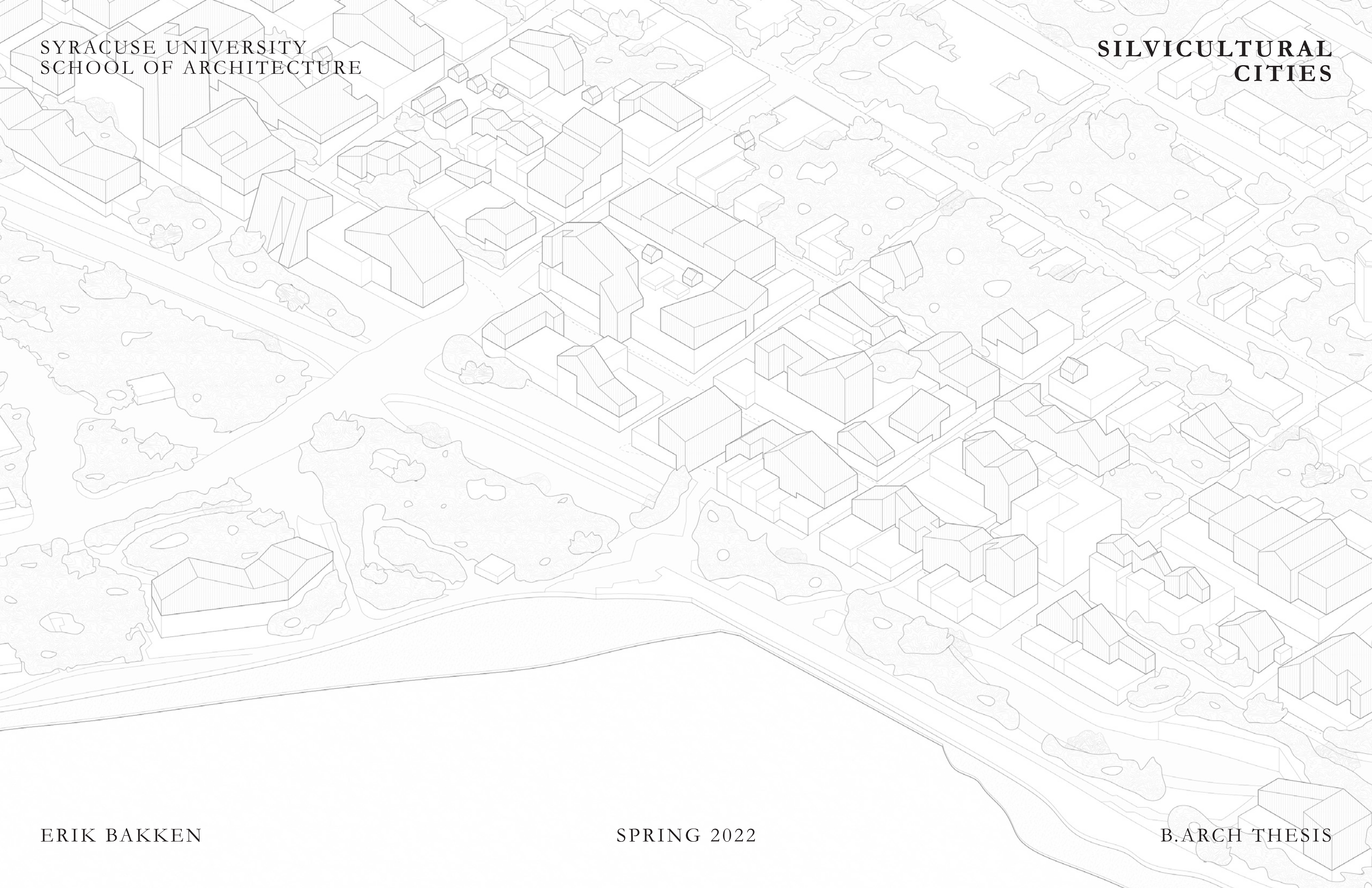
SYRACUSE UNIVERSITY
SCHOOL OF ARCHITECTURE

SILVICULTURAL CITIES



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SPRING 2022

B.ARCH THESIS

Thesis Booklet

Spring 2022

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SILVICULTURAL CITIES

Designing for a Sustainably Sourced Timber Urbanism

Erik Bakken

Contents

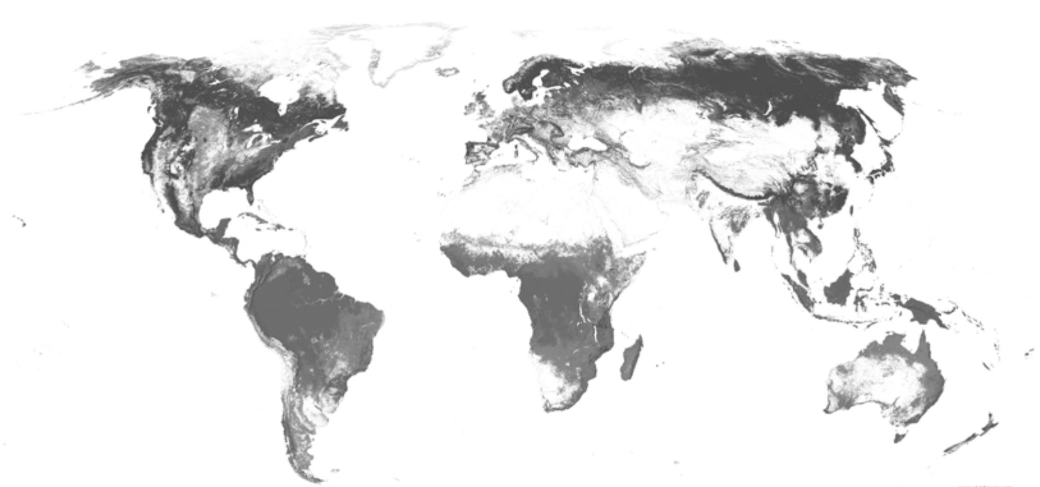
PROBLEM STATEMENT

From the Forest...

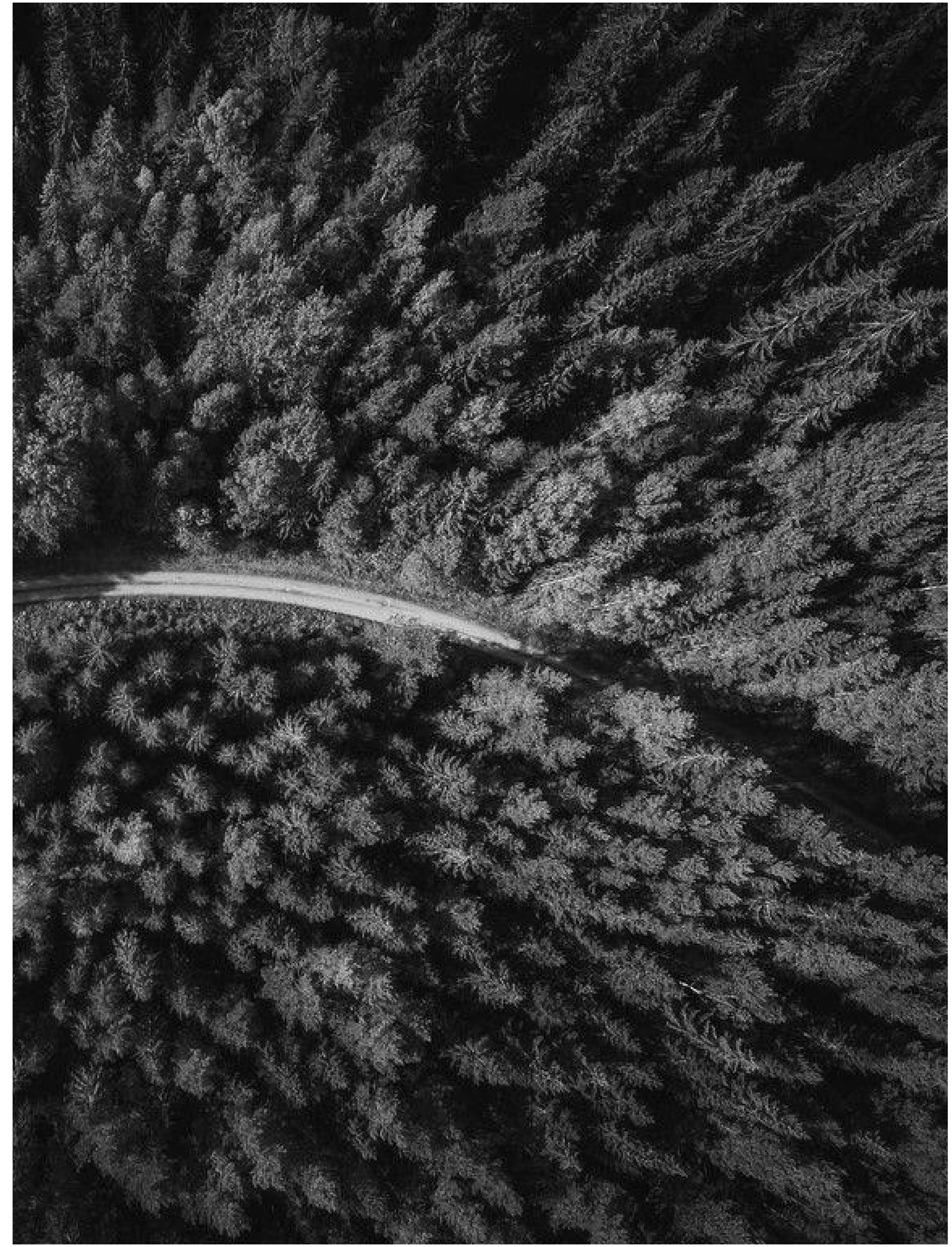
Today, forests cover about 4 billion hectares of land around the globe, which amounts to about 30% of the Earth's total land surface. Forests are the most biologically diverse ecosystems on land, providing habitat for more than 80% of terrestrial species, including animals, plants, and insects. Forests are key in the process of oxygen production, which is essential for human survival, and carbon sequestration, which actively counters anthropogenic emissions.

Yet, over the past twenty-five years, Earth has lost about 100 million hectares of forested land, equivalent to a decrease of 3.1%. Deforestation is the second-largest cause of increased carbon dioxide emissions to the atmosphere, after the combustion of fossil fuels. Deforestation, and forest degradation, is the cause of 12% of human-generated greenhouse gases.

According to the IPCC Special Report on Climate Change and Land, sustainable land management is necessary to mitigate anthropogenic carbon emissions, particularly in forests. Though unmanaged forests play an important role in absorbing emissions, accumulated carbon is increasingly at risk of future loss triggered by disturbances such as flood, fire, drought, or pests as the global temperature rises. Additionally, when vegetation matures and carbon reservoirs reach saturation, the annual removal of CO_2 from the atmosphere declines towards zero. Thus, managed forests, in which material is strategically removed to mitigate density-related risks and promote increased growth, are more effective at combating climate change.



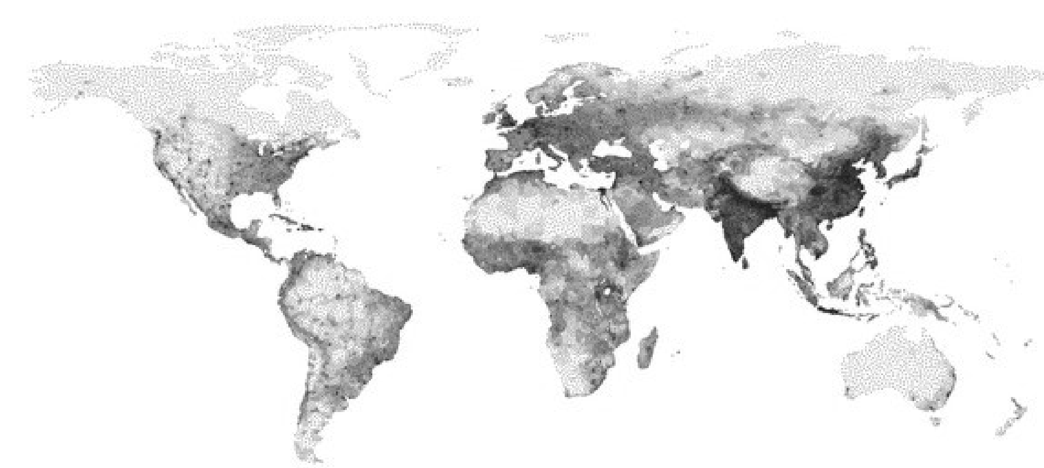
global forest density



...to the Built Environment

Sustainably managed timber removal provides an opportunity for the built environment to play a role in carbon sequestration. While the physical embodiment of carbon in materials such as beams or siding is clear, there is less understanding of the forested environments these products come from. And the provenance of wood products matters; each piece of lumber represents both its own stored carbon and the space it has created for another tree to grow, repeating the sequestration cycle. Plus, the built environment, when designed out of timber, is more efficient at sequestering carbon per area than a forest is.

There is a pressing need to manage forests, particularly in the face of worsening climate change. There is an urgency in architecture for sustainably-sourced and carbon-sequestering materials in the face of climate change, a burgeoning global population, and housing crisis. Can architecture be used to connect and combat each of these issues? Can local forestry management processes be integrated with modern wood construction techniques like glulam or CLT? How can architects design for a symbiotic relationship between forests and the built environment?



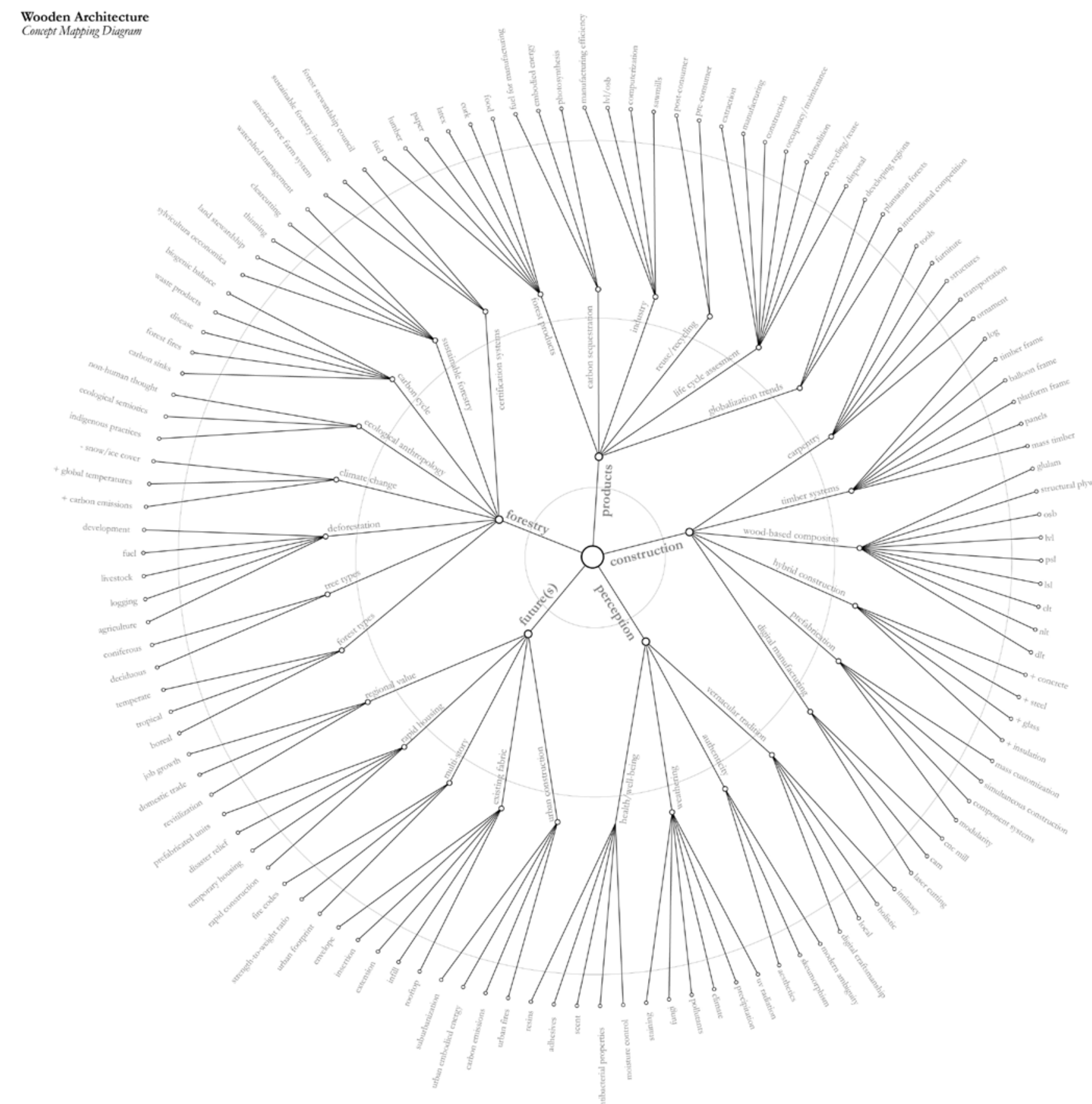
global population density

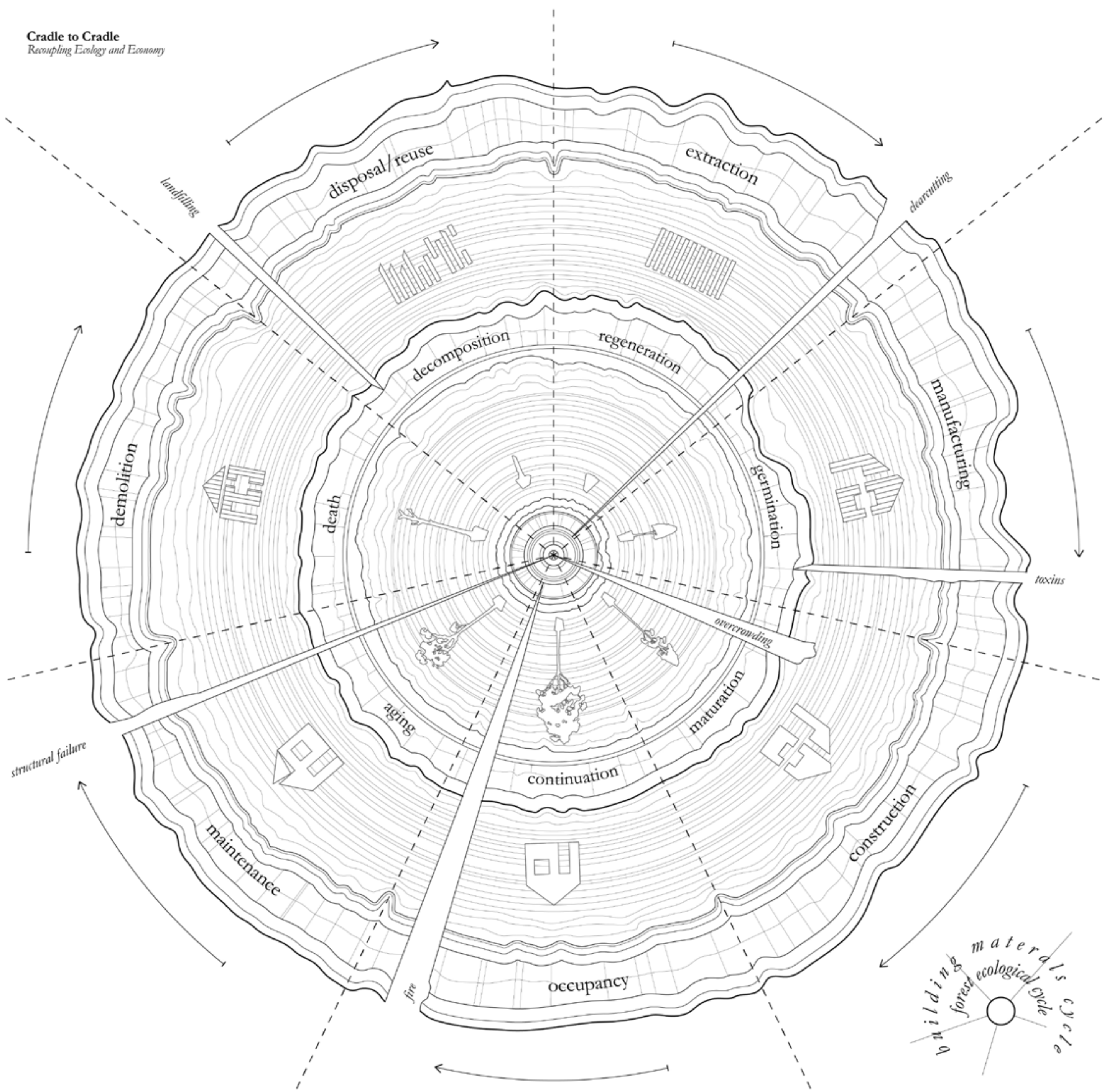
RESEARCH PARAMETERS

Branches

The topic of wooden architecture encompasses a wide array of subtopics, from forestry to construction and perception. This diagram maps out many of the existing strains of research and interest related to wooden architecture.

This thesis aims to design a built component of a system that connects ecological needs with human needs in the built environment. In order to do this, how each decision is read from multiple perspectives is necessary to understand. For example, a decision to coat wood in fire-resistant gypsum has direct impact on aesthetics and perception. The use of a particular construction detail can trace back to forestry strategies. This diagram helps to reveal those connections and all of the varied parameters that bound this thesis.



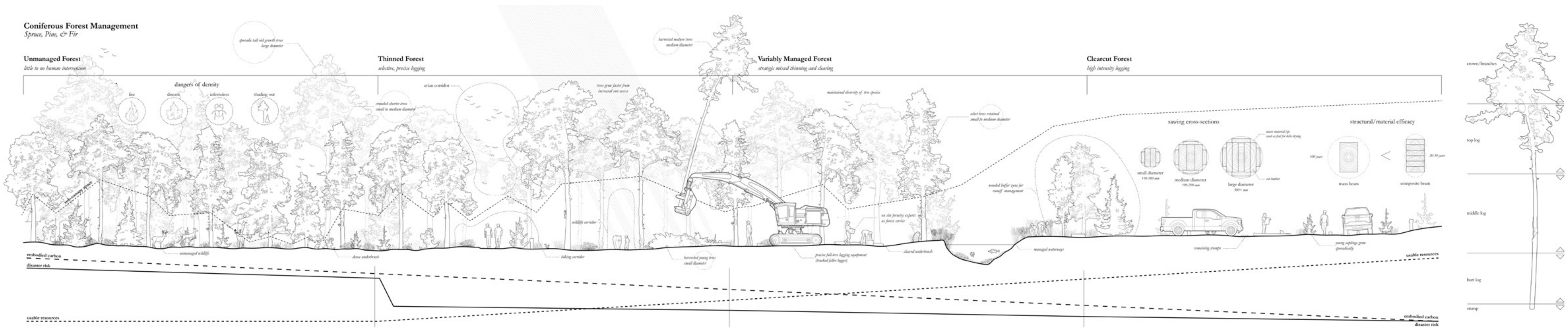


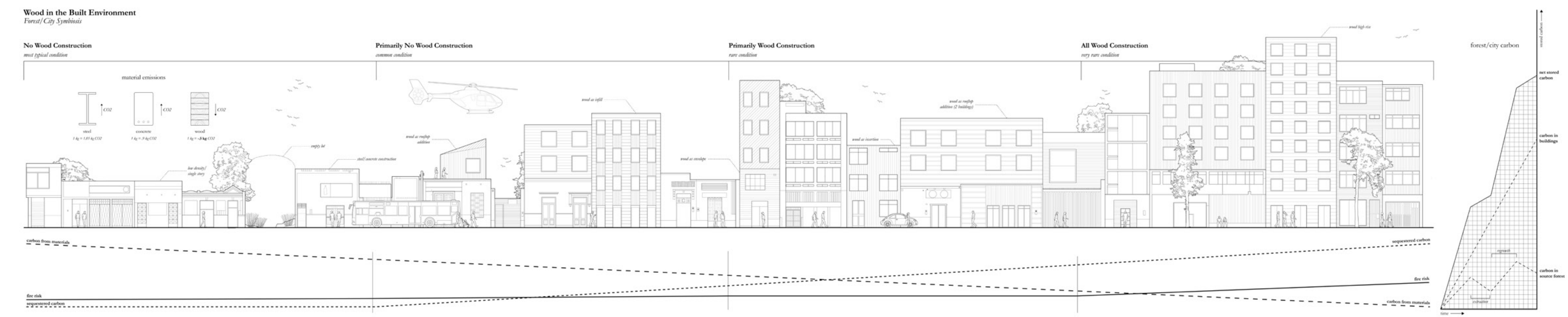
Rings

Timber presents a unique opportunity as a biodegradable and sustainable resource. This diagram connects the parallels between the life cycle of a tree and the life cycle of a building. Typically, architecture does not follow a cradle-to-cradle cycle like that of a forest. And human intervention often interrupts stand succession in the forest. Various scars, such as fire, clear-cutting and structural failure can prevent both cycles from being truly sustainable.

Thus, it is vital to understand the life cycles of both material and building in order to create a sustainable architecture. While architecture is often restricted to construction, occupancy, and maintenance, all parts of the process, from extraction to disposal, must be understood. How can a building live and die like a tree? How can a city grow and decay like a forest?

MATERIAL EXCHANGE



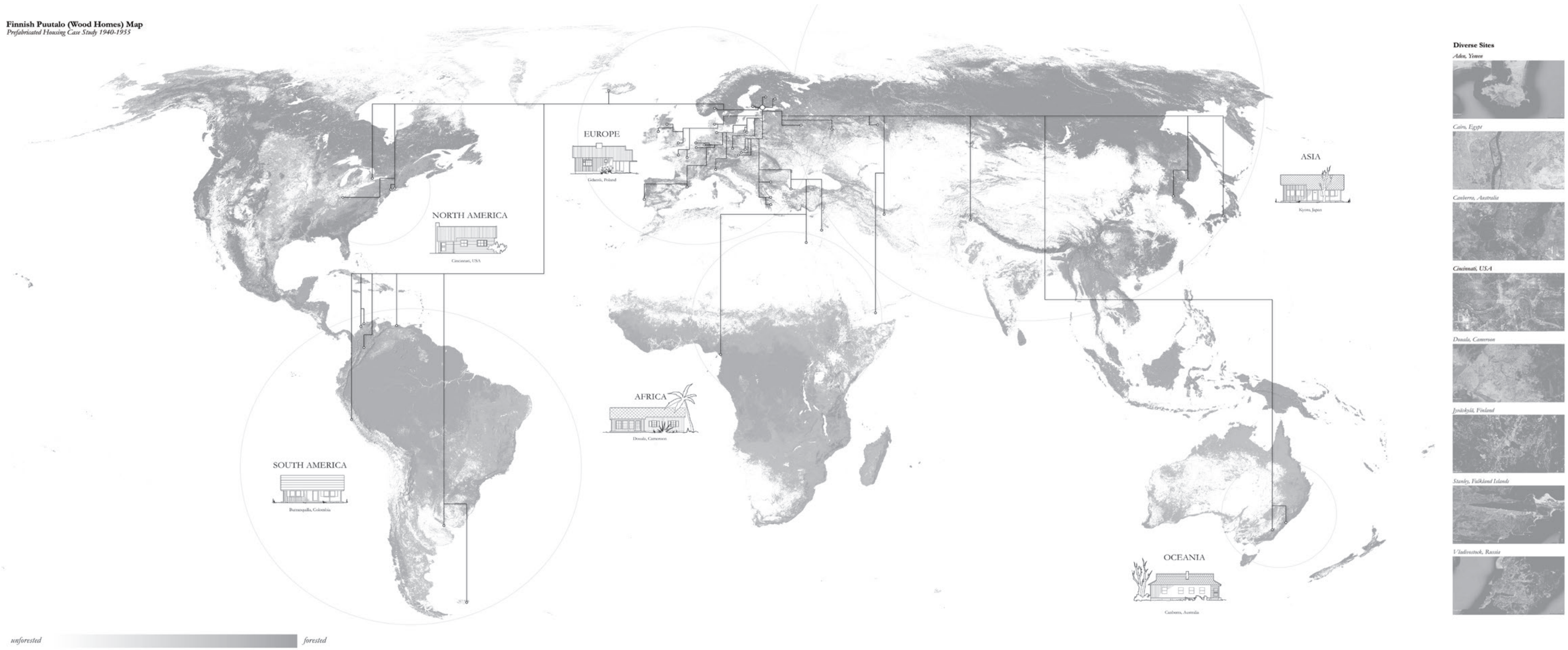


The extraction of materials and the construction of timber buildings have an inverse relationship. The shift in material has varying effects on density, risk, and sequestered carbon. For example, density equals fire risk in cities, but it also means greater carbon sequestration and opportunity for trees to grow in sources forests. Net carbon stored in forest and city grows if forests are sustainably managed. Small diameter laminated wood products from young, thinned forests in particular provide a notable opportunity.

SUSTAINABLE HOUSING

After World War II, a need for rapidly constructed housing became apparent. The Puutalo company in Finland sought to capitalize on this need and developed prefabricated wooden homes that were shipped around the globe. Harnessing abundant local forest resources, the Finnish company managed to address housing needs with sustainable materials on a global scale. The homes, based on a few standardized plans, could be slightly modified to their local climate and culture, taking a universal approach to housing diverse populations.

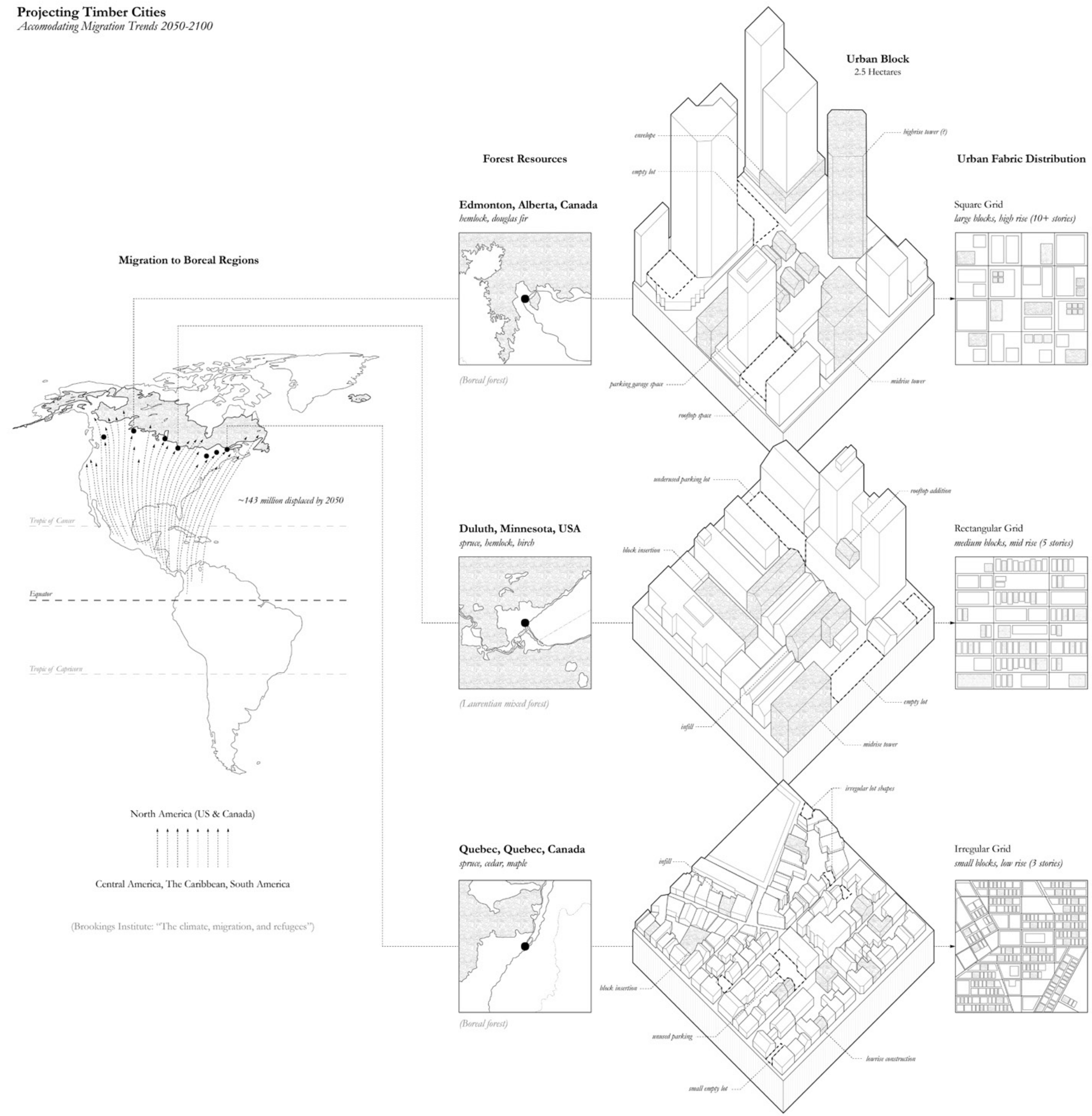
However, this process was not net sustainable. Broad clear-cutting and forest pollution led to a degradation of ecosystems in Finland. Plus, the immense transport emissions from shipping prefabricated wood pieces across the globe countered the initial carbon sequestration of the wood. Many of the cities that Puutalo homes ended up in were completely divorced from forest resources. Thus, this case study helps to reveal the value in using locally sourced materials over materials linked to broad global supply chains.

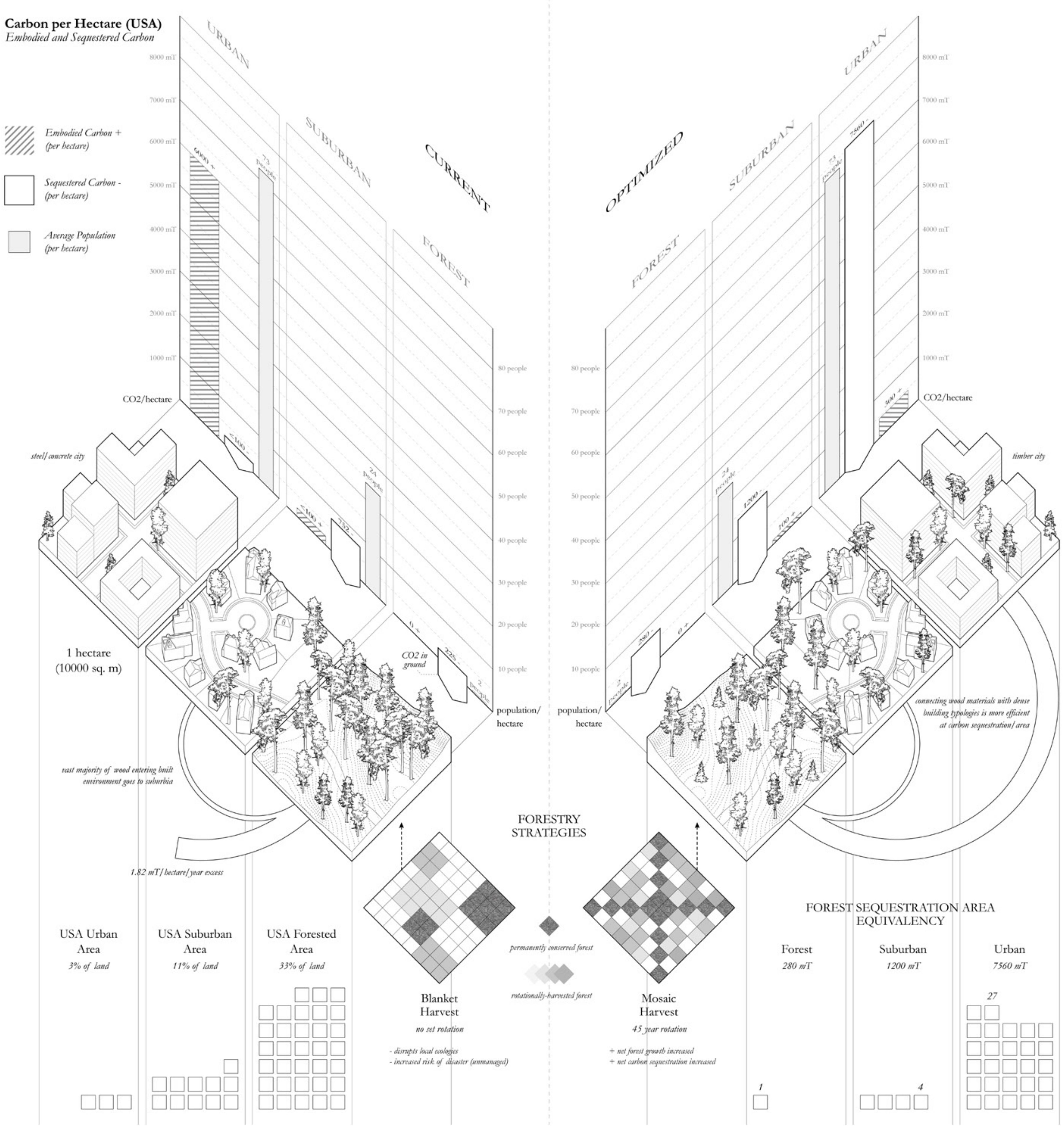


Anticipating housing need and the cities that can best support sustainably-built housing is crucial to situating this thesis. According to the Brookings Institute, around 143 million individuals will be displaced from Central America, the Caribbean, and South America (due to drought, flooding, and governmental instability) and will move north to the United States and Canada by 2050. This diagram maps that movement over current forest resources in the boreal zone, which will be spared from the most immediate and dramatic perils of climate change.

Cities along the southern edge of the North American boreal forest provide a unique opportunity as they are situated at the intersection of future housing needs and potential for local timber construction. Today, the boreal forest is the best managed forest in the world, growing annually. Mid-to-high rise, high density urban areas in the northern United States and Canada will need to grow to accommodate population influx from climate refugees. Growing sustainably using local forestry resources is imperative.

Growing *strategically* is necessary too. While the need for carbon sequestration is apparent now, construction must be couple with sustainable extraction in order to maintain a balance between resource and construction. Forests cannot be depleted to create a completely timber city, but instead timber buildings must be woven into exiting urban fabrics over time to balance ecology and the built environment.





CARBON CALCULATIONS

Forest, Suburb, and City

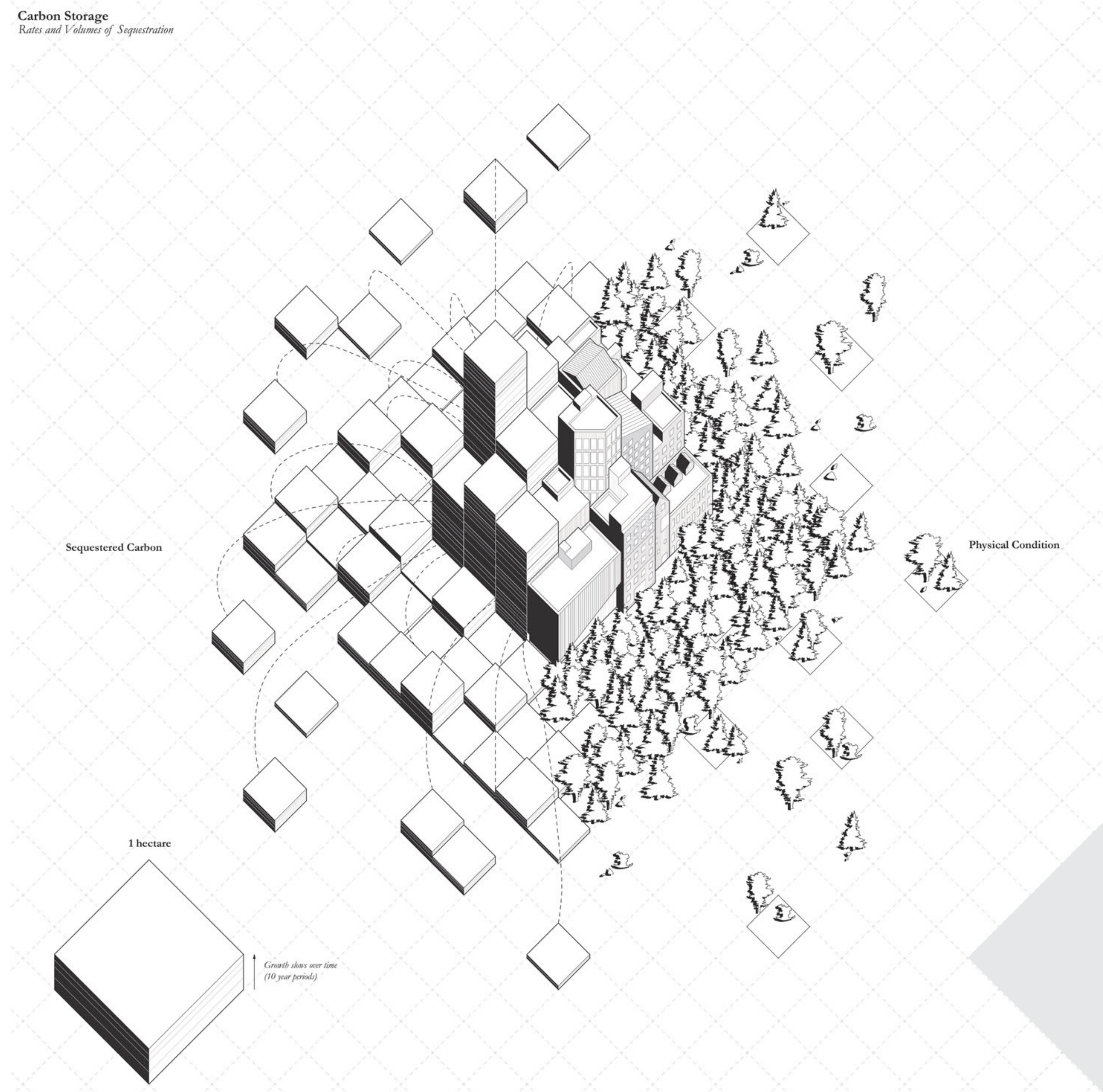
The metrics of carbon sequestration are vital to proving that the proposed connection between forests and the built environment is a balanced, and therefore sustainable, equation. In the United States, the proposition for timber construction in the urban environment is sound.

The reservoir of forest resources in the United States is growing year to year. Yet carbon in wood is more efficiently stored in a denser, urban environment than in a forest, by about 27:1 when comparing equivalent land areas. Thus, designing an a growing urban environment to be a sustainable carbon repository is a strong possibility to combat both the looming climate and housing crises.

Networks of Carbon

Understanding the raw numbers and rates of carbon sequestration at a diagrammatic level is important to clarifying the basic argument that a city, when built from timber, is more efficient at carbon sequestration.

Each mid-rise timber building represents carbon sequestration from several forest plots with the same footprint. Using younger, smaller diameter timber products (typically harvested in ~45 year rotations) from sustainably managed forests allows for buildings to be constructed more rapidly and with less ecological disruption than if the material was sourced from old growth woods. This shorter cycle of usage is synced with the decreasing efficacy of forests as they age past maturity, which typically occurs around 40 years. This thesis does not propose the usage of *all* forest resources in construction, but rather the strategic removal and use of certain trees to allow for greater net carbon sequestration between the built and natural environments.



In the Site

This calculation can be extended into the site in order to make an argument about the potential carbon neutrality or negativity of architecture.

In the proposed site in Duluth, Minnesota, the unique possibilities of wood construction in the urban environment are revealed. Timber's strength-to-weight ratio allows it to span across existing masonry, concrete, and steel buildings and activate the roof scape. Instead of demolishing and disposing of the embodied carbon in buildings constructed from carbon positive materials, wood can be used to reengage and activated the exiting urban fabric while sequestering environmental carbon.

Timber Massing in a Site
Material Opportunities and Calculations

DESIGN PARAMETERS

Ultimately, this thesis prep proposal anticipates a single built project that is a stitch in a larger spatial and temporal fabric of material exchange. The anticipated project seeks to exemplify a potential systematic symbiosis between the forest and built environment and the unique benefits of designing with sustainable timber. Thinking at multiple scales and through the multiple perspectives of silviculture, design, structural engineering, manufacturing, etc. will be important to producing a design that addresses the complex issues of climate change, urbanism, and housing.

What:

Multifamily residential

Where:

Duluth, MN and outlying Laurentian mixed forest

Who:

Climate-displaced migrants

When:

Circa 2050

How:

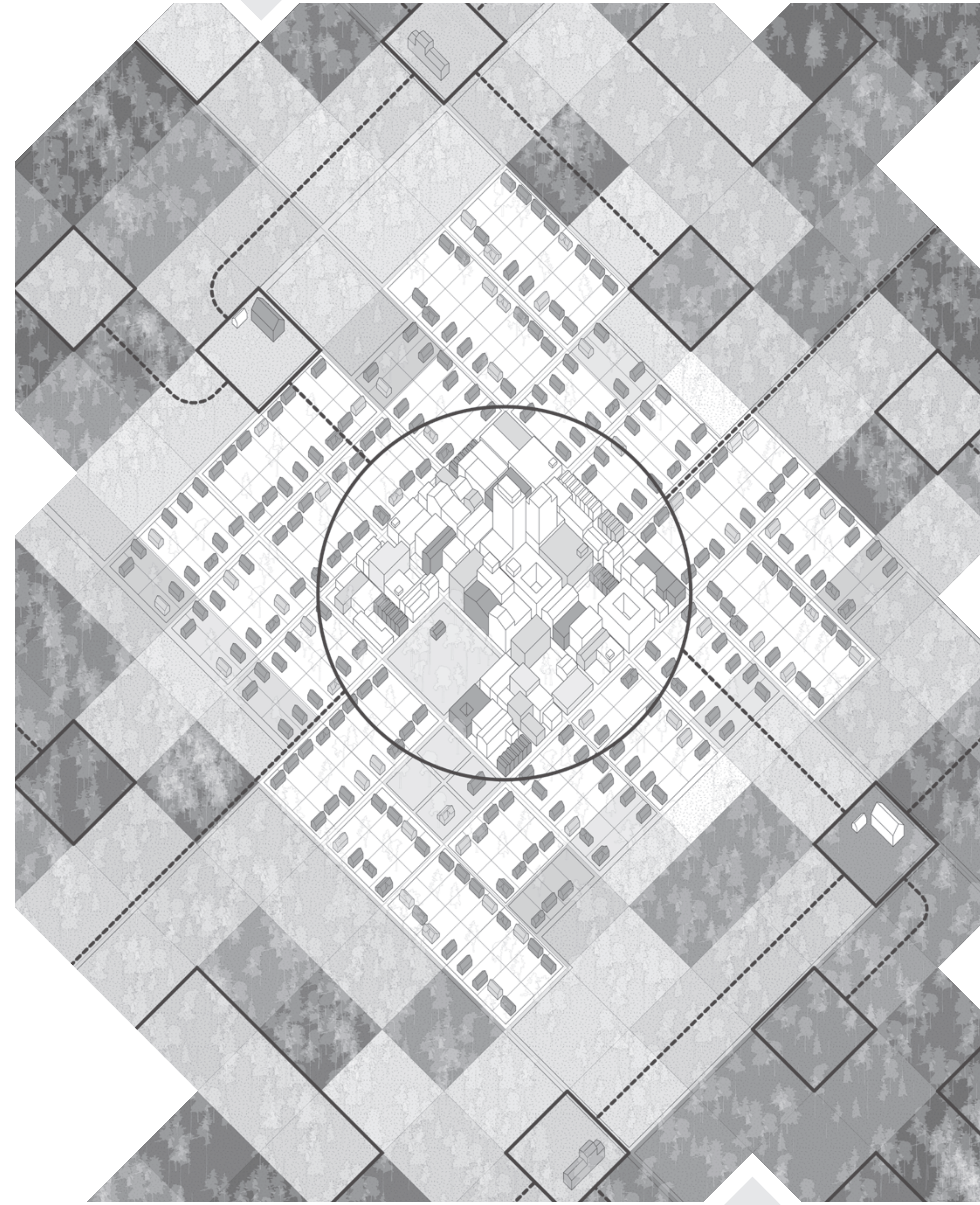
Mass timber coupled with local sustainable forestry

Why:

To link issues of climate and construction at multiple scales

To harness unique structural capabilities of timber in the urban environment

To develop a blueprint for sustainable urban growth



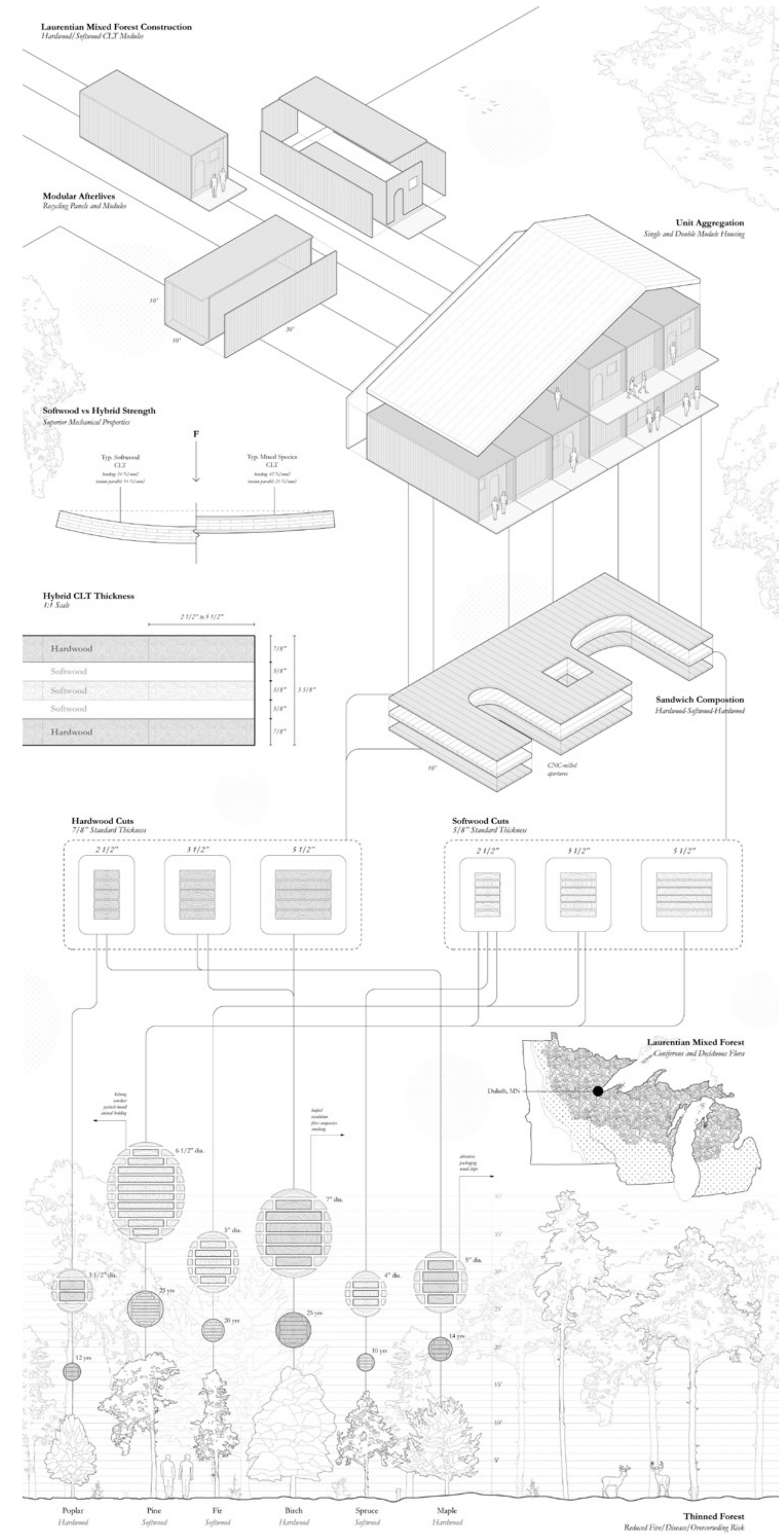
MIXED-SPECIES CLT

Material Provenance

The design relies on cross laminated timber, or CLT, modules of 10' x 30'. CLT can be constructed from small diameter (less than 45-year-old) trees, exactly the kind of material that needs to be thinned from existing managed forests in the region to mitigate risk of fire or other climate-related disasters. The surrounding Laurentian Mixed Forest has both hardwood and softwood species, yet hardwoods are often overlooked for construction value, particularly trees that are not high enough quality to be used as finish materials.

This project specifically embraces mixed-species timber, an innovation that sandwiches three 5/8" thick layers of softwood between two 7/8" layers of hardwood, creating a panel of 3 5/8" that can span in any direction due to its crossed layers. In comparison to typical softwood CLT construction, this scale of constituent pieces allows for the use of smaller trees as young as 20-30 years.

The hardwood layers can be constructed of lower-quality hardwoods (such as from poplars, maples, or paper birches) that do not have as much viability for finishes or furnishings in the current material paradigm. Plus, when hardwood cuts are used on the outside of the panel, they can be unclad; often softwood CLT needs to be topped with concrete or other carbon positive finish materials for flooring or cladding.



Unique Design Opportunities

The thin, layered pieces of lumber create strong and slender planes that can be used to construct modules and facilitate CNC milling apertures like doors and windows (Fig. 8). The typical 5-layer softwood CLT is around 6-7/8" thick, using layered pieces of dimensional lumber (about 1 ½" thick). Mixed species composition is thinner and similarly strong, allowing the use of material that is cut out of panels to be used as movable doors, shutters, or tables in a way typical CLT could not.

This design embraces many possibilities to avoid waste material being created in the fabrication of apertures, whether that's folding down a window cutout to become a bed or cutting a piece removed to make a door into a shelf. Because CLT sacrifices some compostability for durability and longevity, it is vital to think about how all of the material can be used throughout the design and beyond.

THE SILVICULTURAL CITY

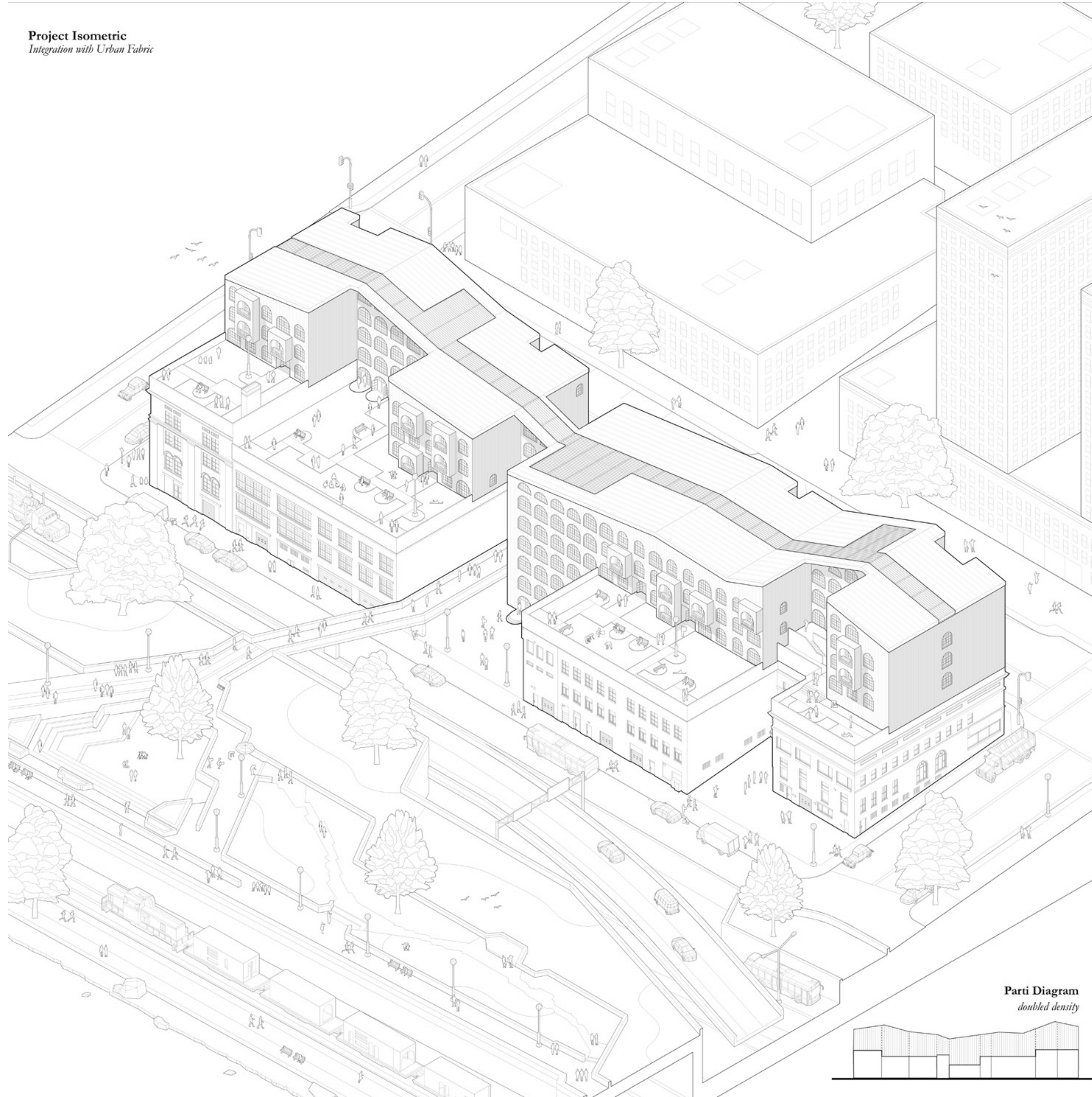
Design Strategy

This design is for a timber housing block situated across the tops of 6 separate industrial buildings built from concrete and masonry. In order to create a cohesive building that could be built up over time, the CLT modules are stacked and aligned atop their respective buildings in plan and section

In this case, modules are 10'x30', about the size of a shipping container, in order to accommodate prefabrication and shipment to site along roads or rail. They contain a wet module, including kitchen and bathroom, and a dry module, including living and sleeping space. The modules are typically doubled up, creating 2-bedroom apartments that can accommodate young families. They are stacked up and aligned along a double-loaded CLT catwalk corridor system that has skylights above and creates a light, outdoor feel in the interior space. Residual space between the top modules and the roof becomes public shared space, fostering a sense of community ownership within the building.

The modules rest atop glulam plinths that span the existing structures. The units connect to the buildings below through vertical cores that pierce through new and existing structures and uniting the commercial spaces below with the living units above.

Lastly, the entire system is clad in a unifying skin that spans the project. This allows for strategic environmental control within the project between public open space and private units. This is especially important in cold climate like that of Duluth. The insulation can be made from wood waste products and the cladding from wood strips, creating a design that sequesters carbon in nearly every material

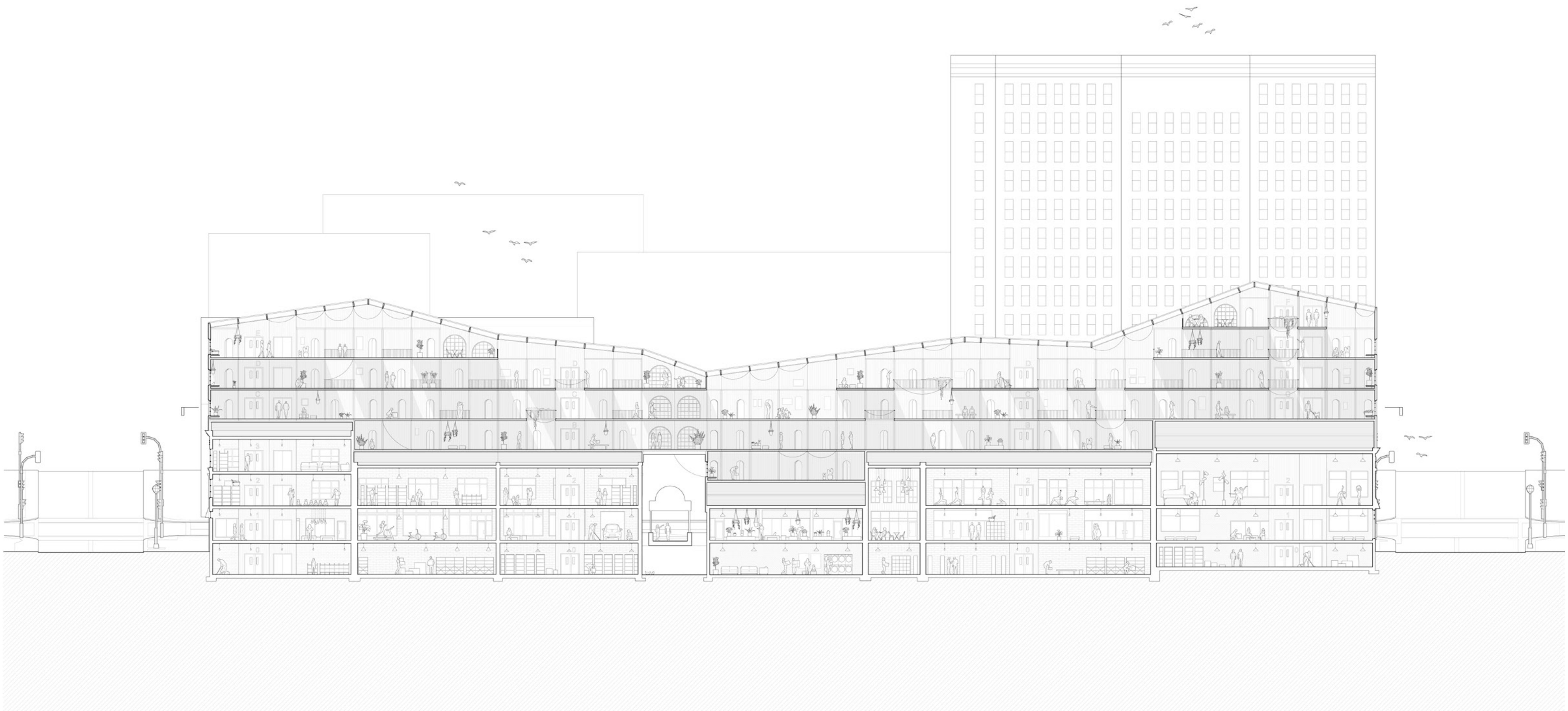


Project Elevations
Lake & City Elevations

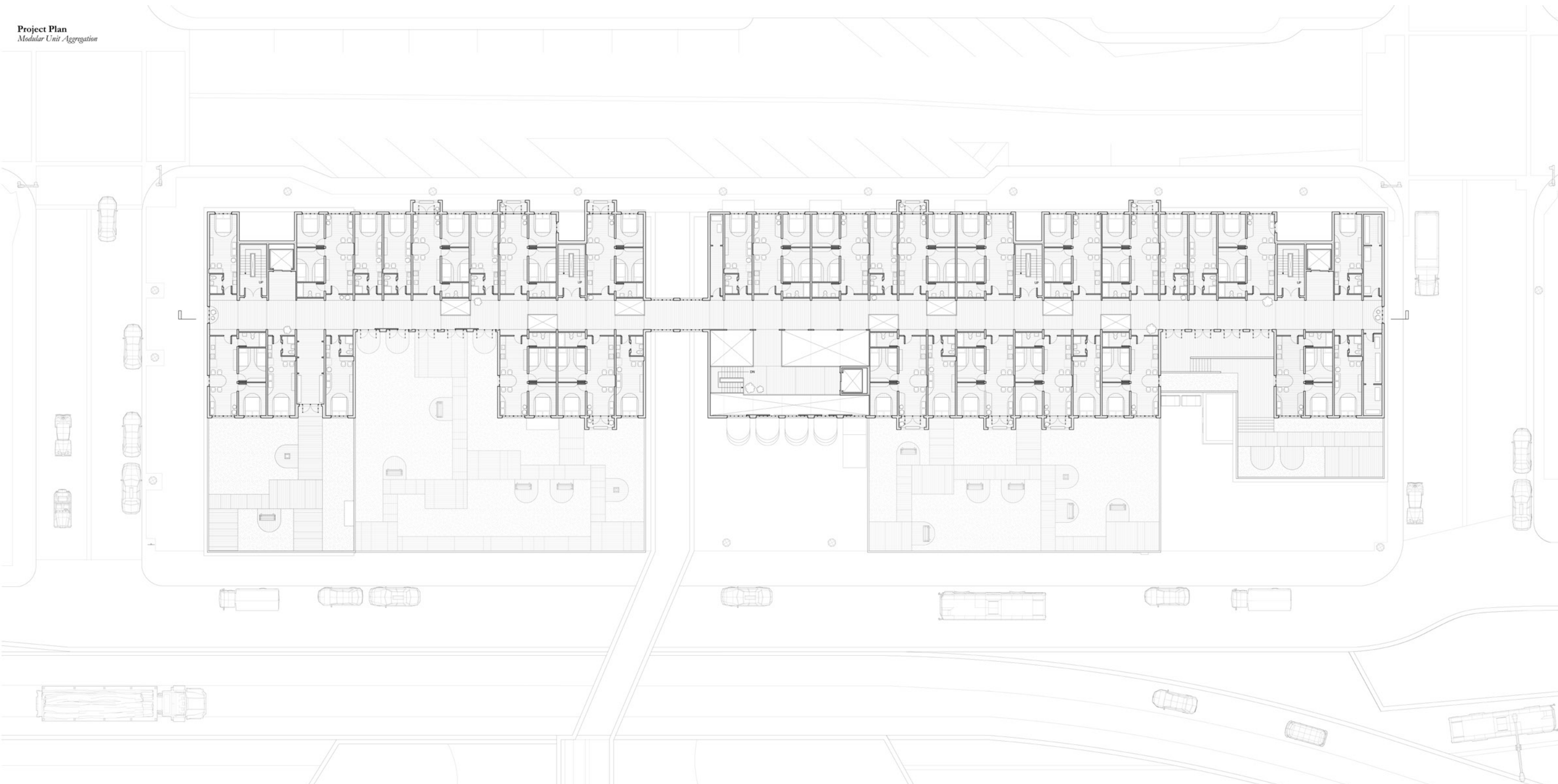
Lake Elevation

City Elevation

Project Long Section
Above and Below



Project Plan
Modular Unit Aggregation



The modules rest atop glulam plinths that span the existing structures. The units connect to the buildings below through vertical cores that pierce through new and existing structures and unite the commercial spaces below with the living units above.

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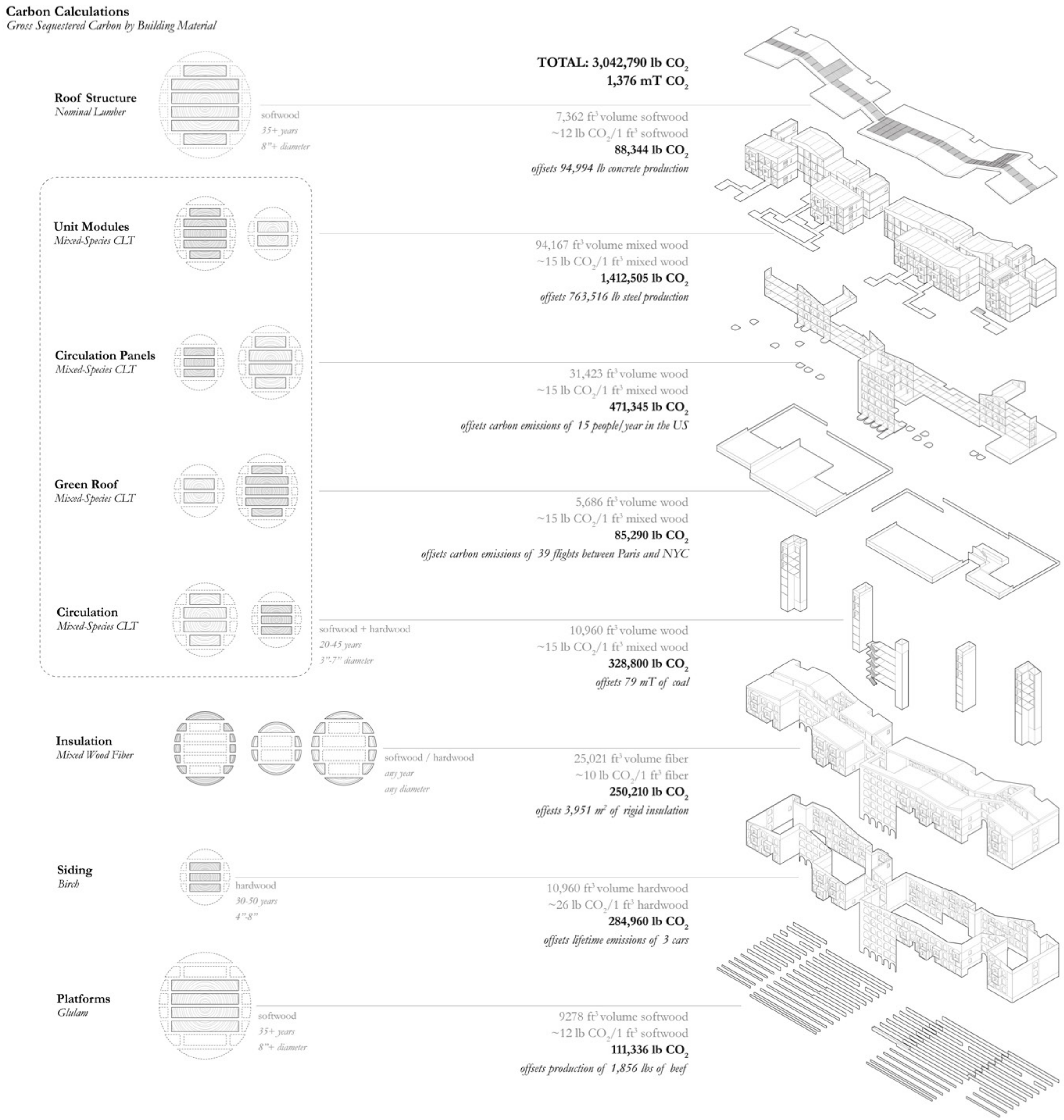


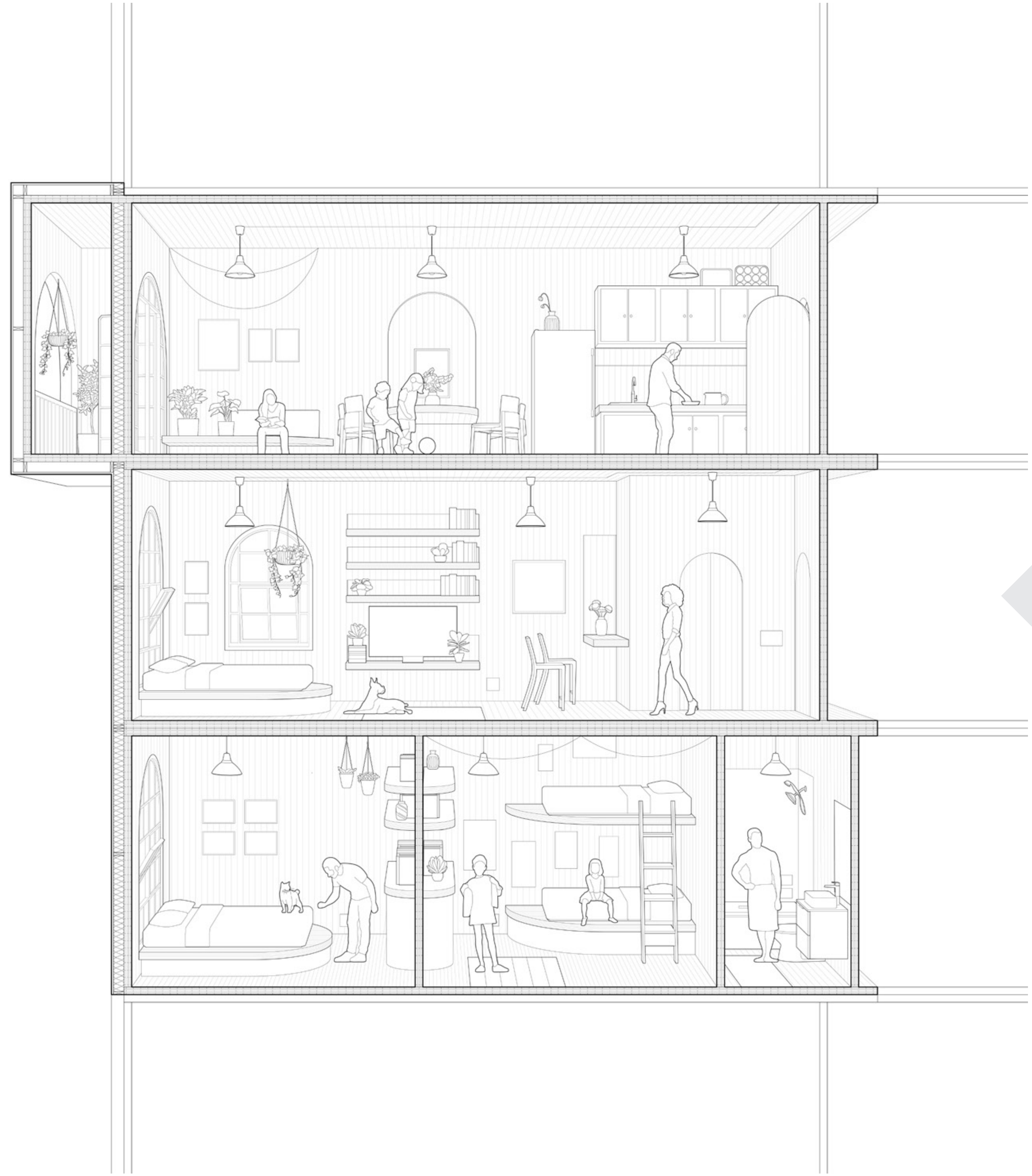
Timber Supercity

The project would be constructed over time, as to not overburden the existing forest resources all at once, with each portion corresponding to a building below being constructed sequentially.

This construction process can also then work in reverse—CLT units can be removed as individuals or groups to be redeployed as housing elsewhere depending on need. The modules can also be broken down and the panels recut into new forms for a completely new purpose or building.

Ultimately, this project seeks to do several things; provide sustainably-built housing for climate migrants, sequester substantial amounts of carbon from the atmosphere in a dense repository, and reactivate an industrial urban fabric found across the United States.

But most importantly, it proposes a sustainable relationship between the urban environment and the forest through design, and to propose an architecture takes advantage of the unique structural and carbon-sequestering properties of timber. This thesis reconceives the timber architecture herein as a relationship between the surrounding boreal forest and the urban structures, and also calls for consideration of a life-history strategy in thinking of architectural materials.



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