An Arborist's Approach To Building Regeneration: *Planting Trees In Obsolescent Soil*

by

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For my children; dream boldly and work hard.

Anything is possible.

Contents

Abstract

Given the environmental impact of utilizing non renewable resources in the open loop carbon cycle of build-use-demolish, it is imperative to effect a fundamental change in how the urban landscape is developed.

This thesis proposes a symbiotic methodology of development based on the relationship between a tree and its soil in order to close the current open loop carbon cycle. Through the analogy of an arborist, a '*tree*' [building element] is '*planted*' [constructed] into '*soil*' [obsolescent building] drawing on '*nutrients*' [structural, architectural, etc.] embedded in the '*soil'.* This method of growth regenerates the '*soil*' and enables the '*tree*' to become a catalyst of new growth through the arboricultural method of grafting.

This shift in perception of regenerating existing buildings is an ecologically effective solution and through the analogy of arboriculture will change the current climate discourse around building from pragmatic to poetic; igniting the imagination with possibility.

Acknowledgements

I wish to thank my wife Shaeline, for your selfless love, unending support and encouragement, my grandfather for instilling in me the desire to create, and my parents and grandmother for their love, encouragement and support.

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Chapter 1: Introduction

This thesis investigates the opportunities that present themselves when obsolescent buildings, “.. alive to evolution” (Brand 1994, 11), are regenerated rather than demolished. The thesis proposes to change the perception of how the urban fabric is developed. Architects, are “... the primary actors in determining the material composition of our buildings” (Fernandez 2006, 59), and have a responsibility to fully understand and communicate the impacts made by the materials they specify for their building designs. Until recently these decisions have not considered impacts on the environment such as the embodied carbon of the material, the extraction of the raw (often non-renewable) resource or the effects after the material has been demolished and transported off site. (König 2011; King 2017). To meet an ever increasing population Architects will need to lead changes to our understanding of how to develop our cities. One such change is the eco-effective (McDonough and Braungart 2002) intervention of regenerating existing buildings by building onto them rather than replacing them. By doing so the Architect is able to encapsulate the embodied carbon in the existing buildings, reduce the amount of ‘new’ material consumed, and eliminate the carbon impact of demolition and transportation of the demolished material off-site.

Utilizing this method of adding onto existing buildings, the Architect acknowledges that the existing building has come to its current state in part due its age. Often when a building has been determined to have exceeded its serviceable life, it is replaced. By acknowledging this service life the Architect is able to capitalize on the strengths of the existing building and only intervene where it is necessary to regenerate the building and thereby extend its serviceable life.

The impact of embodied carbon on the environment has only just recently been realized and is not yet fully understood. As many life cycle analysis' have shown (Skullestad et al. 2016; Borjesson and Gustavson 1999; Nassen et al. 2012; Eliassen, Faanes and Bohne 2019; Zizzo, Kyriazis and Goodland 2017; IEP and UNEP 2018, 43) using wood in place of the concrete and steel will have a positive effect on the environment. Wood is a renewable resource that sequesters carbon and is capable of competing structurally with concrete and steel through the advent of mass timber. While there are many materials from which an Architect can choose when deciding to build onto existing buildings this thesis investigates the potential of utilizing mass timber for the new building elements.

Thesis Hypothesis

Building onto existing urban '*soil'* with a mass timber '*tree*' is ecologically effective because it encapsulates the embodied carbon currently embedded in the existing structures incurred from the extraction, processing, transportation, manufacturing and installation of that material. In addition building with mass timber sequesters carbon in the new construction and closes the open loop cycle of urban re-development

This hypothesis will be investigated through the analogical lens of an Arborist and the arboricultural practices of *planting* and *grafting.* The thesis proposes a method of studying an existing building, identifying its available nutrients, preparing it for the new building element to be planted within it and then planting the new building element and finally grafting on new elements as required.

The lens of the Arborist seeks to shift the conversation around sustainable construction from pragmatic to poetic: igniting the imagination with possibility. Discussing a subject matter poetically or analogically serves to remove ones own prejudices of that subject, shifting their perception and offering a more neutral discourse through which two opposing parties can work toward an amicable solution.

arborist :: architect

soil :: existing building

tree :: new addition to existing building

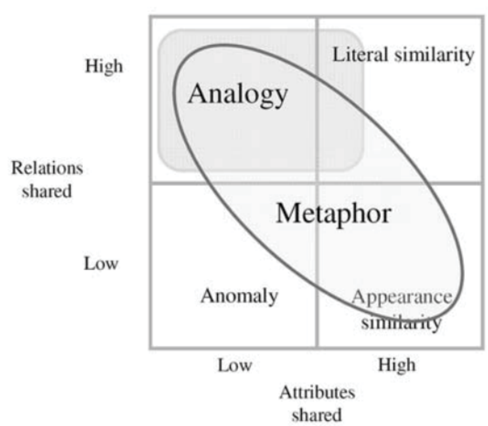
planting :: inserting a new building element (tree) into the soil (existing building)

grafting :: adding onto the tree (new building element) to expand the programmatic opportunity

Terminology

A Note on Analogy

In the field of creative design, analogy is used as a way of mapping the knowledge from one context onto a new one in an attempt to "...foster new inferences" and offer new insight for creative problem solving (Hey et al. 2008, 285). It is a useful tool for allowing a designer to apply their understanding of one subject matter towards another subject that they aren't as familiar with. This can enable them to have an "ah-hah" moment of discovery about a solution to a



Relationship between analogy and metaphor (Hey et al. 2008, 285).

problem such as climate change that they previously were not able to realize.

By utilizing concepts of analogy (Hey et al. 2008; Genter and Markman 1997) this thesis utilizes the analogy of the “arborist”, exploring ideas of arboriculture (the study, management and cultivation of trees using methods of planting and grafting) as they relate to regenerating existing buildings through the addition of new building elements. In addition to being utilized as a design tool, the analogy of the arborist has potential to shift perceptions of designers, developers and the public around the polarizing discussion of climate change.

An arborist is a trained professional in the management of soil and fostering of a tree’s healthy growth. They understand the specific needs of a tree to ensure its successful growth. They monitor the vitality of the soil in which the tree is planted and ensure the tree is receiving the adequate nutrients it requires to grow. They know that a healthy tree is capable of living hundreds of years and that the fruits of their labour will take an equivalently long time to be realized. They also understand the impact a healthy tree can have on its surrounding ecosystem, playing an important role in the lives of hundreds of living organisms ranging from moss to woodpeckers.

Applying this analogy to architecture provides a framework of discourse and practice from which one can regenerate an obsolescent building. Viewing a building as soil suggests that an existing building is capable of sustaining the life, like a tree, and reframes one’s perception of the building from a strictly utilitarian economical definition to a holistic understanding of the building’s potential. Understanding the act of renovating and expanding a building through the lens of an arborist offers an appreciation for the potential of that tree being planted. Just as one doesn't plant an apple sapling and expect to eat an apple the next day, the analogy of planting a tree reinforces the idea that urban development needs to plan for the impact of the next 50 years on a building as well as the building's impact on its surroundings. In the emerging urban landscape this is just as important as the building's return on investment over the next 5 to 20 years.

Throughout this thesis arboricultural concepts such as soil, tree, planting, grafting, rootstock and scion are used as analogy to describe architectural ideas. When a term is used literally it is written in regular font, when it is used analogously it is written in *italics*.

When viewed through the lens of an arborist the potential of regenerating obsolescent buildings can be appreciated. The *arborist* [architect] studies the existing *soil* [existing building] condition of a *field* [city], identifies the areas of obsolescent *soil* and studies the available *nutrients* [structure, architectural etc.] embedded within them. Once these *nutrients* are identified the *arborist* is able to *plant* [construct] the optimal *species* [adobe, mass timber, etc] of *tree* [new building element] that will *grow* in that *soil* and symbiotically regenerate it.

Plot 3CP1593BAR -
top - open loop cycle of development (obsolescent > demolished > replaced)
bottom - regenerated *soil* through *planting* of mass timber *tree*
(adapted from Archibald 2015)

Chapter 2: How a Tree Grows

Arboriculture

Arboriculture is both an art and a science and involves the cultivation of trees and shrubs (Merriam Webster Dictionary n.d.) with the primary goal of fostering the successful growth of trees.

Douglas fir

When an arborist decides to plant a tree they first assess the soil from which the tree will receive its nutrients. They prepare the soil by pulling back the top and digging a hole into which they place the tree. Once the tree has been planted, its roots embed themselves into the soil and the tree begins its growth through the cycle of photosynthesis. Absorbing carbon dioxide from the atmosphere, drawing up water through its roots, and absorbing the sun's energy through chlorophyll rich green leaves, the tree produces sugars and oxygen. These sugars are fed into the soil through the trees roots where fungi convert the sugars into nutrients that the tree uses for growth. As the tree grows its roots bind the soil together and prevent further erosion. The symbiotic relationship between tree and soil is critical for the health of the tree and the soil.

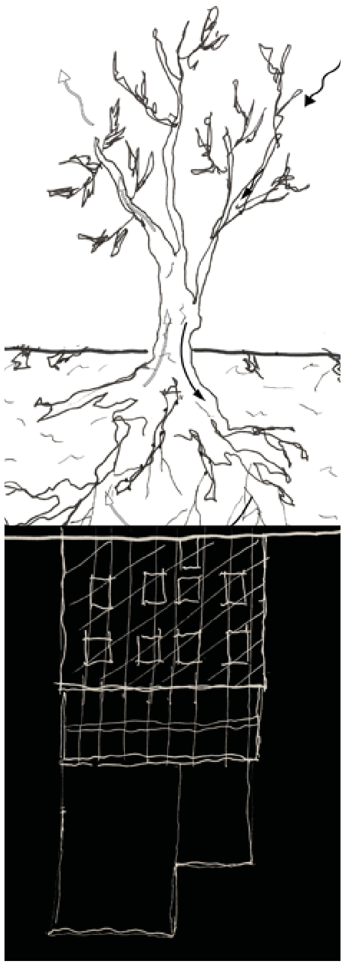
rootstock :: branch of the existing tree that receives the graft.

scion :: a new branch or bud that is grafted onto the existing rootstock

Grafting terminology

Once a tree has matured the arborist may decide to improve its yield by grafting a scion onto it. With practiced precision they make an incision into the rootstock to insert the new scion. Ensuring the successful connection between the rootstock and scion is paramount to the success of both. Once healed the newly grafted scion begins its own photosynthetic growth, drawing nutrients from, and supplying sugars to the rootstock.

Role of the Arborist



Planting a mass timber building into existing obsolescent building

An arborist is a caretaker of trees. They possess a tacit knowledge of trees and are responsible for their overall growth and health. Using techniques such as planting and grafting they are able to regenerate barren soil, while also promoting the growth of trees.

Arborist's understand the critical symbiotic relationship between soil and trees. They know that the success of the tree's growth depends on the nutrients it receives from the soil. And the soil's ability to provide nutrients to the tree depends on the root structure of the tree supplying carbohydrates to the soil and also protecting the soil against erosion.

With their unique skillset an arborist is charged with caring for the wellbeing of not only the trees which they plant but also the soil into which the tree is planted.

Necessity of the Soil

Soil plays an important role in the successful growth of the tree. It is the supplier of nutrients, provided by the soil-bound fungi, and absorbed by the tree's roots. Soil is the primary source of water absorbed through the tree's roots as part of the photosynthesis cycle. It serves as the structural substrate into which the roots are anchored to support the tree.

By understanding the soil composition the arborist can successfully plan and implement a planting procedure. In order to generate the plan we will first look at the practices of other *arborist's* and extrapolate from their ideology and technique.

Arboricultural Practices

Arborist's typically specialize in one aspect of arboriculture. Each practitioner develops their own techniques and best practices.

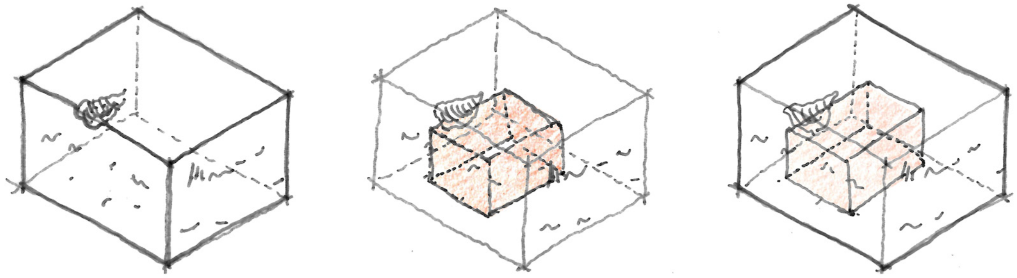
Arboricultural practices

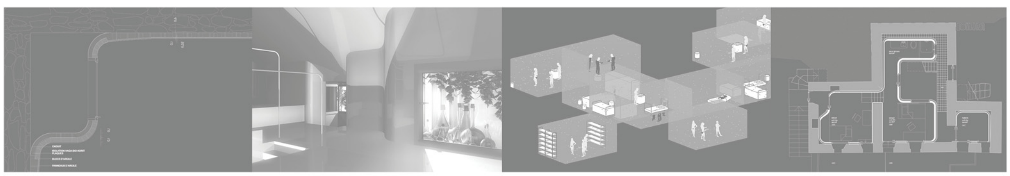
Four unique practices of *arboriculture* have been studied and brought together for the purpose of creating a new methodology of urban regeneration. They are the works of Philippe Rahm, Gordon Matta-Clarke, Carlo Scarpa and Meredith Miller (of TEAM Architects). Each of these *arborist's* offer a unique approach to working with and altering the existing built environment.

Philippe Rahm is interested in creating and identifying micro-climates that can be effectively operated to achieve efficient use of thermal energy. Gordon Matta-Clarke looks at a building as a solid and examines how making intentional cuts through the walls, floors, doors and air can generate a new understanding of how a person inhabits the building while also exposing the language of construction for that building. Carlo Scarpa celebrates a buildings history by pealing back layers and adding complimentary interventions to enrich the story of a building. Meredith Miller looks at a building as material database and will break down the elements to form new ones from which to create space.

In the Mergoscia House, Philippe Rahm builds new rooms within the walls of the existing structure. In doing so he is able to create micro-climates both in the newly enclosed space but also in the space between the existing and new. And the range of environment he is able to achieve is intriguing.

By building within a building Rahm is able to optimize the energy use of that specifically programmed space. He also



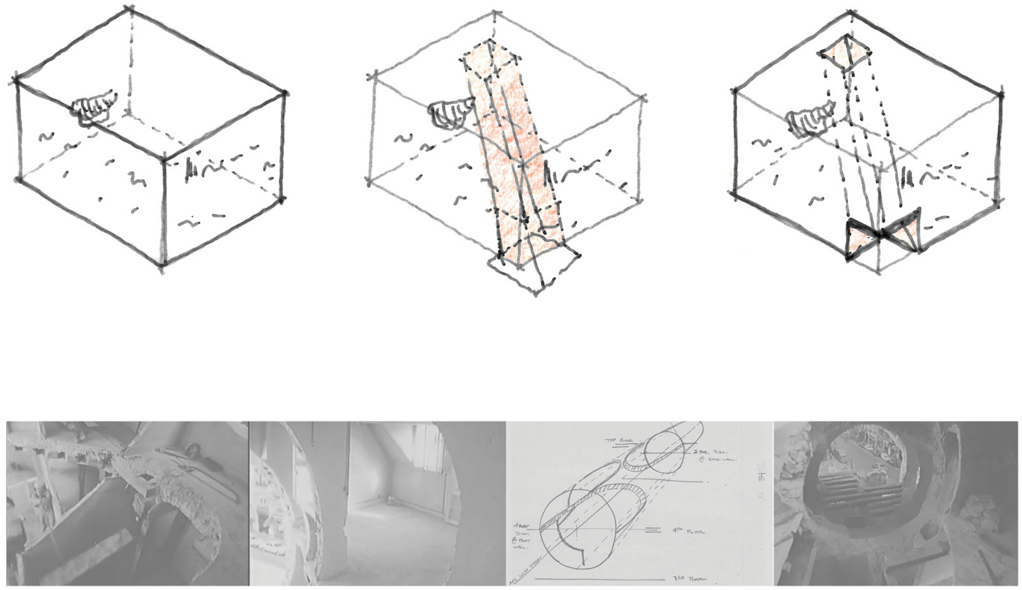


Philippe Rahm - Microclimate
(adapted from Rahm n.d.)

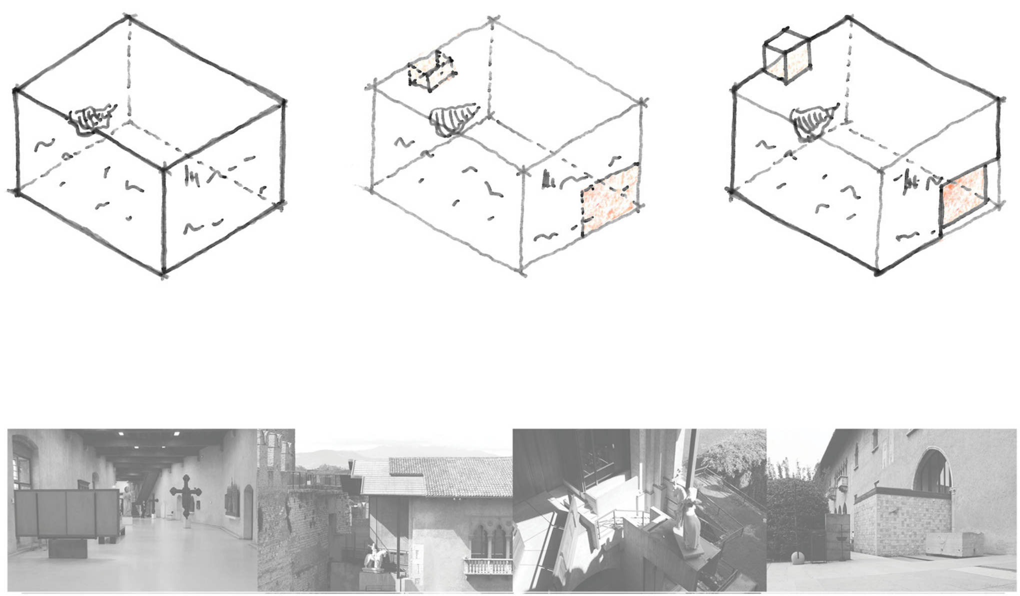
creates a layer between the original and new creating a dynamic gradient of thermal properties as well as textural/ phenomenological/aesthetic.

Gordon Matta-Clark is intentional about the void that he is cutting. He makes the incisions as a way of generating new volumes within but also to accentuate the condition of the building. He is able to re-animate an existing condition and connect previously disconnected spaces together to form a new space within while not being precious about any one part of the building, be it structural or aesthetic.

Carlo Scarpa's Castelvechio Museum showcases the lightness of touch of Scarpa's intervention. He is able to peel back layers to accentuate the filigree of the elements. His small additions throughout the museum combine together to compliment the original building.



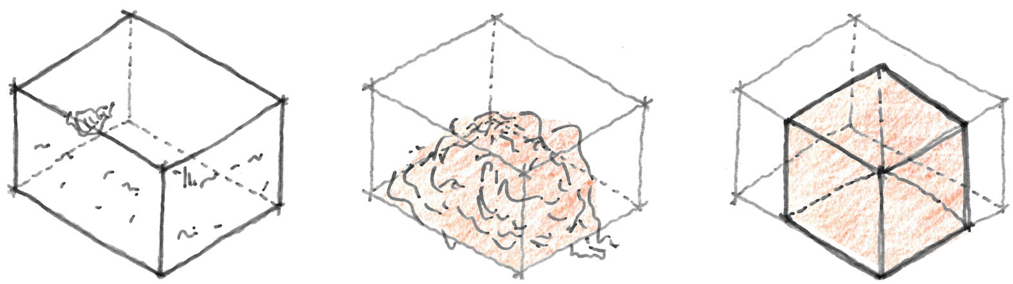
Gordon Matta-Clark - Volumetric cut
(adapted from Public Delivery n.d.)

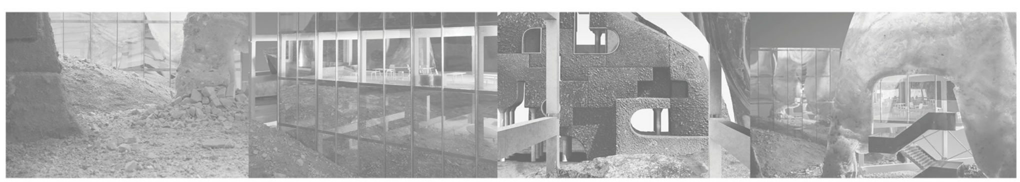


Carlo Scarpa - Peeled layers
(adapted from Puggioni 2016)

Meredith Miller's (along with TEAM) project for Detroit looks at how an abandoned site can be re-purposed. They achieved this by breaking down the existing elements and reconstituting them into different forms/compositions etc. to re-animate the existing condition.

The complete erasure of the original materials structural / aesthetic properties is heavy-handed and energy intensive, and disregards the materials inherent properties.





Meredith Miller - Reconstitution
(T.E.A.M. n.d.)

By studying these four practitioners of *arboriculture*, a methodological procedure has been developed and will applied to show how to regenerate obsolescent soil.

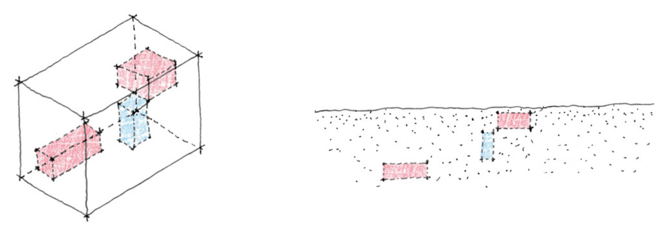
Method of Soil Regeneration

The following procedure was developed by studying the practices of other *arborist's* and generating a hybrid of intervention.

The first step is to identify the dormant *nutrients* locked within the *soil* that will assist the *trees* growth. These *nutrients* may include excess heat generation, programming opportunities, timeline of a buildings growth, untapped energy sources, and also passive and active opportunities for day lighting, ventilation and heating.

Soil contains nutrients that are essential for the growth of a tree and are produced by soil bound fungi that convert carbohydrates from the tree into nutrients and carbon.

Nutrients



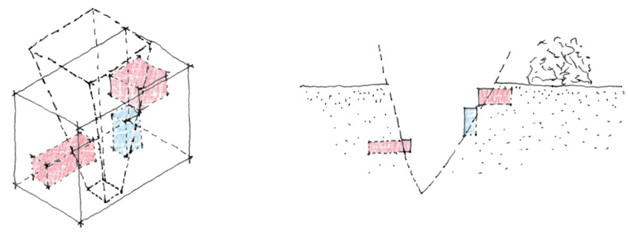
Nutrients

The next step is planning the cut to capitalize on the most nutrient rich area(s) of the *soil* and provide an adequate bed location within which to *plant the tree*. The size of the *tree* to be *planted* is also considered to ensure that adequate space is allowed for its growth. The *soil* removed during *excavation* is stockpiled and sorted further down stream in the process.

Depending on the nature of the program, certain *nutrients* will take precedence over others. Identifying these informs the location of the cut. In certain instances there is opportunity

Excavation is necessary to access soil bound nutrients and also provide space for the tree to be planted. The excavated soil is stockpiled for backfill once the tree is planted.

Excavate



Excavate

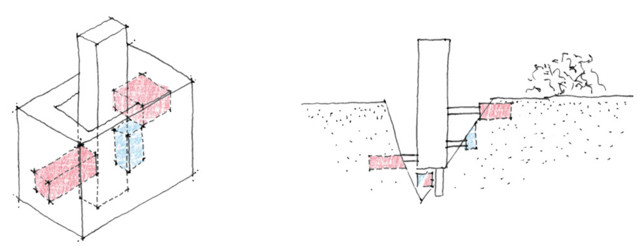
to improve the effectiveness of a *nutrient* such as increasing daylighting by cutting additional openings into a building.

The third step is *planting* the *tree*. Taking care to ensure that it is properly positioned in order to draw from the *nutrients* previously identified.

The final step is *backfilling* (with the *soil* previously excavated) the cut to ensure the *tree* is supported and able to grow successfully. This is achieved by placing the *soil* back to its original position when feasible and beneficial, or remediating the *soil* and using it for fill elsewhere in the void.

Planting the tree requires care to ensure the trees root structure will be adequately supported by the soil and also able to draw from the soil bound nutrients.

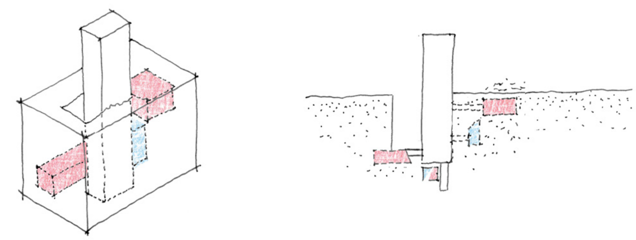
Planting



Planting

Backfilling with the stockpiled soil protects the root structure of the tree from erosive effects of weathering and also provide the tree with essential structural support.

Backfill



Backfill + reposition

Soil plays an important role in the successful growth of the tree. It is the supplier of nutrients, provided by the soil-bounds fungi, and absorbed by the trees roots. Soil is the primary source of water absorbed through the tree's roots as part of the photosynthesis cycles. It serves as the structural substrate into which the roots are anchored to support the tree.

Necessity of the soil

Soil has a high capacity for carbon sequestration. In many fields there are areas where soil is at risk of releasing this carbon.

Embodied carbon

Soil Analysis

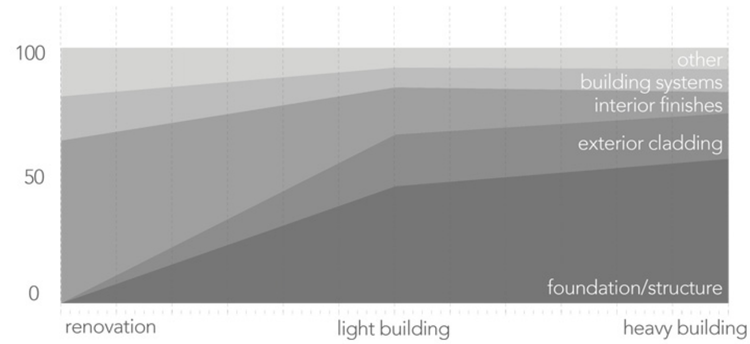
The *soil* is the foundation of the new building. It is the conduit through which all the *nutrients* such as excess heat waste, water, programmatic space, and structure are provided.

Determining the *soil composition* is critical before planning to *plant a tree*. By identifying underutilized *nutrient rich soi*l, the *arborist* is able to optimize the *soil / tree* relationship and ensure the success of the *tree's growth* and the *soil's* regeneration.

Embodied Carbon

Existing buildings have a high level of embodied carbon contained within their fabric. The structure alone accounts for 30-50% of the buildings overall construction based embodied carbon (King 2017, 21).

Generally the higher a buildings embodied carbon value the more successful of a candidate it will be for the *arborist* approach outlined in this thesis.

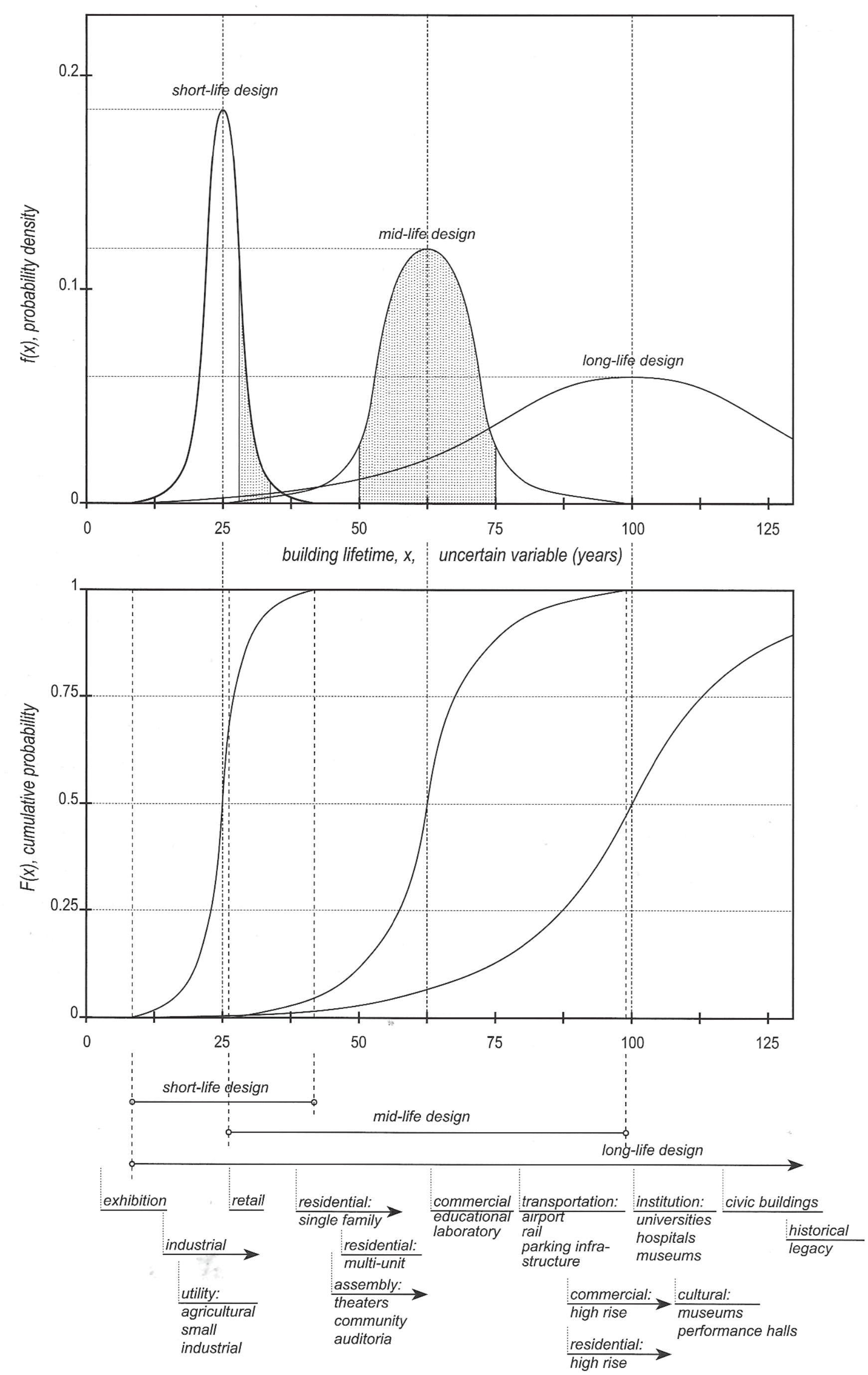


Embodied carbon vs building size
(adapted from King 2017, 36).

Risk of Erosion

The current building stock of any city consists of a range of types from new to old, historic to temporary and public to private. Each building goes through cycles of use and disuse, damage and maybe repair. When a building comes to the end of its serviceable life and for one reason or another is no longer deemed adequate it is often demolished to make way for ‘new development’. This *erosion* of the building comes with an associated cost of environmental and economic impact.

When a site becomes identified as needing ‘redevelopment’ it is important to consider the overall environmental impact of that decision due to the volume of carbon embodied of the material absorbed through the mining, processing, transporting, assembling and commissioning of the original building. In 2017 the building and construction sector accounted for 39% of the total global energy and process related CO_2 emissions (IEA and UNEP 2018). Often when a building is demolished it is not because the building is structurally compromised but is more likely because of some other reason such as a change in the building tenants or a neighborhoods shifting demographic. This foreshortening



Life expectancy of various *soil* types
(Fernandez 2006, 56).

of a building and subsequent disposable has a compound effect on the environment. Not only is the existing material being discarded (along with its embodied carbon) the new building is incurring a new carbon cost from its own processes.

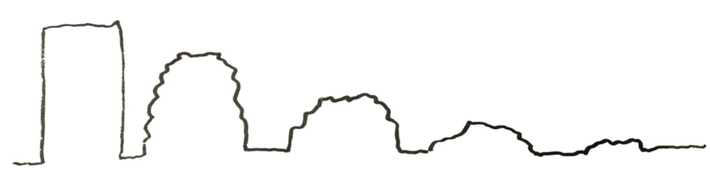
It is evident that the typical practice of demolishing a building before it has reached its forecasted service life, a term known as obsolescence as defined by John Fernandez (Fernandez 2016), has detrimental implications on the environment.

Obsolescence

When a non-arborist, comes across a plot of soil that appears barren and void of any life they may decide the best course of action is to remove the soil and replace it with 'new' soil. This lack of understanding leads to the waste of soil that has plenty of potential left in it to support new growth and disregards the potential of the new soil's future obsolescence.

Obsolescence

A building that has become vacant or unused prior to its intended service life is considered obsolescent. More often than not the factors that led to the buildings premature lack of use have nothing to do with the physical condition of the building itself (Fernandez 2006, 57), but instead are attributed to "aesthetics, planning efficiency, real estate value and the ideals of modernity" (Fernandez 2006, 37). While it could be argued that these causes of obsolescence could not have been anticipated in the building's original design, it stands to reason that a far more ecologically effective method of intervention would be to work with the *nutrient* rich aspects of the building than to demolish it and replace it.



Obsolescent soil

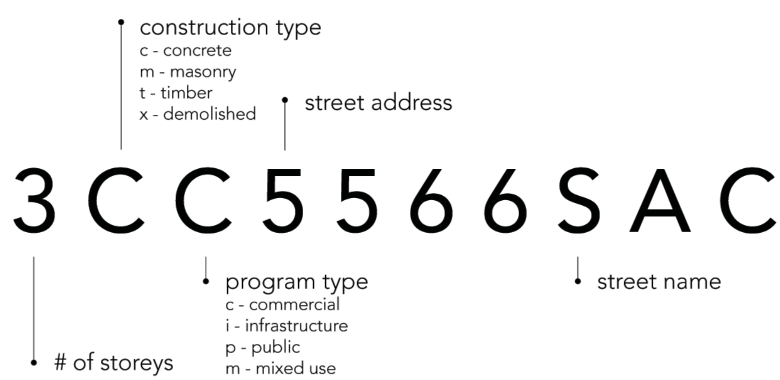
Nutrient Rich

When soil is left barren it will begin to dry out and lose its capacity for generating nutrients and will release the embodied carbon that it has sequestered. Soil absorbs organic matter and carbohydrates from plants and processes it through soil bound fungi. This fungi generates a nutrient rich layer of soil called humus from which the tree draws its nutrients to grow. In many fields there are plots of soil at risk in need of regeneration to prevent them from erosion.

Nutrient rich soil

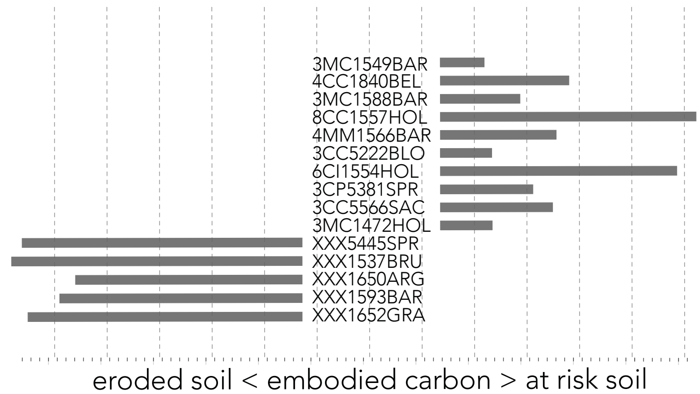
Obsolescent buildings have a great potential for supporting vibrant programming. Buildings that were built in the mid to late 20th century, for example, have poorly designed envelopes and oversized mechanical systems to make up for the loss of energy through the envelope (Dangel 2016, 160). Through *planting* it is possible to improve the performance of the envelope and stretch the existing energy system to service a "... new pattern of consumption" (Cavanagh and Kroeker 2005, 141). *Planting* also has a 50-75% lower impact on the environment as it encapsulates the embodied carbon of the existing *soil* (King 2017, 35).

The following map highlights 10 sites of at risk *soil* and 5 sites that have already *eroded* and been replaced by new *soil.* This map is only a small portion of the peninsula of Halifax but offers a good dataset from which to study the *soil* condition of Halifax.



Soil id nomenclature

A field of *soil* plots; obsolescent *soil* shown in black, *eroded soil* shown in grey (base map from Halifax Open Data 2019).



Estimated embodied carbon of *soil* samples.

Tree Species

There are many different species of *trees* that have associated strengths, weaknesses, desired properties. They are also climate specific. Whereas one might *plant* an adobe *tree* in the south of Europe, another might *plant* a light frame wood *tree* in North America. No one *species* of *tree* is superior to another. The *arborist's* knowledge of the environment allows them to determine which species will thrive best in the given *soil* conditions.

Wood

This thesis will investigate the application of a wood *tree* as the type and more specifically engineered wood such as CLT, DLT, Glulam etc. This species has been chosen based on its strength to weight ratio, its value as a renewable resource, its phenomenological properties and its workability.

Raw Material

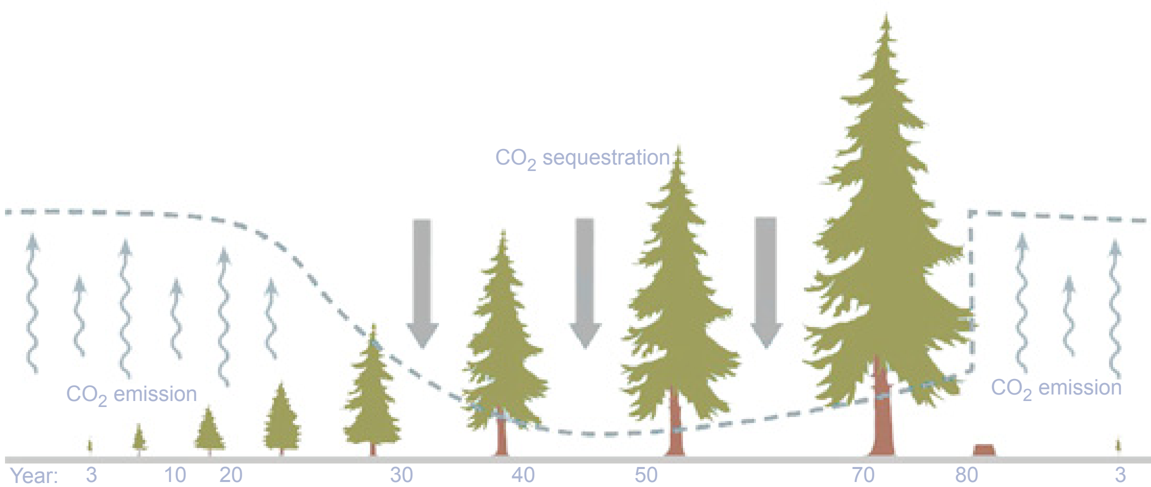
As a tree grows it absorbs carbon dioxide, water and sunlight and converts them into carbohydrates and oxygen through the process of photosynthesis. The tree metabolizes these carbohydrates and sequesters carbon into its fibres. It also deposits carbohydrates into the soil through its roots. These carbohydrates are metabolized by soil bound fungi that convert them into the carbon and necessary nutrients for the tree to grow. The converted carbon is sequestered by the soil and the nutrients are absorbed by the trees roots.

> The amount of CO_2 in the atmosphere can be reduced in two ways: either by reducing CO_2 emissions or by extracting CO_2 from the atmosphere and storing the carbon. Wood has the unique ability to contribute to both of these possible reduction methods. (Kaufmann, Krotsch and Winter 2018, 24)

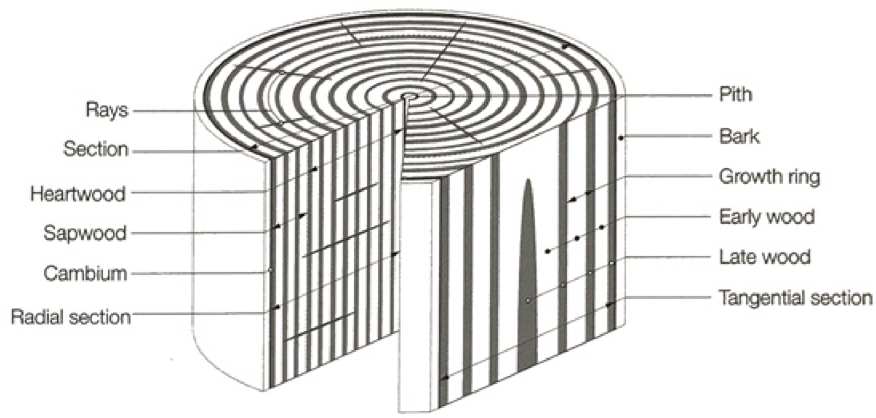
Wood is a natural material that has inherent properties of warmth, aroma, tactility, beauty, utility, and nature. Frank Lloyd Wright said this of wood in 1901; "the beauty of wood lies first in its qualities as wood;... having in itself intrinsically holistic properties of which its beautiful markings is one, its texture another, its color a third" (Wright 1901, 87).

Species

Trees fall under two primary types, geotropic and phototropic. The majority of geotropic trees are softwoods while the majority of phototropic trees are hardwoods. Geotropic



Growth rate of a tree vs. carbon dioxide emission/sequestration (adapted from Swedish Wood n.d.).



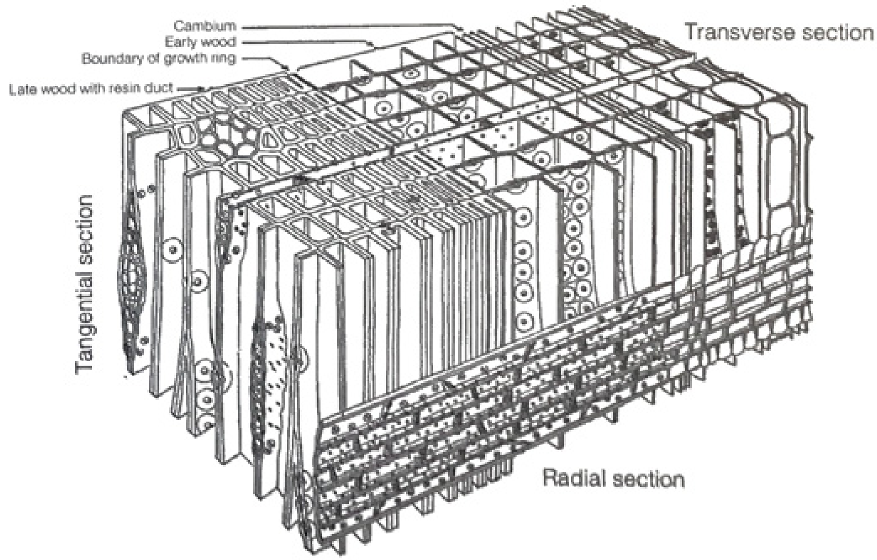
Elements of a tree
(Herzog et al. 2004, 31).

trees grow with respect to gravity which is why inherently the grain in a softwood tree is straighter than that found in a hardwood tree. Phototropic trees grow in relation to the sun as it traces across the sky day to day. The grain of a hardwood tree twists as it is constantly tracking the sun as it grows.

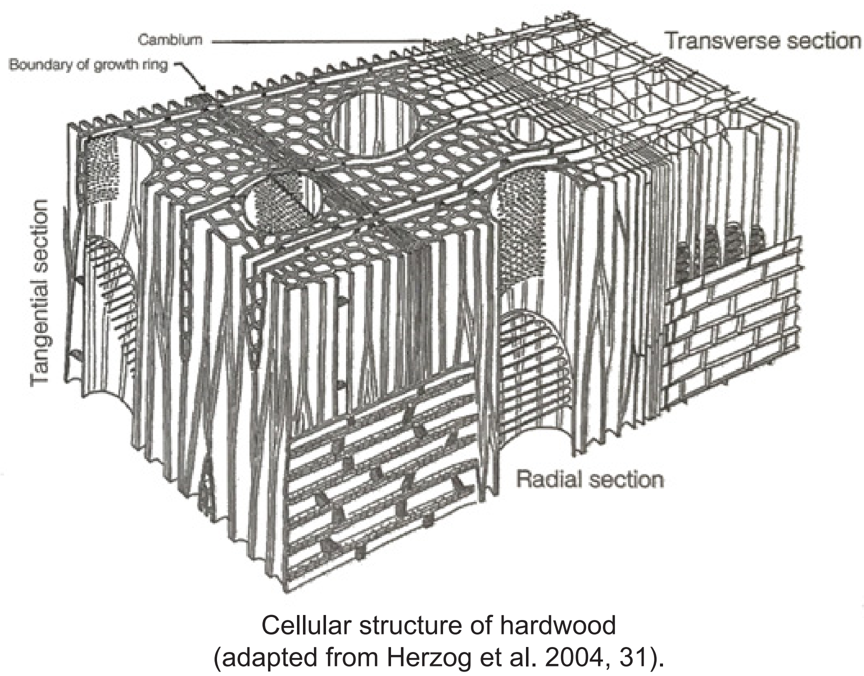
Material Properties

Structural Properties

The cellular structure of softwood trees and hardwood trees is different because of the way in which they grow. Most softwood trees have a ripewood internal structure, where the water and nutrients are transported primarily along the outer rings of the tree. Hardwoods have either a sapwood or heartwood structure. In the former water and nutrients are transported throughout the entire cross section of the tree. In the latter the inner rings, termed the heartwood, have a darker coloration than the outer rings termed the sapwood (Herzog et al. 2004, 31).



Cellular structure of softwood
(adapted from Herzog et al. 2004, 31).



Cellular structure of hardwood
(adapted from Herzog et al. 2004, 31).

The cellular structure also affects the level of relative moisture content in wood. The maximum moisture content of wood, known as fibre saturation, ranges between 22-35%. The moisture content determines the wood's dimensions and strength characteristics. The higher the content, the larger the wood is and the weaker it is (Herzog et al. 2004, 33).

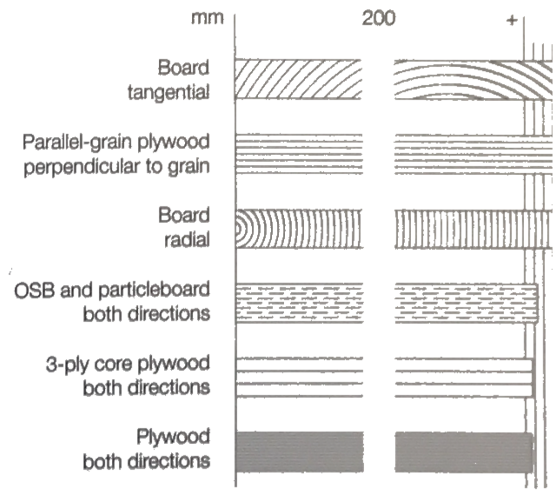
Thermal Properties

The inherent 'warmth' of wood is due to its low thermal effusivity (Kaufmann, Krotsch and Winter 2018, 30). This means that compared to a material such as steel, wood absorbs heat at a slower rate making it feel warmer to the touch. This property of wood contributes to the overall well-being that one feels when in a room containing exposed natural wood.

There is evidence (Pöschl 2011a, 96; Moe 2017) that is challenging the typical method of wall construction when wood is incorporated. Because of its superior thermal performance over steel and concrete it may prove to allow for a 'simpler' wall assembly where "... the physical and structural functions of a building are not distributed amongst as many different planes as possible, but where, instead, just a few layers are able to take over the greatest possible number of functions" (Nagler 2011, 209).

Hygroscopic Properties

Wood is anisotropic and hygroscopic. Anisotropic means the wood behaves differently with respect to the orientation of its grain. Hygroscopic means the wood absorbs and releases moisture. The combination of these two properties means that it expands and contracts differently with respect to the orientation of grains and its overall moisture content.

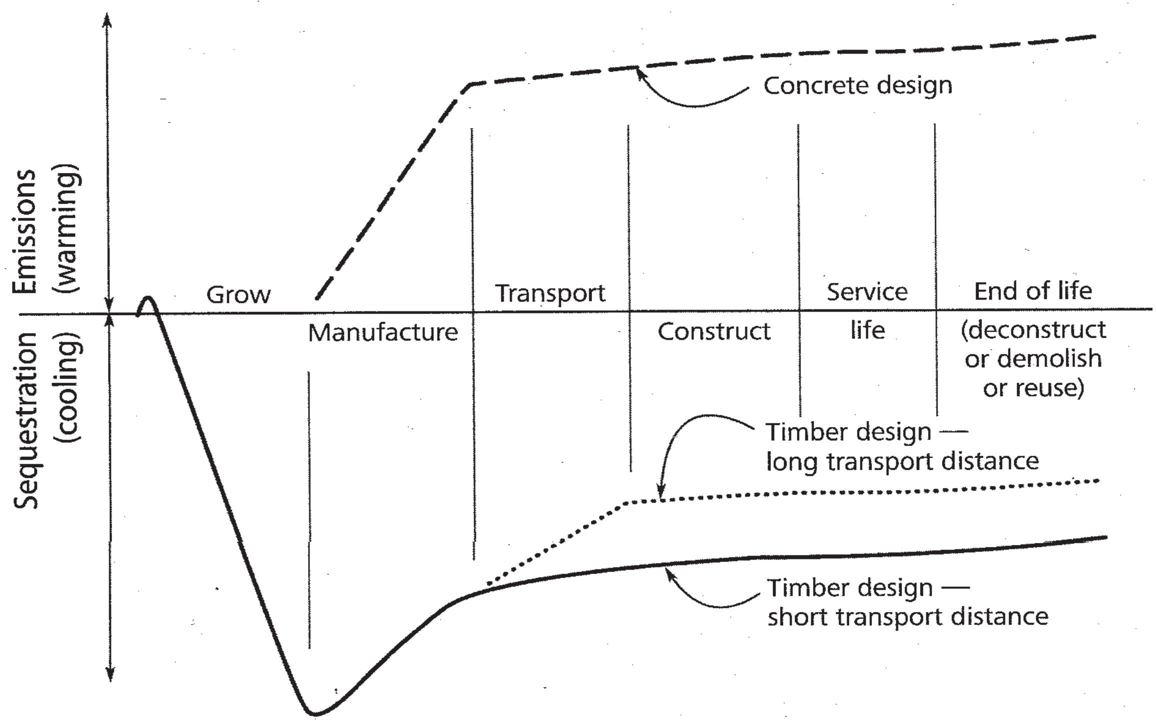


Moisture induced swelling
(Herzog et al. 2004, 33).

> It is enlightening to observe the stressing of roofs in winter. Owing to the higher moisture levels in the upper half of the roof's cross-section, which is away from the interior space, ceilings warp upward in winter - a movement that largely balances out any sagging caused by snow load. (Pöschl 2011b, 131)

Mass Timber

Mass timber is a term used to identify a family of engineered wood products (EWP). Mass timber is made by mechanically or chemically fastening multiple pieces of small dimension lumber to form larger panels. Mass timber, with perhaps the only exception of nail laminated timber (NLT) is manufactured in a plant with very fine tolerances leading to its ability for quick on site assembly. NLT can be manufactured on site as it simply made by face nailing multiple boards together. Mass timber is one of the few materials that can compete structurally with concrete and steel while also benefiting the environment (King 2017, 44).

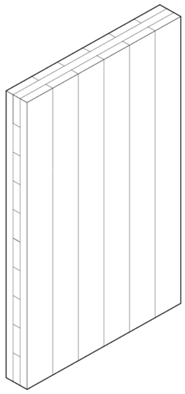


Embodied carbon: concrete vs timber
(adapted from King 2017, 36).

Through mass timber, the applicability of wood in the 21st century has been reinvented, and the ‘shelves of industry’ have been restocked (Cavanagh 2019, 7).

Species

Mass timber comes in a variety of types that each offer unique benefits and constraints. By understanding the material property of each *species*, the *arborist* is equipped to ensure the successful *planting* and *grafting* of the new *tree.* Some of the common *species* include,

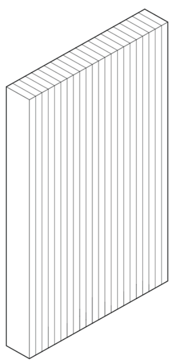


CLT panel

CLT - cross laminated timber

- typical dimension (dependent on number of lamination layers, between 3 and 11) is 60-400mm thick

- boards glued together in layers of alternating orientation, reducing the overall swelling and shrinkage. (Kaufmann, Krotsch and Winter 2018, 54).



DLT panel

DLT - dowel laminated timber

- typical dimension 20-240mm thick

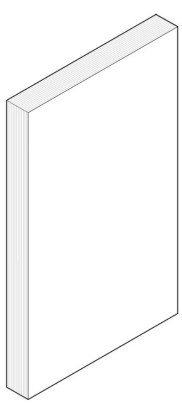
- softwood boards joined together with pre-dried hard wood dowels that swell up once installed, locking the panel together

- capable of very high vertical loads due to the orientation of all the wood grain in a wall panel and the load is perpendicular to grain, (the strongest direction in compression for wood)

- can increase diaphragm strength through the addition of a shear board on one face of wall (Kaufmann, Krotsch and Winter 2018, 51)

- lowest structural height of all timber ceiling structures, but require linear support (Kaufmann, Krotsch and Winter 2018, 57)

- a similar performing species is NLT (nail laminated timber), the primary difference is that it is fastened together with nails as opposed to wood dowels.



LVL panel

LVL - laminated veneer lumber

- typical panel size of 2.5 m wide

- made of layers of veneers typically 3mm thick and glued together

- high volume of adhesive required

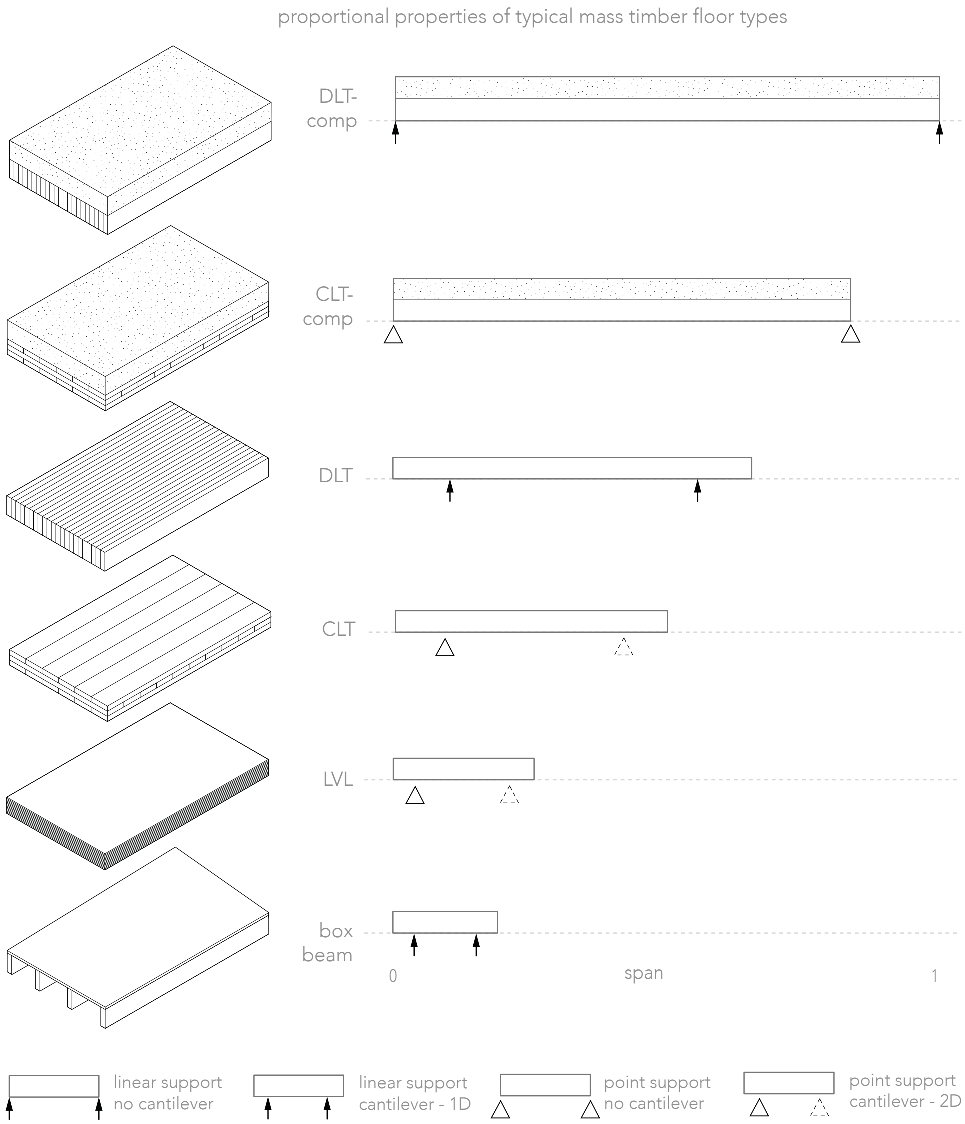
- can utilize crooked and bent logs otherwise unsuitable as squared timber (Kaufmann, Krotsch and Winter 2018, 55).

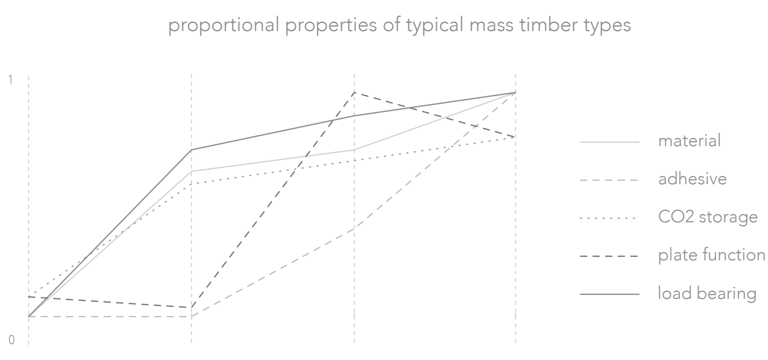
Glulam - used for column and beam applications

- kiln dried to moisture content of 12%

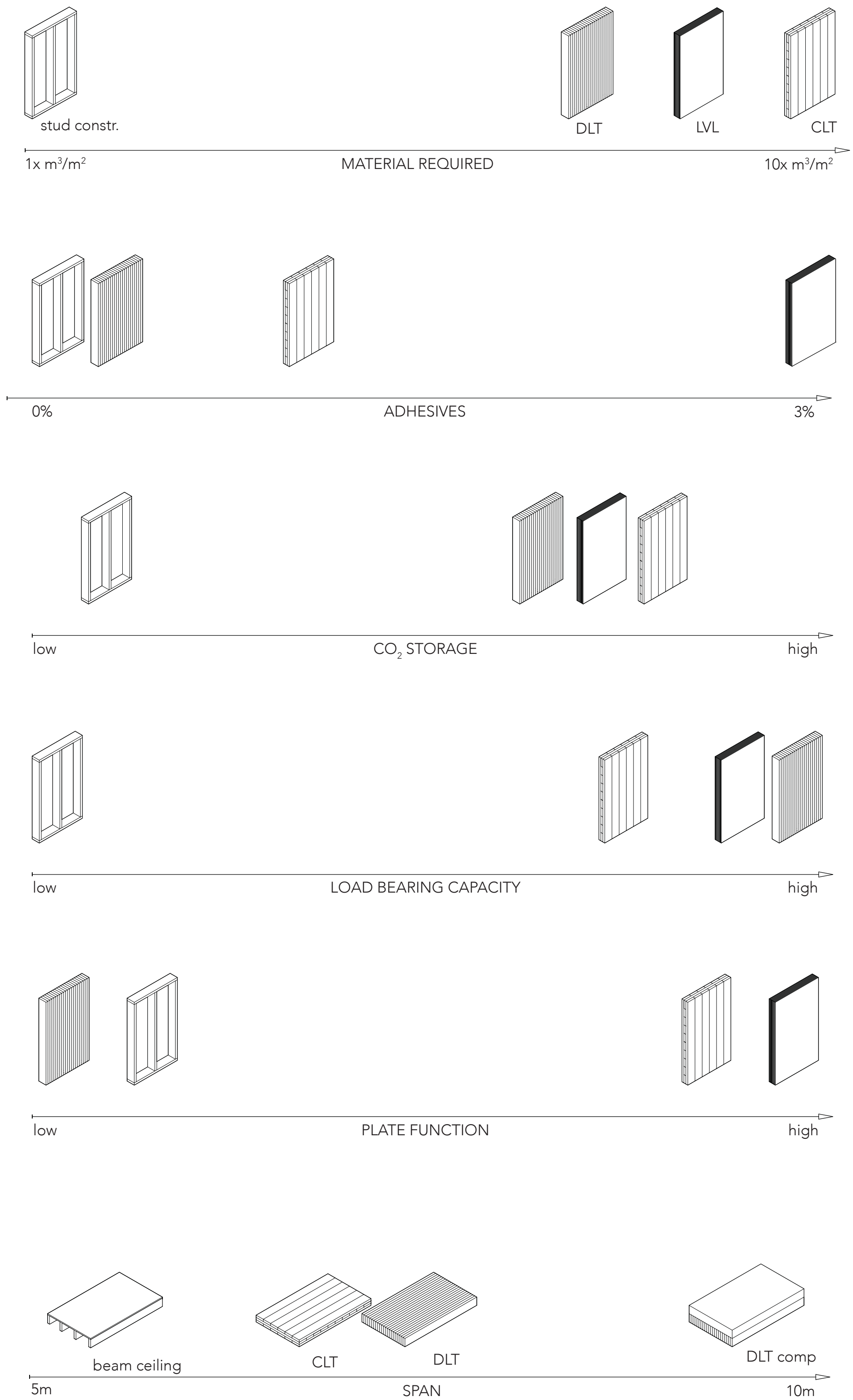
- laminated with use of adhesives

- max dimension: 300mm x 3000mm x 60 m (with slender ratio B/H <= 1/10) (Herzog et al. 2004, 41).





Proportional properties of typical floor types
(adapted from Kaufmann, Krotsch and Winter 2018, 66-67).



Proportional properties of typical wall types
(adapted from Kaufmann, Krotsch and Winter 2018, 66-67).

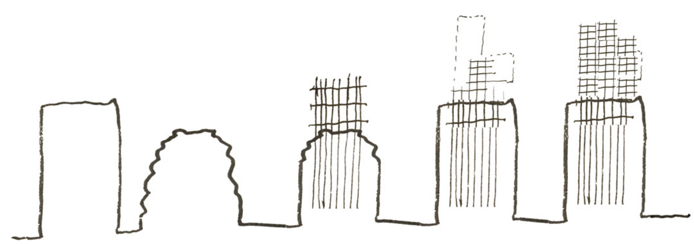
Chapter 3: The Arborist Approach

Planting the Tree

An arborist will plant a tree for one of two reasons. The first is to regenerate the soil. By planting the tree, the arborist is able to ensure that the root system of the tree will secure the soil from eroding away. The tree roots also draw in nutrients and water from the soil. This symbiotic relationship between the tree and the soil is critical for the survival of both. The second reason is to plan for future grafting.

Planting a tree

Mass timber is a comparably light weight, renewable material that is ideally suited for *planting* into existing structures. As it is prefabricated it provides the ability for fast, precise erection (Lattke 2011, 78). The size of the *tree* being *planted* and the structural capacity of the *soil*, will determine the overall size and depth required for the *roots* of the *tree*. This provides opportunity for the *tree* to absorb *nutrients* from the *soil* by means of an integrated column/conduit system, and also ensures that the *soil* is stabilized and can begin to regenerate.



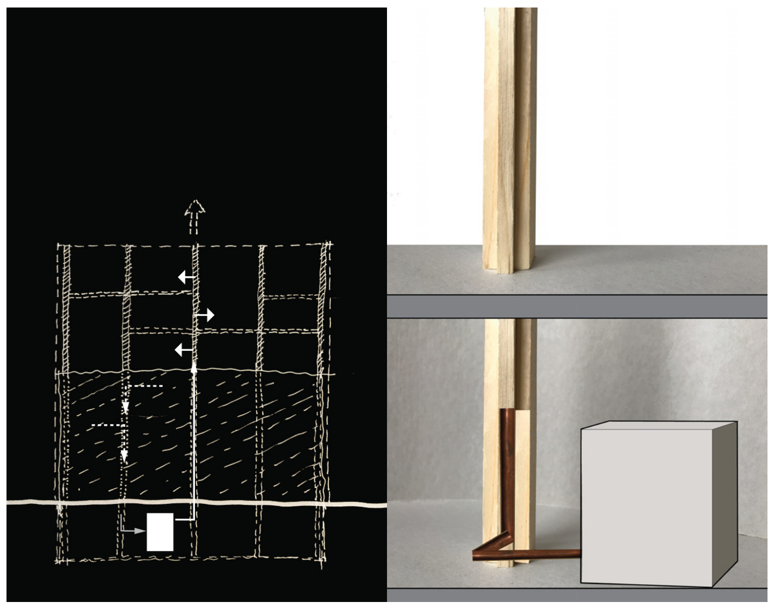
Regenerated soil

Necessity for Planting

It wasn't "...until the second half of the twentieth century that people became aware of a link between environmental damage/health hazards and the activities of the construction materials industry" (König 2011, 18). This awareness has led to admirable efforts to do less bad to the environment. But as argued by William McDonough and Michael Braungart in their book, *Cradle to Cradle,* being less bad is not ecologically effective. Instead they propose that industry and systems "... get bigger and better in a way that replenishes, restores, and nourishes the rest of the world" (McDonough and Braungart 2002, 78). The concepts of *arboriculture* and *planting* proposed in this thesis have shown to be an ecologically effective approach. This thesis hypothesizes that it can regenerate the *soil,* enabling it to be the catalyst of future growth and also increase the demand for sustainably managed forests (King 2017, 57).

A tree's roots provide support for the tree to grow and also absorb nutrients from the soil. These nutrients are essential for the growth of the tree.

Absorbing nutrients



Root system

Absorbing Nutrients

As the *tree* is planted into the *soil,* it provides the opportunity for absorbing waste *nutrients* from the *soil* to promote growth and sustain the life of the *tree.* By tapping into these underutilized *nutrients*, the *arborist* is able to maximize on the embedded energy of the *soil* and minimize the impact of *planting* new *nutrients* that would be necessary for the successful growth of the *tree*. Such *nutrients* may include underutilized structural support, excess heat gains, underutilized daylighting or passive ventilation opportunities.

New Microclimate

As a tree stretches its roots into the soil ever in search of water, nutrients and anchorage, it invariably pushes aside portions of soil and even breaks apart slabs of stone. Its relentless persistence creates in its wake voids that become new microclimates of inhabitation.

Microclimate

Philippe Rahm's work investigates the ideas of creating nested micro climates to capitalize on the diversity of thermal requirements between programs.

> Developing the built environment should not be understood as a mere aesthetic integration task. It is more important than ever to see it as an element of an overarching strategy of ecological urban conversion. (Schittich 2003, 27)

Through the methods of *planting* and *grafting*, the *arborist* is able to create new micro climates within the *soil* by cutting away portions of the *soil* to make room for the *tree's roots* and thus create new microclimates within the *soil* that actively regenerate it.

Methods of Planting

Hole Method

In certain contexts, where the *nutrients* are embedded deep into the *soil*, or the *soil* requires aeration the drastic measure of digging out the *soil* is necessary to allow room for the *tree* to be *planted*. This most often involves cutting away the portion of the roof and first few top floors of the existing building located where the *tree* will be *planted*.

Slit Method

This method is less invasive than the hole method but it does require adequate planning to ensure that the *soil* can support the *roots* of the *tree* as well as future growth of the *rootstock* and *grafting* of *scions*.

Of the two methods, hole planting is the most invasive. It is applicable when the desired tree to be planted is large and requires a deep integration into the soil. It involves pulling back the top soil, digging out the substrate, planting the rootstock and then covering back up with the substrate and top soil.

Hole method

Hole method

Slit planting is far less invasive to the soil and is often undertaken when planting younger, smaller trees as it only requires the pulling back of the top soil. Once planted the tree will naturally embed its roots further into the soil as it grows.

Slit method

Slit method

Grafting

Once the mass timber *tree* has established itself in the *soil,* the *arborist* may observe a need for additional programming not currently offered by the *tree*. Through *grafting,* the *arborist* is able to insert *scions* into the *rootstock*, to accommodate this new program.

The second reason for planting a tree is to enable the growth of a scion through grafting. The scion is a small branch or bud that is incapable of growing on its own. The process of grafting attaches the scion to the rootstock (branch of tree) in such a way as to allow for the transference of nutrients and carbohydrates between the two. Just as the rootstock supports the scion (structurally and nutritionally) so too does the scion provide the rootstock (and consequently the tree) with carbohydrates through the process of photosynthesis. This symbiotic relationship ensures the successful growth of both rootstock and scion.

Grafting

An arborist will decide to graft for a number of reasons; to propagate a new species, to substitute one species for another, to join two species together to capitalize on each ones strengths, to repair damage sustained by another scion or the rootstock, to support the root system of the rootstock, and finally to resolve unwanted defects of structure or growth (Garner 2013, 31).

Reasons to graft

Matching Rootstock and Scion

Ensuring that the graft of the scion and rootstock is successful is paramount to the continued growth of the overall tree. It is dependant on two things, compatibility and contact. Compatibility is necessary to ensure that the rootstock and scion both share the similar cellular structure and contact is necessary to ensure the transference of nutrients. A graft requires surgical precision to ensure that the inner cambia and meristem align and fuse between rootstock and scion (Garner 2013, 45). These are the vital ‘highways’ through which the tree passes its water, nutrients and carbohydrates.

Reasons to Graft

Grafting also allows for ideas of temporality where new programs can be tested with minimal investment and risk (Brand 1994, 28). Brand defines two types of buildings, high-road and low-road. Where the high road building typology is typically found in institutions such as churches, libraries, government buildings and because of their permanent programming they tend to have long service lives with little to no modifications.

Conversely the low-road buildings are typical of sheds and shacks. They are built quickly to meet a need. This need continually changes and the building itself is modified each time. These buildings are flexible, adaptable and not ‘precious’.

Grafting aligns with low-road buildings and as such is applied when more program space is required, or when a change in program is desired. *Grafting* is performed when a new need is identified and is done so at a small enough scale that the *rootstock* is able to sustain its own growth while taking on the additional demand of the new *scion*.

Promoting Growth

The arborist sets in course the growth of a scion, but once healed, new growth between rootstock and scion continues organically, beyond the input of the arborist.

> When responsibility for his city is returned to the citizen, the town will once again be representative of its people. (Habraken 1972, 81)

The *arborist* approach to building regeneration is one that takes time and careful planning. The *arborist* understands that once the *tree* has been planted it will take time for it to mature before it can support *grafting*. Following a successful *graft* it will take more time before that *branch* will produce any *fruit.* The primary goal of planting a tree is to regenerate the soil, produce fruit and support the future growth of fruits.

Chapter 4: Studying Other Trees

Case Studies

The following case studies highlight the two primary methods of *planting*. In both cases CLT was used for the *tree*.

Alex Monroe Studio

Architect - DSDHA

Location - London, England 2012

Program - Jewellers workshop

Soil - originally single storey

Tree - planted 3 storey structure to accommodate expanding business

Soil

- existing masonry store front

Tree

- CLT walls and flooring

Plant Method

- hole planting - in order to support the structure of the mass timber addition, the original structure needed to be excavated and reinforced.

Hole method of planting
(adapted from DSDHA 2014).

Analysis

The project showcases the adaptability of wood as a material to add to an existing structure. The additional load from the addition is transferred through columns that are integral to the window frame.

Alex Monroe Studio
(adapted from DSDHA 2014).

Treehouses Bebelallee

Architect - Blauraum Architekten

Location - Hamburg, Germay 2010

Program - housing estate built in 1959

Soil - 5 two storey and 1 three storey > total of 104 flats

Tree - client goal was to double the living space while reducing CO_2 emissions by half result was 47 additional flats added on top

Soil

- existing masonry apartment block

- portions of strip foundation had to be underpinned to support additional weight of added floor

Tree

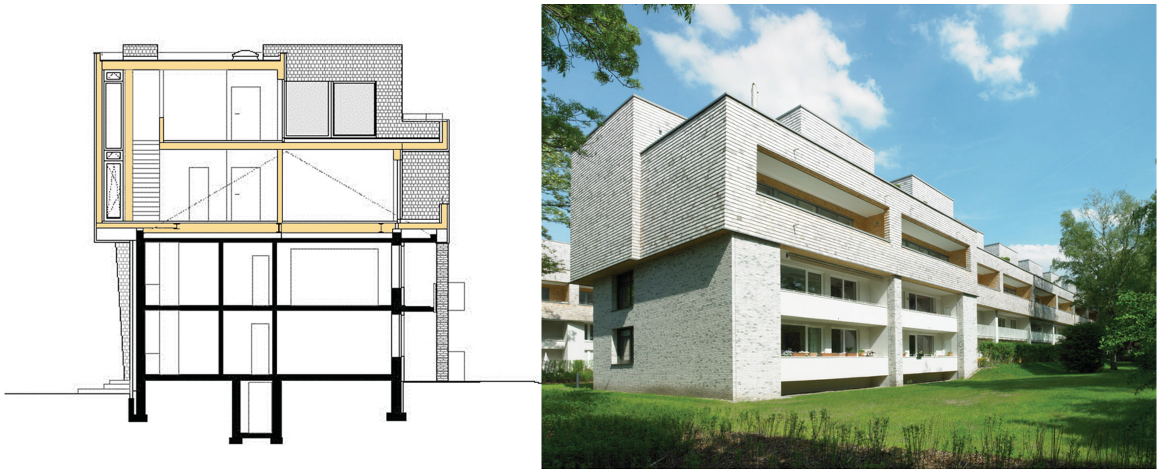
- CLT interior walls and ceilings with concrete staircase and partition walls

Plant Method

- slit planting - the existing structure is capable of supporting the added weight of the *tree* planted on top.

Analysis

This project highlights the lightness of wood, as the 2 storey addition is fully supported by the original structure. There was no need for additional structure to be added.



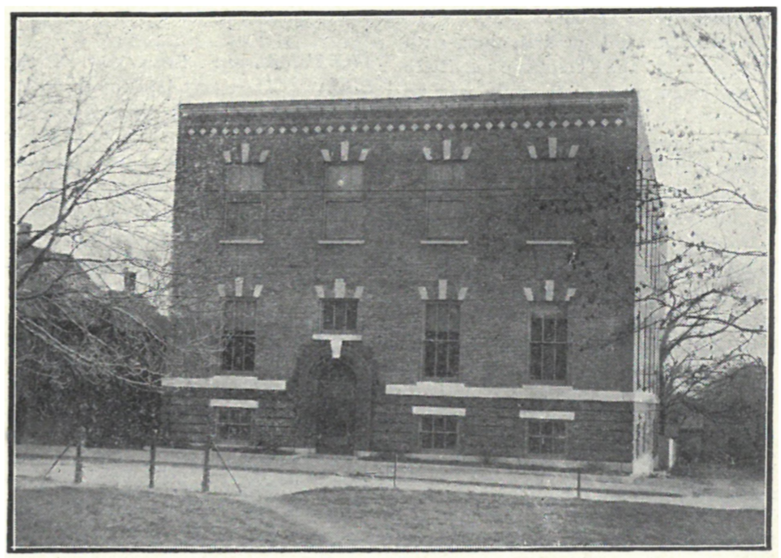
Slit planting
(adapted from Blauraum n.d.).

In both these cases, the owner was interested in keeping the original building and expanding it through the addition of a wood structure. Wood has been shown to be lightweight, carbon sequestering easily adaptable to a wide range of program uses.

Chapter 5: Plot 3CC5566SAC

Soil Analysis

Plot 3CC5566SAC is located in Halifax and was originally built in 1916 by the Maritime Telegraph and Telephone Company as their new switchboard headquarters in Halifax. It's a three storey concrete building with a masonry facade.



Original building, (reproduced from MT&T 1918).

Later on the building was expanded through the addition of a steel structure with similar masonry facade to match the original. The 2 entrances to the building both lead to the first level (basement entry) with the steel addition entrance acting as the primary access. Inside this entrance is a full height atrium that runs adjacent to and covers the exterior side of the original building. Access to each floor is gained via an elevator core that is at the end of the atrium. The remainder of the building is fit out for the unique needs of a telecom company including, large rooms for servers and partitioned spaces for offices. The only windows open to the exterior are located on the North side of the original facade as well

Interior of original concrete building

as the North side of the atrium. The west wall of the original building has had all of its windows infilled presumably at the time of the steel addition based on the similarity in brick between the infill and the brick on the steel addition.

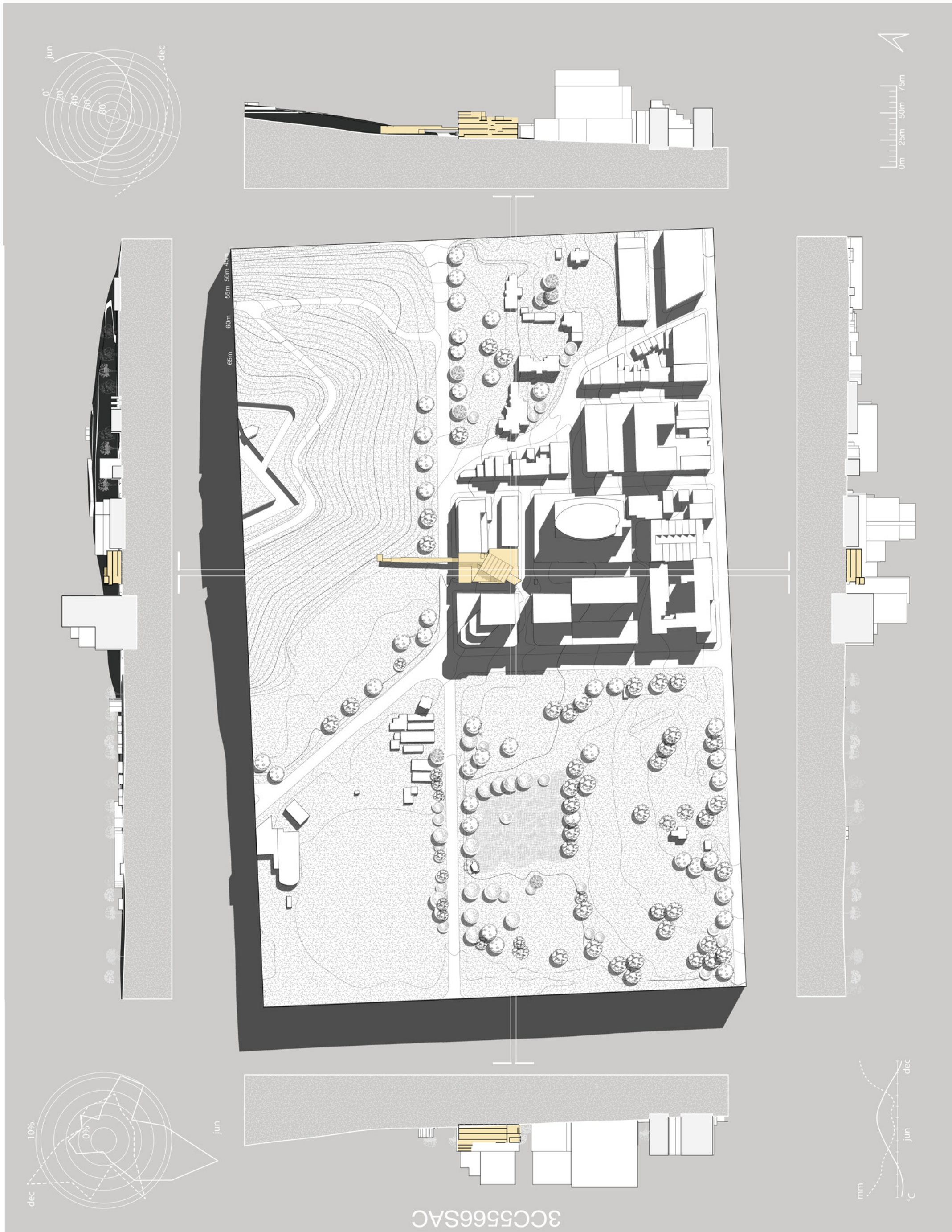
In talking with the current owner of the building it has been identified as at risk of obsolescence because it is currently 60% vacant. In a market such as Halifax where land availability is limited the value of this property is in the lot and not the building itself.

Identifying Nutrients

This plot of *soil* is high in nutrient content. As it was originally built for a telecom switchboard the structural frame is oversized to accommodate the heavy weight of the switchboards. This means that it currently is oversized for more general commercial/retail programming and can therefore

Interior of steel addition

Existing interior - interface between original concrete and steel addition.

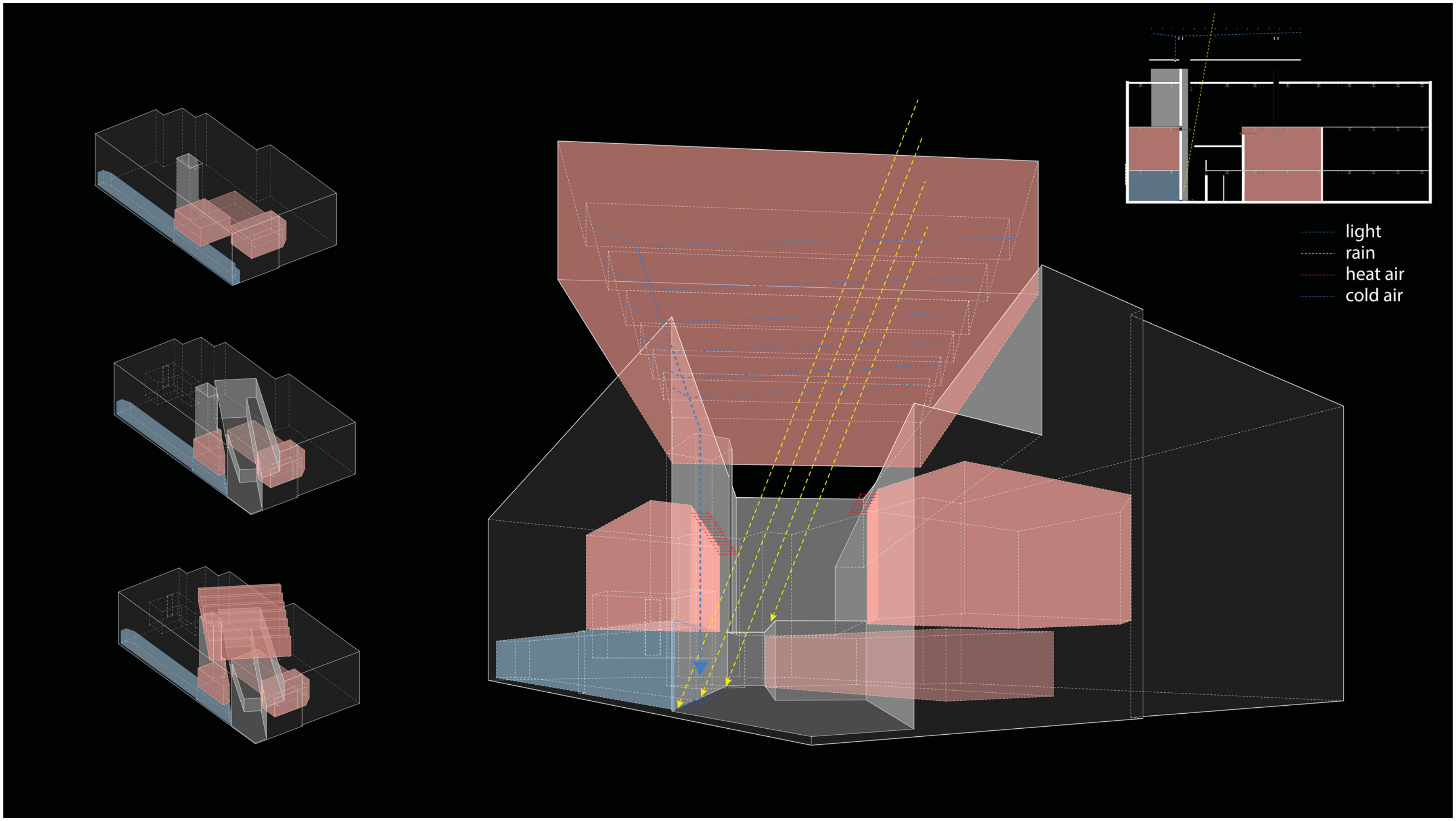


Site plan of 3CC5566SAC.

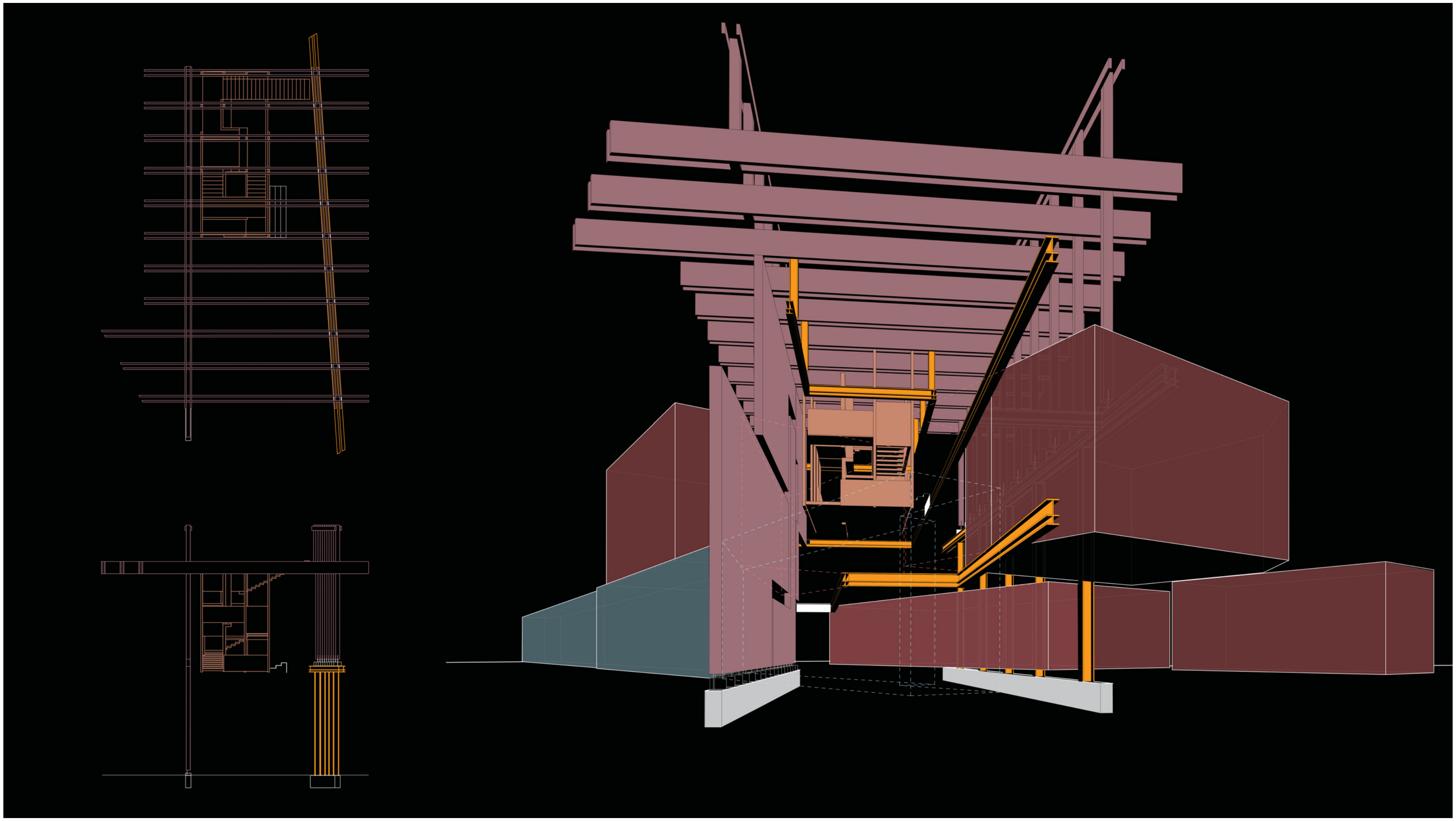
1/4”-1’ model showing structure, cable vault and server room.

support additional levels on the existing foundation.

The current tenant is a datacom server provider that operates 3 server rooms. These room are full of large electronic equipment that generates a high volume of waste heat. This heat is currently exhausted to the outside air and the building is cooled and ventilated mechanically year round. There is also a boiler room that exhausts to the outside. Along the West wall of the basement is a cable vault that



Accessing nutrients of soil and analyzing buoyant forces of natural ventilation.



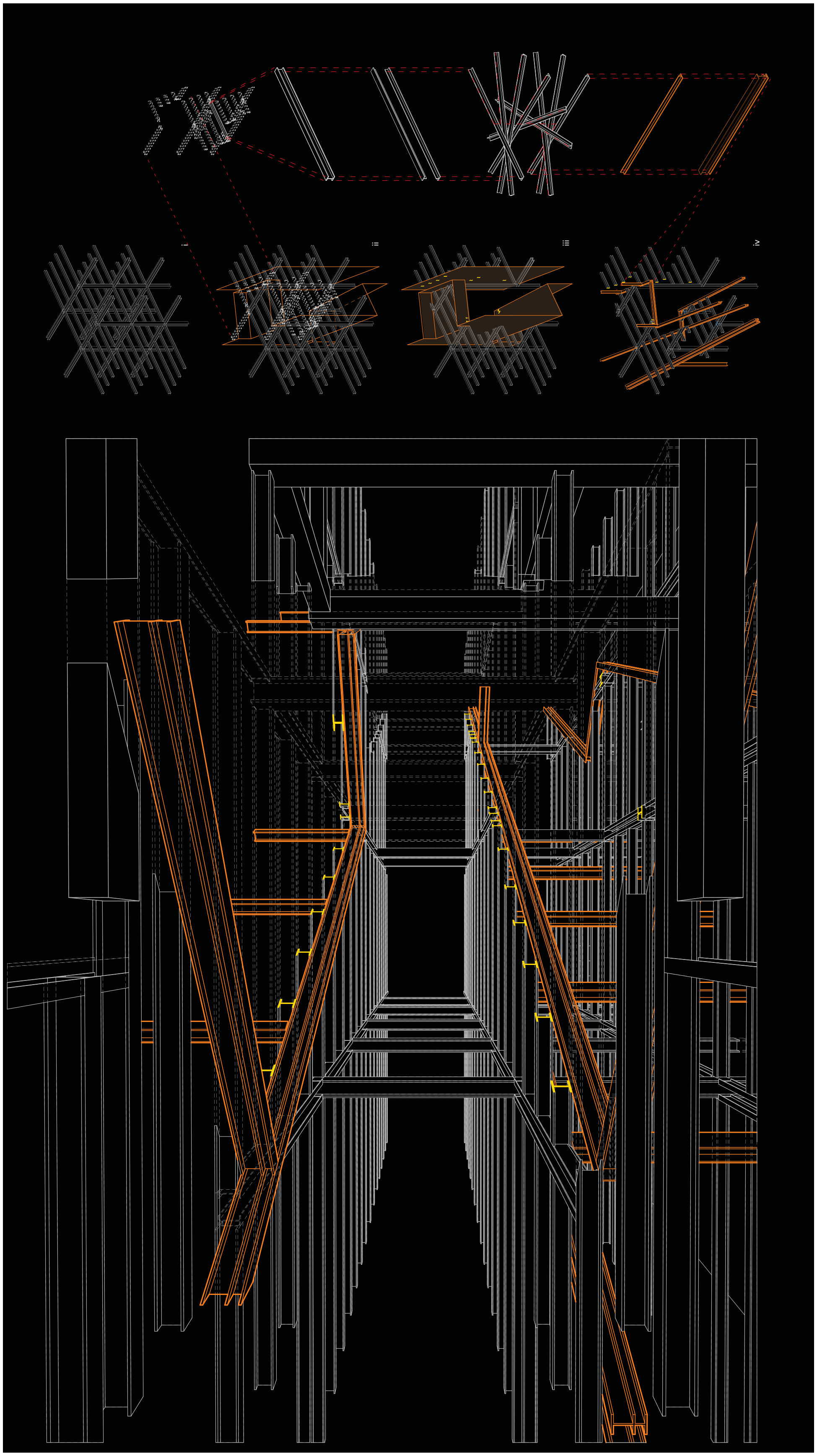
Structure of the *tree*.

Artificially lit interior.

offers a large volume of cool air from which to draw.

The original building has an exposed 2 way beam concrete flooring with 18” square concrete columns. The floor to floor height is 16’ on the second and third levels. The windows are 4’10 by 9’ and provide daylight only to the front portion of the building. The remainder of the building is lit artificially leading to a high consumption of energy as well as increased demand on the cooling system as a result of the heat generation. The addition has exposed steel beam and joists with composite concrete decking and 16” wide W-section columns.

1/4”-1’ model showing concrete and steel structure.



Excavating and repositioning the *soil* to allow for new opening.

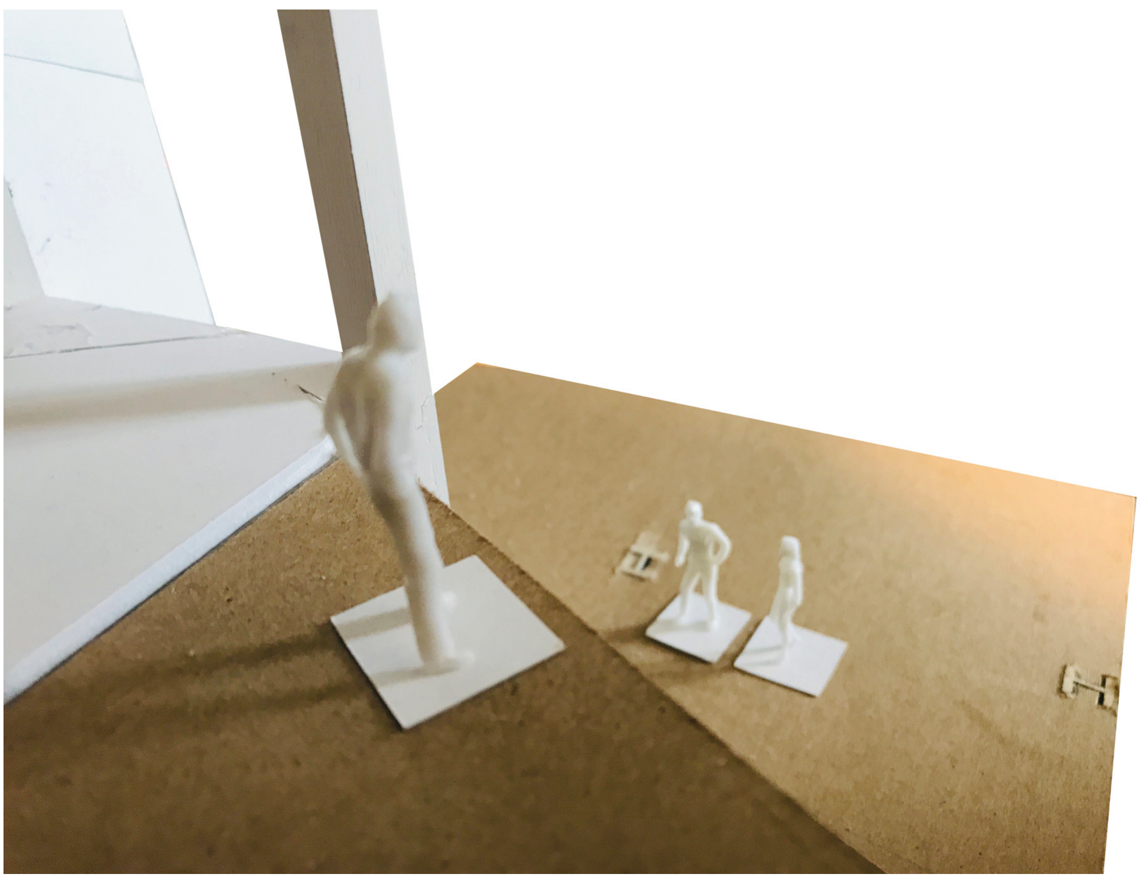
Excavating the Soil

Process of excavation.

In order to access the *nutrients*, the *soil* is removed and stockpiled. Some of the *soil* is repositioned to support the new opening cut into the steel decking and also the new greenhouse on the roof.

Columns that are cut out from the *soil* excavation are repositioned to carry the load of the new greenhouse and transfer beams of the *planted tree*.

The steel decking joists that are cut out are reformed to increase their strength and repositioned as perimeter beams under the existing deck joists.



Excavation highlighting cut columns.

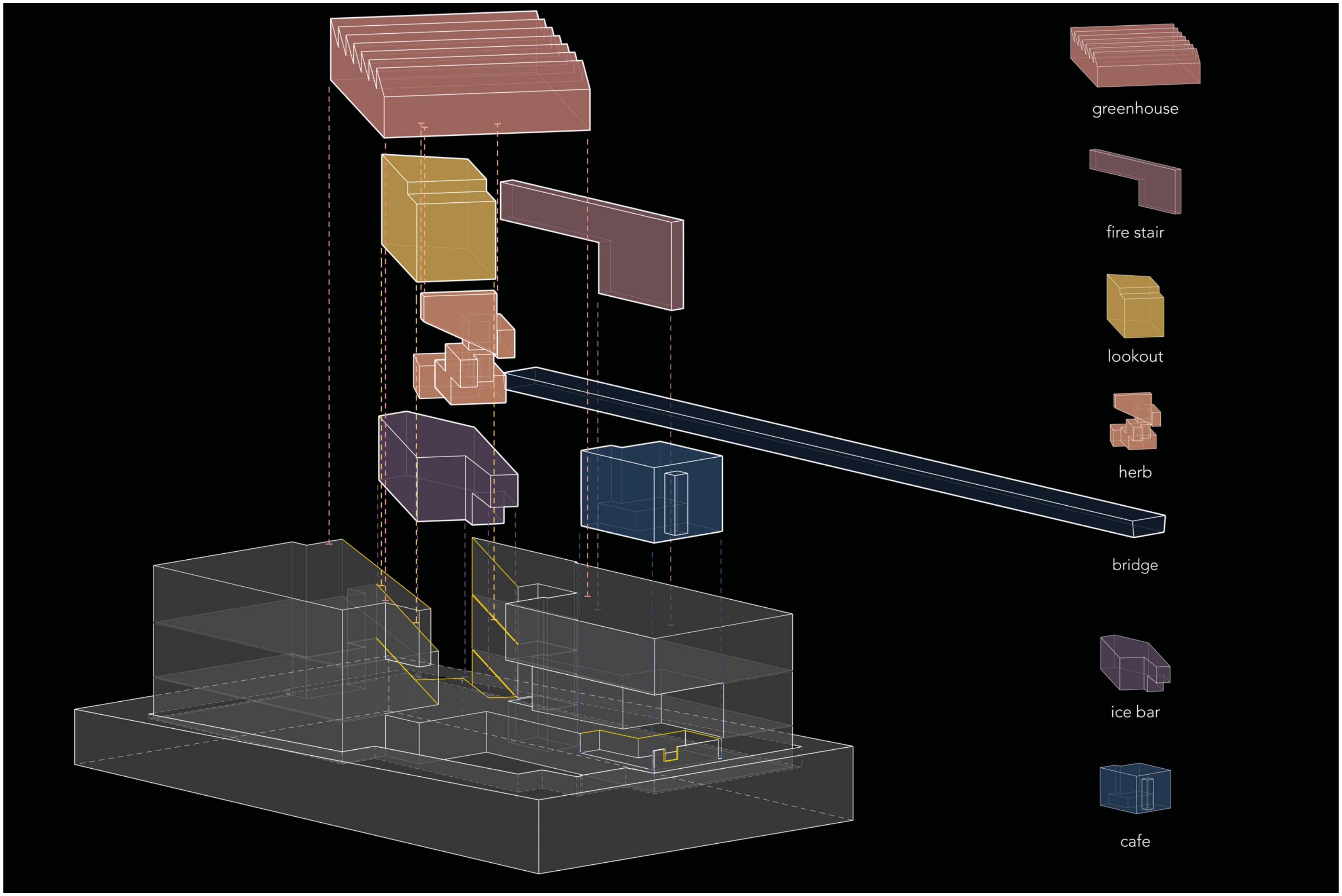
Designing the Tree

The *tree* is designed to capitalize on the *nutrient* currently embedded in the *soil* and also regenerate the *soil.* The primary *nutrients* are the excess heat from the server rooms, the cool air from the basement cable vault, and the oversized structural capacity of the building. The *tree* is designed to generate *nutrients* by opening up the floor plates to activate programming integration between levels, and also create a light void through the building to improve the interior lighting.

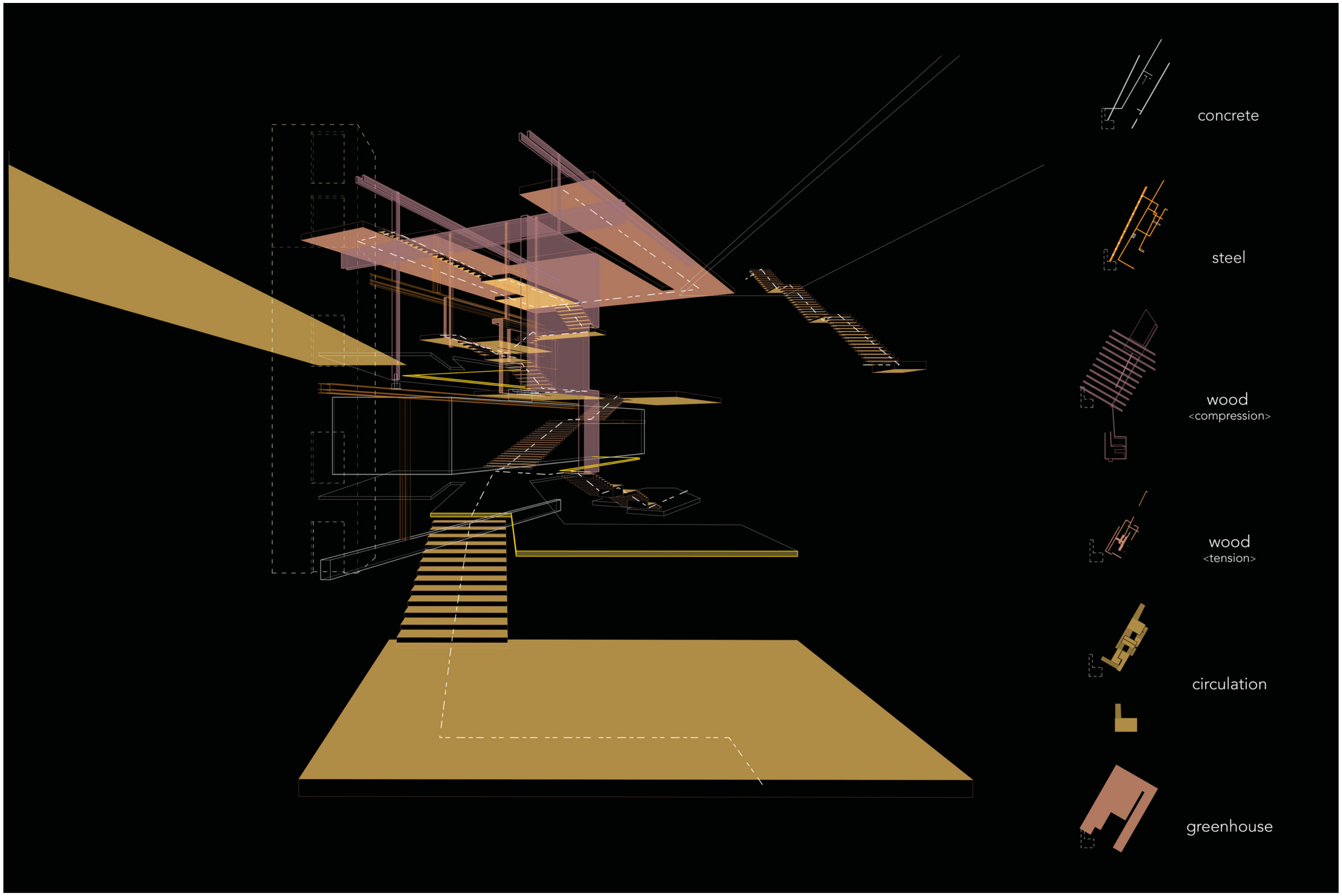
In this newly opened atrium a dried spice market is planted. This vertical market is suspended from new glulam beams above and serves as the vertical circulation from the street level up to the rooftop.

This atrium is connected to a rooftop greenhouse which grows produce year round for the restaurant and kitchen. During the winter months the excess heat from the server rooms is directed to the greenhouse to preheat the ventilation air. During the summer months this excess heat is ducted through the atria and through buoyancy forces aids in ventilation of the building.

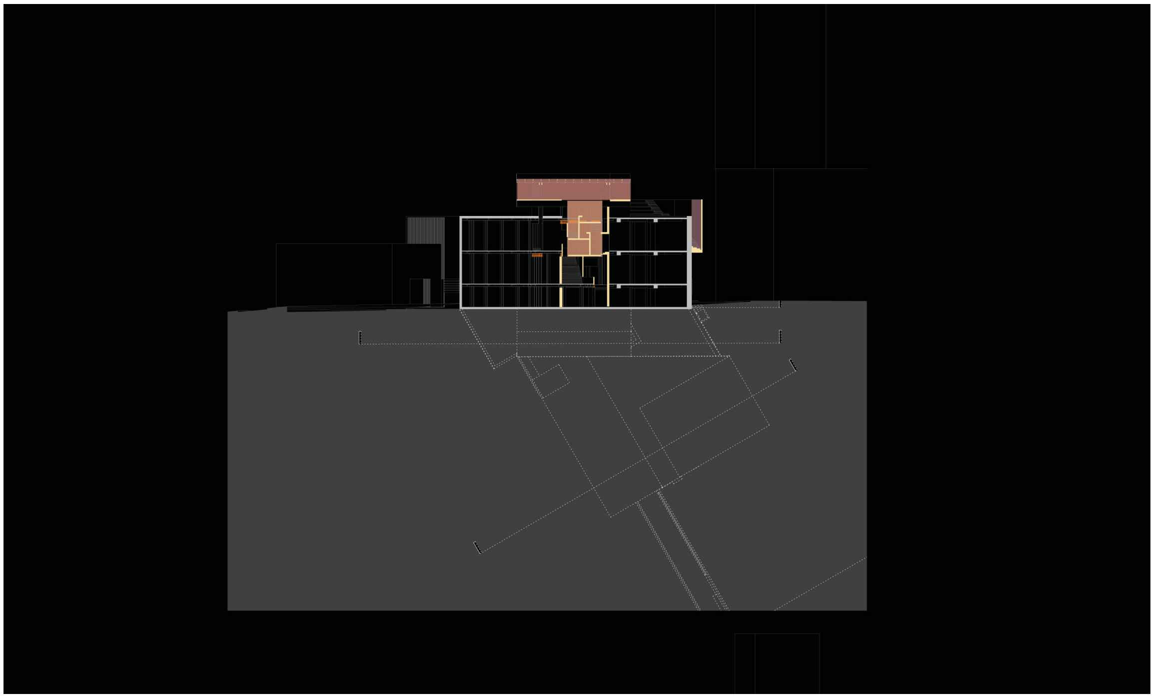
This greenhouse is supported by doubled up glulam beams that span the width of the atrium. The one end of the beams is supported by a full height DLT wall and the other side is supported on glulam columns that are carried by a repositioned steel beam.

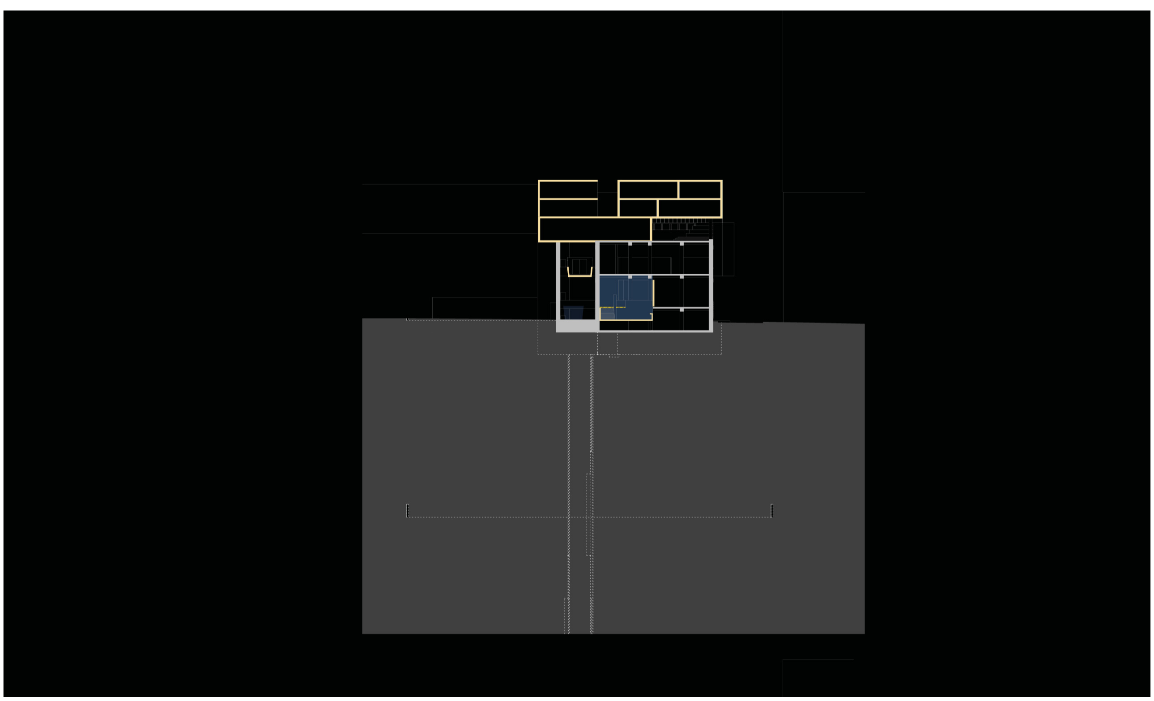


Programmatic elements of *tree*.

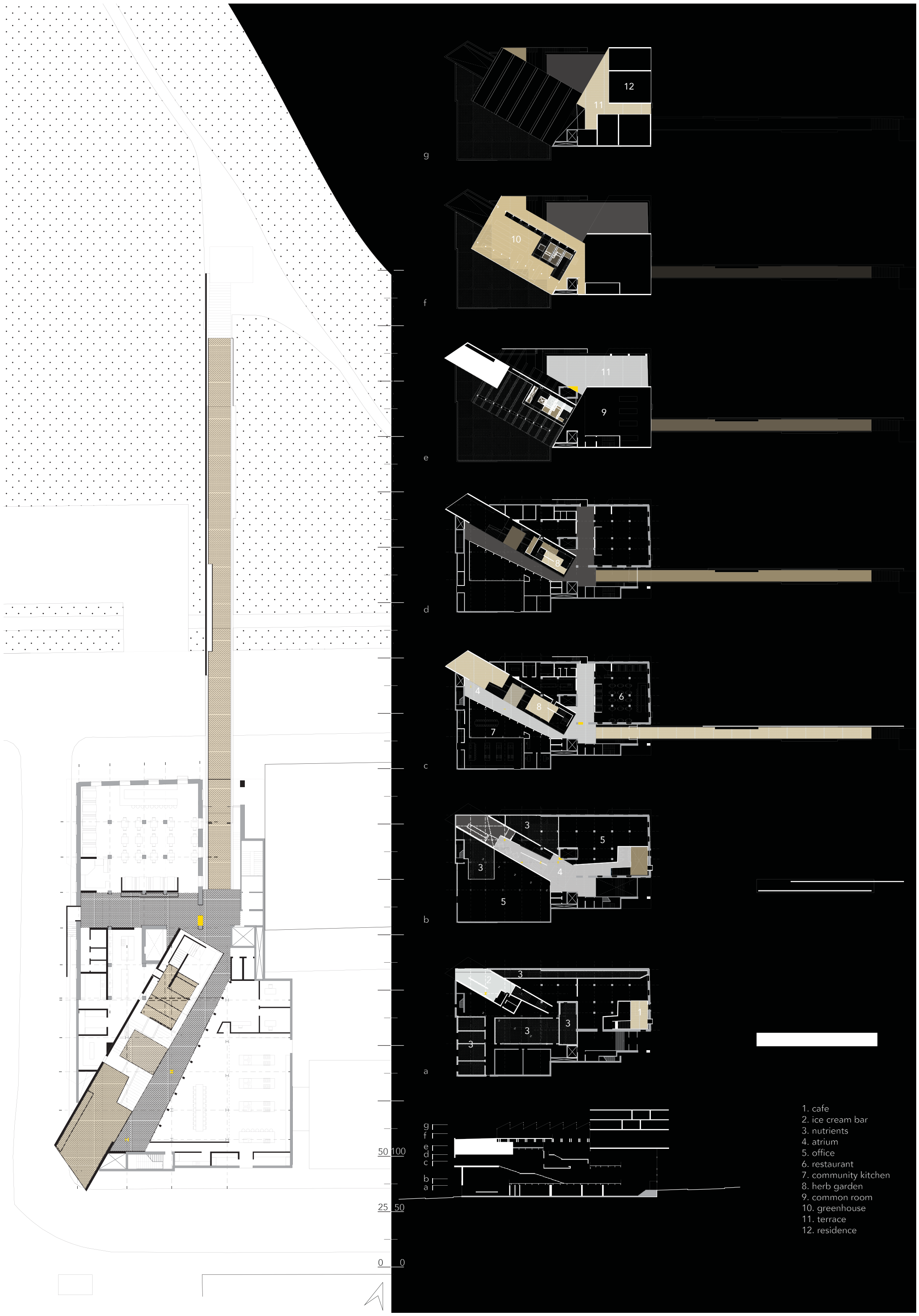


Circulation and elements of the *tree*.





Method of planting.
(bottom: slit, top: hole)


12
11
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0 0
1. cafe
2. ice cream bar
3. nutrients
4. atrium
5. office
6. restaurant
7. community kitchen
8. herb garden
9. common room
10. greenhouse
11. terrace
12. residence

Program

Method of Planting

The two primary *nutrients*, structure and excess thermal energy from the data server rooms, require unique *planting* strategies respectively. The residential tower, common room and rooftop terrace capitalize on the existing concrete structure below and utilize slit *planting*. Whereas the method of *planting* required to access the data server room because of their location is hole planting.

The depth of the tree in relation to the soil highlights these 2 methods of planting.

Program

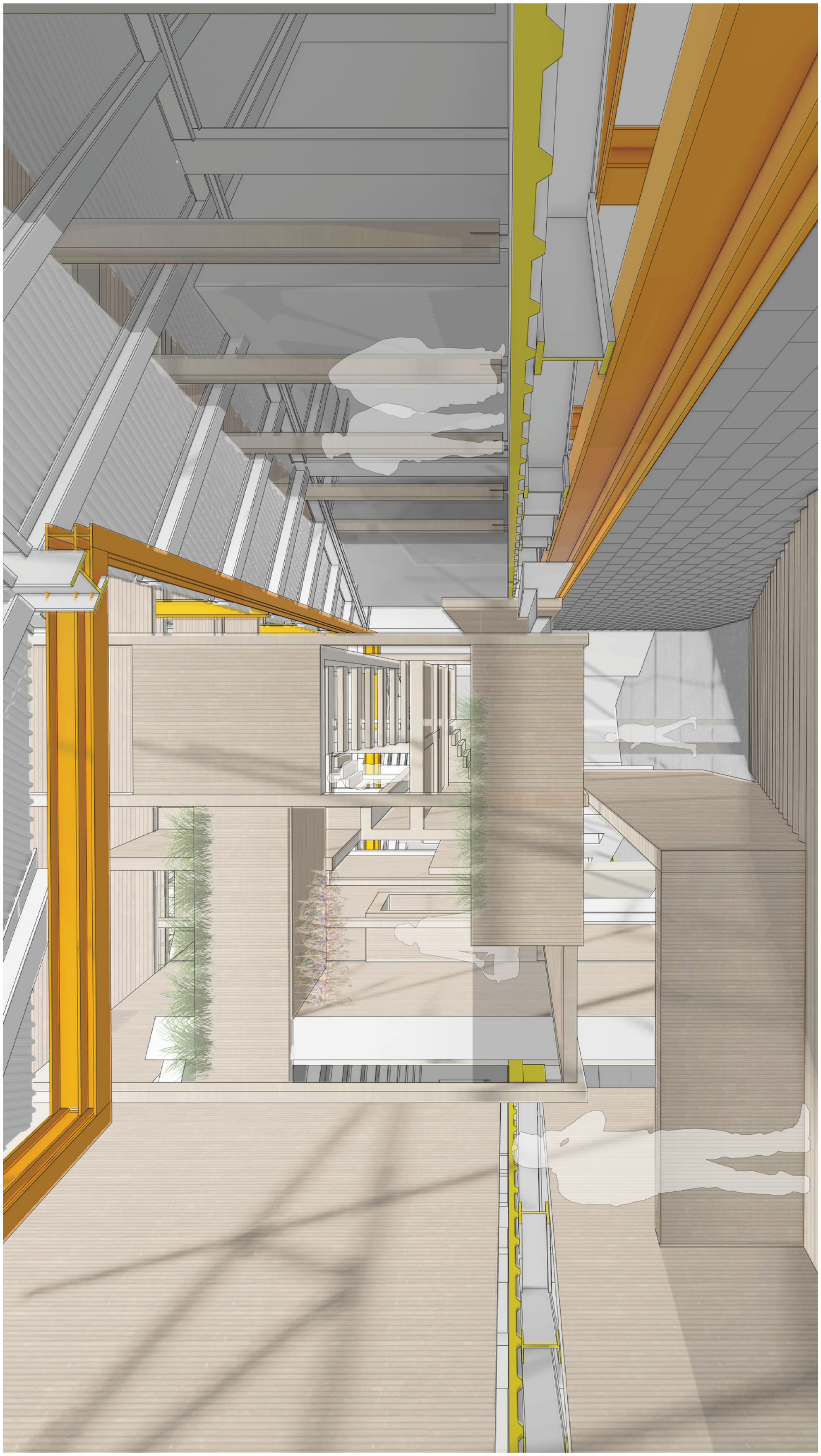
The new *tree*, is *planted* to support the addition of a restaurant, community kitchen, cafe, ice cream bar, spice market and greenhouse and residential housing. All of these new programmed spaces, except for the housing, are publicly accessible and will serve to regenerate the original building, reversing its *erosion*.

The second floor and majority of basement level maintain their original programming with the second floor serving the telecom tenant and the majority of the basement level housing the services and mechanical spaces.

The cafe and ice cream bar serve as the anchors of the building and are the public entrances to the building. The ice cream bar on the south side of the building opens up to a courtyard space that can be activated as a public gathering space around social events such as food festivals and street performances.

The community kitchen is a communal space where people come together around the enjoyment of freshly

Front showing bridge, public room, terrace, cafe.



Atrium looking at herb garden.

prepared food. It also offers opportunities for people to learn the skillset of cooking and then share a meal with friends that they prepared themselves. By offering the opportunity for people to prepare and cook their own food, using produce and spices from the market, the kitchen helps to develop a deeper appreciation for the joys of cooking and share meals together.

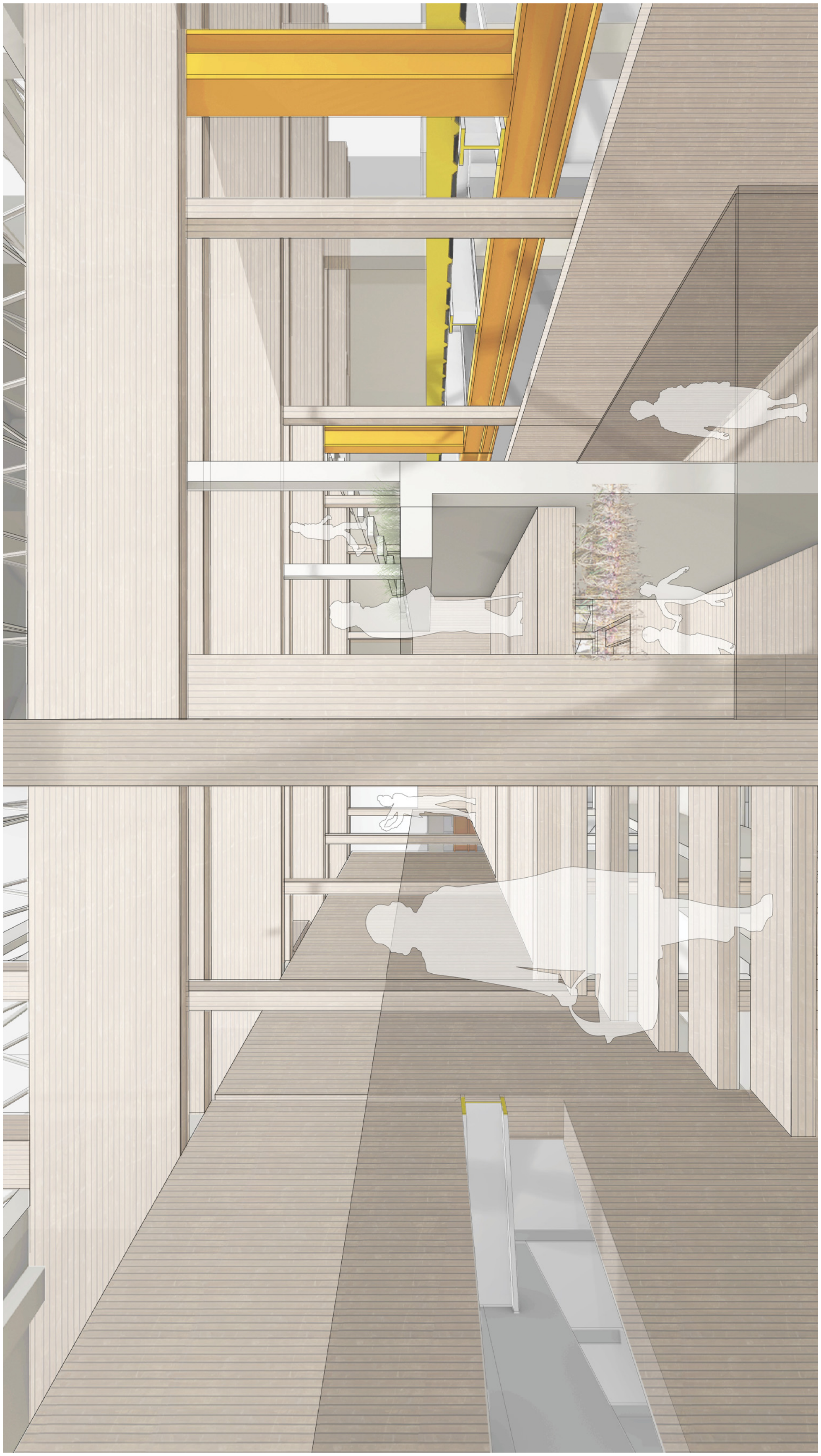
The restaurant is intended to showcase the produce and herbs grown from market and greenhouse. It offers their guests the opportunity to appreciate the flavors of freshly grown produce and prepared food.

Preparing for the Scion

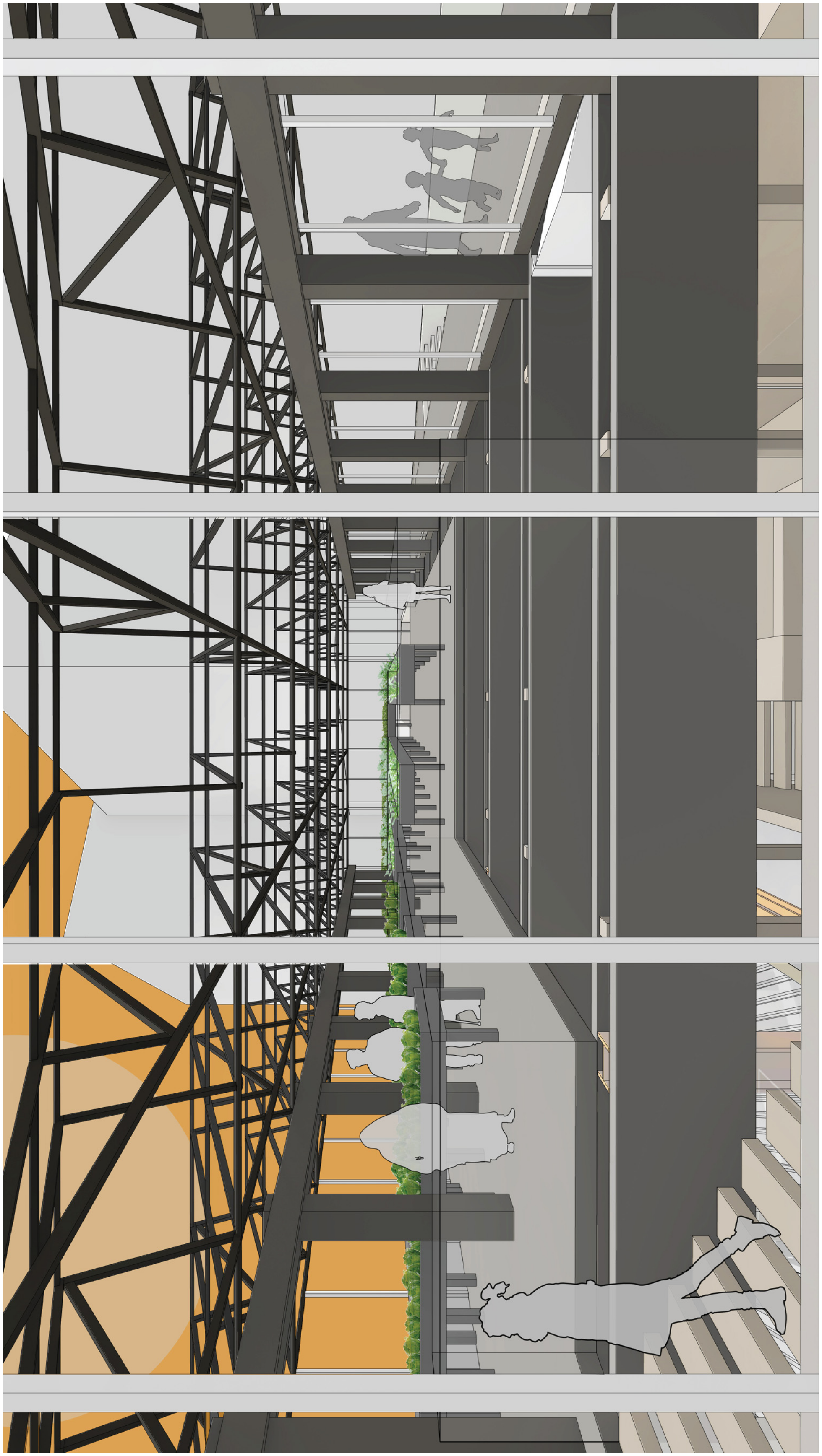
The residential units are designed to meet the basic needs of the tenants but allow them the opportunity of developing their own houses to turn them from residential units into homes. Following the principles of Stewart Brands low-road buildings, these units are designed in a way to be flexible to modification, addition, subtraction, or *grafting*.

Giving the tenants the opportunity to develop their own homes as they see fit enables them to be *arborist's* of their own houses and thus innately empowering them to have a vested interest in the success of the overall *tree*'s future growth.

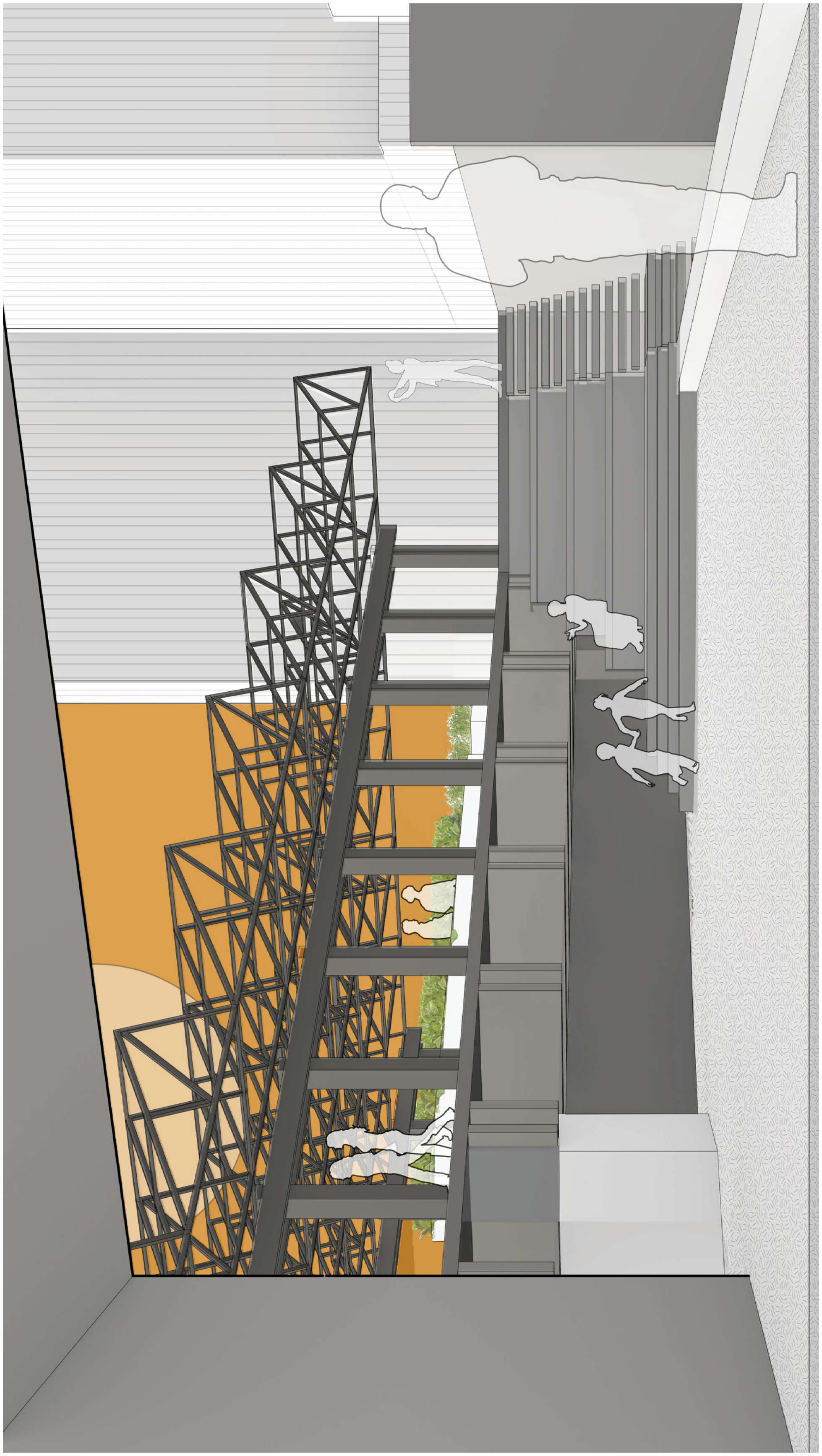
Cafe



Ascending herb garden.



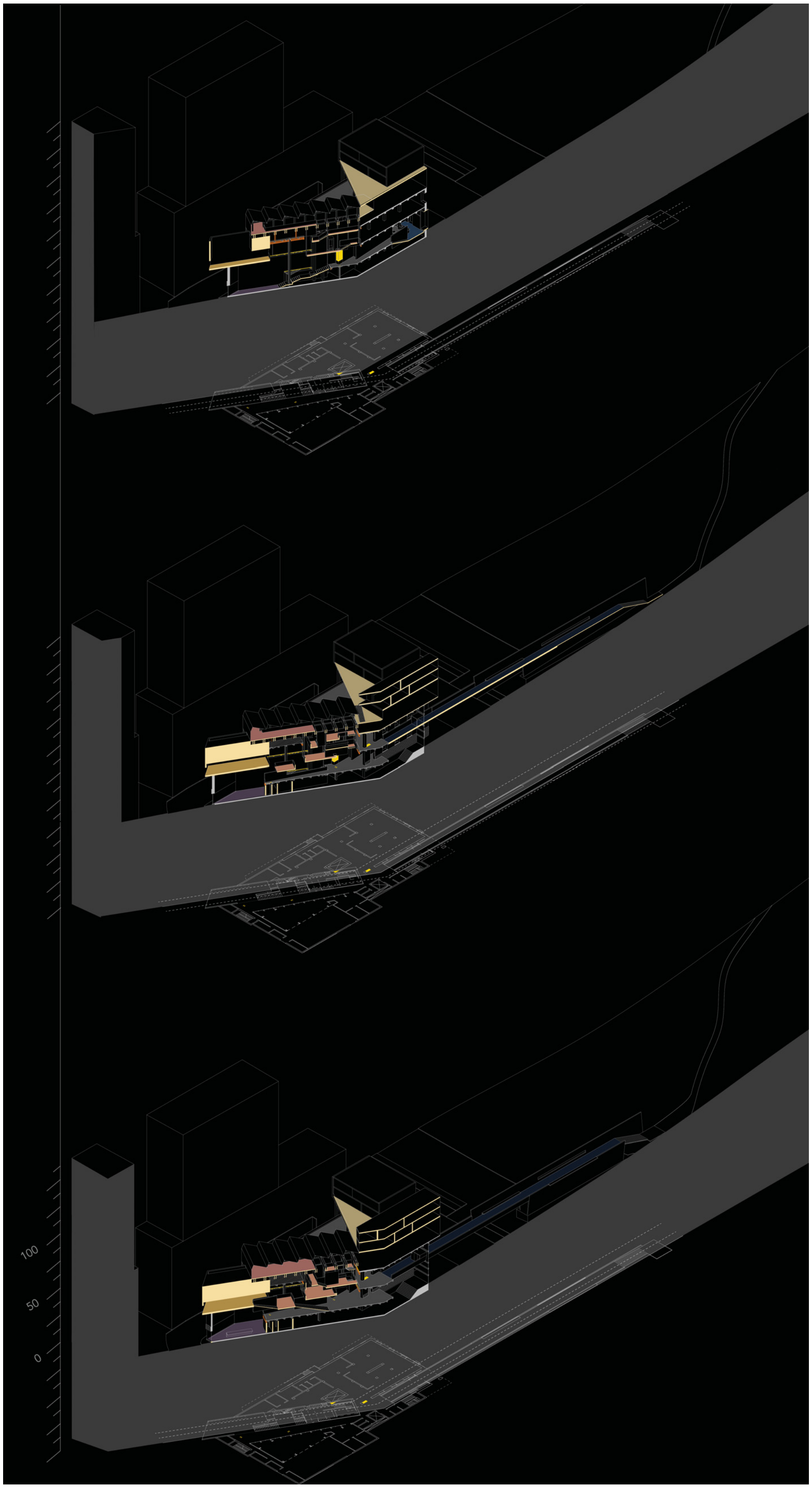
Greenhouse



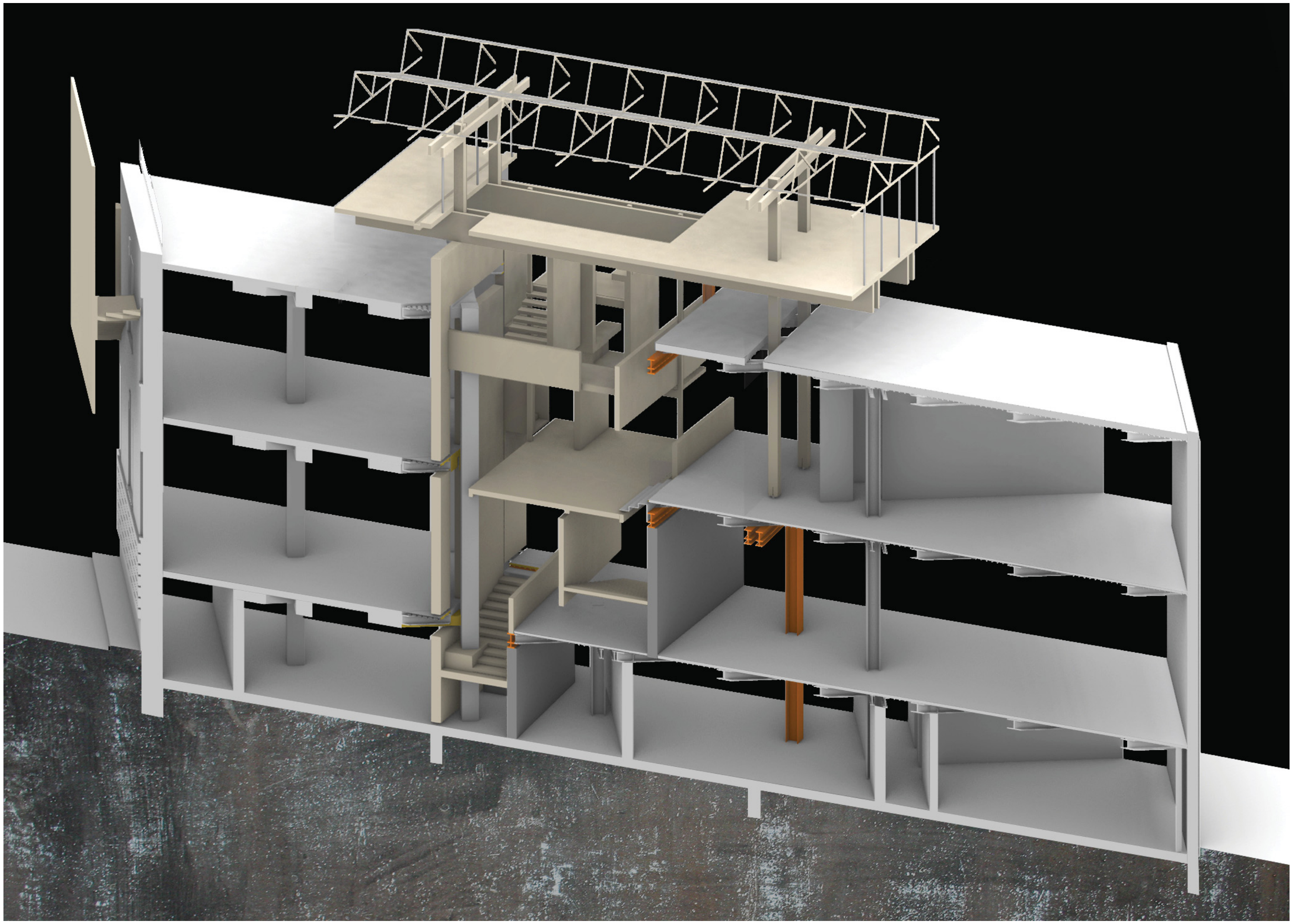
Greenhouse viewed from terrace.

Ice bar

Rear courtyard with lookout and ice bar.



Sections



Model section showing relationship between *tree* and *soil*.

View of third level from stair case.

View from herb garden.

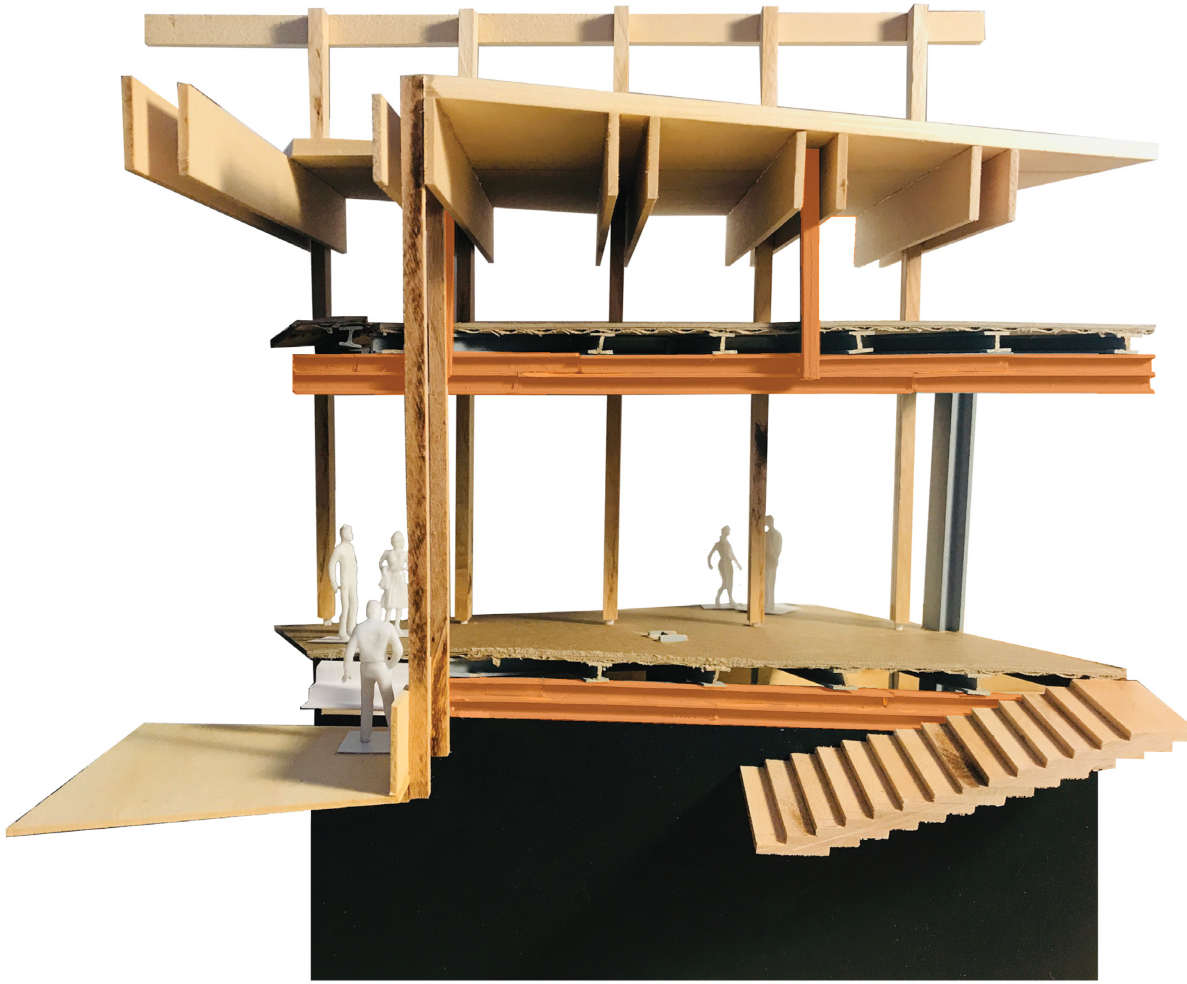
Chapter 6: Conclusion

Through the method of analogy this thesis has set the foundation for investigating how an *arborist* may apply their skillset and knowledge to regenerate obsolescent *soil*. Through the *arboriculture* techniques of *planting* and *grafting* the *arborist* is able to densify the existing urban fabric, minimizing the impact of the built environment onto the natural environment.

By identifying the *nutrients* embedded in the *soil*, *cutting* into the *soil* to unearth these *nutrients*, *planting* the *tree* to access the *nutrients* and *backfilling* the *soil* to support the *tree* the *arborist* is able to regenerate an obsolescent building.

Through the produce-centric programming this *tree* will regenerate the *soil* in which it is *planted* by increasing the public access to the building and bringing people together through the enjoyment of food.

An *arborist* understands the potential of obsolescent *soil.* They posses the skillset required to regenerate the *soil,* and the passion and patience to ensure the successful *growth* of each *tree* they plant. The *arborist* approach is an ecologically effective method of focusing on the symbiotic relationship between a *tree* and its *soil*, regenerating obsolescent building and closing the open loop carbon cycle of development.

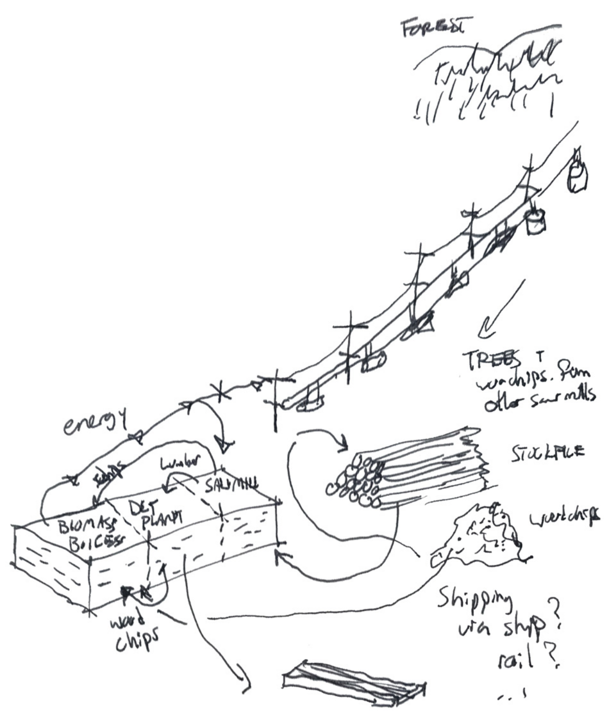


Physical model showing relationship between *tree* and *soil*.

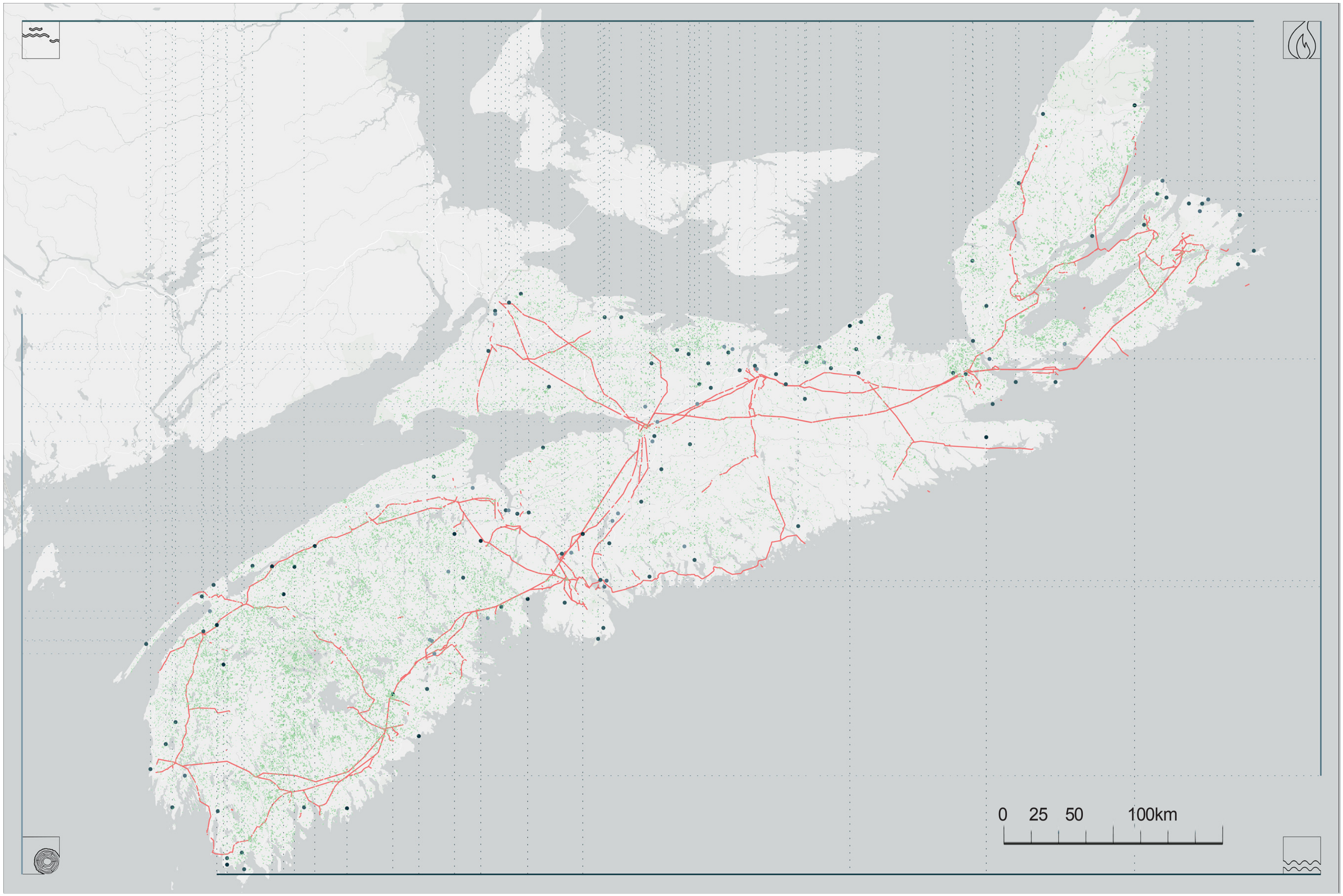
Appendix A: Nova Scotia Forests

Forestry

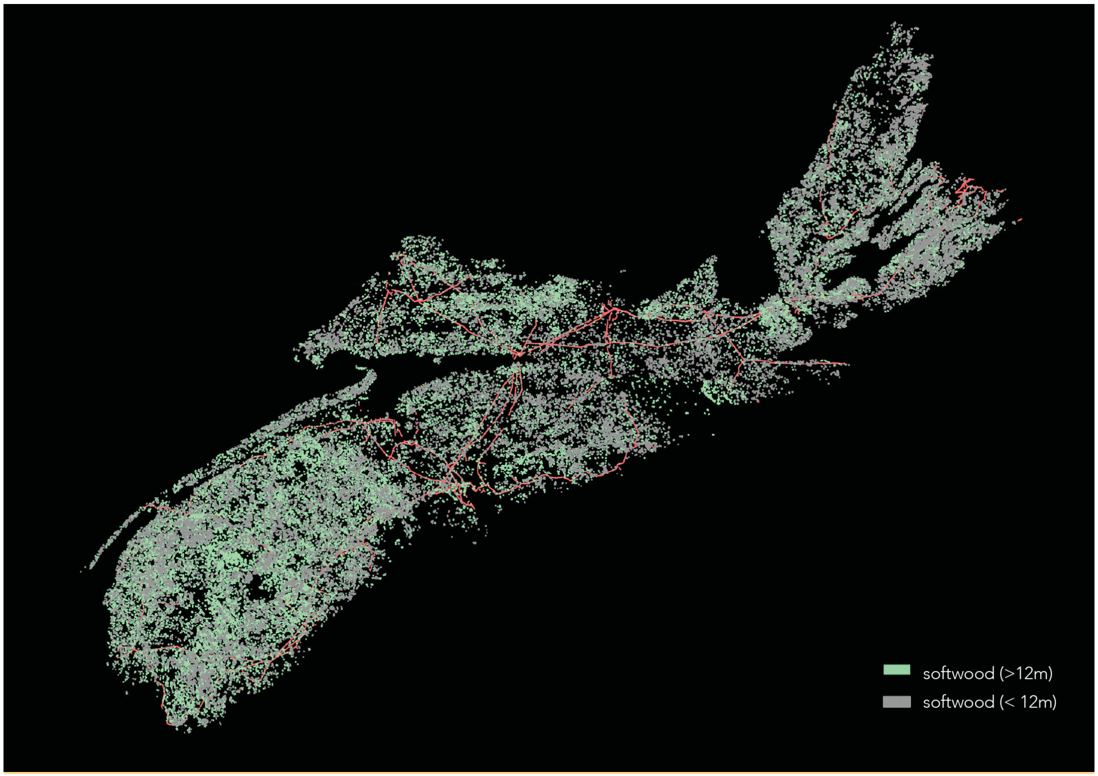
Nova Scotia is home to approximately 30 types of native trees, 18 of which are softwood (Saunders 1970, 5). This section is a study that was interested in understanding the potential of Nova Scotia to support a mass timber manufacturing plant. Attempting to look at synergies between existing infrastructure and forest land, it looked at the potential of utilizing the existing Nova Scotia power grid as a means of transporting harvested trees from deep within the forests to a series of collector plants from which they could be processed. It also proposes a bio-fueled cogen plant, using the sawmills product waste to offset the provinces reliance on coal fired power plants.



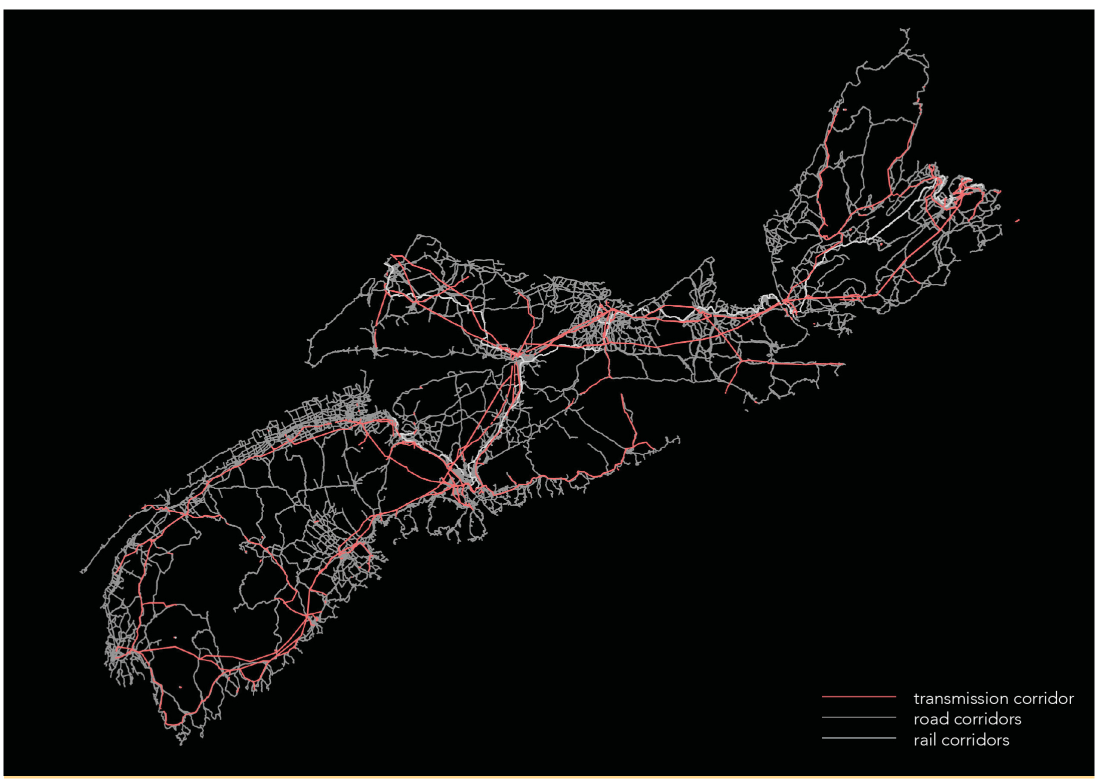
Utilizing existing power line grid to transport wood to bio-fueled Cogen plant.



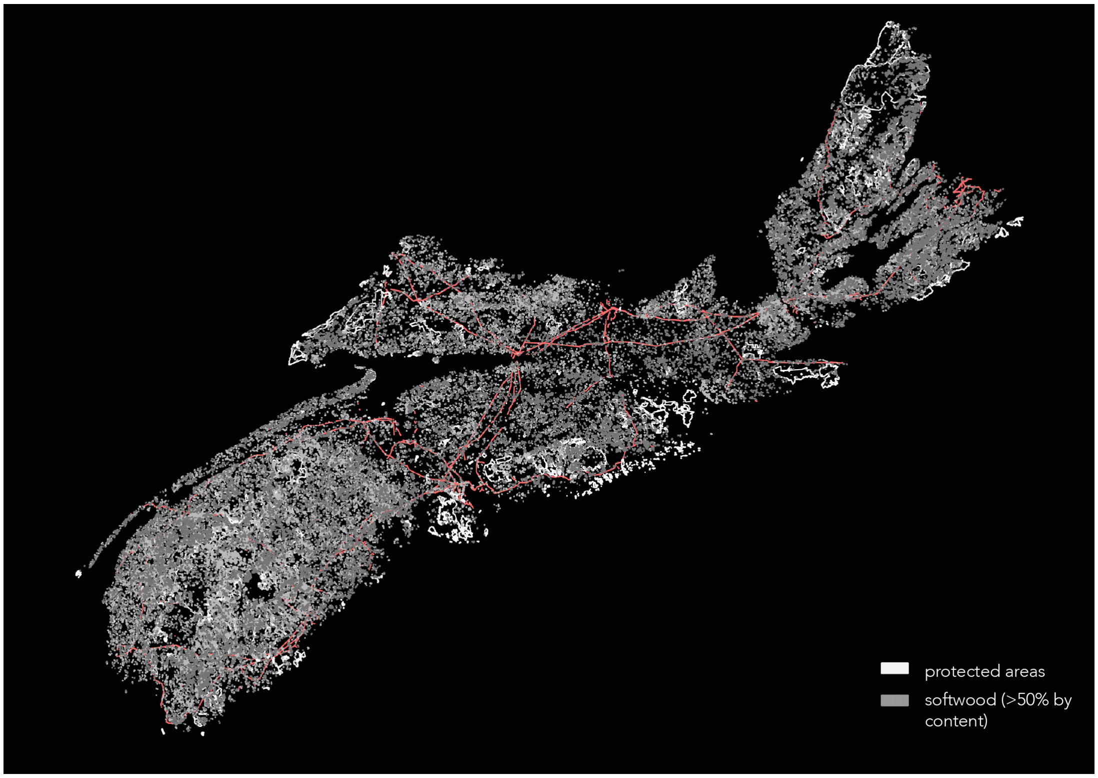
Nova Scotia softwood forests, primary power source generation (clockwise starting at top left: wind, coal/nat. gas, hydro, sawmills), and primary transmission line corridors (data from GIS).



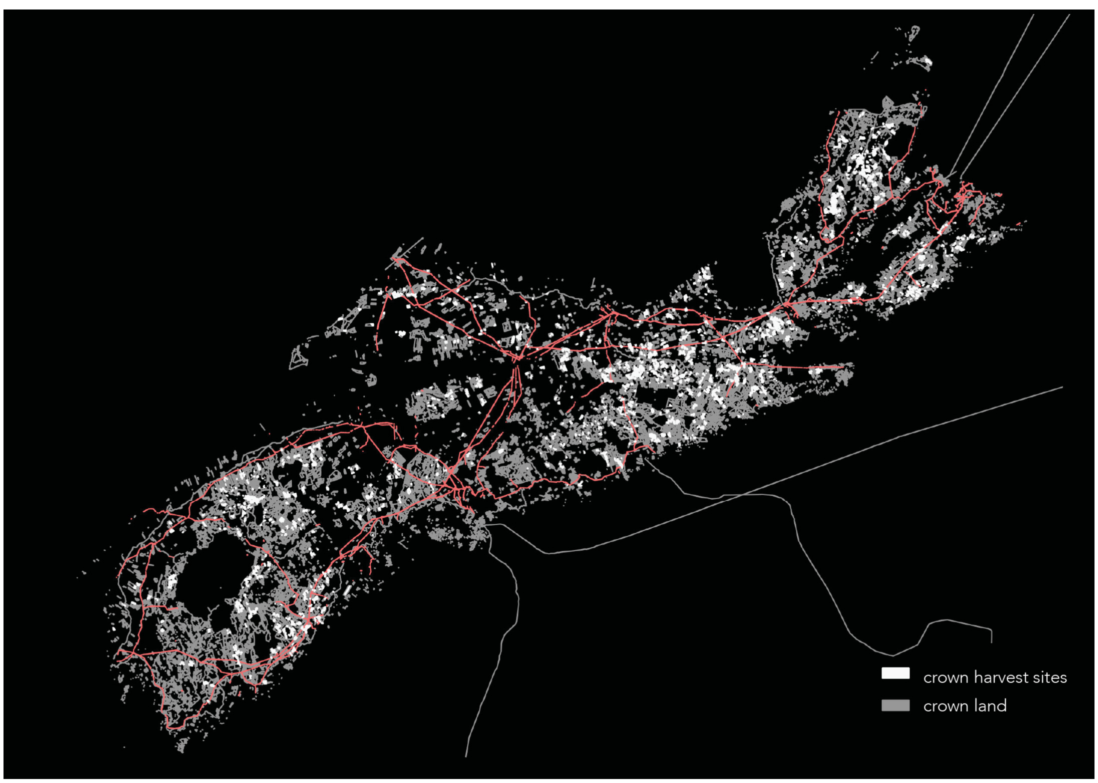
Softwood forest distribution of Nova Scotia with power grid shown in red (GIS information).



Primary transmission lines (in red) and roads (in white) of Nova Scotia (GIS information).



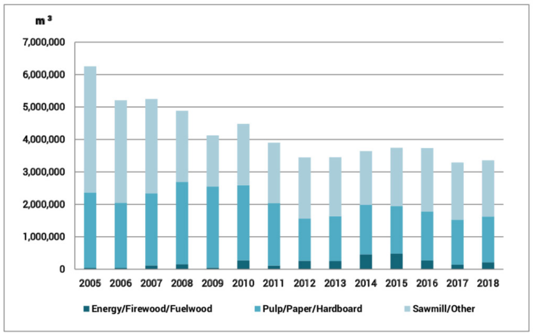
Softwood distribution and protected areas of Nova Scotia with power grid shown in red (GIS information).



Crown land and harvest sites of Nova Scotia with power grid shown in red (GIS information).

Total Harvest Volume

by Product Type



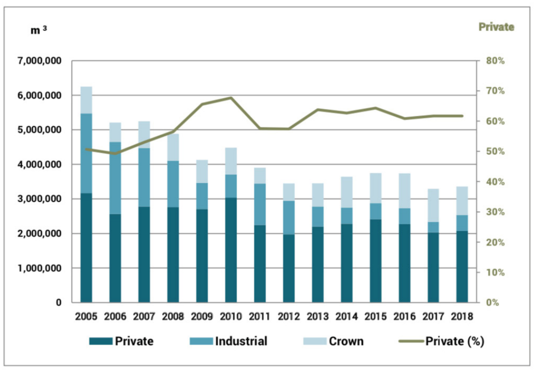
Provincial Harvest

by Primary Forest Product and Species Type

PRODUCT	Percent of Total Harvest	Hardwood m^3 solid	Softwood m^3 solid	Total m^3 solid
Firewood	2%	50,488	86	50,574
Fuelwood	1%	14,873	3,760	18,633
Energy Wood	4%	59,508	87,919	147,427
Posts/Rails, House Logs	<1%	-	1,799	1,799
Pulpwood	42%	480,752	926,861	1,407,613
Studwood/Sawlogs	51%	45,539	1,687,977	1,733,516
OSB Wood/Veneer Logs	<1%	286	24	310
TOTALS	100%	651,446	2,708,426	3,359,872

Provincial Harvest Volume History

by Tenure (m^3)



NOTES: "Tenure" in this report means land ownership.
The Crown volume number includes Federal volume.

Total Provincial Harvest

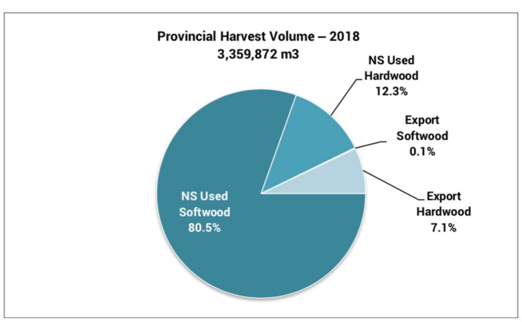
by County of Origin, Species and Use

COUNTY	Percent of Harvest	Species Type	Provincial m^3 solid	Export m^3 solid	Total m^3 solid
Annapolis	5%	S	119,602	-	119,602
		H	29,472	6,115	35,587
Antigonish	4%	S	113,547	-	113,547
		H	24,717	3,743	28,460
Cape Breton	3%	S	98,046	-	98,046
		H	3,012	-	3,012
Colchester	10%	S	239,565	-	239,565
		H	48,129	32,110	80,239
Cumberland	17%	S	391,990	1,533	393,523
		H	91,308	78,213	169,521
Digby	5%	S	179,389	-	179,389
		H	4,572	-	4,572
Guysborough	8%	S	207,120	-	207,120
		H	22,831	26,237	49,068
Hants	5%	S	136,627	-	136,627
		H	27,383	18,940	46,323
Halifax	5%	S	155,161	-	155,161
		H	16,343	12,057	28,400
Inverness	4%	S	121,827	-	121,827
		H	7,206	9,628	16,834
Kings	3%	S	70,670	3,264	73,934
		H	33,184	2,331	35,515
Lunenburg	8%	S	215,188	-	215,188
		H	34,605	9,019	43,624
Pictou	8%	S	205,817	44	205,861
		H	37,279	25,638	62,917
Queens	6%	S	174,658	-	174,658
		H	21,841	13,321	35,162
Richmond	2%	S	67,356	-	67,356
		H	1,963	-	1,963
Shelburne	1%	S	21,992	-	21,992
		H	3,932	-	3,932
Victoria	4%	S	135,399	-	135,399
		H	3,595	-	3,595
Yarmouth	2%	S	49,631	-	49,631
		H	2,722	-	2,722
TOTAL	100%	S	2,703,585	4,841	2,708,426
		H	414,094	237,352	651,446
GRAND TOTAL			3,117,679	242,193	3,359,872

Provincial Harvest Volume

by Species and Use

FIGURE 5



Provincial Lumber Production

by Class (fbm)

PRODUCTION CLASS (fbm) *	Number of Businesses **	Production (fbm)	Percent of Total Production	Average Production per Business (fbm)
no production in 2018	18	n/a	n/a	n/a
1 – 20,000	42	343,179	0.08%	8,370
20,001- 100,000	18	866,769	0.19%	48,154
100,001 - 500,000	10	2,552,784	0.57%	255,278
500,001 -1,000,000	5	3,069,270	0.69%	613,854
1,000,001 – 3,000,000	5	11,444,204	2.56%	2,288,841
3,000,001 – 10,000,000	5	34,512,859	7.73%	6,902,572
over 10,000,000	5	393,757,327	88.18%	78,751,465
TOTAL	108	446,546,392	100%	4,961,627

NOTES:

* fbm (board feet): A board foot is a piece of lumber one foot long, one foot wide and one inch thick or an equivalent volume of lumber

** In 2018, there were 90 businesses that produced lumber and 18 sawmills that had no production, for a total of 108 businesses. Also, while businesses can have more than one type of production (e.g. Energy and Lumber), they can only register as one type of business (their primary production type). Therefore not all businesses that produce lumber are registered as "sawmills."

Source - Nova Scotia Lands and Forestry

Nova Scotia Forestry Data Summary
(Department of Lands & Forestry 2019).

Appendix B: Antithesis

Root growing through rock (Weston 1929).

This thesis acknowledges that not every building can be, nor should be saved from demolition. As a means of remembering the past to learn from it this study investigates the idea of *growing* a mass timber building from the rubble of the demolished building.

In some cases it may be deemed uneconomical to regenerate a building. ex) operating costs are too high, structure is beyond repair.

This study proposes to turn the original building into a ruin that will be left as a timestamp for the way things used to be. By planting the mass timber structure prior to demolition, it can grow out from the rubble.

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Growing out of the rubble.

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