Architecture Against Global Warming: A Research Institute for Sustainable Agriculture

by

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A thesis submitted to the Faculty of Graduate and Post Doctoral Affairs
in partial fulfillment of the requirements for the degree of

Master of Architecture

Carleton University
Ottawa, Ontario

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ABSTRACT

Global greenhouse gas emissions are a serious threat to the environment. Since the Industrial Revolution, humans have exponentially released gasses and chemicals into the atmosphere which have resulted in the warming of the earth. One major source stems from agriculture and the indirect processes surrounding it. Current methods of unsustainable agricultural production including intensive monoculture crop cultivation, industrial animal agriculture and extensive food miles.

This thesis proposes a Research Institute for Sustainable Agriculture, a facility which allows for the research of alternative methods of sustainable food production, praxis of such ideas and a forum for public awareness and education. The institute will be located on Granville Island, British Columbia. The institute will house innovative agricultural practices, including hydroculture and Clean Meat production. It is hoped that the architecture envisioned will assist in developing more innovative agricultural solutions and raise public awareness and interest surrounding current methods of food production.

For Sable

ACKNOWLEDGEMENTS

The crown of a thesis dwells in the synthesis of an original academic endeavor. However, of equal import is the embedded process of discovery leading up to the intellectual promontory. Just as it takes a village to raise a child, the nurturing of ideas cannot be undertaken alone. For this reason, a multitude of people are much deserving of thanks.

First, I would like to thank my mom for her unconditional love, comprehensive wisdom, and steadfast support in my many endeavors. And many thanks to my father for his encouragement to explore the frontiers of science and technology.

I would like to extend my sincerest gratitude to my academic advisor, Professor Federica Goffi, for her guidance and encouragement. This work developed in this thesis would not be possible without her tutelage.

I would like to thank Don Kasian, who introduced me to the field of architecture and who demonstrates, through example, the paragon of architectural achievement. I would like to extend thanks to Professors Tony O'Regan and Yvan Cazabon for acquainting me with the the craft of architecture.

To the countless talented friends and colleagues who I had the good fortune of meeting during my studies at Carleton University, I would like to thank you all for making my stay both memorable and intellectually stimulating.

Finally, I would like to thank Sable, for the unwavering friendship and affection. I am deeply fortunate to have such a wonderful friend.

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*All Images by Author Unless Noted Below

A WORLD THAT MIGHT HAVE BEEN

The land lays bare,
Does anyone care;

The sky is bleak,
The air is meek;

Food is little,
But hunger is far from fickle;

She opens her eyes and looks around,
Her feet have left that forsaken ground;

Here, grass is green,
and the luster of the sky is seen;

The bluejay sings,
while a skein of geese sweep the sky with their wings;

Fruit and vegetables paint the land,
And workers harvest with their hands;

Human contraptions green the space,
Man and nature interlace;

She was lost with what she had seen,
Wisdom and intervention averted what would have been.

THESIS QUESTION:

Current methods of industrial agriculture are unsustainable and a major contributor of global warming. Can architecture serve as a democratic forum for the research and praxis of new sustainable methods of food production and remediate the urban fabric with an agrarian landscape though inspired public education and critical discourse?

"Only that day dawns to which we are awake. There is more day to dawn. The sun is but a morning star."

____Henry David Thoreau, Walden: or, Life in the Woods, 1990

Introduction

In the middle of May 2017, the Svalbard Seed Vault(Figure 0.1), located in the Arctic Circle was partially flooded (Carrington, 2017).The vault serves as a repository for global grain in the event of unforeseen circumstances(Carrington,2017)). The reason for the flooding could be traced to increasing temperatures in the region which resulted in the unexpected melting of the permafrost (Graham, 2017). The sudden unexpected melting of the permafrost has been attributed to climate change (Carrington, 2017) induced in no small part by human actions

The incident at the Svalbard Seed Vault is troubling for it demonstrates the unpredictability of the natural environment and warns of the dangers in assuming a lackadaisical attitude towards the earth's atmosphere. Human action since the Industrial Revolution have been pivotal in changing the physical and environmental landscape (Maslin,2004 p.8). An observable consequence can be observed from the rapid melting of the Arctic Icecaps (Lynch, 2012).One significant cause of human induced global warming occurs from agriculture which is responsible for a significant production of greenhouse gas (GHG) emissions (Kemmerer, 2014, p.15).Conventional forms of agricultural production which contribute both directly and indirectly to greenhouse gas emissions include industrialized monoculture crop cultivation and intensive livestock farming.

Humans are adaptable and their behaviors are plastic (Massey, 2013). Thus, current food production and consumption methods can be transformed to prevent further damage to the environment. It is at this junction where architecture can play a role in the implementation of these strategies. The aim of this thesis is to utilize an architectural framework to present a building which can serve as an Institute for Sustainable Agriculture. Central to this thesis is the premise that architecture is more than just a building. Embedded in the tectonic of construction, is the potential for shaping and influencing those who both dwell and visit a space. This is the social responsibility and potential of architecture.

Figure 0.1 : Svalbard Seed Vault

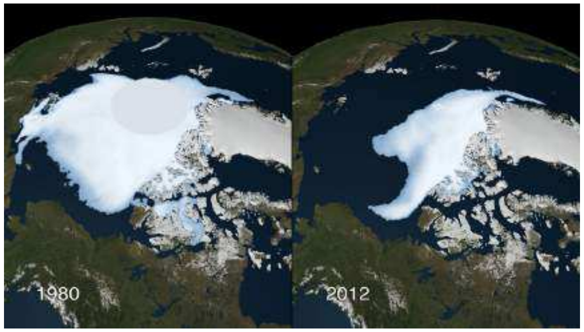


Figure 0.2 : Melting of the Arctic Icecap: 1980 vs 2012

This thesis is organized as follows:

Chapter 1 provides a cursory introduction to global warming and the direct and indirect role of agriculture as a contributor of greenhouse gas emissions.

Chapter 2 presents alternative methods of sustainable food production such as urban agriculture and cultured clean meat and describes how such methods can be implemented with efficiency.

Chapter 3 identifies the site of Granville Island and includes an analysis of the proposed location.

Chapter 4 details the programmatic requisites of the building and presents the design development of the building.

Chapter 5 concludes the thesis, and provides avenues of departure from the questions enumerated in this work.

CHAPTER 01

GREENHOUSE GAS EMISSIONS

“Even the largest avalanche is triggered by small things.”

____Vernor Vinge,1993

Chapter 01 : Greenhouse Gas (GHG) Emissions

The earth is currently the only known planet in the solar system which sustains life (DeGrasse Tyson, 2003). For living organisms to live and grow, they require a conducive environment. One such requisite is stable temperature. The temperature on the earth is regulated by the homeostatic interaction between the energy from the sun and its loss into space (Maslin, 2004, p.4). Naturally occurring greenhouse gases include water vapor, carbon dioxide, ozone, methane and nitrous oxide working together to create a natural greenhouse or blanket effect for the earth (Maslin, 2004, p.4).

Humans have become prolific in their release of greenhouse gases into the atmosphere leading to global warming and climate change (Maslin, 2004, p.15). Since the Industrial Revolution, there has been clear proof of rising carbon dioxide levels (Maslin, 2004, p.8). Atmospheric carbon dioxide has increased from 280ppmv to 370ppmv. This represents an increase of 160 billion tonnes, representing an overall carbon increase of 30%(Maslin, 2004, p.10).

Today, the threat posed by global warming receives much attention; however the discovery of the phenomenon is not new. The concept was first presented in 1896 by Svante Arrhenius, a Swedish scientist who calculated that human activities could substantially warm the earth by adding carbon dioxide into the atmosphere (Maslin, 2004, p.24).This discovery was largely left unheeded as most scientists at the time assumed that there were a multitude of other influences on global warming (Maslin, 2004, p.24).

Figure1.1 : Global CO2 Levels in the Atmosphere

A major event which precipitated global attention occurred in 1985, when the British Antarctic Survey discovered ozone depletion in the Antarctic (Maslin, 2004, p.31). Since no humans live in the Antarctic, the discovery demonstrated the cumulative and interconnected actions of human activities on the earth and was instrumental in the birth of the environmental movement (Maslin, 2004, p.31). The movement has led the to enactment of inter-governmental accords such as the Kyoto Protocol which stipulate a global reduction of carbon emission by about 1-2% (Maslin , 2004, p.136). However, scientists and experts agree that this amount is minuscule – a recommendation of 30-60% reduction has been recommended- and thus unlikely to greatly mitigate against climate change (Maslin, 2004, p.136).

Today, the continued effects of global warming can be intermittently observed. In 2014 , B-34, a 27km iceberg detached from the Getz iceshelf in the Antarctic (Figure 1.3). The increased formation of icebergs as a result of increasing temperatures are concerning as they scrape the ocean floors and decimate the biodiversity of these localized oceanic ecosystems (Chung, 2014). This example demonstrates but one instance of the interconnection between life systems and the global climate.

Human emissions of greenhouse gases can be traced to the British Agricultural Revolution in England in the 18th Century. This chapter outlines in brief, the historical antecedents which have brought us to our current atmospheric state and the pivotal contributing role of agriculture from the past to present.

1.1 From Past to Modernity: The British Agricultural Revolution, the Industrial Revolution and the Birth of the Modern Age

The British Agricultural Revolution was a period in England spanning most of the 18th century and saw great improvements in the agricultural process. Several key developments in the period include technological innovations such as the Norfolk four course crop rotation, improvements to the plough, improved transportation infrastructures such as road, improvements in land use and increases in farm size and animal husbandry (Overton, 1996, p.1). This,combined with political and economic incentives such as enclosure of land and a market free of tolls and tariffs provided the right admixture which was conducive for growth (Overton, 1996, p.1).

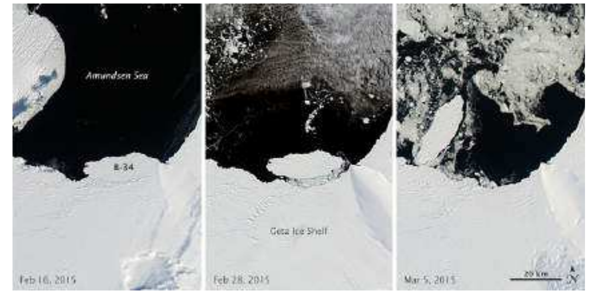


Figure 1.2 : Detachment of B-34 Iceberg - a 27 km long iceberg- from the Getz Ice Shelf

The result of the Agricultural Revolution was a surplus of energy in the human population (Lenton, 2016,p.79). This surplus in human energy increased the working potential of the population and spurred the advent of the Industrial Revolution (Overton, 1996, p.206), commencing with the textile industry and later expanding to other industries such as coal, steam and metallurgy. One industry of note was that of metal tools and in particular the invention of agricultural technologies such as the seed drill and mechanical thrashing machine which increased agricultural efficiency thus creating a positive reciprocity between industry and agriculture.

The success of the Industrial Revolution in England would sweep to much of the surrounding regions and led to the rapid industrialization of Europe. Maritime exploration and trade with other nations would result in the eventual industrialization of many other parts of the world and the adoption of an industrial capitalist worldview.

1.2 The Haber-Bosch Process: Ushering in the Modern Age

The Industrial Revolution was a defining success in human civilization and today, much of modern society borrows heavily from the ideas which emerged from that period. The Industrial Revolution's economic premise of capitalism requires continuous growth(Gordon & Rosenthal, 2003, p.25) which was feasible until the 1900s when the global population was around 1.6 billion (UN, 2004, p.124).

Despite the advances brought by the Agricultural Revolution, crop production was limited by the lack of fertilizer. Demand for fertilizer often exceeded supply. Nitrogen- a key ingredient for fertilizer- was obtained from the mining of niter. However, in the early 20th Century, Fritz Haber successfully converted atmospheric Nitrogen gas into ammonia (NH4) (Fritz Haber , n.d.). In 1915, Carl Bosch industrialized Haber's process, therein leading to a global surplus of ammonia fertilizer (Fritz Haber, n.d.). This discovery was instrumental increasing grain yields and thus to the the rapid population growth from 1.6 billion to about 6.7 billion today (Ritter, 2008).

$$N2 + 3\ H2 \rightarrow 2\ NH3$$

Figure 1.3 : The Haber- Bosch Equation

Today, 146 million tonnes of ammonia is produced. (Mineral Commodities Survey, 2016 p.119). Unfortunately, the nitrogen released from these compounds is a potent greenhouse gas and contributes to detrimental climate change.

1.3 An Individual Assessment of the Climatic Risks Associated with Greenhouse Gas Emissions

Myths of Nature + Myths of Human Nature →Expectations of Greenhouse Gas emissions

While the signs of greenhouse gas emissions have been empirically demonstrated, there remains a great deal of opinion in regards to the phenomenon.Given this project's attempt to facilitate an environmentally conscious outlook, behavioural psychology of this phenomenon is warranted. Maslin's (2004) synthesis of John Adams' "four myths of nature" and "four myths of human nature" is utilized to better understand individual responses to the issues of risk,uncertainty and the attitudes toward greenhouse gas induced climate change.

1.3.1 Four Myths of Nature

Human myths on the risk inherent in nature can be categorized into four categories: 1. nature benign, 2. Nature Ephemeral. 3 Nature perverse/tolerant and Nature capricious (Maslin, 2004, p.37).

1. Nature Benign : This myth presents nature as "predictable, bountiful, robust, stable and forgiving" of human action (Maslin, 2004, p.37).

2. Nature Ephemeral : This myth presents nature as "fragile, precarious, unforgiving" and in danger of collapse. They believe that the earth must be protected from human activities (Maslin, 2004, p.37).

3. Nature Perverse/ Tolerant : This myth is a amalgamation of the first two myths. It posits that nature can be relied to behave predictably within prescribed limits. However, care and safeguards should be placed to ensure that the limits are not exceeded.

4. Nature Precarious : The myth prescribes nature as unpredictable and thus beyond the control of humans (Maslin, 2004, p.37).

1.3.2 Four Myths/ Rationalities of Human Nature

The four myths of human nature refer to the general outlook to which people ascribe. These myths are 1.Individualists, 2.Hierarchists 3. Egalitarians and 4.Fatalists (Maslin ,2004, p.38).

1. Individualists are “self-made” people who are to certain extent free from the constraints of others and who strive to exert control over their environment (Maslin, 2004, p.38).

2. Hierarchists “inhabit are world with strong group boundaries and binding prescriptions”(Maslin, 2004, p.39).

3. Egalitarians are loyal to groups but possess little respect for external rules. They arrive at decisions in a democratic fashion (Maslin, 2004, p.39).

4. Fatalists are resigned to their fate, given the minimal control over their own lives (Maslin, 2004,p.39).

1.3.3 The myth of human nature and the corresponding expectations of global warming scenarios as a consequence of increased Carbon Dioxide emissions, or forcing.

The following presents the expectation of global warming as a consequence of increased carbon dioxide emissions or forcing, based on overlapping of the four myths of nature with human nature.

1. The Individualist: The Individualist envisions two possible consequences from carbon dioxide forcing : muted and linear response or linear and synchronous response. In a muted and linear forcing, the climate system is buffered and thus almost insensitive to carbon levels. A linear and synchronous response involves an direct response from the climate system proportional to the carbon forced into the atmosphere (Maslin,2004,p.41).

2. The Hierarchist: The Hierarchist perceives a delayed or non-linear response(which occurs either non-linearly or in a stepped progression but ultimately in increased global warming).

In this case, the climate system may have a slow response to carbon dioxide forcing due to some buffering; however past this buffer, global warming occurs in a non-linear progression (Maslin, 2004, p.41).

3. The Egalitarian: The egalitarian perceives a threshold response.In this scenario, there is very little to no response in the climate system from the forcing. However, past a certain threshold, a quick climatic response occurs. This scenario is most troubling as it is difficult to predict. In addition, studies of past climates indicate the prevalence of such a system (Maslin, 2004, p.41).

4. The Fatalist: The Fatalist given their resignation to external matters, are uncertain about the effects of global warming and prescribe to inaction (Maslin, 2004, p.41).

The importance of these results are key as they demonstrate the extent of human personality and prevailing predispositions in determining the extent or inherent risk embedded in a phenomenon. Despite the perceived static presentation of human personality, perceptions and cognition are fluid and amenable to change. Given the potential environmental repercussions associated with nonchalance, it would be prudent to exercise a disposition which is deliberate and equipped towards caution.

1. 4 A Major cause of GHG emissions: Industrial Agriculture

Agricultural lands- cropland, managed agro-forestry, and grazing lands- account for nearly one-half of the earth’s land area (Smith et al. , 2007) and contribute to greenhouse gas emisssons (Hathaway,2015). Due to the size and scale of the industry, the environmental effects of agriculture are significant(Hathaway, 2015). Of particular import is industrial farming which refer to “ capital intensive,large-scale,highly mechanized agriculture of crops with monocultures of crops and extensive use of artificial fertilizers,herbicides and pesticides, with intensive animal husbandry” (Knorr and Watkins, 1984 ; Hathaway,2015).

Figure 1.4: Human Deforestation for Crop Production

1.4.1 Industrial Monocrop Cultivation

Modern methods of industrial crop cultivation involves monocrop cultivation(Hathaway, 2015). Monocrop cultivation refers to the practice of annual cultivation of the same crop type on the same parcel of land with inadequate rotations (Hataway 2015).

Monocropping is an economically efficient method of crop production. However, it has several shortcomings. Soil overuse leads to the loss of topsoil and can contribute to soil erosion. Soil erosion leads to the permanent destruction of arable land, thereby rendering once fertile land useless for future crop production of ecologically remediative strategies such as reforestation. Since the advent of industrial agriculture, more than 17% of vegetated lands have been degraded from incompetent managment practices(i.e. poor fertilizer and water management, soil erosion, shortened fallow periods and continuous cropping and inadequate replacement of nutrients removed in either harvested materials or through soil erosion) (Tilman, Cassman, Matson & Polasky, 2002; Hathaway, 2015).

Additionally, forests in many countries are routinely destroyed to make way for farmland(Bergeron, 2010),The destruction of forests is particularly troubling. Apart from hosting biodiversity, forests act as carbon sinks, absorbing carbon dioxide from the atmosphere and replacing it with oxygen (Suzuki, n.d.). This pattern of systematic deforestation is particularly pronounced in recent decades. Since the 1980s to present, 80% of new farmland created in the tropics have been obtained from forests (Bergeron, 2010).

1.4.2 Animal Agriculture

Animal agriculture is the single largest anthropogenic user of land and occupies 30% of ice-free terrestrial surface (Steinfeld et al., 2006, p.4). Annually 70 billion animals are reared and slaughtered for human consumption (Strategic Plan, n.d.).This trend is set to increase as the standards of living of more countries develop and the global population increases by 2 billion (Elferink & Schierhorn, 2016).

The mechanisms inherent in the structures of industialization made their way into animal agriculture in the 1940s, after the second World War. (Woods, 2012, p.166). This led to the transition from small, labor-intensive mixed farming to large-scaled,-mechanized and specialized production(Woods, 2012, p.166). Livestock rearing is fundamentally premised on abuse as it objectifies and exploits living creatures with subjecthood- the capacity to merit propositional attitudes, emotions, will,and an orientation towards oneself and one's future (Regan, 1983, p.243 ; Anderson, 2004, p. 278).

One common physical mechanism of abuse is the Concentrated Animal Feeding Operations (CAFOs). CAFOs are in effect, large warehouses or concentrated spaces where most animals are reared (Hribar, 2010). Animals reared in this way are subject to extreme cruelty (HSUS, 2012). Given the desire to maximize animal meat yields, animals are kept in very tight proximity (HSUS, 2012).Pigs are confined to gestation crates where they can barely turn (figure 1.11), battery hens(egg laying chicken) are held in tight cages which make moving barely possible and veal calves are placed in crates where they neglected (HSUS, 2012).All these animals will be meet their eventual fate: transportation to a slaughterhouse and a painful death.

To combat the frequent diseases associated with intensive rearing animals are routinely fed antibiotics to faciliate growth and prevent the outbreak of contagious diseases (Antibiotic Resistance, 2016; MacKenzie, 2014). This misuse of antibiotics and human consumption of antibiotic laden meat has led to a global heath epidemic of potentially fatal antibiotic resistant bacteria (MacKenzie, 2014).

Figure 1.5 : Intensive Hog- Rearing in a CAFO

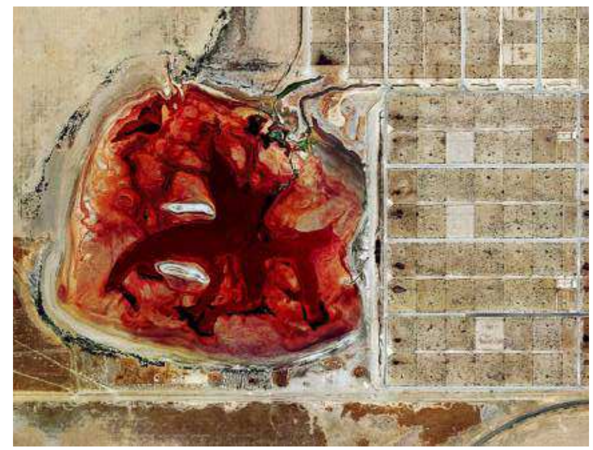


Figure 1.6 : CAFO Generated Waste Lagoon ; Aerial View

From a greenhouse gas emissions perspective, CAFOs operations generate large quantities of greenhouse gas emissions (Kemmerer, 2014, p. 18). One example occurs from the waste generated. Waste on these operations are not treated but rather left in open pits, called lagoons (Kemmerer, 2014, p. 31). These lagoons contribute to emissions in the atmosphere and are toxic to human health and the local ecology (Kemmerer, 2014, p. 33).

Equally troubling is the mismanagement of food use. Despite producing enough crops to feed the world twice over, most crops does not directly feed the population. Rather, the crops are used as feed for livestock. This system of food production is both inefficient and unsustainble in the coming future(Kemmerer, 2014,p.21).

1.5 Food Miles and the Hidden Emissions in Food Transportation

Food miles refers to the distance food travels from the time of production to the point of purchase. In North America, food travels an average of three thousand miles before reaching the consumer(Suzuki & Boag, 2017, p.41). Transportation of these items require the consumption of enormous amounts of fossil fuel which is not realized or taken into consideration by consumers. Taken alone, these actions are insignificant; but when these practices are added as global industry standard practices, the effects are significant.

1.6 Food Wastage and The Rise of the Ugly Food Movement

Food wastage is a serious issue deserving consternation. Annually, close to half of food produced is wasted. This occurs from processing, trasportation, supermarkets and kitchens. As well, one third of the fruits and vegetables produced in North America are discarded since they fail to present themselves in an aesthetically acceptable manner(Figure 1.7) (Royte, 2016).

Figure 1.7 : Ugly Food

The reduction of food waste from the side of production can be addressed though efficient and local methods of production; and the acceptance of less than perfect looking food can be achieved through public education and consumer awareness (Royte, 2016). The Ugly Food movment is one public initiative which accepts and celebrates the aesthetic hetrogenity implicit in produce yields (Mitchell, 2015).The movement has gathered momentum in Europe and Australia through successful campaigns which has encouraged companies in North America to encourage such purchasing behaviours (Mitchell, 2015).

1.7 New Directions

The current trends that have been presented paint a disquieting picture. However, there are several positive considerations that can be extrapolated. First, many agricultural actions undertaken are conducted by a few large business conglomerates rather than individuals farmers (Koba, 2014). Thus the potential for changes can be swift.

Second, many people are becoming aware of their collective power as consumers and have demanded change through their shopping habits (Huddart Kennedy. Parkins & Johnston, 2016). This can be evidenced in the rise of organic foods and other sustainable initiatives (Huddart Kennedy, Parkins & Johnston, 2016). The ability of the public to influence conglomerates suggest that expedient solutions can be achieved in the agricultural industry which can result in less environmentally abrasive methods. Chapter 2 will explore these alternative methods.

CHAPTER 02

URBAN AGRICULTURE:
AN EMERGING METHOD OF SUSTAINABLE FOOD PRODUCTION

" Now, we put out a lot of carbon dioxide every year, over 26 billion tons. For each American, it's about 20 tons. For people in poor countries, it's less than one ton. It's an average of about five tons for everyone on the planet. And, somehow, we have to make changes that will bring that down to zero. "

___ Bill Gates, 2010

Figure 2.1 : Exploratory Collage representing the hidden process mechanisms embedded in modern food production methodologies

Chapter 2 Urban Agriculture: An Emerging Method of Sustainable Food Production

The impact of industrial agriculture's footprint on the earth is troubling. Adding to this, the number of humans populating the earth is set to rise from 7 billion to 9 billion by 2050 (Foley, n.d.). Currently, half of the global population inhabit megacitites-metropolises with more than 1 million people (Bessoudo, 2017, p.90). By the end of the decade, this this proportion is set to rise to sixty percent (Bessoudo, 2017.p.90). This increase is bound to place much great strain on the earth's finite resources. However, despite these setbacks, there lies opportunity to mitigate these issues. Urban environments, with their compact urban form, situate people in close proximity to infrastructure and amenities. This allows for the potential to decrease resource consumption per-capita, while simultaneously contributing to higher per-capita economic and cultural activity(Bessoudo, 2017, p.90). At present, one promising method to address sustainable food production while engaging in civic activity is through urban farming (Van Veenhuizen, 2006, p.2).

2.1 What is Urban Farming

Urban farming is defined as the process of growing plants for food and other uses within and around cities and towns (Van Veenhuizen, 2006, p. 2). It can also encompass related activities such as the production and delivery of inputs and the processing and marketing of products(Van Veenhuizen, 2006, p. 2).Critical to the definition of urban agriculture however is urban agriculture's integration into the urban social, economic and ecological system. Thus, urban farming embodies a holistic methodology which requires the urban context in marriage with the social dynamics for its sustained operational success. One successful example of urban farming is Gotham Greens, a rooftop hydroponic farm typology based in New York.

2.1.1 The Case for Urban Farming

The main purpose of urban farming from the context of greenhouse gas emissions is the lowered food miles associated with such a system. Lowered food miles are also useful in preventing food spoilage and in promoting a local agrarian economy within an urban context. A research study conducted in Cleveland- a city with a population of 389,521 residents- demonstrated that if most of the vacant spaces in the city were used to grow edible crops, it would be feasible to meet and exceed the entire city's fruit and vegetable requirements (Grewal & Grewal, 2012).

In addition to satisfying most of the dietary needs of the population, one perceived shortcoming of current urban environments is the alienation of the inhabitants (Mincyte & Dobernig,2016, p.1771). However, the situating of urban farms in the metropolis serve as spaces of "experiential production" where farm managers can stage work experiences for volunteers who then are afforded the opportunity build new socialities, connect with nature and accumulate social and cultural capital within the city (Mincyte & Dobernig, p 1767).

2.1.2 Soil-less Agriculture : A more Efficient Method to Grow Fruit and Vegetables

As mentioned in Chapter One, global industrial agriculture requires large amounts of resources to operate. Thus, urban agriculture, with its spatial restrictions require alternative methods of food cultivation. One method involves soil-less agriculture, primarily involving hydroponics, or the growth of plants in nutrient rich water solutions. Hydroponic culture systems cover a large range of techniques and include water culture, modified water culture, nutrient film technique or NFT, and aeroponic systems (Chang, Park, Kim & Lee, 2012). This thesis will explore two methods : nutrient film technique (NFT) and aeroponics.

2.1.2.1 Nutrient Film Technique (NFT)

Nutrient Film Technique is a method of hydroponics where a very shallow stream of water containing the requisite plant nutrients is re-circulated past the roots of the plant in watertigh gullys or channels. As well, NFT can be modified to include inert media(such as rockwool) to facilitate plant growth.

MAJOR NUTRIENTS	MINOR NUTRIENTS
Carbon (C)	Boron (B)
Calcium (C)	Copper (Cu)
Hydrogen (H)	Chlorine (Cl)
Magnesium (Mg)	Iron (Fe)
Nitrogen (N)	Manganese (Mn)
Oxygen (O)	Molybdenum (Mo)
Phosphorus (P)	Nickel (Ni)
Potassium (K)	Zinc (Zn)
Sulphur (S)	

Figure 2.2 : Nutrients required for plant growth

2.1.2.2 Aeroponics

Aeroponics is a system of hydroculture where plant roots are continuously or intermittently saturated with nutrient rich fine water particles (or mist). Plants grown using aeroponics can be cultivated with no substrat as the roots are suspended in the air. One distict advantage of aeroponics over hydroponics is the decreased water requirements for operation.

2.1.3 Cellular Agriculture

Demand for animal based proteins is set to increase as the global population grows and the living standards of developing countries continue to rise (Revell,2015). As mentioned in Chapter one, these demands are unsustainable and damaging to the environment. Recently however, innovations and breakthroughs in science have led to the formulation of cultured meat, or clean meat.

2.1.3.1 Clean Meat

A major breakthrough in animal agriculture occurred in 2013 when Dr. Mark Post, a scientist from the Netherlands presented a hamburger whose beef was sourced from cell culture (Jha,2013; Kaufmann, 2017). This new method of production, called cultured or clean meat, represents a breakthrough for meat consumption.

Using the principles of cell engineering, cultured meat involves obtaining stem cells from an animal(assuming a cow) and growing it externally in a medium (See Chapter 4.5.1 Clean Meat Production and Chapter 4.5.1.1 THe Bioreactor for greater details). The meat obtained possesses the same properties as traditionally sourced-meat and the animal which provided the stem cells are left unharmed. Meat produced using this method has the potential to feed more people in a highly efficient and safer manner while being ecologically sensitive and humane in its production. Since the introduction of the first cellular burger, several other companies have began to improve on cellular agriculture and in 2017 cultured chicken strips were produced (Figure 2.6) (Deen, 2017; Purdy 2017).

Figure 2.3 : Prepared Clean Chicken Meat

2.1.3.2 Clean Eggs + Clean Milk

While much research is required to improve the development of clean meat, its successful production marks a great step forward. In addition, clean eggs and milk products are in the process of development (Aubrey,2013 ; Wohlsen, 2015). Given the increasing understanding of the biochemistry underlying these foods, it is a matter of time before these items are ready for mass consumption. These scientific innovations are poised to provide reasonably priced animal based protein to the world. Cultured agriculture is in its infancy and requires greater research and development to fully compete and potentially replace traditional animal agriculture.

2.2 The Psychology of Food and the Factors Affecting Consumption

Innovative solutions to agriculture are requisite for a sustainable future; however these solutions alone are insufficient. The willingness by the public to adopt these strategies are critical for success. One way to understand food consumption practices is to observe the eating habits of children. According to Aldridge & Halford (2009), a child's diet is constructed from what the child likes to eat. This might suggest a genetic or innate preference for food.

However, the role of familiarity should not be discounted. Rather, familiarity plays a strong role in preference formation which leads to an educated preference or "learning to like". (Aldridge & Halford, 2009, p.40). Familiarity can lead to physiologically induced preference as comfort is associated with knowledge (Aldridge & Halford, 2009, p.40). In addition, the physical and emotional associations with the novel foods are of significance. Positive associations are likely to induce preferences; likewise, negative associations are prone to elicit rejection (Aldrigde & Halford, 2009, p.40).

While food consumption practices are a complex process which require interdisciplinary analysis (Grunert, 2016), there are truths which can be extraploated and applied from the aforementioned study. The concepts of familiarity and positive experiences are important sentiments to consider in the presentation of new foods to children or adults alike as these factors will dictate the food's dietary acceptance or rejection. Chapter 4 will consider these factors in the design and program of the building.

2.3 Selecting the Fruits and Vegetables to Grow

An understanding of the type of crops to grow is regionally dependent on the eating and consumption habits of the local population. The best type of crops to grow are the ones that are least intensive in both nutritional requisites and water consumption. However, this might not fully satisfy the demands of the customers. Thus, customer preferences should also be considered. From here, high demand crops which are require the most food miles should be planted.

The most commonly eaten vegetables in America, in order of popularity are potatoes, tomatoes, onions, sweet corn, romaine and leaf lettuce and chili peppers (Khazan, 2014). Many of these vegetables can be grown in greenhouses.

The most commonly eaten fruits is America, in order of popularity are oranges, apples, bananas, grapes, watermelon, strawberries, peaches and nectarines (Khazan, 2014).Of these seven fruits, four of them can be cultivated in greenhouses. Thus, these fruits can be harvested year round. There are many other regional fruit varieties which are conducive to greenhouse growth. Growing these fruits and introducing them slowly in the market, coupled with public education at affordable prices can influence consumers to modify their consumption patterns and eat fruits and vegetables with less food miles. In addition to reducing greenhouse emissions from food miles, local production reduces food wastage and spoilage (Royte, 2016).

2.4 The Economics of Sustainable Urban Agriculture

The concept of urban agriculture shows much promise as evidenced from its exponential growth in the last decade (McIvor & Hale, 2015). The growth demonstrates the willingness of consumers to purchase food which is grown locally(Grebitus, Printezis & Printezis, 2017) and indicates fundamental changes in consumer values and preferences.

Given consumer acceptance and purchasing preference, urban agriculture possesses the characteristics apt for sustainable capitalism- a concept proposed by Al Gore and David Blood. Sustainable capitalism is a framework which proposes to maximise lon-term economic value creation by reforming markets to address requisite needs and to consider all costs while concurrently integrating environmental, social and governanace (ESG) metrics into the business decision process(Sustainable Capitalism, 2012, p.6).

Businesses engendered in this concept expand into new markets as required under a capitalistic economic model; however, these businesses are not destructive. In the context of the business of urban agriculture, this provides a mutually beneficial agreement from both the producers and the consumers. Since urban agriculture operates within the confines of inhabited urban spaces, the proliferation and expansion is less likely to impact the environment in a detrimental way. If the enegy requirements for urban agriculture can be addressed through renewable resources such as solar energy, the expansion of this enterprise could be a positive effect on urban communities (Mincyte & Dobernig, 2016, p.1774).

CHAPTER 03

SITE ANALYSIS

"We have to be looking outside of buildings. We have to be looking at settlements, the combination of infra-structure, the connections, the public spaces, the links and the transport, because the sustainable now and in the future, it's about strong civic leadership, pedestrianisation, people over cars. It's about high density."

____Norman Foster, 2017

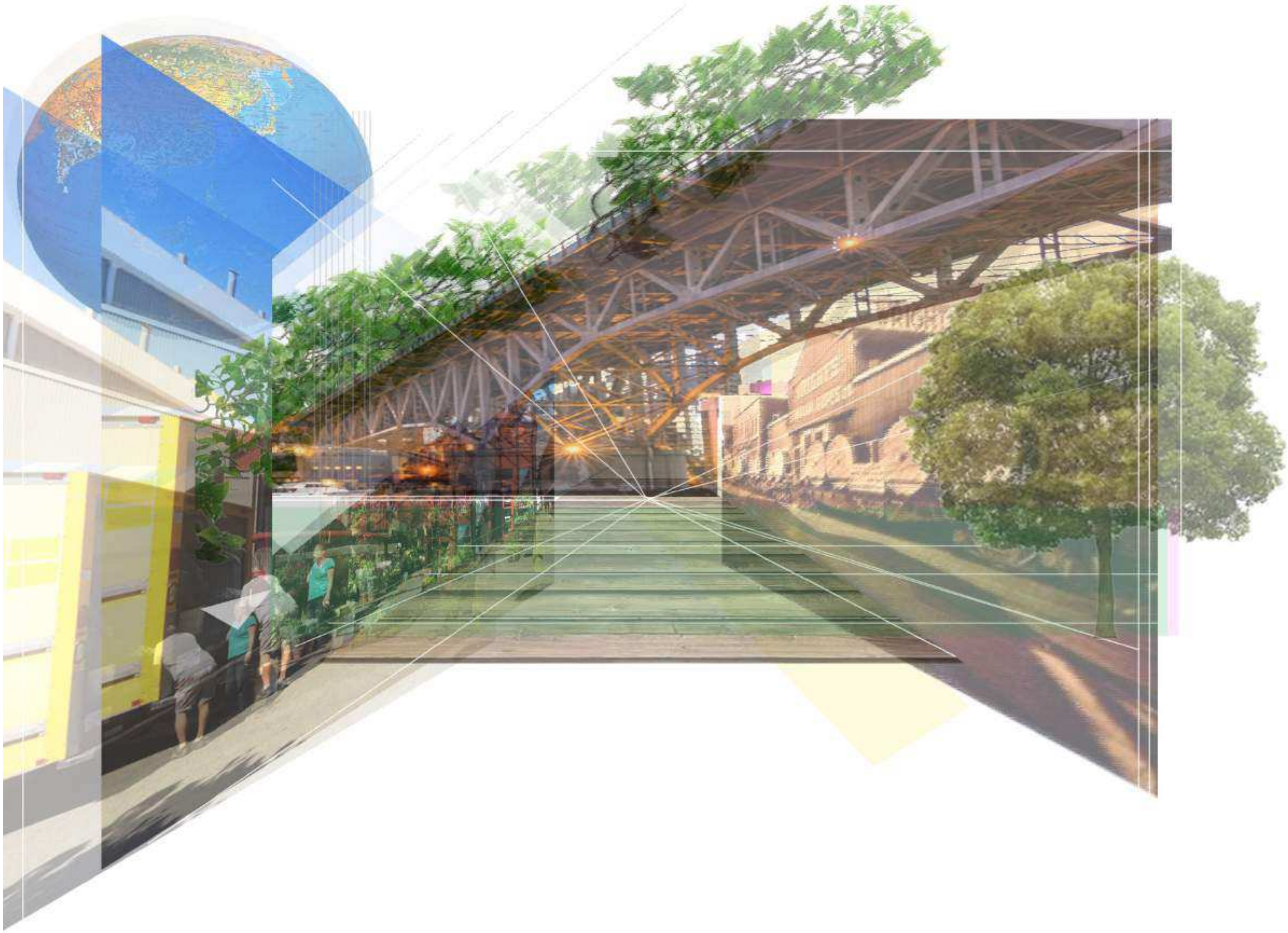


Figure 3.1 : Time-lapse Collage exploring the historical narrative of the site from past to present

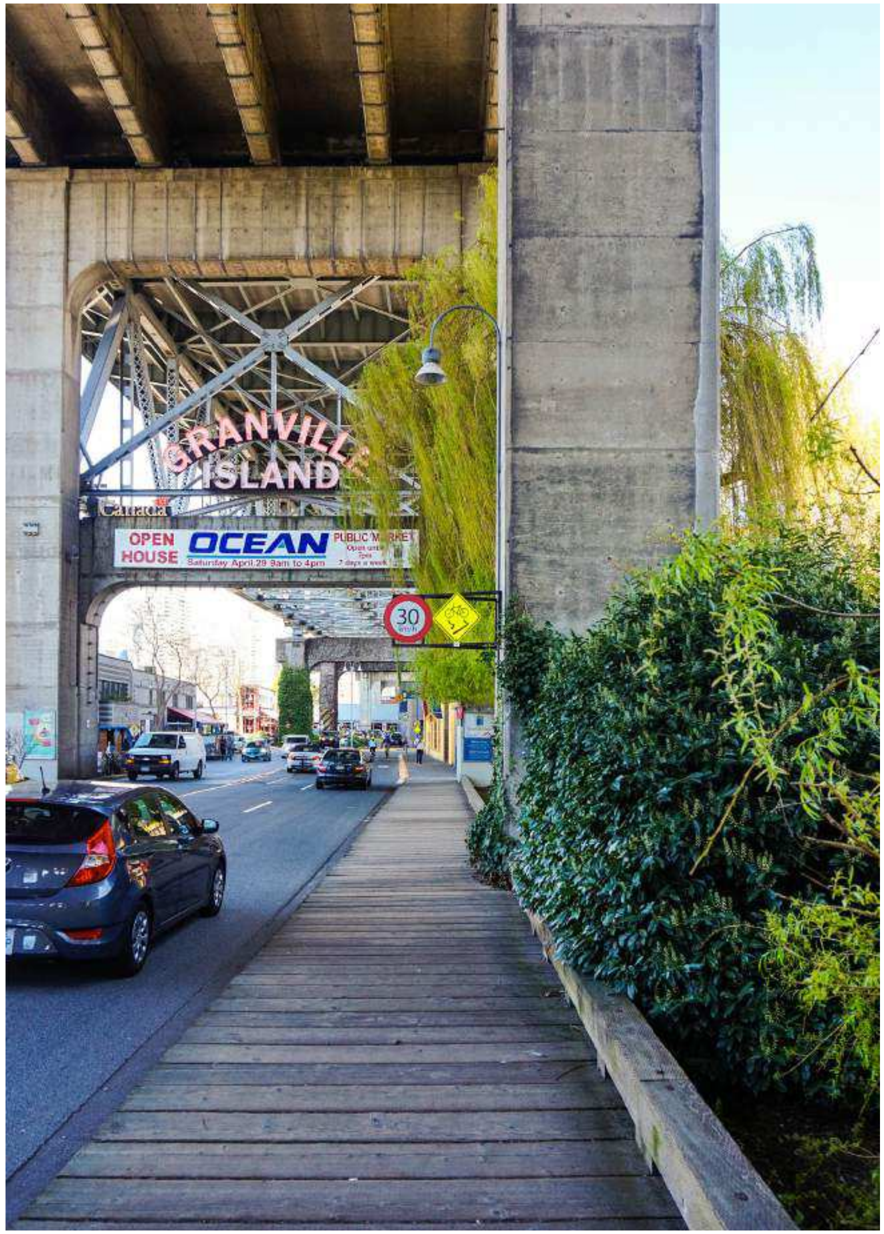


Figure 3.2 : Granville Island Bridge (Entrance to Granville Island)

Figure 3.3: Select Images from Granville Island (Clockwise from Left : Johnston Street Facing Granville Island Bridge, Ocean Concrete Factory, Emily Carr University North Campus)

Chapter 3: Site Analysis

As mentioned, one of the major themes of the thesis is education and the dissemination of knowledge. For that reason, the proposed site for the project must be frequently visited by a multitude of people, preferably from many different locations. Based on this necessary requisite, the site of Granville Island, located in Vancouver, British Columbia was selected.

Figure 3.4 :Early Days of Granville Island

3.1 Brief History

Granville island is a 14 hectare peninsula located across False Creek from Downtown Vancouver, under the south end of of The Granville Island Street Bridge. The history of Granville island is rooted in industry. The island commenced as a First Nations fishing port and later became home to a wood-framed machine shop which would remain today and whose industrial aesthetic- wood and corrugated tin siding- would define the island.

In 1972, the Canadian Mortgage and Housing Comission(CMHC) was tasked to manage the site (Stueck, 2014). In 1979, Dialog Architecture firm engaged in master planning the site and a 50,000 sq foot factory was turned into a public market (Dialog, n.d.) and in1980, Emily Carr University of Art and Design was established on the premises.

3.2 Granville Island Today

At present, Granville island is a tourist destination and the second most visited site in Canada with 12 million annual visitors (Dialog, n.d.). In 2017, Emily Carr University is slated to vacate the island and relocate to The Great Northern Way in East Vancouver (Puri, 2017).As a result, a core element that grounds the site stands to be lost. Such an event threatens the social fabric of the island and thus the core of the island's gestalt could be undermined. This departure demonstrates the feasibility of locating the research institute at this location.

3.3 Proposed site

The selected site is located on the South East quadrant of Granville Island. At present the site is used as a parking space. The site measures 75 m in length and 65 m in width. Adjacent to the site is the North campus of Emily Carr University. To the front of the site is a small private art gallery and the back of the site faces out into False Creek, a short inlet which separates Vancouver from the rest of the city.

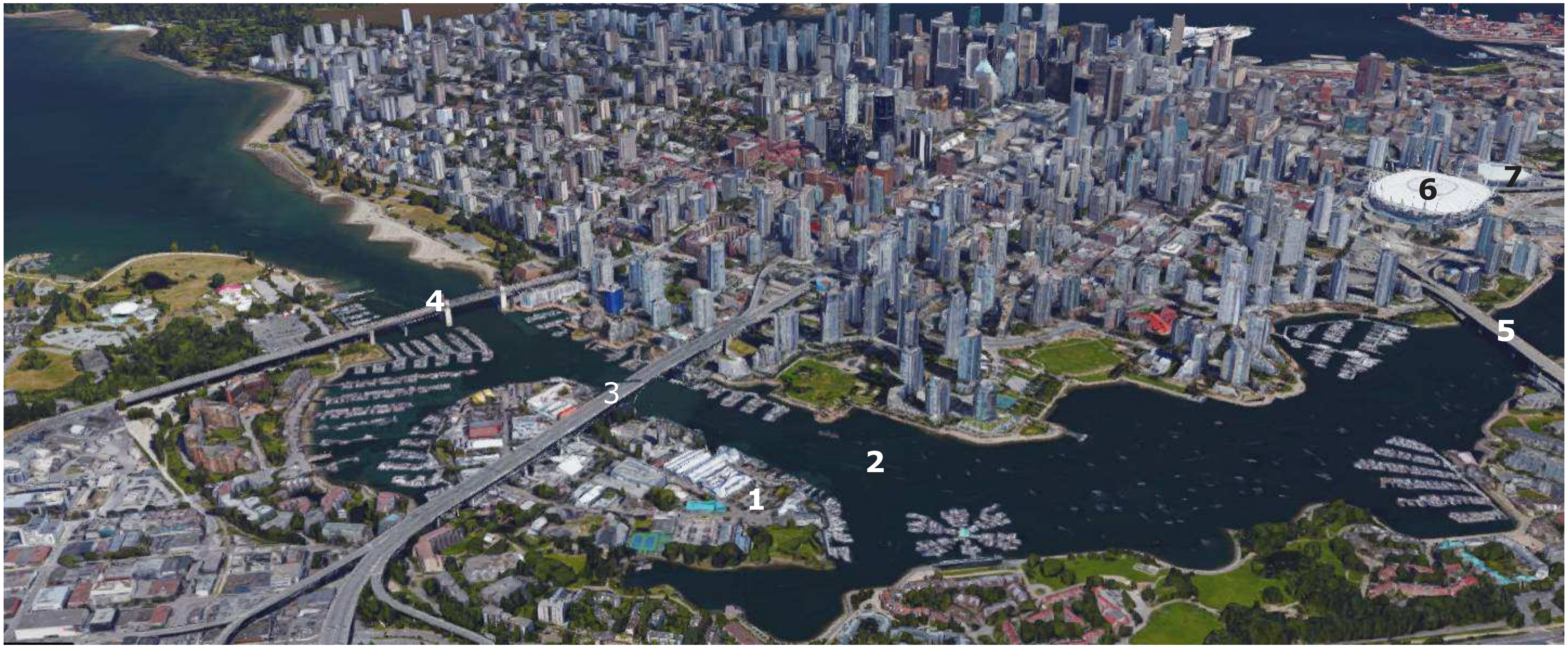


Figure 3.5: Macro-Context of Granville Island in Relation to the Greater Vancouver Area

1. Proposed Site
2. False Creek
3. Granville Street Bridge
4. Burrard Street Bridge
5. Cambie Street Bridge
6. BC Place Stadium
7. Rogers Arena

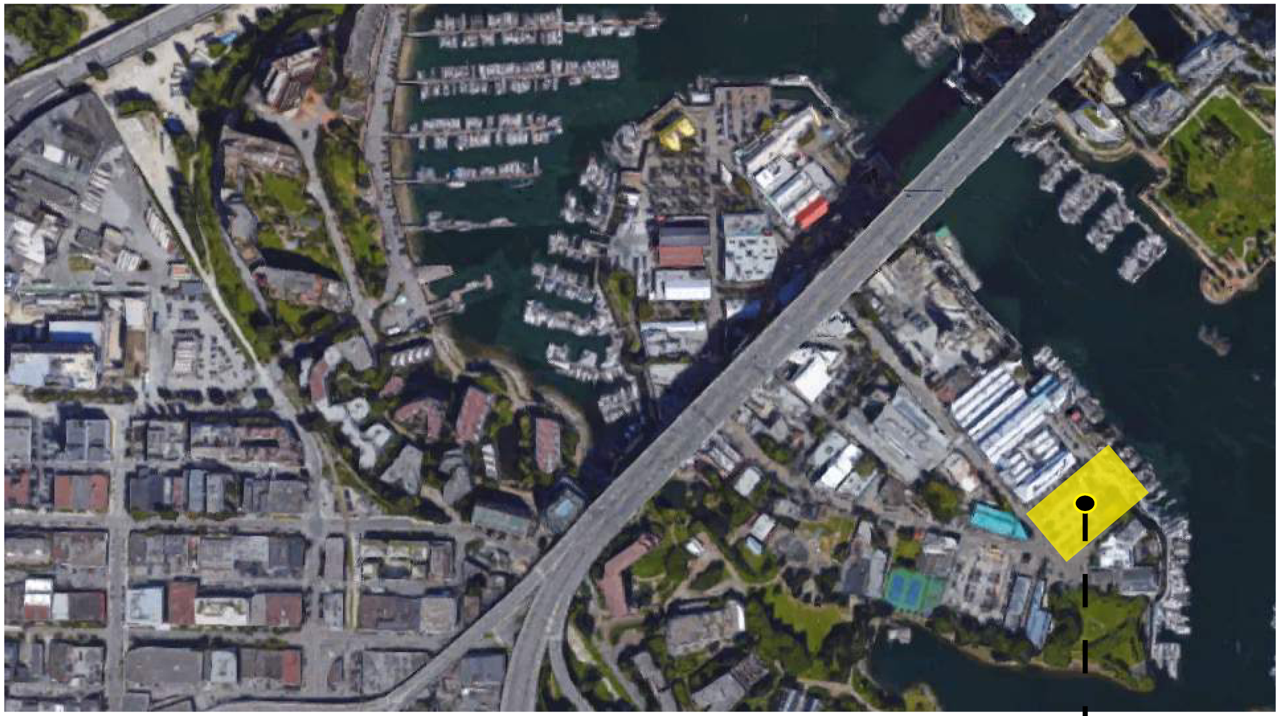


Figure 3.6 : Proposed Building Location
(Aerial Plan View)

Figure 3.7 : Bird’s Eye Perspective View of Proposed Site

Figure 3.8 : Building Location (View From Johnston Street)

3.4 Site Description

The following section provides a description of the elements which define the island.

3.4.1 Green Spaces (Figure 3.10)

Granville island has its roots primarily in industry; however the southern side of the island possess green spaces in the form of the Ron Basford and Sutcliffe Parks. However, one shortcoming of the green spaces is its segregation from the rest of the island. Thus, when traversing the island, the urban environment takes a more central role and the lack of green spaces can be felt.

3.4.2 Major Roads + Vehicular Access (Figure 3.11)

Granville island is accessed through vehicles by Nelson street. Nelson street merges into Johnston street which is the only major road which leads into Granville Island. Johnston street is a single, one way road which loops around the island. However, there are other smaller side roads which lead to parking spaces.

3.4.3 Pedestrian Routes + Bike Paths (Figure 3.12)

The small size of Granville island, coupled with the great influx of people into the area can allow for traffic congestion at certain peak times. However the island embodies the human scale through the urban context. This is achieved through generous pedestrian routes and bike paths which traverse the site, allowing for ease and convenience of mobility.

3.4.4 Food Establishments + Markets (Figure 3.13)

Granville island is a tourist destination and thus is home to many food establishments. As well, there is a large public market -Granville Island market-located on the site. Granville island market sells an assortment of local produce. In addition, there is a food court located in the market.

3.4.5 Academic Institutions (Figure 3.14)

Emily Carr University of Art and Design is the main academic institution on the island. There are two buildings – North building and South building - which form the campus of the university. As well, the institution hosts a multitude of stand-alone continuing education classes to promote and foster art education to the general public.

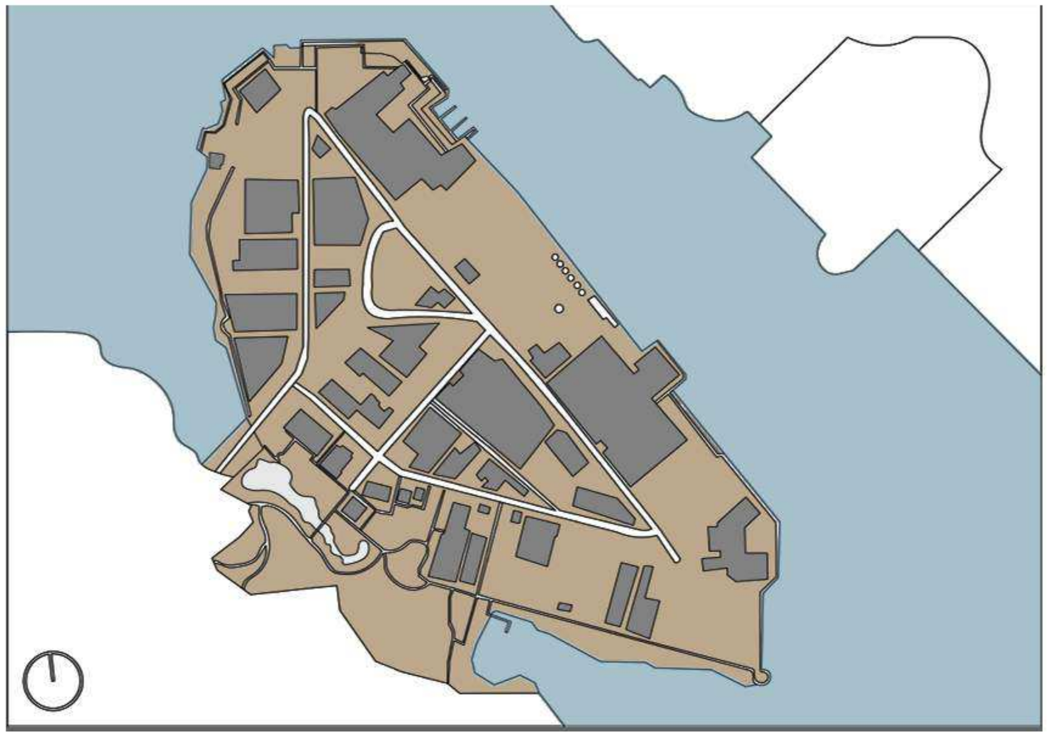


Figure 3.9 : Figure- Ground Relationship

Figure 3.10 : Proximal Green Spaces

Figure 3.11 : Major Roads

Figure 3.12 : Pedestrian Routes + Bike Paths

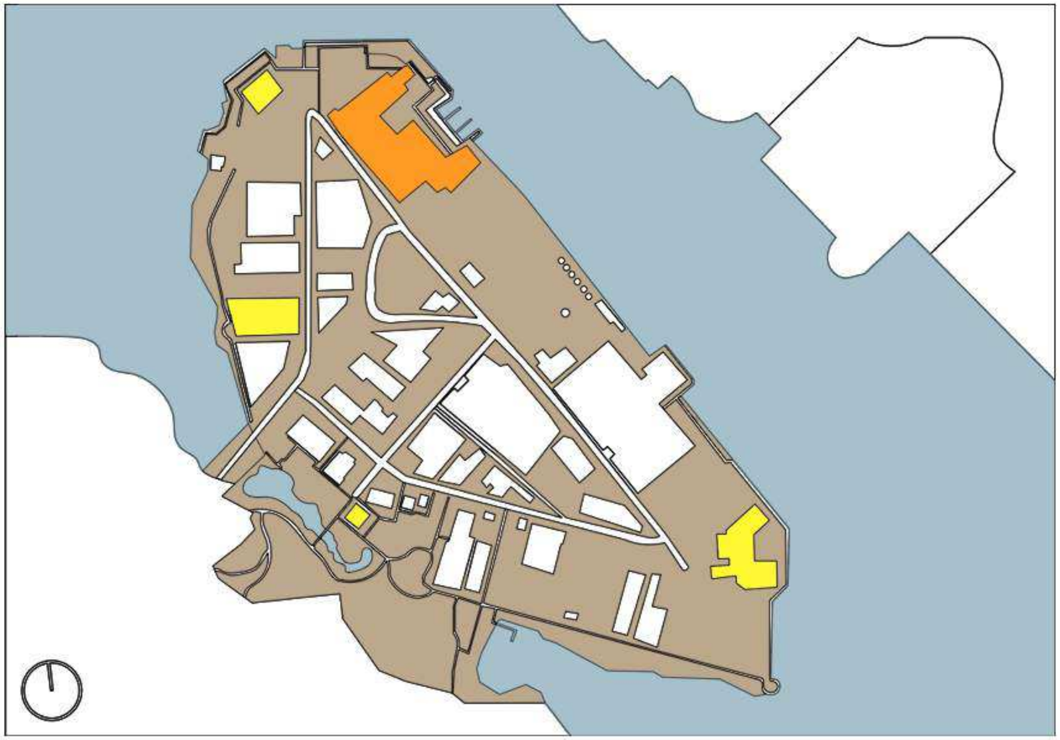


Figure 3.13 : Food Establishments+ Markets

Yellow : Food Establishments
Orange: Market

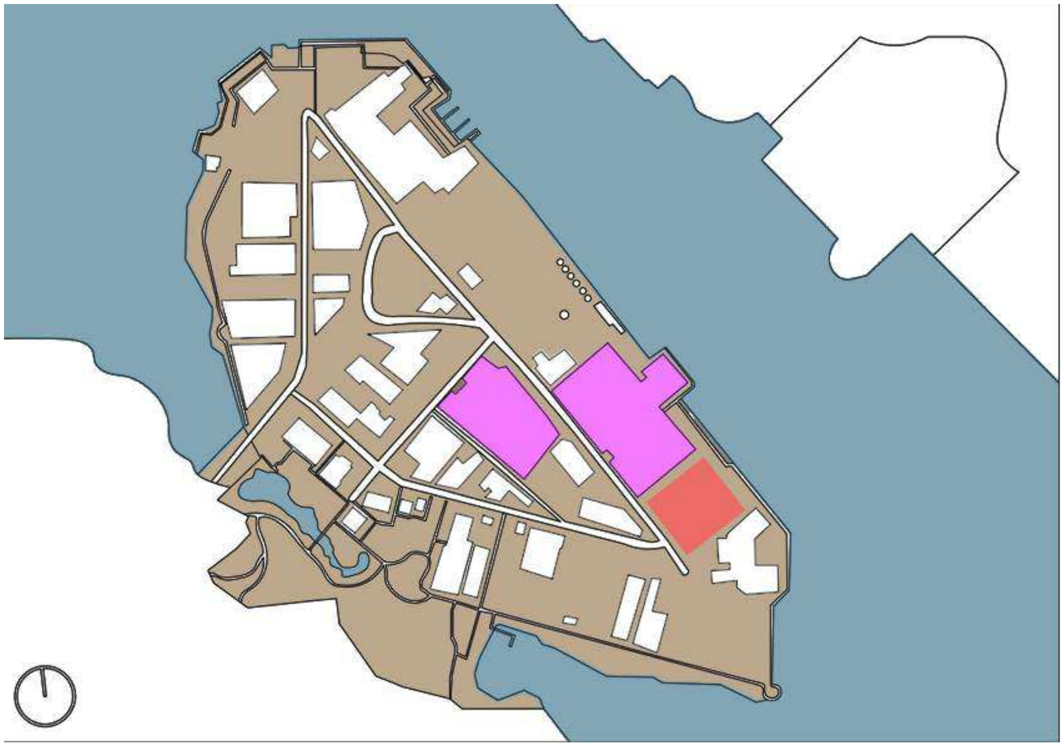


Figure 3.14 : Academic Institutions

Purple : Emily Carr University
Red : Propsed Site for Institute

3.5 Fabric of the Island : The Urban Magnet Theory

The transformation of Granville island by Dialog Architecture from an industrial site to a multi-used site which was human friendly was not achieved by accident (Dialog, n.d.) Guiding the design was the concept of the urban magnet theory (Dialog, n.d.). Urban magnets are unique urban spaces that attract and hold activity group together. The groups that form have a predisposition to "live out loudly", thus sharing their activities and providing vitality and a sense of place to a site (Urban Magnets, n.d.).

The concept of the urban magnet theory is premised on the idea that civic vitalization and re-vitalization is maintained though the inclusion of one or a few subcultures which invite pedestrians to gather, participate and engage in the emerging vitality. Put another way, urban magnet theory strives to create spaces which are favorable and conducive for spontaneous civic engagement (Urban Magnets, n.d.).

3.5.1 Elements of Urban Magnet Theory

Urban magnet theory is composed of six elements : The activity- based subculture, specialty retail, Production and manufacture, Educational/ Institutional/ Office , Programmed Events and urban form and design (Urban Magnets, n.d.).

1. Activity- Based Subculture : The foundation of the urban magnet theory involves the activity and the groups of people who are engaged in it. The activity is paramount to creating the vitality and forms the cornerstone of the successful civic space (Urban Magnets, n.d.).

2. Specialty Retail : Specialty retail refers to the catering of good or services relevant to the activity based subculture (Urban Magnets, n.d.). Thus for example, if the activities of the subculture pertain to sports, it would be sensible to procure sports related goods. In addition to the speciality retail, it is imperative to include additional retail such as cafes to facilitate the daily needs of individuals who utilize the site. This ensures that the space remains inclusive and welcoming, thus encouraging diversity and enhancing the urban fabric.

3. Production/ Manufacture : Production spaces and activities include fabricating or repairing items which are sold or associated with the key activity of the urban magnet.Production is fundamental in creating a site which is authentic in experience. The space for making is a elemental factor in the urban magnet theory and it distinguishes the magnet from a shopping center which is lacks on-site production (Urban Magnets, n.d.).

4. Educational / Institutional/ Office : Educational and/or institutional program are necessary to encourage employment and businesses which are related to the activity. These programs invite students and educators into the space and create an atmosphere which is a wellspring of learning and the exchange of new and innovative ideas. These participants root the site and bring authenticity to the space (Urban Magnets, n.d.).

5. Programmed Events : Programmed events should be provided by the urban magnet frequently to encourage members to converge at the site on a regular basis and serve to knit the community to the activity- first as passive viewers and later into active participants (Urban Magnets, n.d.).

6. Urban Form and Design : The urban form of the site should be designed to respond with the identity of the activities embodied by the subculture group. This is achieved when the building is visibly and actively built around the supporting activity with a rich public realm. In addition, the inherent aesthetics of the activity should be made visible through its formal language. Central to this is the hope that that the magnet presents itself in a unique way to facilitate in the people who engage with site, a memorable and unique experience. Finally, matters such as transparency and human scale should not be left out (Urban Magnets, n.d.).

CHAPTER 04

DESIGN PROPOSAL

" There is no ecological architecture, no intelligent architecture and no sustainable architecture- there is only good architecture. There are always problems we must not neglect. For example, energy, resources, costs, social aspects- one must always pay attention to all these."

___Eduardo Souto De Moura, n.d.

Figure 4.1 : Collage re-imagining the space as a site for urban agriculture and food production. It is a vision of integrating agrarianism into the urban social fabric.

Chapter 4 : Design Proposal

4.1 Design Objectives

The aim of the Institute for Sustainable Agriculture is to bring awareness to the current methods of industrial food production, question current food consumption patterns and to serve as a space for learning and implementing new methods of food production. To achieve this, the thesis utilized the strategies from the Inter-governmental Panel on Climate Change (IPCC) and the urban magnet theory embedded in the fabric of the site's context. From these design inputs, three major themes emerged: inspiration, education and praxis.

These major themes represent the ideals which the building's design and programs intend to fulfill. The articulation of these themes into human- centric behavior are as follows. Inspiration can be achieved from seeing and experiencing the building. It is the intent to create a building which is open and inviting to the people who visit the site. Education can be encouraged through learning mechanisms such as classes and public educational programs and facilities. Praxis can be promoted by research facilities and modern methods of food production. Taken as a whole, it is hoped that the pedagogical initiatives can facilitate the discourse required to challenge and change people's expectations and preconceptions/understanding of food production and consumption and perhaps initiate more innovate methods of agriculture (Kerton & Sinclair, 2009).

Finally, while the goal of the building is to reduce greenhouse gas emissions caused by industrial agriculture, it must not be forgotten that buildings are responsible for more than 40% of global energy usage and as much as 33% of global greenhouse gas emissions (Peng, 2016). Thus, for the reflexive logic of the thesis' argument to hold, the building's construction should adhere to sustainable ecologically sound design principles.

4.2 Programming

Based on the requirements of inspiration, education and praxis, the following programs were conceived for the building (Figure 4.2). Some programs are complimentary and multi-faceted in achieving the aims outlined in the design's intent.

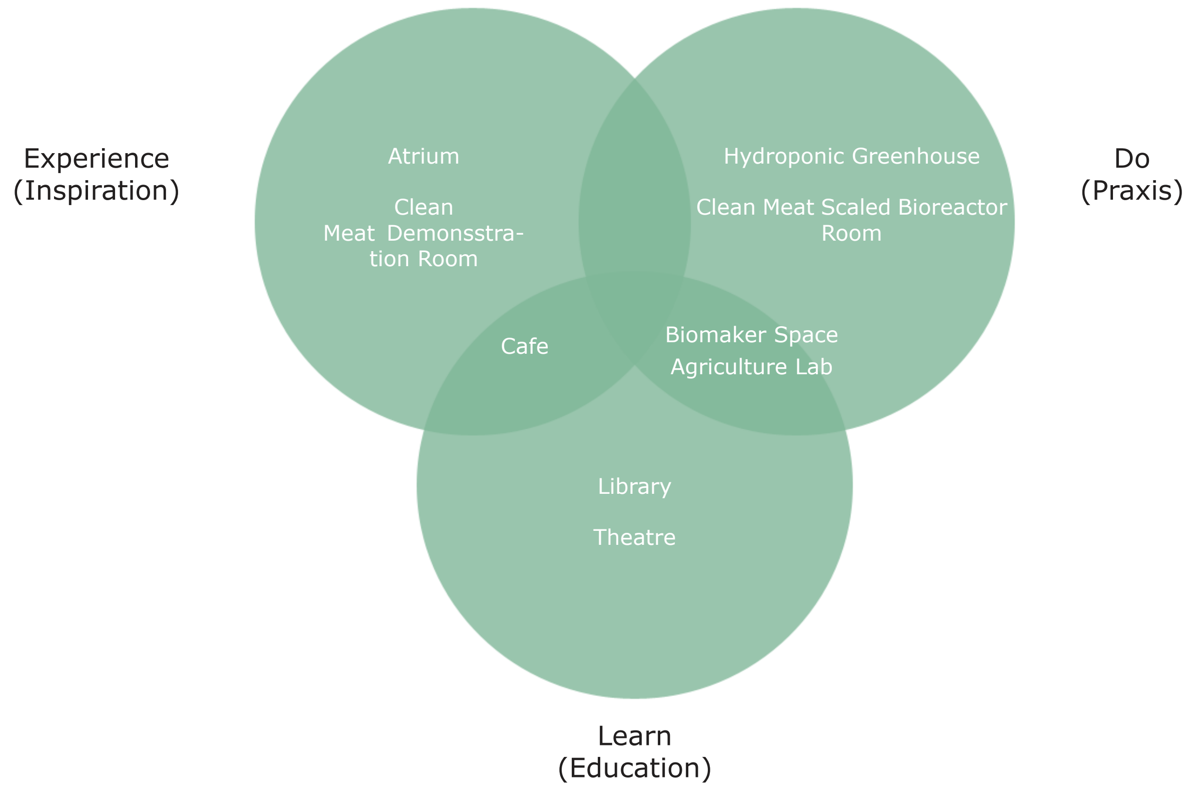


Figure 4.2 : Venn Diagram Relationship between Program and Design Objectives

4.3 Design Formalism: Evoking the Industrial Iceberg

A physical manifestation of greenhouse gas emissions is the melting of the icecaps and the formation of icebergs (Chung, 2014). Thus from a symbolic and iconographic perspective, there is a unifying theme between the iceberg and greenhouse emissions, which when coupled with agriculture can create a paired association which assists in invoking awareness. In addition, the iceberg's lexical semantic includes embedded connotations of warning as evinced by the phrase " the tip of the iceberg" which assumes a small, noticeable part of a larger problem. Since the effects of greenhouse gas emissions and global warming are but minor warning signs of a larger global situation, this metaphor gains added strength.

The architecture of the building's exterior formal language was evoked and inspired by the geometry of icebergs. In addition, the urban condition of the buildings are industrial in their design, owing to their manufacturing heritage.Consequently, the proposed building should utilize an industrial aesthetic to blend in with the surrounding buildings. Thus, the building takes on the form of an "industrial iceberg".

However, if the building is similar to the context, it would be difficult for the building to succeed in attracting visitors. After all, the building would simply blend in and be pedestrian in nature. To mitigate against this concern, the building is designed to be slightly taller than the surrounding buildings. This servers several pragmatic functions. Since the commercial forest greenhouse is located on the top floor, a taller building provides greater clearance from obstacles and increases sunlight into the building. As well, taller greenhouses have greater air masses enclosed within thereby facilitating the ease of control of the air mass (Components of the Greenhouse System, n.d.).From an aesthetic consideration, taller buildings can command greater attention. The building next to the Institute of Sustainable Agriculture is the North building of Emily Carr University which is around 14 m in height. The highest point of the Institute for Sustainable Agriculture is 21 m, making it 7m taller and thereby more noticeable and capable of piquing attention.

Agriculture → Greenhouse Gas Emissions

Greenhouse Gas Emissions → Icebergs

Agriculture → Icebergs

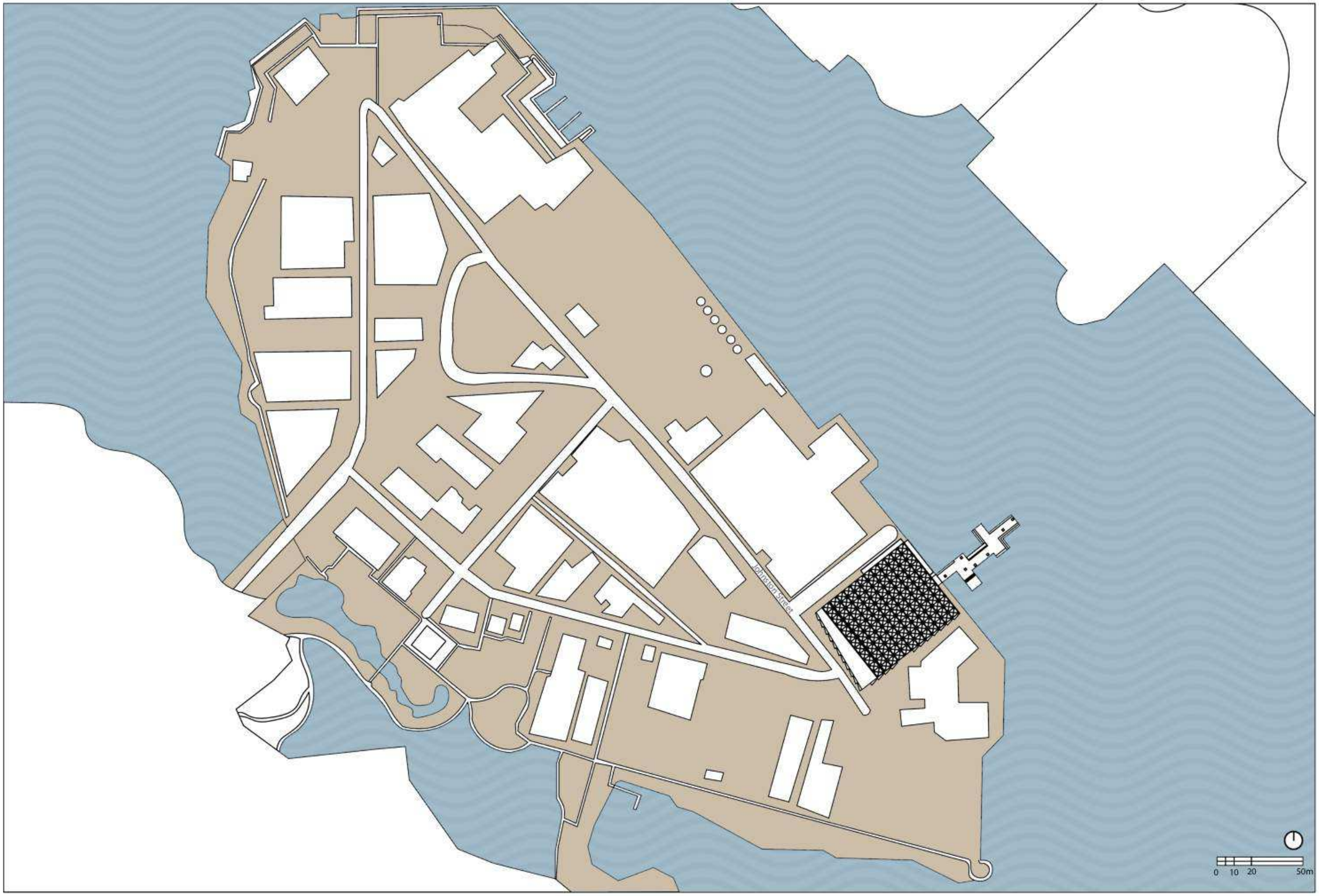


Figure 4.3 : Site Plan

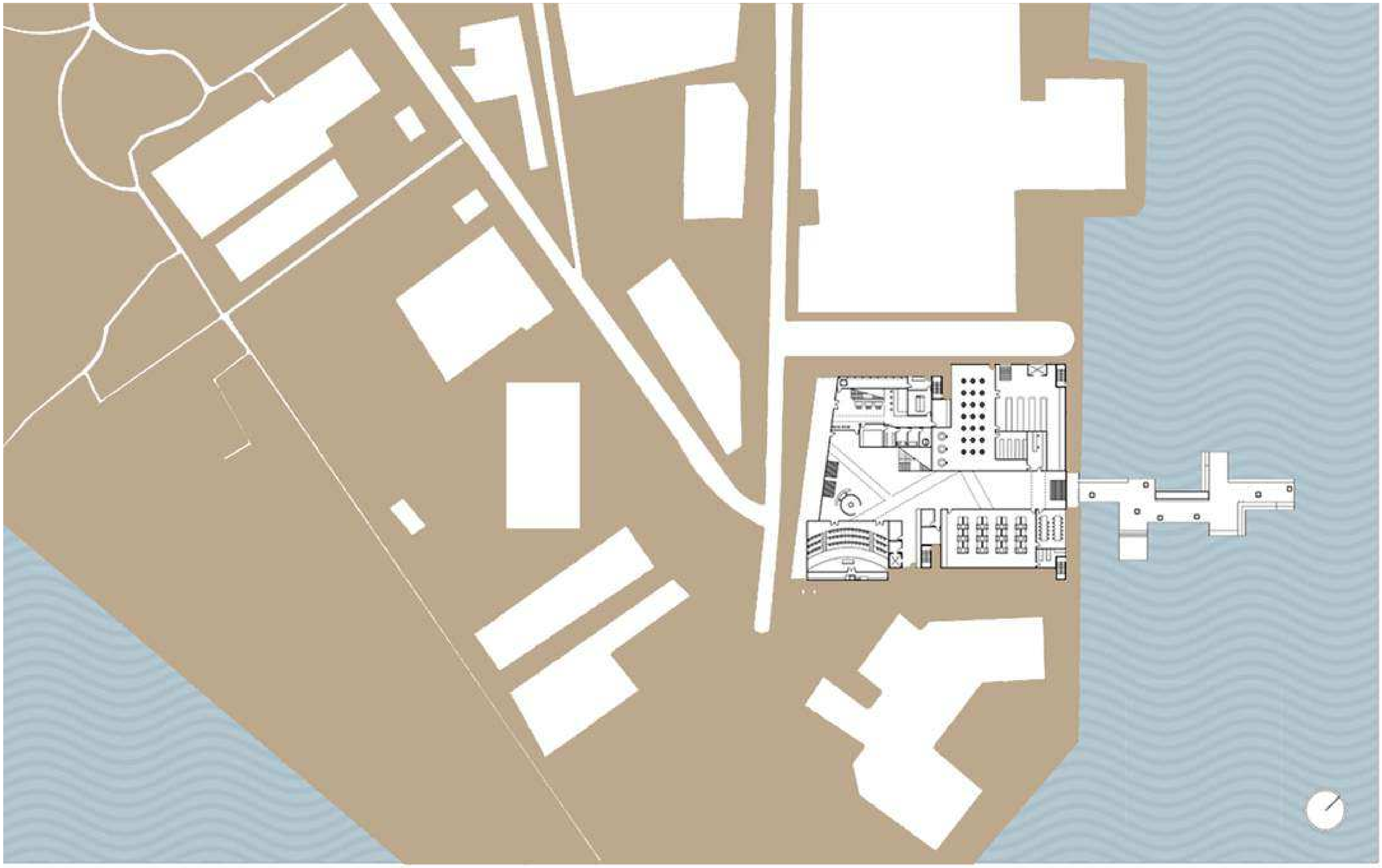
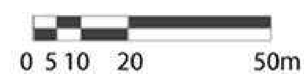
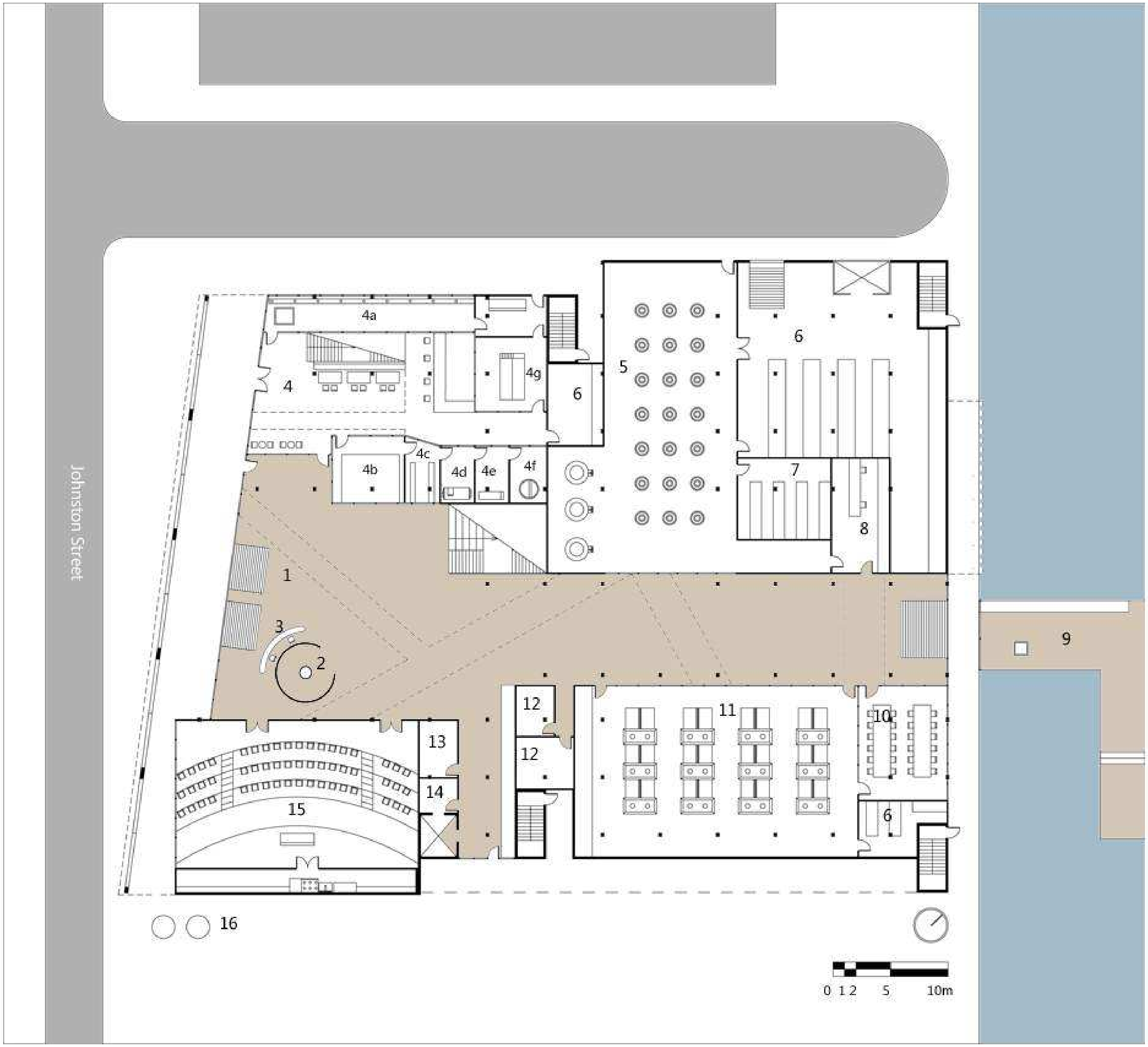


Figure 4.4 : Ground Floor Plan with Site Context





1. Atrium
2. Clean Meat Demonstration Room
3. Reception
4. Hydroponic Tea Cafe
   a Growth + Harvesting
   b Heated Withering
   c Withering
   d Disruption
   e Fixation
   f Pelleting
   g Firing
5. Clean Meat Scaled Bioreactors
6. Storage room
7 Freezer
8. Office
9.Deck
10. Communal Dining Area
11. Learning Kitchen
12. Washrooms
13. Maintenance Room
14. Bridge Hydroponic Maintenance room
15. Theatre
16. Harvested Rainwater Tanks

Figure 4.5 : Ground Floor Plan

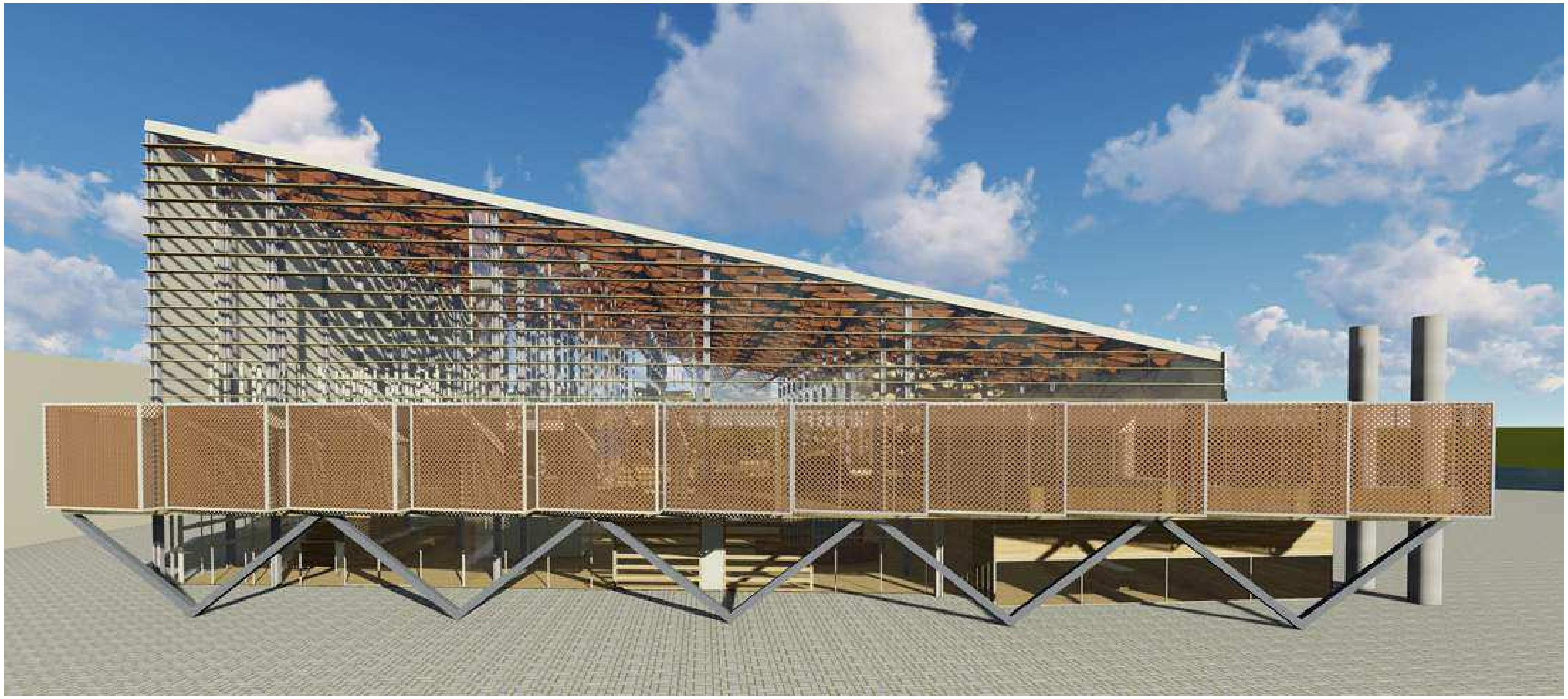


Figure 4.6 : Exterior View from Johnston Street (Main Entrance View)

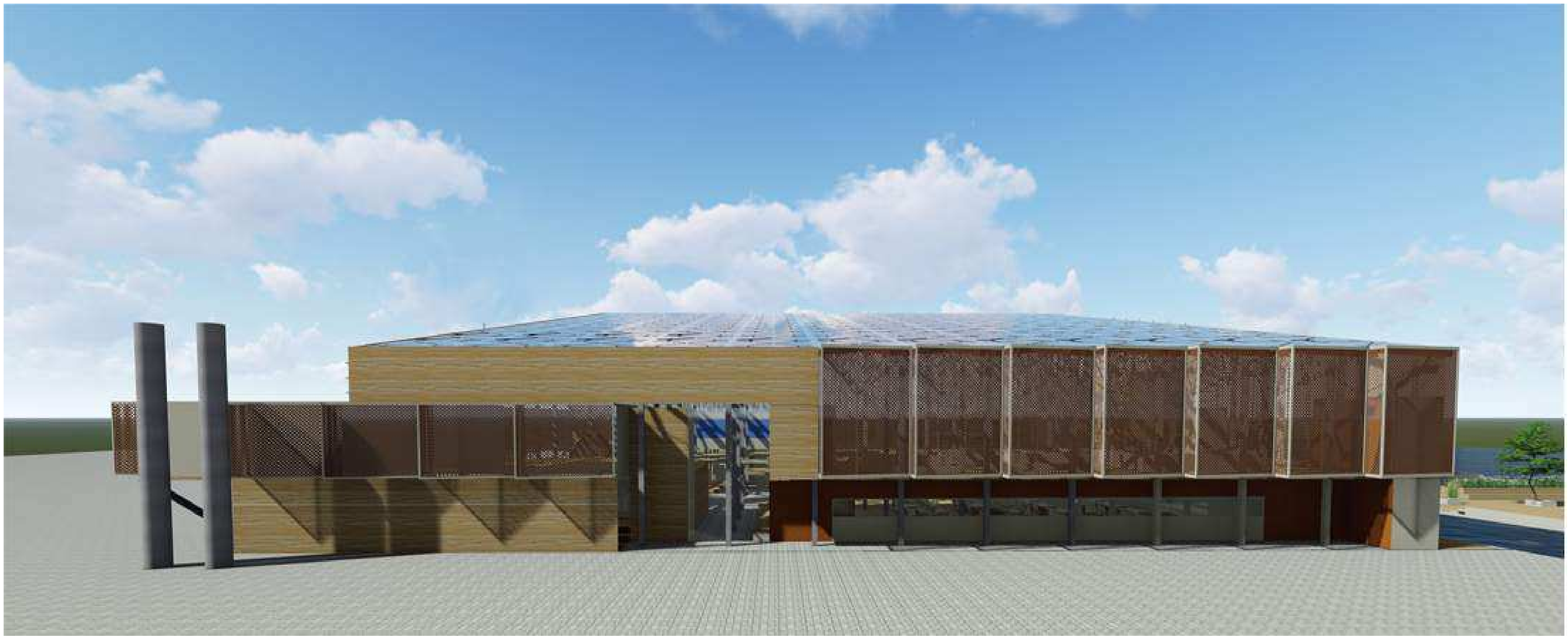


Figure 4.7 : Exterior View (South Facing)

Figure 4.8 : Main Entrance Perspective

Figure 4.9 : South Side Entrance Perspective

4.4 Organizing Principle : The Central Atrium

The organizing principle of the building is derived from the concept of the urban magnet theory mentioned in Chapter 3. According to rule 6, programmed public spaces should be made available to pedestrians to encourage their convergence and participation (Urban Magnets, n.d.). To allow for this, the building possesses a programmtically flexible central atrium which serves as the spine of the building.

The central atrium is 64 m in length and runs through the building. It is 23m wide at the Johnston Street entrance and tapers to 9.5m on the opposite end of the building. There are two garage styled doors, each 4 m in width on the Johnston street entrance and one 4m wide door on the opposite end of the building. These doors can be opened in the summer and during clement weather allowing for easy public access. In addition, public events can be hosted in the space. In so doing, the atrium becomes a public agora in a private building.

4.5 Outdoor Garden Deck

In Chapter 1.3.2, there was mention of the four human personalities- individualist, hierarchist, egalitarian and fatalist -and their corresponding perception of greenhouse gas emissions. Their personalites dictated the extent of their concerns. It is likely that the indivualist personalities might be most inclined to visit the building. However, the success in this building stems in educating those who might have a more care-free or indifferent attitude towards the issue. To encourage these individuals to traverse the building, a garden deck- most easily accessed through the building's atrium and extending out onto the water- has been added.The deck features a variety of edible berries and native vegatation to inspire the visitors

Accessing the deck encourages frequent foot traffic and allows for the intermingling of the workers of the institute with the general public. In addition, vistors are able to peer into the rooms of building an observe the activities. Since repeated exposure has been cited as a key characteristic in creating affinity (Janiszewski & Meyvis, 2001), these frequent traversings could change the minds of those who are indifferent to agriculture driven climate change.

Figure 4.10 : Central Atrium Perspective

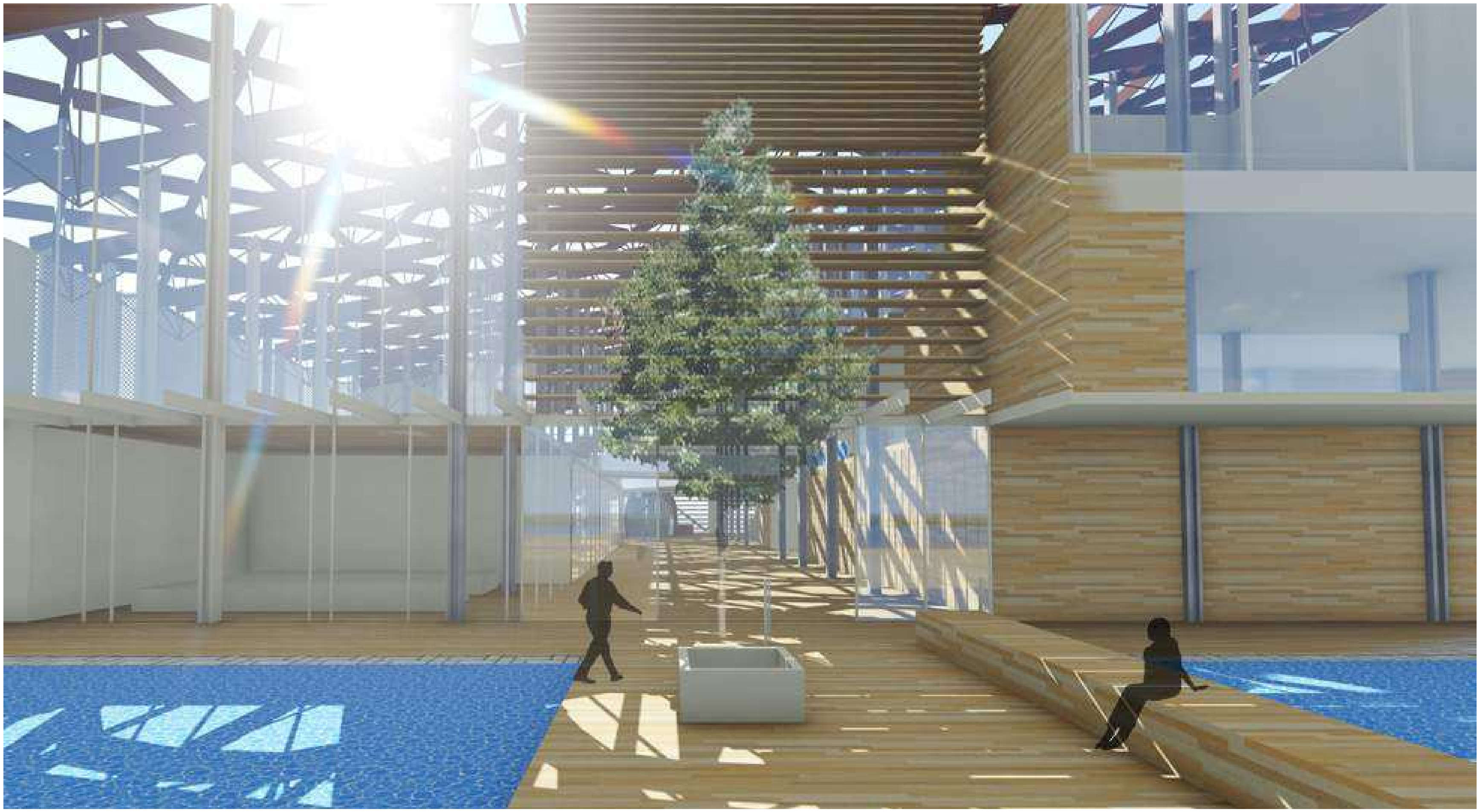


Figure 4.11 : View from Garden Deck looking into Atrium
(Note the continuous path connecting each end of the building)

Figure 4.12 : Garden Deck Perspective

4.6 Key Programs of the Ground Floor

The following section details the key programmatic features located on the ground floor.

4.6.1 Clean Meat Production

As mentioned, industrial meat production is a serious threat to the environment (Kemmerer, 2014, p. 18). Compounding this issue is the fact that meat consumption is scheduled to increase as global standards of living increase (Elferink & Schierhorn, 2016). The advent of clean meat has presented a novel solution to allow for the resolution of these issues (Friedrich, 2015).

There are two aims of clean meat production in this institute: pedagogy and scaled production. Pedagogy comes in two forms: observation and praxis. On the main floorof the building, next to the entrance, is a conical room with translucent glass walls. This is the clean meat demonstration room. In the middle of the room is a tranparent glass bioreactor growing meat. Visitors have the option of entering this space and observe the processes of clean meat production. While some people might be initially apprehensive and recalcitrant towards novel methods, repeated exposure, coupled with education on current meat production methods, can evoke gradual acceptance (Janiszewski & Meyvis, 2001). The issue of praxis is addressed in the section on biomaker spaces (See Chapter 4.6.1: Biomaker Spaces and Collaborative Classrooms).

Scaled production is another pivotal issues in need of address. Currently, clean meat is expensive to produce. The resolution of the cost factor,however lies in the economies of scale. As items become are produced in greater quantities, their unit cost decreases, making them more affordable to the population. The inclusion of 21 clean meat bioreactors allow for the issues pertaining to scaling to be tested.

Central to the production of clean meat is the bioreactor, the device which is instrumental in the production of clean meat.

4.6.1.1 The Bioreactor

The bioreactor is the place where clean meat is grown. An ideal bioreactor should facilitate an environment which provides cells with orderly and rapid tissue development.Since clean meat aims to grow cells-primarily muscle cells which are the primary constituent of meat- ex-vivo, a well-designed bioreactor is essential.

The main functions of the bioreactor are to control the environmental conditions- pH, temperature, pressure- and the concentrations of nutrients and products during the bioprocess (Wendt et al. 2008, p.484). In the role of meat production, the key features of a bioreactor is to provide control and standardization (Wendt et al. 2008, p.484). This is achieved by establishing control over the physiochemical culture parameters during the culture and standardizing and possibly scaling the the synthesis of engineering tissue (Wendt et al. 2008, p.484).

The process of meat growth on a bioreactor are as follows. First, the cells are seeded on a scaffold which acts as the platform for cellular growth(Wendt et al, 2008, p.484). Since the initial cell distribution on the matrix can influence the quality of cell density and ultimately the quality of meat, the method of seeding is of great import (Wendt el al. 2008, p. 485). The bioreactor designed will use perfusion, an efficient method for seeding (Wendt et al, 2008, p.486).

After this proces, the cells proliferate. During this time, the cells consume nutrients(or glucose) required for growth. Following this, the cells depose on the matrix, differentiate, migrate and finally expresses themselves(Wendt et al. 2008, p. 485). It is at the point of protein expression that the meat is obtained.

The design of the bioreactor can assist in facilitating the expression of protein, or meat.This is achieved by attempting to replicate the biomechanical environment of the body's tissues and organs: dynamic stresses and strains,fluid flow and hydrostatic pressure (Wendt et al., 2008, p.489).The requisite conditions to enhance cellular synthesis are dynamic compression, simulated articular motion, torsion and tension (Wendt et al., 2008, p.489).

The bioreactor is designed as follows: (See Figures 4.17, 4.18)

1. The bioreactor's growth trays are enclosed in a double glazed glass shell to maintain thermoregularion. Heating and cooling fans are located to assist with homeostasis.

2. The growth platform on which the extracellular matrix is located is designed to facilitate perfusion.

3. The bioreactor rotates at varying speeds and compression lids can be added over the matrices to stimulate the dynamic environments required for cellular growth.

As well, bioreactors require several support functions to operate.These include food tanks where glucose required for meat growth is stored and waste tanks to discard the waste generated during cellular respiration, a precondition for growth. In addition, a monitoring facility is functional in observing the meat to ensure that it is grown in a scheduled and efficient manner.

4.6.2 Multi-Functional Theatre

The theatre is a multi-functional space which measures 15m in length by 21 m in depth and possess a seating capacity for 54 individuals. The theatre overlooks Johnston street. The facade of the theatre overlooking Johnston Street is clad in glass with retractable screens. This allows people who are located on the outside to peer in and offers the opportunity to increase the curiosity of people who pass by the building.

Since the research institute includes a community culinary institute, the theatre can be used as a demonstration kitchen where students can observe an instructor teaching culinary methods. The required kitchen preparation facilities – faucet, sink, preparation table and portable stove are located in a storage space behind the podium.

4.6.3 Learning Kitchen and the Community Culinary Institute

While the building is about food production, it is important to note that that food consumption patterns play a pivotal role in shaping people's eating habits, which in turn affects their consumption and eating patterns. To translate the praxis of emerging food into preferred gastronomical traditions, the repeated act of food preparation can be of great import (Aldrige, Dorey, Halford,2009, p.33).Thus, a community culinary institute is incorporated into the Institute for Sustainable Agriculture.

The community culinary institute features a learning kitchen which is 20m in length and 15 m in width. The kitchen has 24 individual cooking stations for students. Each station possesses its own counter top stove and storage space.

The learning kitchen is designed with large glass windows -as are most programs in the building- to facilitate public observation. This is built off urban magnet's elements of production and programmed elements (See Chapter 3.5.1 : Elements 4 and 5) which state that the encouragement of public viewership of the activities can lead to spectator participation. In this setting, the observation of the praxis of food preparation is intended to inculcate interest and facilitate greater consumer knowledge in food production methodologies.

4.6.4 Hydroponic Bridges

Suspended above the atrium are bridges which connect the various parts of the building. The underside of the bridges is are with an aeroponic system which allow for the growth of local fruit such as berries (See Figure 4.21). The plants grow in an inverted manner and their arrangement along the atrium creates a meadering effect through the space and evokes the character of an orchard, thereby enhancing the quality of the spatial experience and thereby potentially lengthening the duration of the visitor's stay.

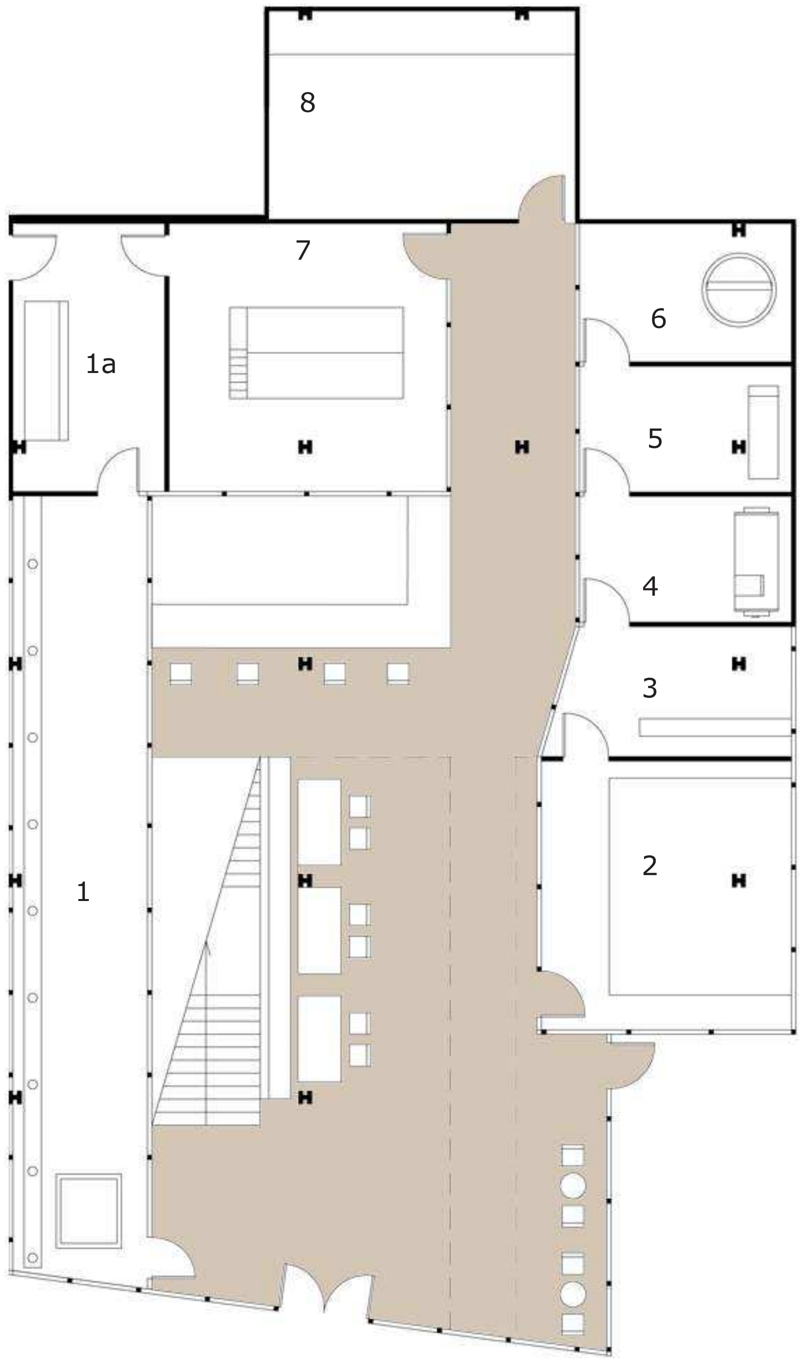


Figure 4.13 : Hydroponic Tea Production Cafe

4.6.5 Hydroponic Tea Cafe: On-site Tea Production

The hydroponic tea cafe allows for the comprehenisve production and manufacture of tea. Visitors can enter and observe the entire process of tea production and purchase tea which is made entirely on-site. The following lists the spaces and processes for the production and manufacture of tea.

1. Growth and Harvesting: Tea leaves are grown in a stacked horizontal hydroponic system. Workers pick out the flush- a growing of two young leaves and a bud which grow at the top of the plant. During season, the flush is produced every seven to fifteen days (See Figure 4.20 Hydroponic Tea Wall Detail).

2. Heated Withering: The leaves are spread on the floor and left to oxidize. Radiant panels are placed on the ceilings to facilitate the process. This commences the oxidation and fermentation of the leaves.

3. Withering: The leaves are placed in trays and left to wither for a further 6-8 hours. They are stirred every 20 minutes.

4. Disruption: The leaves are placed into a rotating drum. This breaks down the cell structure of the leaf and greatly accelerates fermentation.

5. Fixation: When sufficient oxidation is achieved, the leaves are placed in a gas heated dryer and left for 10-15 minutes. This is the most important stage as the tea's taste, colour and aroma is achieved here.

6 Pelleting: Leaves are shaken on a sieve to filter dust particles. Leaves are then gathered in a cotton cloth and placed in a kneading machine, followed by a rolling press. This process transforms the leaves into pellets

7. Firing: Leaves are placed in an oven and dried in 3 cycles of 20 minutes each.

8. Storage : The tea leaves are placed in storage where they are packed and ready for purchase.

(* 1a - Hydroponic Tea Wall Equipment Room)

Figure 4.14 : Clean Meat Demonstration Room

Figure 4.15: View into Learning Kitchen

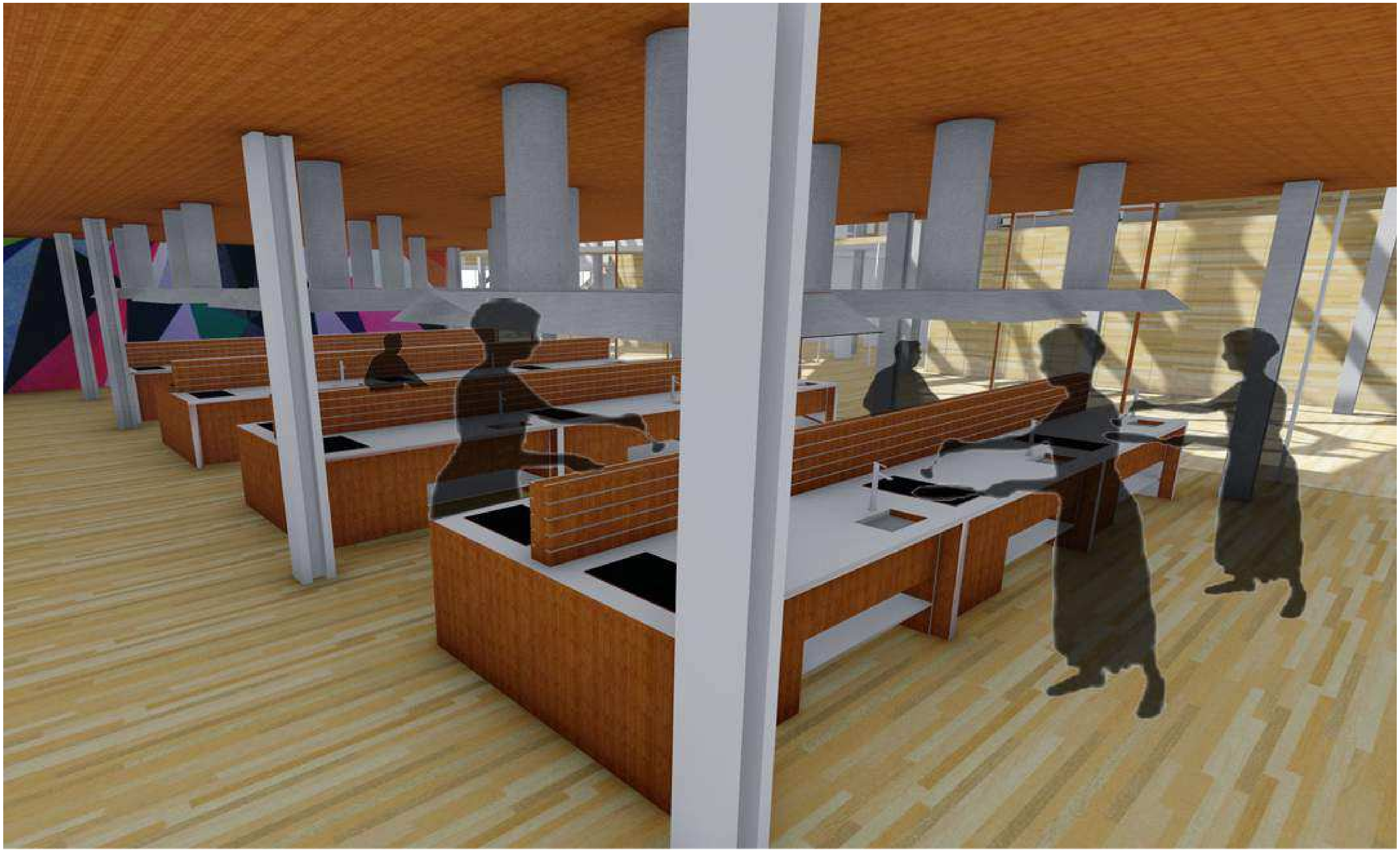


Figure 4.16 : Learning Kitchen

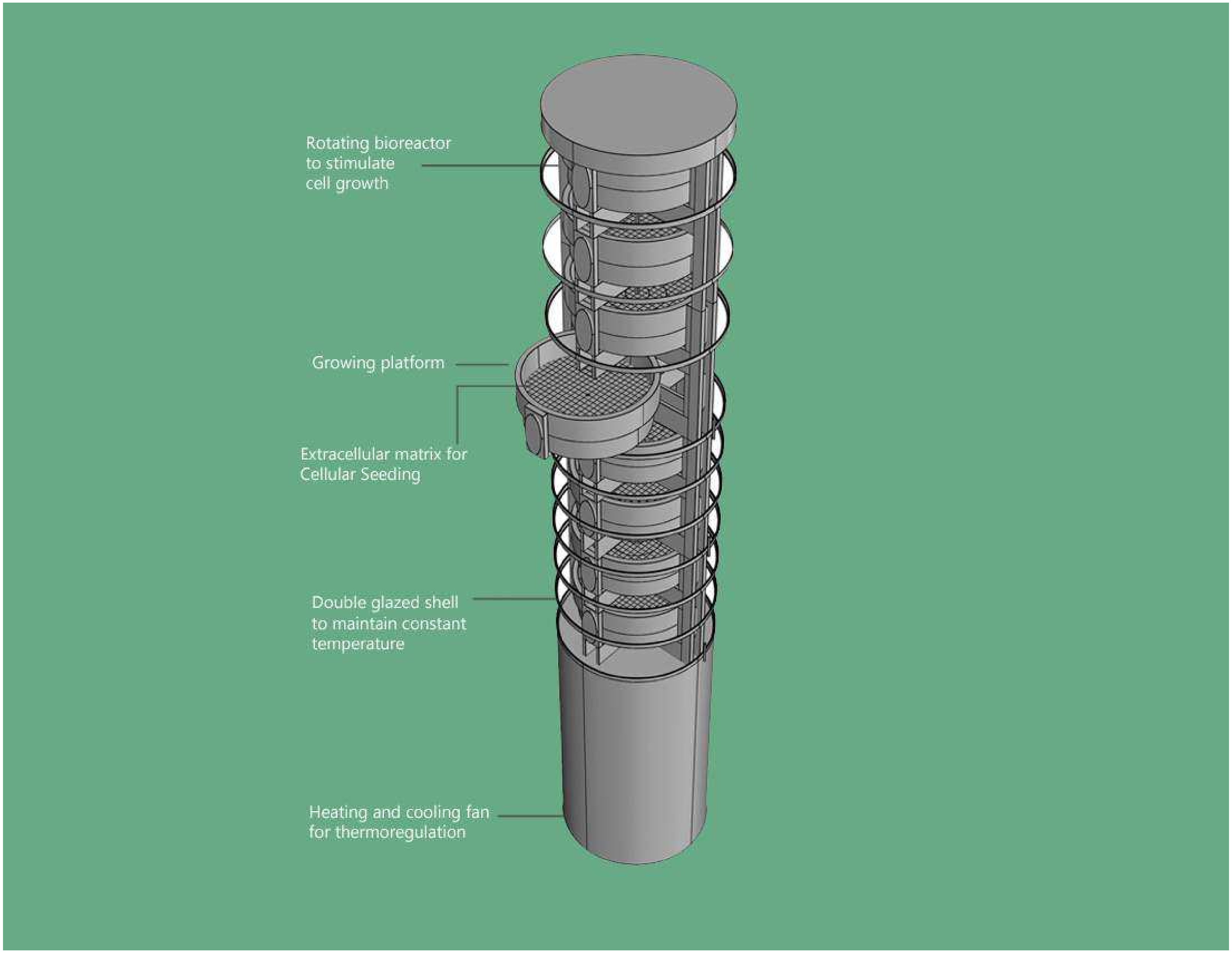


Figure 4.17 : Clean Meat Bioreactor System

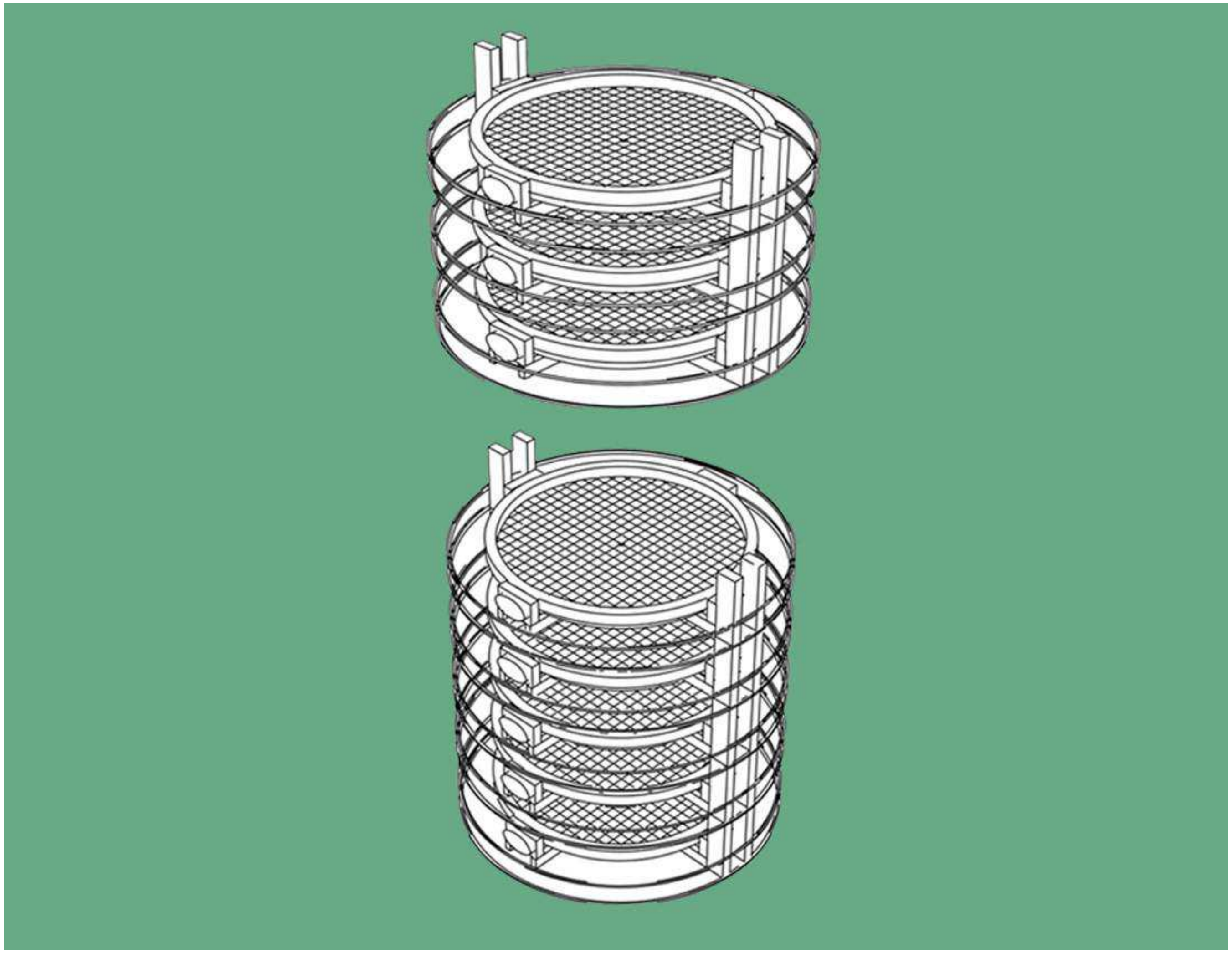


Figure 4.18: Detail of Clean Meat Growing Platform

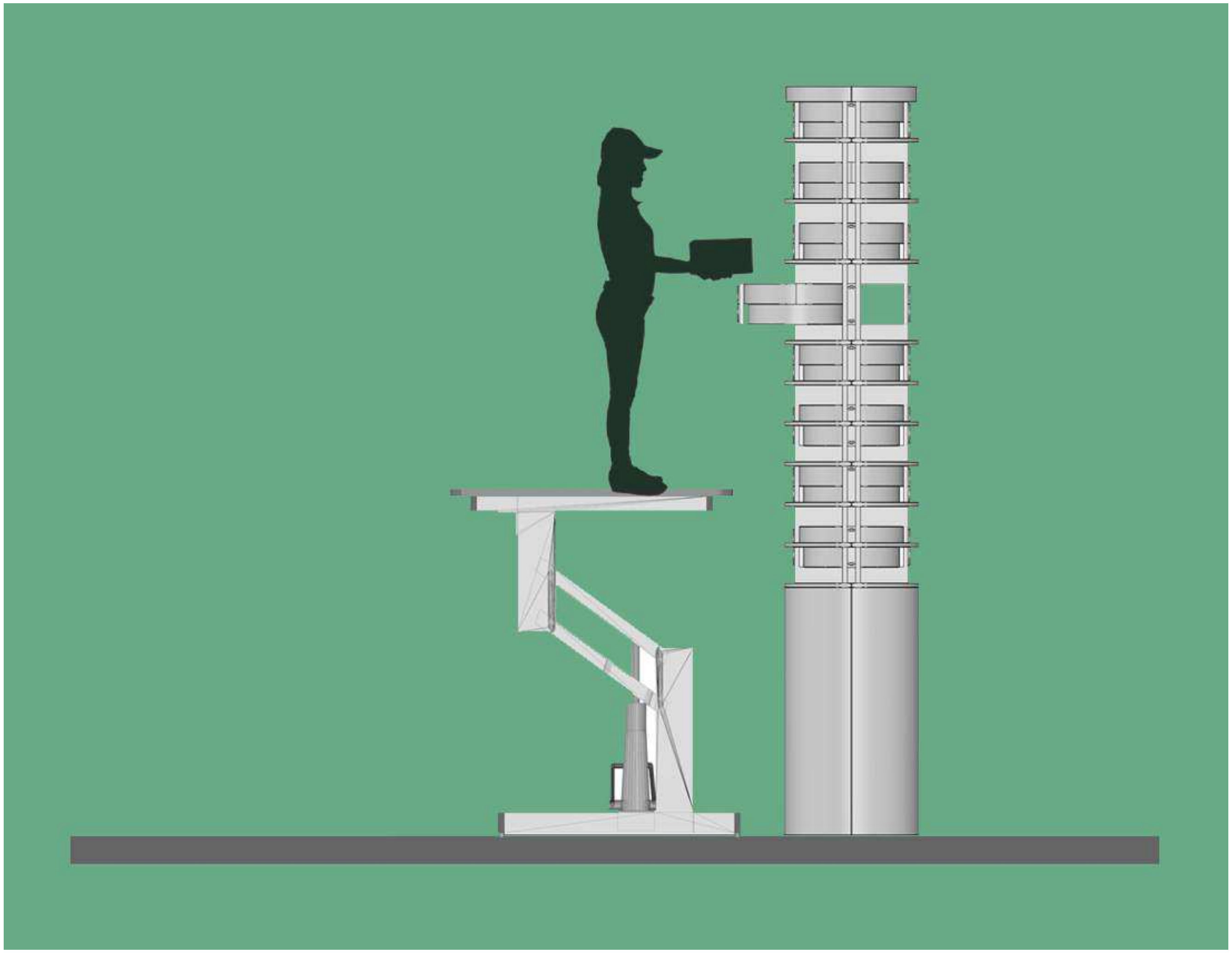


Figure 4.19 : Clean Meat Harvesting

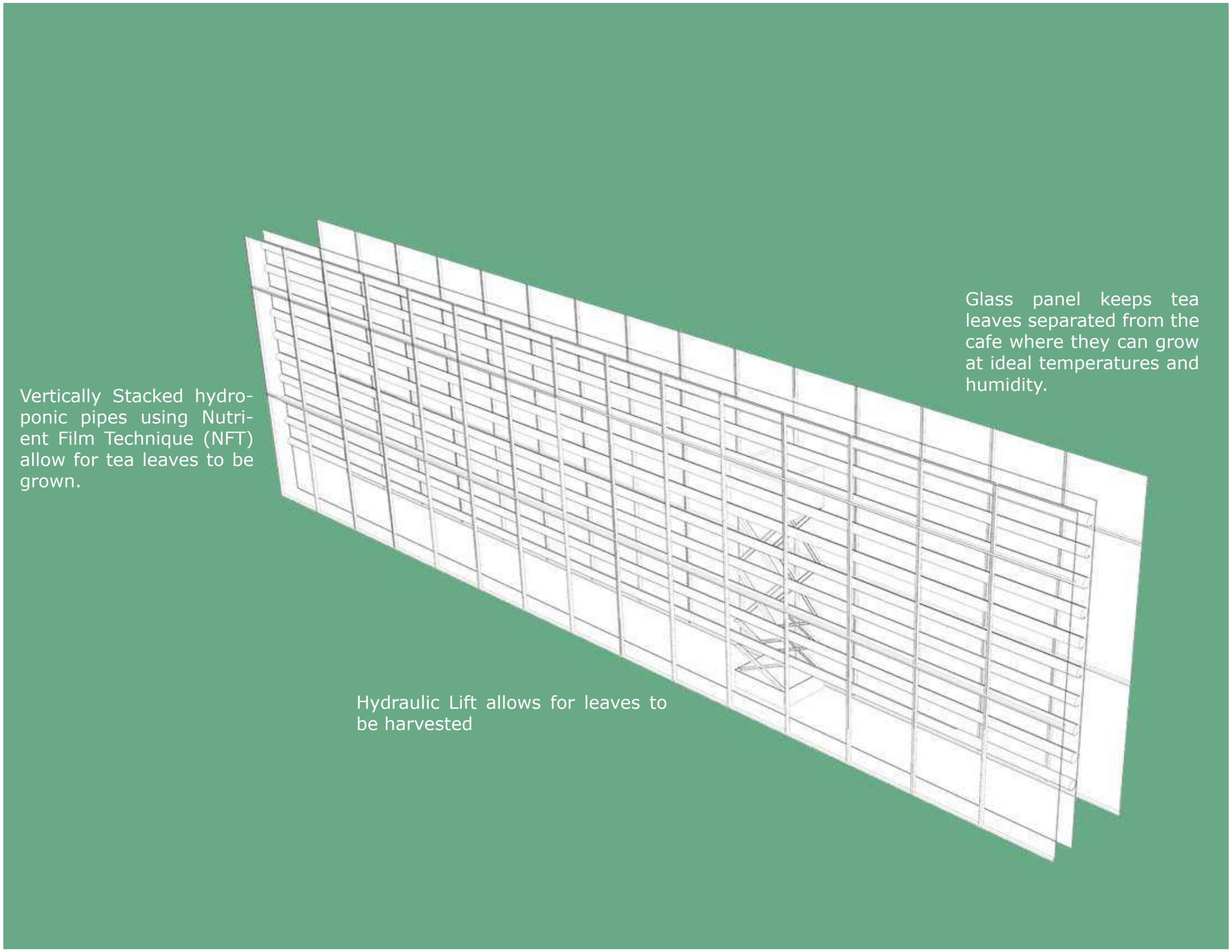


Figure 4.20 : Hydroponic (Nutrient Film Technique) Tea Wall Detail

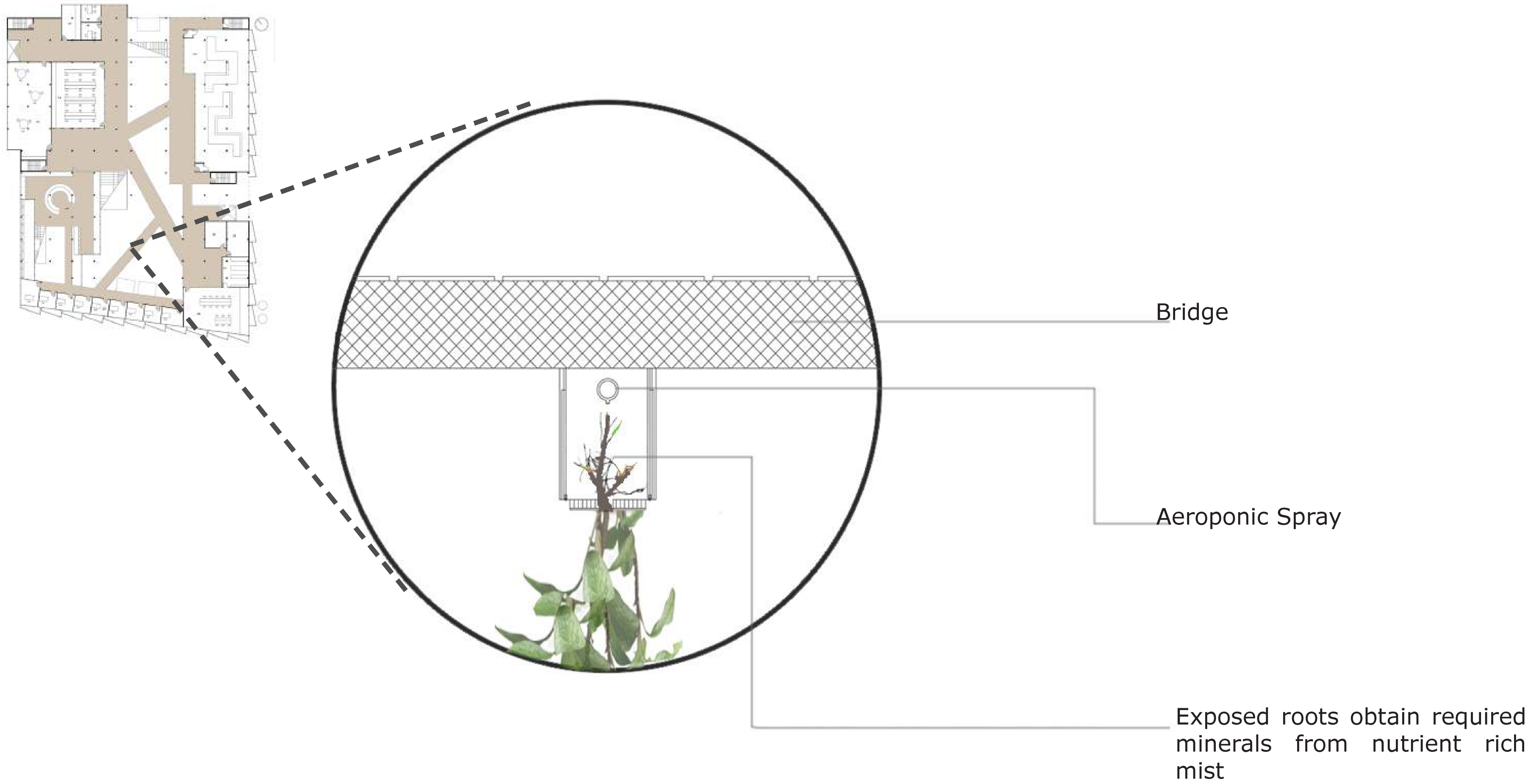


Figure 4.21 : Detail of nutrient- delivery system for Aeroponic Bridge Plants

4.7 Key Programs of Second Floor

The following section details the key spaces located on the second floor.

4.7.1 Biomaker space + Collaborative Classrooms

Clean meat and other bio-engineered innovations are in their infancy and require greater development and research to succeed. Research funding for such innovations are scarce and difficult to come by, thereby limiting the potential for discovery. Yet many discoveries can be uncovered by the average person with a little guidance intellectual guidance. One example of innovaction involves an African teen, who with nothing but a science textbook, designed a windmill which powered energy to his village(Sheerin, 2009).

It is in this vein that the biomaker spaces and collaborative classrooms have been designed. Biomaker (or bio-hacker) spaces are democratized learning spaces which are premised on the concept of open learning and shared collective information to assist the interested individuals to learn from experienced professionals in an interactive open forum. Individuals learn through praxis and pick up the requisite skills.

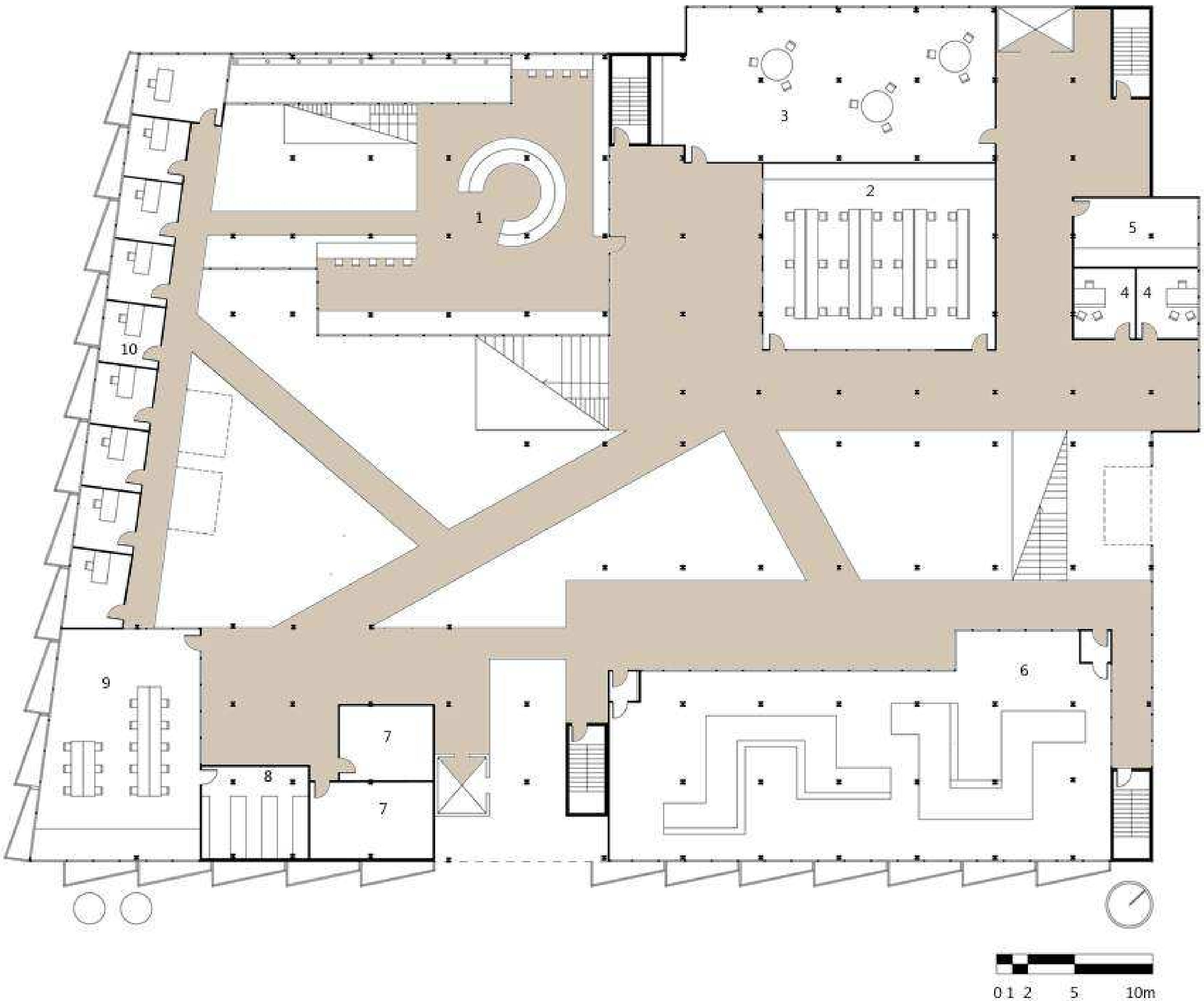
The biomaker space is 15m x 11m in size. The space has seating for 21 students and possesses the various equipment necessary for a bio-maker space: cell culture hood, incubator, nitrogen tanks(cryogenic freezer), fridges, Carbon dioxide tanks, PCR machine, real time PCR machine, gel electrophoresis equipment, shake flasks and 10l bioreactors.

There are two collaborative classrooms located behind the biomaker space. These spaces allow provide informal learning environments for the discussion and discovery of ideas.

4.7.2 Plant Nursery

Hydroponic systems require plants to be partially germinated before they can be transferred into the growing hydroponic platforms. The germination of the seeds to seedlings require a seeding area. There are three major requirements for seeding: light, temperature and nutrients and the seedling room offers these requisites to ensure efficient yields.

The plant nursery is 32m in length and 11.5 m in width and located at the south-east corner of the building. There is direct sunlight into this space from the glass roof which assists in optimal plant growth. The seedling room is a public space; however, such a space should be adequately sanitized. To ensure this, shoe covers are provided at the entrance to reduce contamination. In addition, visitors to the nursery first enter an air shower chamber which utilizes High Efficiency Particulate Air (HEPA) filtered air to remove surface contaminants. This system is also used in the commercial forest greenhouse located on the thrid floor.



1.Library
2. Biomaker Space
3.Collaborative Classroom
4. Administration
5.Storage
6. Plant Nursery
7. Washrooms
8. Seed Storage
9. Agriculture Research Lab
10. Faculty Offices

Figure 4.22 : Second Floor Plan

Figure 4.23 : View of atrium from bridge

Figure 4.24: Collaborative bio-maker space

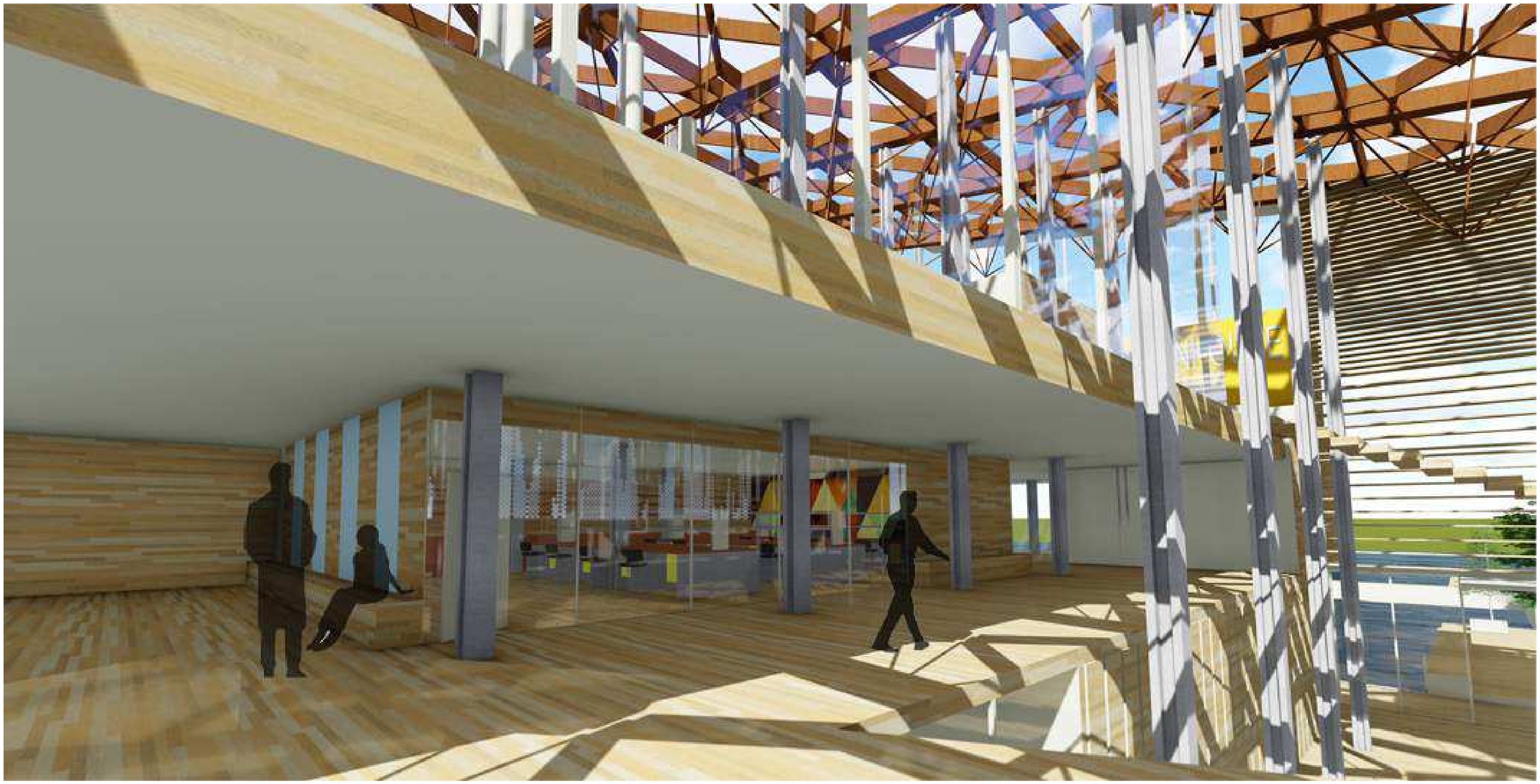


Figure 4.25 : View into collaborative bio-maker space from bridge

Figure 4.26 : Plant Nursery


Figure 4.27 : View from Second Floor leading to Commercial Forest Greenhouse

4.8 3rd Floor : Commercial Forest Greenhouse

The commercial greenhouse is located on the third floor of the building. The greenhouse is 63m in length and 27 m in width at its widest point. The greenhouse serves as a space for the growth and production of vegetables and fruit using hydroponic technology. The produce yielded from the greenhouse can be sold to the Granville Island Market located near the institute.

4.8.1 Greenhouse Layout

Most greenhouses are designed for maximal spatial efficiency. Thus the plants are grown closely together with small aisles for people to maintain and harvest the plants. However, the commercial greenhouse will be designed for visitor engagement. The layout of the greenhouse takes a meandering design pattern, one which attempts to mimic the pattern of walking in a forest or the woods. Research has demonstrated that time spend in a natural setting can facilitate a personal connection with nature (Tang, Sullivan & Chang, 2014). It is hoped that this connection can be translated to a vested interest in sustainable urban farming. In addition, visitors who visit the space will be able to notice the genetic variability of the plants and fruits which can assist in their acceptance of ugly food, thus minimizing food waste (See Chapter 1.6: Food Wastage and The Rise of the Ugly Food Movement).

In select areas, covered sheltered spaces or gazebos have been included. These spaces can be used by the public or the students and faculty as spaces for relaxing and socializing in a recreated natural setting.

The Forest Greenhouse utilizes hydoponic trees of varying heights to grow the fruits and vegetables. Figure 4.32 demonstrates the process of nutrient delivery to the plants.

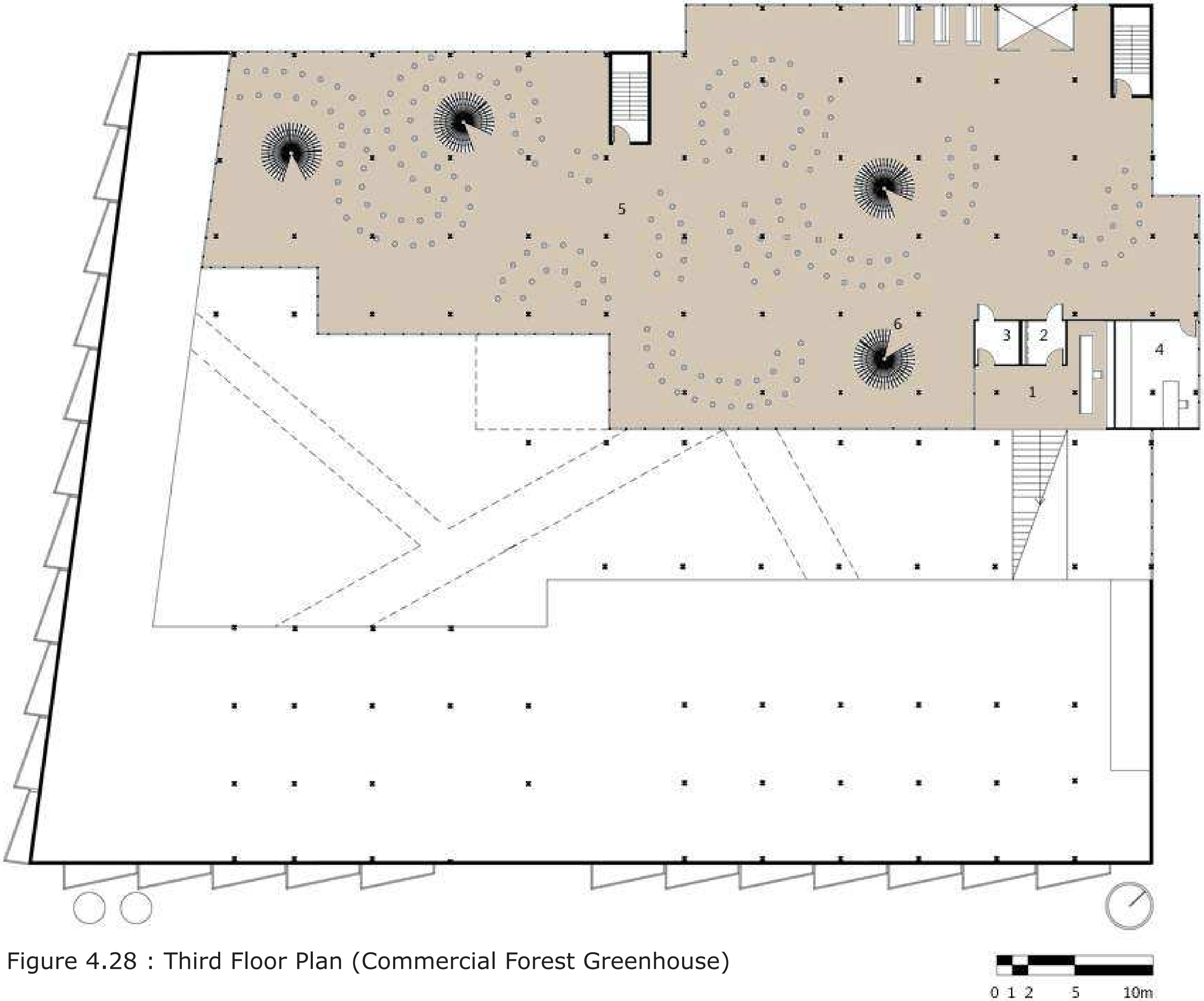


Figure 4.28 : Third Floor Plan (Commercial Forest Greenhouse)

1. Reception
2. HEPA Filtered Enterance
3.Exit
4. Main Office
5.Forest Greenhoues
6. Gazebo

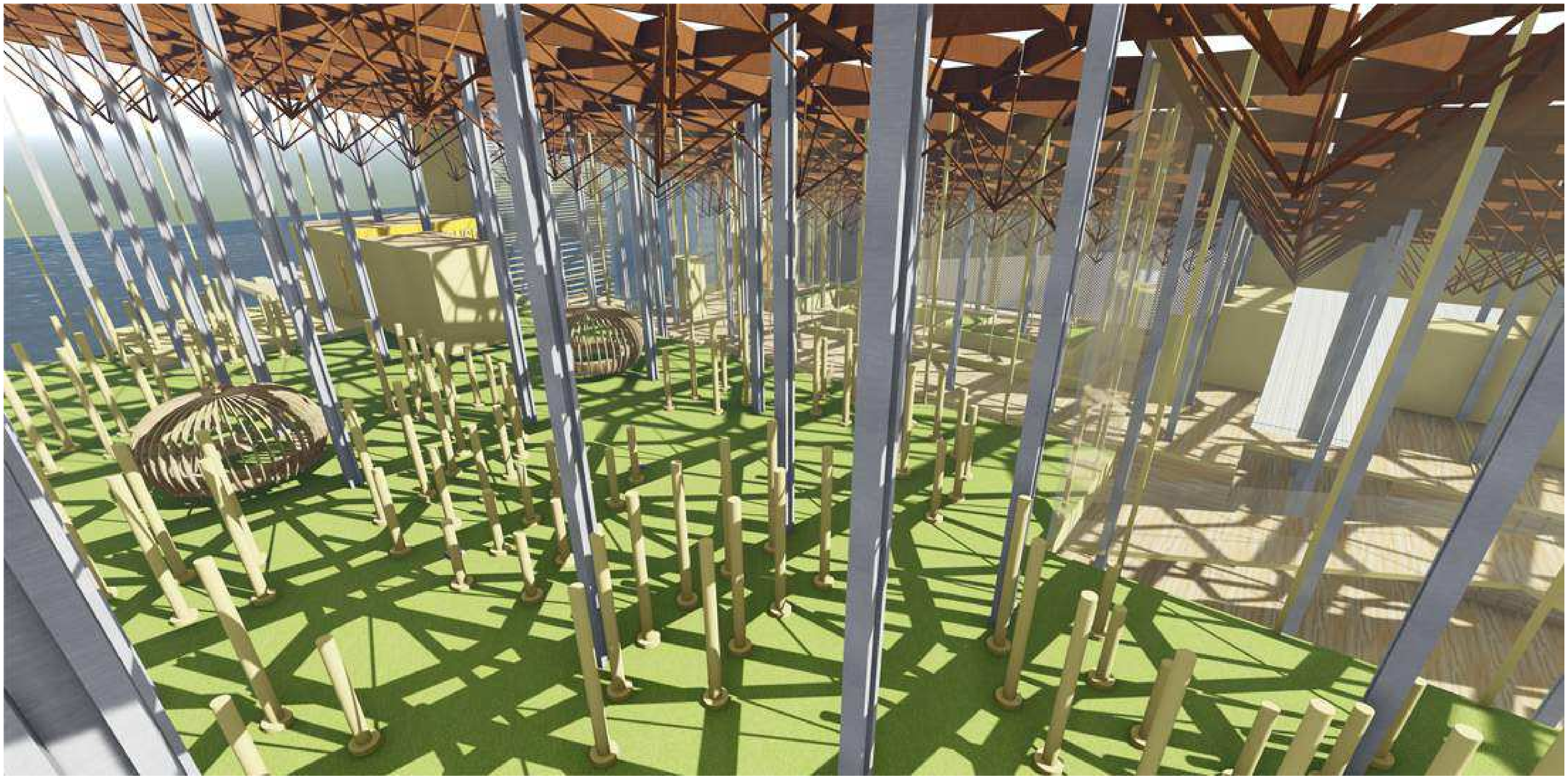


Figure 4.29: Aerial Perspective view into Commercial Forest Greenhouse

Figure 4.30 : Commercial Forest Greenhouse with Hydroponic Trees where Ugly Fruits are Grown

Figure 4.31 : View From Gazebo into Commercial Forest Greenhouse

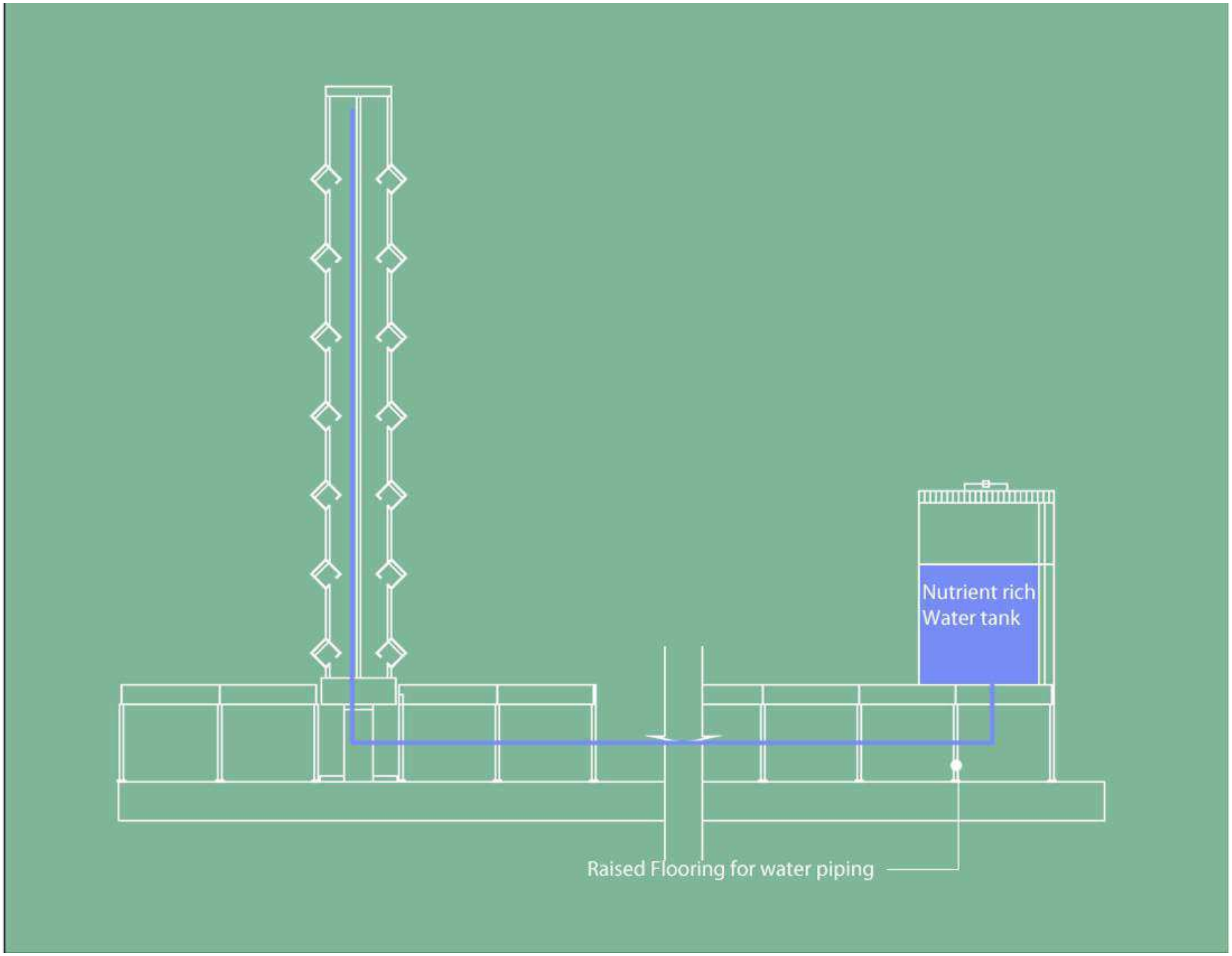


Figure 4.32 Aeroponic Tree system used in Commercial Greenhouse with nutrient rich water tank

4.9 Building For Sustainability

This thesis is primarily focused on the greenhouse emissions which occur from industrial agriculture. However, it is equally important to realize that buildings and energy emissions from buildings are another major leading factor in greenhouse gas emissions (Peng, 2016). A life-cycle assessment of building's have demonstrated that 85.4% of the total carbon dioxide emissions were generated during the operation and 12.6% of carbon dioxide emissions were generated during the demolition stage (Peng, 2016).

Thus, for the logic of greenhouse mitigating strategies to hold, the life-cycle of the building's construction should demonstrate a commitment towards sustainable practices. There are three areas of focus for this building: sustainable construction techniques, energy usage and water consumption.

4.9.1 Sustainable Construction Techniques

Buildings do not last forever. Often they have a lifespan, after which they might be demolished. During the demolition phase of a building, much of the building's materials are destroyed and sent to landfills. This demonstrates a serious design flaw as the availability of the building to be reused and re-purposed reduces embodied greenhouse emissions associated with creating newer products . Designing for deconstruction (DfD) is the method of design which addresses the issues related to material re-use and thinking about design with the end in mind allows for the entire spectrum of sustainable construction to be thought out in a rational and clear manner (Design for Deconstruction, n.d., p.10).

Designing for deconstruction can be best achieved by utilizing a number of strategies which allow for the facilitation of the deconstruction process. One such strategy is material selection.

4.9.1.1 Materials

Design for deconstruction requires a careful analysis of materials to avoid harmful and toxic materials. In selecting materials, it is advised that the number of materials be kept to a minimum (Design for Deconstruction, n.d. p.22). Minimizing the amount of materials simplifies the process of deconstruction, which in turn minimizes the cost, and thus promotes its use rather than demolition (Design for Deconstruction, n.d. p.22)

Material selection is guided by The Living Building Challenge, a building metric system which aims to create sustainability conceived buildings. There are five requirements presented by the Living Building Challenge which are related to the life-cycle impact of building materials.

Imperative 10: Red List : The project cannot contain any of the following Red List materials or chemicals, although temporary exceptions for certain items are permissible due to limitations in the material economy (Living Building Challenge, 2014, p. 44).

Imperative 11: Embodied Carbon Footprint: The project must account for the total embodied carbon (tCo2e) impact from its construction through a one time carbon offset in the Institute's new Living Future Carbon Exchange or an approved carbon offset provider (Living Building Challenge, 2014, p.45).

Imperative 12: Responsible Industry: The project must advocated for the creation and adoption of third- party certified standards for sustainable resource extraction and fair labor practices. Applicable raw materials include stone and rock, metal, and timer (Living Building Challenge, 2014, p.46).

Imperative 13: Living Economy Sourcing: The project must incorporate place-based solutions and contribute to the expansion of a regional economy rooted in sustainavle practices, products and services (Living Building Challenge, 2014, p.47).

Imperative 14: Net Positive Waste: The project must strive to reduce or eliminate the production of waste during design, construction, operation, and end of life in order to conserve natural resources and to find ways to integrate waste back into either an industrial loop or a natural nutrient loop (Living Building Challenge, 2014, p. 48).

Based on the following recommendations, the following materials were selected for the building:

Recycled Steel

Most of the building's structure is composed from steel. Steel is a highly efficient material. Unlike many materials which have limited to no recycling potential, steel can be endlessly recycled and reused (Steelconstructioninfo, n.d.) Current recycled recovery rates for steel at demolition sites stands at 99% for structural steel work and 96% for other steel construction. (Steelconstructioninfo,n.d.).Thus, most steel used in buildings include recycled steel content.

In addition, steel framework designs are primarily a kit of parts. Steel connectors are bolted together which makes them well-suited for quick deconstruction, an important sustainable consideration in the building's life-cycle (Design for Deconstruction, n.d. p.21).

Recycled Wood

Most of the interior of the building (i.e. flooring, wall panels) are sourced from recycled wood. Recycled wood is obtained from previously used buildings. Wood obtained from these buildings are carefully extracted and treated. Since the construction industry in North America is one of the largest users of timber(Design for Deconstruction, n.d. p.9), utilizing recycled wood is a viable method in minimizing the ecological damage caused by deforestation.

Pine Beetle damaged Timber

Utilizing recycled wood is dependent on supply and the proximity of local availability. It is illogical to obtain recycled wood from far distances as the environmental costs associated with transportation has to be considered. If additional wood products are needed, Pine beetle damaged timber would be used. Pine beetle damaged timber is oft found in British Columbian forests, which are relatively close to the proposed site. Timber obtained in this way is sourced from forests which were infested by mountain pine beetles. Pine beetle damaged timber is usually discarded. Thus incorporating these wood prevents such building materials from going to waste. Additionally, pine beetle damaged timber presents a unique visual aesthetic which can provide authenticity to a building's design.

Minimally Painted Interiors + Low Volatile Organic Compound Paints

To minimize the use of harmful substances in the building, much of the building's interior is left unpainted. The choice to minimize painting reduces the use of chemicals which possess embodied greenhouse gases during production,transportation and application. Whenever painting is required, paints with low volatile organic compounds (VOCs) are used. Since much of the building uses recycled wood, the decision to minimize paint use allows for the material and textural qualities of recycled wood to be visually appreciated.

4.10 Energy Usage

85.4% of a building's greenhouse gas emissions occur during its operation (Peng, 2016).Thus, it is logical that the building maximize sustainable and renewable resources for its operational requirements. There are three main sustainable resource initiatives utilized by this building: solar panels, geothermal energy and rainwater recapture and re-use, the former two directly affect greenhouse emissions, while the latter is a strategy in keeping with the gestalt of sustainable building operations.

4.10.1 Photo-voltaic Glass Panels

Solar panels used to be cumbersome and aesthetically unappealing. This has changed rapidly since the advent of transparent photo-voltaic glass which is visually indistinguishable from regular glass. One example is Onyx standard Photo-voltaic Glass. Since the long side of the building runs from south-west to north east, much of the building's area is exposed, maximizing solar radiation. Photo-voltaic glass can be installed on this side of the building.

4.10.2 Passive Design Strategies : Cross -Ventilation

The windward direction in Vancouver is South(S) and South-SouthWest (SSW) and the leerward direction is North- North East (NNE) (See Appedix IV: Supplemental Climate Data for Granville Island, Vancouver, BC). The main entrance of the building-opening up both sides of the atrium- faces Southwest and North East respectively. In the spring and summer, when the weather is hot, the main doors of the entrance on both sides of the can be opened on both sides. This opening provides continuous cross-ventilation throughout the atrium and thus reducing energy required for cooling in summer months.

4.10.3 Geothermal Energy System

Geothermal energy is another system which can be used to provide sustainable energy and promote decentralized energy procurement. Geothermal energy is derived from heat in the earth's interior (Grasby, 2011, p.4). This heat is generated from the natural radiogenic decay of elements in the upper crust as well as primordial heat generated from the formation of the planet (Grasby, 2011, p.VII).

There are three major geothermal systems: vertical closed-looped systems, horizontal closed-loops and open- looped systems (Reynolds, n.d.).The urban site of this project coupled with the desire to minimize construction footprint calls for the use of a vertical closed-loop system (Reynolds, n.d.).

The vertical closed-loop system has a sealed u-shaped pipe which is fabricated from high density polyethylene and carries a heat transferring fluid in a continuously circulating loop allowing for heat exchange by way of conduction. As the heated liquid returns to the surface, the thermal energy obtained is utilized to heat the building.

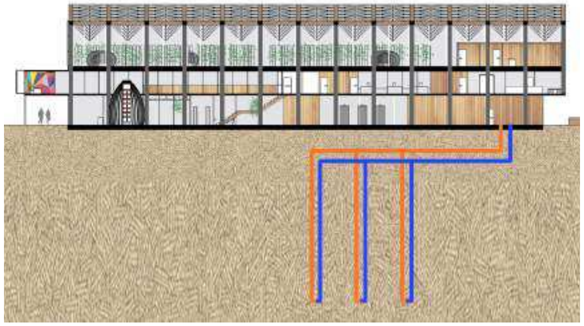


Figure 4.33 : Vertical Closed-loop Geothermal System

4.11 Water Consumption : Harvesting Rainwater

Vancouver is a rainy city with an annual average rainfall of 1474mm. This makes rainwater harvesting particularly feasible. To maximize rainwater collection, the roof is designed with a pitch of 11 degrees.

There is a water tank with capacity of 100,000L located underground by the enterance of the building. The tanks are partially extruded and a portion is enclosed in glass allowing visitors to observe the amount of water stored. This demonstrative feature facilitates public knowledge on resource conservation and the role of design in mimizing waste.

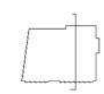
There are two primary uses for the harvested rainwater: Agriculture and grey-water use. Agriculture is a water intensive endeavor. Thus, utilizing rainwater can minimize the water footprint associated with crop growth. Second, building systems such as faucets and toilets can utilize rainwater, thereby reducing the reliance on municipal water.

Figure 4.34 : Rainwater Harvesting Tanks (Tanks are partially extruded to indicate the amount of water in the water tank, located under the building)

Figure 4.35 : Long Section

1. Clean Meat Scaled Production Bioreactors 2. Atrium 3. Culinary Kitchen 4. Collaborative Classroom
5. Biomaker Space 6. Faculty Offices 7. Plant Nursery 8. Greenhouse

Figure 4.36: Cross-Section



CHAPTER 05

CONCLUSION + POSTSCRIPT

“Cities change. It is their nature. Those which stop changing stop being cities.”

___ Adam Gopnik, 2015

Chapter 5 : Conclusion + Post Script

The Anthropocene world is at an interesting juncture in its nascent history. This century has been gifted with numerous discoveries, and the exponential rate of breakthrough show little signs of diminishing (Kurzweil, 2001). Science and technology have greatly improved human life and the human condition. We enjoy much from the advances in transportation, telecommunication, information technology and design. Concurrently, human actions and behaviors have contributed seriously to the degradation and pollution of the natural environment (Milman,2015). Some of these, such as deforestation are reversible while others like systemic ecological extinctions cannot be resolved (Cafaro, 2015).The earth is a complex but finite system and human activity pattern suggests one modeled on infinite abundance. The peril in assuming such an attitude is cause for concern.

However, the rapid dissemination of knowledge of the risks of human encroachment on nature has resulted in the vox populi demanding change and the birth of the environmental movement (Maslin, 2004, p.31).This has been translated into the economy in the form of “green and sustainable” initiatives. While some changes have been productive, others are superficial (Dahl, 2010). This thesis attempted to achieve the values enshrined in the former by formulating through an architectural paradigm, a building which would raise awareness, educate and foster critical discourse surrounding the issue of greenhouse gas emissions arising from unsustainable industrial agricultural methods.

This thesis explores but the tip of the proverbial iceberg. There are many other sources of greenhouse emissions and ecological degradation that require rigorous analysis and rapid and systematic remediation. This thesis hopes that the issues presented from one industry will inspire much needed dialogue which can result in a better world for tomorrow. A brighter future awaits.

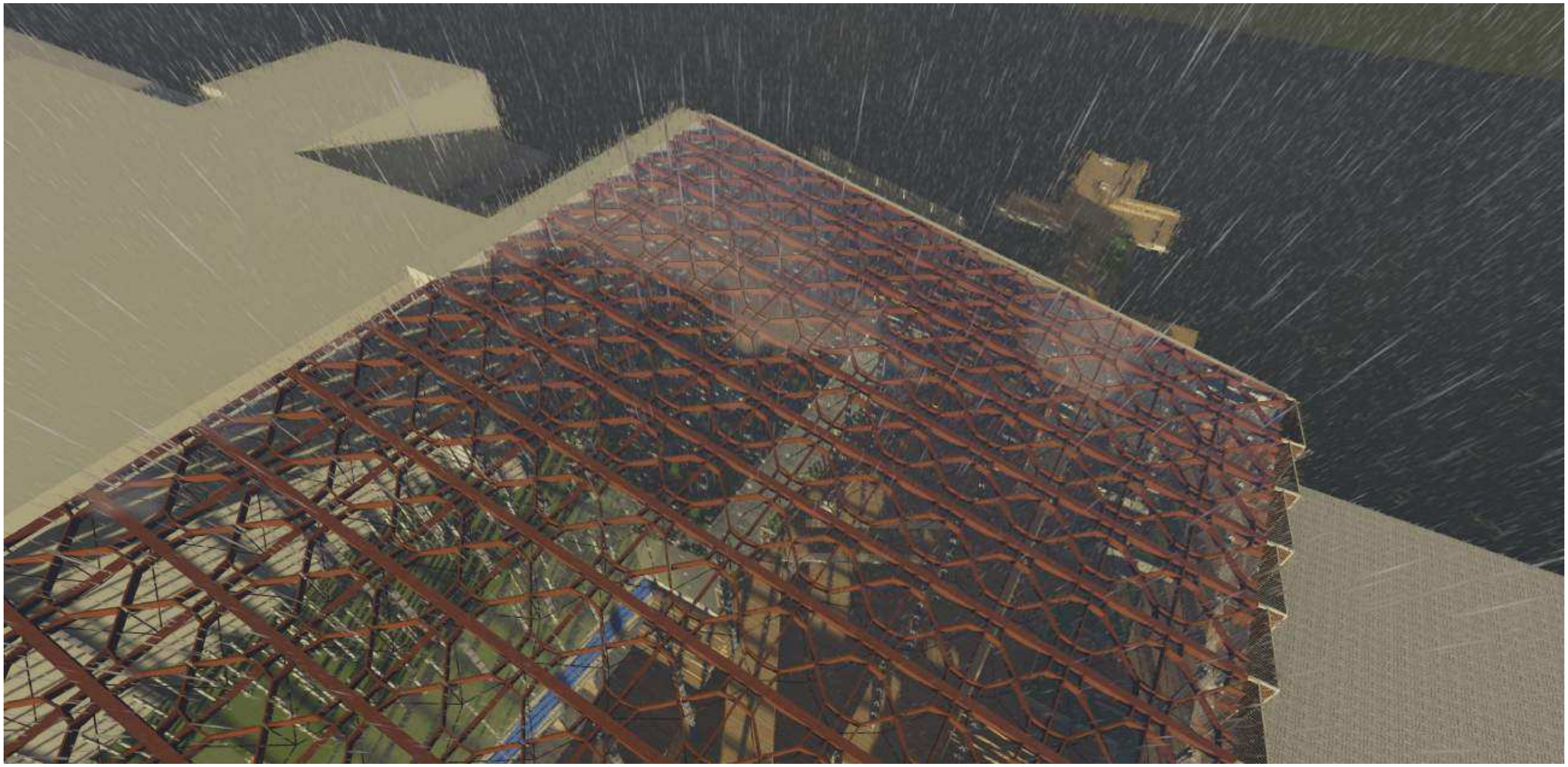


Figure 5.1 : Aerial Roof Perspective

Appendix I :

Thesis Defense Presentation Panel

Figure A1 : Thesis Defense Presentation Panel (September 7 2017)

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