPD). IPD and IDP are giving architects a stronger influence on the built environment and consequently the natural environment. The architect’s traditional role is to manage human behavior by manipulation of natural resources, and today he can be empowered to do so on the next level with mass timber. Mass timber is generating an economy in itself (Figure 15), and is on trajectory to become the driving force behind the restoration economy.

Figure 15. CLT Supply Chain[44]

[44] *Insights into the Global Cross-Laminated Timber Industry* (Society of Wood Science & Technology, 2017)

2.2.7 Further Analysis

CLT presents a variety of compelling reasons to build with it. However, there are studies indicating that CLT manufacturing can be even more carbon-intensive than steel if the lumber is not produced to FSC standards or better. Again, responsible forest management is critical to CLT's capacity to combat atmospheric carbon levels, as much of the carbon storage needed to make a difference happens in the forest's vegetation and soils rather than just the wood fiber from tree trunks. It should be noted that when accounting for carbon sequestered by supporting forests, CLT is still more earth-friendly than building with steel or concrete. Traditional stick-frame wood construction with small dimensional lumber remains the best choice for small structures, but efficiencies gained by economies of scale, ease of construction, and density (more stories per building) make CLT a more appropriate choice from an economic and life-safety standpoint. CLT is a composite material made of small diameter lumber, meaning it can be made from young trees. This means there is a quick return on investment, with trees for CLT only needing 20-40 years of growth before harvest. Dead trees and other forest-thinning products can be used in addition to freshly cut lumber. However, because of the ease of using young trees, there is a risk of monocrop plantation and clear-cutting which can cause more harm to the environment than good.

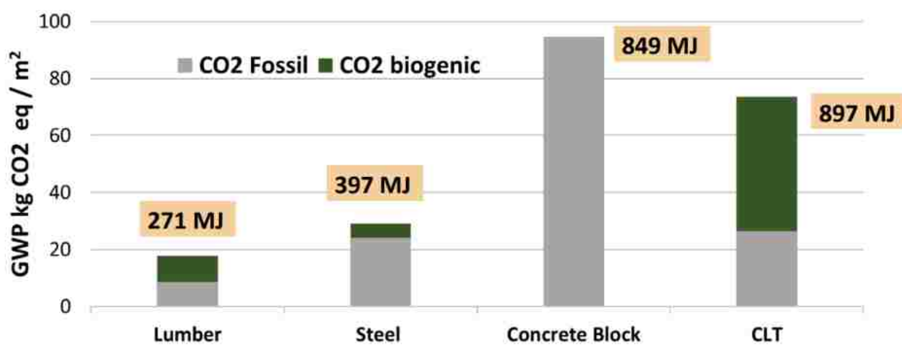

Figure 16. Carbon Emissions per Sq. Meter of Wall[45]

Even with promising statistics in favor of CLT, it is important to make sure the lumber is produced

[45]Maureen Puettmann, *Life Cycle Assessment Can Improve Decisions to Optimize Wood Use* (Woodlife Environmental Consultants, Consortium for Research on Renewable Industrial Materials, 2018)

sustainably. Studies suggest that CLT can be as carbon-intensive to produce as steel, if not enough trees are re-planted to offset production emissions (Figure 16).[46]

New research from Ecotrust and the University of Washington has concluded that long-rotation harvests (75-90 year tree age) managed with generation ecological retention and riparian zone buffers can improve the carbon-sequestration potential of forests as well as lumber lumber yield by almost a factor of two per year compared to conventional 40-year rotations. This research is making a case for heavy timber, that is, solid sections of wood for beams and columns, being the most sustainable choice of all construction systems. This is assuming FSC certification or similar standards for bio-retention and tree replacement protocols… intelligent forest management is crucial to sustained profits and ecological integrity. This data is very interesting, as it has been assumed for a while now that harvesting older trees was unsustainable, making heavy timbers prohibitively expensive to build with for most applications. In light of this new research, heavy timber construction is suddenly relevant again. It will take some adjustments of business practice to make long-rotation harvests competitive to short rotations, but a simple device such as carbon offset sales could be implemented to close the gap.[47] Once again, innovative solutions are continually being developed to improve sustainability and business feasibility. Let's take a look at some of these innovations.

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[46] Maureen Puettmann, *Life Cycle Assessment can improve Decisions to Optimize Wood Use* (Woodlife Environmental Consultants, Consortium for Research on Renewable Industrial Materials, 2018)
[47] David D. Diaz, Sara Loreno, Gregory J. Ettl, Brent Davies, *Tradeoffs in Timber, Carbon, and Cash Flow Under Alternative Management Systems for Douglas-Fir in the Pacific Northwest*, (Ecotrust, 2018)

2.3 The Tech Industry

This section will present several case-study companies in the restoration economy which are already positioning themselves accordingly. Katerra is a prime example of a company that is innovating by implementing all of the tools available in the new era. Describing themselves as a technology firm, they offer a complete range of in-house products and services in many sectors of the forest economy represented above, including CLT manufacturing, engineering, project management, construction management, architecture. Their IPD process for off-site construction is experimental and aims to optimize "every aspect of development, design, and construction to transform the way buildings and space come alive."[48] The start-up was founded in 2015 and by 2018 had raised 1.1 billion in investments, had 1500 employees, and had opened the first CLT plant in Washington State[49]. The apparent interest in the business model reaffirms that the construction industry market is moving toward the tech-industry model of service based companies using information technology and data management to sell products for distributed vendors.

2.3.1 Innovations in Forestry Business Models

The Nature Conservancy's *Business of Planting Trees* report conducted case studies of companies serving the restoration economy and provides descriptions of their services and analysis of their business models[50]. Of the wide range of business types represented in the report (categorized by technology, consumer products, project management, and commercial forestry), several businesses are directly involved with on-the-ground planting and management initiatives. Some of the highlights include BioCarbon Engineering, who uses specialized drone technology to reforest remote landscapes, Brinkman and Associates, who manages private plantations and federal projects, Lyme Timber Co., which manages conservation investments and sustainable timber plantations, and Komaza, which works with small farm owners to plant and process trees for timber. These companies each offer specialized services to private clients to aid in managing their land for forest products.

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[48] *https://katerra.com/en.html*

[49] Michael J. de la Merced, *Katerra, a Construction Start-Up, Raises $865 Million* (New York Times, 2018) https://www.nytimes.com/2018/01/24/business/dealbook/katerra-softbank-vision-fund.html

[50] *The Business of Planting Trees: A Growing Investment Opportunity World Resources Institute,* (The Nature Conservancy, 2018)

On the financial side of things, various business models are emerging for land management and sustainable forestry backed up by real estate development. For instance, Weyerhaeuser Timber Company has established a program for selling plots of working forest land to prospective home owners for low cost on the condition that the company may periodically manage the forest and harvest timber from it. In this model, all three aspects of the problem are directly addressed on one building site: people are housed, forests are managed, and economy is made. Though the model is currently sized for small plots suiting single-family residences, it could conceivably be scaled up for multi-family dwellings wherever the economy can support density.

Another new model is *distributed plantations*, where a corporate umbrella organization manages and sells timber on behalf of small private forest owners. It is similar to the tech-industry model used by Amazon.com, where a management corporation handles and distributes the wares of smaller sellers in the marketplace. Komaza is one such company, whose slogan is "revolutionizing African forestry by building a 'virtual plantation' across tens of thousands of smallholder farms."[51] It works with farmers to sustainably grows woods which are in high demand and limited supply, providing over 9000 farmers with income from their land.[52]

There is also a market for capitalizing on *conservation easement* opportunities, which entails making a deal with local or federal governments to allow sustainable developments to occur on protected forest land, on the condition that the developer manages the land according to strict conservation principles and protects it from further development. Lyme Timber Company LP sells such conservation easements across the united states as a way to finance deeper conservation efforts. Each of their six major land holdings has an associated Lyme-owned forest management company situated locally to carry out conservation programs and selective harvesting. They are a good example of a shift in the paradigm of traditional corporate timber companies to timberland investment management groups and real-estate investment trusts (Figure 17), which empower small land owners.

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[51] *https://www.komaza.com*

[52] *The Business of Planting Trees: A Growing Investment Opportunity World Resources Institute,* (The Nature Conservancy, 2018)

Figure 17. Changes in Forestland Ownership.[53]

Another exemplary company is Brinkman & Associates, who plants trees for corporate and government contracts. As a social service, it also partners with indigenous communities to foster partnerships for sustainable development. Brinkman started planting trees for the Canadian government in the 1970s and has made many developments in planting techniques[54]. The company has planted 1.4 billion trees as of 2018, and its estimated revenue for 2020 is $44 million dollars. The *Business* report considers Brinkman & Associates a replicable business model.

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53 *The Business of Planting Trees: A Growing Investment Opportunity World Resources Institute,* (The Nature Conservancy, 2018)

54 http://www.brinkmanreforestation.ca/about-us-reforestation

2.3.2 Emerging Forest Management Technologies

Information technology (IT) is huge for forestry, just as revolutionary in this field as it was in computer- and internet-based industries. All major timber companies and federal land management agencies use Geographic Information Systems (GIS) and Global Positioning Satellites (GPS) for surveillance and monitoring of every type of data describing a forest. LIDAR uses 3D laser scanning to generate point-cloud maps for 3D modelling topography, ground cover, and tree stock species, positions & diameters (Figure 18). Many other types of sensory scanning are being developed for high-resolution data imagery such as 'hyperspectral, multitemporal landsat imagery' which can be used to map forests by tree species (Figure 19).

CT scanning (Figure 21), similar to medical body scanning, is now being utilized to make cut charts for tree felling and lumber milling. By knowing the precise location of knots and other defects inside a log, the cutting pattern can be optimized for maximum board-footage yield. Similarly, by knowing where the strongest wood grain orientation lays, boards can be cut to optimize structural performance.

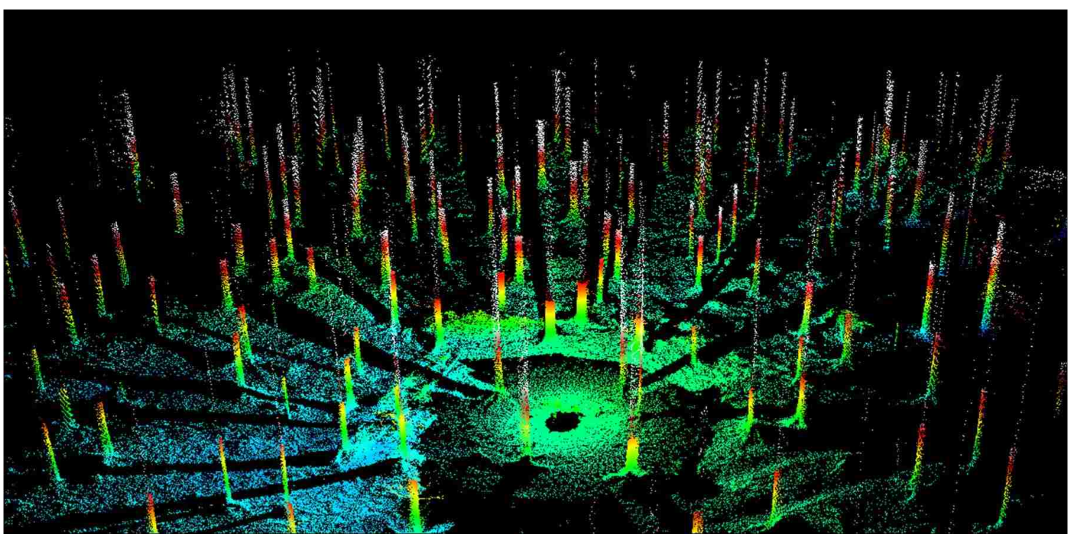

Figure 18. Terrestrial LIDAR Scan Mapping Tree Locations and Trunk Diameter[55]

[55] *WW-IRIS: New Technologies to Optimize the Wood Information Basis – Developing an Integrated Resource Information System* (Faculty of Environmental Sciences and Natural Resource Management, 2010)

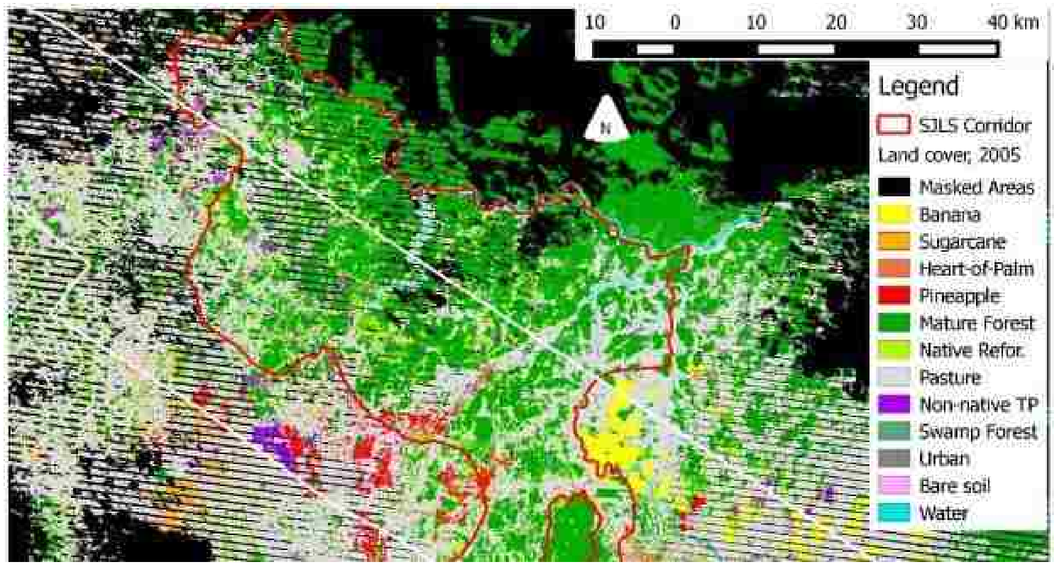

Figure 19. Mapping Tree Inventory by Species[56]

Figure 20. LIDAR Forest point cloud model[57]

56 Matthew Fagan, Ruth DeFries, Steven Sesnie, J. Pablro Arroyo-Mora, Carlomagno Soto, Aditya Singh, Phili Townshend, Robin Chazon, *Mapping Species Composition of Forests and Tree Plantations in Northeastern Costa Rica with an Integration of Hyperspectral and Multitemporal Landsat Imagery* (Remote Sensing, 2015)

57 www.3dforest.eu

Figure 21. 3D model of log produced by CT scan for most efficient milling[58]

Now that forest data exists in the digitally, companies like Komastu Forest (a sub-division of Komaza) are inventing ways to use this data to generate management and harvesting plans. Komatsu is primarily an industrial equipment manufacturer, but they have also been developing a cloud-based forestry software interface for harvest analysis, inventory quantification, cut planning, etc. (Figure 22). This makes their fleet management services more effective, adding digital precision and algorithmic analysis to strategic harvesting based on GIS, GPS, and LIDAR data.

Many other forestry equipment companies are producing automated logging machines now that this information technology is available. Logging can be one of the most difficult and dangerous jobs, and robotic equipment is designed to improve site accessibility, operator safety, labor costs, and line efficiencies. There is also software to control automated and remote-controlled logging machinery equipped with LIDAR scanners for awareness of forest conditions, tree location coordinates and trunk diameters, machine/tool paths, etc.

[58]Federico Giudiceandrea, Alexander Katsevich, Enrico Ursells, *A Reconstruction Algorithm is a Key Enabling Technology for a New Ultrafast CT Scanner* (Siam News, 2016) https://sinews.siam.org/About-the-Author/a-reconstruction-algorithm-is-a-key-enabling-technology-for-a-new-ultrafast-ct-scanner

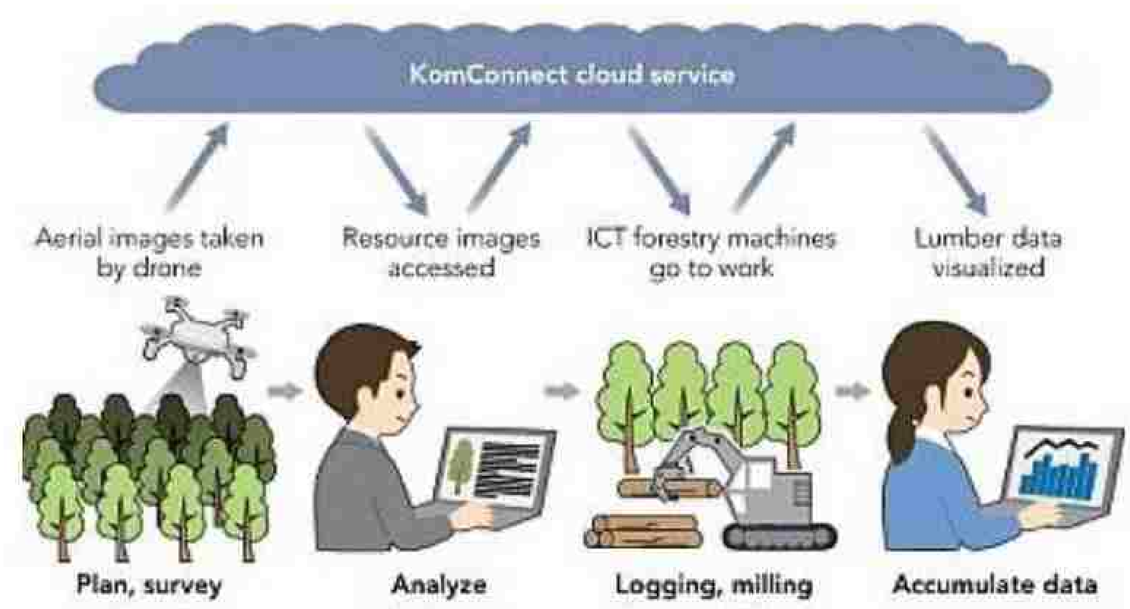

Figure 22. Komatsu 'Smart' Forestry Cloud Service[59]

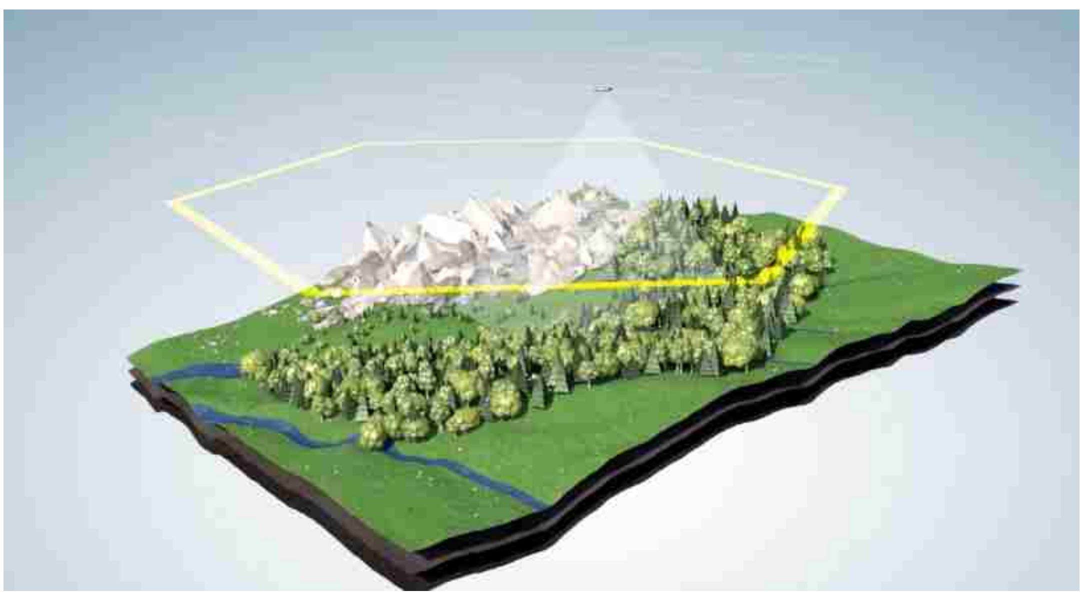

Figure 23. Biocarbon Engineering drone-based forest surveillance system[60]

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[59] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018), 6

[60] www.biograbonengineering.com/

Robotics can also assist in planting, a very labor-intensive process when done by hand. Biocarbon Engineering is a company using drones on pre-programmed flight path to plant trees in remote places and on industrial scales, with a high rate of success. Specialized drones shoot seed pods into the ground at a rate of nearly 5000 per hour, 120 times faster than planting by hand. Drones can record mapping data at high-resolution, and can therefore precisely find the best places to plant seeds. The company also offers planting planning and management services, using their drones to capture imagery for tree inventory, topographic survey, etc. The process (Figure 23) is extremely efficient, and the company has committed to planting 1 billion trees per year[61]. Started in 2014, its estimated revenues for 2020 are $95 million dollars… impressive for a forest start-up of less than ten employees[62]. By comparison Brinkman & Associates does hand-planting trees, and it took almost fifty years to accomplish what Biocarbon Engineering is able to accomplish in *one* year. Such is the efficiency afforded by automation!

Figure 24. Biocarbon Engineering seed planting drone[63]

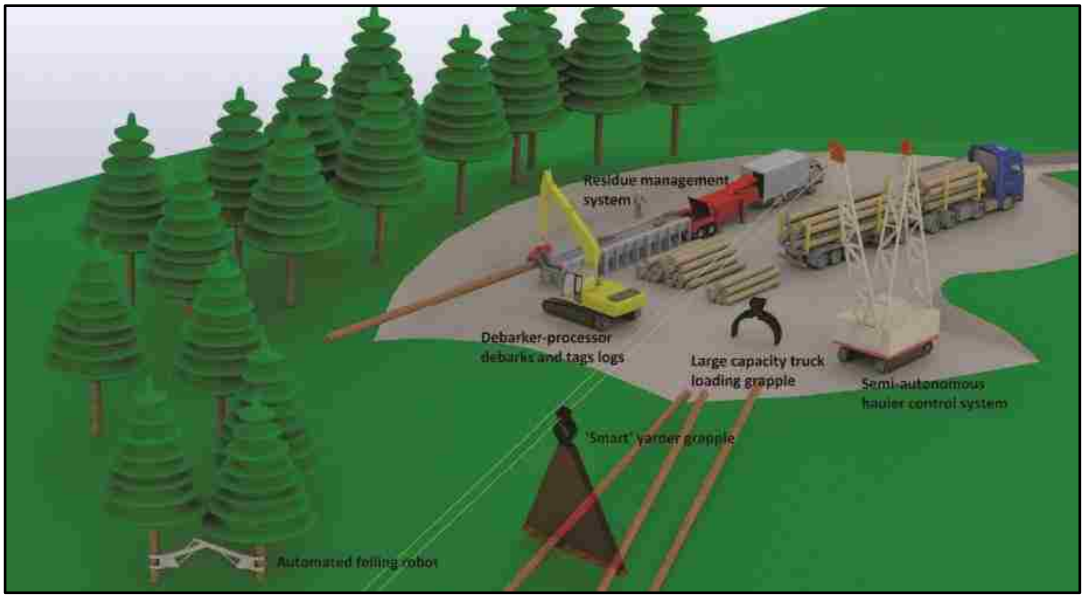
61 https://www.biocarbonengineering.com
62 https://pitchbook.com/profiles/company/155810-44
63 https://www.biocarbonengineering.com

The industry is gearing up for full automation in other areas as well. The organization Forest & Wood Products Australia published a journal entitled *Next Generation Timber Harvesting Systems: Opportunities for remote controlled and automated machinery*[64], where it previews prototypical equipment. Of notable interest is the robotic log sorting facility, a temporary/situational arrangement of automated equipment is arranged to facilitate job-site management and log distribution during tree-felling activity (Figure 26).

While these new systems eliminate a lot of human labor, they still require humans to interpret the data, make planting plans, pilot the drones, etc. The cloud-based remote forest management strategy greatly expedites planting and harvesting, saving cost, and is in line with the information technology revolution.. Rather than toting saws into the woods on foot, foresters will now operate remotely from offices or purpose-built trailers (Figure 25) equipped with communications, an array of LCD monitors displaying live camera feeds from the robotics, and control joysticks.

Figure 25. Camera Locations and Remote Control Apparatus[65]

[64] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018)
[65] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018) 17



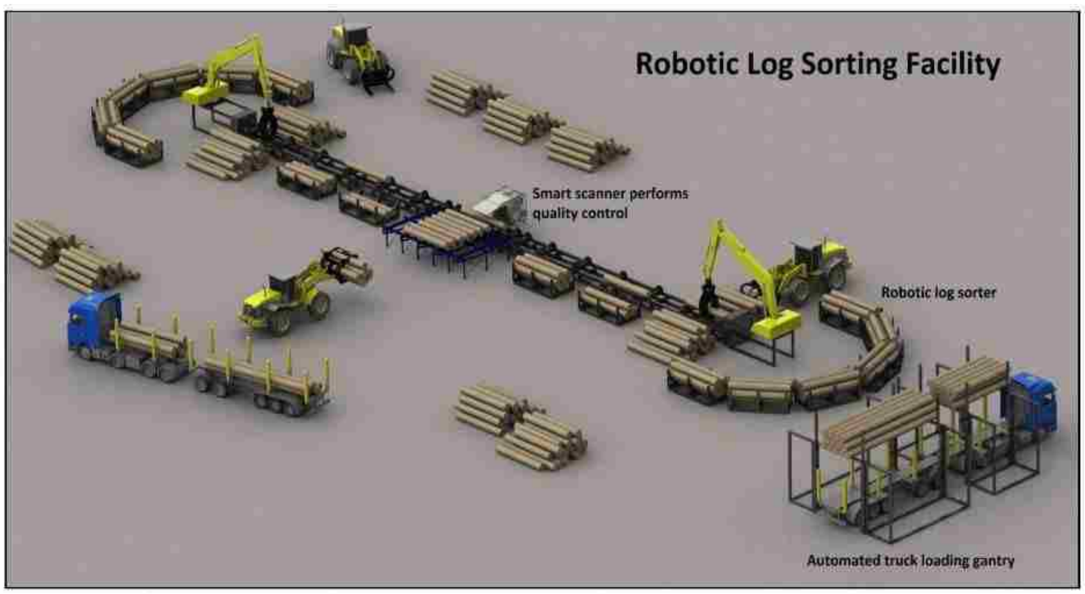


Figure 26. Conceptual Automated Logging Systems[66]

[66] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018) 20

2.3.3 Improving Sustainability

The computer interface workflow is the future of logging from forest planning to harvest and processing, and many tasks are expected to be picked up by artificial intelligence programs for further efficiency in data analysis and mechanical processes. It is clear that the forestry industry can benefit from automation from a safety and labor standpoint, but digital workflows can offer improved precision in many other aspects of forestry as well. Algorithmic scenario modelling programs can make calculations faster and without human error, for instance, and specialized robotic harvesters are designed to reduce destructive impacts from traditional logging vehicles which have large tank tracks. New developments in robotic harvesters include sensors to help the computer identify trees by diameter and species (Figure 27), tree-climbing saw configurations which can swing tree to tree (Figure 28), and spider-legged carriages which enable equipment to crawl over -rather than trample- the delicate ecosystems being restored (Figure 29).

Given that periodic thinning operations can improve the health, resiliency, and growth rate of forests, precision equipment like this can allow for far less ecological disturbance. The point of forest thinning is to strategically remove dead, diseased, or thin-diameter trees… Once removed, the rest of the trees can grow faster and stronger thereby increasing the board-footage yield and carbon sequestration potential. However, this practice requires precision in calculations as well as execution, since the purpose is conservation-oriented. Again, this is where these technological developments help make sustainable harvesting tactics like thinning and mixed age / mixed species harvest rotations competitive to fast-return clear cuts and monocrop plantation forests.

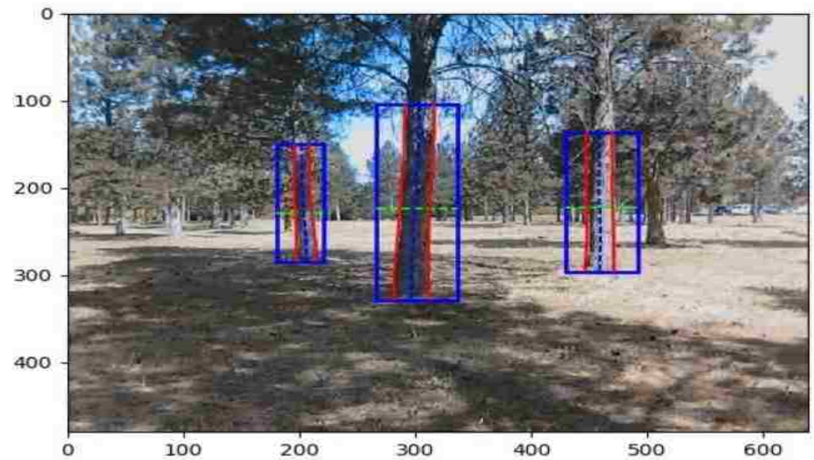


Figure 27. Automated System for Identifying Trees[67]

Figure 28. Tree-To-Tree Swinging Forest Harvester[68]

Figure 29. John Deere Walking Forest Harvester[69]

[67] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018), 24

[68] *Next Generation Timber Harvesting Systems: Opportunities for Remote Controlled and Automated Machinery* (Forest & Wood Products Australia, 2018), 24

[69] Brad Brooks-Rubin, *John Deere Displaying World's First Walking Forest Machine Prototype,* (Metal Miner, 2012)

3. METHODOLOGY

3.1 Putting the Pieces Together

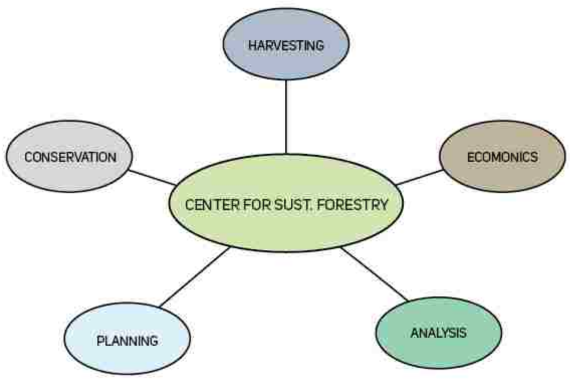


Figure 30. Areas of Innovation

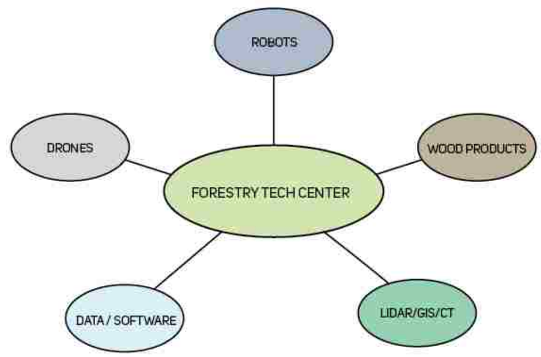


Figure 31. Corresponding technologies

Each innovation in management practice (Figure 30) has corresponding technological developments (Figure 31). Every aspect of forestry from business model to wood product is evolving. All of this innovation suggests a revolution is at hand in the forest industry, which requires a new set of skills, techniques, and equipment. Even in conventional forestry there is a current disconnect between resources, workers, economy, and ecology, so educational outreach is essential in making the transition from business-as-usual to the restoration economy. Not only do business and management practices need to be reprogrammed, the massive amount of work to be done necessitates next-generation knowledge and equipment. Conversion of private and federal land to working forests called for by mandates such as the United Nations' Agenda 21 and all of the other literature reviewed in this paper; such a shift is also needed to supply the global housing market so there is certainly a demand for these systems to make forests more productive.

As AI programs and automated machinery come in to improve productivity, foresters will be able to accomplish more with less personnel. A specialized, tech-based skill set is becoming more about operating software and robotics than manual labor and vocal coordination. Therefore, human jobs become more productive as workers are able to command multiple machines simultaneously and use computer programs to interpolate data. The skills that are required for modernized forestry jobs are based in information technology, a field that millennial-generation workforce is familiar with. The decline in rural forestry jobs can perhaps be reversed by the decentralized nature of the tech industry, in the manner of start-up businesses, off-site work capabilities, social networking, and equipment-share platforms. The concept of deploying the tech industry into working forests to combat climate change is the essential focus of this thesis.

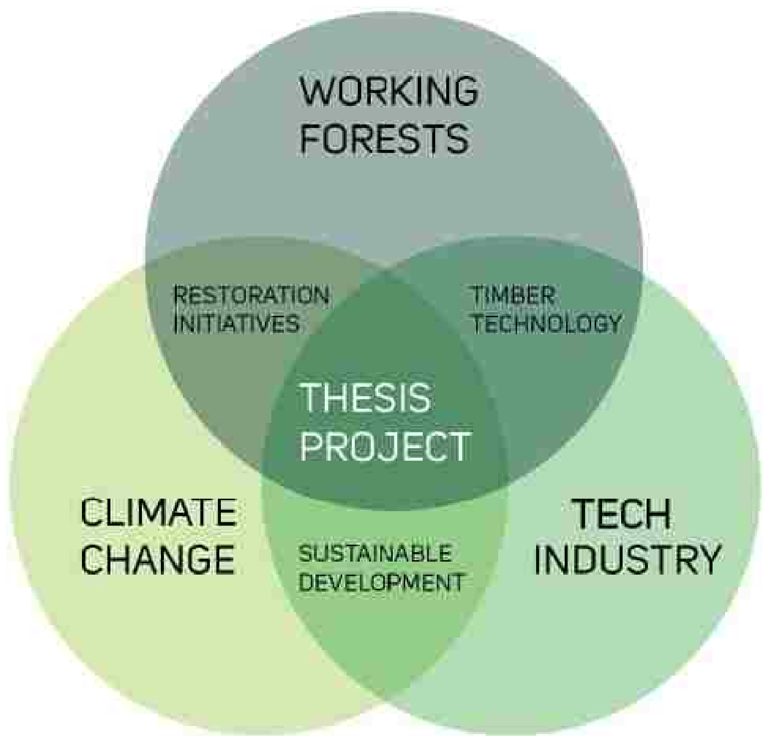


Figure 32. Thesis Concept

3.2 An Architectural Intervention

Assuming the technologies and market trends remain on trajectory, it is predictable that many of the specialized services and hi-tech equipment presented in this paper will become streamlined and standard practice once patents begin to expire mid-century. Family forest owners whom have unmanaged forests may find it difficult or intimidating to manage an array of different consultants and contractors to piecemeal together a forestry plan for their land (for the Wildfire Preparedness Act, for instance). A place that brings all the aspects of forest management together could provide this demographic with an understanding of the opportunities presented with sustainable forest management, and more importantly, knowledge of the best practices to ensure sustainability.

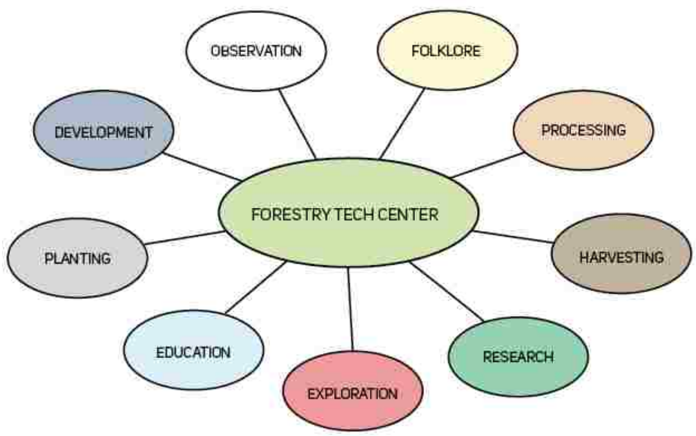


Figure 33. Requisites for the Advancement of Forestry

Given the complexity of modern forestry and the increasing need for forest products of all kinds, a purposeful building to for research, development, and demonstration of progressive land management undertakings can help make high-tech forestry more economical and accessible. Centralization of this specialized research and development can improve these technological applications by providing an environment where they can be studied together as a holistic workflow rather than compartmentalized industrial product offerings. The urgency of engaging the restoration economy means this place should serve as many people and disciplines as possible for maximum impact. It ought to be accessible not only to scientists, technicians, and loggers, but also to forest service agencies, non-industrial private landowners, students, and casual visitors. A demonstration aspect for dissemination of best practices is essential to promoting the restoration / afforestation agenda.

3.3 Defining a Scope

The most widespread forest-related ecological damage is occurring in Africa and South America. However, it the position of the author to focus efforts in domestic soil in order to leverage the proximity of the local expertise from intellectual community, business and industry, and abundant forest resources. The United States exhibits moderate success of land management policy and state-of-the-art forestry practices. However, the nation still experiences many difficulties in the field. Dwindling federal funding, poor private land management, exploitative agricultural practices, and climate factors such as drought and wildfire all present challenges which should be met before the system this thesis proposes can be evaluated for international application.

According to the Nature Conservancy, a charitable environmental organization that operates the United States to "conserve the lands and waters on which all life depends,"[70] forests:

- store and filter more than half of the nation's water supply;
- provide jobs to 1 million forest product workers;
- generate $13.6 billion in recreation-based economic activity on U.S. Forest Service lands alone;
- are habitat to more than 4,000 forest-dependent wildlife and plant species, 27 percent of which are at risk to extinction;
- offer a million square miles to sportsmen and families for outdoor recreation;
- are a major carbon sink that sequester 15 percent of all fossil fuel emissions in the United States.

The Nature Conservancy claims "a forested area larger than Oregon is at immediate risk to extreme fires, pests and climate change. Future generations of Americans risk losing the natural benefits our forests provide if we do not work to restore forest health now". They have implemented a program called Restoring America's Forests, which is coordinating Federal, State, non-profit, and private business interests to double the pace of forest

[70] Restoring America's Forests Fact Sheet (*The Nature Conservancy, 2017) https://www.nature.org/en-us/what-we-do/our-priorities/protect-water-and-land/land-and-water-stories/restoring-americas-forests/*

restoration on federal lands to at least 7 million acres per year.[71] This information provides a challenge, a call to action.

To further investigate where to do the most good, we can look more specifically at the effects of climate change facing the United States. Below is NASA's published summary of the findings of the Third Climate Assessment Report by the US Global Change Research Program[72]:

> **Northeast.** Heat waves, heavy downpours and sea level rise pose growing challenges to many aspects of life in the Northeast. Infrastructure, agriculture, fisheries and ecosystems will be increasingly compromised. Many states and cities are beginning to incorporate climate change into their planning.
>
> **Northwest.** Changes in the timing of streamflow reduce water supplies for competing demands. Sea level rise, erosion, inundation, risks to infrastructure and increasing ocean acidity pose major threats. Increasing wildfire, insect outbreaks and tree diseases are causing widespread tree die-off.
>
> **Southeast.** Sea level rise poses widespread and continuing threats to the region's economy and environment. Extreme heat will affect health, energy, agriculture and more. Decreased water availability will have economic and environmental impacts.
>
> **Midwest.** Extreme heat, heavy downpours and flooding will affect infrastructure, health, agriculture, forestry, transportation, air and water quality, and more. Climate change will also exacerbate a range of risks to the Great Lakes.
>
> **Southwest.** Increased heat, drought and insect outbreaks, all linked to climate change, have increased wildfires. Declining water supplies reduced agricultural yields, health impacts in cities due to heat, and flooding and erosion in coastal areas are additional concerns[73]

The Pacific Northwest region of North America, home to the University of Washington, is one of the world's largest carbon sinks and most productive forests on the planet. The University is a rich resource of forestry knowledge and tradition due to the region's historic timber-based economy. The State of Washington is an appropriate region for case-study because it has already implemented a well-developed forestry management protocol, which has resulted in a sustained lumber yield and a stock of trees that has been growing faster than it can

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[71] *Restoring America's Forests* (The Nature Conservancy 2017) nature.org/ourinitiatives/urgentissues/land-conservation/forests/restoring-americas-forests.xml

[72] *Third Climate Assessment Report* (US Global Change Research Program, 2014) https://nca2014.globalchange.gov/report

[73] *The Consequences of Climate Change* (NASA, 2018) https://climate.nasa.gov/effects/

be harvested. This region is fertile ground with a rich history to build upon, well positioned as a center for innovation in forest management. Washington supplies heavy quantities of lumber to domestic and foreign markets and maintains a positive ratio of trees planted-to- cut which is projected to sustain the US demand of softwood lumber (including CLT demand) beyond 2050. Still; wildfire, insect outbreaks, and diseases are causing massive tree die-off which must be mitigated to maintain stable conditions in the changing environment.

In summary, even the most lush forestland in the country needs significant management and new plantings. Ultimately, due to human development of land, natural fires no longer clear underbrush periodically. What we are left with is a state full of overstocked forests, which not only grow slower but pose the risk of disastrous mega-fires. Forest thinning is one of many triple bottom-line ways to profit from timber while cleaning up the natural environment and reducing the effects of climate change. There are various strategies emerging to curb climate change while providing goods and services, but these techniques are still being developed and far from being common knowledge.

3.4 Tapping into an Existing Network

To maximize impact of a new facility, a project location should be chosen with widespread accessibility to the forestry community in mind. The Pacific Northwest is home to a century-old timber industry which draws from the largest carbon sink in North America, and Washington State has some of the most progressive regulations in terms of sustainable harvests (requiring two or more trees to be planted for each one cut down regardless of FSC certification). Many of these regulations are in place because of the vigilance and foresight at the University of Washington.

The University of Washington's College of Forest Resources owns and operates a working forest in Western Washington for the purposes of experimentation and demonstration of sustainable forestry practices. It is called the Charles W. Lathrop Pack Experimental and Demonstration Forest, or simply Pack Forest, and covers 4300 acres. Located within 20 miles of Mount Rainier National Park, the UW shares the forest with partner the Mount Rainier Institute, a non-profit organization that brings 1500 students to Pack Forest annually to learn about forest ecosystems. It is prime location central to the highest concentration of forestry jobs in Washington and at the heart of North America's largest forest economies: Vancouver BC, Tacoma, Seattle, Portland, and Spokane (Figure 34).

Within Pack Forest is the Center for Sustainable Forestry. This organization implements and monitors many types of land-use scenarios, from ecological retention to experimentation to production… the College sells logs from the forest to cover operational costs. The “working forest” is another aspect which makes this Center for Sustainable Forestry a compelling site for new facilities; it has a tangible business connection to the timber economy, and it has the raw materials available on-site for experimentation and close examination.

Figure 34. Proximity to Regional Timber Economies

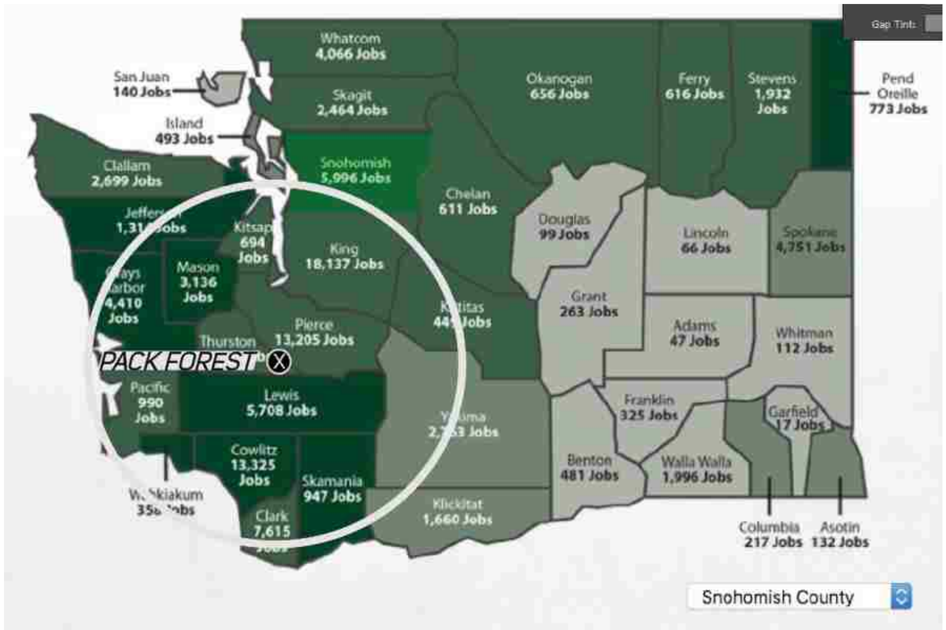

Figure 35. Forestry Job Concentration and Forest Cover in WA[74]

Figure 36. Geographic Context of Pack Forest

[74] www.data.workingforests.org/

3.5 Site Analysis

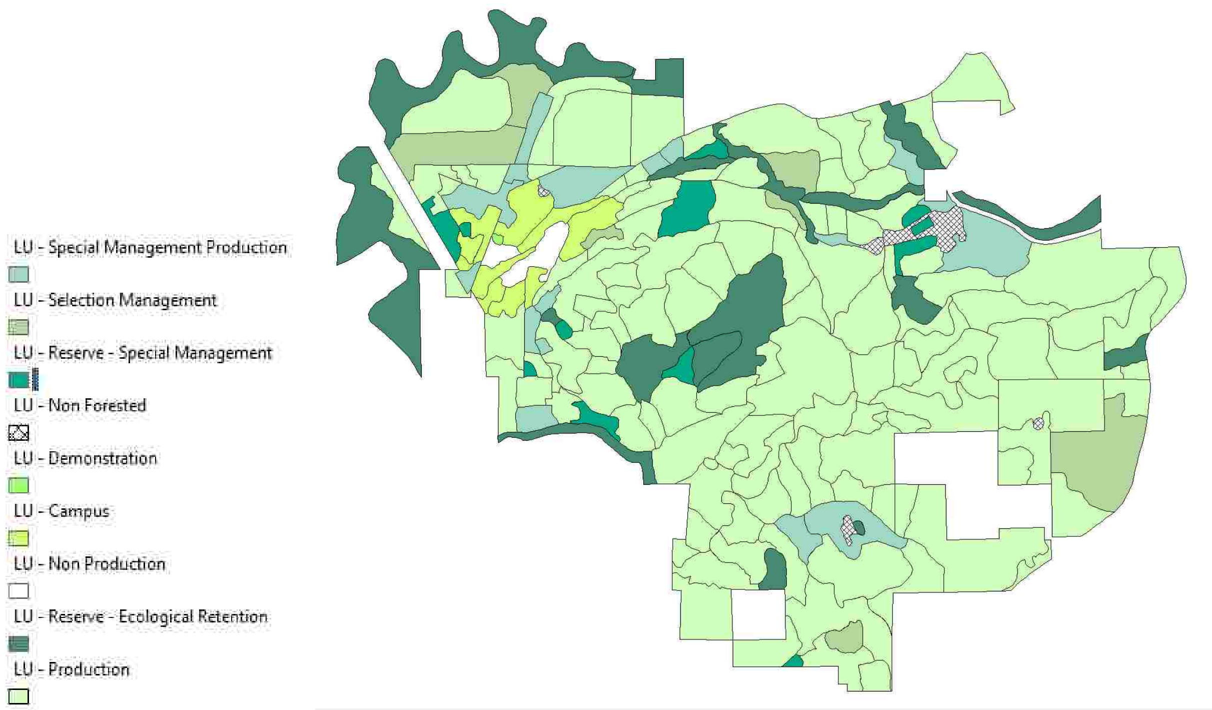

Figure 37. Land Use at Pack Forest

The forest is not only used for research and production, but also demonstration. Staff at Pack Forest describe it as a “show window forest” because there is a network of hiking trails which take students, scientists, and casual hikers through almost every type of forest stand imaginable. You can find homogenous stands of pure Douglas Fir, slash-and-burn piles, old growth reservations, mixed species stands, clear-cut prairies, etc. Pack Forest serves to study a variety of foresting techniques for the development of best practices in sustainability and is open to the public so that anyone may learn from activities taking place at Pack. Detailed information on the management plan can be found at the Pack Forest web page, as a resource to document the trails and results of Pack forestry operations and experiments.[75]

[75] Pack Forest, *Ten Year Field Plan*, (University of Washington College of Forest Resources Silviculture Lab) http://www.packforest.org/plan/introduction.htm

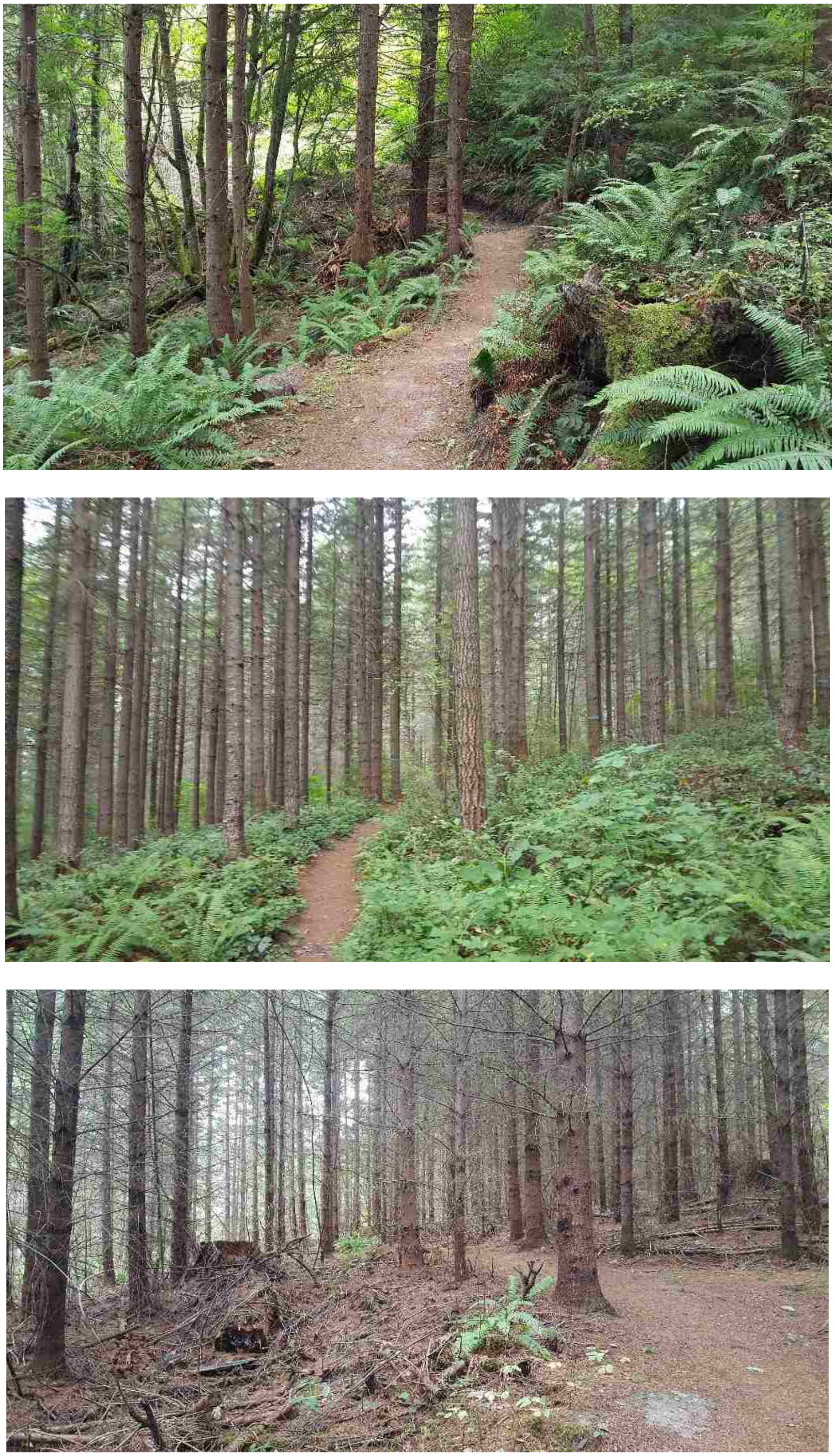

Figure 38. Various Types of Forest Stands along Hugo Peak Trail

To support its demonstration / education agenda, Center for Sustainable Forestry maintains an on-site conference center for forestry events and conventions. There is a campus with lodging cabins and a dormitory for 130 beds, a mess hall, administrative offices, and some sheds for equipment storage. These facilities are effective for small gatherings, but they are limited. There is no saw mill (logs are sold at auction and then milled by a private company near-by), biological samples must be sent to UW's Seattle Campus for analysis, and many of the structures are out of date, built in the 1930's by depression-era Works Progress Administration programs.

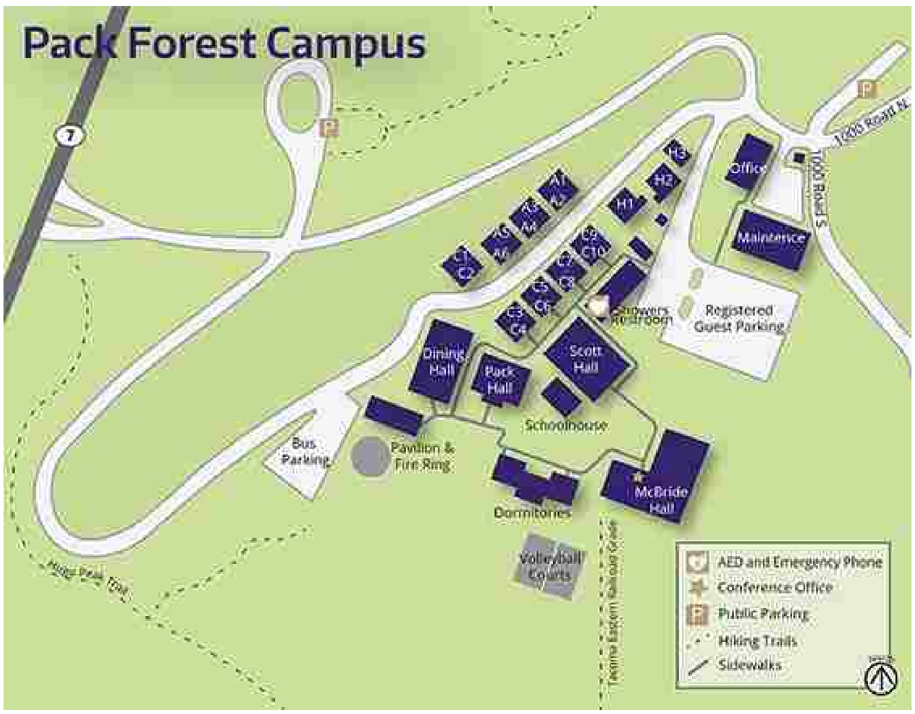

Figure 39. Map of Conference Center[76]

[76] http://www.rainierinstitute.org/lodging.html

Figure 40. Campus Character

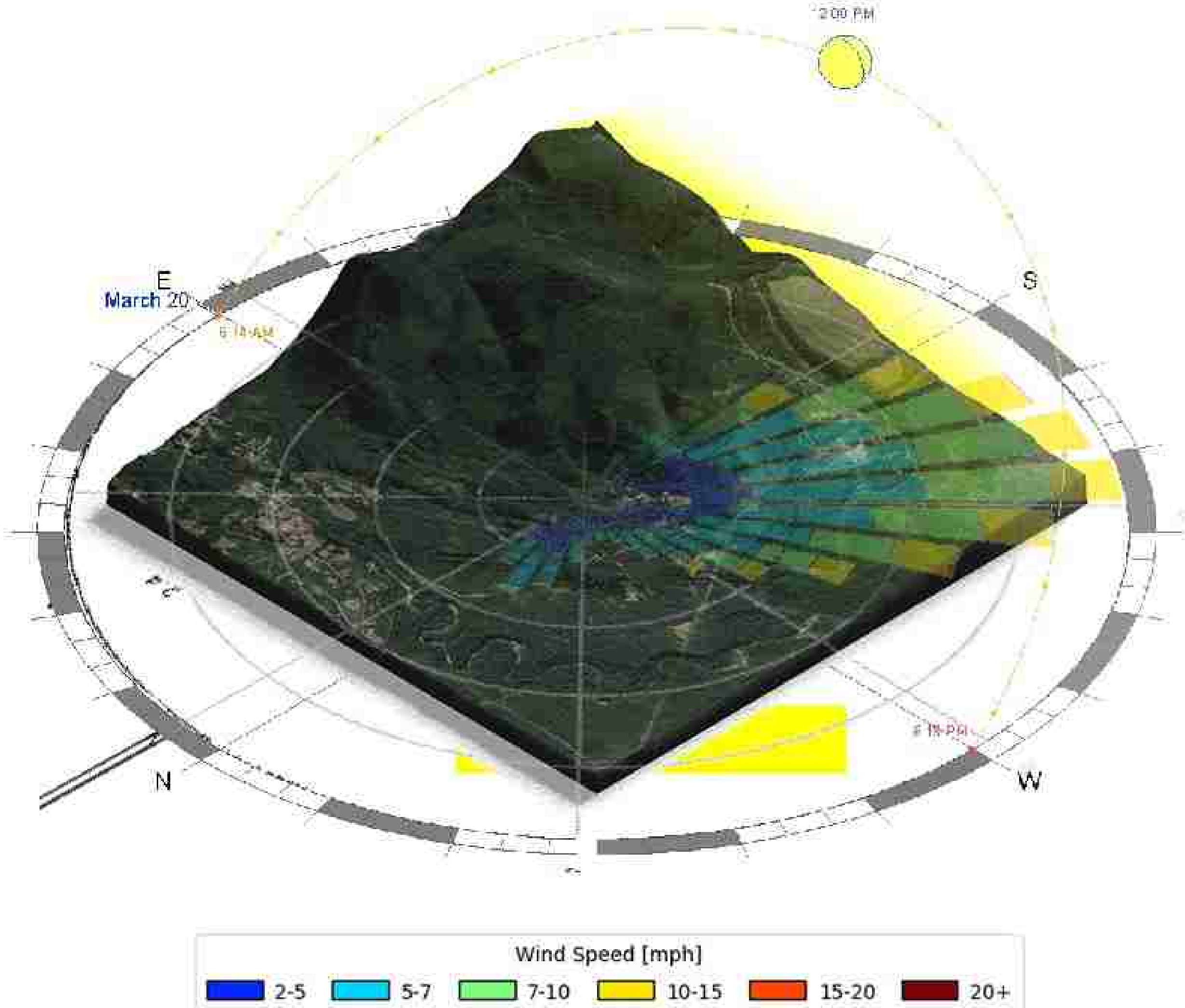

Figure 41. Site Characteristics

The site is distinguished by a flat spot between two slopes, terminating in a large retention pond. To the South-East is Hugo Peak, a small mountain with an elevation of 1740 feet, not quite tall enough to shade the site. There is a predominant South-Eastern wind, though the site is fairly well protected from tall trees and nearby hills.

CHAPTER 4. PROJECT PROPOSAL

Pack Forest's location is more than favorable for developing and demonstrating forestry technology, but the existing facilities cannot accommodate much in the way of research on the technologies reviewed in this study. It is set up for conventional (old-fashioned) forestry methods, and due for an upgrade considering local economic conditions identified earlier in this study. Of course, this is because funding is scarce, but an investment here has the potential to bring about a new age of prosperity in the forestry business. Certainly, application of these technologies can make Pack's operational management more efficient and therefore more profitable, which can then be demonstrated to the forestry community at large. It is in the best interest of UW and the College to keep current with cutting-edge technology, as presumably there will be a surge in forestry students aiming to take on the new timber markets: this thesis proposes new facilities for the Center for Sustainable Forestry to bring existing operational capacities into the digital age for the development and demonstration of 'smart' forestry goods and services.

4.1 Site Selection

Figure 42. Existing Conditions at Selected Site

When arriving at Pack Forest, the casual visitor lands in a trailhead parking lot where there is an abandoned warehouse and greenhouse, which are hiding views to a large and scenic retention pond. Because this it is the first stop on arrival and the land here is spacious and mostly unused, the derelict warehouse is an excellent location for new facilities. The warehouse has been unused for about twenty years and is in a state of disrepair. If it could be salvaged, it is too small to accommodate the suggested program. Laboratories are sensitive and require reliable structural performance for stability. The barn-like warehouse structure is stick framed, not heavy timber, and having been unconditioned for a long period of time in this damp maritime climate, there is likely to be rot.

Figure 43. Derelict Warehouse & Pond

The proposed building its sited at the head of the campus and within a few minutes walk of anywhere on campus. It is right on the main road in and out and flanked by woods on both sides, with Mount Rainier looming just out of sight behind Hugo Peak.

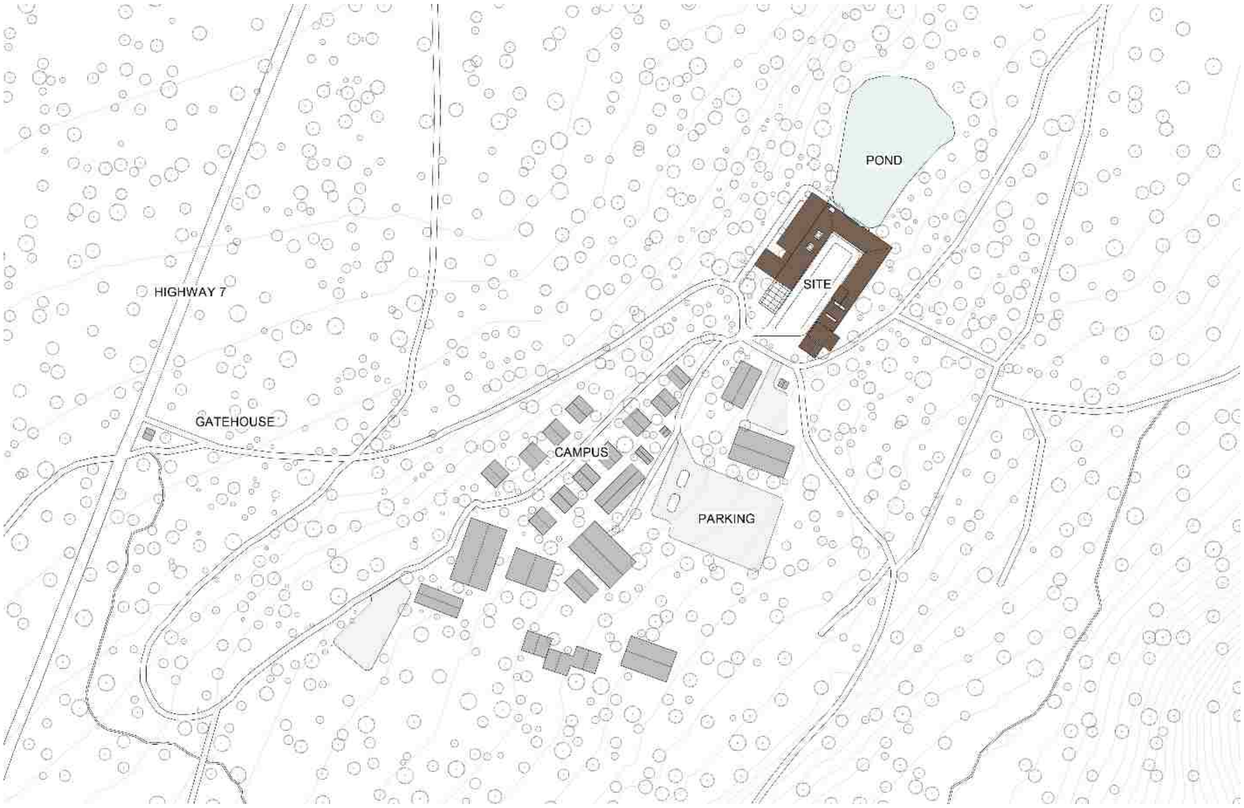

Figure 44. Site Plan

Figure 45. Proposed Siting of New Facility

4.2 Program Planning

Adapting the program requirements identified earlier into a study of relationships in the form of massing volumes helps to inform the layout of the building. The layout is designed to follow a timber through its course of production, and the various functions are laid out in a sequential order counterclockwise around the courtyard.

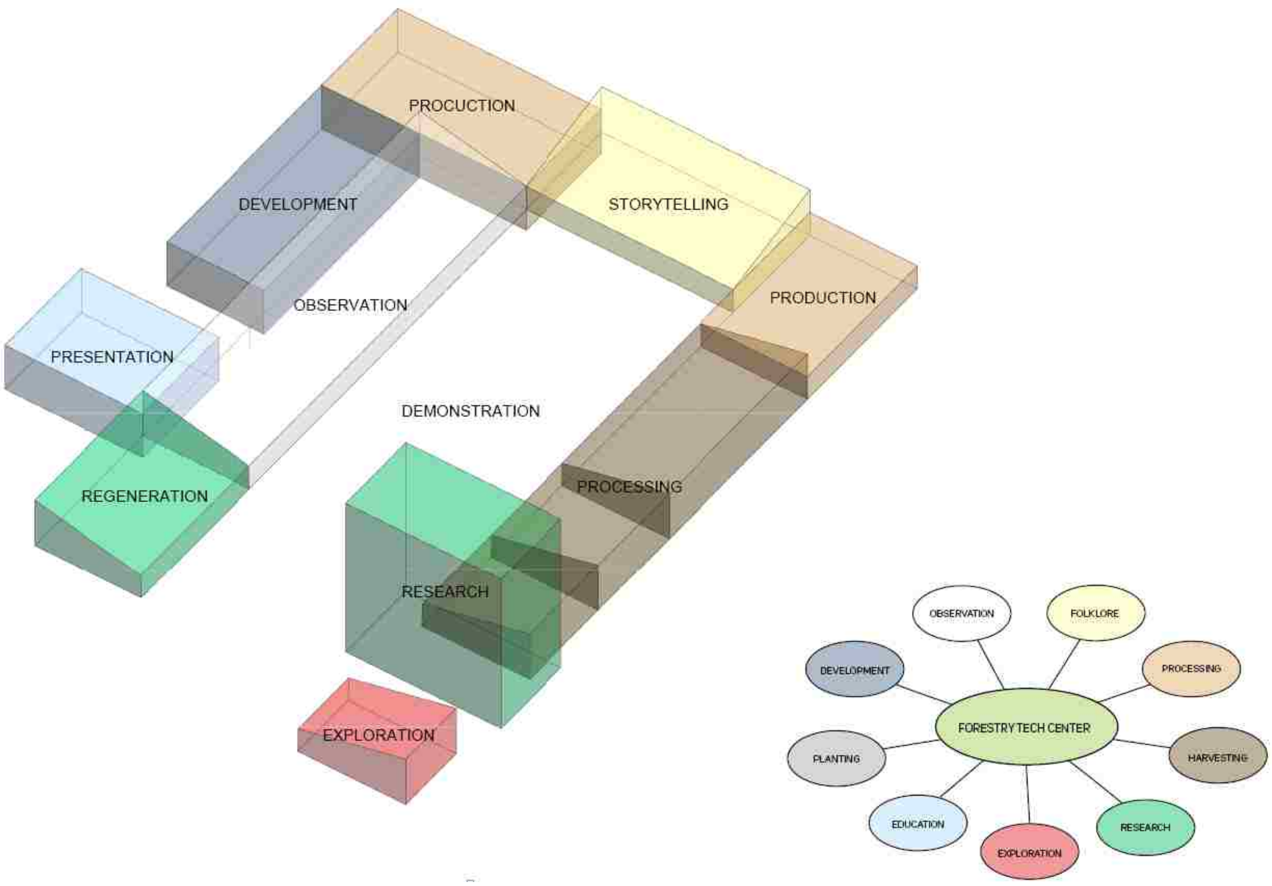

Figure 46. Program Relationships

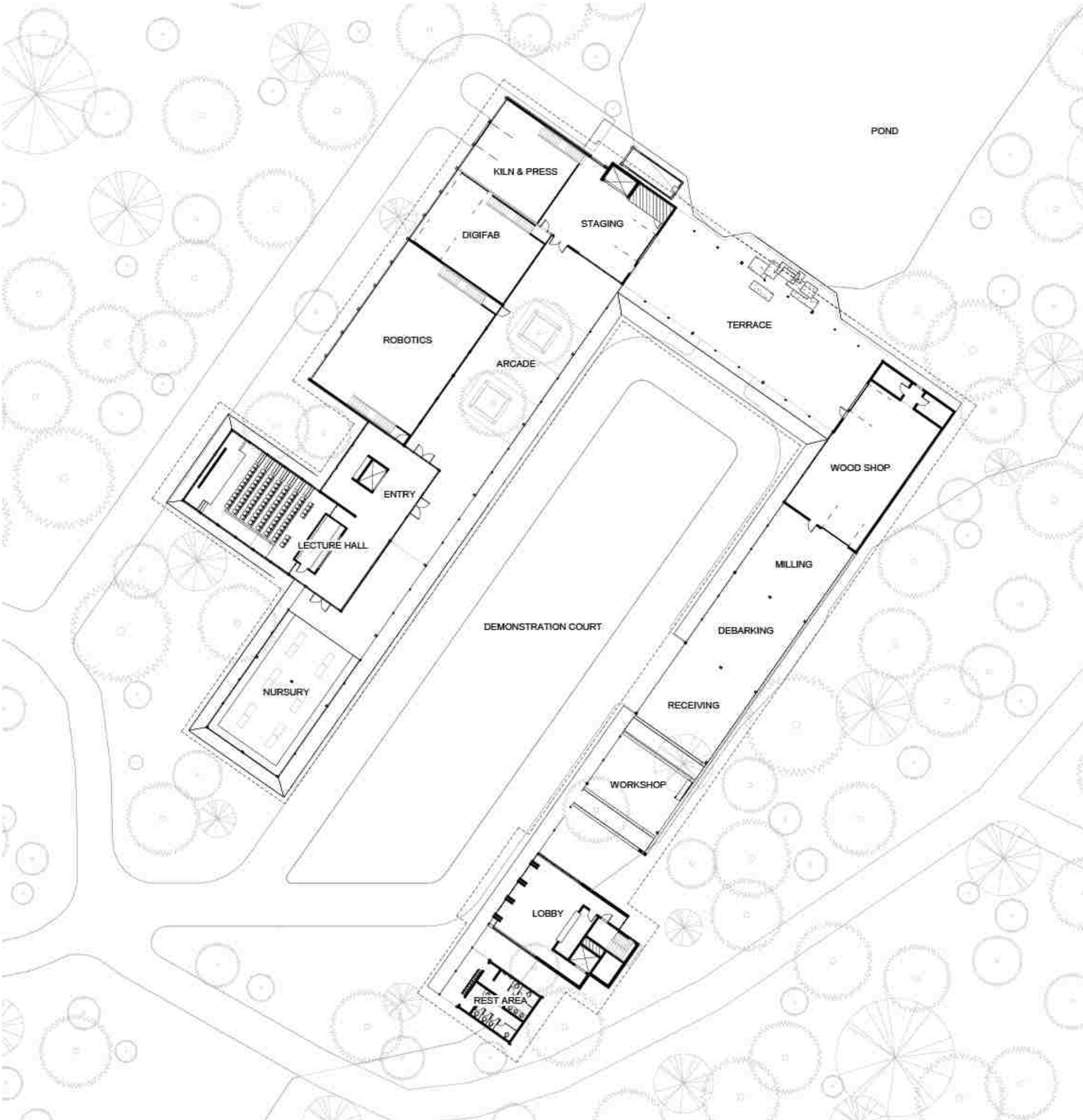

Figure 47. Ground Floor Plan

4.3 Design Considerations

In contrast to the sleek and glassy tower, the low-slung heavy timber roof structure flows through the tower and around the courtyard. The scale is akin to the other buildings on campus, and the covered walkway around the courtyard keeps with the porch entry theme as well. A sense of community and connection is fostered by a courtyard scheme layout of the various activities. The courtyard defines a truck loop for receiving logging trucks. The timber-framed roof ties the string of various activities together and provides shelter for the exterior functions. All the program elements plug into a 32'x 24' grid module to keep a sense of rigor and rationality in the name of science. A wooden deck covered by the canopy leads people around the facility.

The residential scale keeps the facility approachable and helps blend the old with the new while distinguishing the building from utilitarian or industrial facilities. The detailing of the laboratory functions, on the other hand, is designed for a more institutional and contemporary aesthetic more appropriate to its purpose. To keep in character with the other buildings on campus, the new facility has a white zinc standing seam roof and a protective coat of brown paint on the cedar siding and exposed beams and columns.

Figure 48. Longitudinal Section

The roof is articulated for whatever function happened below it; there are holes in it for trees to grow through, the receiving bay tips up to let in logs, it wraps around the court, and finally transitions to glass for the greenhouse. Southern-exposed surfaces can accommodate photovoltaic panels for an extra measure of sustainability. Various timber structural systems are visible to portray wood as a highly versatile material.

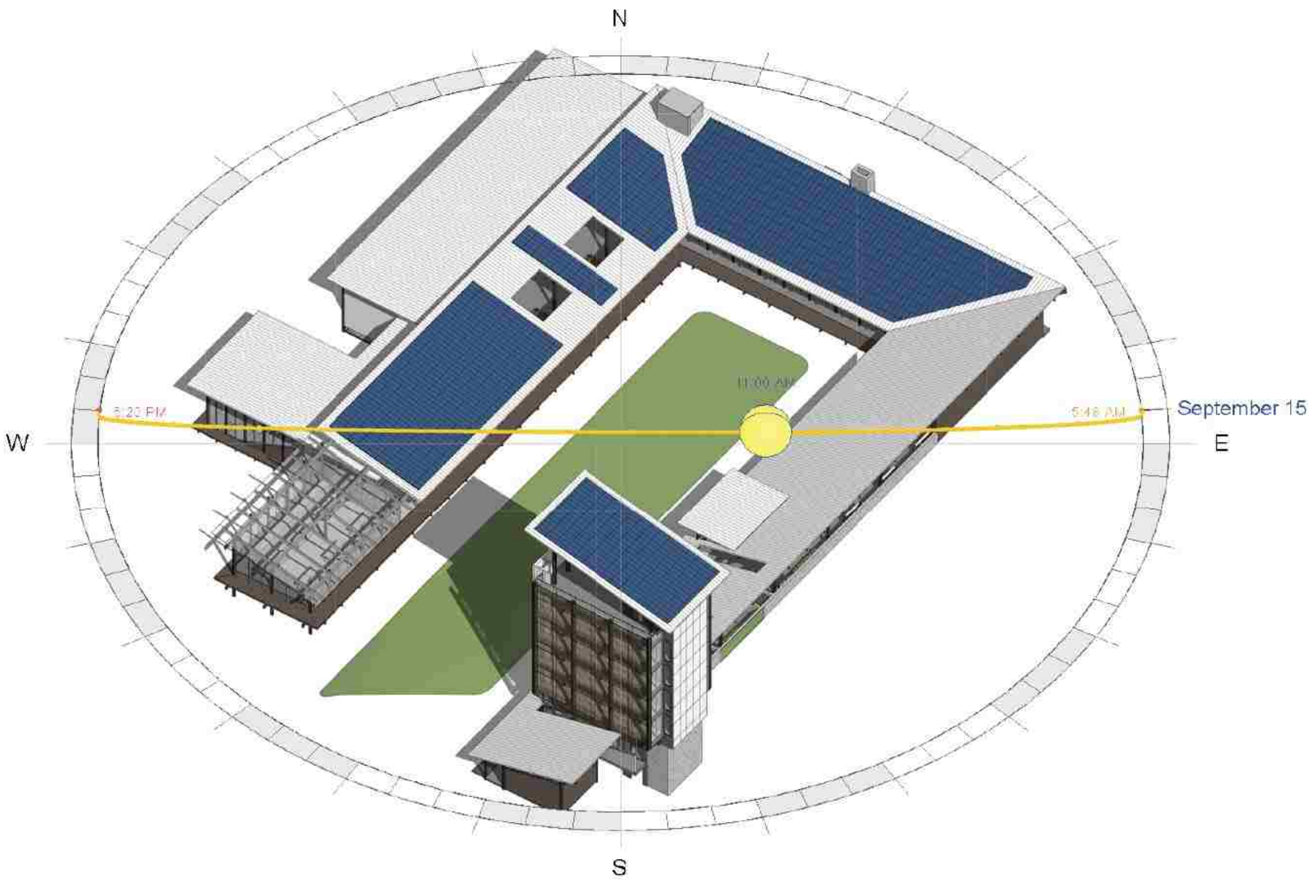

Figure 49. Articulated Roof Systems Accommodate Various Uses

4.4 Wood Construction Systems

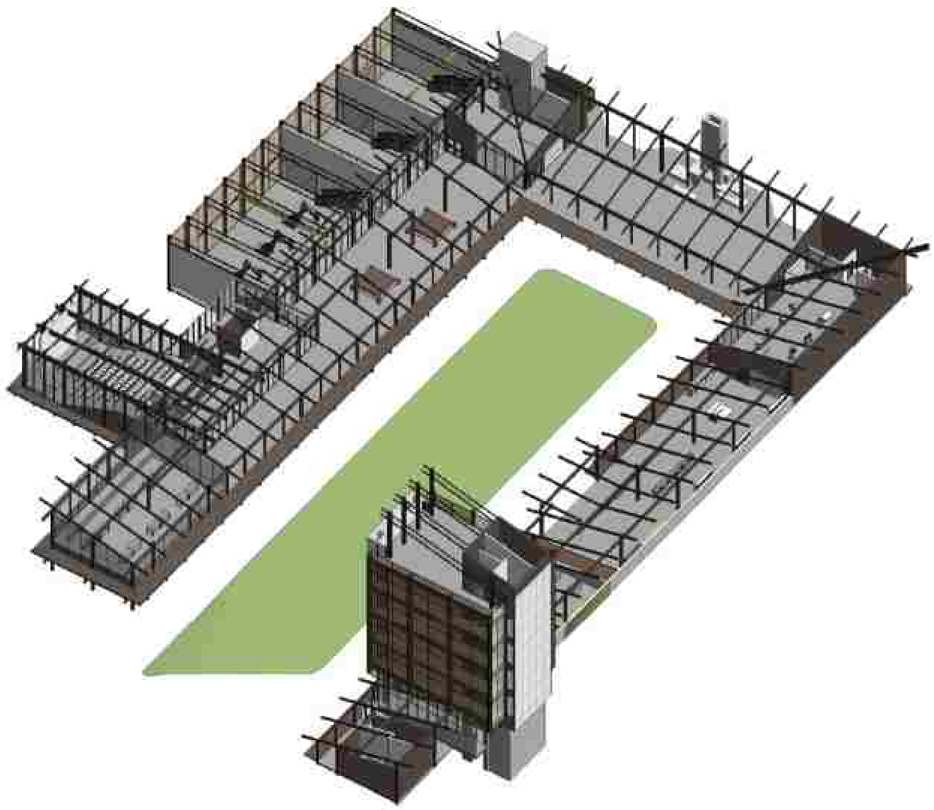

Figure 50. Structural Systems on Display

In this experimentation and demonstration facility, various wooden structural systems are employed to their greatest strengths. The exterior portion, covering the most square-footage, is a timber framed deck and roof made from solid sections of lumber felled on site. The modular framing plan allows the saw mill to be built first so that it can cut the logs for the rest of the building.

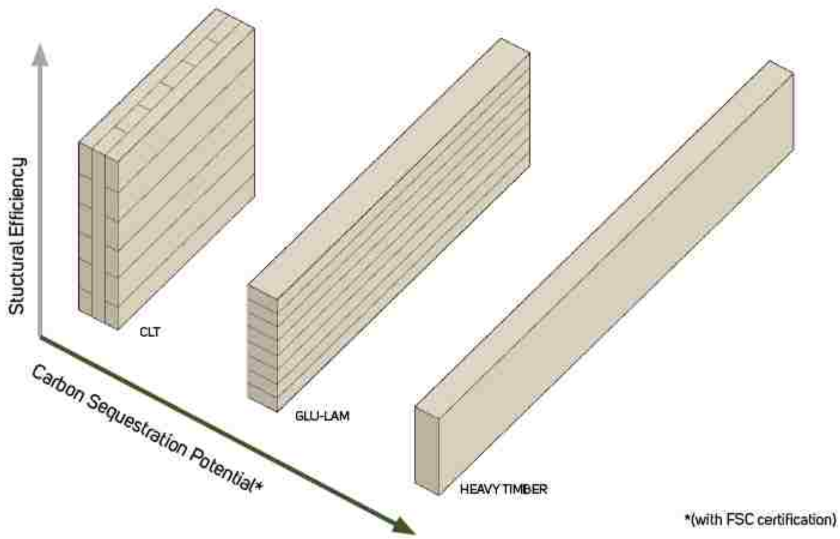

Figure 51. Comparison of Wooden Structural Systems

The heavy timber-frame structural strategy represents the principle of sustainability; As the research has shown, large diameter trees (75+ years old), necessary for heavy timber sections, sequester almost twice the carbon per year as typical 40 year-old trees when harvested under FSC standards[77]. Pack Forest can offer this product, and it can demonstrate the benefit of waiting the extra forty years to harvest. The framing lumber is left uncovered so that one can see how much wood goes into a structure this size.

Laboratory functions require clear space, so a long-span wooden trusses carry the roofs. Engineered wood products such as LVL and glulams are used here where engineering occurs, i.e. the laboratories. To provide additional stability and bring in the new era of mass timber products, the shear walls and floors of the tower and labs are made of cross-laminated timber. If heavy timbers represent suitability goals, engineered lumber stands for innovation and CLT for peak performance.

[77]David D. Diaz, Sara Loreno, Gregory J. Ettl, Brent Davies, *Tradeoffs in Timber, Carbon, and Cash Flow Under Alternative Management Systems for Douglas-Fir in the Pacific Northwest*, (Ecotrust, 2018)

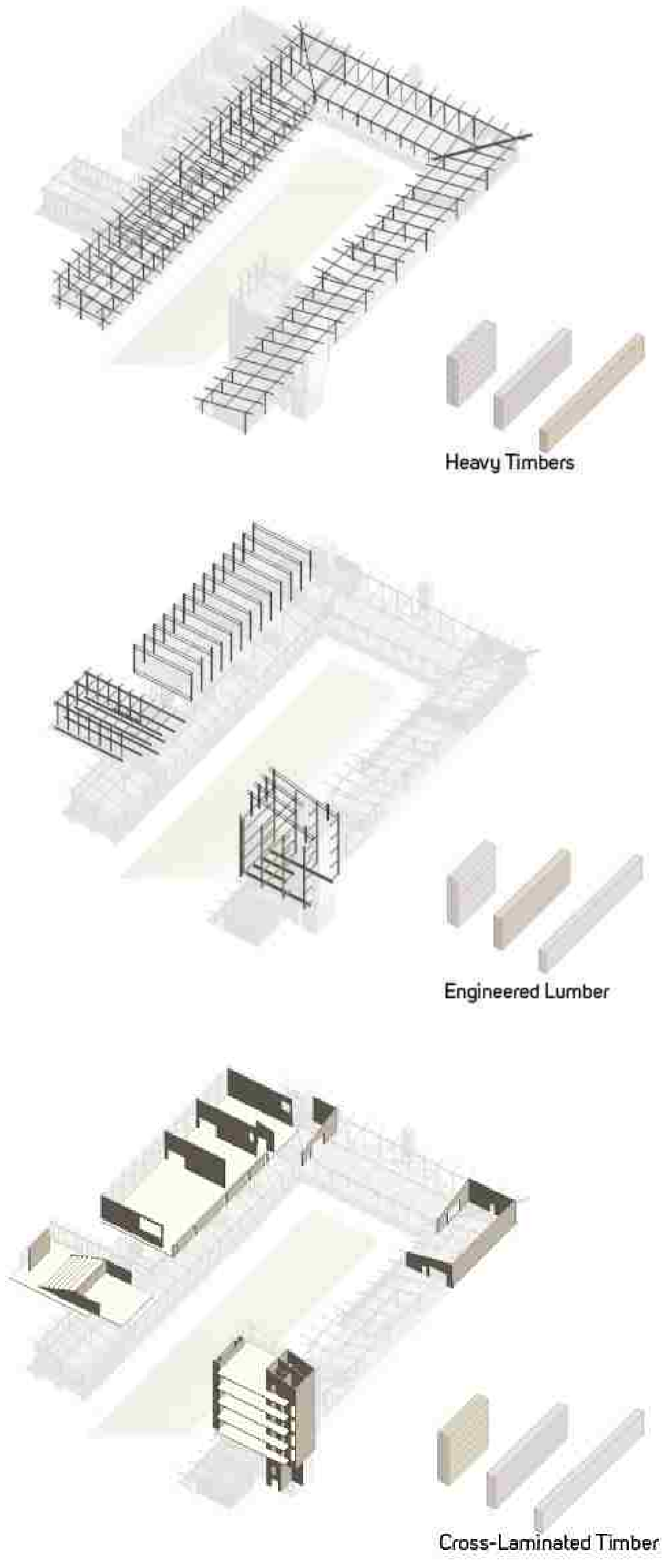

Figure 52. Structural Systems for Sustainability, Innovation, and Performance

4.5 User Experience

Figure 53. View Approaching the Center for Advancement of Sustainable Forestry

When driving into Pack Forest, right away the visitor sees the new lecture hall and greenhouse, symbolic of Pack's commitment to education and regeneration. The first stop when approaching the technology center is a sign post to update the existing trail information and map. This standard trailhead wayfinding device marks the beginning of the building, where there are lockers and restrooms for hikers and visitors, and it connects casual visitors to the greater purpose of the Center. Adjacent to the rest area is an 80ft tall timber tower soaring out of the canopy structure, a 21st century building typology to strike a visual impact from afar. It aims to present timber research as something contemporary, bold, and exciting. Sensitive laboratory uses are housed in the tower, but the scientists and foresters may be seen working though the fully glazed facades.

4.5.1 Research

Inside the tower is where the scientific aspects of forestry take place. The laminated veneer lumber (LVL) post & beam structure carries loads to the perimeter of the building. The exposed structural system, visible when approaching the campus. The framing is protected from the elements by a glass curtain wall. The double-skin wall is fully glazed and helps regulate temperature. There is bronze reflective tint on the east and west facades to maintain stable lighting conditions for the labs. The exo-structure enables an open plan so laboratories can support a range of uses. Each deck is concrete-topped CLT diaphragm. For shear stability, the vertical circulation, and wet services, a CLT core grounds the floating floor plates. On the front end is another CLT core serving the mechanical and ventilation systems. A roof canopy provides solar power and shelter for an observation deck.

The territorial view unveiled by a tower taller than the trees that made it puts Pack Forest in context with Mt Rainier National Park and the global timber trade port known as Seattle-Tacoma.

Figure 54. Transverse Section

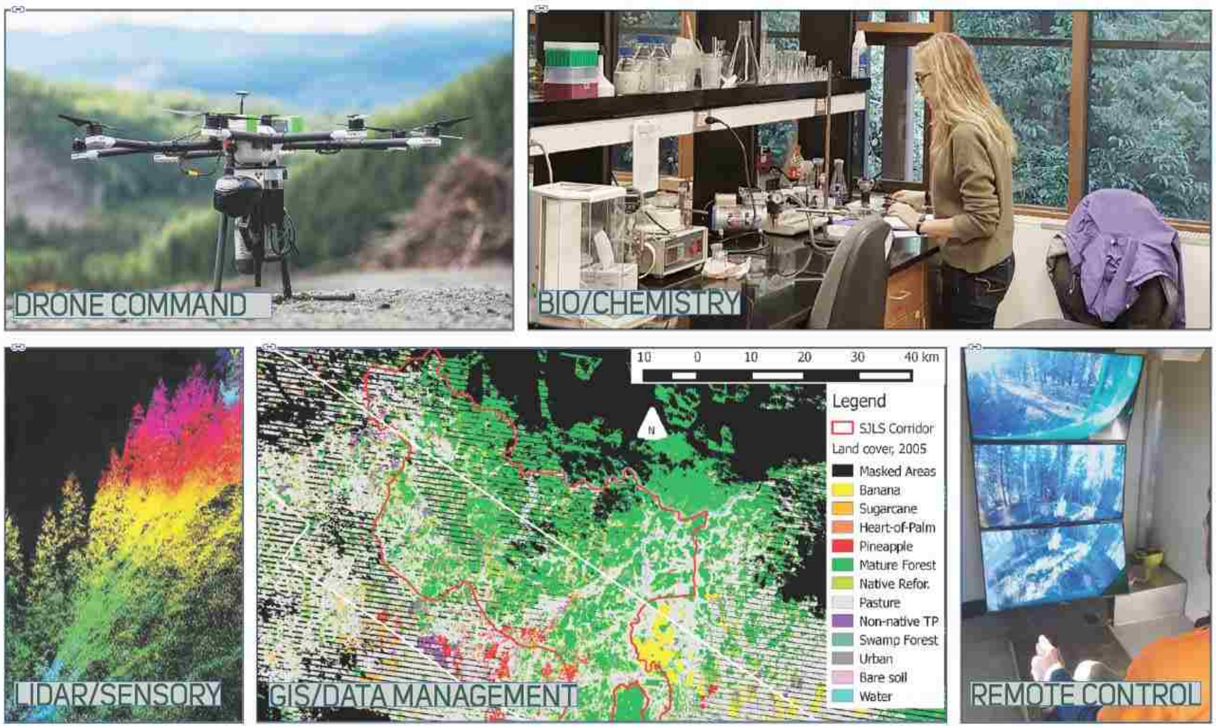

Figure 55. Research Programs at Tower

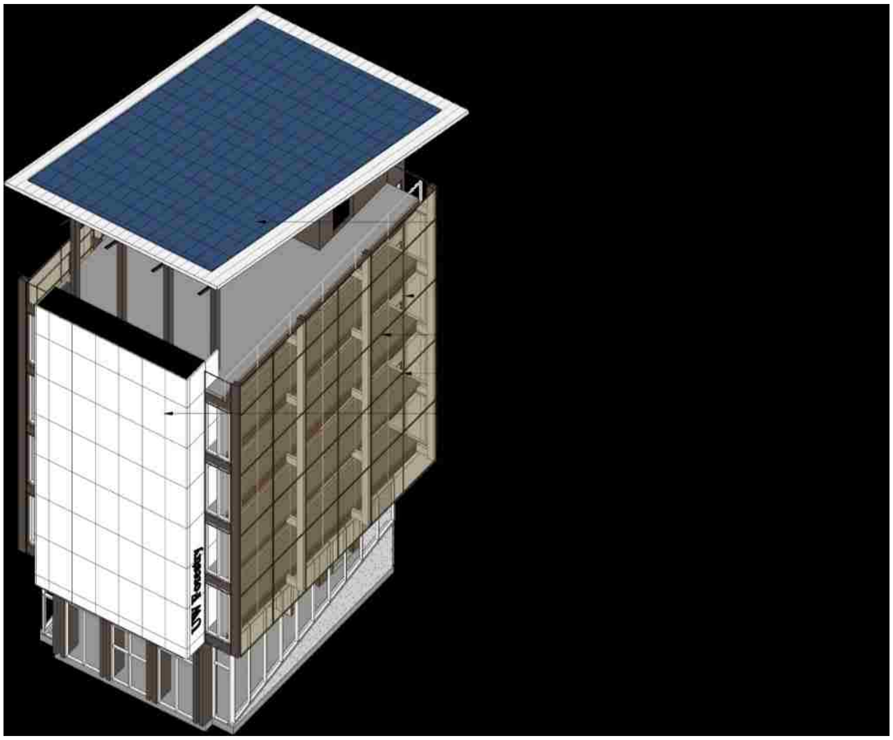

Figure 56. Forest Products Research Tower

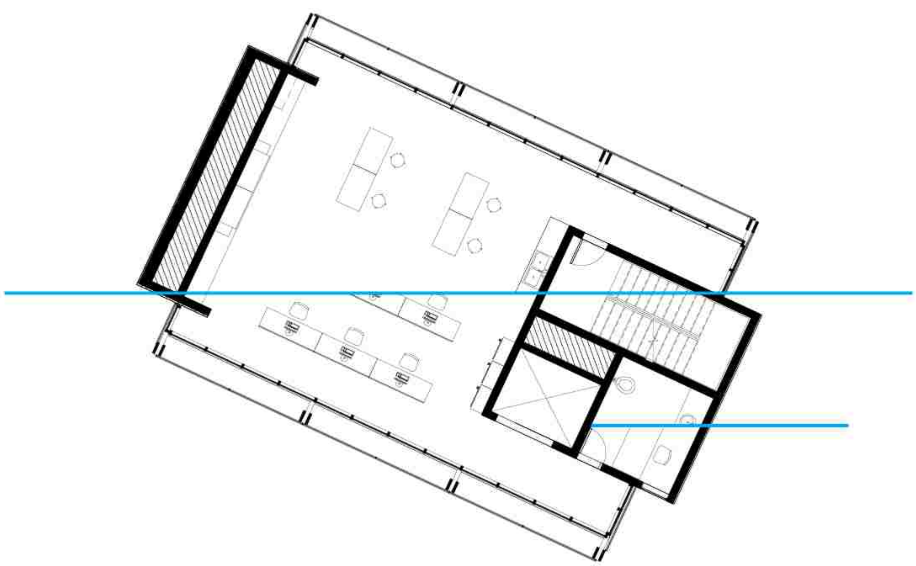

Figure 57. Open Plan for Flexible Labs

4.5.2 Development

While software development happens in the research tower, the digital fabrication lab across the court is ready for CNC routers and other precision woodworking equipment, as well as 3D printers for when components are needed in electronics and chemistry experiments. The next area is a robotics division, also connected by large roll-up doors. Studies in robotic harvester functionality and other automated systems are conducted here. Behind the laboratories are support rooms and more storage.

Figure 58. Section through Robotics and Sawmill

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Figure 59. Laboratories Rear Access

4.5.3 Demonstration

Because the double-height laboratory sits on the low point of the hillside grade to accommodate logs and large equipment, it needed a solution to maintain public visibility. To keep the robotics in plain sight, the timber roof hollows out again for an observation arcade with seating and a walkway that looks right into to the laboratories.

Once the visitor has made their way around all the processes, they arrive at an information display in a glassy lobby. The lobby serves the labs below but also the lecture hall used for presenting topics in forestry. The building terminates with the greenhouse seen on the way in, putting tree saplings in a glass showcase for a well-rounded educational experience. In the middle of it all is an open lawn for equipment testing, demonstrations, and the erection of experimental wooden structures.

Figure 60. Perspective - Robotics from Observation Arcade

Figure 61. Perspective - Tower Entry

The tower lobby is right next to the rest area on arrival, tempting visitors in with floor to ceiling windows, massive timber columns, and information displays. Just past the laboratory tower lobby is a flexible use workshop for outdoor class sessions, building projects, and mechanical repairs. Adjacent is a receiving bay leading into the saw mill by way of a conveyor belt and overhead rail system. Debarking, band-sawing, and rough sizing of lumber happens here, inside a chain-link cage for security. At the end of the mill is the woodshop, and the timbers can be brought in directly to be shaped up before seasoning. Across the yard is a staging area connecting to the kiln, press, and storage. Here the lumber is cured and processed, and it can be shipped out of the loading dock or pass directly into the digital fabrication lab.

Figure 62. Perspective - Flexible Use Workshop

The courtyard scheme allows for the various functions to face each-other, offering a high degree of transparency with all the activity on display. With as many functions as possible placed out of doors or on display behind glass walls, anybody can simply walk up and learn something about timber processing. Experimentation inside, demonstration outside.

The courtyard loop terminates at the pond. No structure obstructs views to the water from down the lawn except for a large, sculptural hearth that forms a seating area for fireside gatherings. Traditional methods of sharing knowledge such as storytelling and dialog are still effective and should not be lost in the digital revolution, so a space for intimate social interaction as well as larger gatherings is provided here. The retention pond is celebrated a reminder of forests' integral role in protecting water systems, and waterways have always been used to float timbers away to trade. The hearth sits on a bulkhead forming a pavilion overlooking the pond for a scenic, relaxing, and inspired work environment rooted in the lush forest setting that this facility serves.

Figure 63. Demonstration Court

CHAPTER 5. CONCLUSION

Technological advancements in software, communications, and robotics are proving that intelligent forest management can benefit the economy and the ecology at the same time. A ‘restoration economy’ is emerging, a holistic business approach that can solve many problems simultaneously. Artificial intelligence and automation are showing promise in greatly improving efficiencies in planning, planting, and harvesting, and innovative forestry businesses are finding ways to turn carbon-dioxide into cash. These developments hold great potential for reversing environmental degradation, but they are still in their infancy and are generally inaccessible to the majority of forest owners. With smart forestry management tools designed to capitalize on 21st century revenue opportunities, private property owners and government agencies alike can be empowered by economic drivers to make climate change intervention happen at a faster pace.

Working these intelligent and labor-saving technologies into business as usual is in itself not the answer. The greater importance is still sustainable forest management, because without this principle, these technologies could be used to tear down forest ecosystems faster than ever. It is critical to make sure large timber companies as well as small landowners fully understand the value of their forests and how to keep them healthy. There is a great fortune to be made in timber because of new building technologies supplying excellent products for the ever-growing housing sector. It is a miracle that the environmental interests and business interests coincide but will take work to ensure that this does not become a false claim.

Placing the proposed technology center under control of the Center for Sustainable Technology ensures that the focus placed on these technologies is guided with the interests of the planet above all else. The location of a technology center for forestry needed to be central to a wide range of forest owners; Pack Forest is the perfect host for such a facility. It connects University research with real world practice, and now it can connect the region’s historic timber industry with its contemporary tech industry.

As an academic facility, the new building aims to bring together every discipline in the science and industry of forestry to form a community. As a visitor’s destination or discovery, it offers an up-close learning experience.

“Forest-driven futures” is the premise of planting trees to ensure a sustainable tomorrow: The Center for Advancement of Sustainable Forestry provides a place where hikers, students, scientists, programmers, machinists, loggers, carpenters, and engineers can become the next generation of foresters. It is designed to bring the existing UW Forestry program up to date by expanding capabilities of the Center for Sustainable Forestry at Pack Forest. The building rounds up the many disciplines that contribute to the continuous development of sustainable forest management practices, and it embodies the spirit in a robust display of age-old materials paired with cutting-edge technology. The transparent and interactive site layout tells the story of wood products development. The proposed facility is both a destination and a discovery center. The technologies it fosters have the potential to greatly improve forest restoration efficiency, and the educational environment it creates will promote best practices for co-generative stewardship. At the core of the design concept is demonstration, for education is the foundation of the future.

It is the hope of this thesis that the Center for Advancement of Sustainable Forestry will plant the seeds for a new age of harmony between the built environment and the natural environment.

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