[charleston] VERTICAL FARM

Charleston Vertical Farm Design Feasibility Study

November 2011

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REPORT FORMAT

The report for the Charleston Vertical Farm Design Feasibility Study is organized into nine sections preceded by a project partner list and glossary and followed by the acknowledgements, references and appendices index.

The nine sections include:

(1) Executive Summary
(2) Introduction
(3) Project Objectives
(4) Workplan
(5) Strategy
(6) Charrettes
(7) Design Feasibility Study Elements
(8) Lessons Learned
(9) Studio Building Designs for the Charleston Vertical Farm

GLOSSARY OF TERMS AND ABBREVIATIONS

aeroponics The process of growing plants in an air or mist environment without the use of soil.

aquaponics The method of growing crops and fish together in a re-circulating system.

blackwater A term for the fraction of wastewater containing pathogenic sewage.

BMP, Best Management Practices Structural and non-structural controls designed to prevent or reduce the release of pollutants into the environment.

CAD, Computer Aided Design The use of computing technology for digitally processing architectural and engineering design documentation.

carbon footprint A measure of the impact human activities have on the environment, and in particular climate change. It relates to the amount of greenhouse gases produced through burning fossil fuels for electricity, heating and transportation etc.

charrette An intensive planning session wherein participants from different disciplines explore and present ideas to collaborate on a vision for a project.

Community Research & Design Center (CRDC), Clemson University The CRDC focuses on a multidisciplinary approach to design and brings together resources to assist community initiatives. Planners, architects, builders, researchers and more collaborate to solve community problems.

cyberinfrastructure Research environments that support advanced data acquisition, data storage, data management, data integration, data mining, data visualization and other computing and information processing services distributed over the Internet.

EBT, Electronic Benefit Transfer An electronic system that automates the use of public assistance benefits.

environmental informatics The science of information applied to environmental science.

ETFE, Ethylene Tetrafluoroethylene A resilient engineered plastic with high corrosion resistance and strength over a wide temperature range.

food desert Geographic areas within a community with limited access to healthy, reasonably priced food.

GIS, Geographic Information Systems Computer programs to assist in analysis and visualization of geographically referenced data.

graywater Water from sinks, showers and washing machines or water from other domestic activities.

green infrastructure Strategically planned and managed networks of natural lands, working landscapes and other open spaces that conserve ecosystem values and functions and provide associated benefits to human populations.

green roof Vegetated roof covers.

green wall A wall, either free-standing or part of a building, that is partially or completely covered with vegetation and, in some cases, soil or an inorganic growing medium.

hydroponics A method of growing plants using mineral nutrient solutions, in water, without soil.

IAE Institute of Applied Ecology, Clemson University The Institute focuses on the application of novel and emerging technologies, innovative management strategies, and multi-scale outreach programs to solve major natural resources problems (www.clemson.edu/appliedecology).

Intelligent River® The Intelligent River® is developing and operating hydrological observation systems to support research and provide real-time monitoring, analysis and management of water resources in South Carolina. These observation networks vary in purpose, scale and density of observation platforms and sensor types, but have a common need to be managed in real time with a well developed software and hardware architecture that is intended to provide 24/7 access to data and visualization products (www.intelligentriver.org).

MDF, Medium Density Fiberboard An engineered wood product used commonly in architectural model displays.

MoteStack A battery operated computer with the technology to allow an unprecedented number of sensors to be deployed across a large area and operate as a highly efficient network.

rainwater harvesting Accumulating and storing rainwater using rain barrels, cisterns or other catchment systems.

Renewal Community Renewal Communities are federally designated geographic areas that have been identified as particularly distressed zones. Because these areas have a hard time attracting the businesses and residents needed for economic revival, the federal government offers monetary incentives to businesses that are located in these areas and hire employees within these communities. Businesses working within a RC or employing residents that reside in a RC are eligible for several specialized tax incentive programs as well as more traditional programs open to all businesses. Additionally, businesses may also be eligible for assistance with tax preparations, legal and accounting referrals, and links to local employment agencies and job banks.

repurpose To use or convert for use in another format.

rooftop gardening The practice of gardening on rooftops, can be an energy-saving alternative to a conventional rooftop.

SmartState Program The South Carolina SmartState Program was established by the South Carolina General Assembly in 2002, funded through South Carolina Education Lottery proceeds. The legislation authorizes the state's three public research institutions, Medical University of South Carolina, Clemson University and the University of South Carolina, to use state funds to create Centers of Economic Excellence in research areas that will advance South Carolina's economy (www.sccoee.org)

social justice The view that everyone deserves equal economic, political and social rights and opportunities.

South Carolina Centers of Economic Excellence in Urban Ecology and Restoration The Urban Ecology and Restoration Center at the Clemson University Restoration Institute supports the growth of the state's environmental industry and attracts world-renowned faculty in restoration development. This Center is unique for its interdisciplinary, integrative approach to the restoration of historic, ecological, and urban infrastructure resources through the integration of basic science, engineering, and urban planning.

South Carolina Centers of Economic Excellence in Sustainable Development Established in 2010, the Center's mission is to advance sustainable development through technological innovation. This includes the development of new technologies, from optically-based chemical sensors to wireless networking platforms, as well as the development of new environmental and ecological models designed to support real-time monitoring and management of natural and built environments.

sustainability Relating to, or being a method of harvesting or using a resource so that the resource is not depleted or permanently damaged.

S.W.O.T. Analysis Strategic planning method used to examine the Strengths, Weaknesses, Opportunities and Threats of a specific project or design.

urban gardening Growing plants in pots or other containers, rather than in ground or growing crops or ornamental plants in urban or semi-urban setting or food production in urban setting

vertical farm A concept that argues that it is economically and environmentally viable to cultivate plant or animal life within skyscrapers, or on vertically inclined surfaces.

WIC Federally funded health and nutrition program for Women, Infants and Children.

PROJECT PARTNERS

Institute of Applied Ecology
Community Research and Design Center
Restoration Institute

The City of Charleston
The City of Charleston Green Committee
Environmental Protection Agency, Region 4

SmartState Center of Economic Excellence in Urban Ecology & Restoration
SmartState Center of Economic Excellence in Sustainable Development

<u>Pilot Project Partners</u>
Clemson University Department of Biological Sciences
Green Roof Outfitters

EXECUTIVE SUMMARY: OVERVIEW AND FINDINGS

Clemson University's Institute of Applied Ecology received EPA contract funding to conduct a feasibility study to explore the potential of repurposing a building in Charleston, SC as a vertical farm. The study was conducted in conjunction with the City of Charleston, Clemson University Research and Design Center and the SmartState Centers of Economic Excellence in Urban Ecology and Sustainable Development. Work products include a final report and PowerPoint presentation on the study (EPA contract EP-W-10-002, Agreement 8070-CLEMSON).

To begin the project, an interdisciplinary team of faculty was assembled with the following project objectives:

1. Develop a feasibility study, which will include design options for the vertical farm and innovative research and educational components.

2. Conduct two charrettes for stakeholders to insure community input into the vertical farm project.

3. Incorporate the Intelligent River® cyberinfrastructure network into the design to provide real-time remote data acquisition to monitor and operate the vertical farm and link the vertical farm into the Intelligent River® research portal (www.intelligentriver.org).

4. Develop a long-term funding plan for construction and operation of the vertical farm.

5. Develop a partnership Memorandum of Understanding between Clemson University and the City of Charleston, which provides a mechanism for bringing in local universities, technical schools, and local high schools into a collaborative research and management program for the Vertical Farm.

Concurrent with the feasibility study, Clemson University's Institute of Applied Ecology and Research and Design Center independently funded a semester-based Vertical Farm Architecture Graduate Studio to provide technical and charrette support for the feasibility study and to develop a graduate student architectural perspective on vertical farming. Graduate students prepared the charrette meeting rooms, produced background materials for participants, served as technical support teams for participant groups, rendered drawings during the charrette process to reflect participant ideas, and rapidly assembled PowerPoint presentations utilized by participant teams to present findings at the end of each charrette.

Specific elements of the feasibility study are documented in detail within the feasibility study report, including extensive appendices with meeting notes, charrette documents, photographs, studio documents and links to archived materials.

Major findings of the feasibility study were:

1. Extensive planning was required to develop a talented pool of stakeholders from which to form balanced teams of architects, planners, restaurant owners, community nonprofits, artists and community leaders necessary to address the very technical concept of building a vertical farm. Arranging meeting times proved to be difficult and required extensive follow-up contact by email and phone calls even though there was great interest in the study.

2. Identification of exhaustive design elements was a valuable exercise for faculty and student participants. Some elements however were beyond the community engagement scope outlined for the feasibility study, funding and time line to conduct the study. The primary elements of site, location, building selection, community engagement, project acceptance, funding, planning and zoning, safety and general building design were drivers in the feasibility study. Specific design elements such as energy and water sources, building materials, equipment

components, operations and management will be utilized to define the building program leading to the Request for Proposal to build the vertical farm but could not be addressed in detail in the feasibility study.

3. Engaging the City of Charleston throughout the charrette process was challenging. Changes in key personnel resulted in a lack of follow-through on critical assignments, particularly in developing a working Memorandum of Understanding. City personnel and the city's Green Committee were very helpful and engaged in early working meetings to develop the building site list and assisted in arranging team visits leading to the three candidate building sites. However, working schedules prevented significant participation in charrettes as envisioned. Several individuals from the City were engaged throughout the process and their support will continue to prove valuable in moving the project forward to the building stage.

4. The charrette process employed was extremely well received by team participants who dedicated many hours to the two charrettes – particularly the level of technical assistance provided to visualize design concepts in real-time. The studio and student involvement proved invaluable in engaging the participants, assisting charrette teams, and providing immediate visual feedback on participant's ideas. Work products from the feasibility study would not have been possible without the technical assistance of the graduate architecture students. In turn, the charrette process and community engagement enriched all studio participants and made the studio experience much more meaningful and valuable. Unfortunately, faculty participation in the Charleston-based charrettes was limited due to teaching schedules and EPA participation was limited due to travel budgets.

5. All participants in the charrette process strongly supported the social justice and building repurposing components of the potential vertical farm, and this was very evident in both the building selection charrette and the building design charrette. There is strong support for moving the feasibility study forward and a potential vertical farm is viewed an important opportunity to bring healthy foods into a lower socio-economic part of Charleston. Participants expressed concerns about the vertical farm being too technical in design, viewing the potential vertical farm as a sterile laboratory with limited opportunity to employ under-educated members of the receiving community.

6. Participants suggested that a pilot-scale vertical farm be developed as a proof of principal project and operated for a three to five year period to test various operational strategies, gain understanding of the economics of vertical farming, evaluate community engagement and optimize full-scale deployment. There was a consensus among participants that vertical farming should be combined with other types of urban farming such as backyard, patio, and rooftop gardens to engage the culturally and ethnically diverse community where the potential vertical farm would be located. Participants supported cultural activities that would make the vertical farm more of a community gathering site, suggesting the bottom floor include a local produce stand and classroom for educational programming and cooking classes.

7. Charrette participants are looking forward to the public presentation of the final building models and designs that will be produced from the vertical farm studio. Ideas and suggestions will be incorporated into designs that will be on display in Charleston for community feedback. This element of the feasibility study is beyond the scope and funding of this contract but is anticipated to be a critical element in moving the potential project forward.

8. Several recommendations are offered from this feasibility study. Future feasibility studies of this magnitude should be funded at an appropriate level to provide full technical assistance as that provided by the architecture graduate studio. Some level of matching grant funds should be considered a requirement for future projects. Future studies should have an expanded time frame due to the complexity of vertical

farming and the extended community-engagement time frame required to introduce the potential opportunity. Lastly, for the city of location to be fully engaged, grants should be awarded directly to the city with a match requirement to insure full participation.

The Charleston study area evaluated for the vertical farm project is within a federally designated "Renewal Community" and is eligible to share in an estimated $17 billion in tax incentives to stimulate job growth, promote economic development and create affordable housing. The 7.3-square-mile Renewal Community is made up of 19 neighborhoods with a total population of 20,250. An estimated 18,834 people live within a one mile radius of the property on King Street that was selected by charrette participants.[1] The select demographics of that population are as follows[2]:

- Number of Families: 4,024
- Percent of Families Below Poverty: 26.0%
- Unemployed Civilian Labor Force: 26.9%
- Families with Income below $10,000: 17.4%
- Families with Income below $15,000: 23.4%
- Families with Income below $35,000: 53.7%
- Families with Income below $50,000: 67.0%

The Renewal Community mission is to foster economic and community development by creating programs that will empower businesses and residents residing in the community. Charleston's effort is focused on:

- Fostering economic development
- neighborhood revitalization and
- improving the delivery of health and human services.

In summary, the vertical farm engagement process was very successful in gaining support to move such a project forward. The City of Charleston provided a letter of support to Clemson University for the project (*see Appendix A*). Providing fresh produce to Charleston's socially and economically-depressed communities living in food deserts is important to community leaders. Vertical farming is viewed as a viable alternative to fresh food production by community organizations dedicated to social justice and food distribution within the lower socio-economic communities within cities. Weaving the vertical farm within the fabric of the community will require extensive community engagement from the site selection process through operations. A vertical farm for Charleston is envisioned to enhance economic growth and foster environmental and social justice through a socially responsible business model.

Designated Renewal Community (green shading)

Google Map showing the locations of the three final properties evaluated for the vertical farm project.

INTRODUCTION

As the world's population increases, developing farmable land will be a challenge. One option is to farm vertically instead of horizontally. Dense urban centers would have multistory buildings with floor atop floor of fruits and vegetables grown in highly environmentally efficient ways, such as using hydroponics and aeroponics.

Clemson University's Institute of Applied Ecology (IAE) in collaboration with The City of Charleston, SC (City), Clemson University Research and Design Center and the SmartState Centers of Economic Excellence in Sustainable Development and Urban Ecology conducted a design feasibility study to build a vertical farm in downtown Charleston. The study evaluated the repurposing of an existing building to house a vertical farm which would support both the City's and Clemson University's sustainability initiatives. The feasibility study defined criteria for candidate properties and key elements to consider; explored community engagement and social justice through a charrette process; identified potential crops of importance to stakeholders; and evaluated the use of solar and wind energy to power the farm and enhanced cyberinfrastructure and environmental informatics to monitor and operate the farm. This study incorporated three charrettes. The first two charrettes, a steering charrette and a design charrette were focused on stakeholder engagement, essential for community input. The third charrette was a technical resolution charrette among faculty, invited experts and the graduate architecture students to review conceptual building plans and seek resolution to technical issues raised by participants and faculty.

The Vertical Farm project for Charleston incorporates principles of sustainability through ecological design. The project would: (1) promote environmental and social justice by supporting innovative approaches to bringing healthy foods to socio-economically stressed citizens and neighborhoods; (2) promote alternative energy within the urban context; (3) reduce urban watershed impacts related to stormwater by optimizing green roof technologies; and (4) incorporate cyberinfrastructure technology to monitor and manage the farm. The project would be research-based and provide a collaborative environment for Clemson University's faculty and graduate students to link with regional university undergraduates, technical schools and high schools to move sustainability forward within a receptive urban environment. Taking the leap from conceptual design to a working small-scale pilot farm will move the vertical farm initiative forward and encourage citywide and regional initiatives of healthy food, a reduced carbon footprint, green infrastructure and sustainability. Research elements identified for the pilot-scale vertical farm include water and energy self-sufficiency by incorporating elements of alternative energy sources and graywater collection and reuse; green-roof and vertical garden technologies; sustainable production of high quality organic foods within a reduced urban footprint; enhanced hydroponics; roof-top and vertical wetlands for urban farm water quality treatment; cyberinfrastructure and multi-level community-based sustainable development education.

The Vertical Farm Concept

The idea for vertical farming was first envisioned by Nancy Jack Todd and John Todd in 1993 in their book "From Eco-Cities to Living Machines". The concept was later expanded in 1999 by Dickson Despommier, a professor of environmental sciences and microbiology at Columbia University. In the last few years, mainstream and scientific articles have been written about the vertical farm concept. Publications from Time to Science have fostered the concept of the vertical farm, a high-rise approach to bringing fresh healthy produce from "tower to fork", emulating the "field to fork" movement towards a more sustainable and healthy lifestyle.

It is important to educate audiences on the true vertical farm concept to distinguish it from other types of farming projects that may be referred to as 'vertical farming'. In concept, vertical farms are multistory buildings with highly controlled environmental conditions and access that house year-round crop production in artificial environments by using hydroponics, aeroponics and aquaponics. All food is grown organically without herbicides or pesticides, and black and graywater is collected and recycled. The vertical farm is powered by solar and wind energy to balance out the high-energy consumption the internal environment requires. Rooftop farming and urban gardening are two other practices that are often confused with vertical farming. Rooftop farming uses the roof footprint of a building to cultivate crops in raised beds that are open and exposed to weather elements or to cultivate crops that are partially or fully enclosed in a greenhouse structure. Urban farming is growing crops on the ground in or around a community in vacant lots or green space. Although both of these practices may utilize aeroponics or hydroponics and use container beds or vertical scaling of crops, they do not meet the actual concept of a vertical farm. An actual vertical farm requires a substantial investment in building or repurposing and outfitting a building to create the necessary indoor environment for year round maximum crop production that utilizes a small urban footprint and minimal water and energy resources.

Another issue with the concept of a vertical farm is that audiences may have a negative view of the interior space used to cultivate crops by comparing it to a 'laboratory' environment. There can be an impression that crops are grown in an unnatural contained environment that may allude to genetic engineering or cultivation that does not produce a natural crop. When in fact, the environment would allow for seeds to germinate and plants to grow in a highly controlled environment free from pollutants, herbicides and pesticides that would otherwise alter their true natural state.

The City of Charleston

The City of Charleston is well known for its history and tradition, and the historic architecture of its downtown neighborhoods is widely revered. New construction or repurposing projects are subject to strict guidelines in order to harmonize with the common traditional look of the surrounding community. A thorough understanding of the city's zoning ordinances and an application submittal to the Board of Architectural Review is required. But there is strong support among citizens and established organizations for forward thinking to make Charleston a sustainable community. The Preservation Society of Charleston works to promote interest in the preservation of buildings and prevent the destruction or defacement of buildings with historical or aesthetic significance. The Society supports the re-use of existing buildings to reinvest in the community, and South Carolina offers tax credits for the rehabilitation of historic properties. The Society also has a newer program called "Green Preservation Charleston" that advocates for applying 'green' principles to current historic buildings and re-use of historic building materials to make them operate more efficiently and produce less greenhouse gas emissions – "The greenest building is one already built".[3] The City also has a Green Committee (CGC - Charleston Green Committee), established in 2007, made up of citizen volunteers who "inspire individuals and organizations to take actions and implement polices that help make Charleston a model of health and ecologically sustainable living."[4] The Charleston Green Plan is the creation of over 800 citizens who want to have "cleaner, greener and more sustainable choices". The plan's recommendations are divided into five categories: (1) better buildings; (2) cleaner energy; (3) sustainable communities; (4) improved transportation and (5) zero waste. To implement the recommendations in the Plan, the City developed a "Sustainability Strategic Plan", a set of initiatives designed specifically to elevate and prioritize combined sustainability and economic development activities.

Downtown Charleston Food Deserts

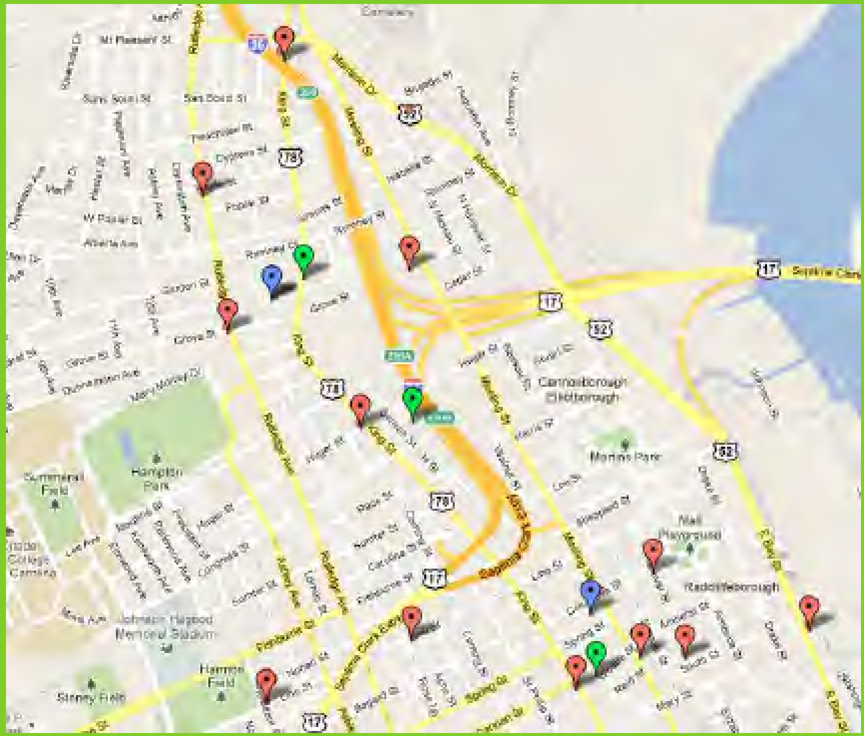
According to the U.S. Census Bureau, the percentage of people living in poverty in the City of Charleston was 17.2% for 2005-2009[5]. Since 2008, there has been a 53% increase in the number of households who receive food stamps in Charleston County[6]. For many lower income residents in the downtown area, the closest stores with food are the convenience stores, which offer no fresh produce and mostly processed food items. These areas with limited access to healthy, reasonably price food are considered "food deserts". The downtown area evaluated for candidate properties has many convenience stores, but only one grocery store which is inaccessible to many residents unable to walk this distance or pay for transportation.

One option for downtown residents who can obtain transportation is to purchase fresh produce at the Charleston Farmers Market, which operates on Saturdays from April to December. The farmers at the market accept WIC and EBT vouchers. There has been a recent and growing movement in the Charleston area to strengthen community support of local independent businesses and farmers. Reasons given to buy local range from fresher and better tasting produce to healthy eating and supporting the local economy and sustainable land use. Ten percent of farmers selling produce at the city farmers market are located within a five mile radius of the market. The average vendor travels 25 miles and 35% of vendors travel from more than 20 miles away[7].

In order to address social justice issues related to access to fresh and local produce within lower socio-economic communities, direct local produce distribution must be provided. A vertical farm within or nearby such a community could not only provide the produce and distribution sources, but it could also become a resource providing educational components to teach about the importance of good nutrition and creating jobs within the community.

Renewal Community

The area from which the property candidates were selected is within the "Renewal Community". The Renewal Community mission is to foster economic and community development by creating programs that will empower local businesses and residents. Charleston's effort is focused on: (1) fostering economic development; (2) neighborhood revitalization; and (3) improving the delivery of health and human services.The Greater Charleston Empowerment Corporation (GCEC) a 501 (c) (3) non-profit organization administers the Renewal Community Program in partnership with the City of Charleston. The GCEC board of directors, which includes representatives form the 19 neighborhoods making up the Renewal Community, meets regularly to make decisions regarding the implementation of various programs offered in the Renewal Community.



Google Map showing Renewal Community area in downtown Charleston.

- Green Pins = property candidates
- Blue Pins = major grocery stores
- Red Pins = convenience stores

PROJECT OBJECTIVES

1. Develop a feasibility study, which will include design options for the vertical farm and innovative research and educational components.

2. Conduct two charrettes for stakeholders to insure community input into the Vertical Farm project.

3. Incorporate the Intelligent River® cyberinfrastructure network into the design to provide real-time remote data acquisition to monitor and operate the Vertical Farm and link the Vertical Farm into the Intelligent River® research portal (www.intelligentriver.org).

4. Develop a long-term funding plan for construction and operation of the Vertical Farm.

5. Develop a partnership Memorandum of Understanding between Clemson University and the City of Charleston, which provides a mechanism for bringing in local universities, technical schools, and local high schools into a collaborative research and management program for the Vertical Farm.

WORK PLAN

PHASE 1

Task 1: Work Plan Preparation, *Target Date: November 10, 2010*
Clemson University will prepare a draft work plan that outlines, describes and includes the technical approach, resources, timeline, due dates for deliverables, cost estimate and staffing by task.

Task 2: Work Plan Revision, *Target Date: November 15, 2010*
Upon receipt of comments from the Contracting Officer, Clemson University will revise the work plan and resubmit.

PHASE 2

Task 1: Kick-off conference call between Clemson University, the City of Charleston and WA COR. *Target Date: Mid January 2011.*

Task 2: Design Feasibility Analysis Study Outline, *Target Date: June 2, 2011*
Task 1 will include a Clemson University shall prepare a design feasibility study for the City of Charleston. Clemson University will work with the City of Charleston under technical direction from the WA COR to identify existing under utilized building stock that could be potential sites for the Vertical Farm. An interdisciplinary team will conduct the analysis, which focuses on agriculture, horticulture, green building and architectural potential of the sites. The design analysis will result in the identification of at least one primary building to support development of the Vertical Farm.

Task 3: Working Partner Meetings, Dates: May - July, 2011
Clemson University shall organize meetings with the City of Charleston to define the building criteria, select candidate properties and establish a working MOU between Clemson, the City and other institutions.

Task 4: Stakeholder Design Charrettes, Fall 2011, *Dates: September / October 2011*
Prior to development of the first draft of the feasibility study, Clemson University shall work with the City of Charleston to conduct two design charrettes with stakeholders. Clemson University will provide note-taking support and logistical support to record and document the input from charrette sessions and produce a comprehensive summary report of the findings and lessons learned from the charrettes. Feedback from the charrettes will be incorporated into the first draft of the feasibility study.

Task 5: Technical Resolution Design Charette, *Date: November 2011*
After completing the design charrette, faculty and invited experts will meet with the Vertical Farm Architecture Studio to review conceptual building plans and seek resolution to technical issues raised by participants and faculty.

Task 6: Design Feasibility Study Document, *Target Date Draft: November 7, 2011, Target Date Final: November 17, 2011*
Clemson University shall develop a draft Design Feasibility Study, which incorporates the findings of the charrettes and will be distributed to identified stakeholders for review and comment. Upon receipt of feedback, Clemson University will produce a final report and PowerPoint presentation of the final study. The PowerPoint will be presented to the City of Charleston by EPA Region IV personnel.

Prepare the Work Plan *November 2010* ➔ Kick-off Meetings, Team & Partner Meetings, Prepare Study Outline *January - July 2011* ➔ Stakeholder Design Charrettes *September - October 2011* ➔ Technical Resolution Design Charrette *November 2011* ➔ Design Feasibility Study Document *November 17, 2011*

LOGIC MODEL

The outputs and outcomes are outlined in the logic model below:

Design Feasibility Study for Innovations in Building Repurposing through Vertical Farming.

Assumptions: Management of urban-based agriculture in the 21st century will require a transformational shift in the farming concepts and methods for acquiring data, storing data, processing data, and utilizing the data to monitor and manage agricultural resources at multiple scales. This leap will require innovations in urban farming and advanced environmental informatics.

Baseline and Program Impediments	OUTPUTS			OUTCOMES		
	ACTIVITIES	**OUTPUTS**	**PARTICIPANTS**	**SHORT TERM**	**MEDIUM TERM**	**LONG TERM**
Current Conditions 1. South Carolina is losing 35 acres per day of prime farmland, resulting of critical loss of farms "at the edge" which is responsible for 91% of fresh fruits and 78% of produce. 2. Urban agriculture provides an opportunity for increasing fresh, organically grown produce. 3. The development of urban-based farms and Vertical Farms or Tower Farms offer an opportunity for city dwellers to raise a significant amount of fresh fruits and vegetables. 4. Various observational systems are being developed for earth monitoring but most are too costly and power inefficient to provide the robust real-time remote data acquisition system necessary to transform management of agriculture on multiple watershed and landscape-scales. 5. The leap from concept to operational Vertical Farm will require new computer hardware and software for monitoring and management. 6. Adequate funding is a critical issue	1. Establish an interdisciplinary research team of ecologists, computer scientists, agricultural engineers, horticulturalists, civil engineers, electrical engineers, green building experts, architects, landscape architects, and market analysts to work with the City of Charleston to develop the conceptual plan and feasibility study for creation of a vertical farm through repurposing a building in downtown Charleston. 2. Prepare a work plan that outlines, describes, and includes the technical approach, resources, timeline, and due dates for deliverables; a detailed cost estimate by task; and a staffing plan, 3. Conduct kick-off conference call with EPA and contractor. 4. Identify buildings for farm. 5. Conduct two public charrettes or workshops with stakeholders for up to 50 participants. 6. Develop novel hardware and software to enable an energy efficient remote data acquisition system to operate the vertical farm and link into the Intelligent River. 7. Develop funding options.	1. Feasibility study to support the development, construction, and operation of the Charleston Vertical Farm 2. MoteStack (patent protected) novel hardware and software system that is easily integrated into the Vertical Farm monitoring and management which incorporates extensive power-management and multiple connectivity options 3, Novel middleware applications and long-term database management system that is highly scalable. 4. Visualization technologies that utilize GIS and 3-D photo-documentation with real-time data to produce virtual photo-realistic images of the Vertical Farm and to project future scenarios based on data inputs. 5. Journal articles and presentations on technology.	1. An interdisciplinary faculty and graduate students that bridge science, agriculture and informatics 2. City of Charleston 3. Key stakeholder groups 4. EPA Region 4 and WA COR 5. Web-based interested parties. .	1. Development of the feasibility study and conceptual design for the Charleston Vertical Farm project that incorporates novel hardware, software, and integrated technologies to monitor and operate the Vertical Farm and link the project to the Clemson COEEs in Sustainable Development and Urban Ecology and the Institute of Applied Ecology. 2. Develop pilot scale connectivity to the Intelligent River© environmental informatics system. 3. Presentation of the Vertical Farm and Intelligent Farm© research through journal articles, conference presentations, and short-term demonstrations. 3. Development of a working group of stakeholders, including City of Charleston, Clemson University, EPA, and local stakeholders to move the concept forward. . 4. Introduction of the Vertical Farm and Intelligent Farm© research to appropriate municipality sectors that would best utilize the technologies. 5. Seek funding partners.	1. Demonstration of a pilot-scale Vertical Farm that incorporates Intelligent River© real-time remote data acquisition IP to monitor and manage all key sectors of the Vertical Farm; incorporates wind and solar energy to power the farm; and incorporates harvesting of rainwater, composting, recycling, and sustainable agricultural practices. 2. Develop long-term public-private funding agreements and begin to license novel technologies or internally create a knowledge-based business to bring the Vertical Farm concept to the market.	1. Build a fully functional Vertical Farm. 2. Develop novel sensors to expand the water quality and water chemistry parameters of the farm. 3. Fully incorporate wind and solar energy to power the farm. 4. Enhance Vertical Farm technologies through the incorporation of advanced materials to create recyclable and nonhazardous components that are deployed in the Vertical Farm.

STRATEGY

The Charleston Vertical Farm Design Feasibility Study was initiated by forming an interdisciplinary research team of faculty and students from multiple disciplines within Clemson University who would identify and evaluate key elements associated with building a vertical farm. The study elements were identified through a series of team meetings and data sharing tools. The next step was to engage a broad team of planning and building experts within the City of Charleston to evaluate potential building sites and communities and to assist the Clemson team in developing a short list of candidate buildings for repurposing into a vertical farm. The community engagement process followed through two charrettes. The Clemson team and invited experts then met for a third internal charrette to seek technical resolution to design issues. A final report was developed that incorporated all elements of the study.

Interdisciplinary Research Team

An interdisciplinary team of faculty and graduate students was created to bridge the multi-discipline elements intertwined within the vertical farm feasibility study. A spreadsheet (*see Appendix B*) was developed to identify each team member and their expertise, general topics they would evaluate for the project and specific topics they would champion. All elements could not be evaluated within the scope of this study but were identified for inclusion into a future building program document necessary to issue a Request for Proposal to construct the vertical farm.

A secure online WikiSpaces site was created at no cost and utilized for data sharing and project management among the team members. The WikiSpaces site was used to share documents, links, news, important dates and materials from the charrettes.

Team member assignments were as follows:

- LOCATION - all team members
- BUILDING - architect, civil engineer, landscape architect
- ENERGY - civil engineer
- WATER - water quality scientist, civil engineer, agriculture specialist, ecologist
- CROPS / AQUACULTURE - agriculture specialist, water quality scientist
- OPERATIONS - all team members
- ECONOMICS - all team members
- FUNDING - ecologist, development
- LEGAL - ecologist, City of Charleston
- SECURITY - all team members
- MARKETING / EDUCATION - all team members

Partner Engagement

Effective communication with partners is essential for a successful feasibility study. Early meetings with the City of Charleston's Director of Sustainability focused on engaging the talent pool needed from the City of Charleston, communication issues between partners, and development of a working MOU to outline team responsibilities. Community engagement for the charrettes was handled by the Clemson team in an effort to develop three balanced teams of participants with expertise in architecture, design, planning, community engagement, urban revitalization and culture.

Student Involvement

Both graduate and undergraduate students were assigned roles within the project to allow them to work beyond traditional classroom assignments to enhance their knowledge and develop a greater understanding of their discipline. To facilitate the learning process, a pilot vertical farm program was initiated on campus by faculty and students which included cyberinfrastructure-enabled hydroponics and green roof technologies.

The location of the pilot project is the Biological Sciences greenhouse facility located on the roof of Jordan Hall. Elements being evaluated include an installed 10' x 10' green roof donated by Green Roof Outfitters of Charleston and a cyberinfrastructure-enabled aeroponics unit. Elements soon to be added include a vertical wall and moveable garden beds. The Intelligent River® cyberinfrastructure network is being incorporated into the elements to provide real-time remote data acquisition to monitor and operate any installed equipment and link into the Intelligent River® research portal (www.intelligentriver.org). The pilot project will assist in identifying educational components as well as test the technology.

A graduate student from the School of Computing was brought in to assist with the pilot program. The student's principal responsibility was the development and deployment of a prototype system for automated vertical farming. The project involved the construction of a vertical growing system with integrated sensing (TDS, pH) and actuation (pH pumps, nutrient pump).

Additionally, an undergraduate student from the School of Architecture was provided a summer internship to focus on pilot project opportunities and interact with the graduate students during the charrettes for the undergraduate research experience.

Green Roof installation on roof of Jordan Hall

Architecture Graduate Studio

To meet the design challenge posed by the feasibility study, a graduate architecture studio was conducted in concert with the feasibility study. Although not funded through the feasibility study contract, this studio became a key driver in conducting meaningful charrettes and executing the design portion of the feasibility study. Charrette participants needed to visualize the vertical farm concept and the studio team provided that critical frame of reference.

Architecture graduate students worked within their teaching space on campus and traveled to Charleston to evaluate potential buildings and to attend and assist faculty with the charrettes. These students were tasked with researching the vertical farm concept and the region for the proposed project location and developing PowerPoint presentations for the participants at the first charrette. During their research, the students designed and provided a project logo for project materials. The students also assisted charrette participants by creating PowerPoint presentations to provide immediate feedback on team assessments. This immediate feedback was greatly valued by participant teams and allowed them the freedom to explore ideas within a limited time frame. After the first charrette, the students worked in teams to design small-scale models of designs to repurpose the selected building, incorporating participant input. Students attended the second charrette to explain their design process, how they incorporated participant input, and to solicit participant S.W.O.T. analyses of all the models. This feedback was utilized to refine models for review by the faculty team during the Technical Resolution Charrette.

ARCH 893 Graduate Students with Professor Dan Harding

Project statement for ARCH 893 Comprehensive Studio

Topic - Charleston Vertical Farm: Funded and sponsored by the Environmental Protection Agency, the Charleston Vertical Farm is a direct continuation of the research initiated by Gene Eidson and the Clemson Institute of Applied Ecology. The project acts as a feasibility study in collaboration with the Clemson Centers of Economic Excellence in Urban Ecology and Sustainable Development to retrofit an existing historic structure in the city of Charleston. Through a series of community charrettes, members of a variety of disciplines in the Charleston community have the opportunity to share ideas about their expectations for the unprecedented vertical farm. In the first charrette, community members presented pros and cons for each of the three potential historical sites and voted on the most appropriate site for the feasibility study. In the second charrette, students presented project proposals for critique and community members presented a SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis for each of the projects. With these suggestions, students redeveloped their designs for a final public presentation.

Challenge - By the year 2050, nearly 80% of the earth's population will reside in urban centers. According to conservative population estimates, the world population will increase by about 3 billion people during the interim. It is also estimated that about 80% of current farmable land throughout the world is in use. It is likely that there will not be enough farmable land in the future to feed the world population. One potential solution is vertical farming in urban spaces. In Charleston, South Carolina, the EPA has sponsored a grant to explore the feasibility of this vertical farming solution in a selected site on the downtown peninsula. The existing building must be retained, however, any new construction on or around the parcel is allowed. The height restriction for this neighborhood is a 50' maximum. The challenge for the students is as follows:

1. Provide a design scheme that meets the production needs of a vertical farm within the constraints of the program and existing building envelope on the site in downtown Charleston. This requires that at least 3 floors of the building are dedicated to production only farming.

2. Balance the aspects of a new production-oriented building with the needs of the surrounding community. This can be through public market space, comunity gardens, or educational opportunities within the building.

Program Development / Building Requirements - Develop a program for the EPA to assess the feasibility of a vertical farm in Charleston, SC. The final design should contribute to a "playbook" for the EPA with a focus on produce yields and vertical arrangement of space. It should address the controlled growing environment as required by indoor farm systems. It should take advantage of the existing 33,000 SF building, and it should be sensitive to the community in which it's sited. As zoned, the final design should not exceed 50 feet in height. The vertical farm should provide space for public use, yet maximize the building's farming potential. Following is a list of program spaces to consider. It is the responsibility of the student designer to determine the programmatic spaces based on their individual understanding, research, and approach to the project.

- farming facility
- seed germination facility
- offices
- loading and deliveries
- parking
- storage

Community Engagement:
- restaurant
- market
- classrooms

Research - Working in teams of two, develop and present poignant and complete research on the following topics (*see Appendix C for research presentations*):

1. Regional, state, and local (Charleston, South Carolina) climate, farming, transportation,culture, historical, environmental, context information
2. Regional, state, and local (Charleston, South Carolina) economic, demographic statistics, from social view point
3. Architectural precedents and case studies of urban farms
4. Design references and specific issues (including regulatory issues), in designing for vertical farm
5. Journal references, specific research and critical scholarship focused on vertical farm
6. Web references and specific groups/coalitions that focus on vertical farm
7. National food production, transportation, and starvation on the larger impact of vertical farm in the neighborhood
8. Understanding the how to function an urban farm, the ecology system behind the production
9. Skin in contemporary architecture: history, precedents and case studies
10. Structural: construction, material and methods, assemblies and logistics
11. Critical architectural history and theory platforms for different opportunities: Mobile Architecture, Convertible Architecture, Roll-up Structures, Expanding Structures
12. Critical architectural history and theory platforms that address social justice and the human condition (location, transportation, services)
13. Critical architectural history and theory platforms that address phenomenology and the human experience
14. Critical architectural history and theory platforms that address architecture's role in community connectivity, accessibility, and assistance
15. Critical architectural history and theory platforms that address sustainability, intelligent building practices as associated with the environment, place, and significant cultural factors
16. Critical architectural history and theory platforms that address vertical farming and facility for community
17. Understanding the history, precedent, design graphic communication, case studies, specific details/requirements for vertical farm, past projects and publications

In addition, following is a list of references on how a community center for vertical farming can greatly impact lives, organizations dedicated to helping the residents, along with examples of successful built projects. It is the responsibility of the student designer and / or faculty to determine the programmatic spaces based on their individual understanding, research, and approach to the project.

Charleston Context References

- Charleston, South Carolina From Wikipedia, the free encyclopedia http://en.wikipedia.org/wiki/Charleston,_South_Carolina

- Charleston, South Carolina's official web site for travel information and planning. http://www.charlestoncvb.com/

- Charleston Garden Tradition, Rosengarten- In the Master's Garden Beardsley- Art and Landscape in Charleston and the Lowcountry, 1998

Web References

- Architecture for humanity www.architectureforhumanity.org
- Next American City www.americancity.org/
- The Vertical Farm www.verticalfarm.com/
- The Vertical Farm www.iees.ch/EcoEng041/EcoEng041_verticalFarm html

- Urban Vertical Farming www.ateliersoa.fr/verticalfarm_en/urban_farm.htm

Precedents
- “Green Wall at the Solar Planetarium in Nagoya, Japan.
- Design Technologies: green wall panels, hydroponic pods, environmental controller, and LED grow light. http://ledgrowlightsreviews.net/.
- Green walls: Green Wall design, Greenworks; the Symbiotic Green Wall , Kooho Jung + Hayeon Kelly Choi
- Hydroponics: Rendering of Hydroponic System, Becoville + meldynique Group. AeroFlo hydroponic System. Diagram of Aeroponics System, Aeroponic systems
- Environmental Controllers: Seawater vertical farm, Studio mobile, Diagram-ventilation, Chris Jacobs. 5c. Circular Symbiosis Tower | 2011 eVolo Skyscraper Competition Winner
- Sustainable Energy: Methane digester for vertical farm design by Chris Jacobs. Underground organic farm training facility in Japan. 6c. Newark Urban Farm | Weber Thompson
- Dickson Despommier + Chris Jacobs. http://www.farmvertical.com Despommier. http://www.examiner.com/green-living-in-national vertical-farming-solution-to-climate-changedamage
- La Tour Vivante | SOA. http://www.ateliersoa.fr/verticalfarm_en urban_farm.htm
- The Living Skyscraper: Farming the Urban Skyline | Blake Kurasek http://blakekurasek.com/thelivingskyscraper.html
- LOFT London 2011 Competition Winner | VAWA. http://www.awrcompetitions.com/competition/2/loft-london-farm-tower
- Plantagon | Plantagon. http://plantagon.com/international/
- Eco-Laboratory | Weber Thompson. http://www.weberthompson.com eco-laboratory.html
- The Inka Sun Curve | Inka Biospheric Systems. http://www.inkabio.com/ag_suncurve.html
- Vertical Farm | The Kubala Washatko Architects + Growing Power http://www.growingpower.org/verticalfarm.html
- EDITT Tower | TR Hamzah + Yeang. http://inhabitat.com/editt-tower by-trhamzah-andyeang/
- The Dragonfly | Vincent Callebaut Architectures. (All) http://vincent.callebaut.org/planchedragonfly_pl07.html and http://www.gapuak.net dragonfly-building-concept-by-vincentcallebaut/

Design References
- The Vertical Farm: Feeding the World in the 21st Century, Dr. Dickson Despommier, Publisher: Picador (October 25, 2011)
- Vertical farming by Gilbert Ellis Bailey (Aug 27, 2011) Publisher: Nabu Press (August 27, 2011)

Case Studies
- Title Graphic: Green Wall at the Solar Planetarium in Nagoya, Japan
- La Tour Vivante | SOA.

- The Living Skyscraper: Farming the Urban Skyline | Blake Kurasek
- LOFT London 2011 Competition Winner | VAWA.
- Plantagon | Plantagon.
- Eco-Laboratory | Weber Thompson.
- The Inka Sun Curve | Inka Biospheric Systems.
- Vertical Farm | The Kubala Washatko Architects + Growing Power
- EDITT Tower | TR Hamzah + Yeang.
- The Dragonfly | Vincent Callebaut Architectures.

Site - The Charleston Vertical Farm Project is a redevelopment of the Port City Paper building located at 1056 King Street. The project strives to take the most historical part of the United States and combine it with some of the most innovative technology of architecture to continue to move Charleston into the future.

Sustainability - The main issue behind this project is that of population growth and food availability. It is predicted that by the year 2050 the world population will reach 9 billion and 80% will reside in urban areas. Concerns regarding limited land availability and the current amount of farmland have demanded a need for sustaining our agricultural practices in efforts to prepare for increasing food demands. The densification of urban areas will require traditional farming methods to move into the cities which can be achieved with methods in vertical farming. The world's rapidly increasing demand for nutritious foods creates an agricultural problem that can only be solved with sustainable farming practices.

Sustainable agriculture is not a new idea as there are many current farming operations that practice sustainability. In regards to vertical farming, these sustainable farming methods can be implanted into the vertical farm model in order to create a new method of urban sustainable agriculture. Technology in hydroponic, aeroponic and aquaponic systems allow for crop production to be increased between 4 and 30 times the yields achieved in horizontal farming and crop volume also increases as one acre of hydroponics can equal approximately nine acres of farmland. Since these technologies require very high energy levels, the vertical farm building itself has to also use sustainable building systems. The controlled environment of the vertical farm can incorporate solar technologies, wind turbines or methane digesters in order to generate its own electrical needs. Other technologies like thermal and aerodynamic ventilation, thermal mass storage and rainwater collection systems are additional self-regulating elements that can add to the efficiency of a vertical farm.

The planning and construction vertical farm environment must aim to provide healthy and organic crops to the local residents in the long term. The quality of the food grown and the volume of food produced is the essential goal of the vertical farm and the area in which the architect should apply sustainable practices. Additionally, these sustainable practices should also be efficiently sustained to create a self-regulating environment and operation. The main objective is to achieve overall sustainability in the vertical farm through the integration of form and function, construction and aesthetic, architecture and nature into a complex ensemble.

Following the 2011 goals of Clemson University, a minimum requirement of the University is that all projects achieve a LEED silver rating. Although the project will not be evaluated by the LEED rating system, the level of sustainability will be verified by a checklist, developed at Clemson University and similar to the LEED rating system.

Structure / Material - One of the requirements was to maintain a large portion of the existing structure of the Port City Paper building. The existing building is composed on a concrete pile foundation, a series of 24 concrete columns, 12 steel bow trusses, and brick infill.

The addition to the structure is open for interpretation, which includes but is not limited to: steel, concrete, glass, or wood. Considerations of material choice should be taken because Charleston, South Carolina is located in an earthquake and hurricane climate zone.

Structural steel offers strengths in building design, which includes high resiliency and performance under hard weather conditions while maintaining the ability to span a great distance allowing for a more open floor plan for higher crop yield.

A popular choice for greenhouse construction includes ETFE, which may be applicable for vertical farming. The use of glass or translucent materials would be strongly encouraged to allow maximum daylight and avoid the dependency on artificial lighting.

Presentation Deliverables

MODELS: The studio will explore designing a vertical farm through both digital and physical models. The physical models will place a strong effort on craft and will strengthen the studio dialog.

WEBSITES: To connect the public with the project every team is required to build and maintain a website that displays their research and progress of their project. There will also be a general information website for the entire studio. The site will feature basic research information and links to the other team's individual websites.

DESIGN CHARRETTE: To comply with the guidelines of the EPA the studio will take part in two design charrettes in Charleston, SC. Information from these charrettes will directly inform the work and culture of the studio.

PUBLIC EXHIBIT: At the end of the semester the work of the studio will be exhibited in Charleston, SC. The exhibit will be open to the public and eventually be exhibited at EPA Region 4 headquarters, in Atlanta, GA.

Schedule for Design Studio

Review Project Research ➔ Pre-Programming for Charrette ➔ Charrette 1 ➔ Review Concept Schemes ➔ Phase I Deadline - Program / Schematic Design ➔

➔ Review Massing & Building Planning ➔ Charrette 2 ➔ Review Final Designs ➔ Review Structure & Mechanical ➔ Review Envelope ➔

➔ Phase 2 Deadline - Design Development ➔ Exams & Final Reviews ➔ Phase 3 Deadline - Final Design

Community and Media Relations

Community engagement strategies were organized to educate audiences on the project and provide information on the project progress, building future support to construct a pilot-scale vertical farm in Charleston, SC.

A news release (*see Appendix D.1*) was distributed on May 10 by Clemson University to announce the award and project focus. Media coverage (*see Appendix D.2*) from the release included:

Clemson University institute to study 'vertical farming' feasibility in Charleston (Clemson University Newsroom - May 10, 2011)

- Charleston Regional Business Journal
- GSA Business (Greenville, Spartanburg, Anderson)
- upstatebizSC.com
- The Times & Democrat (Orangeburg, SC)
- MidlandsConnect.com
- Assorted online sites: The Digitel.com / InsideUrbanGreen.org

City may get 'vertical farm'
The Post and Courier (Charleston) - May 14, 2011

Clemson to conduct vertical farming study in Lowcountry
WCIV-TV ABC News 4 (Charleston) - May 25, 2011

To strengthen community engagement after the media announcement, an e-list was developed to keep interested audiences updated on the progress of the project, as the Institute received numerous inquiries from Charleston citizens, nonprofit representatives and other University faculty (*see quotes below*).

> ***"I read with great interest about your project on vertical farming. I live in downtown Charleston and would like to know more about the project."***
>
> ***"I have been very interested in hydroponic, vertical gardening centers for a very long time. It was music to my ears when I heard of your program. I would be interested in getting involved with this project with whatever I could help with, if such an opportunity exists."***

A project web site (www.clemson.edu/appliedecology/vf_project) was developed and is hosted within the Institute site to provide background information about vertical farming and to keep interested parties informed as the study progressed. It will serve as a permanent archive for the project. The site provides summaries of the charrettes with video compilations, presentations and photo slide shows.

Project Web Site

Chronology of Team and Partner Meetings

All meetings took place in calendar year 2011 (*select meeting minutes are included in Appendix E*).

March 11 - Kick-off conference call between Clemson University and contractor.

March 22 – The first faculty team meeting was held to introduce team members, discuss deliverables, confirm due dates and begin development of an outline of what was to be included in the study *(see Appendix E.1)*.

April 18 – Faculty team meeting to develop an agenda for meetings and work plan and discuss how to bring students into the project.

April 20 – The official kick off meeting with EPA representatives to introduce the faculty team, member roles and discuss the work plan and deliverables *(see Appendix E.2)*.

April 25 - Conference call with City of Charleston to discuss planning for June 2nd partner meeting.

May 2 – Faculty team meeting held to work on the study outline.

May 9 – Faculty team meeting to review a current draft of the outline and assign categories to team members.

May 17 - Meeting with Biological Sciences greenhouse staff to discuss pilot project and student involvement.

May 25 – Faculty team meeting to prepare presentations and logistics for the meeting with the City of Charleston and finalize the design study outline.

June 2 – Partner meeting in Charleston with City representatives to discuss the concept overview, present key topics of the study outline, discuss site selection and charrette planning, as well as discuss 3 prospect sites. A local media outlet reported on this first meeting with the City of Charleston representatives *(see Appendix E.3)*.

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First vertical farm study meeting held in Charleston

WCIV-TV ABC News 4 - June 3, 2011

June 23 – Second partner meeting held as a conference call with faculty team, city partners and EPA to discuss the necessary criteria to meet the building selection. Eight candidate properties were presented and discussed *(see Appendix E.4)*.

July 8 – Faculty subcommittee members traveled to Charleston to meet with City of Charleston representative to tour and evaluate eight potential properties.

August 31 – Faculty team members discussed and developed an agenda and logistics for the first charrette.

September 5 – Students in the design studio presented research topics to the project principal investigator that would be shown at the first charrette.

September 16 – Faculty team members and partners attend the first charrette in Charleston.

October 4 – Faculty team members meet to discuss logistics of second charrette.

October 14 – Faculty team members and partners attend the second charrette in Charleston.

October 27 – Faculty team members meet to discuss project milestones to date, the organization of a third ‘technical resolution’ charrette and the organization of the final report.

November 9 – Faculty team members meet with design studio to resolve technical issues related to building concepts for the final report.

Preliminary Research

DESIGN FEASIBILITY STUDY ELEMENTS

1. Location
    - Constraints
    - Scaling
    - Zoning
    - Property Ownership, Purchase or Short/Long-Term Lease
    - L& Use
    - Public Perception
    - Transportation Access
    - Local Workforce
    - Carbon Footprint Audit
    - Brownfields Assessment

2. Building
    - Structural Integrity
    - Access
    - Environmental Assessment
    - Cost
    - Property Ownership, Purchase or Short/Long-Term Lease
    - Surrounding Structures
    - Building Dimensions
    - Amenable for Alternative Energy Options
    - Growing Structures (greenhouses, movable beds, covered areas)
    - Scaling
    - Repurpose versus New Construction

3. Economics
    - Cost-Benefit Analysis
    - Purchase versus Lease
    - Pilot Vertical Farm as Proof of Principle
    - Community Impact
    - Community Acceptance
    - Sustainability
    - Workforce
    - Environmental & Social Justice

4. Energy Analysis
    - Primary Energy Source
    - Alternative Energy Sources (wind, solar, geothermal, tidal)
    - Energy Back-Up
    - Access to Utilities
    - Building Size
    - Lighting Requirements
    - Seasonal Energy Requirements
    - Energy Usage Tracking

5. Water Analysis
    - Source, Utility Access, Guaranteed Supply
    - Rainwater Harvesting
    - Water Usage, Reuse, Recycling
    - Irrigation Requirements
    - Water Quality (continuous nutrient analysis, contaminant analysis, buffering requirements)
    - Water Budget

6. Crops
    - Candidate Crops
        - Harvest Time
        - Market for Products
        - Value of Crops
    - Growth Mechanisms
        - Organic or Traditional
        - Aeroponics
        - Hydroponics
        - Grafting
        - Vertical Growth
    - Pollinators (for enclosed crops)
    - Natural Pollinators
        - Mechanical Pollinators
        - Beneficial Insects
    - Aquaculture
    - Environmentally Friendly Pest Control
    - Composting

7. Operations
    - Maintenance
    - Personnel
    - Energy Costs
    - Recycling
    - Automation
    - Monitoring & Diagnostics
    - Intelligent River® Integration – novel hardware & software

8. Funding Mechanisms
    - Public/Private Partnership
    - Municipality Ownership
    - & Control
    - Non-Profit Ownership & Control
    - Consortia Pilot Program

9. Legal Issues
    - Liability
    - Ownership
    - Insurance
    - Covenants

10. Security Issues
    - Property
    - Access & Entry Limitations

11. Marketing & Education Component
    - Analysis
        - Identify Audiences
        - Identify Messages
        - Communication Methods
    - Audiences
        - Surrounding Communities
        - Regional Educational Institutions
        - Partners
        - Prospective Donors
        - Media
    - Messages
        - Community Benefits of Healthy Foods, Local Produce, Job Creation
        - Benefits of Research & Innovation for Healthy Foods
    - Methods
        - Project Web Site
        - E-List for Ongoing Communication & Updates
        - Media Articles, Coverage, Placement
        - Local Associations & Chamber Communications
        - Workshops, Public Charrettes, Seminar Series
    - Cooperative Extension Program
        - Supporting Teams
            - Horticulture
            - Natural Resources & Water
            - Agronomic Crops
            - Food Safety & Packaging
            - Economics

Identify Buildings

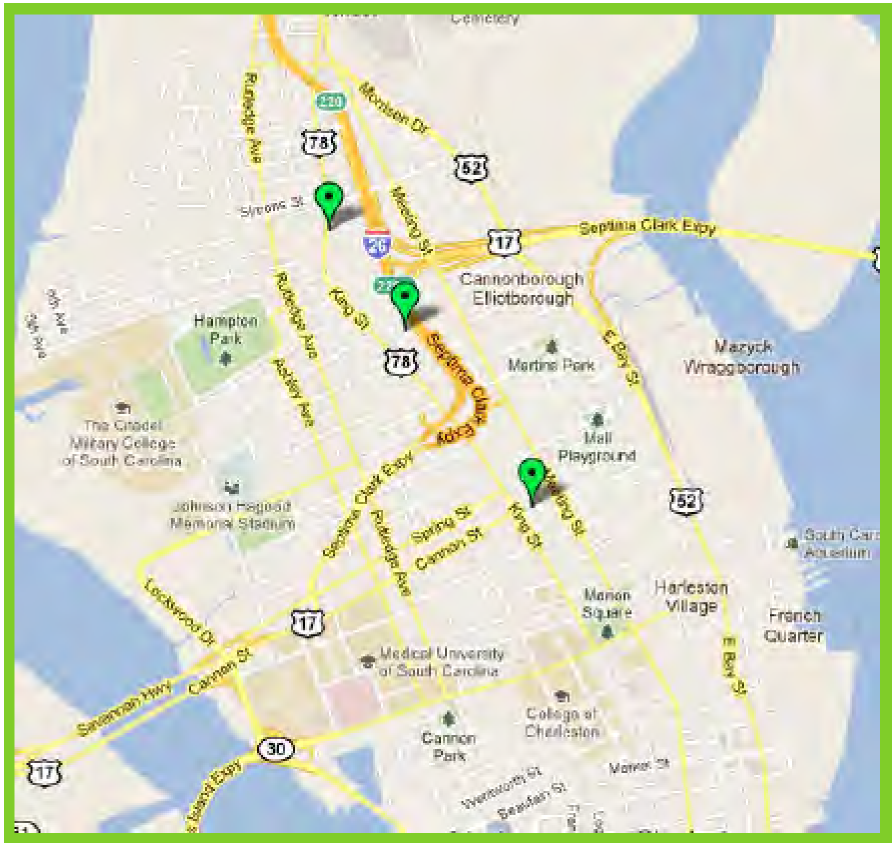
The City of Charleston was tasked with identifying candidate buildings for the study. The basic criteria for a building included:

- those that were for sale or for long-term lease,
- zoned as commercial, multistory or with multistory potential, and
- located in the more northern part of the peninsula.

In March 2011, the City of Charleston began pre-screening buildings for the candidate list. For the June 2nd partner meeting, four buildings were presented for consideration including a parking garage, a dairy facility, a historic trolley barn and a historic cigar factory. Except for the parking garage, all the properties had no operations and were for sale or long-term lease. City representatives at the meeting felt they could add more properties for consideration after they learned more about the concept of vertical farming and viewed the first round of property candidates. During the meeting, the building list was expanded to consider both purchase and five year lease options with the idea of conducting a 3-5 year pilot project that would later be replaced with a full-scale vertical farm. Some prospects were added at the meeting and more were suggested over the next few weeks.

Sites were added and deleted from the list over the next several months including an old football stadium, the top floors of an assisted living high rise complex, an old tire warehouse, under-utilized warehouses on S.C. State Ports Authority property and a former paper factory that housed a skating rink in the recent past. New construction sites that were in the planning process were also considered. In early July, faculty team members toured five buildings with a city representative to view the exterior and interior of each building. After the site tours, the list was finalized to present three candidate properties at the first charrette.

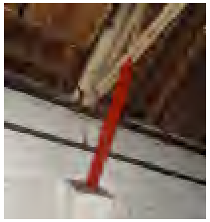
- Port City Paper Building at 1056 King Street
- Meddin Building at 32 Wolfe Street
- Target Tire Warehouse at 311 Huger Street



Locations of three candidate properties

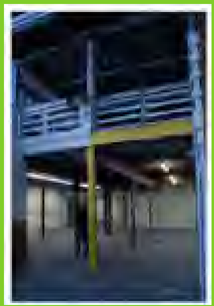
Port City Paper Building
1056 King Street

For sale, this property was originally constructed as a warehouse circa 1940, was later used as a roller skating rink and then retail use. The building features office and warehouse space on the first floor. The second floor is almost completely open warehouse space (roller skating rink area) covered by a free span barrel vaulted ceiling with exposed wooden and steel beams with a mezzanine area (*see Appendix F.1 for brochure*).



Meddin Bros. Building
32 Woolfe Street

For lease, 17,000 square foot brick warehouse with thick brick walls and mezzanine. 13,000 SF Main Floor, 4,000 SF Mezzanine Floor. Previously leased for storage, the building is structurally sound though in need of envelope improvements, plumbing upgrades, insulation, and conditioning improvements. Access to the mezzanine does not meet code (*see Appendix F.2 for brochure*).



Target Tire Warehouse
311 Huger Street

For lease, 1-story, 44,000 SqFt warehouse with 1,500 SqFt of office. Dock high loading across the front with five 8x8 overhead doors. Fenced-in side storage yard with additional loading dock & overhead door. Built in 1960. Interstate 26 and Ravenel Bridge on-ramps each one block East (*see Appendix F.3 for brochure*).

Charrettes

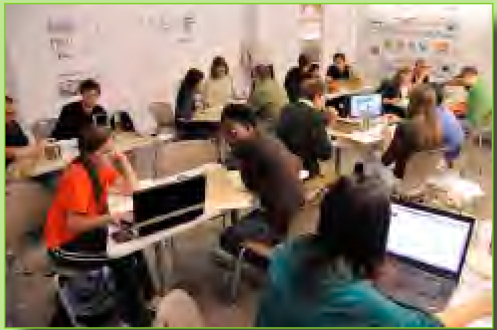
The purpose of the charrettes was to give the participants (stakeholders) enough information to make good decisions during the planning process and receive feedback and input. An invitee list was compiled with the assistance of local university contacts and included over 50 people who had expertise as architects, landscape architects, city and neighborhood planners, community food advocates, restaurateurs and those involved in the arts and culture community.

The first charrette, titled “Building Selection”, allowed the participants to learn more about the vertical farm concept and the candidate properties and then analyze and vote for the most appropriate property. The second charrette, titled “Building Design”, introduced the participants to various design models created by the architecture students as part of their design studio. The participants were then asked to help analyze each design with the students.

A third charrette, titled “Technical Resolution of Building Design”, was conducted on campus with faculty members and invited experts to resolve technical issues with the building concepts generated during the design charrette. This technical charrette challenged students to consider critical operational issues associated with the proposed vertical farm and provided a forum for important feedback between faculty and students.

Charrette 1: Building Selection

Charrette 2: Building Design



Charrette 3: Technical Resolution of Building Design

CHARRETTES

Charrette 1: Building Selection

Purpose

The purpose of the first charrette was to select one property in downtown Charleston as the candidate building for the vertical farm.

Planning

An invitee list was compiled with the assistance of local university contacts and included over 50 people who had expertise as architects, landscape architects, city and neighborhood planners, community food advocates, restaurateurs and those involved in the arts and culture community. The charrette administrator sent an email on August 31 to the invitees introducing himself, explaining the purpose of the project and the charrette process and notifying them that they would be receiving an invitation via email that requested an RSVP. An 'Evite' (www.evite.com) was then emailed on the same day to the list. Evite is a free online invitation and social planning service. Followup with invitees was as follows:

- A direct email sent as follow-up on September 6
- phone calls made on September 12 to all invitees who had not responded, and
- confirmation email sent on September 14 to invitees who had confirmed their attendance.

Format

The first charrette was held on Friday, September 16, 2011 in the community room of the Historic Charleston Foundation offices for a rental fee. The charrette began at 9:30AM with a coffee social and officially began at 10:00AM. There was a working lunch scheduled from 12:00PM until 1:00PM, and the charrette ended at 3:30PM. In keeping with the vision of the project the lunch was catered by a restaurant established by a Culinary Institute of Charleston graduate, with a menu focus on local and organic products.

A faculty team member was selected to facilitate the charrettes due to his experience in organizing and managing charrettes. The charrette administrator brought his students from the Clemson University Graduate School of Architecture's Community Resource and Design Center (CRDC) into the project by establishing a design studio focused on the project. The students developed presentations and materials for the charrettes and created PowerPoint presentations during the charrettes. Observers of the first charrette included members of the faculty team and several City of Charleston representatives.

A project overview was given by the principal investigator and the charrette administrator. The students created three introductory presentations for the participants: The Theory Behind the Concept of Vertical Farming; What Does Vertical Farming Mean for Charleston; and Charleston Vertical Farm Economics (*see Appendix G*). Charrette participants were divided into three groups for the day and were asked to consider many variables in making a case for the property they were assigned, including location in the community, needs and demographics of the surrounding community area, building structure and property footprint. The teams developed S.W.O.T. analyses (Strengths, Weakness, Opportunities, Threats) and site-concept profiles for their assigned property using three large 'chalk boards' that were imprinted with three views of the site – from its location on the peninsula, to the surrounding community and the actual footprint of the property (*see inset describing creation of the chalk panels on next page*).

Participants were able to bring a great amount of insight about the locations as they lived, worked or frequented areas where the sites were located. They looked at aerial views of the sites and considered surrounding community profiles such as nearby organizations and businesses, schools and educational facilities, transportation issues, resident demographics, housing types, safety issues and availability of grocery outlets. Participants also suggested what the vertical farm might house besides crops including community and education centers that would offer instruction on topics such as cooking and nutrition and information about the vertical farm itself. And there was discussion about how the vertical farm would distribute its produce throughout the neighborhoods.
Final presentations from the three groups were made at the end of the day

HANDSTORMING: Chalkboard Site Panels
The first charrette convened a diverse group of community members who were asked to help determine which of three pre-selected sites would be the “best” site for a vertical farm in the city. In order to encourage the generation of ideas and analysis, rather than building designs or plans, the CRDC fabricated a series of custom chalkboard site maps.

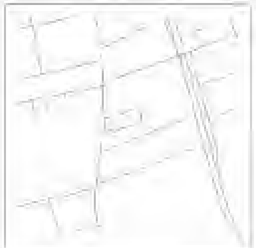
The process began by gathering aerial images at a variety of scales. The decision was made to create three scales of maps: one at the regional scale that showed a roughly five state area of the southeastern United States, one at the scale of the peninsula that showed surrounding bodies of water and other communities, and one at the scale of a neighborhood which showed the site and several blocks of context. The first step in creating the panels was to translate the GIS information into a CAD line drawing showing the centerline of streets and the outline of buildings. In order to encourage charrette participants to “fill in the map,” the information was condensed even further to simply show the surrounding roads and the outline of the site. A computer numerical controlled router (CNC) machine was used to cut the line drawings into 40” by 40” MDF panels. The MDF panels were then painted with chalkboard paint.

There were a total of three panels for each site, one at each scale. Participants were given chalk of various colors, sizes, and thicknesses and asked to fill in the map and document their conversation on the site panels. The chalkboard proved to be a novel approach to site diagramming that was accessible to all participants. Because the context was inscribed into the maps, every chalk line drawn physically intersected and interacted with the surrounding context. Participants were also much more comfortable drawing and writing with chalk, a medium that many had not used since childhood.


GIS Aerial


GIS Building Outline


CAD Overlay


Final Site Drawing

(*see Appendix G*), followed by a ballot vote by the participants to choose the candidate building for the vertical farm. The Port City Paper building on King Street was selected. Strengths of this location included the proximity of social service, educational and community-based organizations and transportation access such as bus stops and parking. Participants suggested an opportunity to partner with the Food Lion grocery store nearby and create a prototype for national business models.

Charrette 2: Building Design

Purpose

The purpose of the second charrette was to focus on a vision for the Vertical Farm building by reviewing and openly discussing numerous building design strategies for the Port City Paper site. Participants were charged with examining prototypes while providing meaningful, critical, and insightful feedback via a typical S. W. O. T. analysis (strengths, weaknesses, opportunities, and threats). The charrette shared a similar structure as the first event to capitalize on the diverse group of community members that had been invited.

Planning

A direct email was sent on October 5 to the same list of invitees. Follow-up phone calls were made on October 7 with another round of phone calls made on October 11 to all who had not responded. A confirmation email was sent on October 13 to all who had confirmed their attendance.

Format

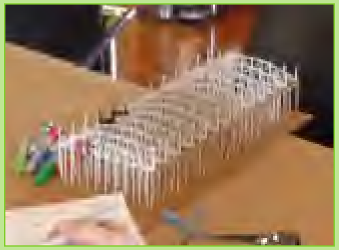
The second charrette for the Charleston Vertical Farm Design Feasibility Study was held on October 14, 2011, in Charleston. The charrette was held in the community room of the Historic Charleston Foundation offices. Participants who had not attended the first charrette were encouraged to bring their lunch to a 12:00 noon overview of the project and summary of the first charrette. The second charrette officially began at 1:00PM and lasted until 4:30PM. The same faculty team member served as the charrette administrator due to his experience with charrette development and management. For the second charrette, his students developed seven small-scale models of possible design ideas for repurposing the Port City Paper building into a Vertical Farm.

Eight participants attended the second charrette, four had attended the first charrette. Four other invitees who had RSVP'd, did not attend. The participants were assigned to one of the seven designs. For the first part of the charrette, the students explained their own model to the assigned participant, and after about 45 minutes, only the students rotated to another table to perform a S.W.O.T. analysis on a different model with the assigned participant.

Students and participants analyzed features such as floor plans, building height and length, building positioning on its lot, exterior and interior building materials, availability of natural lighting and overall design related to its location in the community. The students incorporated the discussion of each model into a PowerPoint presentation given by participants near the conclusion of the charrette (*see Appendix H*).

Participants and Students at Charrette 2

Student Design Models From Charrette 2



Charrette 3: Technical Resolution

Purpose

The purpose of the third charrette was to unveil design changes to each team's prototype that were made in response to participant input from the second charrette and to resolve technical issues related to each prototype.

Overview

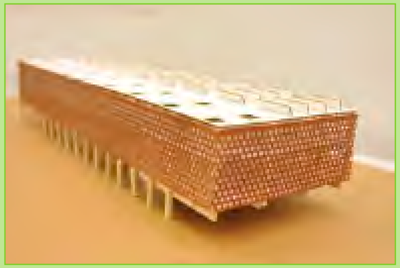
Project faculty were invited to the architecture studio to provide input on critical operational issues related to the seven proposed design models. The designs reflect an iterative process and further changes will be made to incorporate faculty input.

Format

The students were organized into seven teams of two persons each, and each team presented a six minute PowerPoint (*presented in* Studio Building Designs for the Charleston Vertical Farm *section beginning on page 45*) showing the exterior design and interior floor plans, describing the reasoning for their design model and explaining the services it would house for the community. Next faculty members spent ten minutes with each project team to provide feedback on the design elements that related to their areas of expertise. These comments will be utilized in the final refinement of each team's building.

Faculty talking with students at Charrette 3

Student Design Models From Charrette 3



Student Feedback from Charrette 3

"The charrette helped identify issues about farming and the related equipment that I don't know as an architecture student. That feedback will help us attempt to design the mechanical systems for farming as part of the building design." - Chris W.

"This week's Charrette was a helpful push towards a more developed understanding of some of the complex systems and strategies that go into a successful Vertical Farm. We had the opportunity to speak with an ecologist about the ecological aspects of our farming system and the life cycle of plants. He also brought to our attention the necessity of separation between plants to reduce the chance for the spread of disease amongst the plants. We also spoke with a water expert who helped us develop a more integrated water strategy for our structure. The experts that attended helped us to realize the amount of collaboration necessary, between disciplines, to design and achieve a successful Vertical Farm." - Thomas J. & Meghan W.

DESIGN FEASIBILITY STUDY ELEMENTS

Project Specific Information for the Port City Paper Building

Location

The location of the Port City Paper building offers a unique opportunity for a vertical farm pilot project. This building offers several benefits including its location within a 'food desert', a dense surrounding urban neighborhood and adjacent public uses. The surrounding area is a mixed urban neighborhood with a variety of residential and commercial uses. Its location on King Street makes this project both visible and accessible.

The adjacent buildings include the John Dart Library, Lowcountry Children's Center and a Head Start facility. The Port City Paper building is also across the street from a Food Lion. This location and building suggest that the vertical farm project should engage this public potential. Programming and design should conceptualize this project not just as a vertical farm, but also as an important catalyst for urban revitalization through educational and public uses.

Access - While the Port City Paper building has frontage and visibility on King Street, its primary access is from Poinsett Street. As with any urban building, careful consideration should be given to truck access, loading dock and parking requirements.

Stormwater BMPs - Most of this property consists of either building or paved surface. Consideration should be given to reducing the amount of impervious area with the use of pervious pavers for parking areas, on-site storm water treatment through constructed wetlands, bioswales or other bio-infrastructure methods.

Educational / Public - The Port City Paper building has a small area in the front along King Street that could be utilized as demonstration gardens or other educational uses. The space could reinforce the urban farm concept, sustainable farming, water recycling and sustainable materials.

Building

The Port City Paper building was chosen as the preferred building for repurposing into a vertical farm due to its location, existing structure, availability, and price point. The building has significant structural integrity in a hurricane and earthquake prone area due to the concrete pile foundation, 24 concrete columns, 12 steel bow trusses, and brick infill. The building has sufficient truck access with side and back parking lots that can accommodate moderate sized trucks and is surrounded by structurally sound buildings that do not impose serious restrictions on repurposing requirements, particularly natural light.

The City of Charleston has building height restrictions in the Port City Paper community that limits the building to 50 feet. The current configuration of two floors can be expanded to accommodate three floors plus rooftop solar panels and possibly small wind turbines. There is adequate space on the northern exposure to accommodate mechanical functions. A portion of the current parking area in the back of the building will accommodate new construction to house elevators and loading docks. Two vacant lots in the rear could be converted to parking and required outbuildings.

Economics

The economics of the project is case specific and beyond the scope of the feasibility study. The cost-benefit analysis that includes design, repurposing and building costs, outfitting costs, operational costs, workforce costs, etc. balanced against social justice and healthy food benefits for an economically depressed community could not be developed within the time frame and budget restrictions of the feasibility study. If the vertical farm is to move forward, the City of Charleston must develop a very detailed economics study to justify the project.

Energy

The energy demands of the Charleston Vertical Farm potentially located in the Port City Paper location will be dependent on many factors:

1. **Lighting** – Depending on the types of crops to be grown in the vertical

farm, natural and artificial lighting will be in high demand to ensure success. In its current condition, the building does not have any windows to the exterior, so there is no natural light on the interior of the building. Renovations to the building will address this deficiency, but will depend on the selected design. To supplement natural lighting, there will likely be a need for artificial lighting suitable for growing. In addition, there will need to be additional lighting for daily activities. It will be important to select lighting that has low energy demand and long life.

2. **Climate control** – Year round crop growth requires careful control of the growing climate depending on the types of crops to be grown. Fortunately, Charleston does not experience extreme cold, which will enable growing during the winter with relatively minimal need for artificial heating during the winter months. However, in the case of Charleston, the larger concern may be the extreme heat of the summer time and potential for drought conditions. This will require the growing climate within the farm to be monitored and kept at ideal temperatures, which may require significant cooling demands. Heating and cooling will also be dependent on proper insulation of the building. This is an old building and the current building envelope is not properly insulated. The redesign and renovation should focus on creating an efficient building envelope.

3. **Technologies selected for growing and harvesting** – Energy requirements for the farm will also greatly depend on the types of systems employed to accomplish the growing and harvesting at the farm. The larger the system, the larger the energy demand. Additionally, the more systems that are required for the operation will multiply the demands.

To make the vertical farm a sustainable operation it will be important to take advantage of renewable energy sources. The location and orientation of the Port City Paper building lends itself to use of photovoltaics as a source of electricity. The orientation is such that the long face of the building has a southern exposure and the building is not shaded on that side of the property.

Water

All crops require a quantifiable volume of water to reach full yield potential. High quality water is essential within a vertical farm framework for several reasons, including lowering the cost of screen or disk filtration, prevention of plugging in irrigation nozzles, and potential staining of containers or foliage. Many of the engineered systems needed to capture, treat, distribute, and recycle water within the context of a vertical farm are known. However, optimizing its use within the structural framework of a stacked, compartmentalized and controlled environment for urban food production remains to be fully explored.

1. Rainwater Harvesting: Depending on site selection, several techniques and practices might be utilized to harvest rainwater and minimize the necessity of accessing and treating potable water sources. Captured rainwater would be routed for temporary storage, distillation/ purification and eventual circulation.

2. Irrigation: Sensor-based open and closed irrigation systems will be employed to ensure peak delivery of water, nutrients and trace minerals for crop production. Analysis will include system determination for:
   a. Minimum and maximum volume required by specific crop and irrigation technique;
   b. Analysis for pressure, nozzle characteristics, pipe diameter;
   c. Discharge efficiency analysis feedback loop for supply and return lines.

4. Water Reuse and Recycling: It is assumed that all water not utilized directly by crops within the vertical farm will be collected, reused and recycled. Such a closed-loop system will lower the risk of pest infestation; reduce the use of costly pesticides and fertilizers, and eliminate agricultural runoff. Within the vertical farm construct, use categories will be defined (specific crops, aquaculture, heating/ cooling) with corresponding specifications for water quality and quantity.

5. Monitoring: Wireless networked sensors will be deployed to monitor water quality and quantity through the vertical farm. Minimum parameters would include flow, nutrient and micronutrient concentrations, electrical conductivity (TDS), hardness, bicarbonate alkalinity, pH and temperature.

Providing additional detailed information will require specifying design criteria for irrigation, fertigation, aquaculture, HVAC and plumbing, which is difficult to accomplish before deadline for the final report.

Crops

1. High Value Crops: Many crops can be used under vertical farm growing conditions. The following high value crops are selected for Charleston Area.

   - LEAFY GREENS: kales, mesclun mixes, specialty lettuces, mustards, and spinaches.
   - HERBS: cilantro, basil, and Oregano.
   - TOMATOES: different varieties of tomatoes suitable for greenhouse environment will be used.
   - CUCUMBERS: grafted cucumbers, rootstock to be determined.
   - SPROUTS: several different types.
   - STRAWBERRIES: suitable varieties.
   - EDIBLE FLOWERS: pansies, violas, nasturtiums.

   Other crops will be considered once we determine the environmental conditions of this specific operation.

2. Growth: Most of these crops can be grown in
   a) Soil,
   b) Aeroponics (air/mist environment with no soil and very little water). Aeroponic growing systems provide clean, efficient, and rapid food production.
   c) Hydroponics (growing plants using mineral nutrient solutions, in water, without soil). The water stays in the system and can be reused - thus, lower water costs.

3. Pollinators: Honey bees are not recommended as pollinators under greenhouse environment. Semi domesticated bumble bees and mechanical pollination will be used for the vertical farm.

4. Environmentally friendly pest management: insects such as (white fly, spider mites, thrips, aphids) and diseases such as powdery mildew and several others could create significant problems for food production under “vertical farm” conditions. These pests can be brought inside the vertical farm by workers, potting soil, plant containers, air coming through cooling pads, etc. Concepts will be adapted /developed to effectively manage diseases and insect pests with an emphasis on non-chemical approaches approved for certified organic crop production.

5. Fertigation: Since fertigation is a common practice with soil-grown crops, improvements in both irrigation strategies and nutrient supply are required for sustainable vertical farm production systems. Reuse of water and model-based systems in which irrigation and fertigation strategies are linked to crop demand provide the best prospect for improving sustainability. Additional improvements in sustainability could be achieved through reduction of nutrient application by utilizing advanced sensor technology.

6. Aquaculture: The vertical farm setting could serve as a fully contained and sustainable approach to processing seafood in an urban environment. Recirculating aquaculture systems, with many advances made by Clemson University researchers, provide the opportunity to scale production of certain commercially viable freshwater species within confined spaces. While the technology exists and can be integrated with other vertical farm systems, there are issues related to the building (structural integrity, system maintenance), energy (power consumption and refinement), and economic forces (competition from

pond aquaculture, low market prices) that must be reconciled before production could be fully optimized.

7. Water requirement: Water is becoming an increasingly scarce resource and there is increasing pressure on the greenhouse and nursery industries to use water more efficiently. For many years, it has been a common practice to water until water runs out of the bottom of the pots, and up to 50% of all the water may be lost this way. In addition to inefficient water use, excess watering results in leaching of fertilizer out of the pots. For soil-grown crop production, sensors will be used to water according to the needs of the plants, to minimize leaching while still achieving optimum growth. Aeroponic growing systems have potential to reduce water requirements by 70%. For hydroponics crop production, since the water can be reused, water requirements will be significantly reduced.

8. Light, temperature, and humidity: The most advanced cooling system available for hot weather production will be utilized.

9. Composting: Excess organic matter such as potting soil, plant material, and other material needed to produce high quality compost will be produced in conjunction with the vertical farm system.

10. Scaling: All above technologies can be scaled to the project operation size.

11. Effects on local market and local farmers: Green house varieties are different from field varieties and market windows are different therefore competition with local farmers will be minimum.

12. Other potential Crops: Trellised miniwatermelons.

Operations

Due to the likely implementation of sophisticated and hi-tech equipment, the vertical farm will require careful attention to maintenance requirements. This will also be necessary to maintain mechanical systems for climate control, irrigation, and lighting necessary for successful growing. Additionally, material selection will be key to the longevity of the farm. Equipment, furnishings, etc. in growing areas will be exposed to water, fertilizers, ultraviolet light, and other elements that can lead to the degredation of the materials comprising the systems.

During the operation of the vertical farm, recycling should be a consideration from the beginning. Recycling practices can be included through the life-cycle of the farm from construction through operation and then ultimately at decommissioning. Recycled materials should be considered for use in the construction of the farm. More importantly, the use of the existing materials in the renovation of the building for the vertical farm should be considered. This will reduce the demands of virgin materials and the embodied energy associated with their use. Throughout the operation phase of the vertical farm, every effort should be made to recycle growing media, water, fertilizer, and compost. This will enable the creation of a relatively closed-loop and highly sustainable system.

The Intelligent River® program at Clemson University is a campus-wide interdisciplinary initiative focused on the design, deployment, and commercialization of new technologies to support large-scale environmental monitoring and control. Since 2007, the team has developed a suite of new technologies that have been piloted across a range of applications. Specifically, the team has developed new (i) hardware and software platforms to support low-cost, long-lived, high-fidelity sensing; (ii) middleware systems to support high performance data collection, validation, storage, and dissemination; and (iii) data analytics tools to support interactive data exploration and discovery. When deployed, these individual components are assembled into a coherent sensing instrument designed to support real-time monitoring and control of both the natural and built environment.

While the architectural, economic, and social requirements of the vertical farm installation in Charleston are numerous and varied, the central goal of the effort is to enable dense and rapid crop growth in a confined planar footprint. To achieve this goal, each of the concept designs developed by the student teams rely heavily on hydroponic and aeroponic growth solutions. For these systems to maximize crop growth, a number of environmental and water parameters must be continuously monitored and controlled. The most important parameters include (i) pH/water, (ii) nutrient level/water, (iii) temperature/water, (iv) dissolved oxygen/water, (v) ambient temperature/air, (vi) ambient humidity/air, (vii) carbon dioxide concentration/air, and (viii) photosynthetically active radiation. Each of these parameters is readily captured using common-off-the-shelf sensors that provide industry standard analog and/or digital connectivity interfaces. These are precisely the interfaces the Intelligent River® system is designed to support.

The Intelligent River® is a central component of the Charleston vertical farm installation. A wireless network of in situ sensors will be deployed throughout the growing space to monitor individual growing cells, nutrient reservoirs, and ambient conditions. This information will be transmitted via the Internet to Clemson’s high performance computing backbone, where it will be received and processed through Clemson’s middleware system. In addition to routing the collected observation data to custom-designed analytics applications engineered to support real-time management of the vertical farm, the observations will be used to actuate the growing space, controlling each of the critical growth parameters.

Clemson has led active field deployments of the Intelligent River® sensing, middleware, and analytics tools for several years. The required actuation component is new. To assess the feasibility and technical challenges associated with this new component, the team constructed a fully automated, vertical aeroponic system similar in design to those proposed for the vertical farm. The growing chamber support approximately 100 plant sites, arranged vertically to reduce the horizontal ground footprint. The chamber includes integrated sensors to monitor (i) pH and (ii) nutrient levels. Sensor readings drive the actuation of integrated fluid pumps to automatically adjust the chamber’s pH and nutrient levels to ensure optimal plant growth. The design relies on the MoteStack sensing platform at the core of the Intelligent River® design, supplemented with additional control circuitry and supporting software. The system was successfully piloted in Clemson’s Jordan greenhouse for a period of approximately one month during the summer of 2011.

Funding Mechanisms

It is anticipated that the funding mechanism will be a public-private partnership between the City of Charleston, state and federal funding agencies, and private philanthropists. Once completed, the project is envisioned as a self-sustaining non-profit entity that will consist of a viable farming operation that will seek research and educational grants for community engagement.

Legal

Legal issues will have to be addressed by the City of Charleston if the project is to move forward. If a future Memorandum of Understanding (MOU) is developed between the City and multiple parties, the issues to be addressed will be outlined in that MOU.

Security

The property is bordered in the rear by an area that has experienced significant crime and is adequately fenced off. The general neighborhood is considered safe but there will need to be access and entry limitations and a heightened security placed on the vertical farm. The building is surrounded by properties in use for a host of community supports and is in a highly visible area that is undergoing positive change.

Marketing and Education

Primary audiences will need to be identified for marketing and education purposes. Audiences for this project include stakeholders, the media, educational institutions, local farmers, local grocers, architects, engineers and contributors. Stakeholders are made up of those who live and work in the surrounding community. These audience members may be prospect employees, recipients of the products, business owners or neighbors. Messaging for this group will include information about construction phases, services the program will offer and general security in regard to program operations and the building. The media will be an important audience through which project administrators will disseminate structured communications. Information disseminated through the media will keep other audiences updated on the program progress, events, milestones and operations. Educational institutions are an audience that the project will attract for research and learning purposes for students of all ages. Primary and secondary school students can learn about urban farming and nutrition, while higher education students in undergraduate or graduate status can be engaged through research programs developed around vertical farming operations. Local farmers could be an important partner and will certainly have ideas and networking possibilities to share. There are opportunities to partner with this audience to distribute their produce alongside the vertical farm products, as well as share farming education. Local grocers could be an additional source to distribute the fresh, local product. If needed, partnerships with this audience could provide an opportunity to distribute the program's products outside of the initial distribution areas and promote the program to a larger audience. Architects and engineers in the community should be engaged so they can share their knowledge about the project with residents and promote the project outside of the area through their professional associations and connections. Contributors are a primary audience as it is their funding that will support the project and allow it to grow and prosper.

Messaging from the program will include subjects such as community benefits of local fresh produce, good nutrition strategies, job creation, community sustainability and the educational benefits of research related to the program's operations and products. It will be important to highlight the benefits the program will bring to the community and region. The main source of communication for the vertical farm program will be its web site. The web site will provide detail on all facets of its operations, plans and progress. Other vehicles for communication would include subject specific e-lists, regular media coverage or scheduled articles, open community meetings and presentations and local professional and environmental associations.

Branding and messaging ideas were presented from charrette participants and students during the project. Creative marketing included tag lines such as:

- Grow. Cook. Eat.
- get hooked on ponics
- re:planting Charleston's urban food culture with local ROOTS

Strong branding for the program should include consistent images as well as wording. Logo ideas submitted included:

central farms

port city ponics

local ROOTS

Utilizing the expertise of local university faculty and Extension personnel will assist in disseminating educational benefits of the vertical farm program. Experts in the fields of horticulture, agriculture, landscape architecture, civil engineering and natural and water resources can not only provide their expertise in different facets of the program, but can also share their knowledge with application of the program operations to the general public.

Several educational components were recommended by participants and students during the charrettes and design studio which revolved around establishing a community center in the vertical farm building. Recommendations included a community garden, daily market, open-air farmer's market, a demonstration kitchen, market cafe, donation program, co-op program, and demonstration 'grow pods'.

LESSONS LEARNED

- Extensive baseline information is required before engaging a community with the concept of building a vertical farm in a highly urbanized area. A major university provides the interdisciplinary pool of expertise necessary to assemble baseline information around an initial concept of a vertical farm. Faculty members must be committed to many hours of meetings and travel necessary to participate in the community engagement process. During the study period, faculty teaching and research commitments proved problematic resulting in lower faculty participation in the charrette process than envisioned. Excellent communication through WikiSpaces and websites kept all faculty apprised of activities. In retrospect, greater faculty attendance would have been possible if charrettes were conducted during summer months, however, public participation would have been less so it is a delicate balance to achieve desired participation by all parties.

- The host city must be fully engaged throughout the feasibility study. For future studies, a fully executed Memorandum of Understanding should be in place prior to commencing baseline studies. During this study, the City was very engaged during the initial process of choosing a location, selecting candidate properties, and evaluating the concept within the constraints of planning and zoning. The city participation was less than envisioned for the community engagement process and charrettes. Faculty and city employees were asked to serve in an “observer” role during the charrettes to insure strong community engagement. It appears that this role of “observer” and not “participant” decreased ownership of the process and may have resulted in lower city participation.

- Extensive planning is required to assemble dedicated and balanced teams of charrette participants. To address the complex issues of siting a vertical farm in a highly regulated urban environment, balanced teams of architects, city planners, relevant nonprofit leaders, cultural experts, restaurateurs and community engagement experts, are necessary to carefully evaluate background technical information and buiding concepts.

- The architecture graduate studio was critical to the success of this feasibility study due to the short time frame, budget constraints, and technical expertise required to conduct this vertical farm feasibility study. The charrette process employed was extremely well received by team participants who dedicated many hours to the two public charrettes. The architecture graduate students provided the immediate feedback necessary to keep the charrettes on a fast pace and to help participants visualize their design concepts. The work products from the feasibility study would not have been possible without the technical assistance provided by the architecture students.

- The feasibility study is by nature a long-term iterative process and collapsing all the elements within a one-year time frame is ambitious even with the level of expertise involved in this study. The community engagement process involves building trust among a wide audience, which can result in a protracted process. The ideal time frame appears to be approximately two years, with the first year focused on developing a team of experts that will drive the initial concept and conduct baseline studies. The second year is one of community engagement, shifting the initial concept and vision to a community-based shared vision and utilizing the baseline information to move the design process forward. Charrette participants greatly appreciated the baseline work that gave them a strong frame of reference.

- All participants in the charrette process strongly supported the social justice and building repurposing components of the potential vertical farm and this was evident throughout the community-engagement process. There is strong support for moving the feasibility study forward and a vertical farm is viewed as a great opportunity to bring healthy foods into a lower socio-economic section of Charleston.

- Participants suggested that a pilot-scale vertical farm be developed as a proof of principle project and operated for a three to five year period to gain an understanding of the concepts of vertical farming and evaluate community engagement and acceptance. A major concern was dispelling the view of a vertical farm as a sterile laboratory that by its technical nature does not fit within the fabric of a community.

STUDIO BUILDING DESIGNS FOR THE CHARLESTON VERTICAL FARM

Design presentations from Charrette 3: Technical Resolution:

Design Model 1 - Informative Transparency by Kelly Fehr and Elissa Bostain

Design Model 2 - (no title) by Victoria Wright and Megan Craig

Design Model 3 - Conveyance System by Meghan Welford and Thomas Jasper

Design Model 4 - LOCAL ROOTS: Replanting Charleston's Urban Food Culture by Kristin Kolowich and Jon Michael Williamson

Design Model 5 - Port City Ponics by Chris Felegie and Joe McNeill

Design Model 6 - Grafted Vertical Farm by Chris Wilkins and Jared Moore

Design Model 7 - White Forest by Heather Zhang and Johnhoon Ahn

Design Model 1

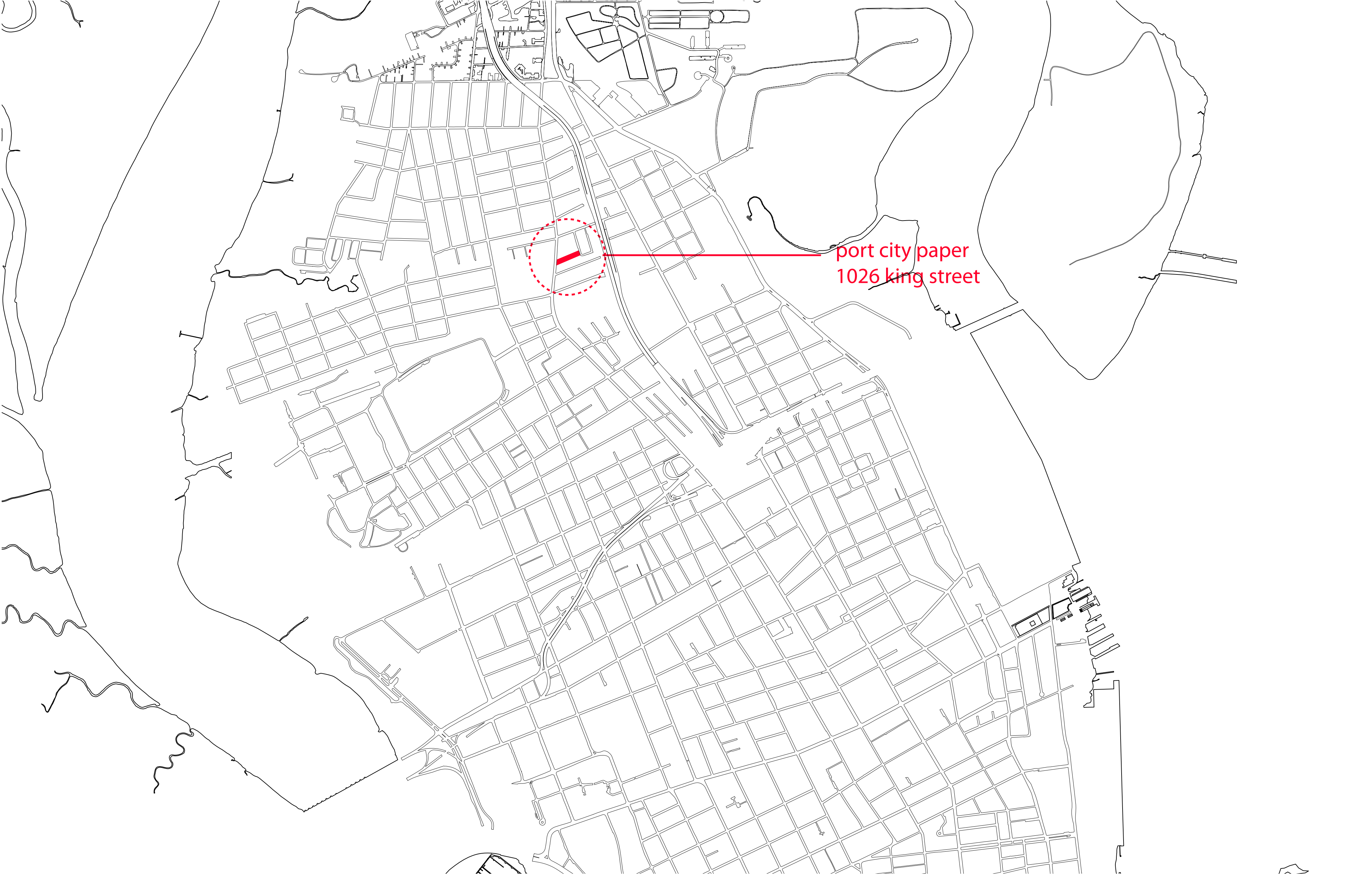
Informative Transparency by Kelly Fehr and Elissa Bostain

Design Summary

Our vertical farm proposes to use the existing structure to create a rhythm for our building. We have created 12 vertical volumes that house the 3 floors of grow rooms leaving the ground floor open for a farmer's market and other community programs.

Our concept derived from a symbiotic relationship merging the old and the new to successfully sustain the community. The success of the farmer's market depends on the vertical farm grow rooms for produce. The effectiveness and impact of the vertical farm on the community depends on the farmer's market.

We have several goals for the project overall. We have designed a roof structure on the first floor that pulls to King Street to create a Charleston front porch space, but also to pull the visitors through the building. This roof structure plays a role in the education of the visitors. We have created a layer of transparency throughout the building that allows the community to learn, view, and absorb the energy from the vertical farm.

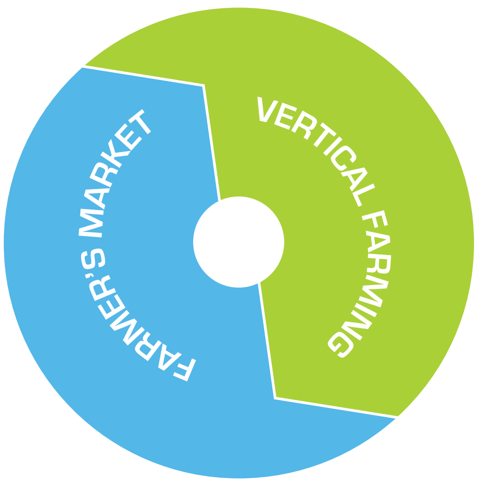


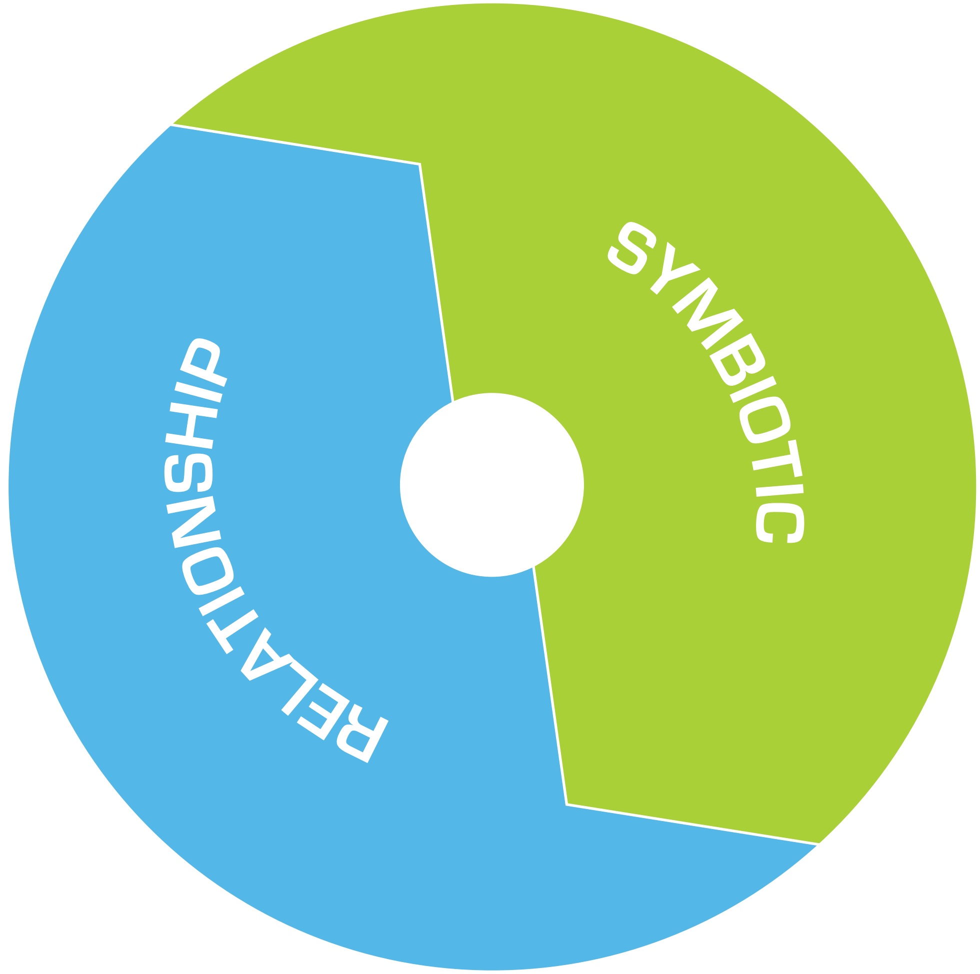
[charleston]
VERTICAL FARM

EXISTING PORT CITY PAPER BUILDING

[charleston]
VERTICAL FARM

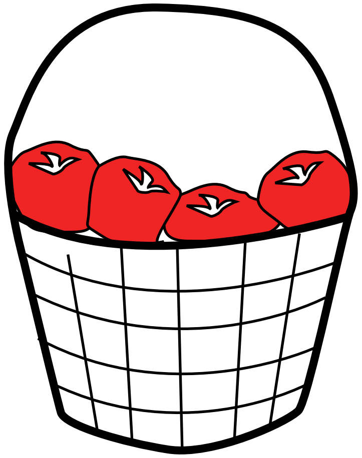
SUPERIMPOSED ON EXISTING





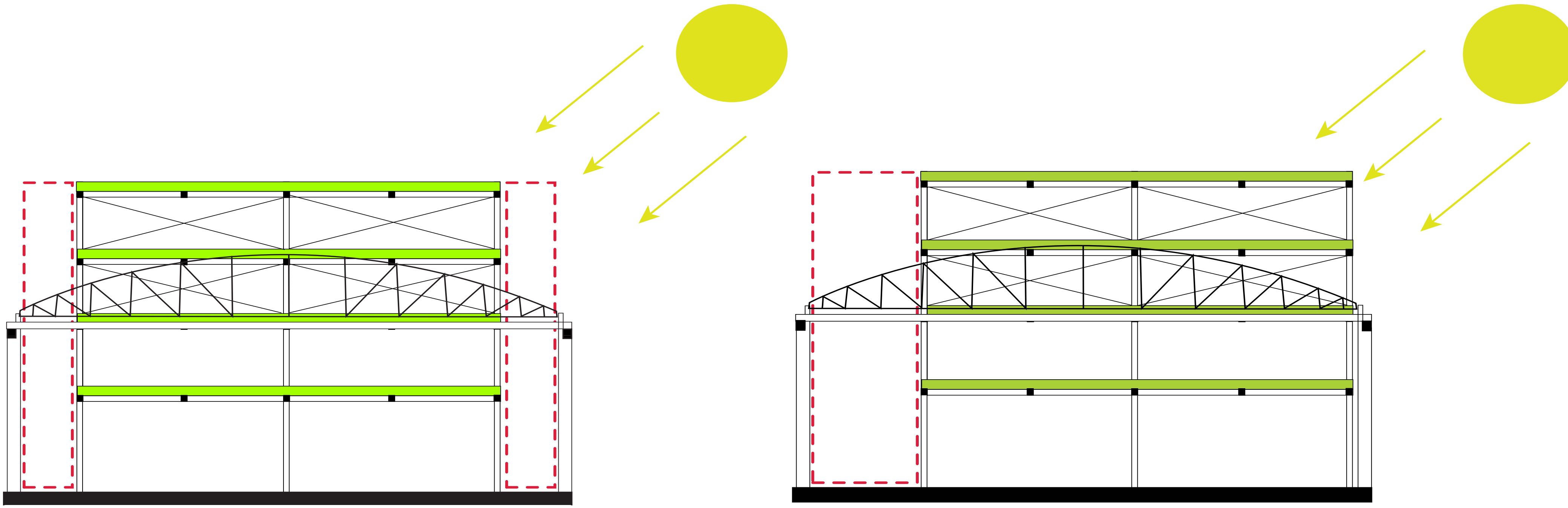
[charleston]
VERTICAL FARM

SYMBIOTIC RELATIONSHIP CONCEPT



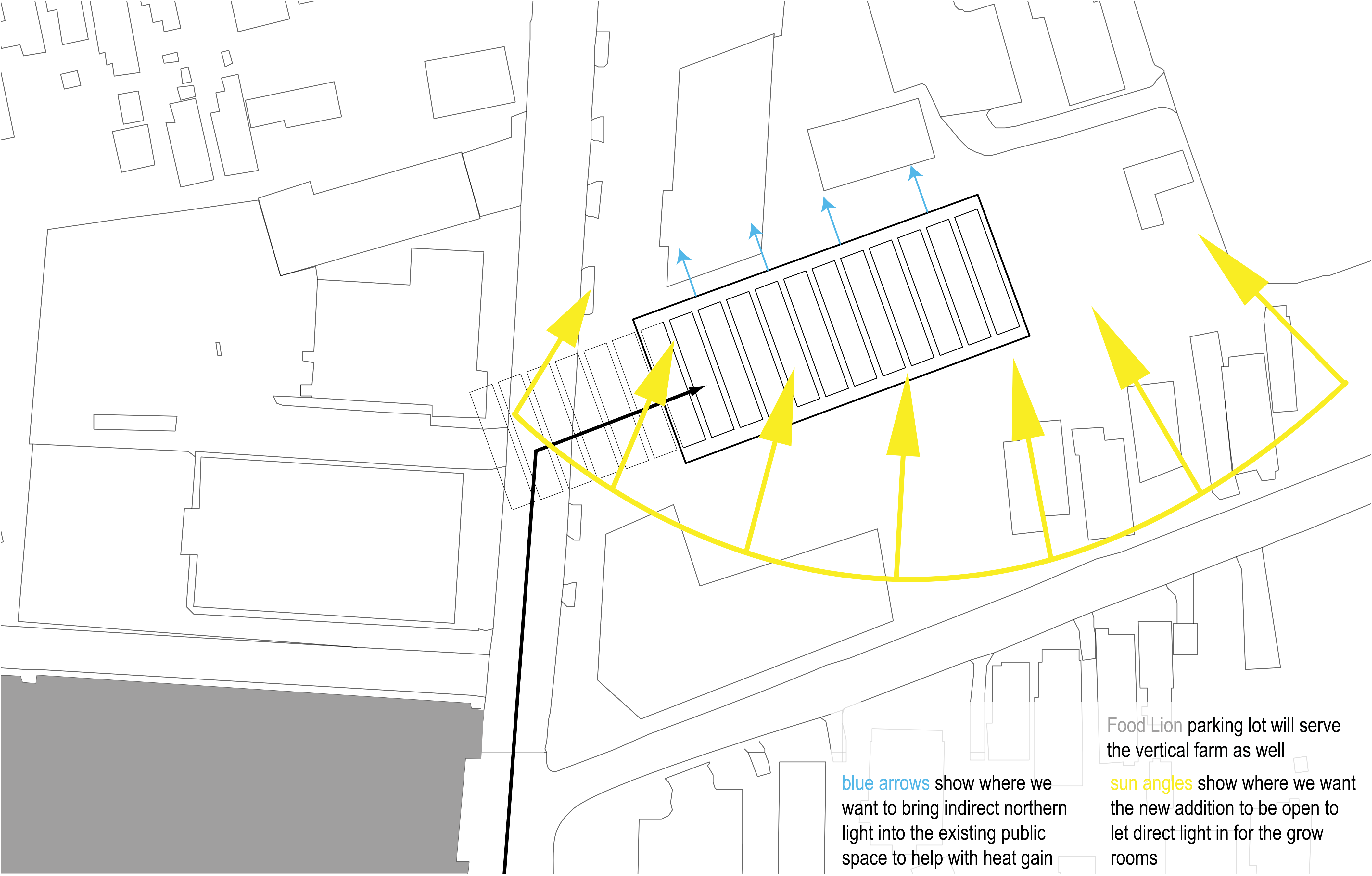
The success of the farmers market **DEPENDS** on the vertical farm grow rooms for produce.

The effectiveness + impact of the vertical farm on the community **DEPENDS** on the farmers market.



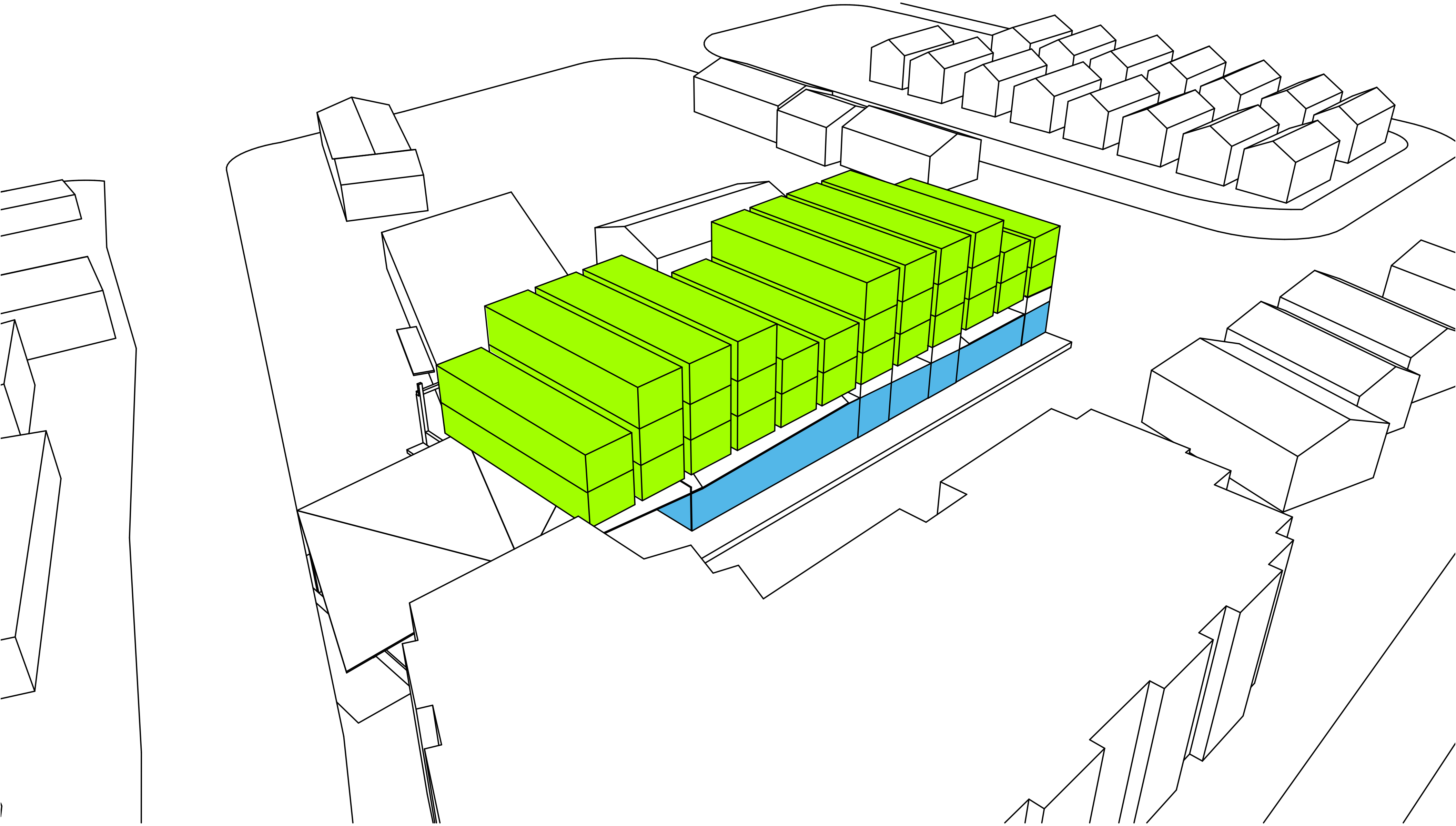
[charleston]
VERTICAL FARM

SHIFT WITHIN THE EXISTING FRAMEWORK



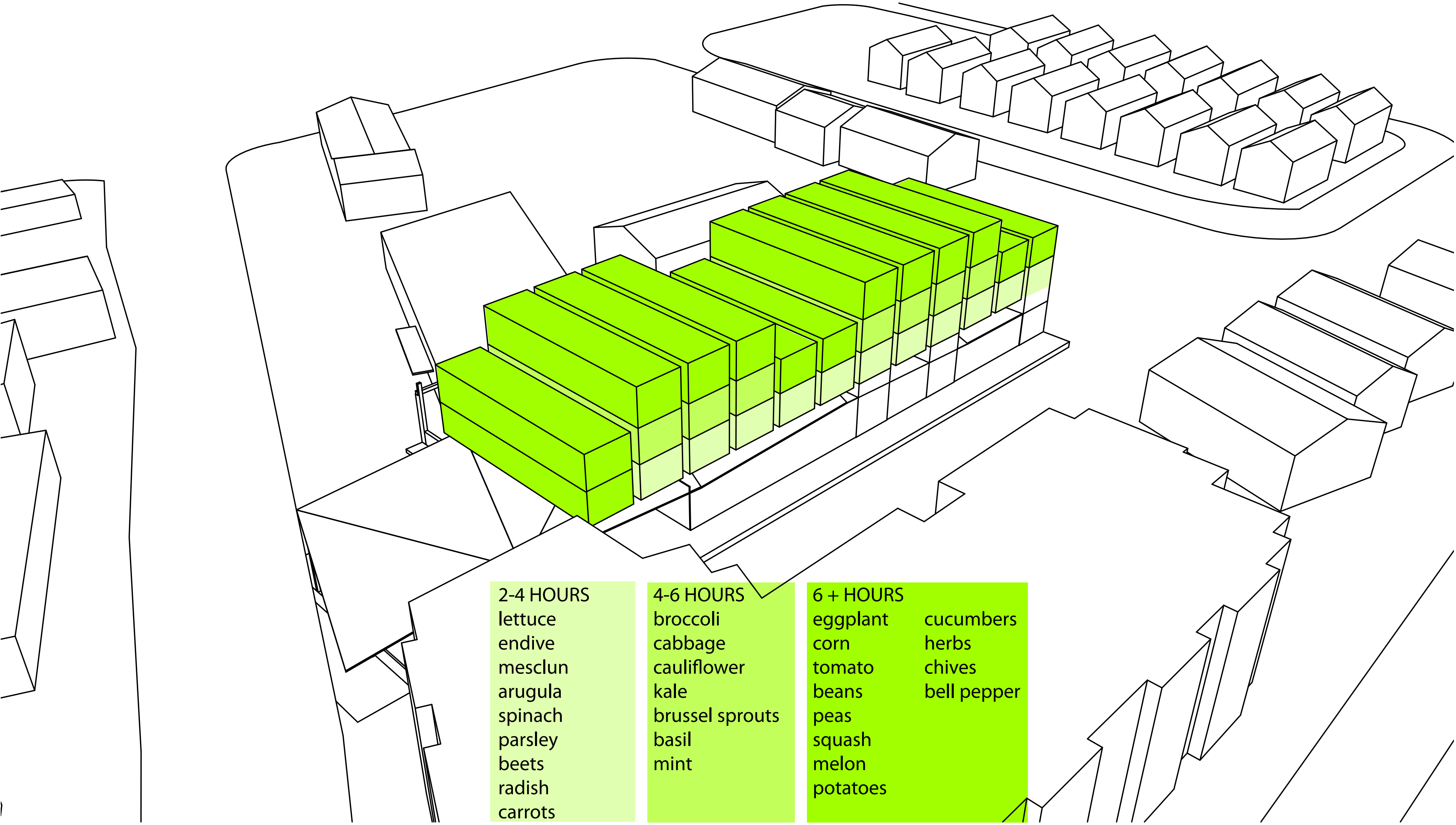
[charleston] VERTICAL FARM

SITE ANALYSIS



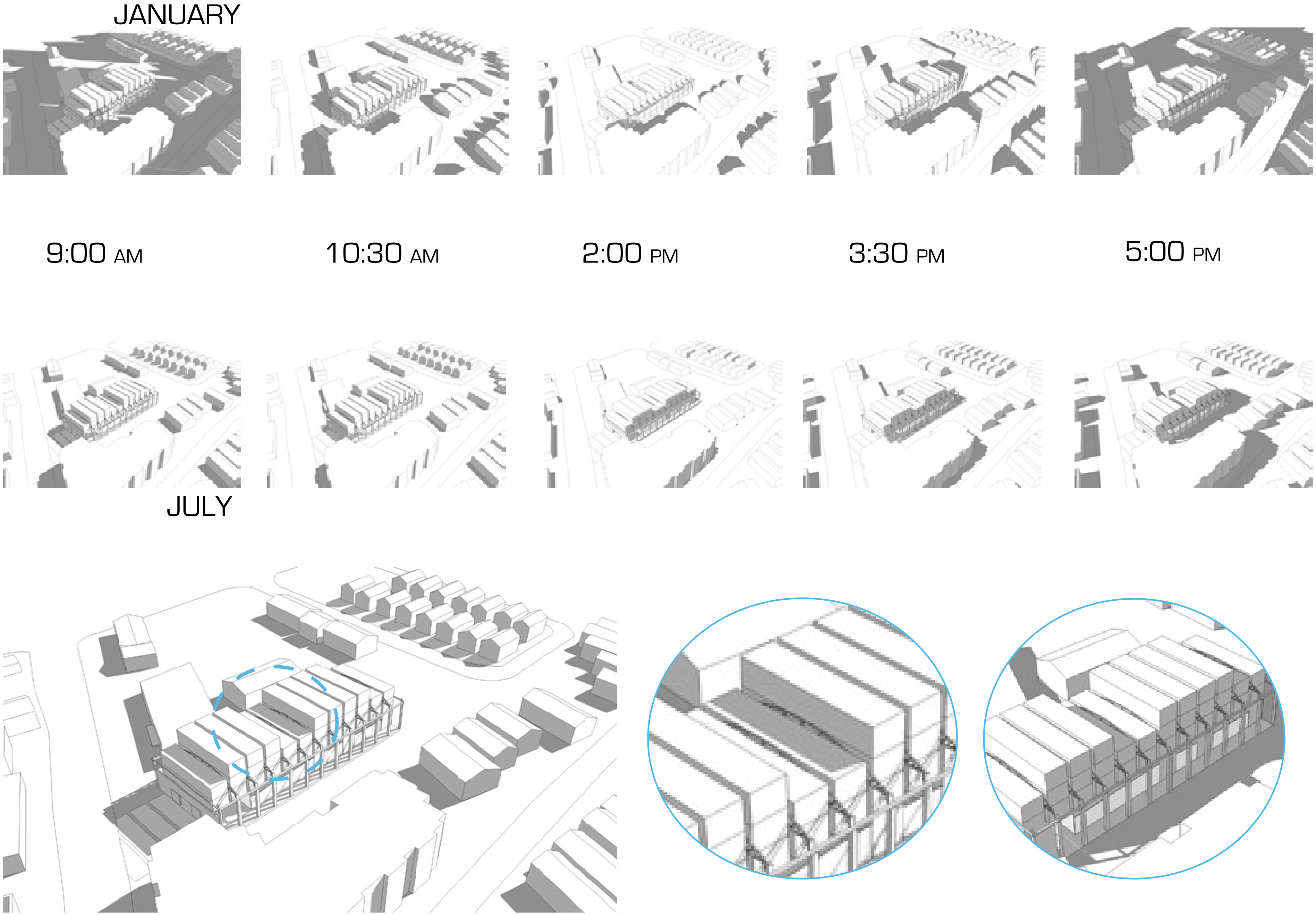
[charleston]
VERTICAL FARM

PUBLIC VS. PRIVATE



[charleston]
VERTICAL FARM

PLANT SUNLIGHT NEEDS



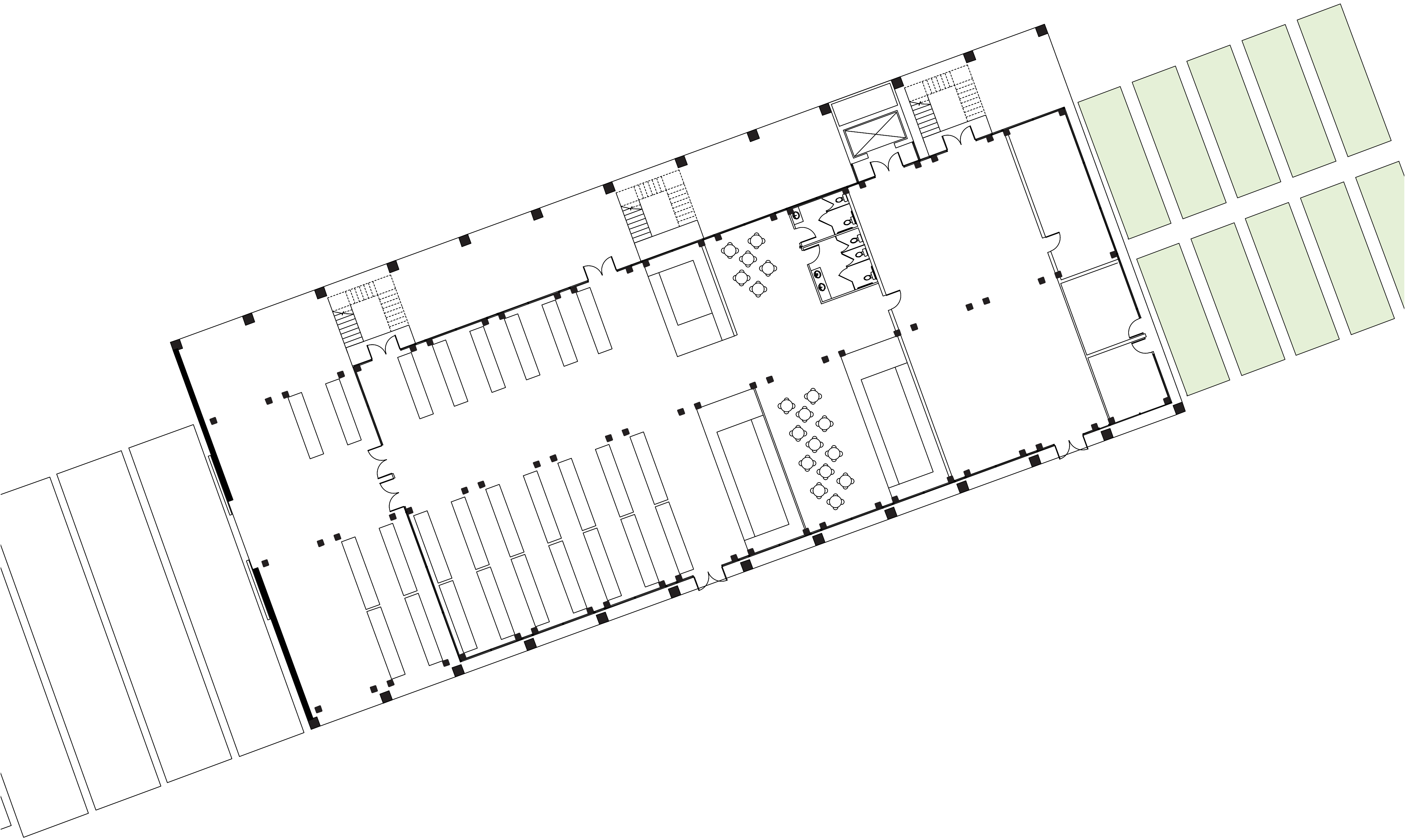
[charleston]
VERTICAL FARM

DESIGN GOALS

[charleston]

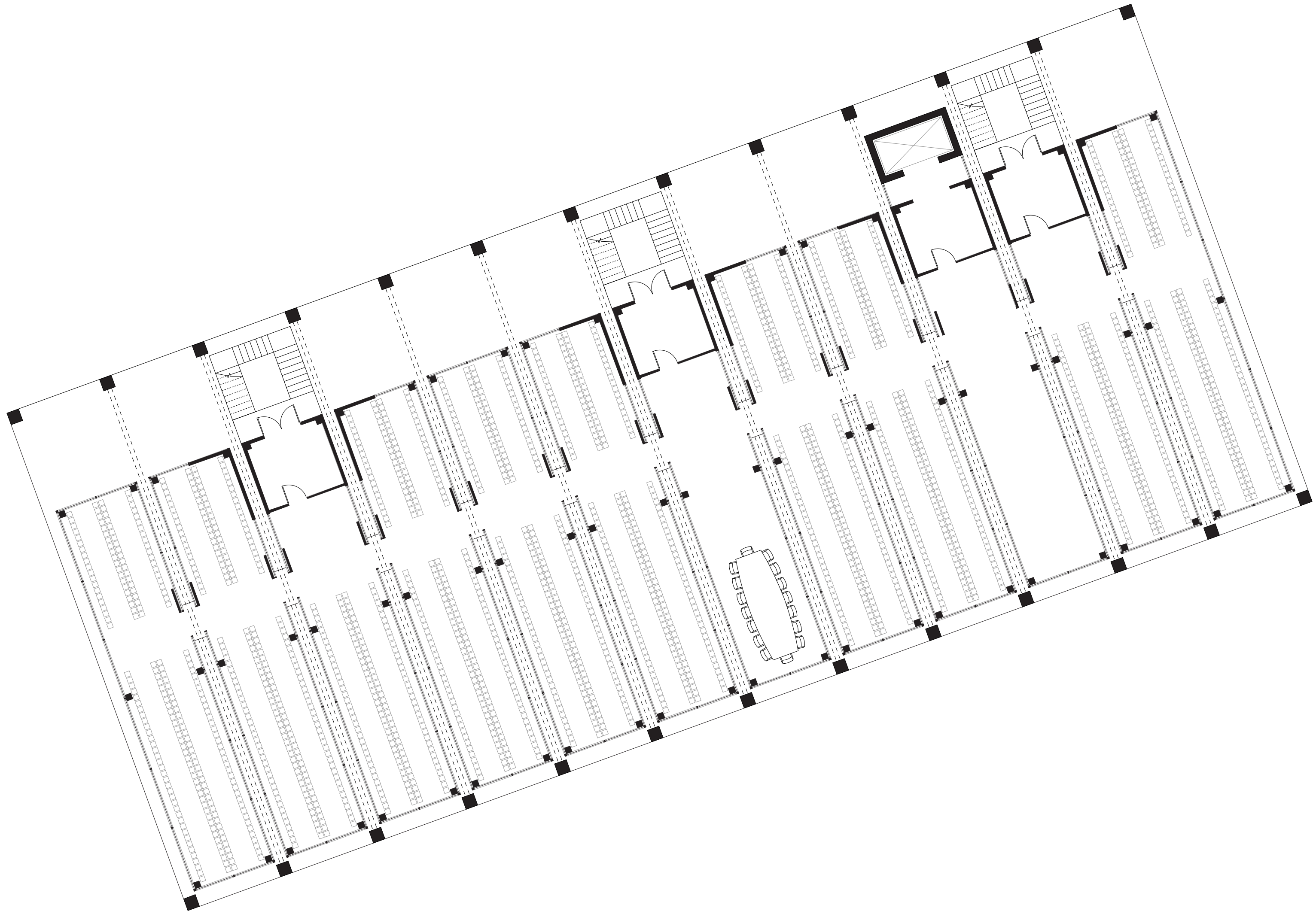
VERTICAL FARM

SITE PLAN



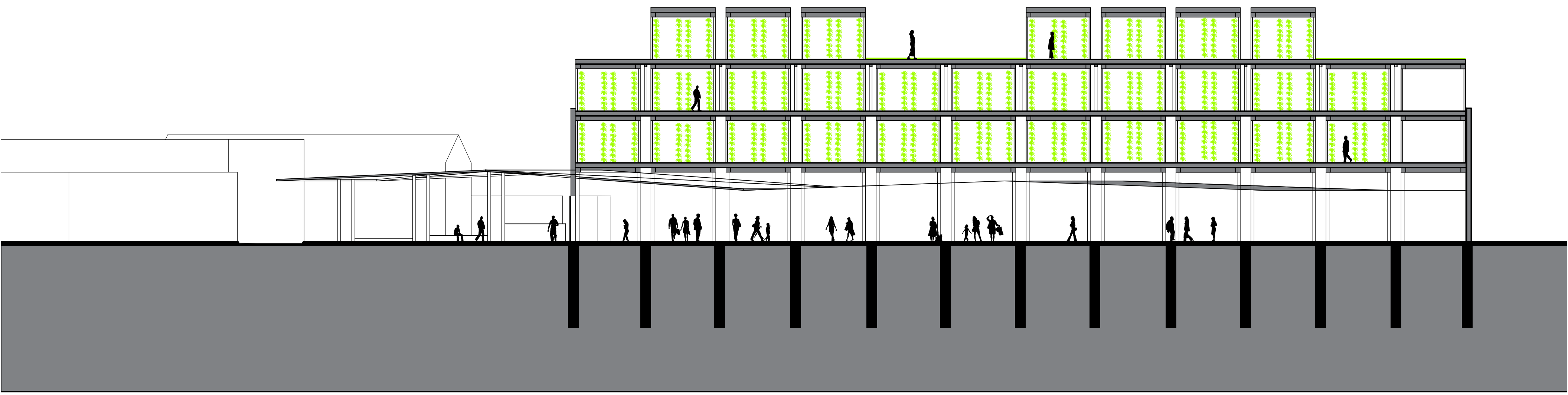
[charleston] VERTICAL FARM

FIRST FLOOR PLAN



[charleston]
VERTICAL FARM

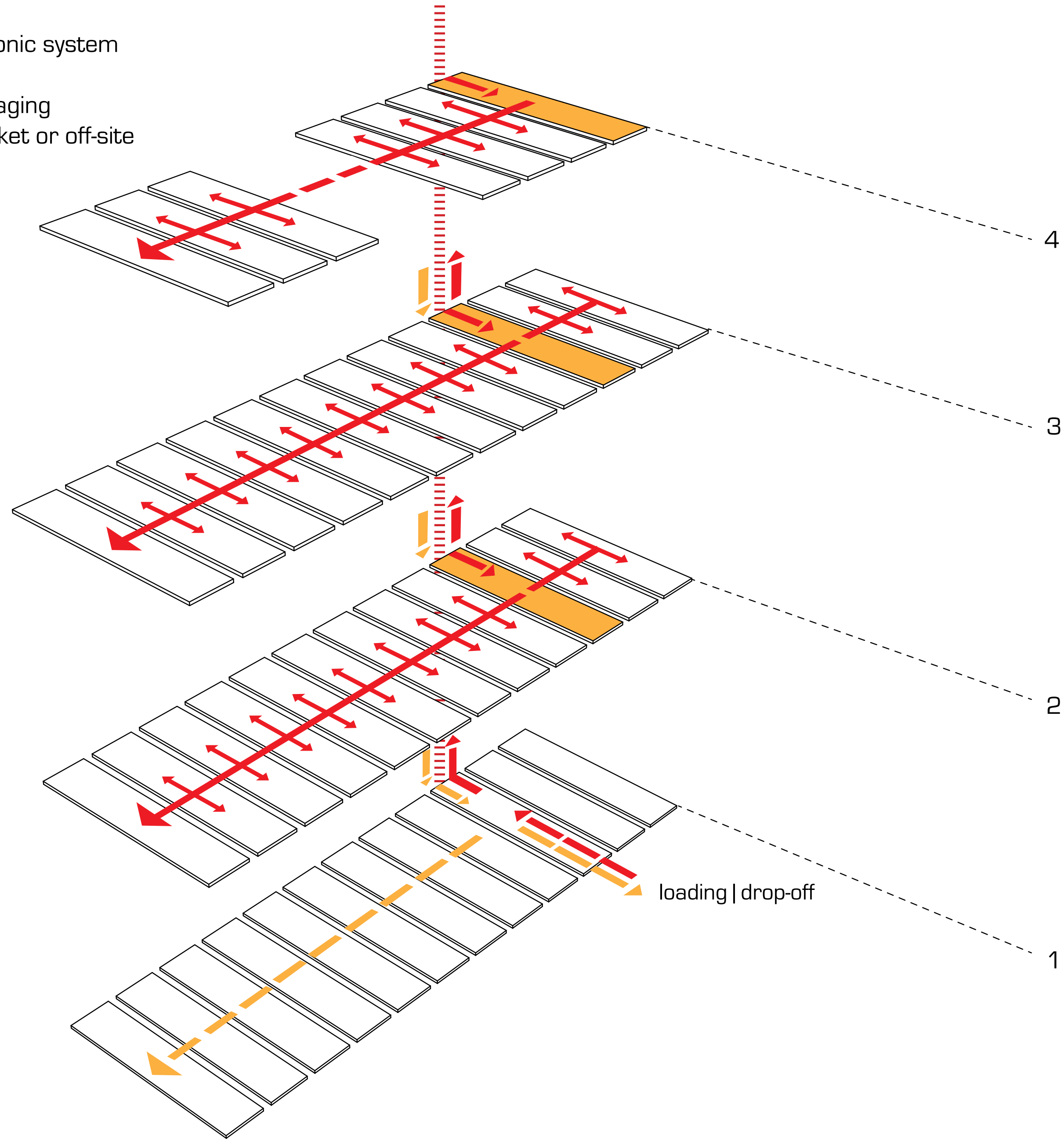
SECOND FLOOR PLAN



[charleston]
VERTICAL FARM

SECTION

1. delivery | drop off
2. seed sorting
3. transfer to hydroponic system
4. plant growth
5. organization | packaging
6. distribution to market or off-site

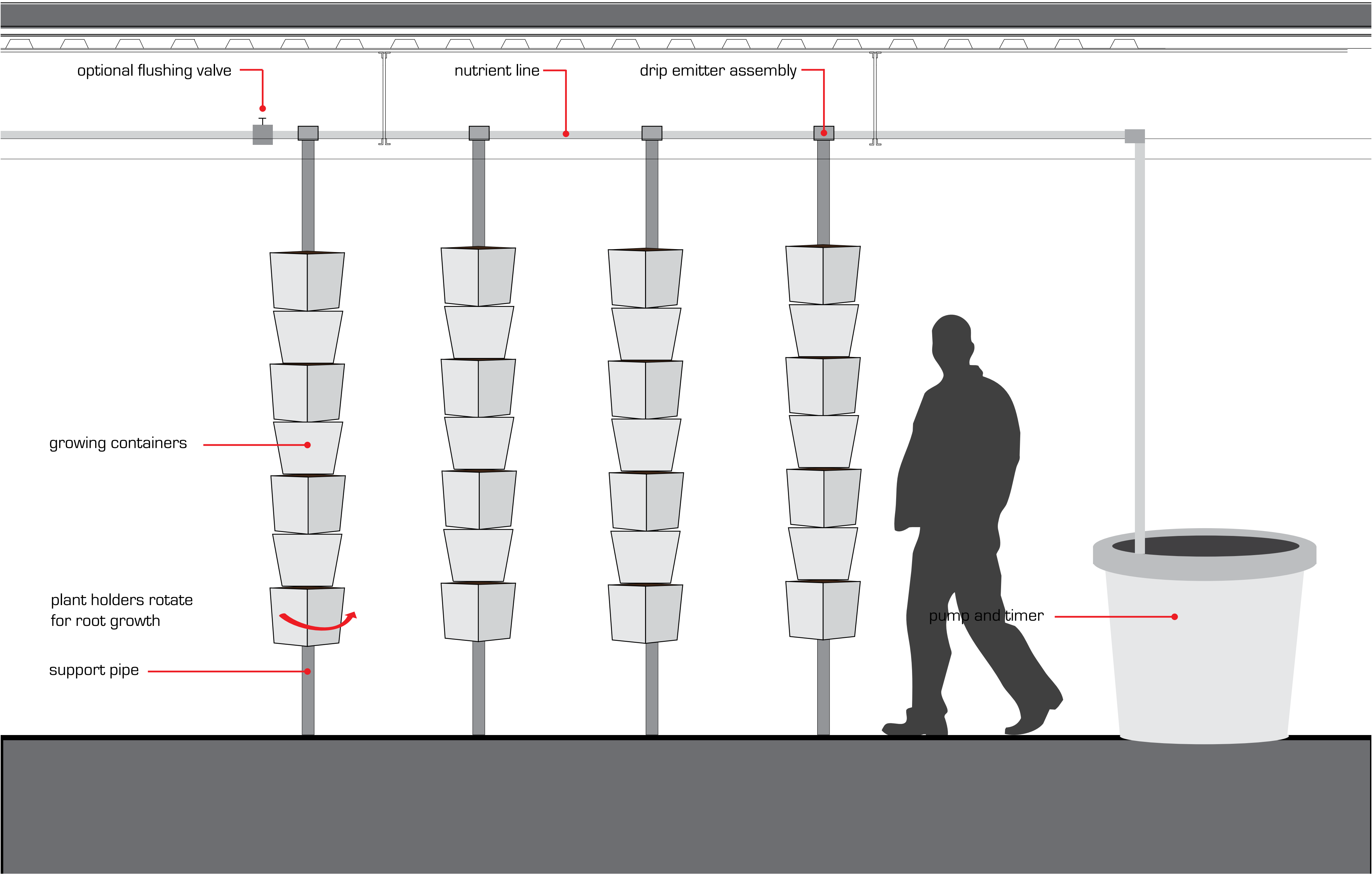


elevator
plant growth
plant distribution

[charleston]

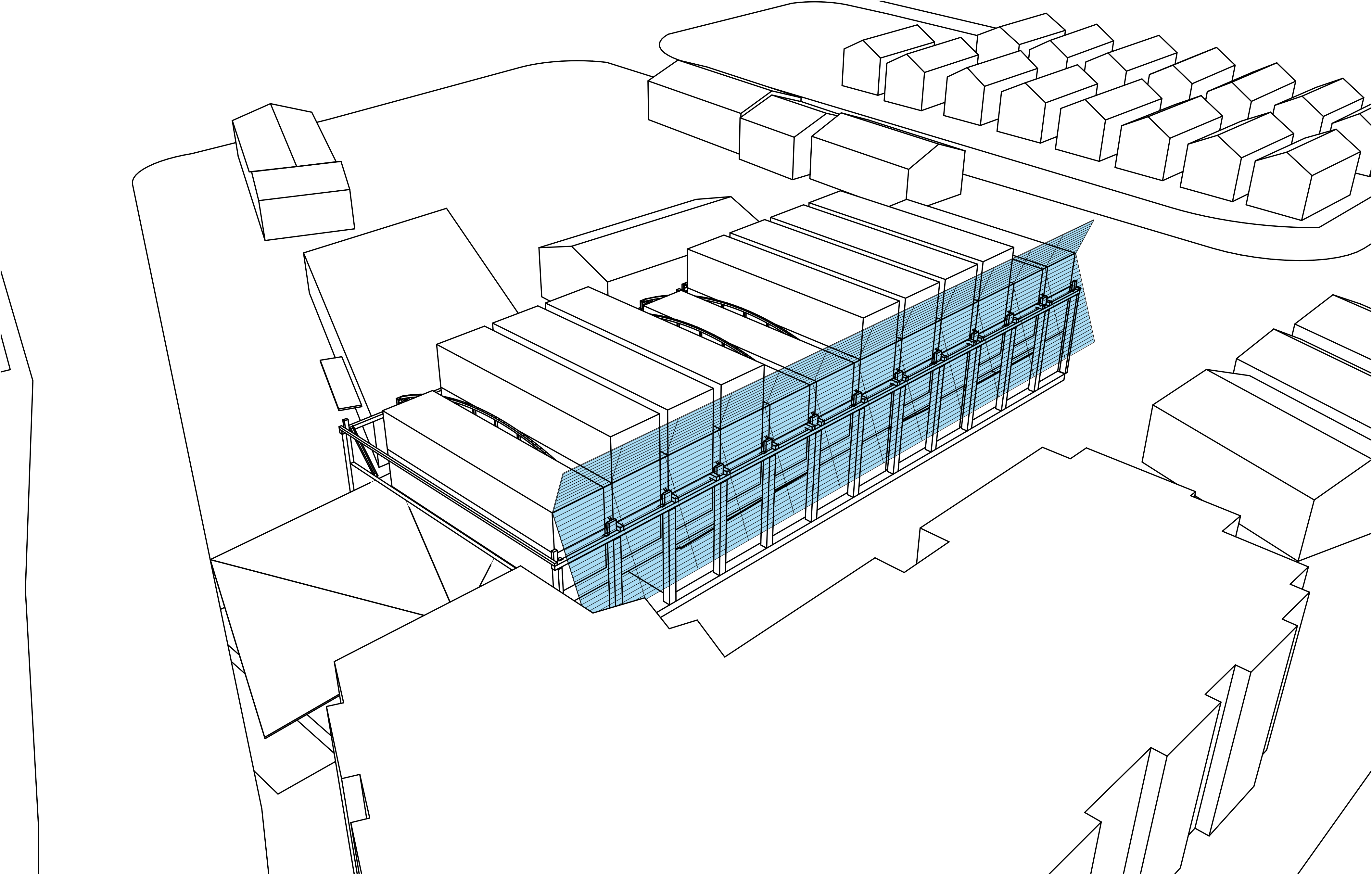
VERTICAL FARM

PLANT PRODUCTION CYCLE



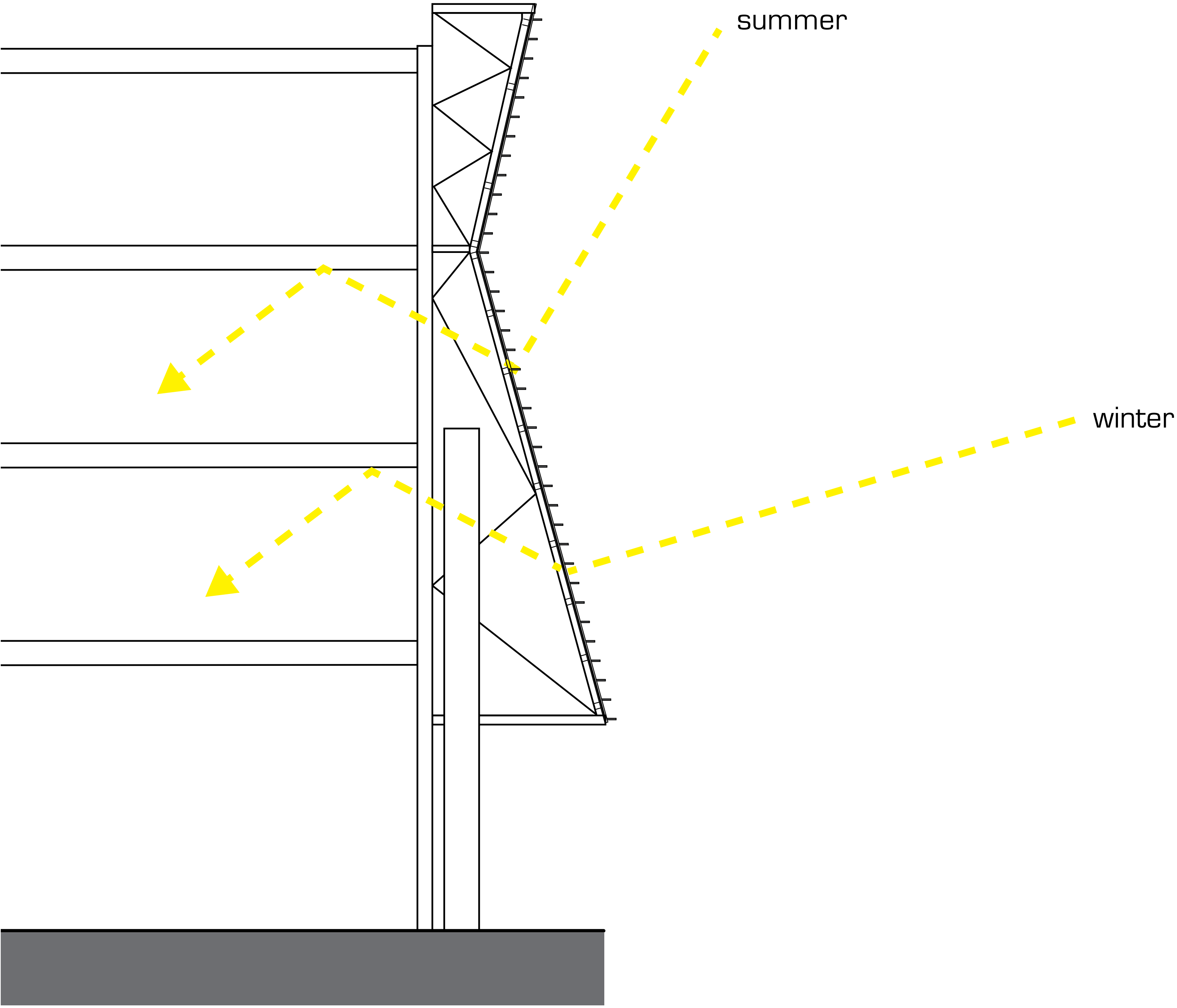
[charleston]
VERTICAL FARM

GROWING SYSTEM



[charleston]
VERTICAL FARM

LOUVRE FORM

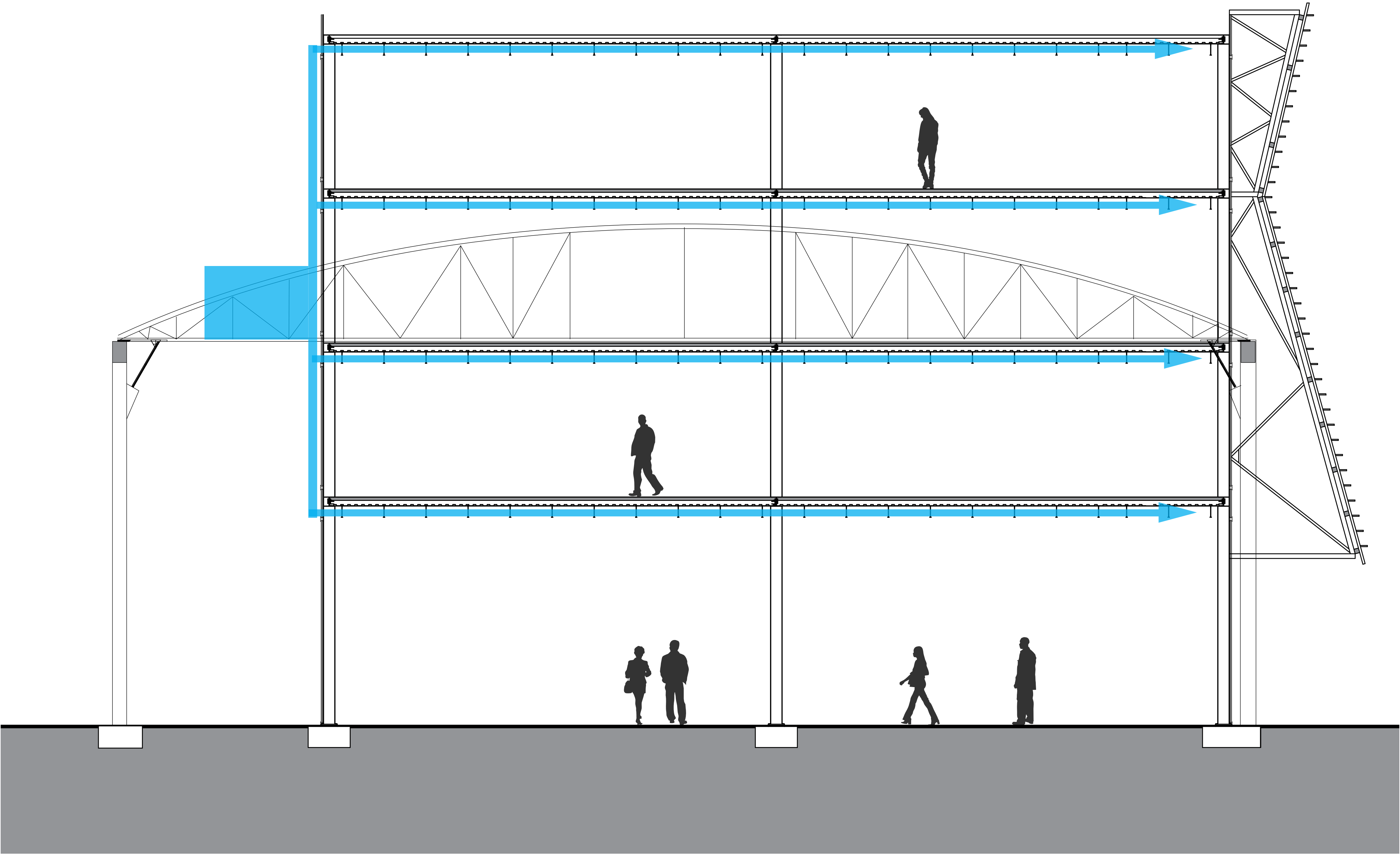


[charleston]
VERTICAL FARM

LOUVRE CONCEPT DIAGRAM

[charleston]
VERTICAL FARM

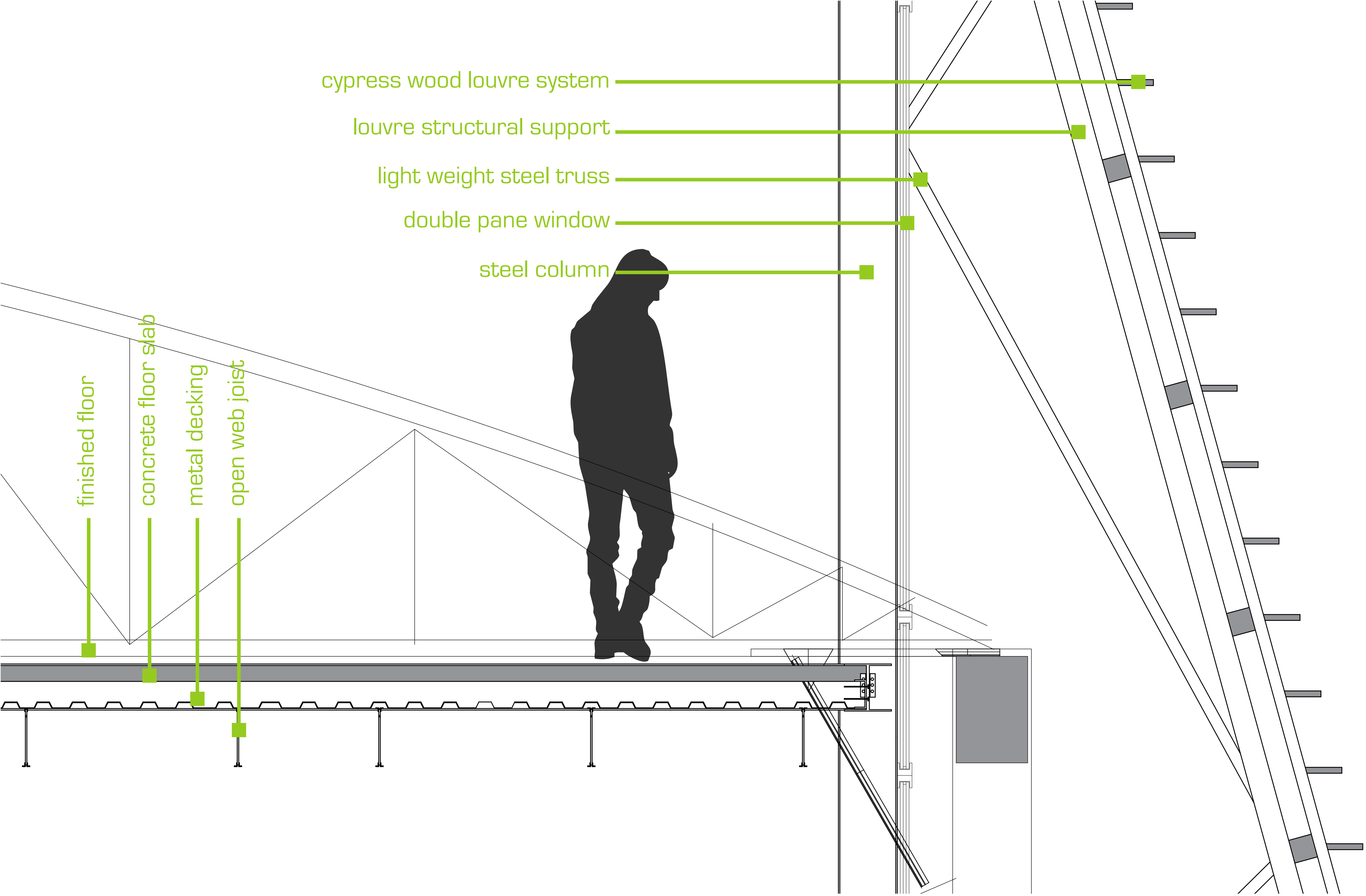
UTILITY LOCATION



[charleston]

VERTICAL FARM

BUILDING SECTION



[charleston]
VERTICAL FARM

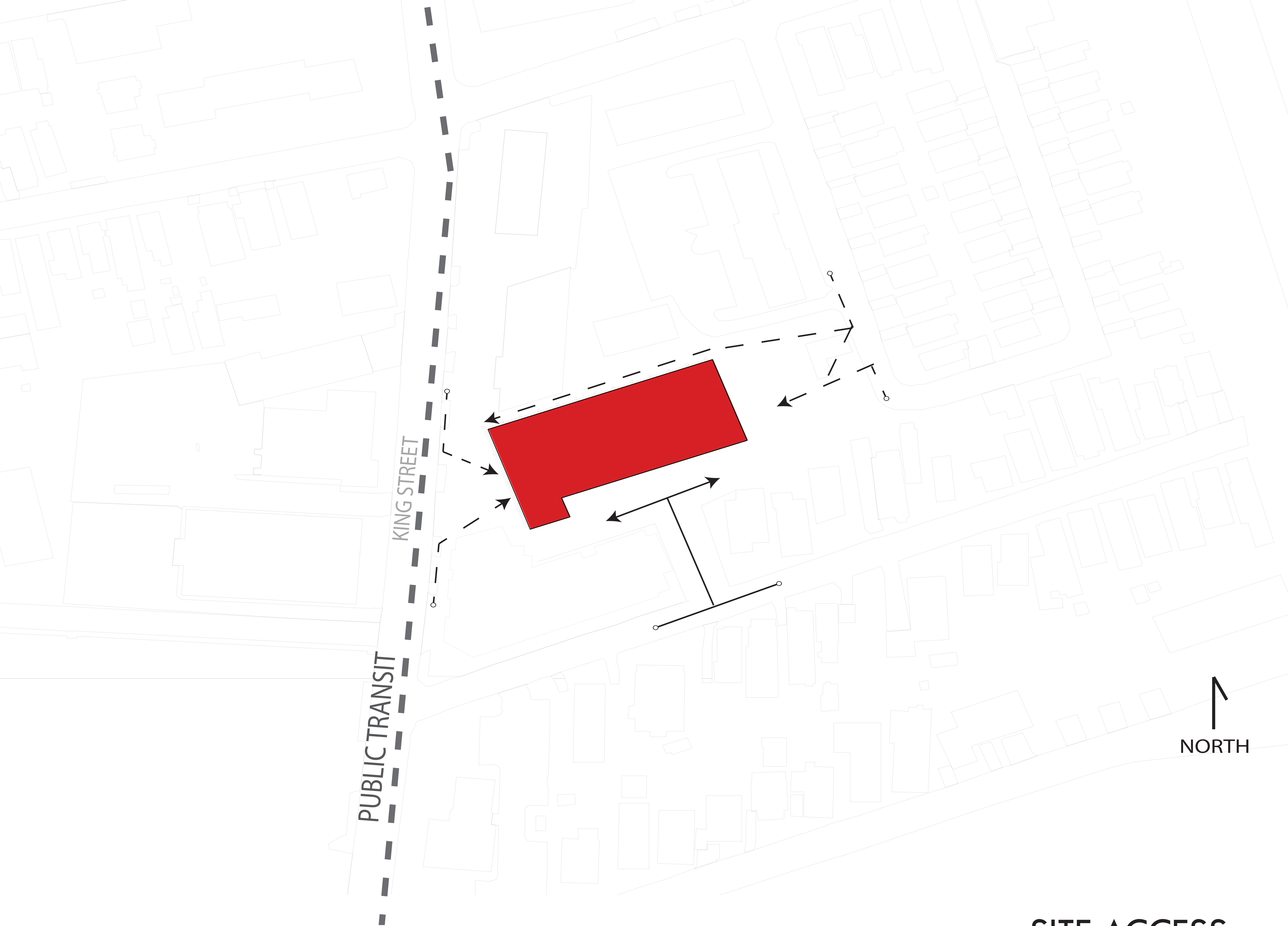
BUILDING SECTION DETAIL

Design Model 2

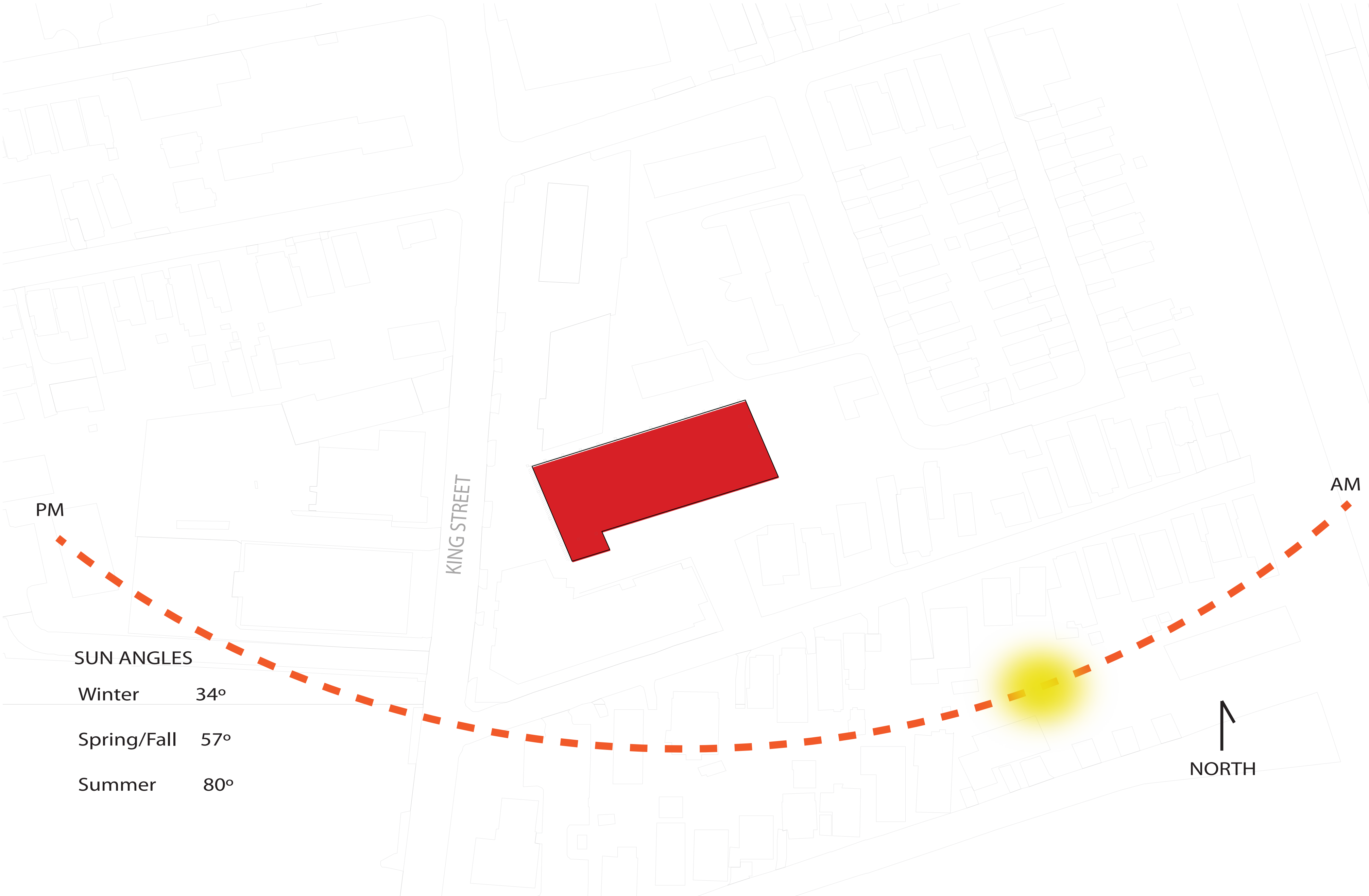
Transparency Through the Ribbon by Victoria Wright and Megan Craig

Design Summary

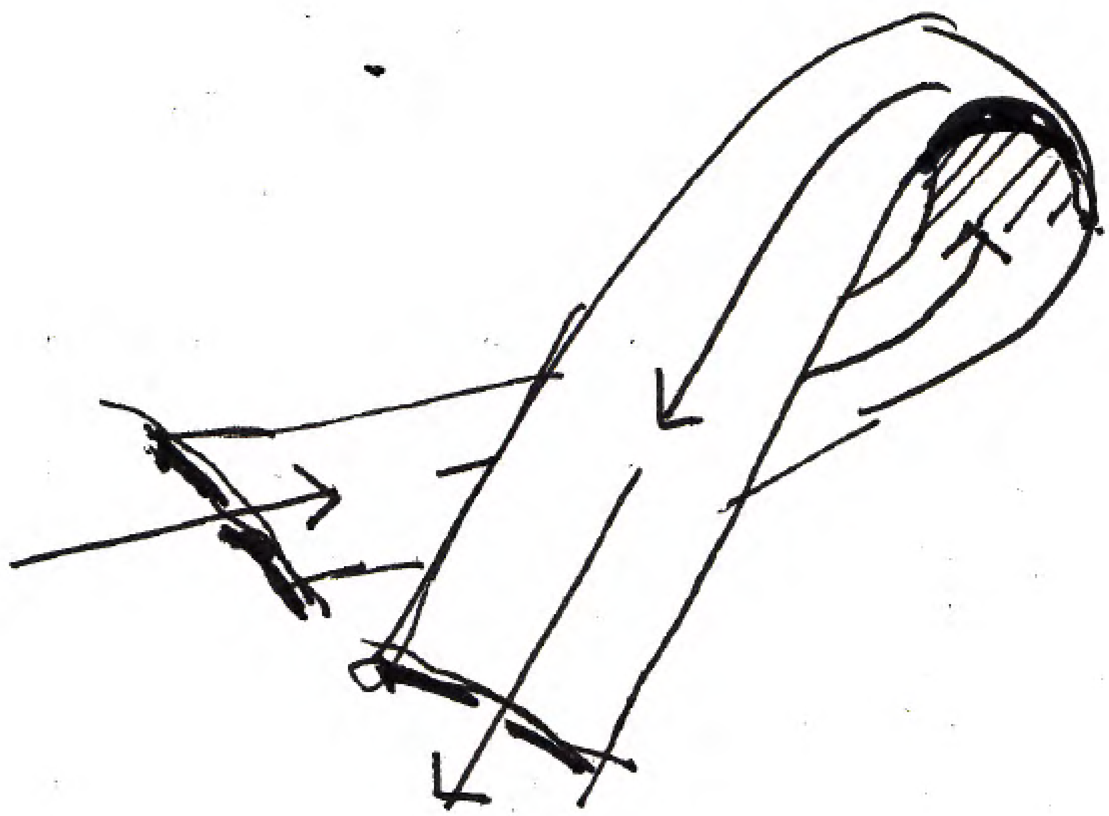
Something that was important to us was maintaining a transparency through our space. Where the public and private can speak the same language by the way the building takes them to their designated spaces. Another significance of this ribbon is to allow a visual transparency, creating educational opportunities where the public can learn how vertical farming works and trust the process.



SITE ACCESS


KING STREET
PM
AM
SUN ANGLES
Winter 34º
Spring/Fall 57º
Summer 80º
NORTH

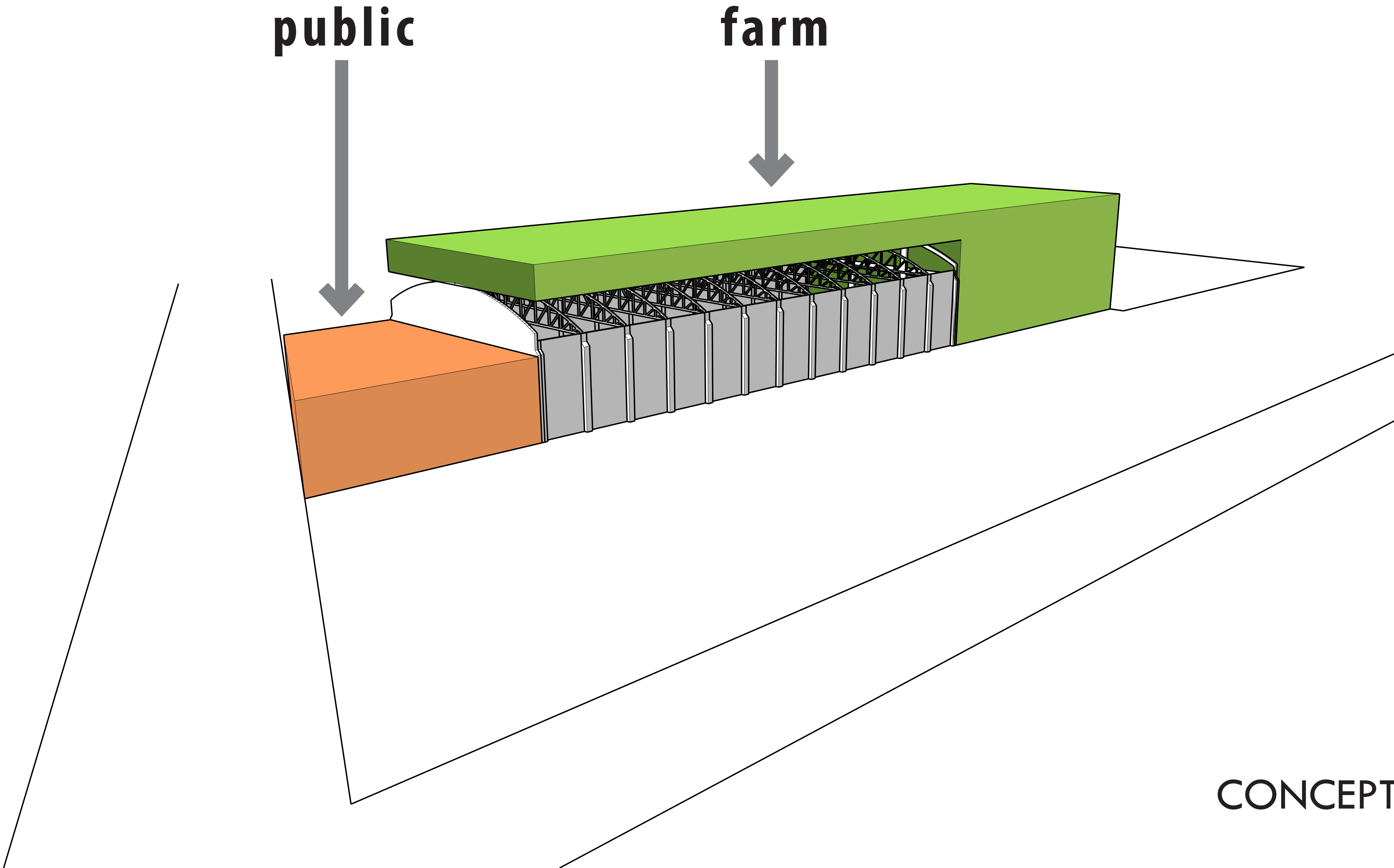
SUN DIAGRAM

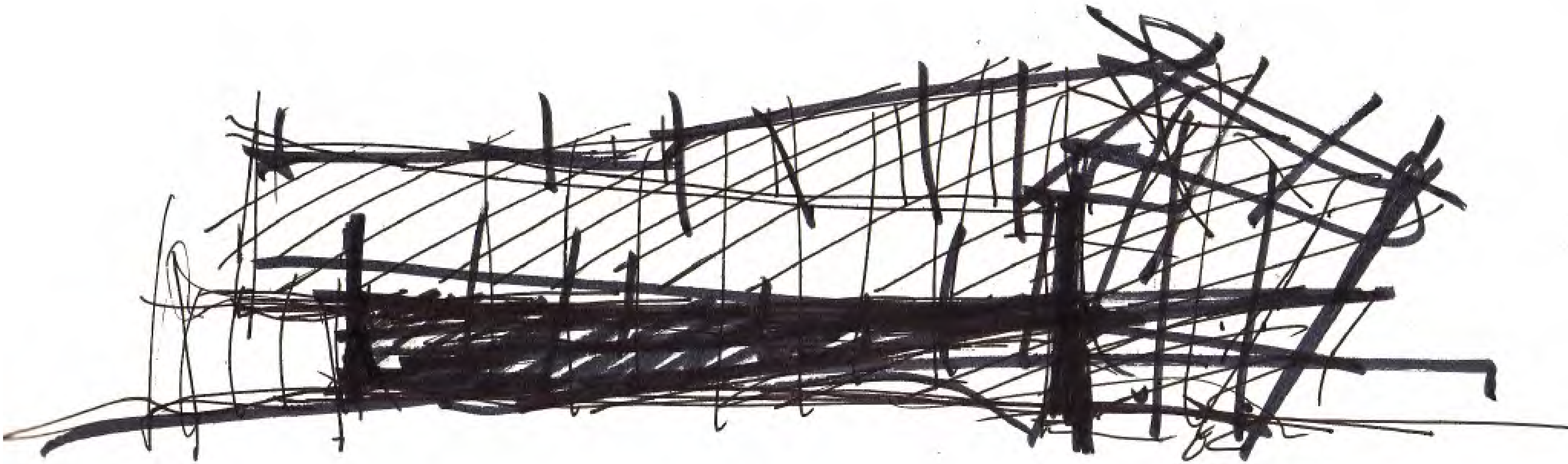


Transparancy through the RIBBON

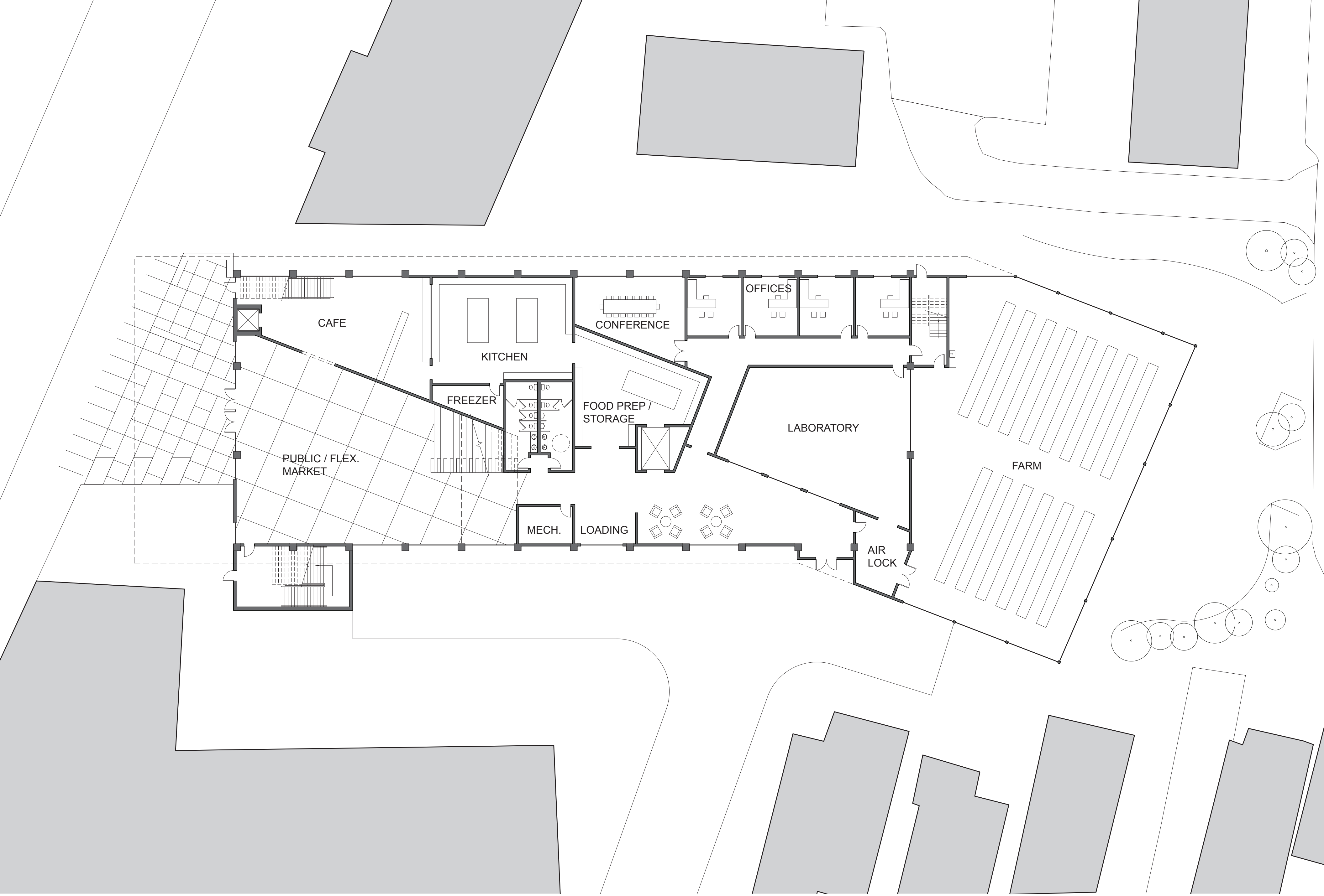
Something else that was important to us was maintaining a transparancy through our space. Where the public and private can speak the same language by the way the building takes them to their designated spaces.

Another signifiance of this RIBBON is to allow a visual transparancy, creating educational opportunities where the public learn how vertical farm works and trust the process of vertical farming.

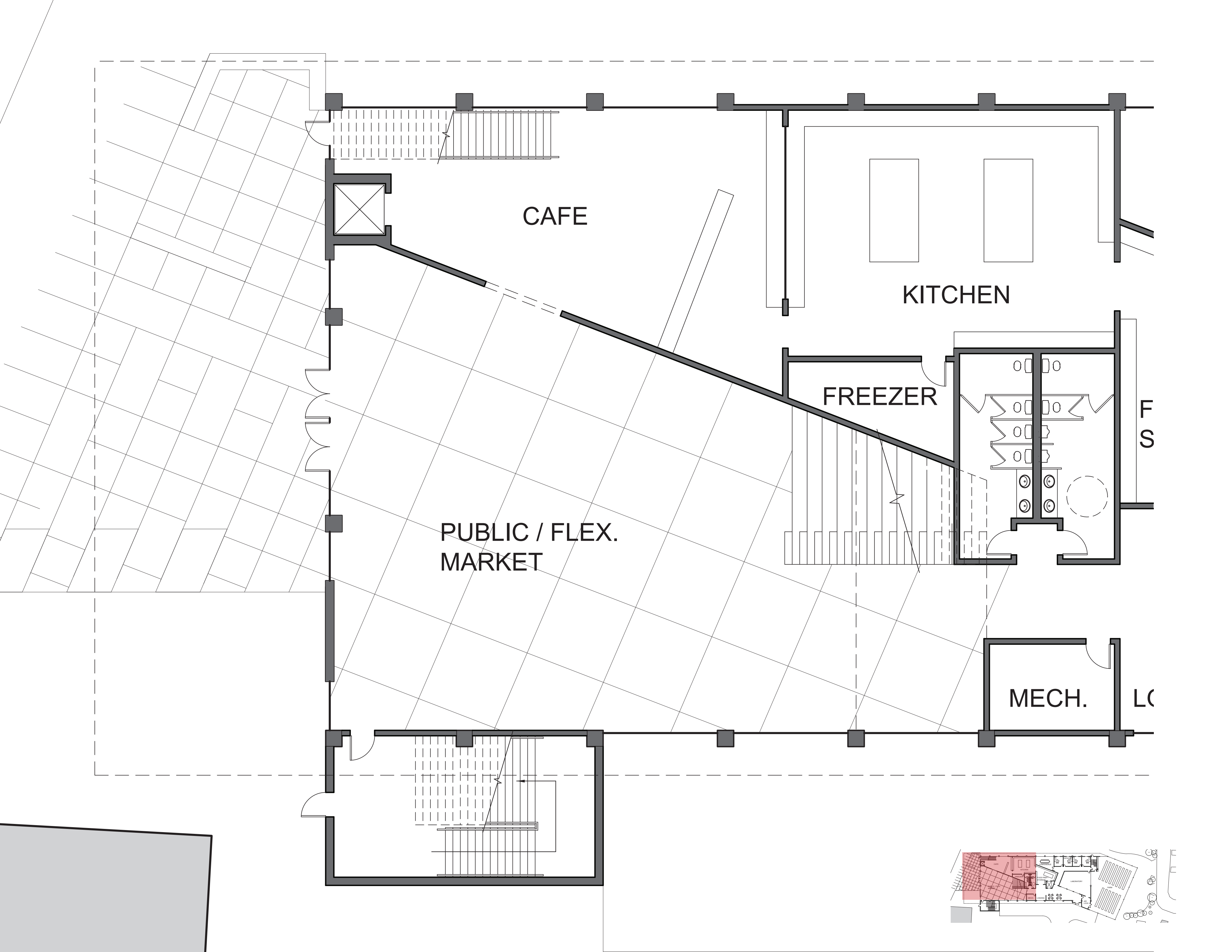

public
farm
CONCEPT

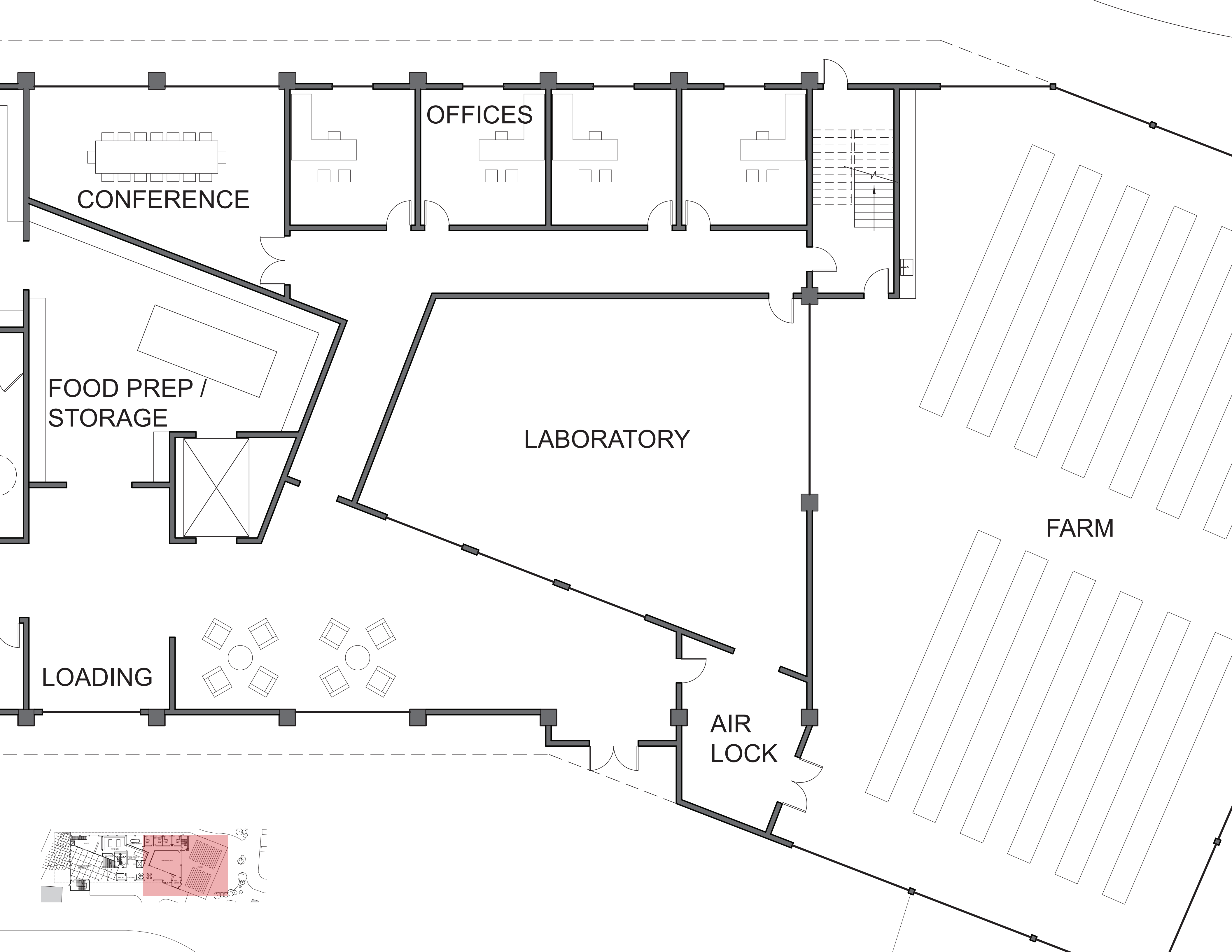


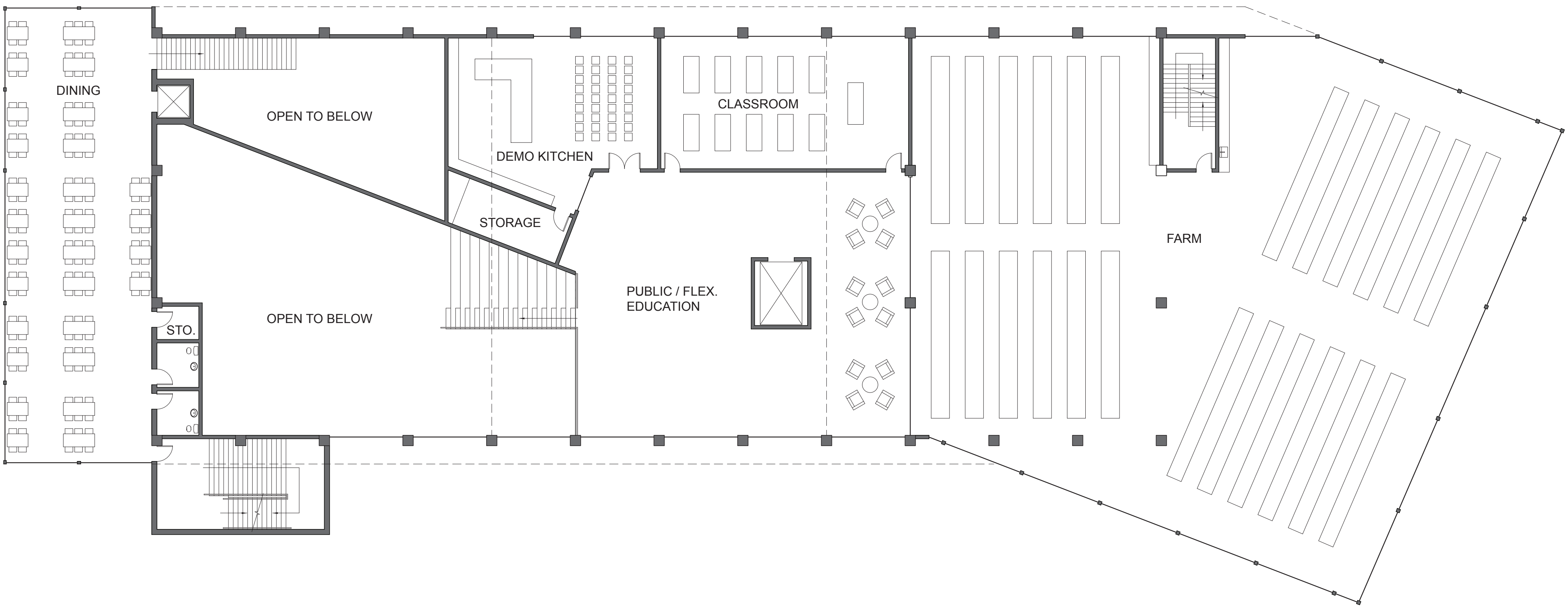
CONCEPT


CAFE
KITCHEN
CONFERENCE
OFFICES
FREEZER
FOOD PREP /
STORAGE
LABORATORY
FARM
PUBLIC / FLEX.
MARKET
MECH.
LOADING
AIR
LOCK

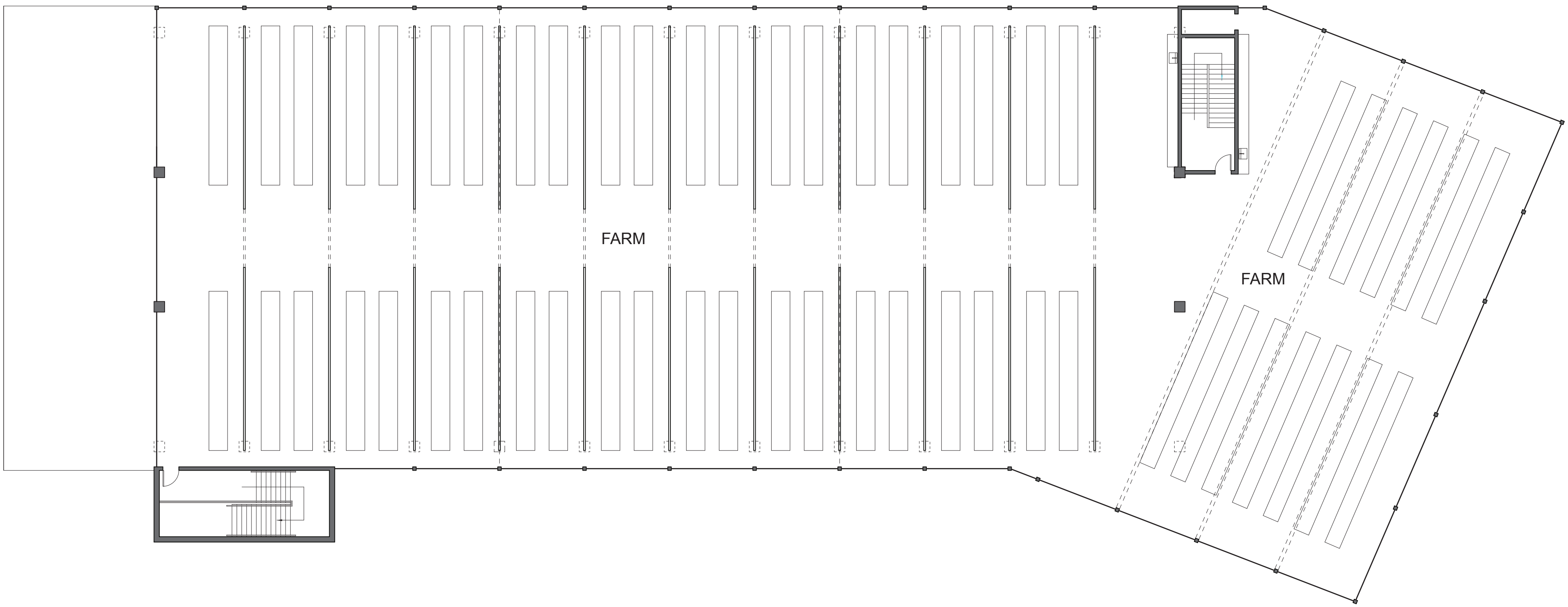
MAIN LEVEL


CAFE
KITCHEN
FREEZER
PUBLIC / FLEX.
MARKET
MECH.

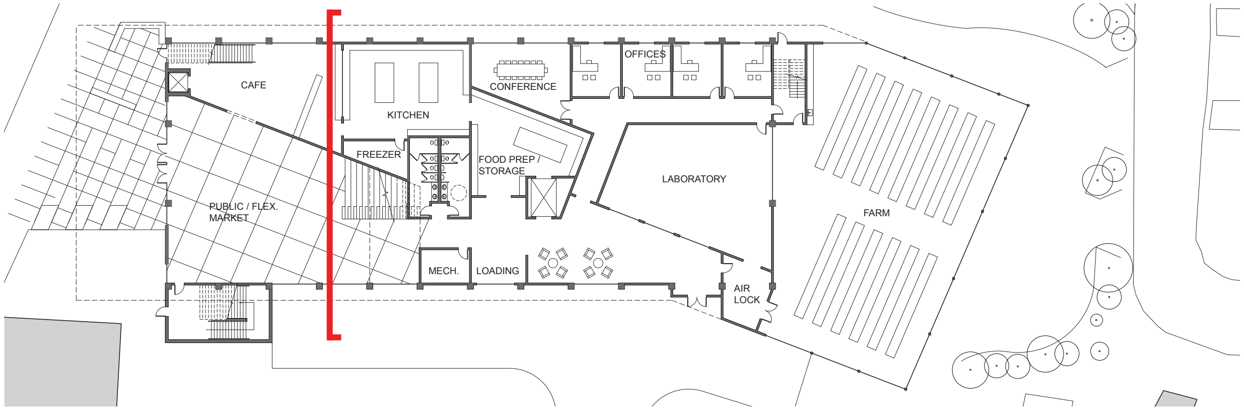

OFFICES
CONFERENCE
FOOD PREP / STORAGE
LABORATORY
FARM
LOADING
AIR LOCK



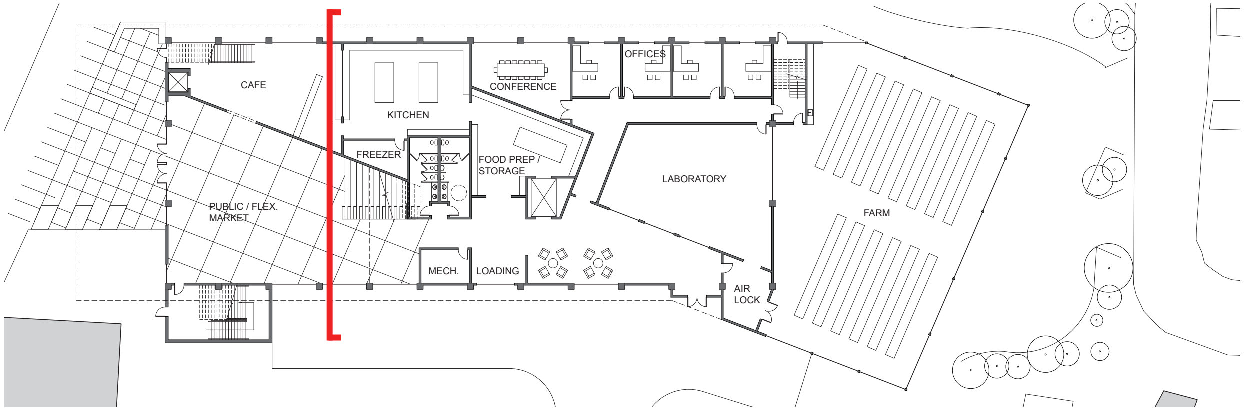
SECOND LEVEL

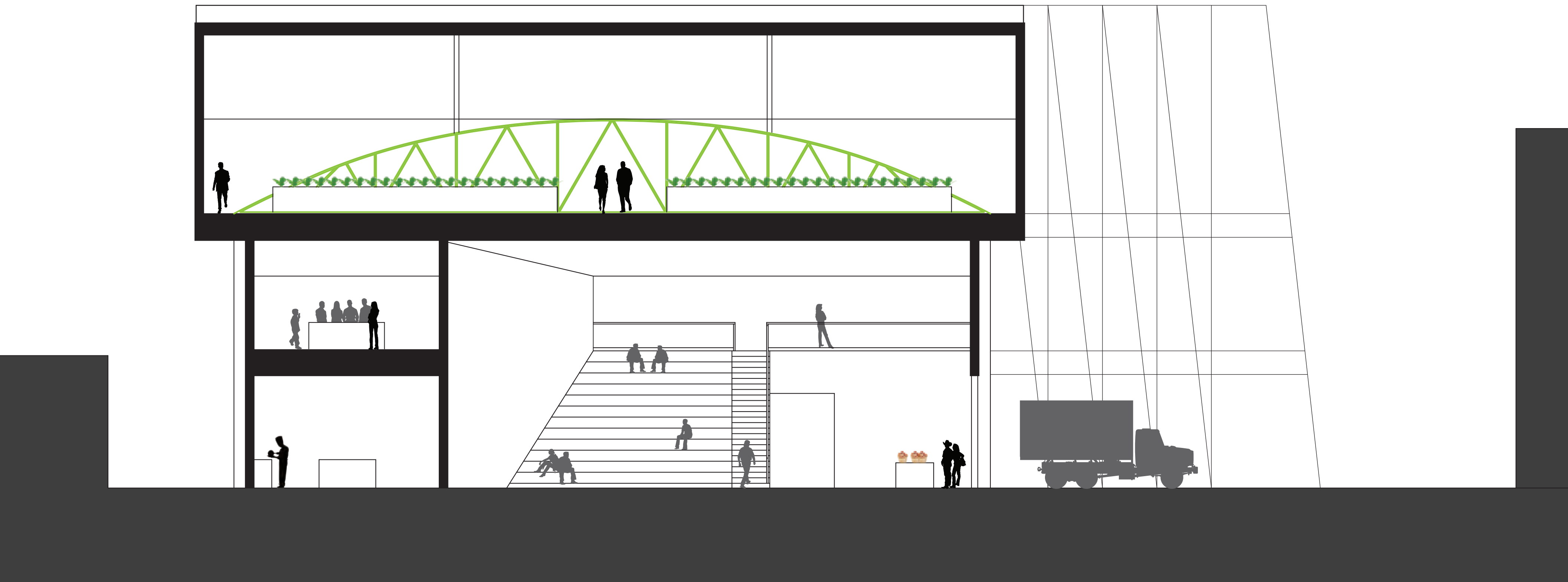


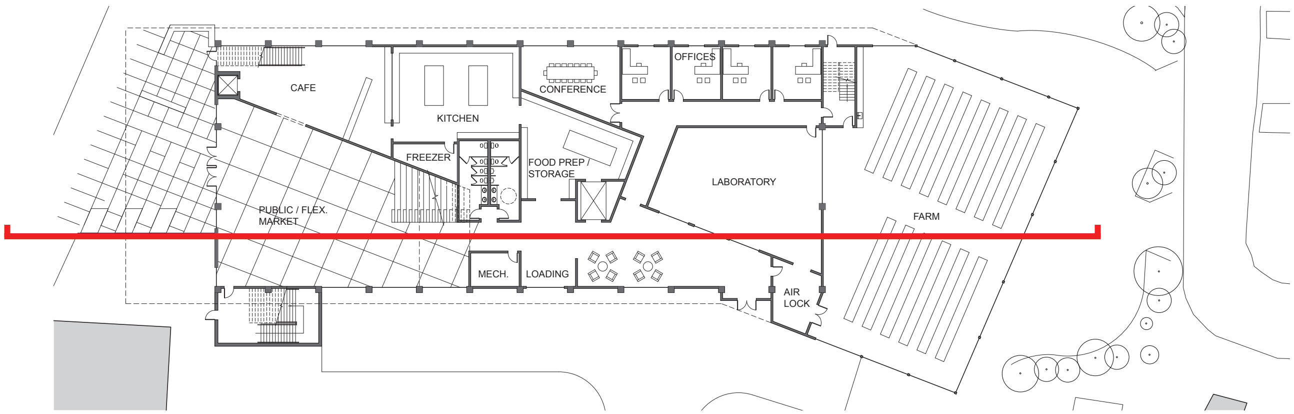
THIRD LEVEL

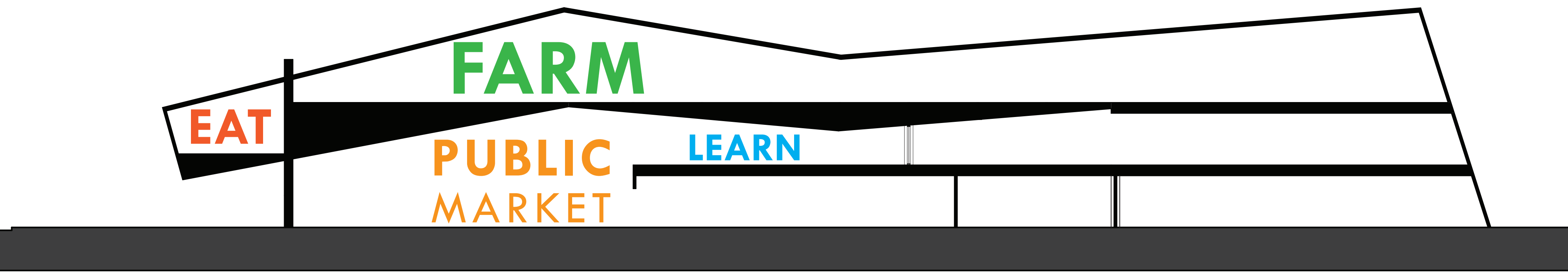

CAFE
KITCHEN
CONFERENCE
OFFICES
FREEZER
FOOD PREP / STORAGE
LABORATORY
FARM
PUBLIC / FLEX. MARKET
MECH.
LOADING
AIR LOCK

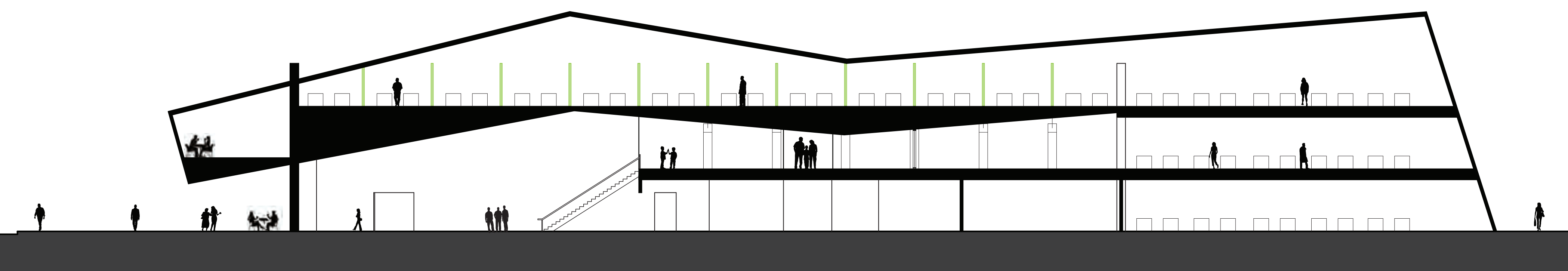

FARM
LEARN
EAT
PUBLIC MARKET

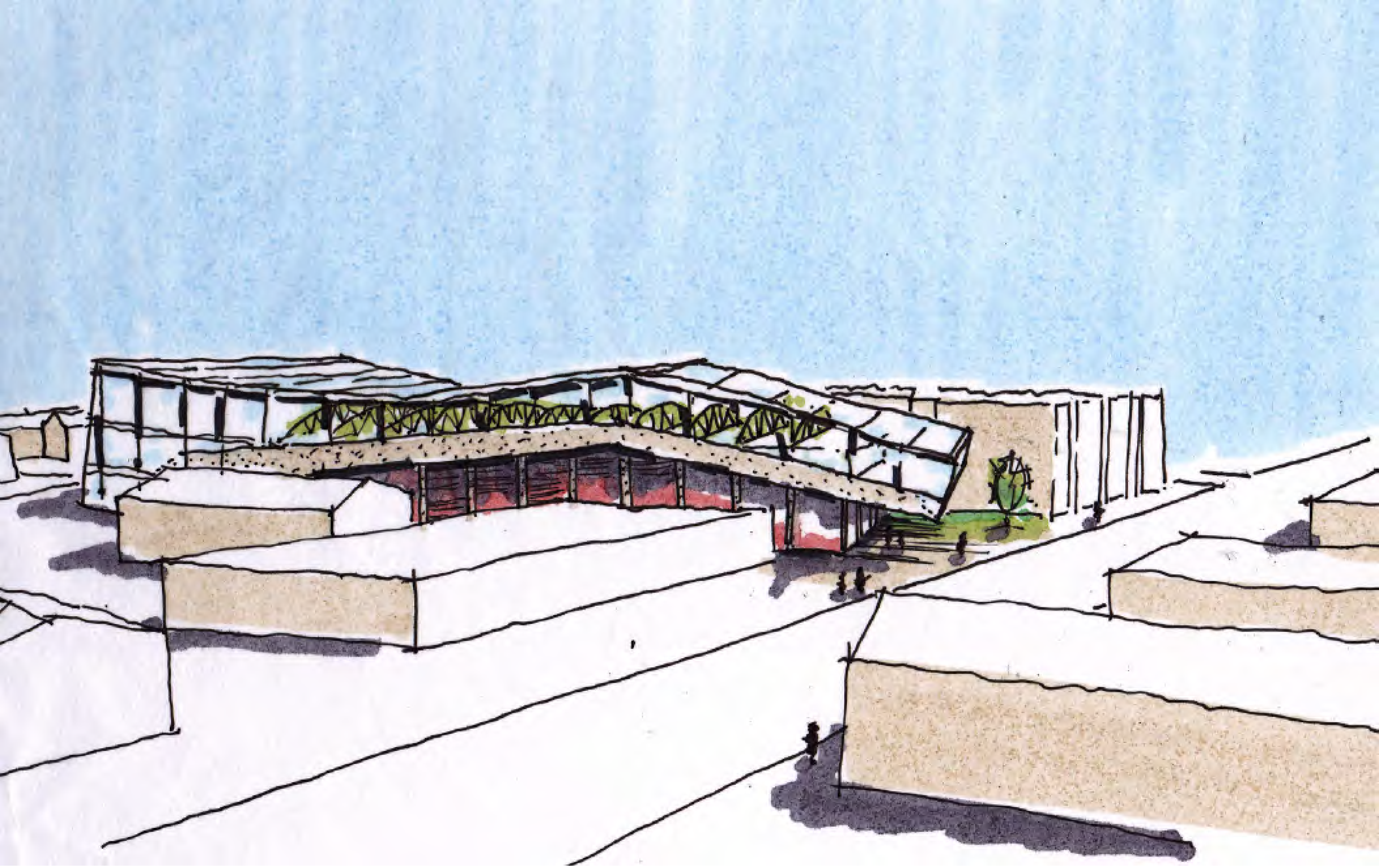

CAFE
KITCHEN
CONFERENCE
OFFICES
FREEZER
FOOD PREP / STORAGE
LABORATORY
FARM
PUBLIC / FLEX. MARKET
MECH.
LOADING
AIR LOCK



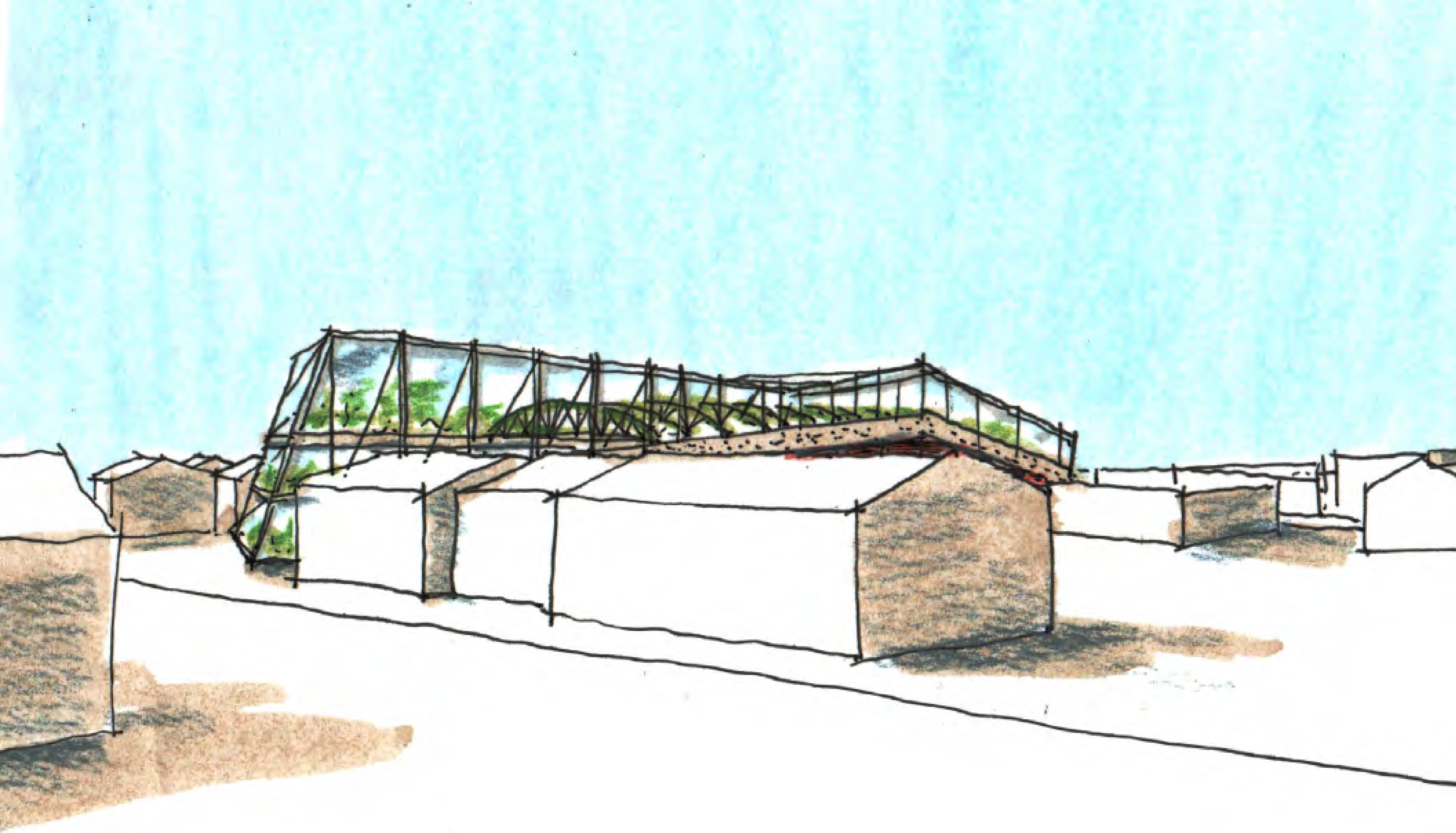

CAFE
OFFICES
CONFERENCE
KITCHEN
FREEZER
FOOD PREP / STORAGE
LABORATORY
PUBLIC / FLEX. MARKET
FARM
MECH.
LOADING
AIR LOCK


FARM
EAT
PUBLIC
MARKET
LEARN

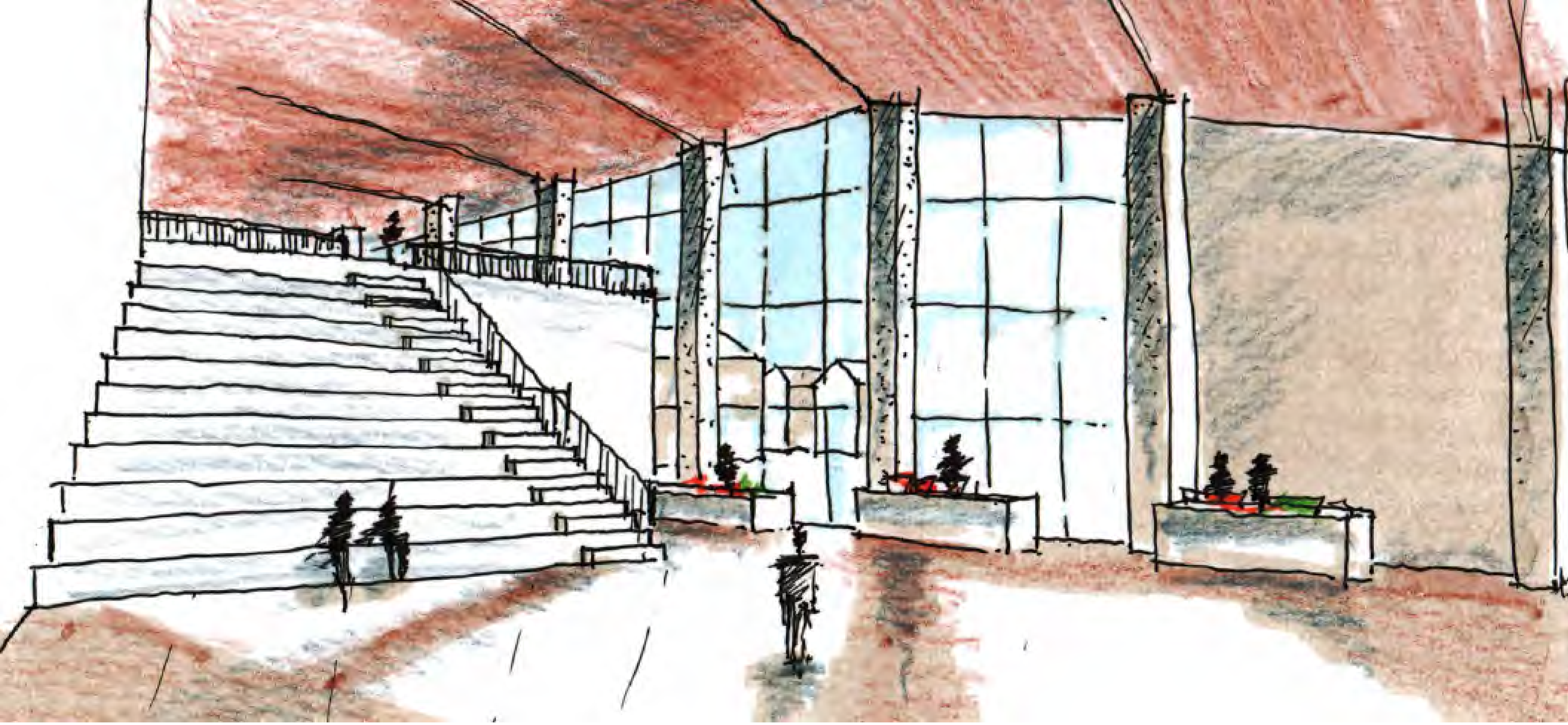




BIRDSEYE



ROMNEY AT ATHENS CT.



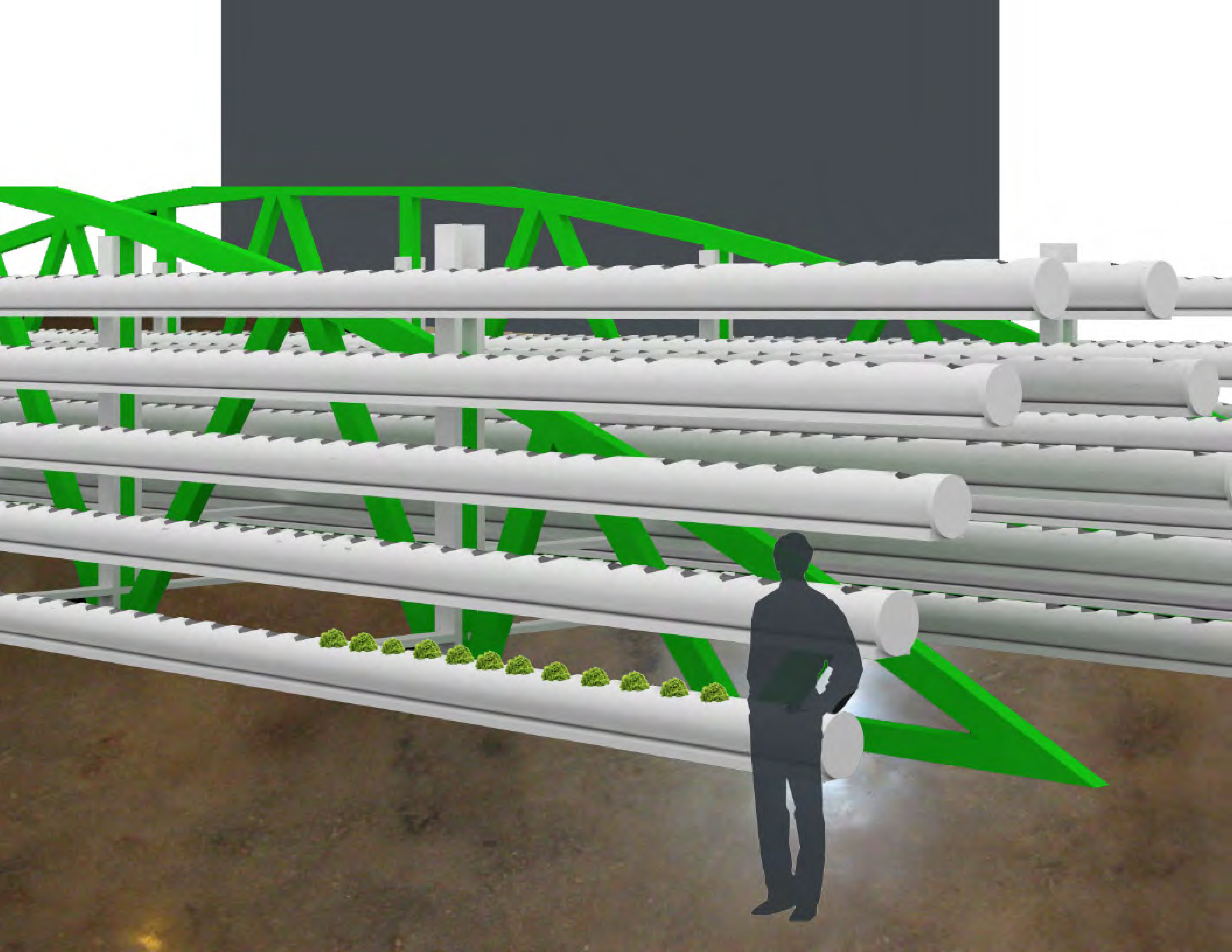
ENTRANCE

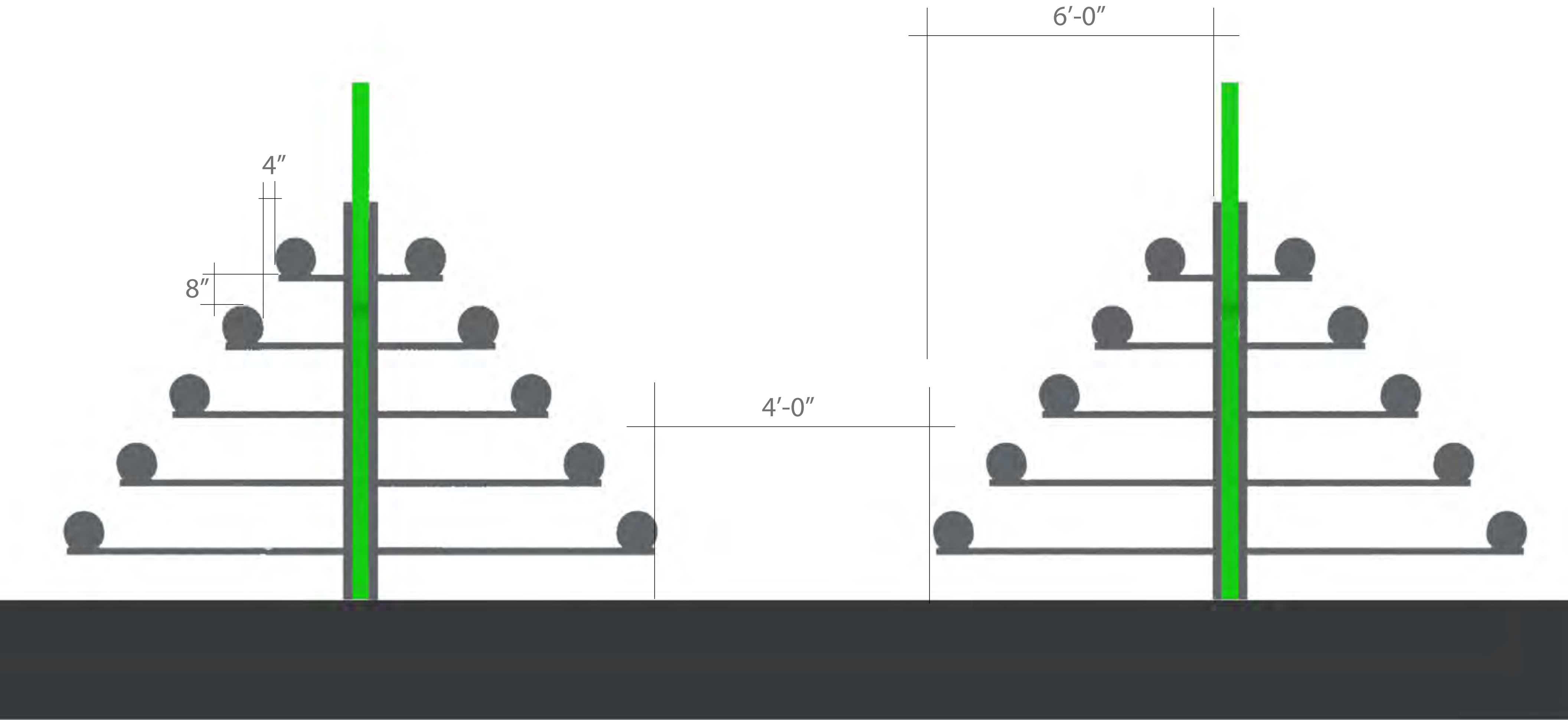
38,390 SF
OF FARMING

AEROPONICS
Tomatoes
Strawberries
Cucumbers

HYDROPONICS
Potatoes
Lettuce
Beans

THE FARM




6′-0″
4″
8″
4′-0″

KING STREET

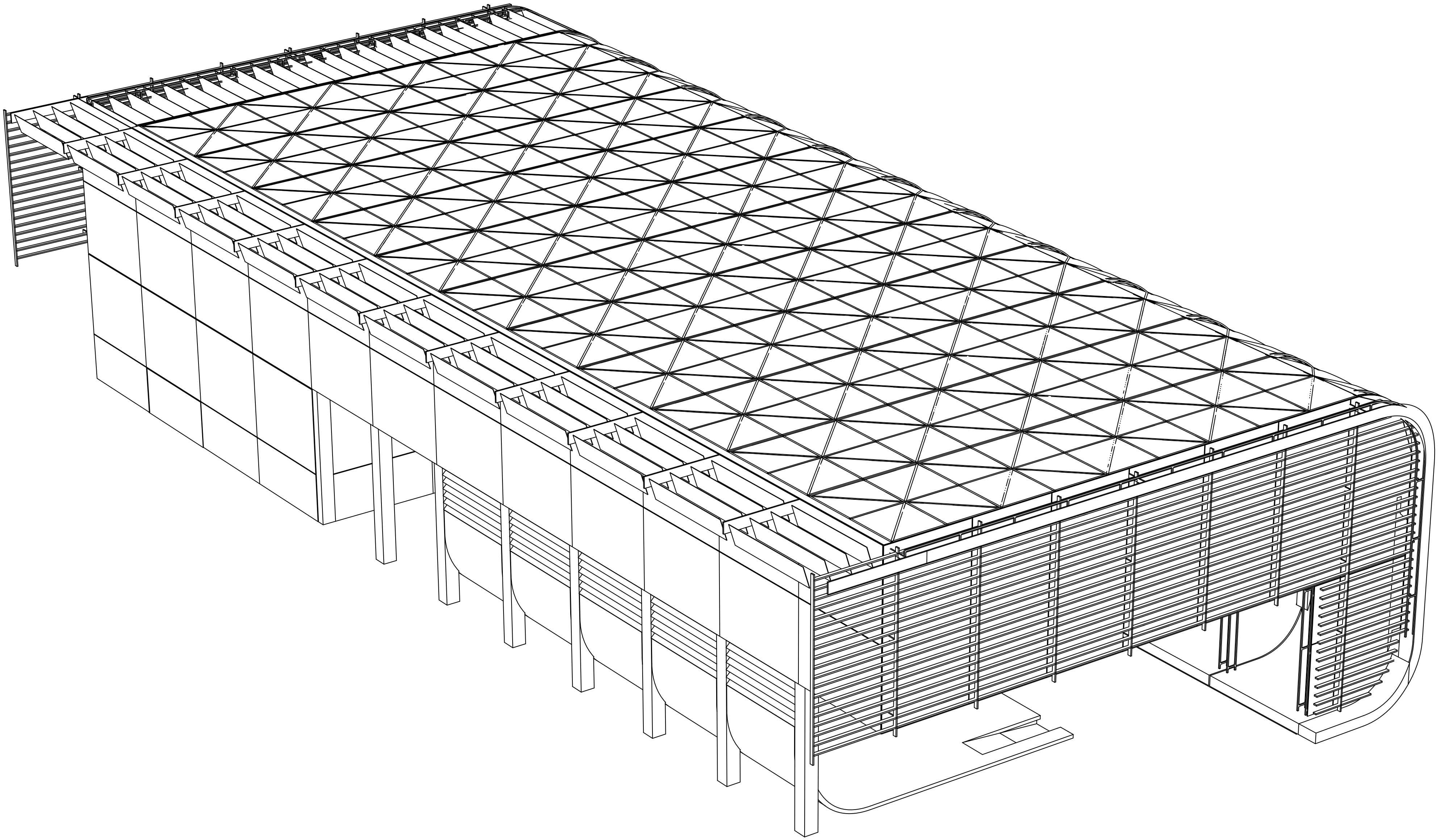
Design Model 3

Conveyance System by Meghan Welford and Thomas Jasper

<u>Design Summary</u>

This Vertical Farm Design is based directly on the “conveyance system.” This system maximizes the amount of southern sun exposure and amount of yield of plants. The L-shape of the conveyance system, designed to utilize the sun along the roof and southern façade, informs the structure of the remainder of the building. The mechanically operated conveyance system circulates plants throughout the day along this edge to ensure sunlight and simplify the loading and unloading process for plants. Each of these conveyance tracks contains a number of hydroponic bag units that contains many plants that are constantly hydrated by water pipes throughout the system.

To engage the public, an open-air farmer’s market invites locals into the building, with a daily market and juice café to bring in daily revenue. Throughout the open-air market, there are glass openings to follow a conveyor of plants to discover the process from below.

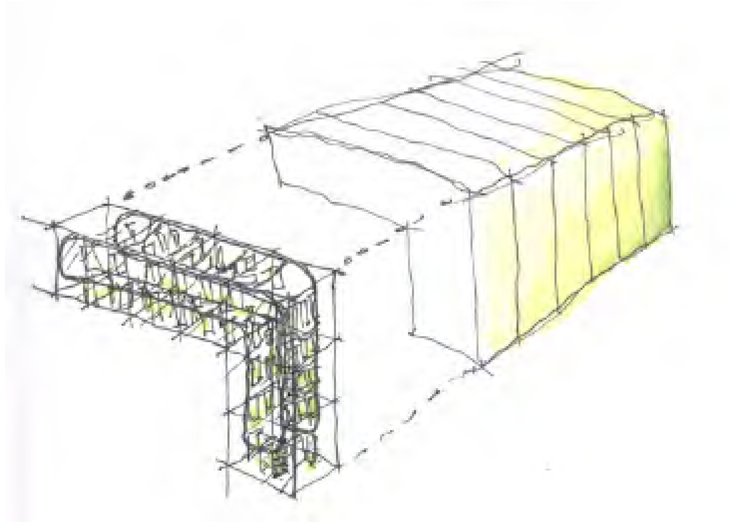


PRODUCTION CALCULATIONS

HYDROPONIC BAG UNIT

20 plants per row
8 rows
2 sides

320 plants



CROP ROTATION UNIT

320 plants per bag unit
4 plants per rack
26 racks per crop unit

33 280 plants

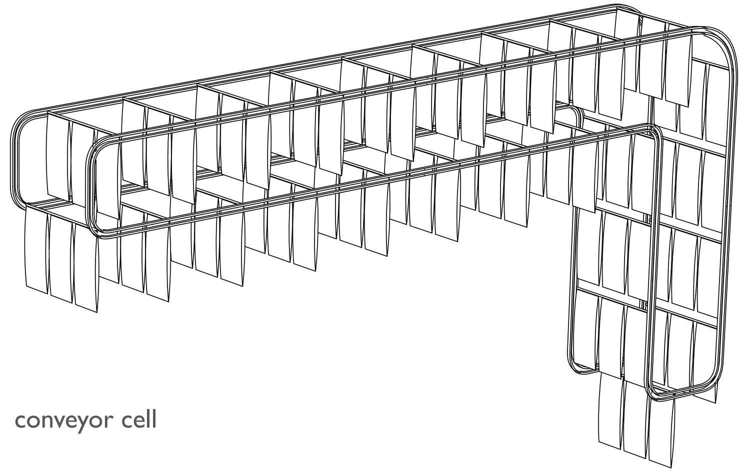
x11

366,080 plants

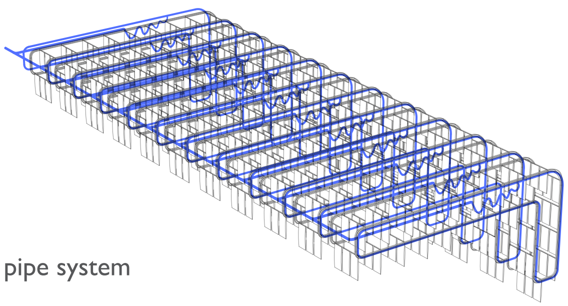
AVG. CROP ACRE CONSISTS OF 7,000 TO 13,000 PLANTS

~36 acres

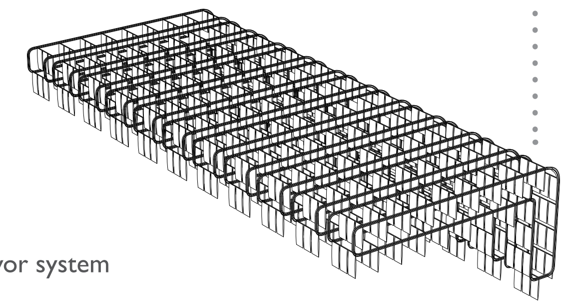
each conveyor cell fits between the exsisting barrel vaults arrayed every 16 feet from east to west



conveyor cell

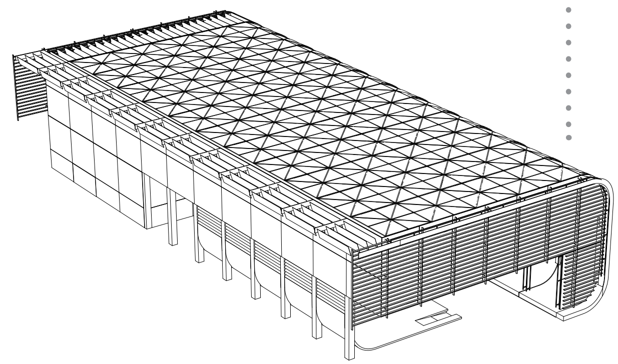


water pipe system



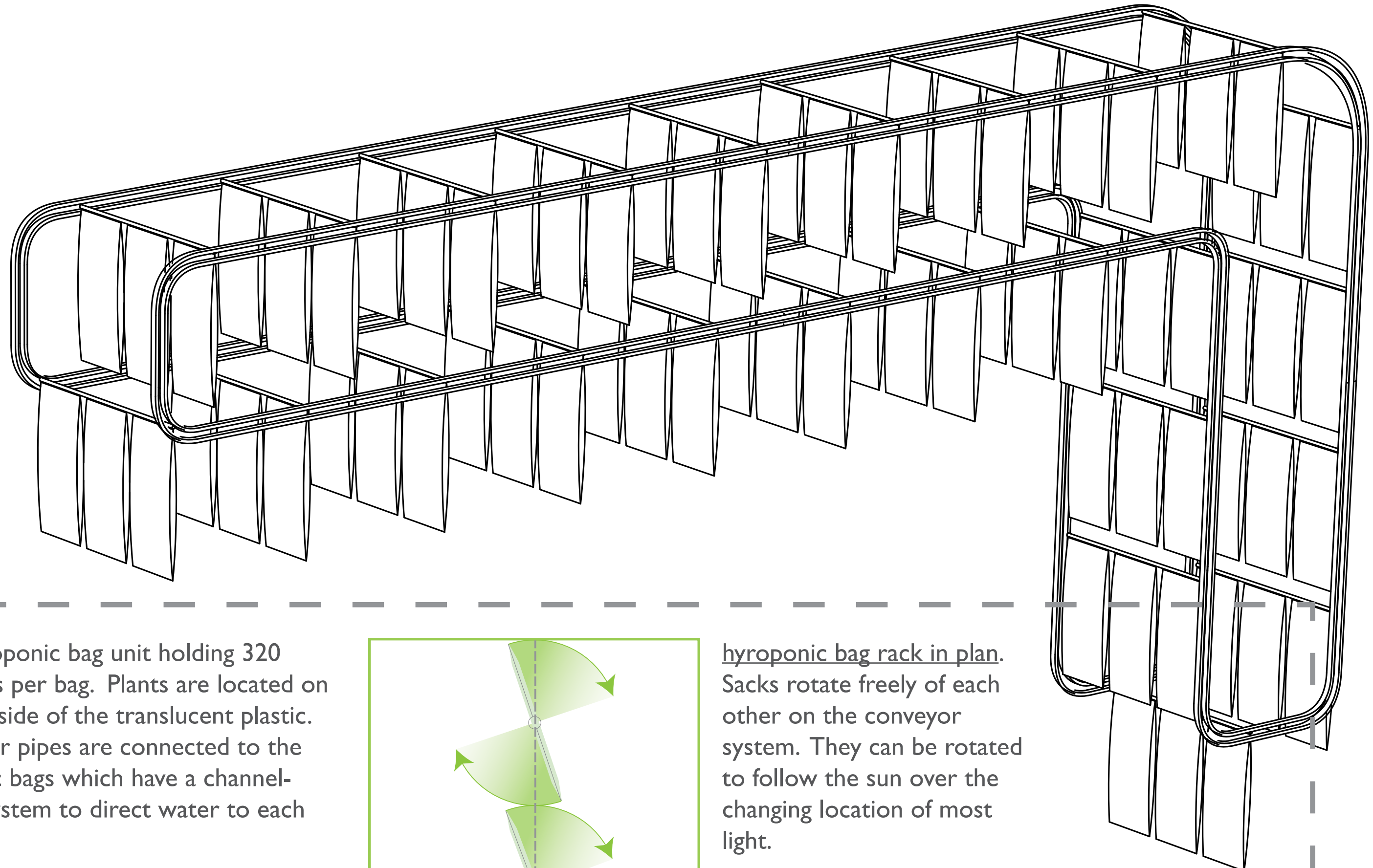
conveyor system

provides water for the hydroponic bags rotating within each conveyor cell

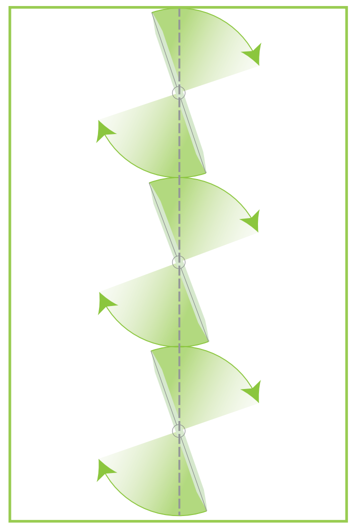


conveyancefarming

thomas jasper + meghan welford



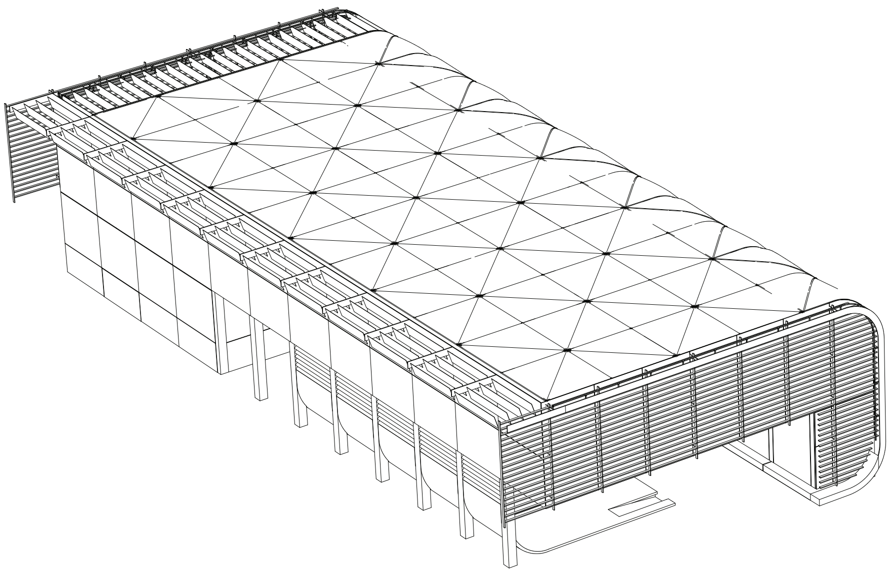
hydroponic bag unit holding 320 plants per bag. Plants are located on each side of the translucent plastic. Water pipes are connected to the pastic bags which have a channeling system to direct water to each plant.

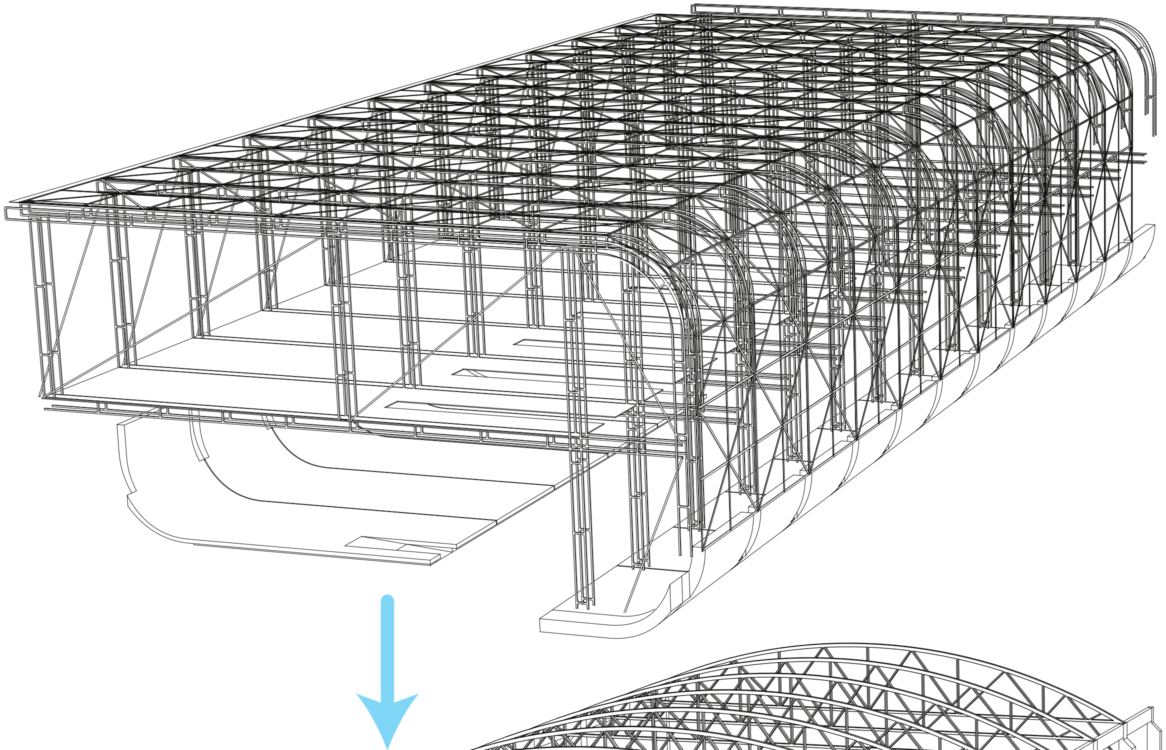


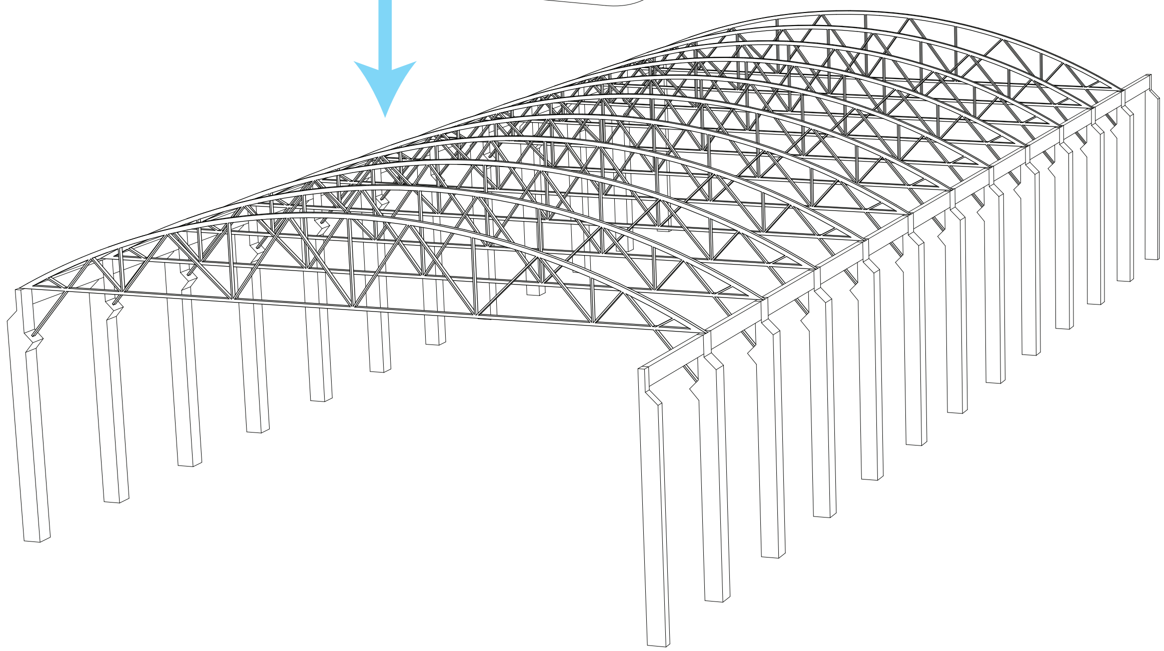
hyroponic bag rack in plan. Sacks rotate freely of each other on the conveyor system. They can be rotated to follow the sun over the changing location of most light.

conveyancefarming

thomas jasper + meghan welford

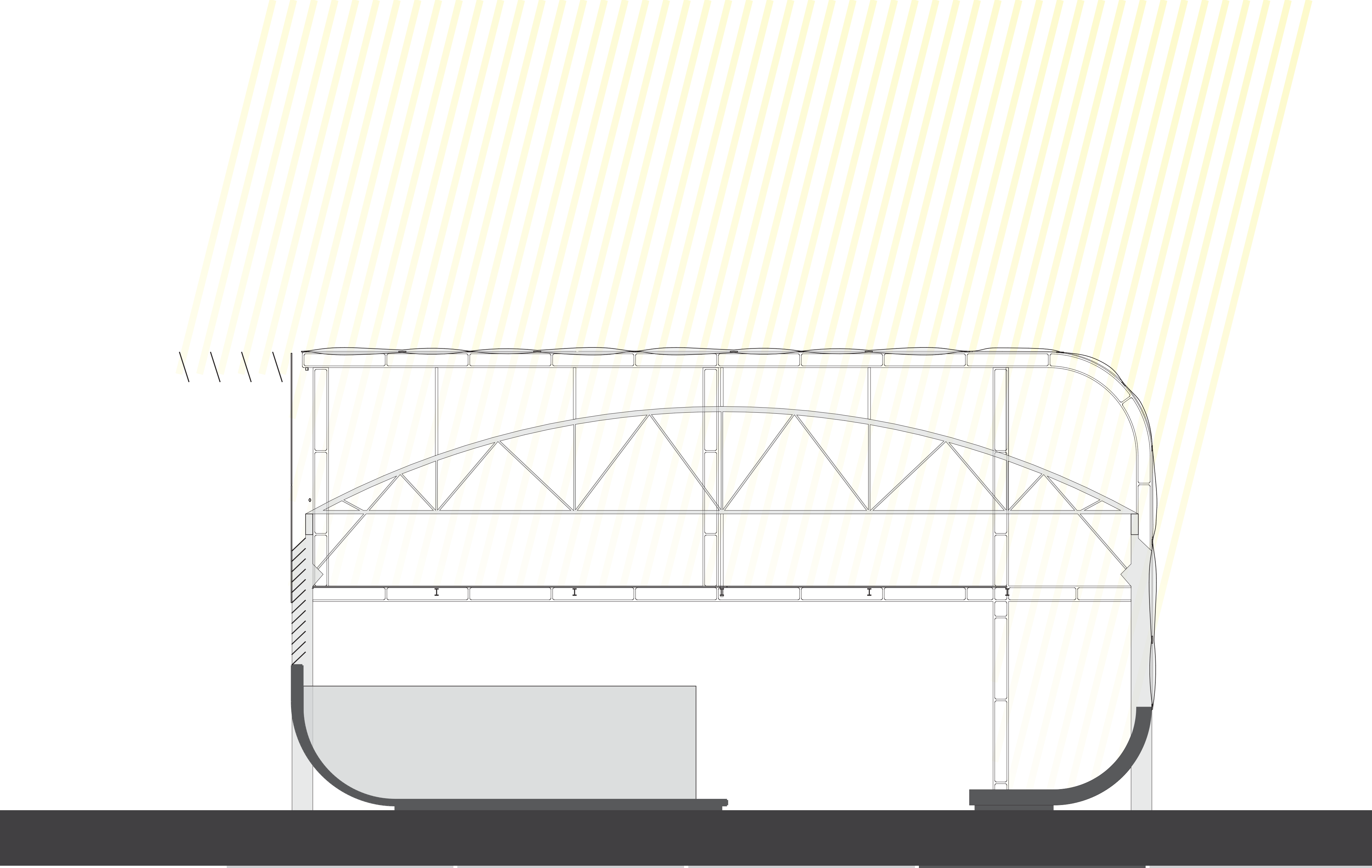






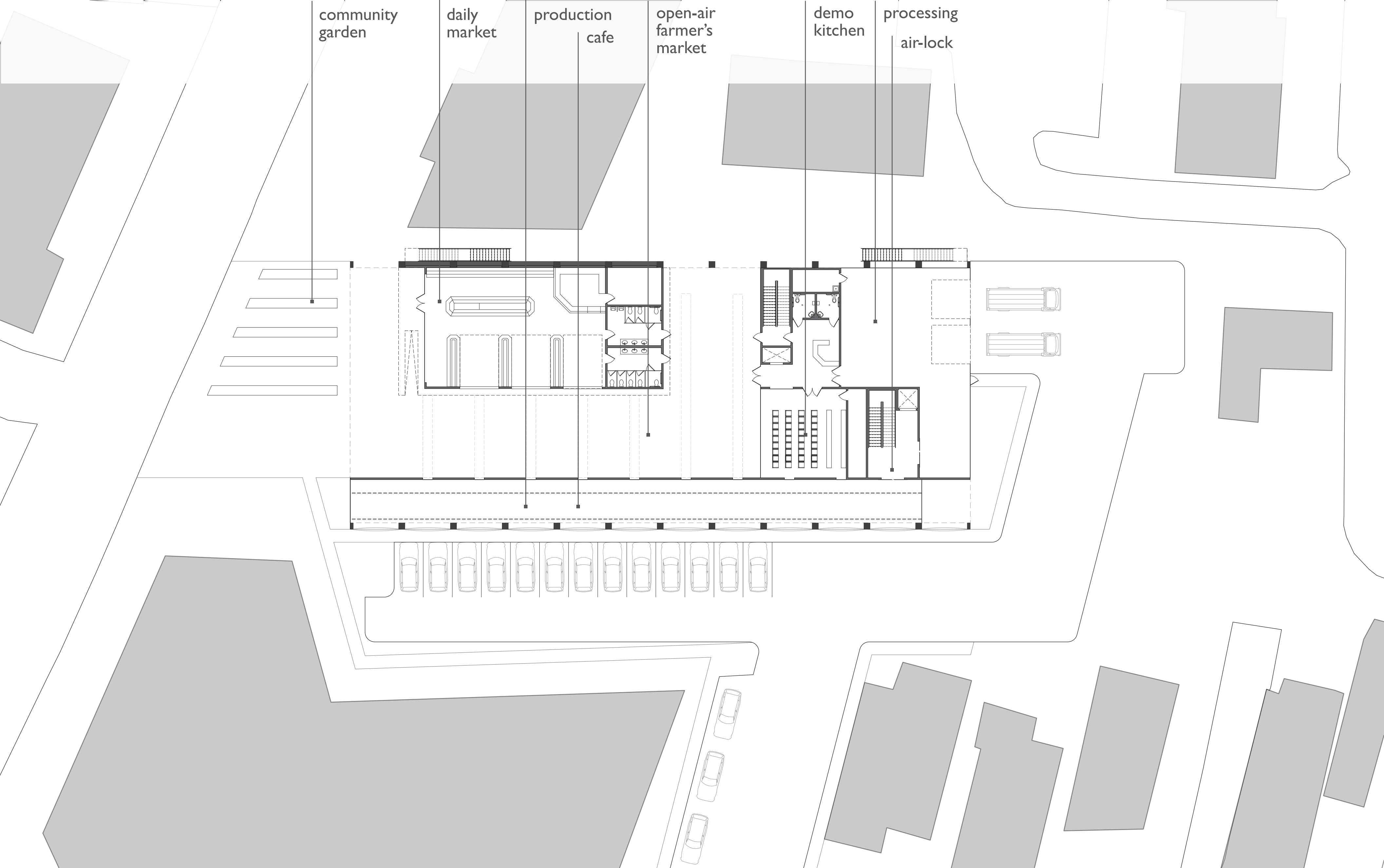
conveyancefarming

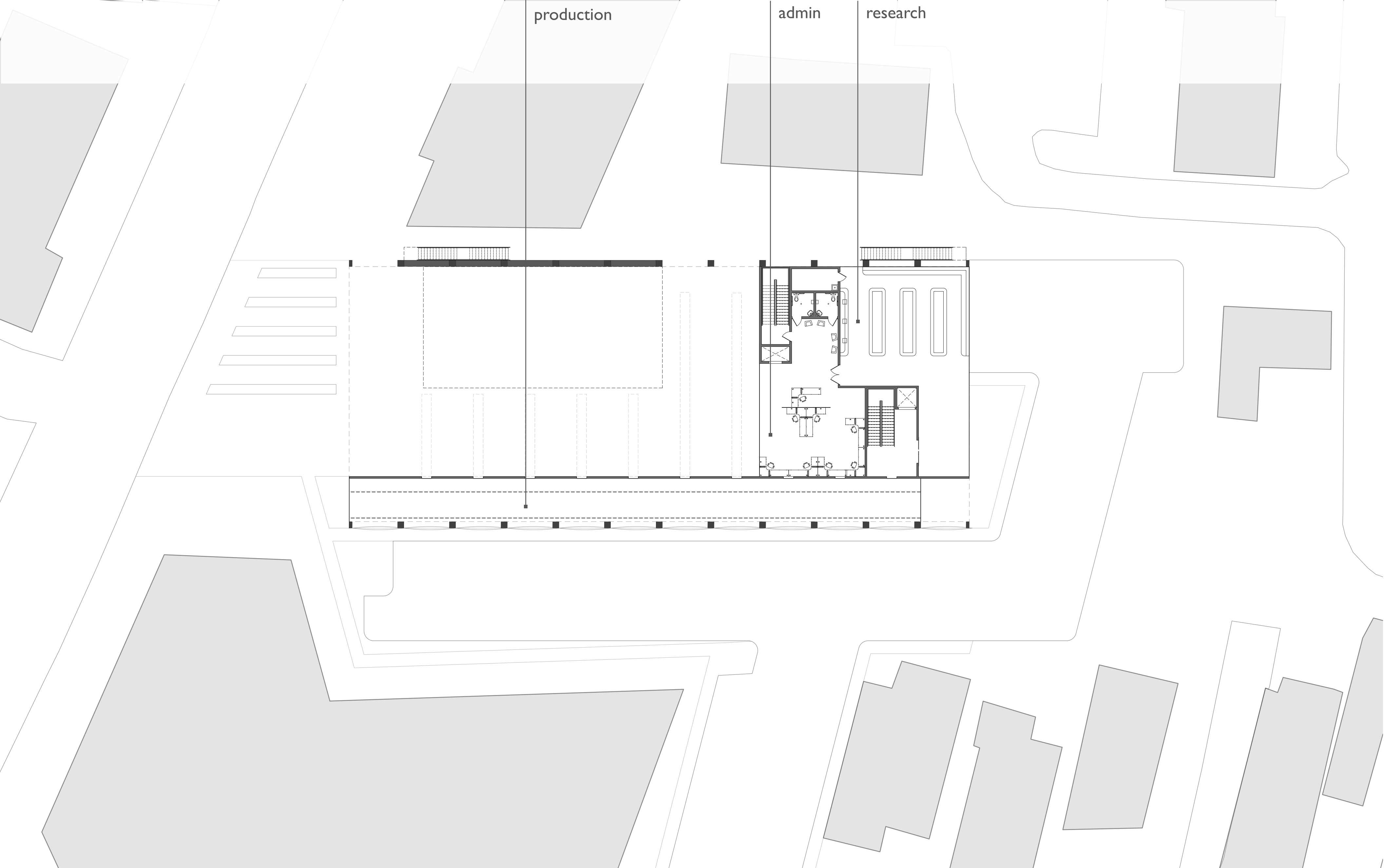
thomas jasper + meghan welford



conveyancefarming

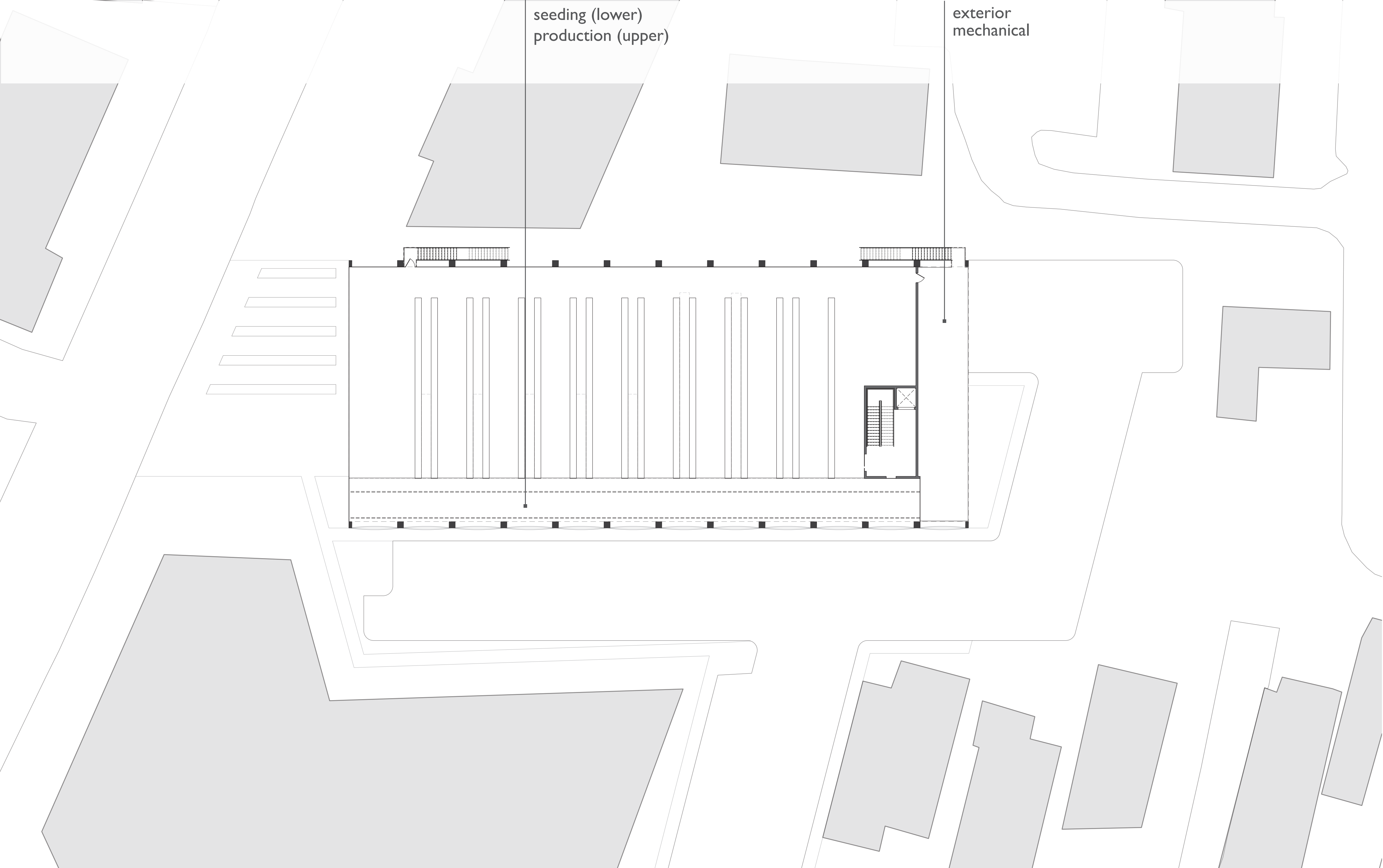
thomas jasper + meghan welford


community
garden
daily
market
production
cafe
open-air
farmer's
market
demo
kitchen
processing
air-lock



conveyancefarming

thomas jasper + meghan welford

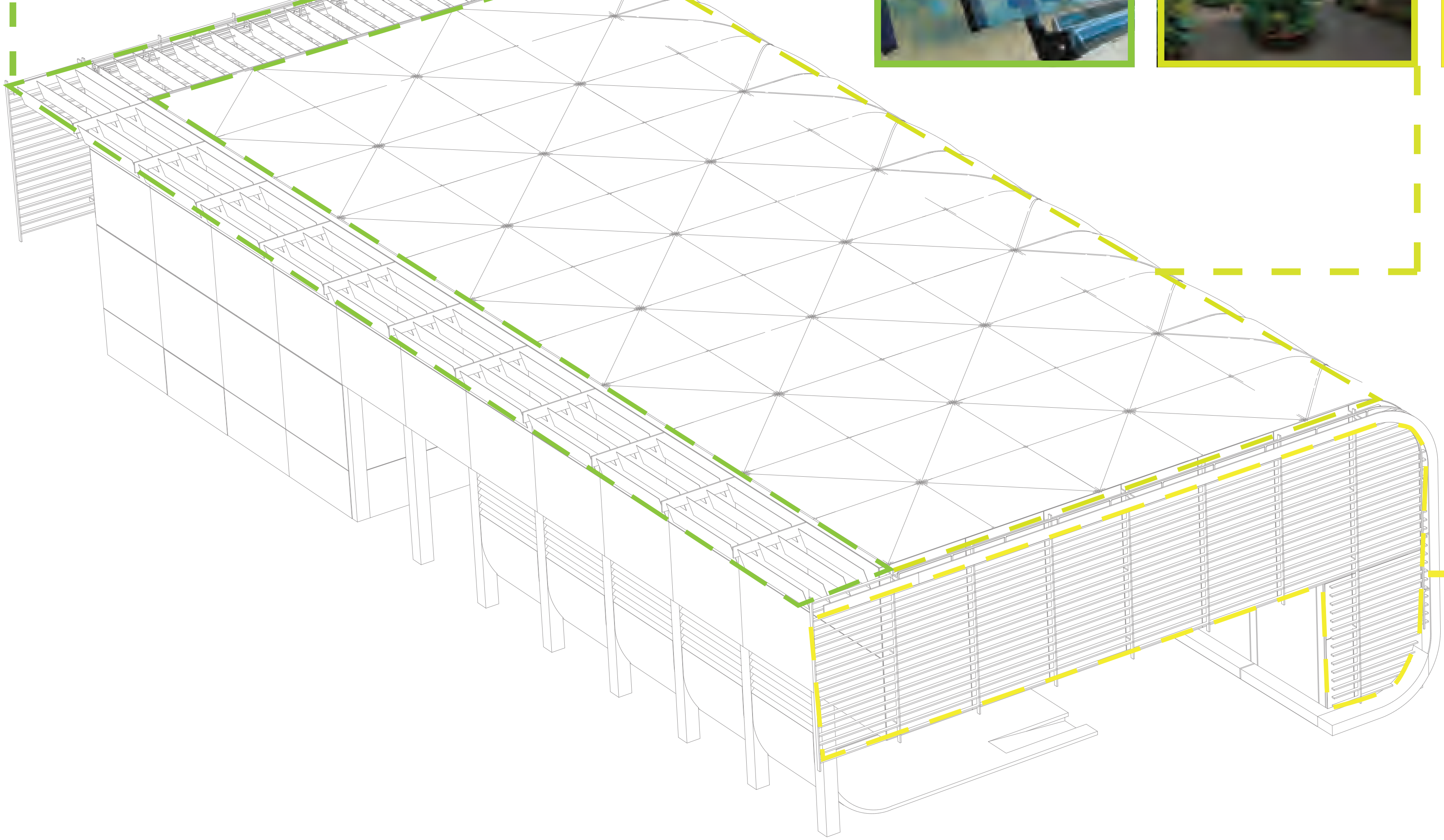


seeding (lower)
production (upper)
exterior
mechanical

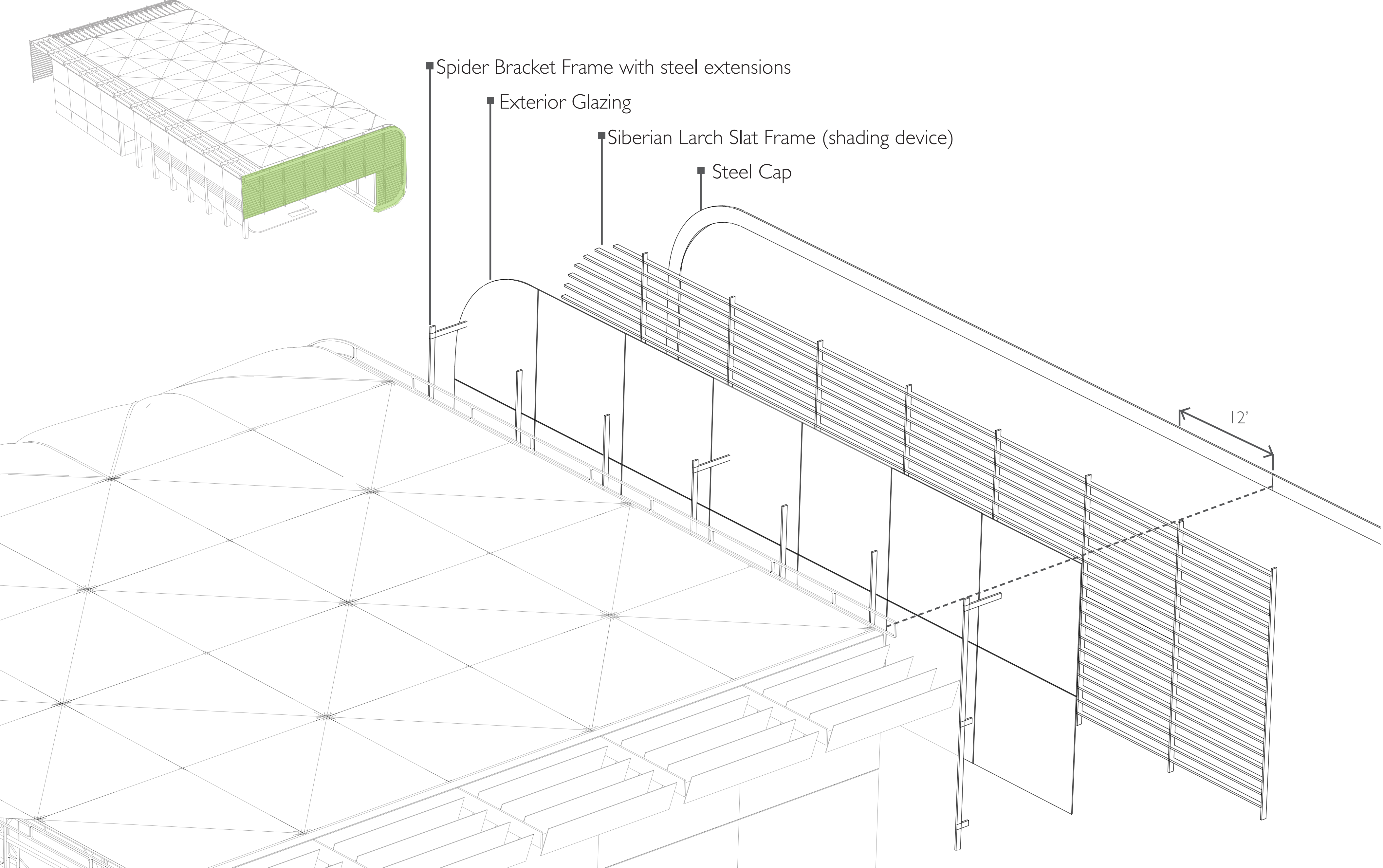
Photovoltaic Paneling

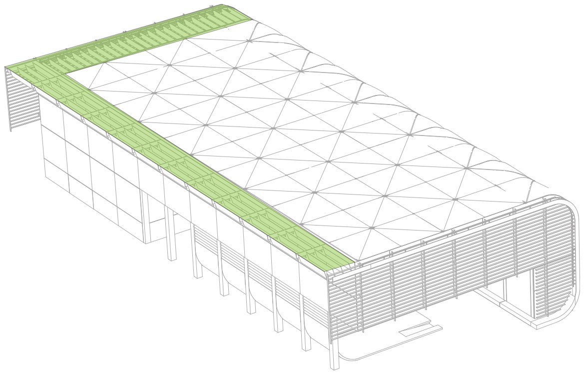
ETFE Envelope

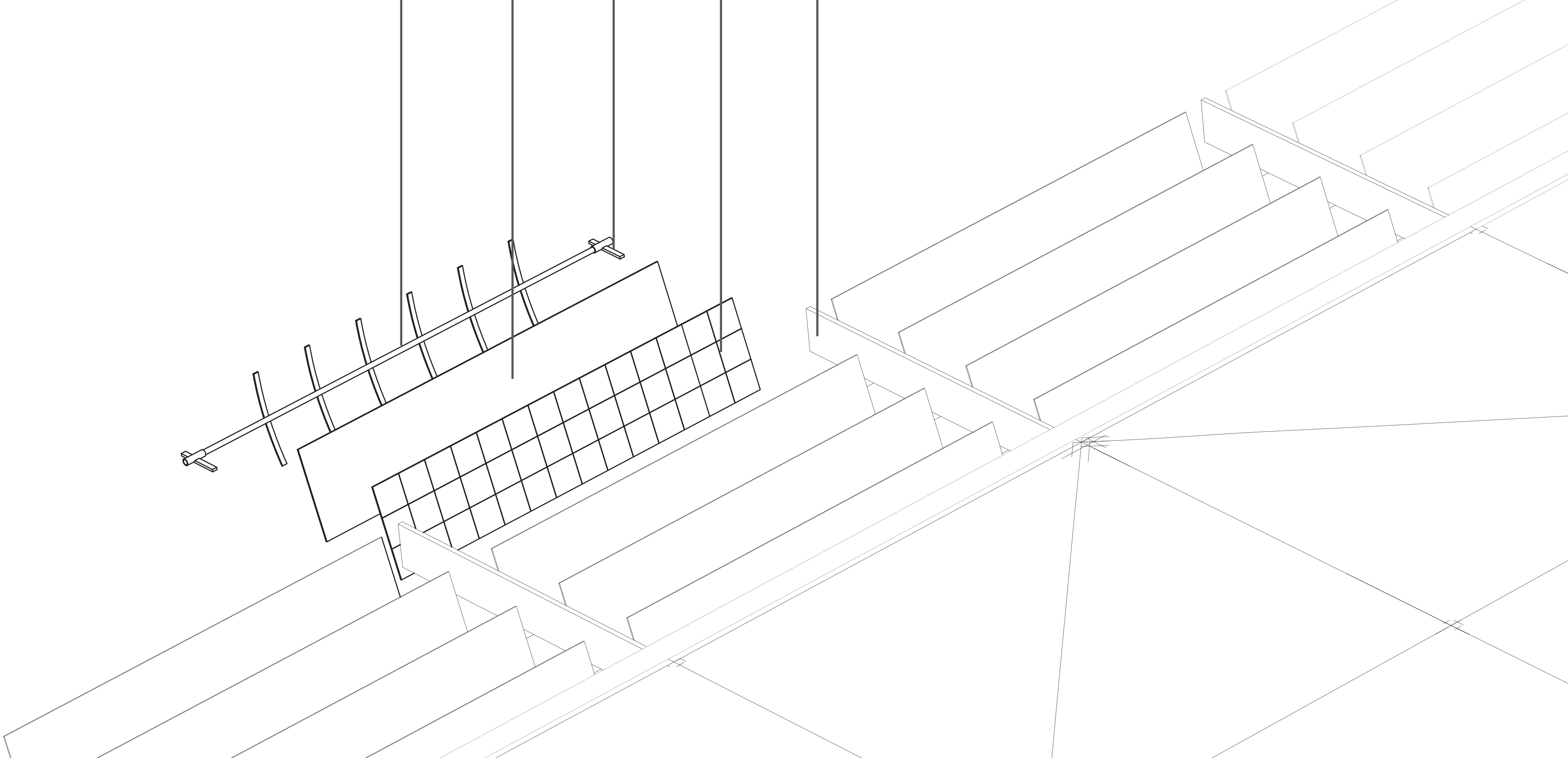
Wood Frame



conveyancefarming
thomas jasper + meghan welford

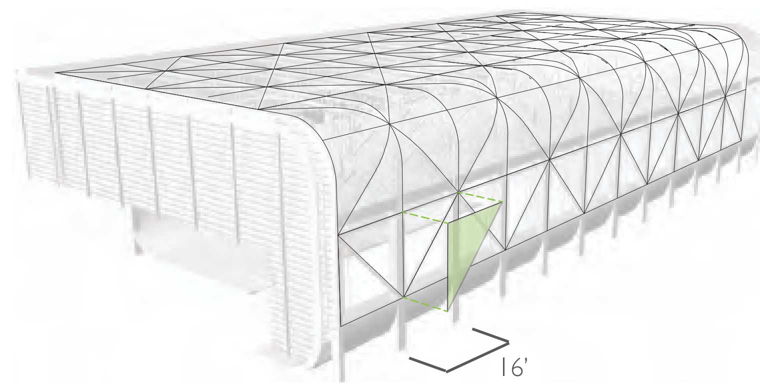

Spider Bracket Frame with steel extensions
Exterior Glazing
Siberian Larch Slat Frame (shading device)
Steel Cap
12'

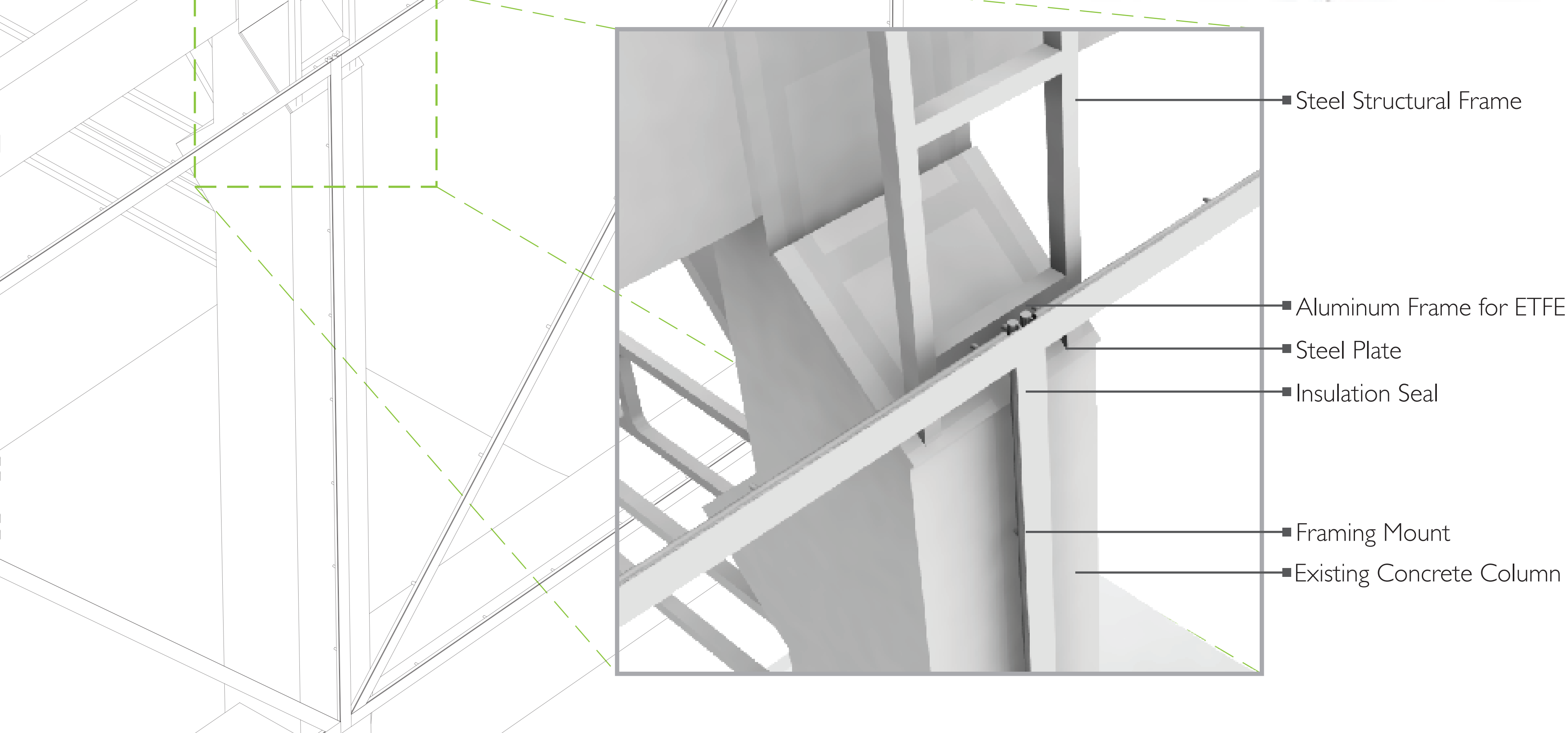


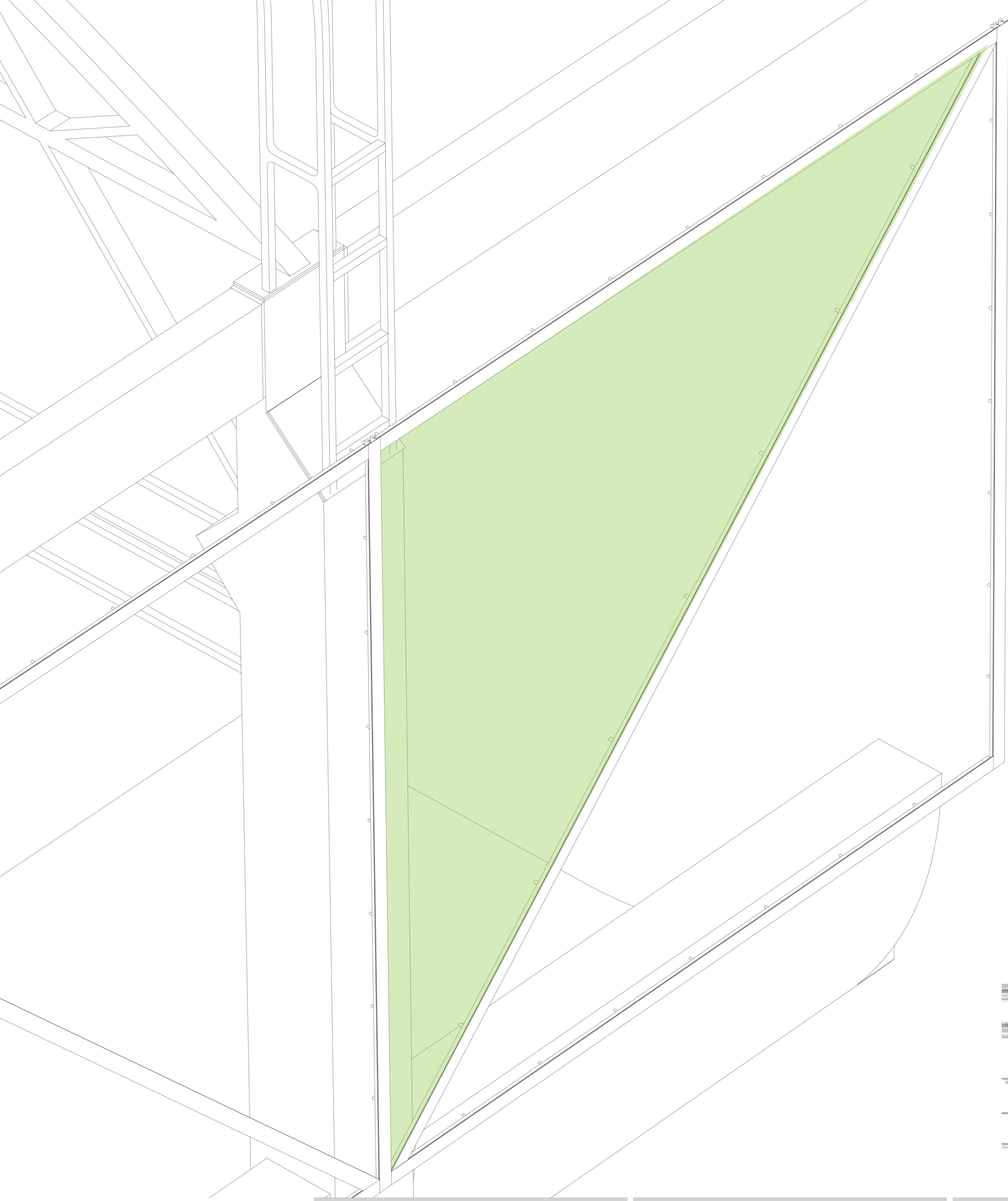


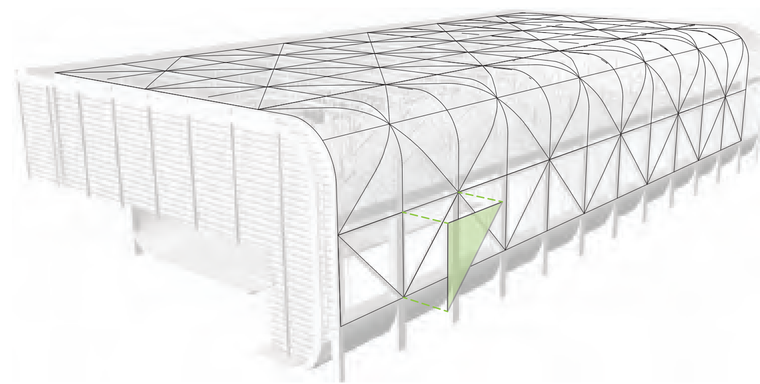
conveyancefarming

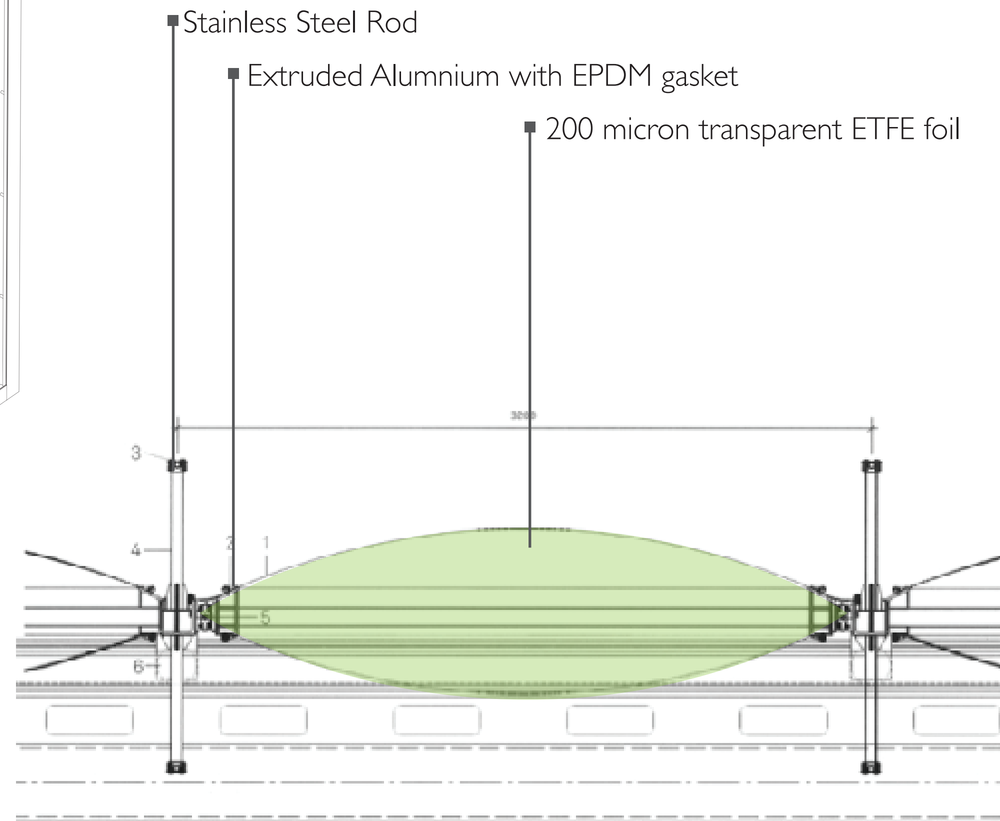
thomas jasper + meghan welford


16'


Steel Structural Frame
Aluminum Frame for ETFE
Steel Plate
Insulation Seal
Framing Mount
Existing Concrete Column







conveyancefarming

thomas jasper + meghan welford

Design Model 4

LOCAL ROOTS: Replanting Charleston's Urban Food Culture by Kristin Kolowich and Jon Michael Williamson

Design Summary

The idea behind vertical farming takes the horizontal component of farming and begins to repeat and stack grow areas in the vertical direction. Many vertical farm design proposals to-date take this concept and repeat dozens of floors which results is a skyscraper design. Since Charleston does not have a tall skyline, a skyscraper would dominate the cityscape which would take away from the city's historic ambiance. On site there is also a height restriction that prevents this exact thing from happening. Therefore we can use the horizontal stacking method to maximize grow space within our allowed height.

The approach we took towards our vertical farm design focused primarily on the socioeconomic relationship between the farm and the community. A majority of the criticism on vertical farming focuses on the inability of the design to be economically sustainable, let alone a profitable operation, due to the costs of buying and operating the technology needed to grow the plants. The programmatic composition of our vertical farm prioritized the development of an efficient and effective business model that would make the whole operation economically sustainable.

The first component of our business model is to start a CSA membership program in our building. The CSA model (Community Supported Agriculture) is a form of an alternative food network and a socioeconomic model of agriculture and food distribution. The community pledges to support the farming operation by purchasing seasonal or annual memberships. Both the growers and the consumers share the risk and the benefits of the farming operation through this direct marketing approach. CSA members can only get what the vertical farm grows but they are guaranteed a box full of fresh vegetables every week. The average CSA membership in the United States ranges from $350 - $500 per growing season, which lasts between 14 - 20 weeks. The membership is very affordable at $20 per week.

The second component of the business is to set up a wholesale distribution operation for the city of Charleston. The wholesale operation will specialize in farming only leafy greens like kale, spinach and green cabbage. Local groceries and restaurants can purchase organic, locally grown and harvested crops at a wholesale price throughout the year. Leafy greens are excellent crops to specialize in. They are high in nutrients and can be used in millions of ways. If the vertical farm dedicates 6 cubic acres space to growing leafy greens, we can grow more than one million plants per harvest and an average of six million plants per year. Using hydroponic technologies, we can decrease the growth period of the plants to 50 days which gives us an average of six harvests per year. Even though the farm will be selling the crops wholesale, it is still estimated that the wholesale operation alone will produce around 2,276 tons of produce per year and generate approximately $1,277,800.00 per year.

The crops that will be grown in the vertical farm were selected based on a number of economic factors. The overall business model of the whole vertical farming operation aims to maximize diversity and yields through crop selection while maintaining positive profit margins. A sustainable-farming economic model achieves strength in crop diversity. Crops with offsetting growth patterns and market prices will produce the most stabilized revenue. In order to create this offset, crops were selected based on profits at market, volume per harvest, yields per year and number of harvests per year. The first floor of the farm, which will serve the CSA program, will grow yellow squash, green onions, leeks, zucchini, snow peas, tomatoes and bean sprouts through hydroponic and aquaponic technologies. The second floor of the farm, which primarily serves the wholesale operation, will grow spinach, kale and green cabbage through only hydroponic systems.

The success of the vertical farm depends entirely on the support of the community. The farm itself will provide crops for a variety of community-based program elements but in order for the whole system to be cyclical, the community must be able to actively support the farm. The Local Roots design places all of the public spaces on the ground floor so that people can easily participate in the facilities and amenities. The top two floors are completely dedicated to vertical farming operations. This "top-down" organization allows for the vertical farm to be conceptually- and literally, supported by the community.

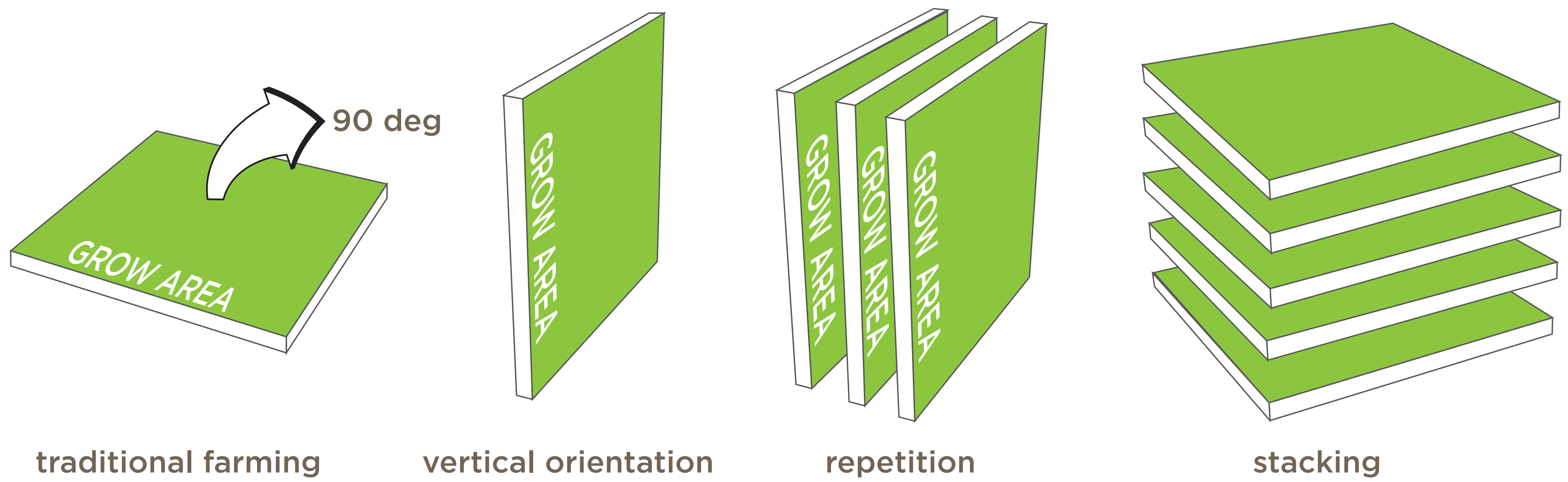

re:planting charleston's urban food culture with local
ROOTS

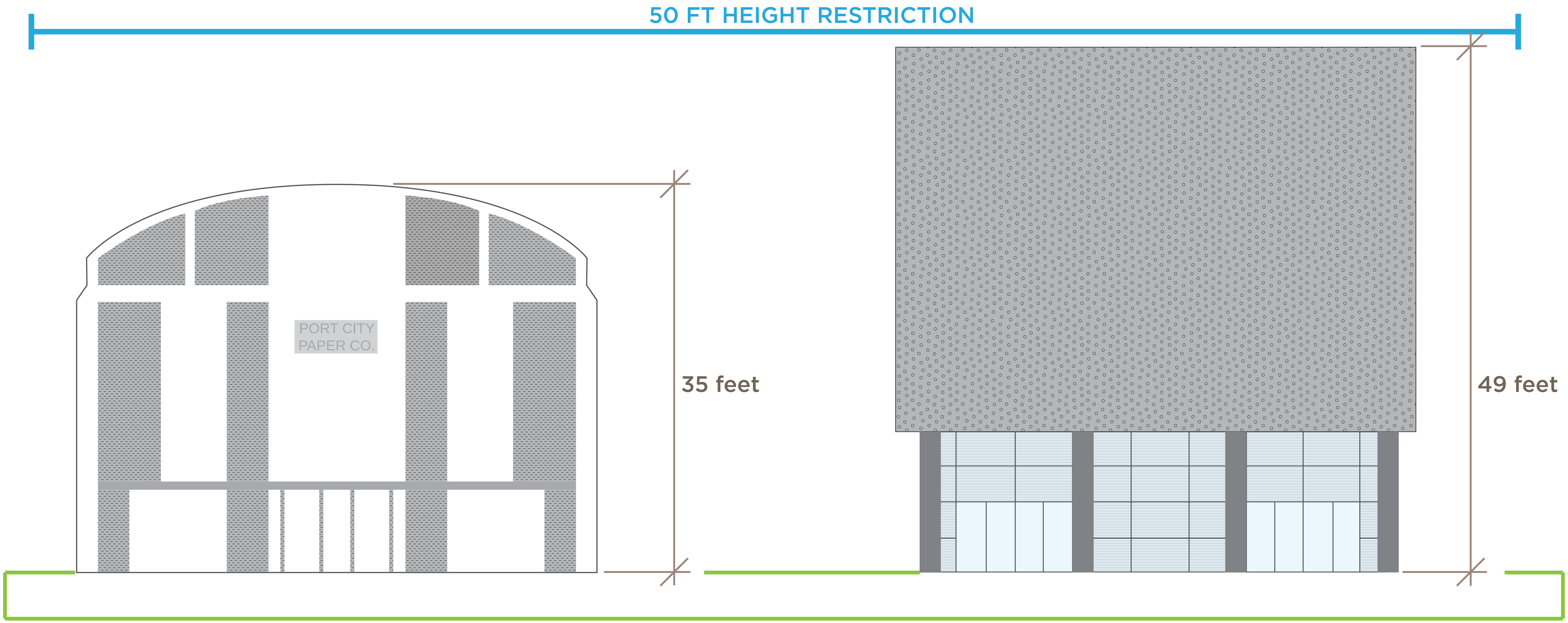
SITE LOCATION
1056 KING STREET
CHARLESTON, SC

CITY ZONING REGULATIONS

The idea behind vertical farming takes the horizontal component of farming and begins to repeat and stack grow areas in the vertical direction. Many vertical farm design proposals to-date take this concept and repeat dozens of floors which results is a skyscraper design.

Since Charleston does not have tall skyline, a skyscraper would dominate the cityscape which would take away from the city's historic ambiance. On site there is also a height restriction that prevents this exact thing from happening. Therefore we can use the horizontal stacking method to maximize grow space within our allowed height.





COMMUNITY SUPPORTED AGRICULTURE

"THE BOX SCHEME"

Community Supported Agriculture is a form of an alternative food network and a socio-economic model of argriculture and food distribution.

The community pledges to support the farming operation by purchasing seasonal or annual memberships. Both the growers and the consumers share the risk and the benefits of the farming operation.

CSA members can only get what the vertical farm grows but they are guaranteed a box full of fresh vegetables every week.

The average CSA membership in the United States ranges from \$350 - \$500 per growing season, which lasts between 14 - 20 weeks. The membership is very affordable at \$20 per week.

BENEFITS OF BECOMING A CSA MEMBER:

- ☑ *Seasonal and annual memberships*
- ☑ *Weekly pick-ups at the Local Roots Market*
- ☑ *Pay a fixed rate for fresh produce*
- ☑ *Start or stop your membership at any time*
- ☑ *Discounts and benefits for members*

LOCAL ROOTS FARMING DISTRIBUTION

WHOLESALE OPERATION

The wholesale operation of the Local Roots Vertical Farm will specialize in farming leafy greens like kale, spinach and different types of lettuce. Local groceries and restaurants can purchase organic, locally grown and harvested crops at a wholesale price throughout the year.

Leafy greens are excellent crops to specialize in. They are high in nutrients and can be used in millions of ways. If the vertical farm dedicates half of an acre of space to growing leafy greens, we can grow more than 300 plants per harvest. Using hydroponic and aquaponic technologies, we can decrease the growth period of the plants to 50 days which gives us around seven harvests per year. Even though the farm will be selling the crops wholesale, it is still estimated that the operation will earn approximately $250,000 of revenue in it's first five years.

BENEFITS OF A WHOLESALE OPERATION:

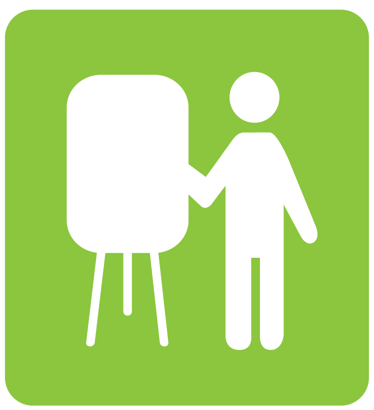
- ☑ *High yields and high density*
- ☑ *Frequent harvesting*
- ☑ *Provides organic crops to local groceries and restaurants*
- ☑ *Eliminates distribution-related transportation time and costs*

FARMER'S MARKET

The farmer's market will be available to the general public. Non-CSA members can purchase fresh vegetables from the vertical farm in a boutique grocery setting. The market will also help encourage CSA

MARKET CAFE

Adding a cafe to the farmer's market will further encourage visitors to eat local produce from the vertical farm. It will be a great way to showcase different recipes using the vegetables grown right upstairs.



EDUCATION KITCHEN

An educational lab and test kitchen will be available to CSA members to use for sustainable food education, testing recipes. learning how to cook with their fresh vegetables. Non-members can also pay to take classes as well.

DONATION PROGRAM

The vertical farm can plege to give back to the community every week by donating the unsold crops from the farm to local non-profit relief organizations.

COMMUNITY SUPPORTED FARMING

The success of the vertical farm depends entirely on the support of the community. The farm itself will provide crops for a variety of community-based program elements but in order for the whole system to be cyclical, the community must be able to actively support the farm. The Local Roots design places all of the public spaces on the ground floor so that people can easily participate in the facilites and amenities. All of the farming takes place on the second and third floors. This organization allows for the vertical farm to be conceptually- and literally, supported by the community.

ARCHITECTURAL DESIGN CONCEPT

1

+ Transparent public/community space on ground floor
+ Heavy, opaque farm space floats above

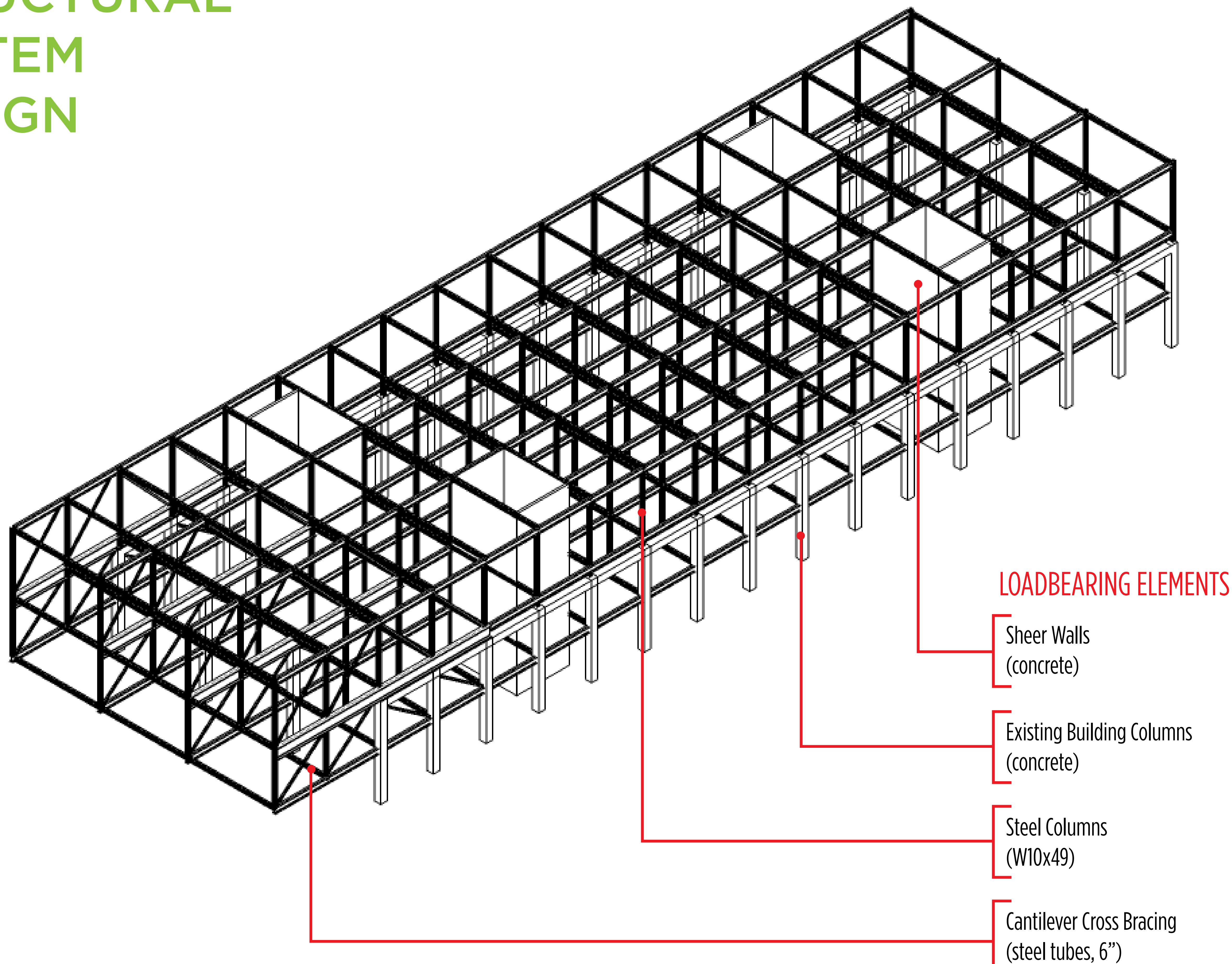
2

+ Glass curtain wall for transparent ground floor
+ Utilize existing grid and concrete columns
+ Extend farming space out towards the street

3

+ Vertical farm space “floats” on community space
+ Floating occurs visually with a glass ground floor
+ Floating occurs literally with the large cantilever
+ Public moves from street to building transparently

STRUCTURAL SYSTEM DESIGN



local ROOTS

GROUND FLOOR PLAN

A. OUTDOOR CAFE AREA
B. MARKET AND CSA PICK UP
C. RESTROOMS
D. EDUCATION LAB/KITCHEN AREA
E. EDUCATION LAB/CLASSROOMS
F. STORAGE AREA
G. ADMINISTRATION
H. PRIVATE OFFICES
I. LOADING ZONE
J. SEED LAB AREA

FARMER'S MARKET

FARM CROP SELECTION

The crops that will be grown in the vertical farm were selected based on a number of factors. The overall business model of the whole vertical farming operation aims to maximize diversity and yields through crop selection while maintaining positive profit margins.

A sustainable-farming economic model achieves strength in crop diversity. Crops with offsetting growth patterns and market prices will produce the most stabilized revenue. In order to create this offset, crops were selected based on profits at market, volume per harvest, yields per year and number of harvests per year.

$ HIGH PROFITS PER CROP

HIGH VOLUME CROPS

HIGH YIELD PER YEAR

HIGH HARVEST RATES

SPINACH

YELLOW SQUASH

GREEN ONIONS

KALE

LEEKS

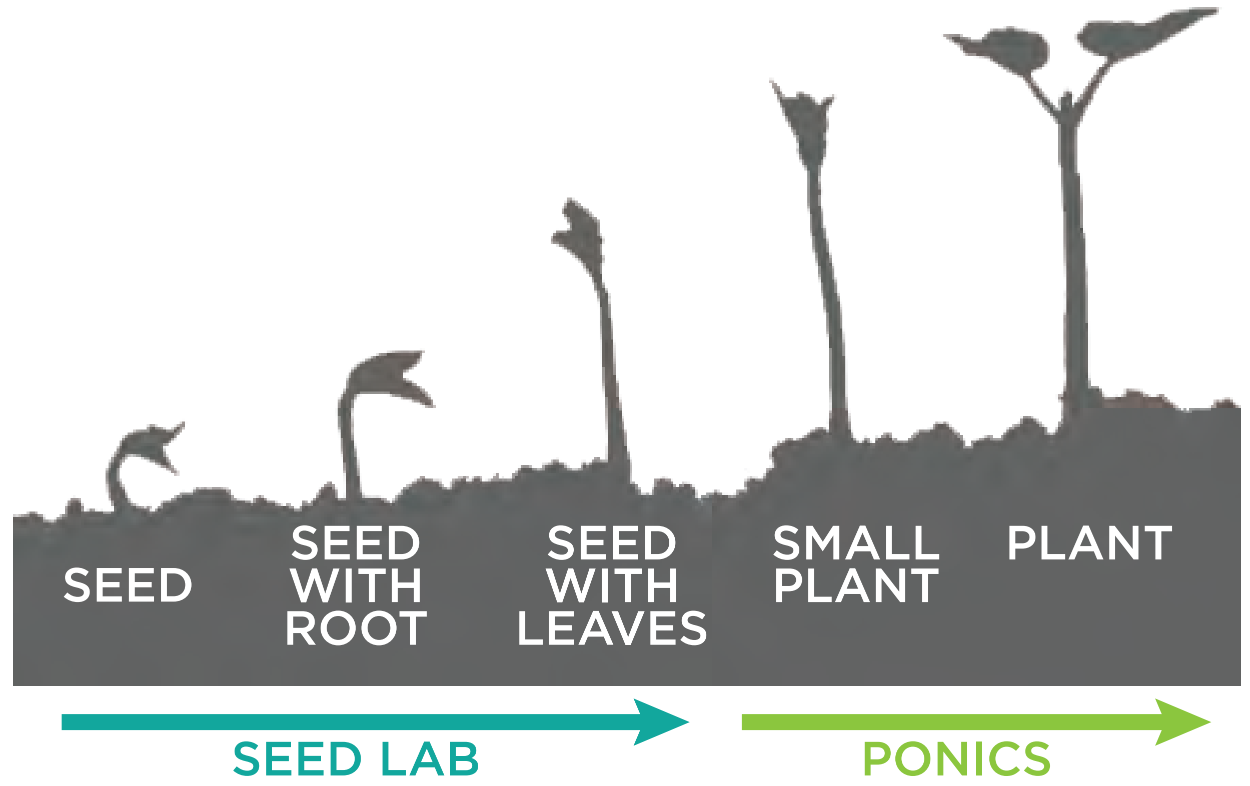
ZUCCHINI

SNOW PEAS

TOMATOES

BEAN SPROUTS

SEEDING SYSTEMS DESIGN

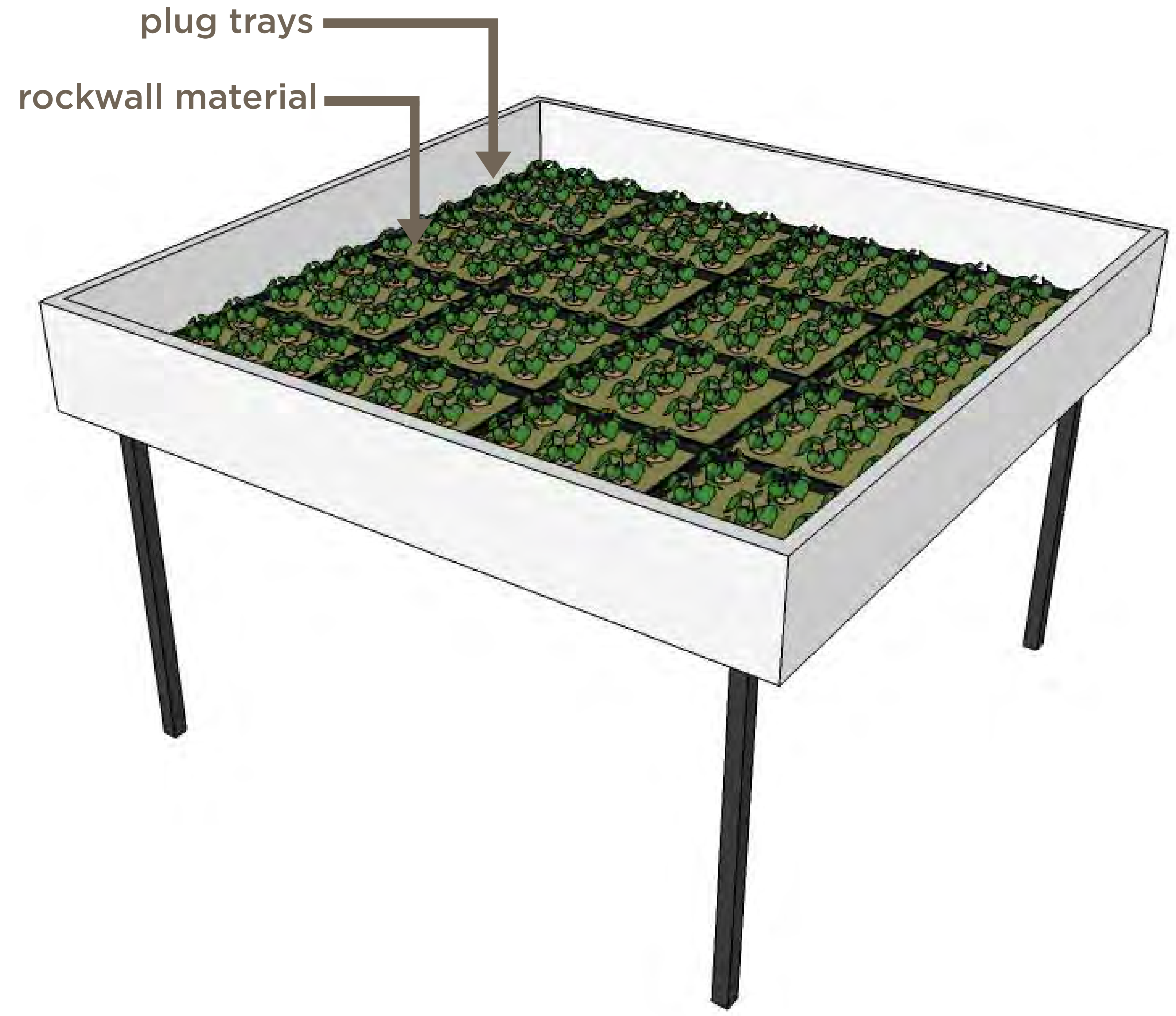


Before a plant can be placed into a hydro-, aero-, or aqua- ponic system, they must be nurtured as seedlings in a seed lab, or nursery. The seed lab has specialized technologies that quickly accelerate the growth of seedlings and are specific to the different ponic systems.

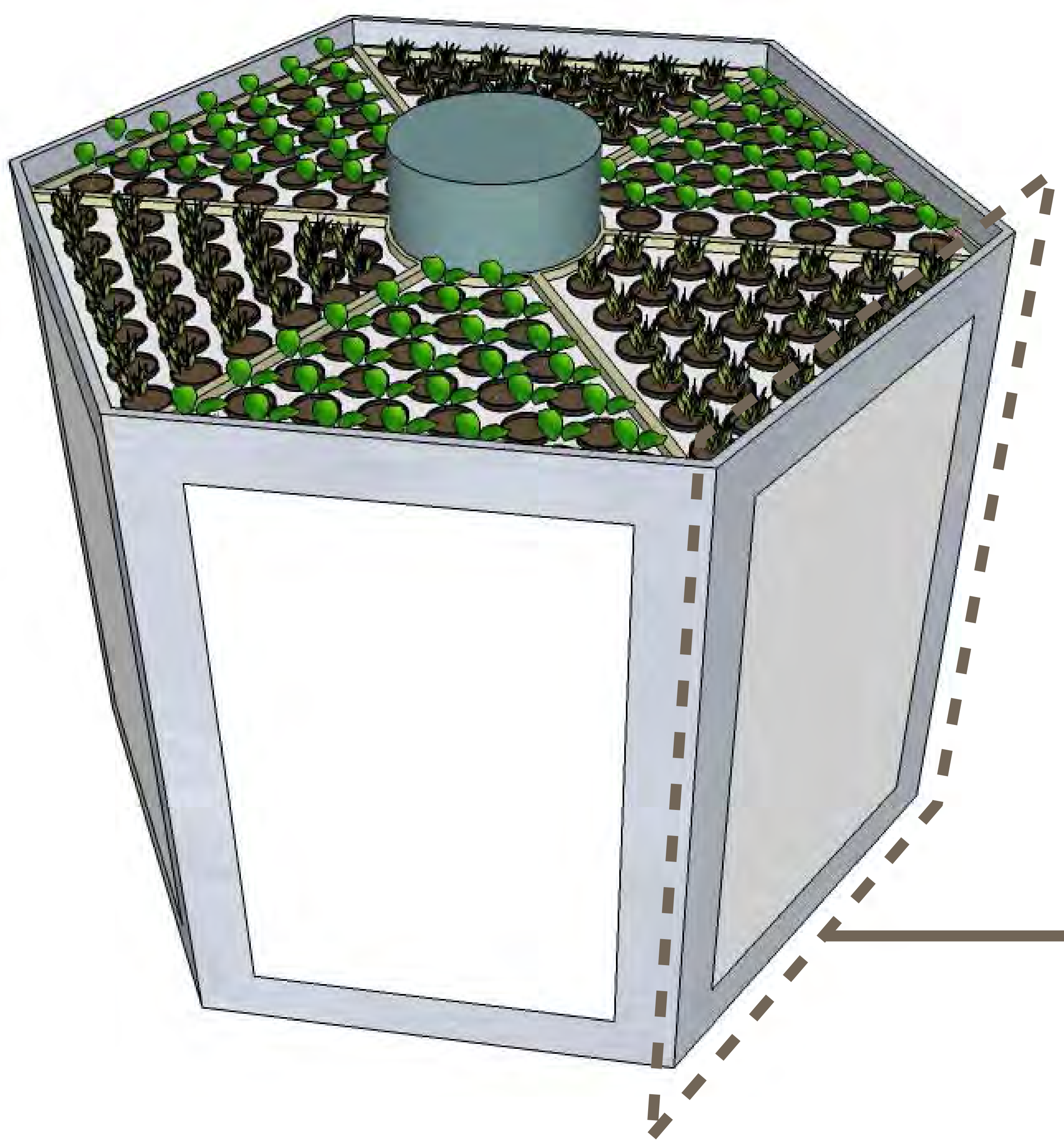
Hydroponic and aquaponic seeds are started in the tray system. Two seeds are placed into each “plug” which is made up of inorganic material. Once the plants are 2-3 inches tall (from 1-4 weeks), they can be transplanted into the larger systems for full maturation.

Aeroponic seeds are nurtured in a separate system where each seed is implanted into 1-5/8” thick neoprene inserts in the plug trays. The vortex spray constantly sprays the roots with an oxygen-rich nutrient solution.

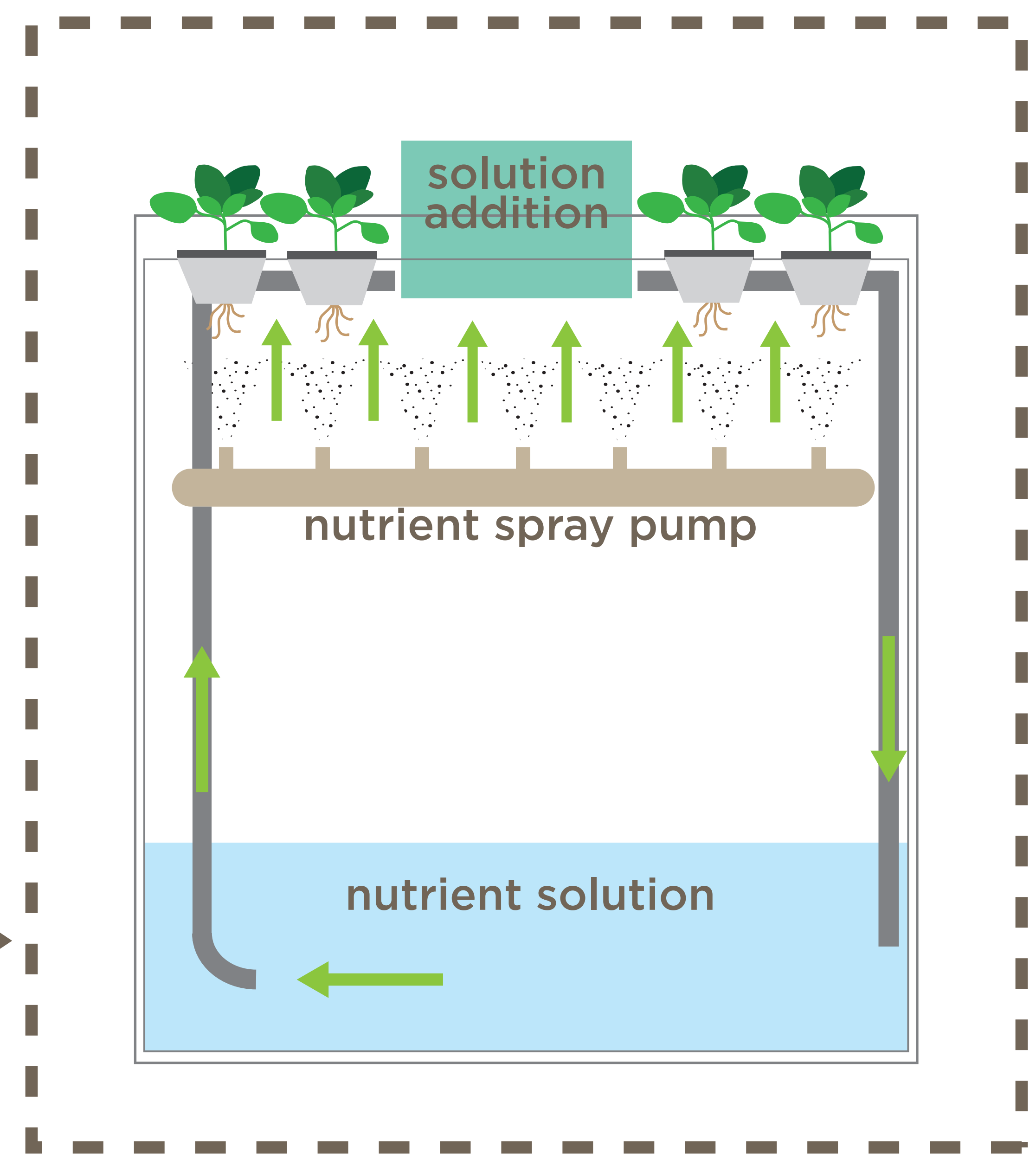
HYDROPONIC AND AQUAPONIC SEEDING TRAY SYSTEM



AEROPONIC SEEDING SYSTEM



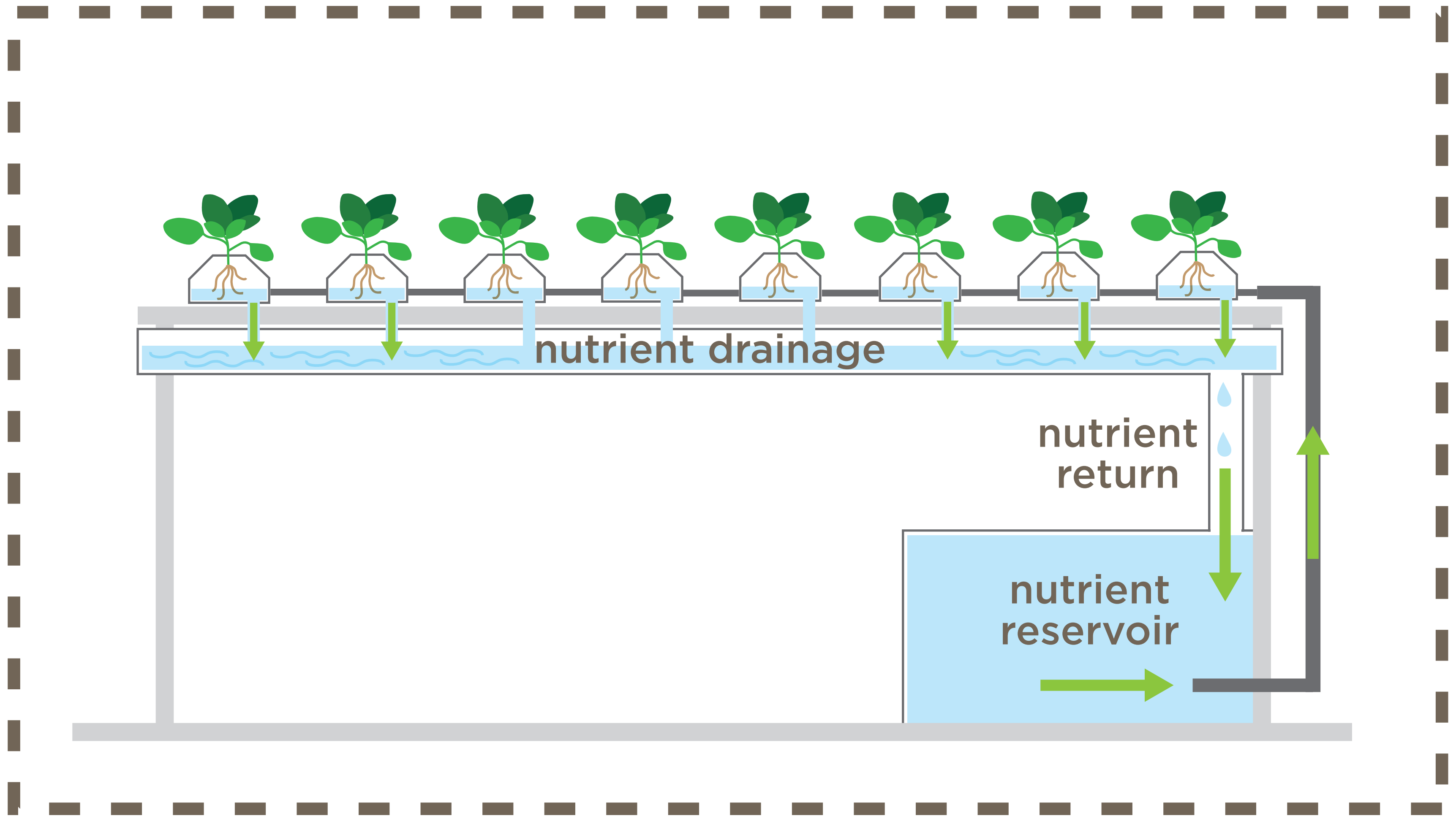
AEROPONIC SEEDING SYSTEM SECTION



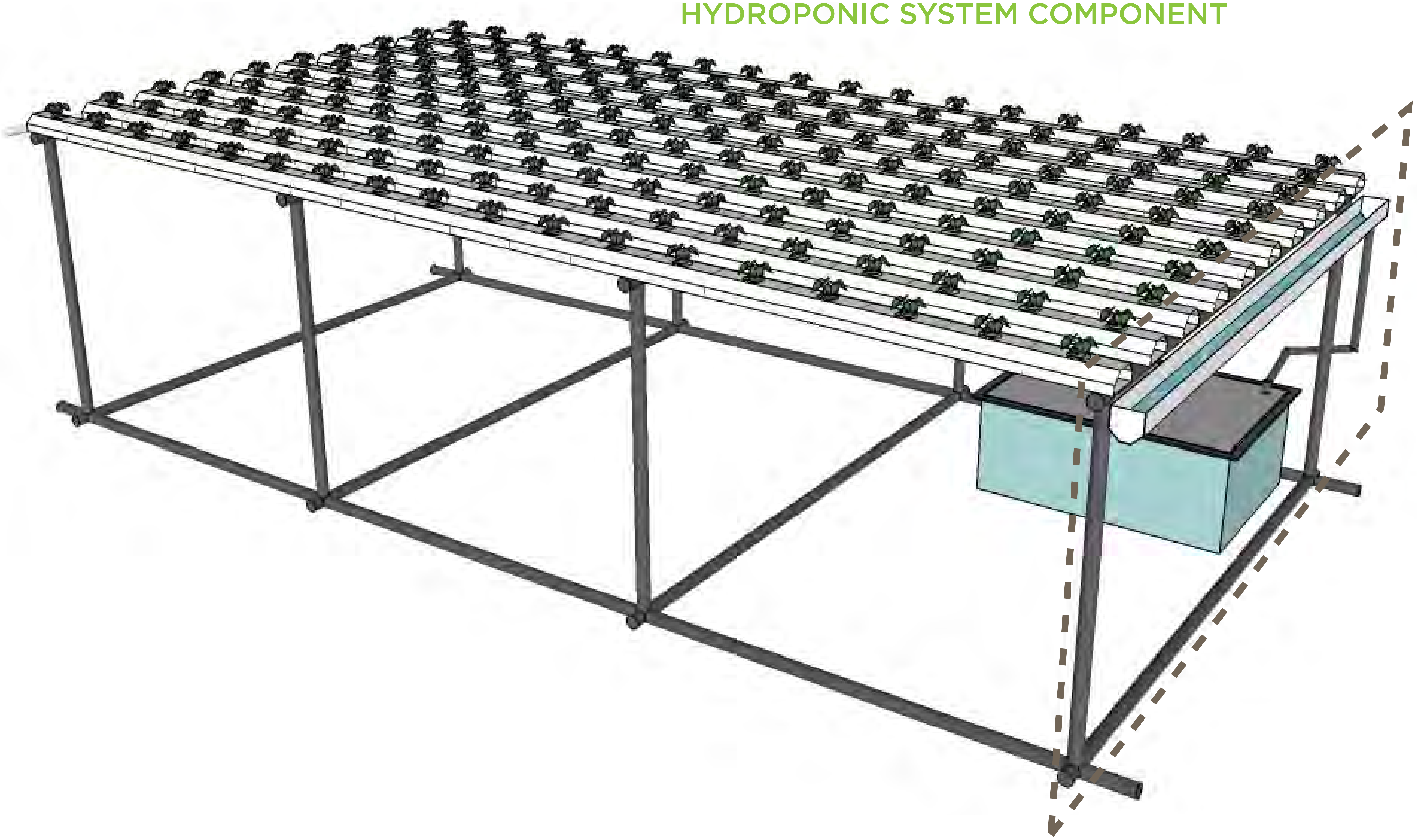
HYDROPONIC SYSTEM DESIGN

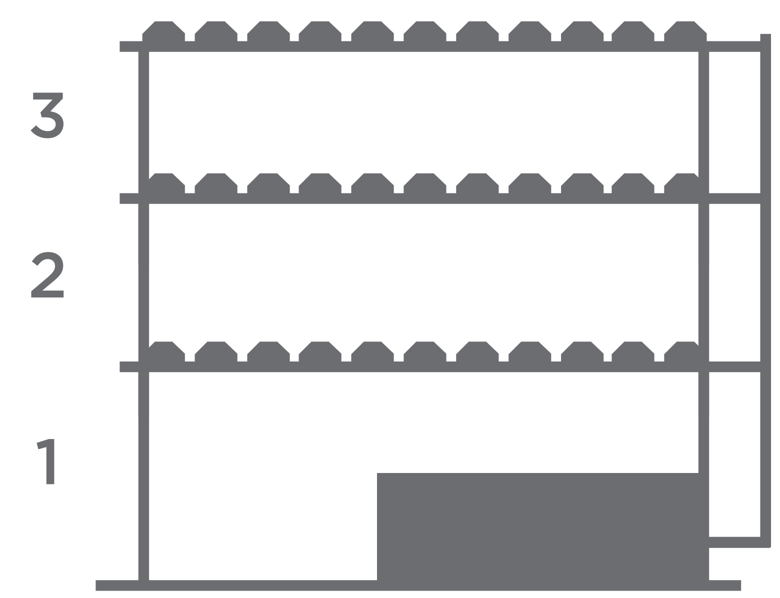
This system grows the plants in water without the use of soil. The water is infused with a mineral nutrient solution which is easily absorbed by the plant roots, thus eliminating the need for soil. The nutrient solution can also be reused which keeps water usage very low. This system is very versitile in that almost any terrestrial plant will grow in hydroponics and produce stable and high yields.

HYDROPONIC SYSTEM SECTION



HYDROPONIC SYSTEM COMPONENT

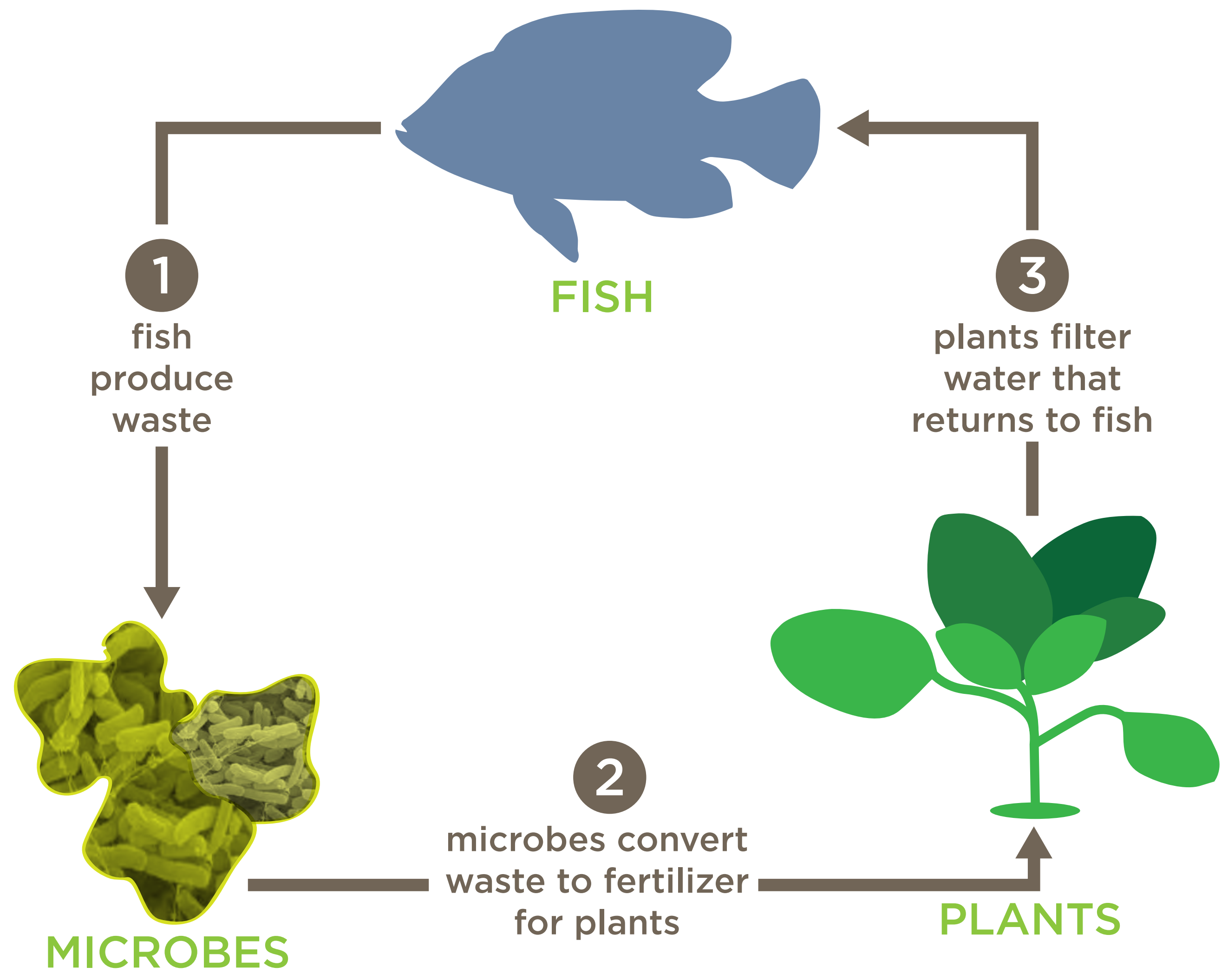




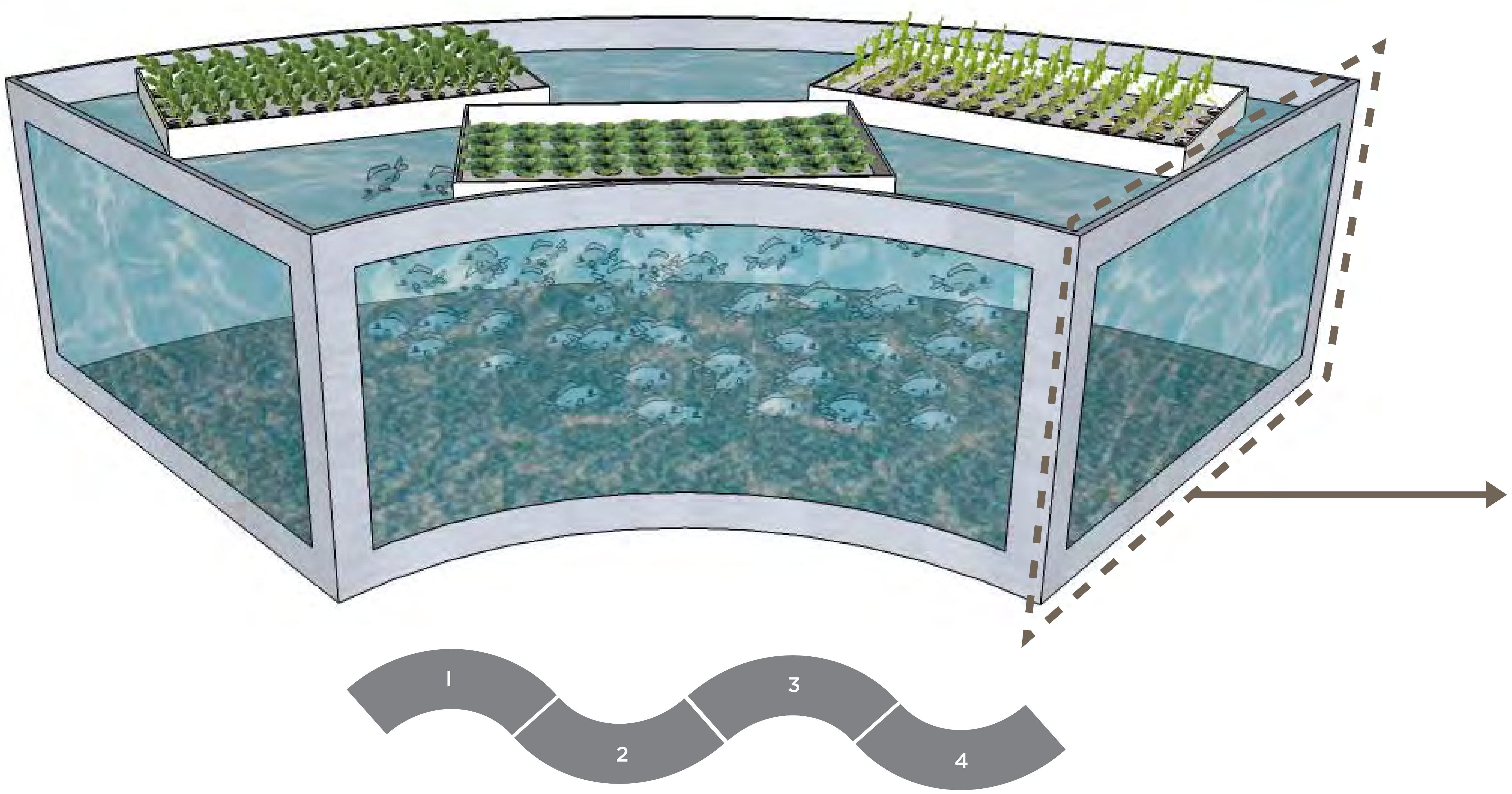
SYSTEM STACKING

AQUAPONIC SYSTEM DESIGN

This system combines traditional aquaculture with hydroponics in a symbiotic environment. In the aquaculture, effluents accumulate in the water, increasing toxicity for the fish. This water is led to a hydroponic system where the by-products from the aquaculture are filtered out by the plants as vital nutrient, after which the cleansed water is recirculated back to the fish.

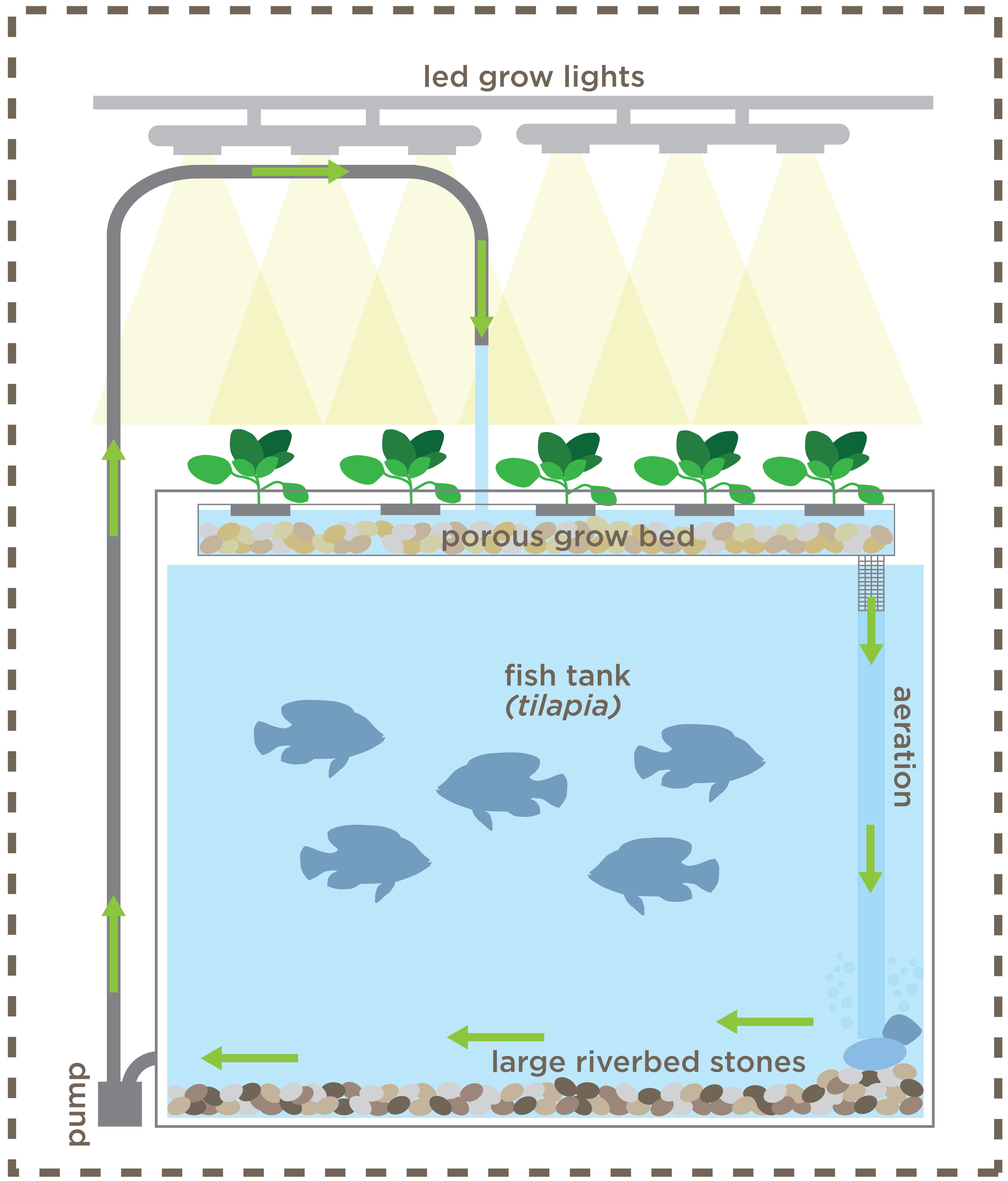


AQUAPONIC SYSTEM COMPONENT



SYSTEM ARRANGEMENT

AQUAPONIC SYSTEM SECTION



local ROOTS

SECOND FLOOR PLAN

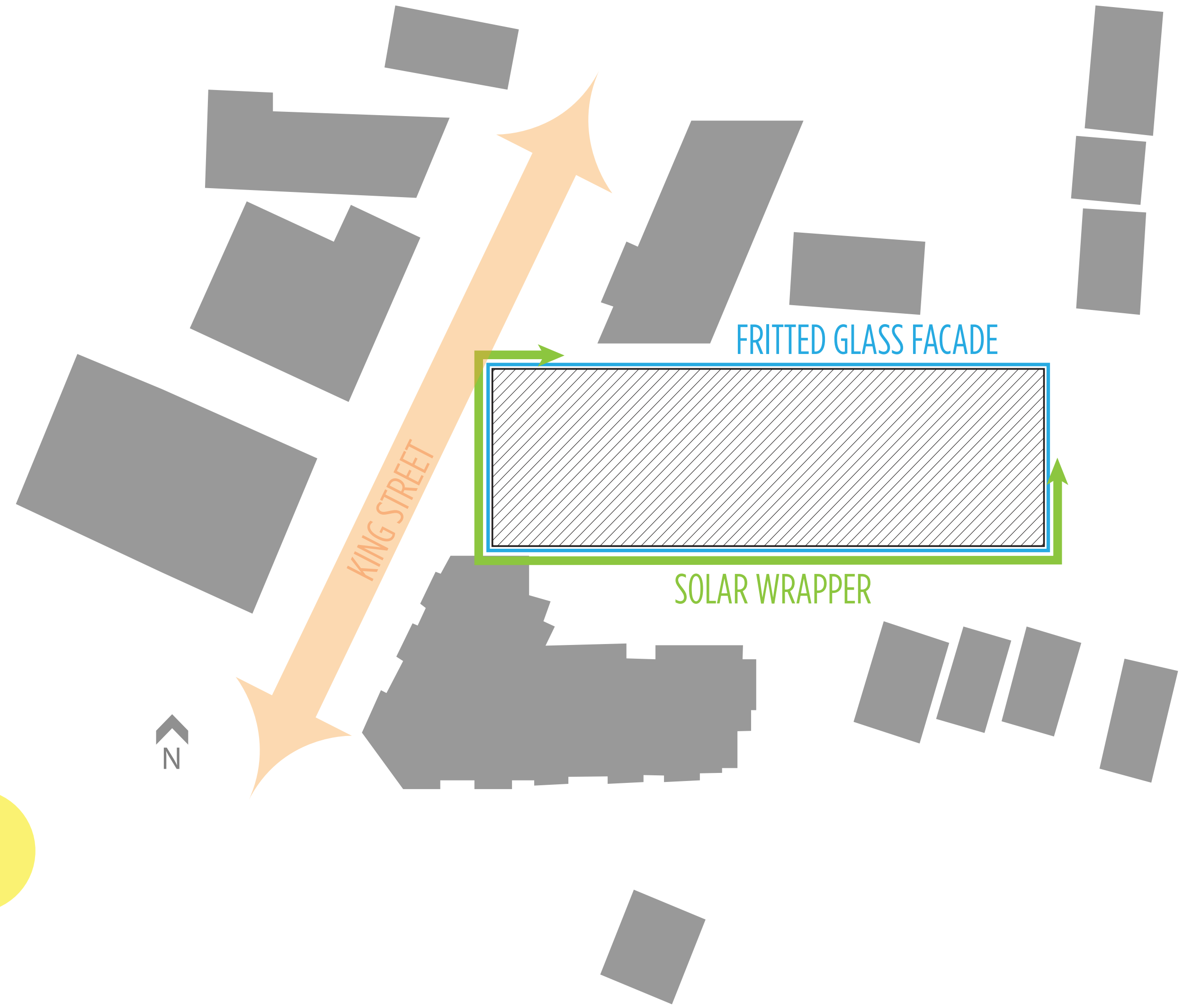
A. HYDROPONICS
B. AQUAPONICS
C. RESTROOMS
D. HARVESTING AREA
E. CSA BOX PREP AREA

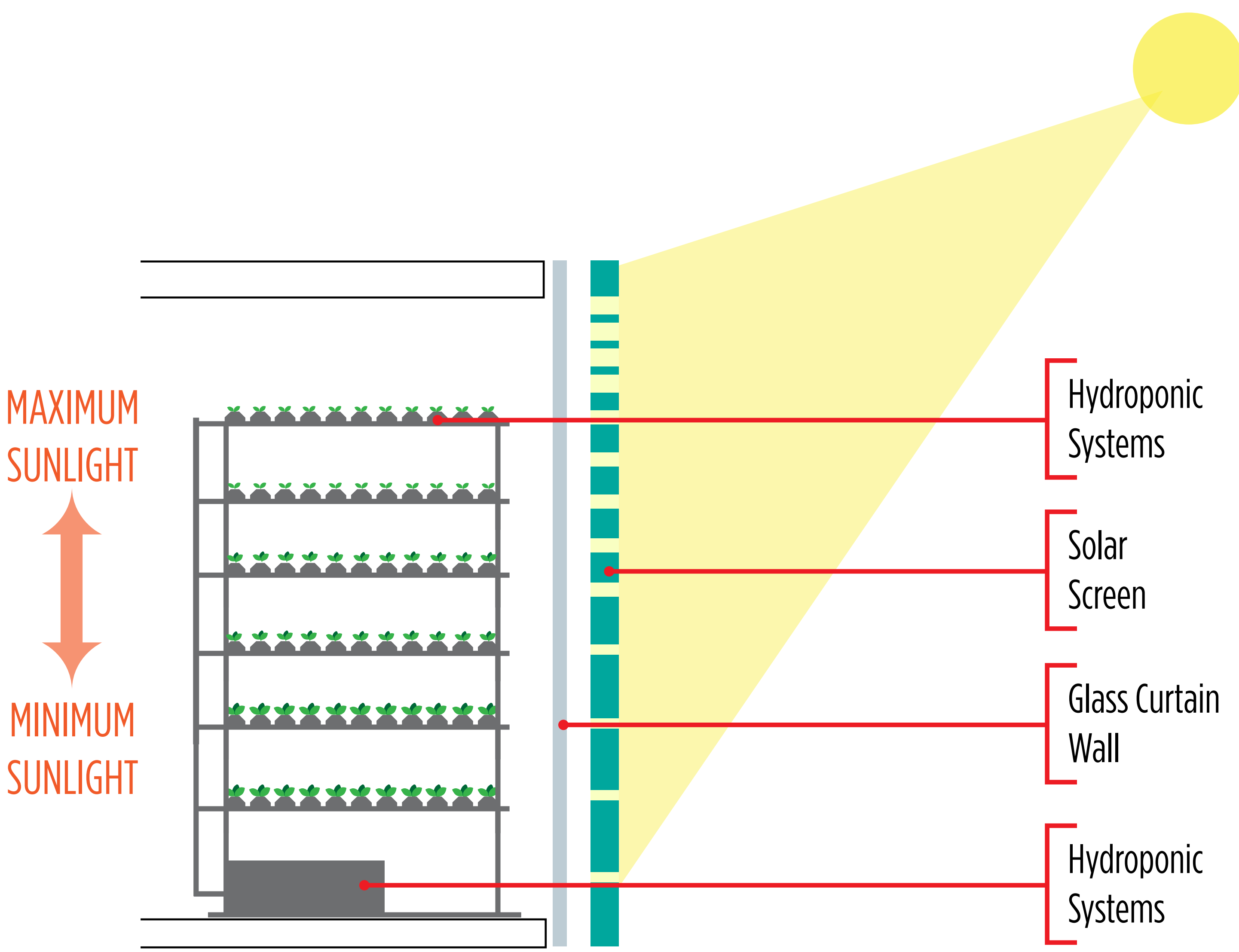
THIRD FLOOR PLAN

A. HYDROPONICS
B. AEROPONICS
C. RESTROOMS
D. HARVESTING AREA
E. WHOLESALE PACKAGING AREA

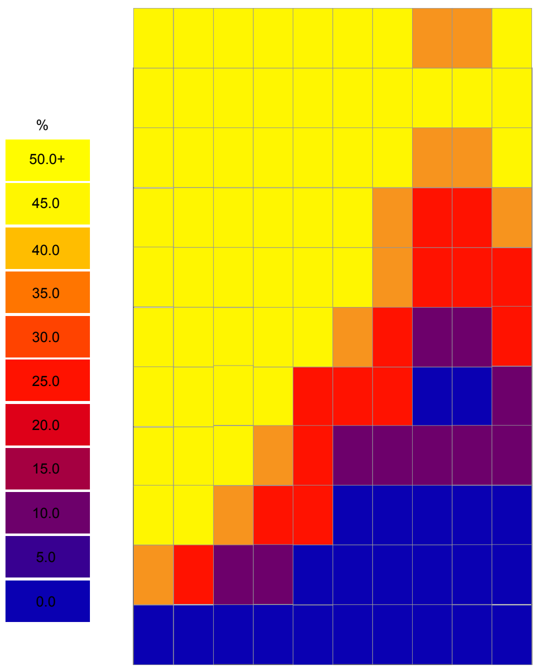
INTELLIGENT BUILDING SKIN

The envelope of the building follows the architectural concept of a heavy mass floating on top of a transparent base. Since the top two floors are farming, there has to be some daylight exposure through the skin. Crops that are early on in development will require more direct sunlight than matured crops so the openings in the skin can help determine where certain crops will go inside the farm space. The openings themselves will be determined by a solar analysis of the building mass.



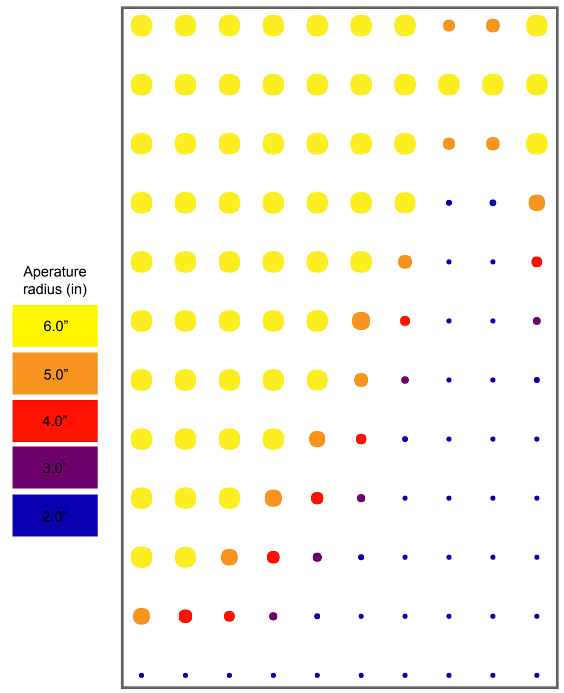


PARAMETRIC PERFORATED PATTERN



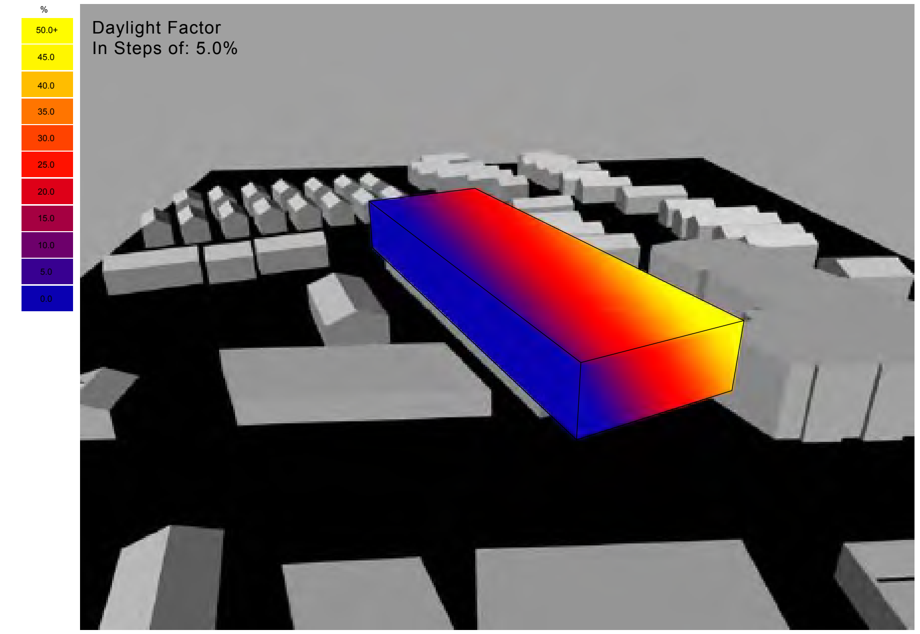
EXPOSURE GRADIENT > GRID

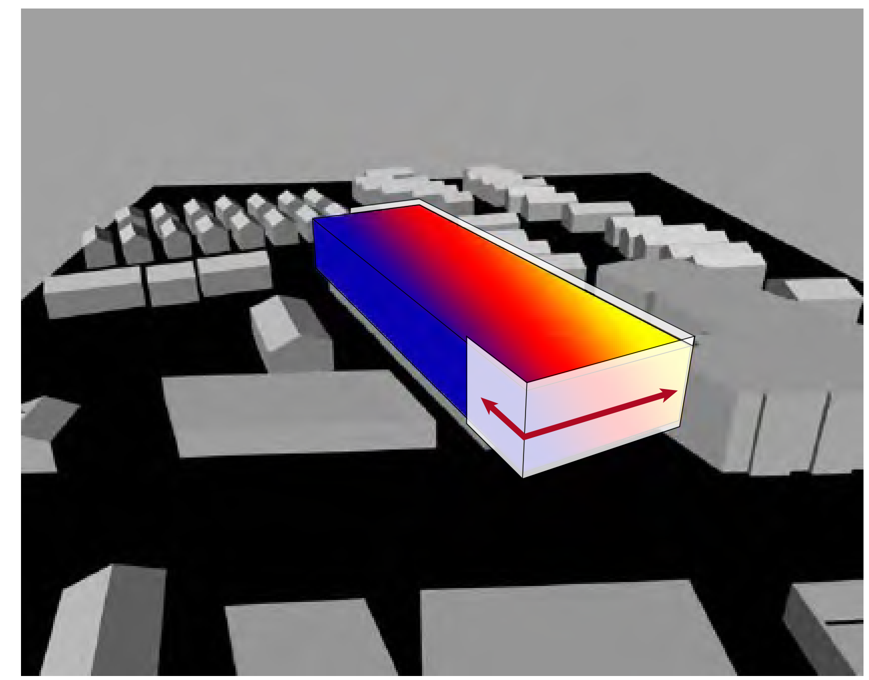
Colors from the gradient are isolated into a grid so each color can be assigned an aperature opening

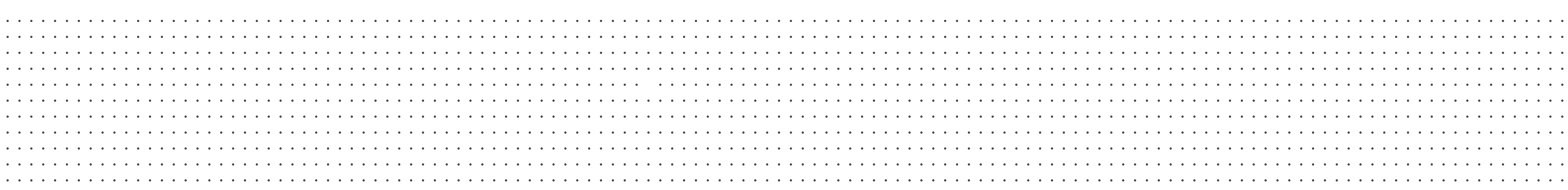


EXPOSURE > APERATURE

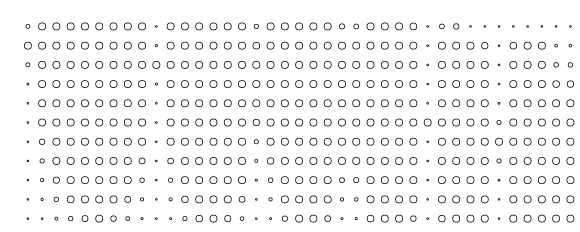
Using the established parameters from the solar analysis, the openings of the aperatures will decrease based on the % of solar exposure.



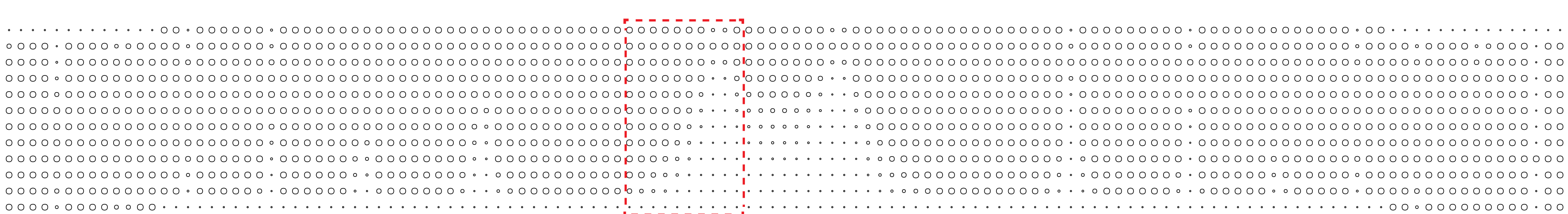




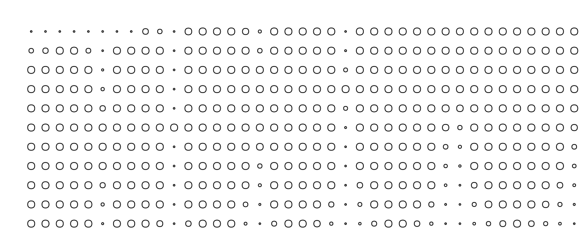
NORTHERN FACADE



WESTERN FACADE

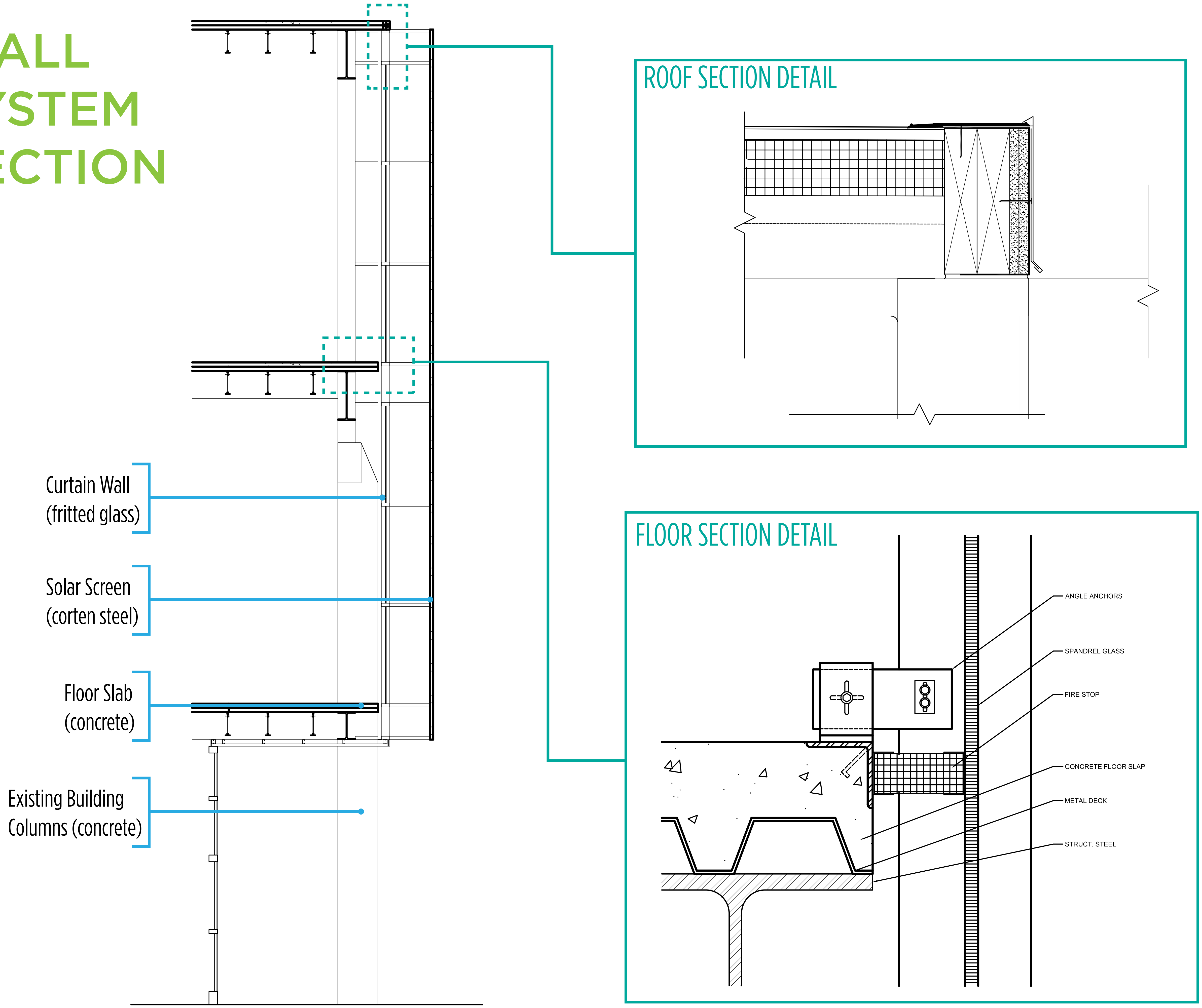


SOUTHERN FACADE



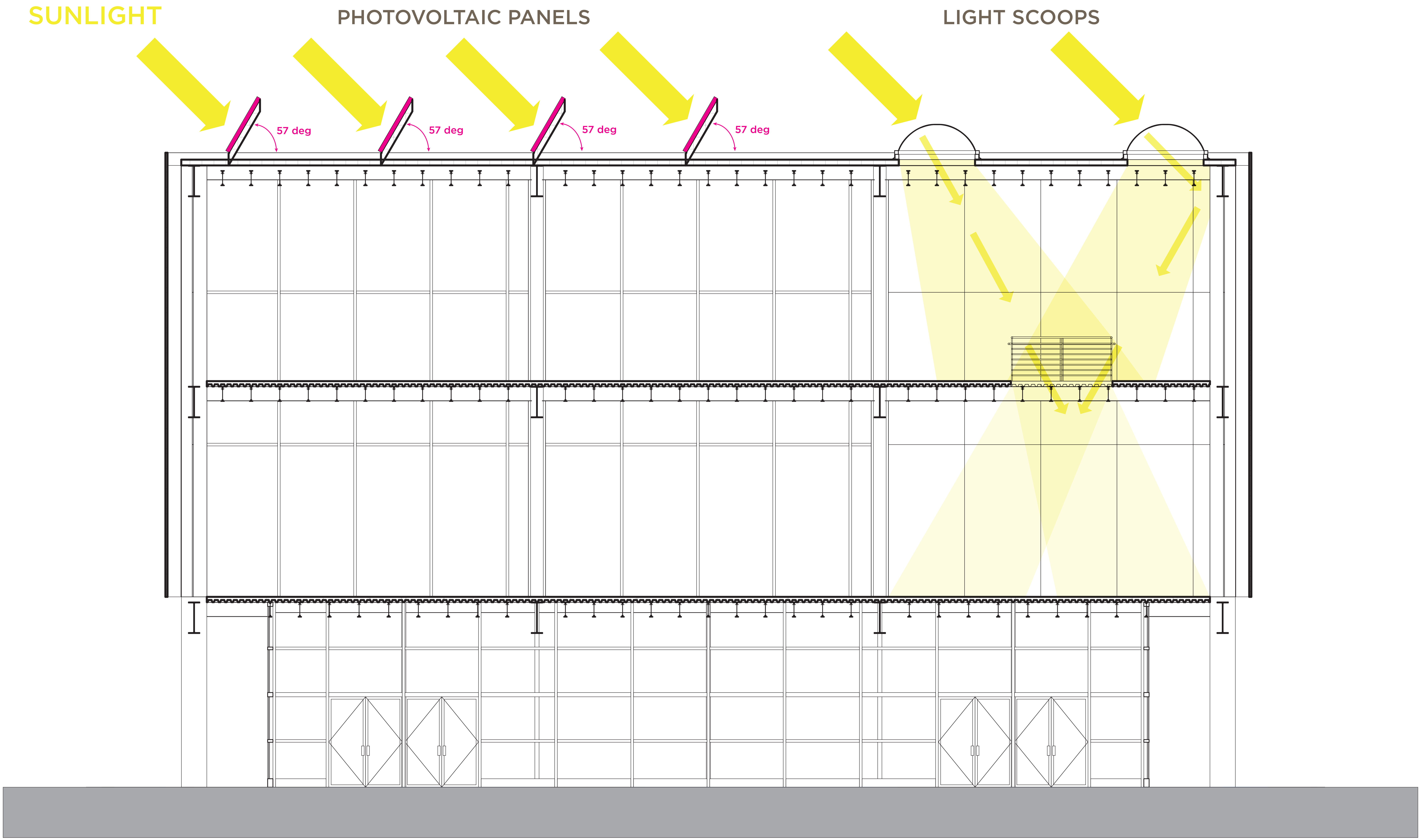
EASTERN FACADE

WALL SYSTEM SECTION



DAYLIGHTING AND SOLAR SYSTEMS

The second and thirds floors of the vertical farm have very little solar exposure. A majority of the growing systems require LED or flourescent lights but daylighting is still desirable for the people who inhabit the building. Photovoltaic panels will help generate electricity needed to power the grow lights. Domed light scoops will bring daylight into the third floor and light wells will continue the light into the floor below.



Design Model 5

Port City Ponics by Chris Felegie and Joe McNeill

Design Summary

We think our project is strong in the sense that it does not over-think the architecture of the existing space which we are given. We are not adding much to the Port City Paper building - in fact, we are taking away things and leaving the overall building shell. In addition, we are making use of a resource (shipping containers) which are a local source and a municipal identity to shape the spaces for the actual farming techniques to occur on the interior of the building. This helps to avoid creating an overall sealed environment and instead, creates MANY smaller sealed environments. It also allows for true vertical farming with the use of aeroponics towers and the stacking method of the containers in a vertical array.

One challenge we face is maximizing the natural light into the containers. Some containers on the bottom (of the 3-stacked towers) will not absorb much light. We must resolve this, either through alternate sources of power and light or by re-configuring our system to do so. We need to be able to farm year-round. In order to do this, our support systems for the farming must work seamlessly, ie: water purification, nutrients, LED lights, temperature control, germination, etc.

port
city
ponics

get hooked on ponics.

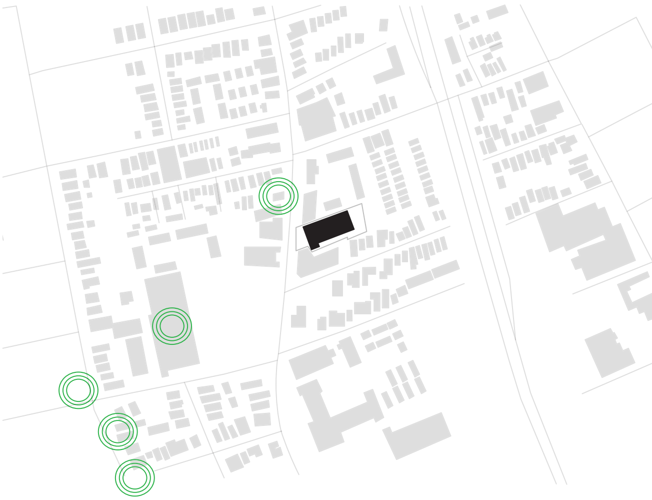
chrisfelegie | joemcneill

site analysis.

chrisfelegie | joemcneill

existing Port City Paper building

50' maximum building height

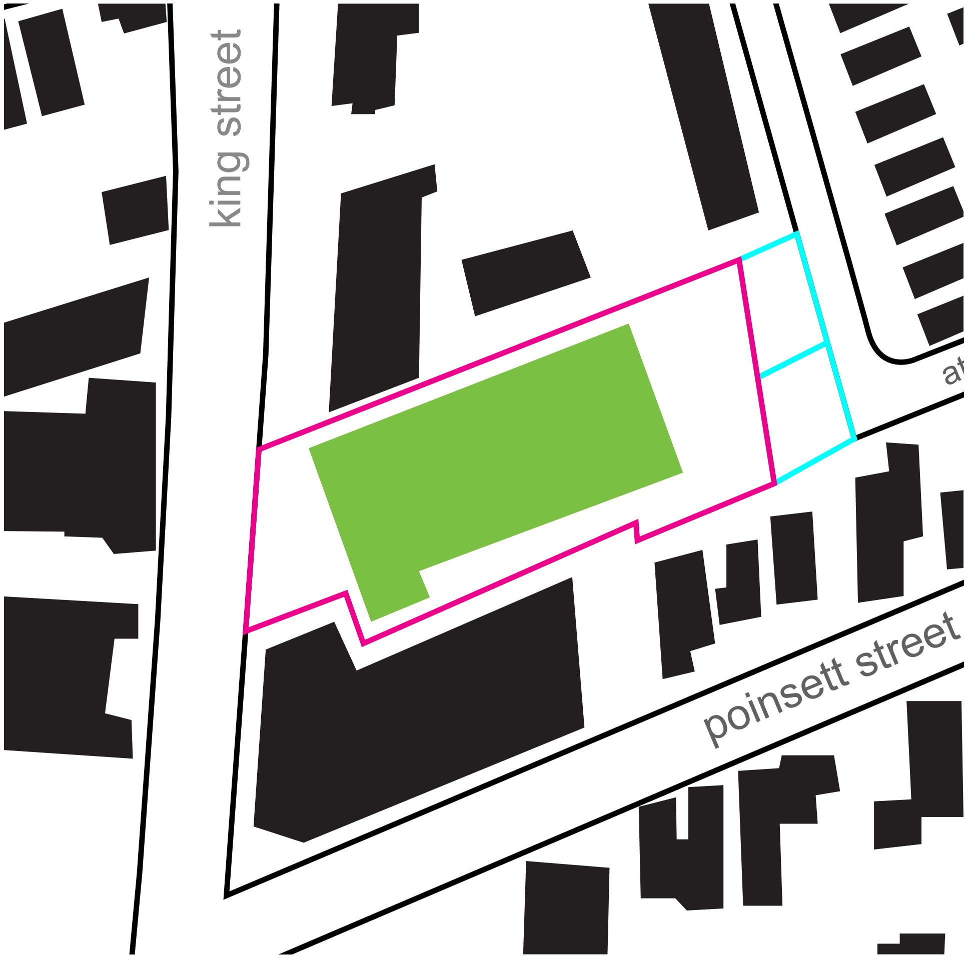


nearby food establishments

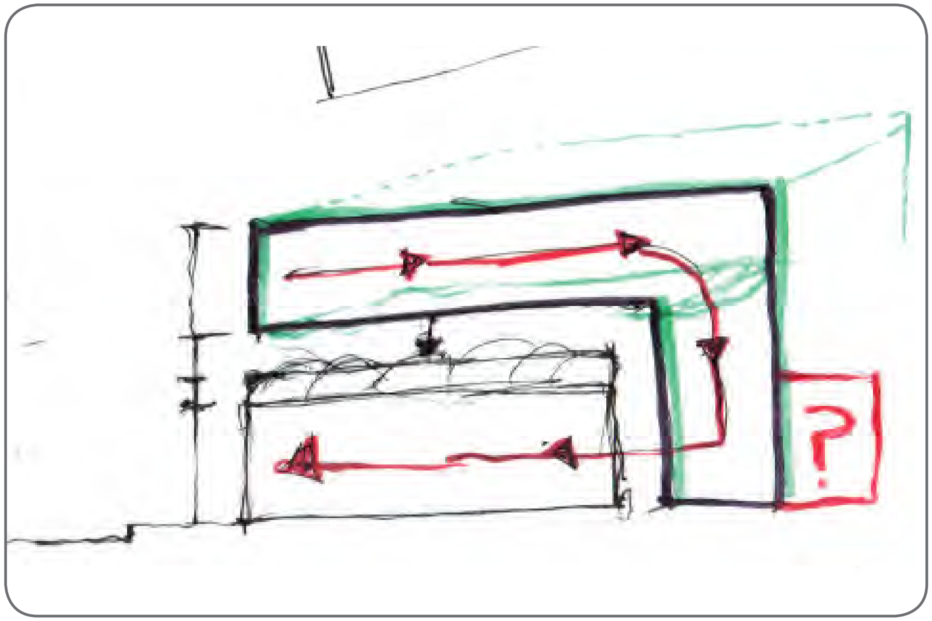
major arteries

site analysis.

chrisfelegie | joemcneill



site analysis.



adapt.

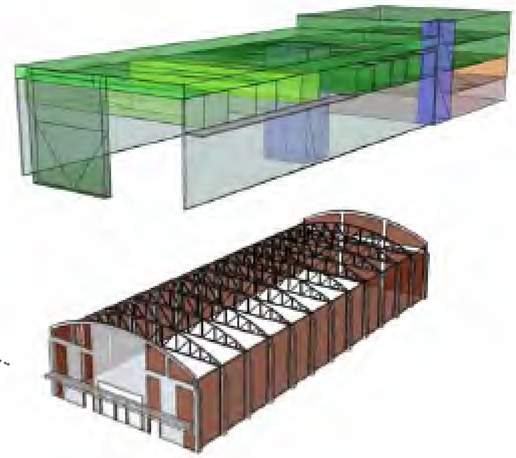
reuse.

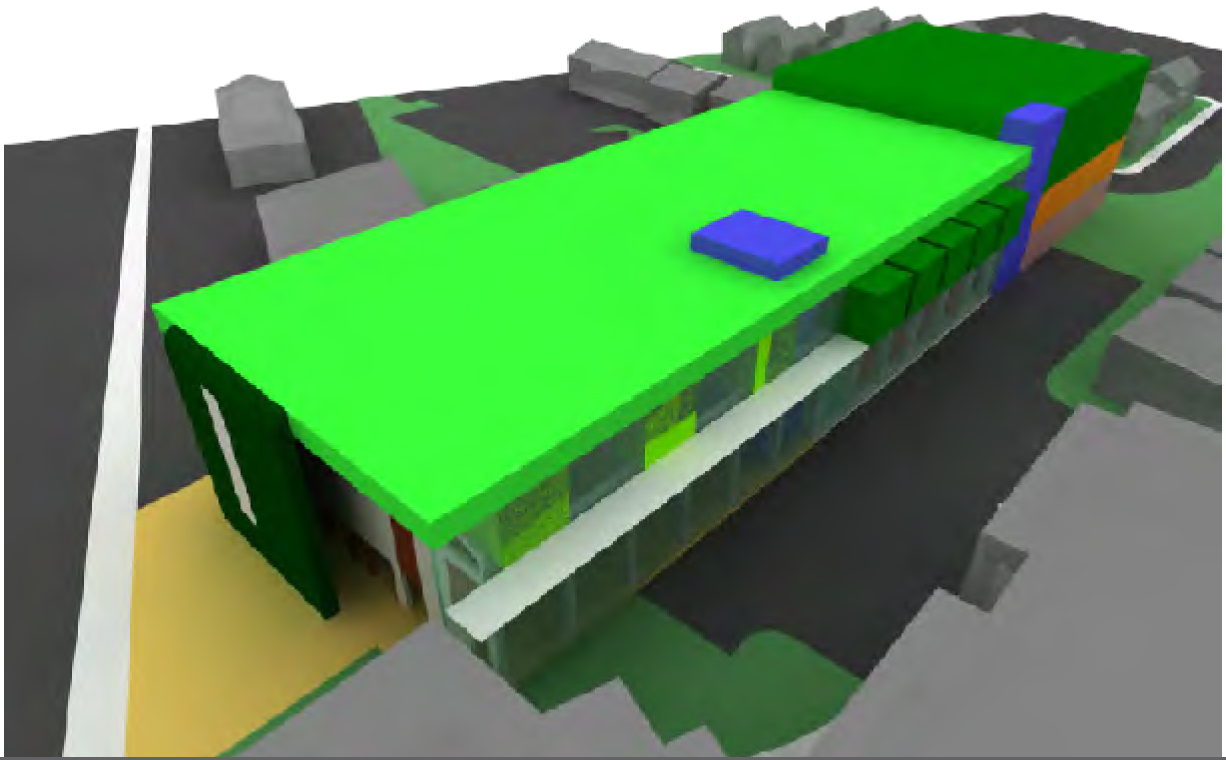
construct.

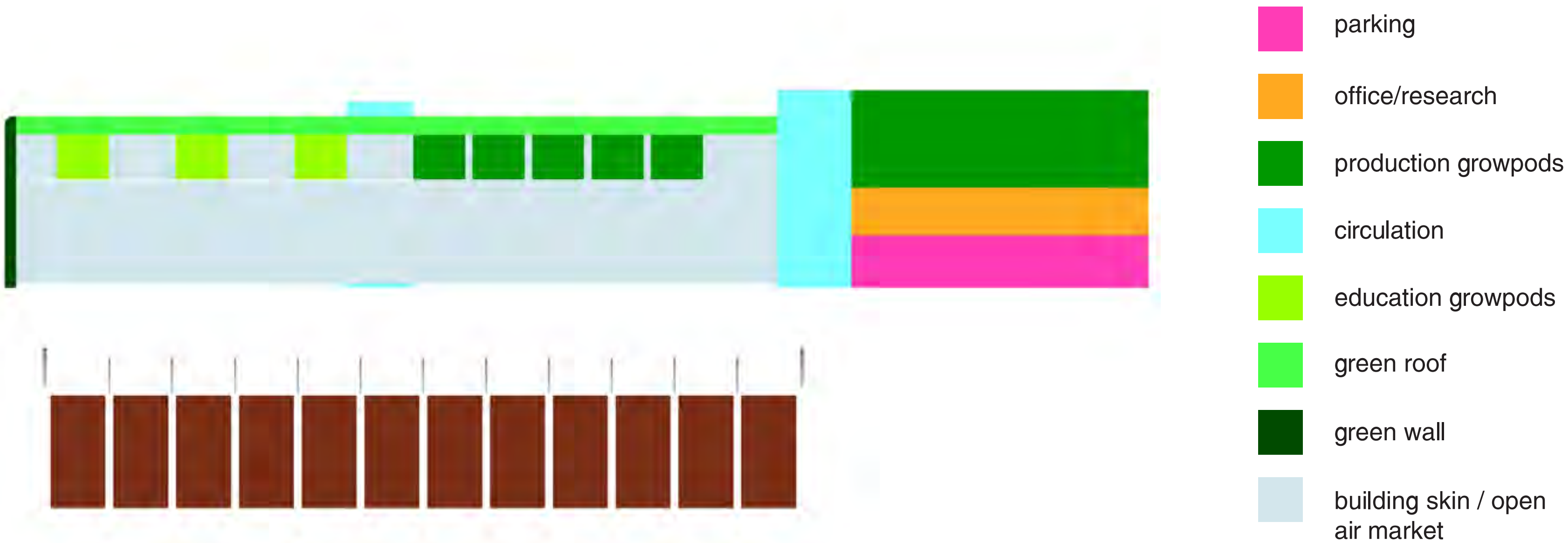
merge.

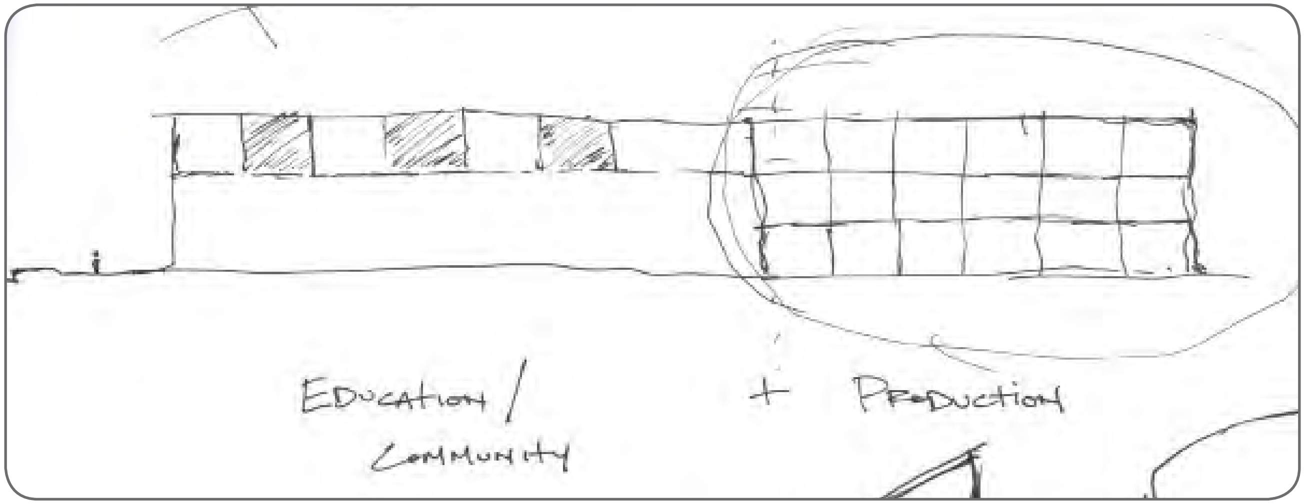
integrate.

enjoy.






parking
office/research
production growpods
circulation
education growpods
green roof
green wall
building skin / open
air market



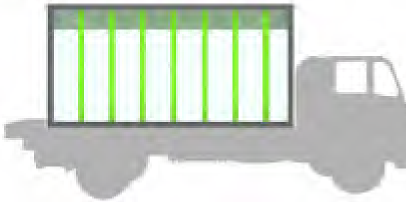
how do we strike a balance?

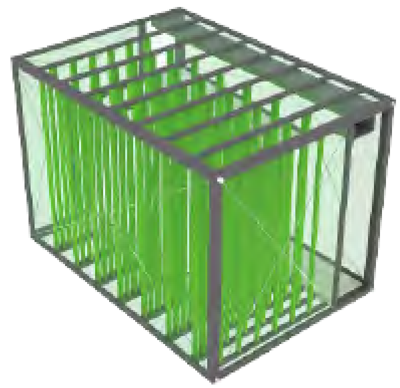
3 shades of green

farming

sustainability

cost





= $

a custom growpod

= $

a retrofitted shipping container.....

recalling the local history of Charleston as one of the largest port cities in America....

The Port of Charleston is the **sixth largest U.S. port** in terms of cargo value.

5 marine terminals in the area [**2 downtown**]

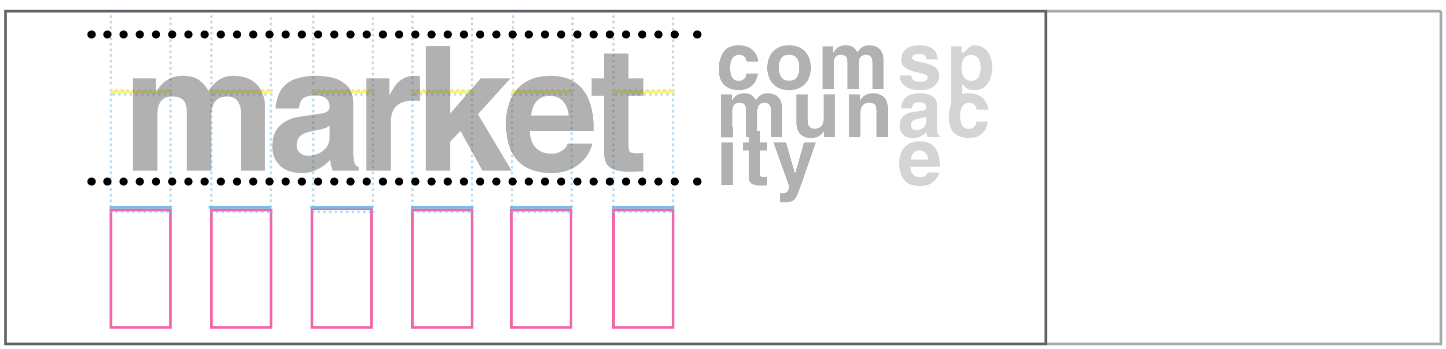
It is a **heavily-invested resource** - enacted a recent 10 year, $1.3 billion capital plan.

A new terminal has been planned that will boost **total container capacity in the port by 50%** is set to open in 2018.

production is important, but serving the local community is **KEY.**

grid stacked

single row, stacked

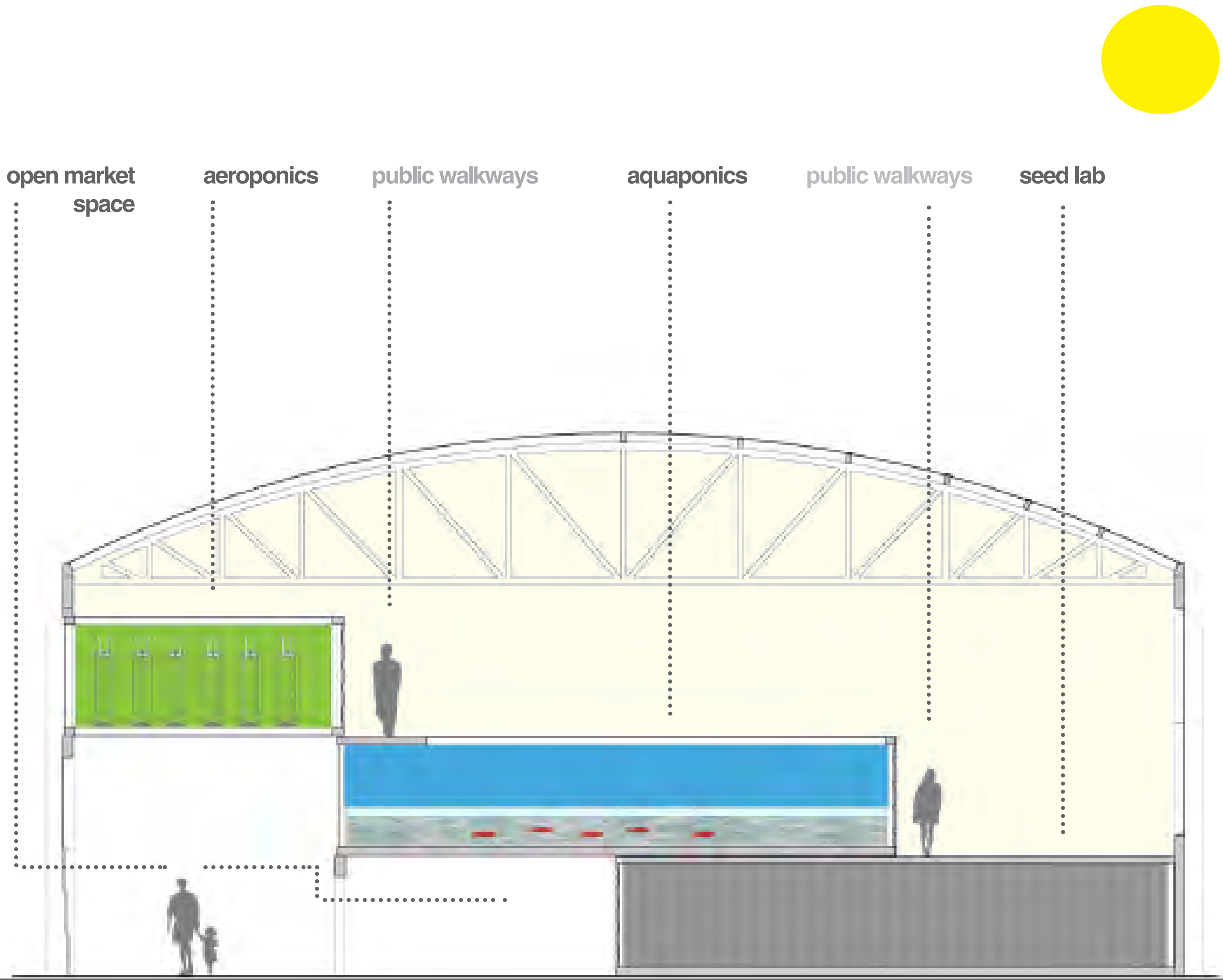


stepped *

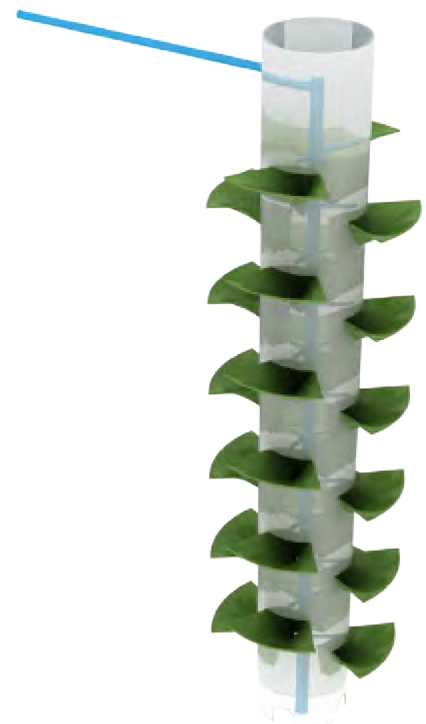
schematic design.

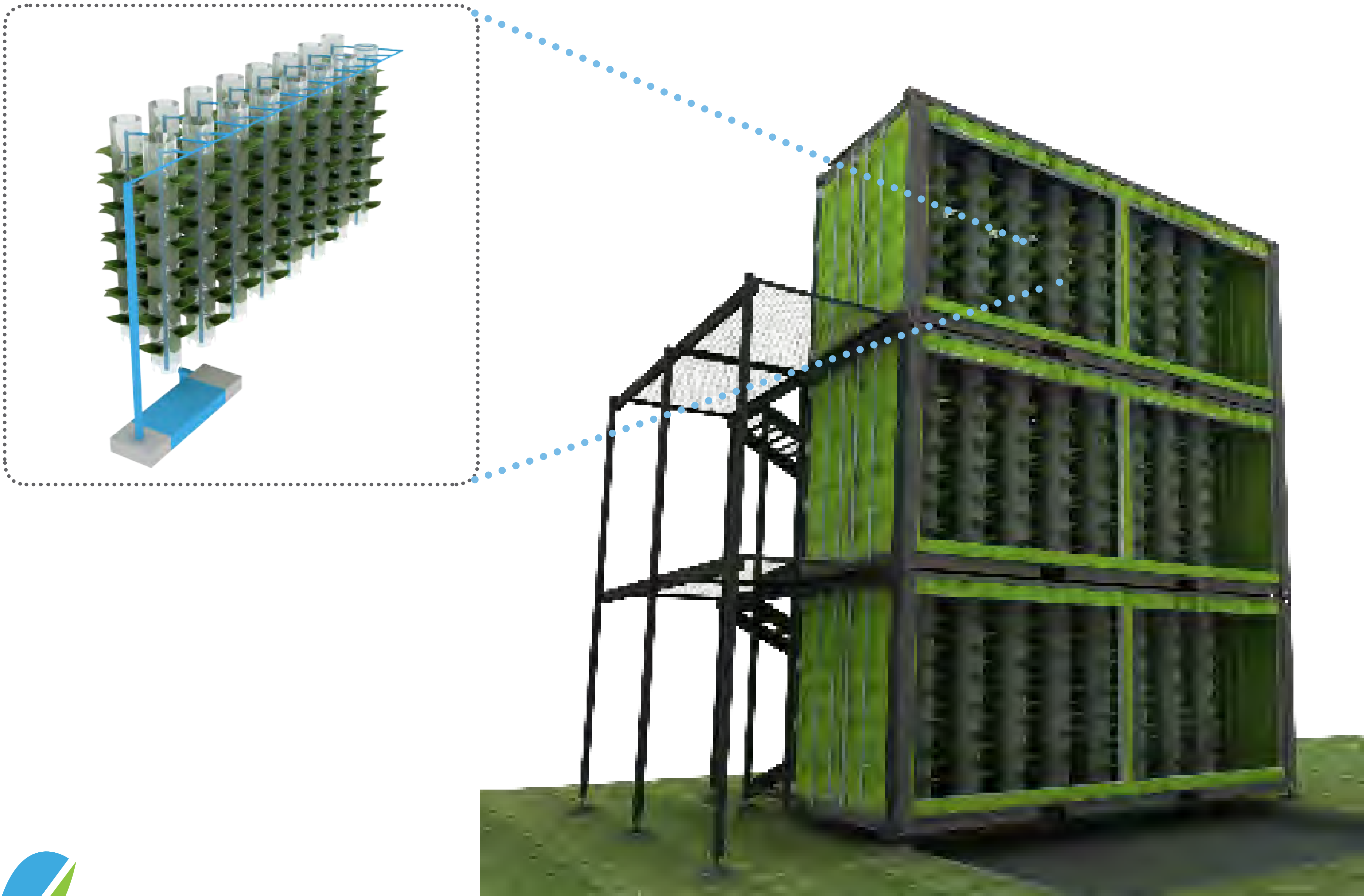
chrisfelegie | joemcneill

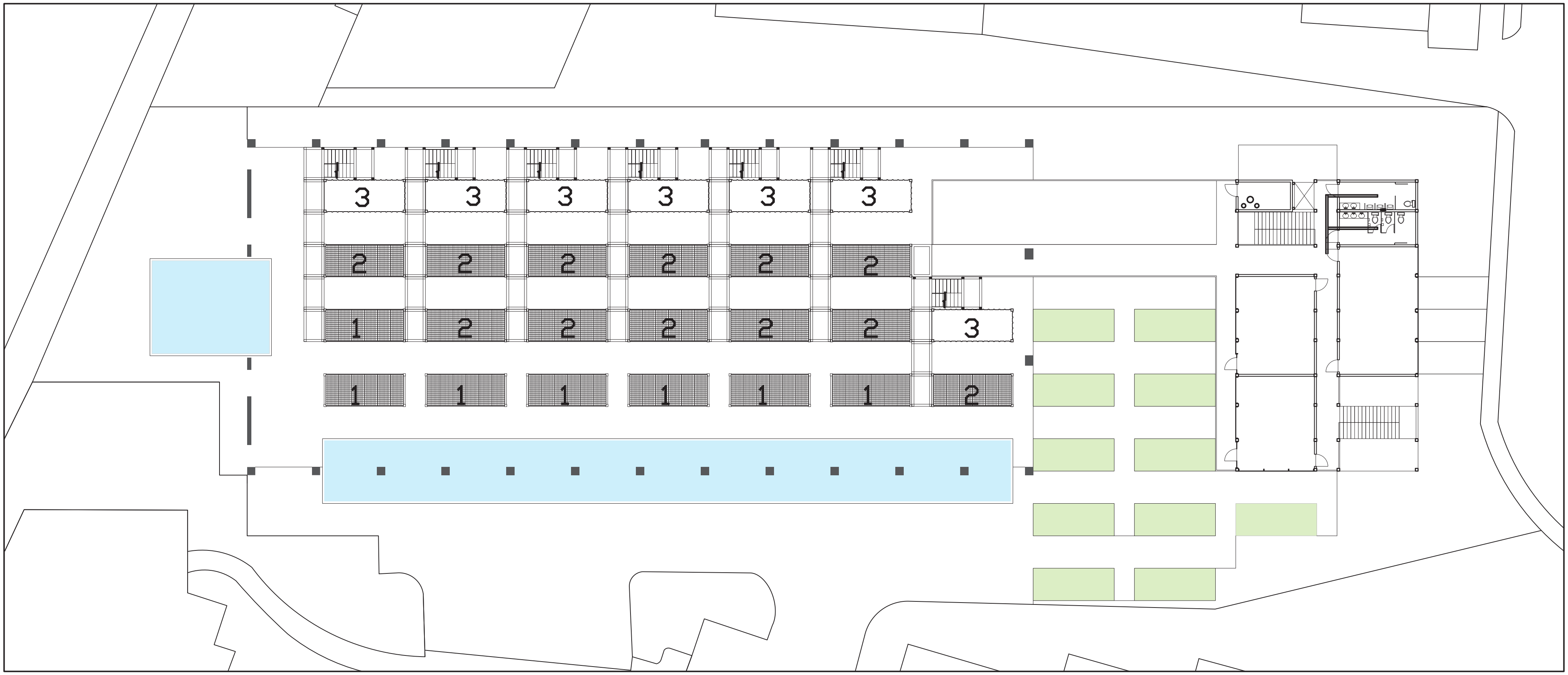
20 and 40 foot shipping containers




20 feet
8 feet
8.5 feet

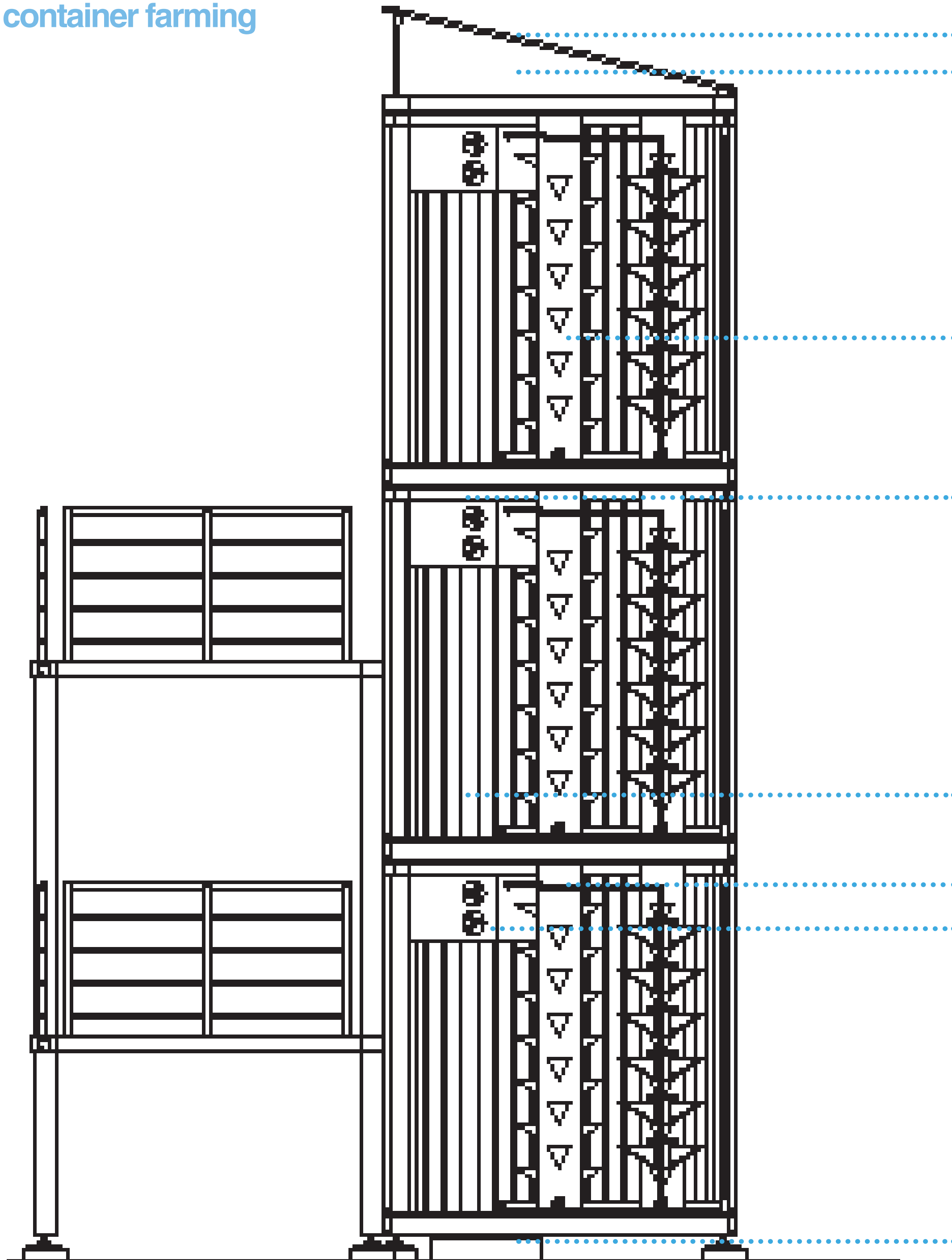






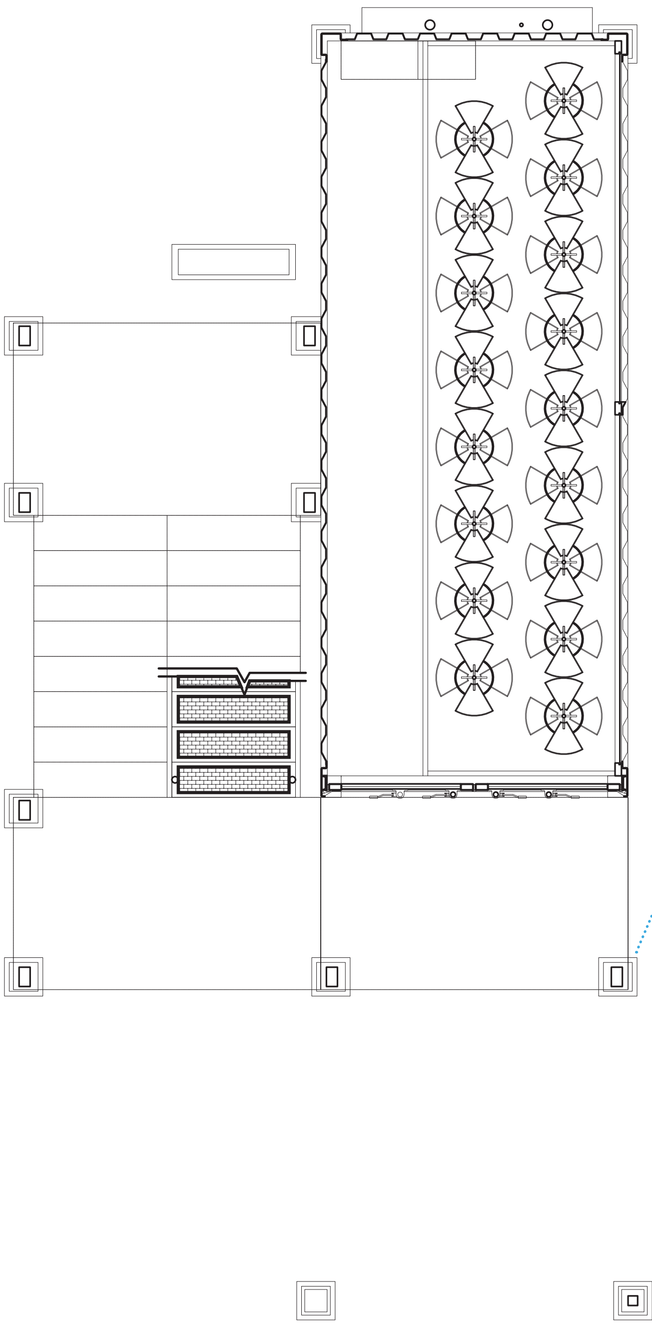
third floor plan

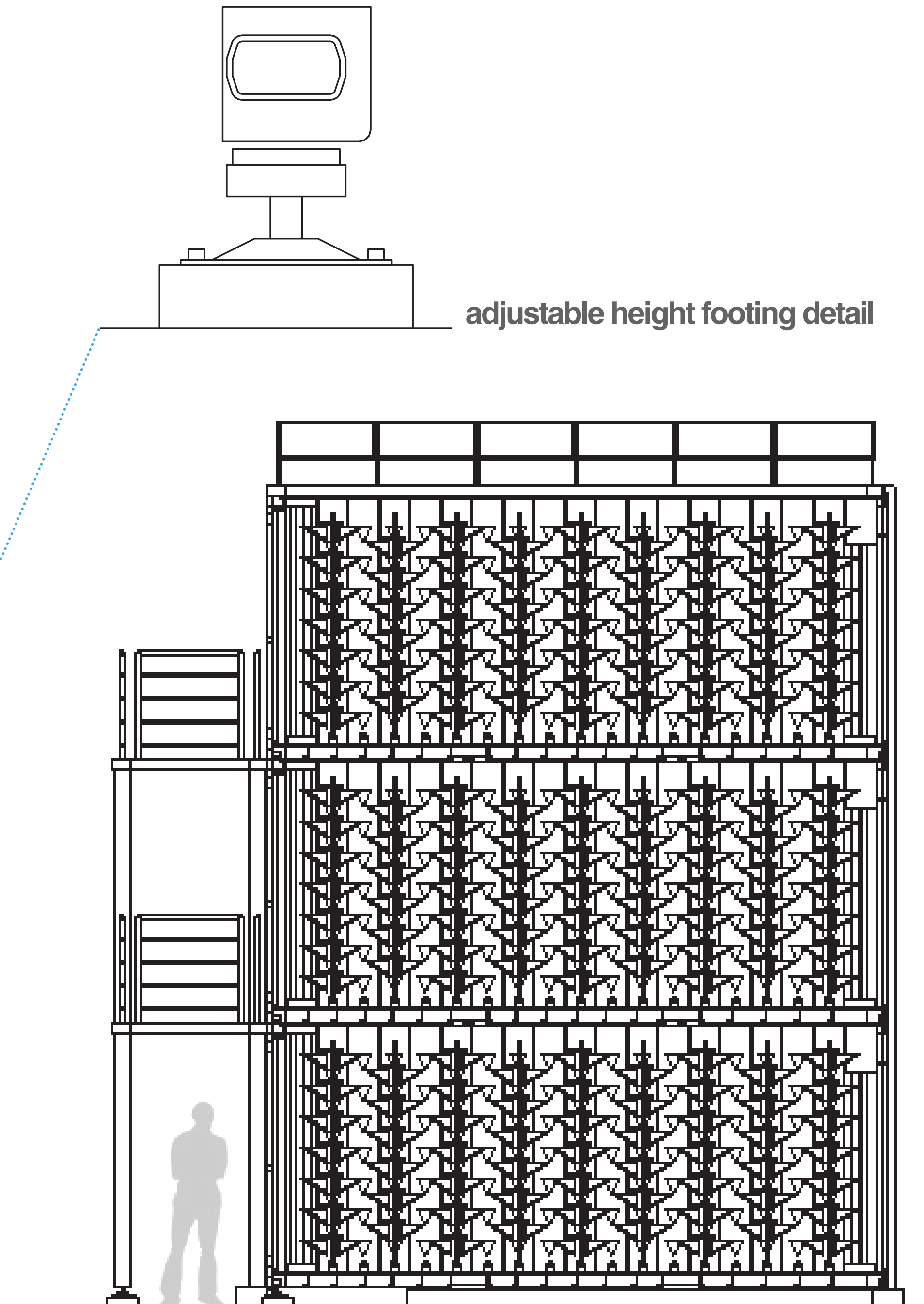
triple-stacked container farming



schematic design.

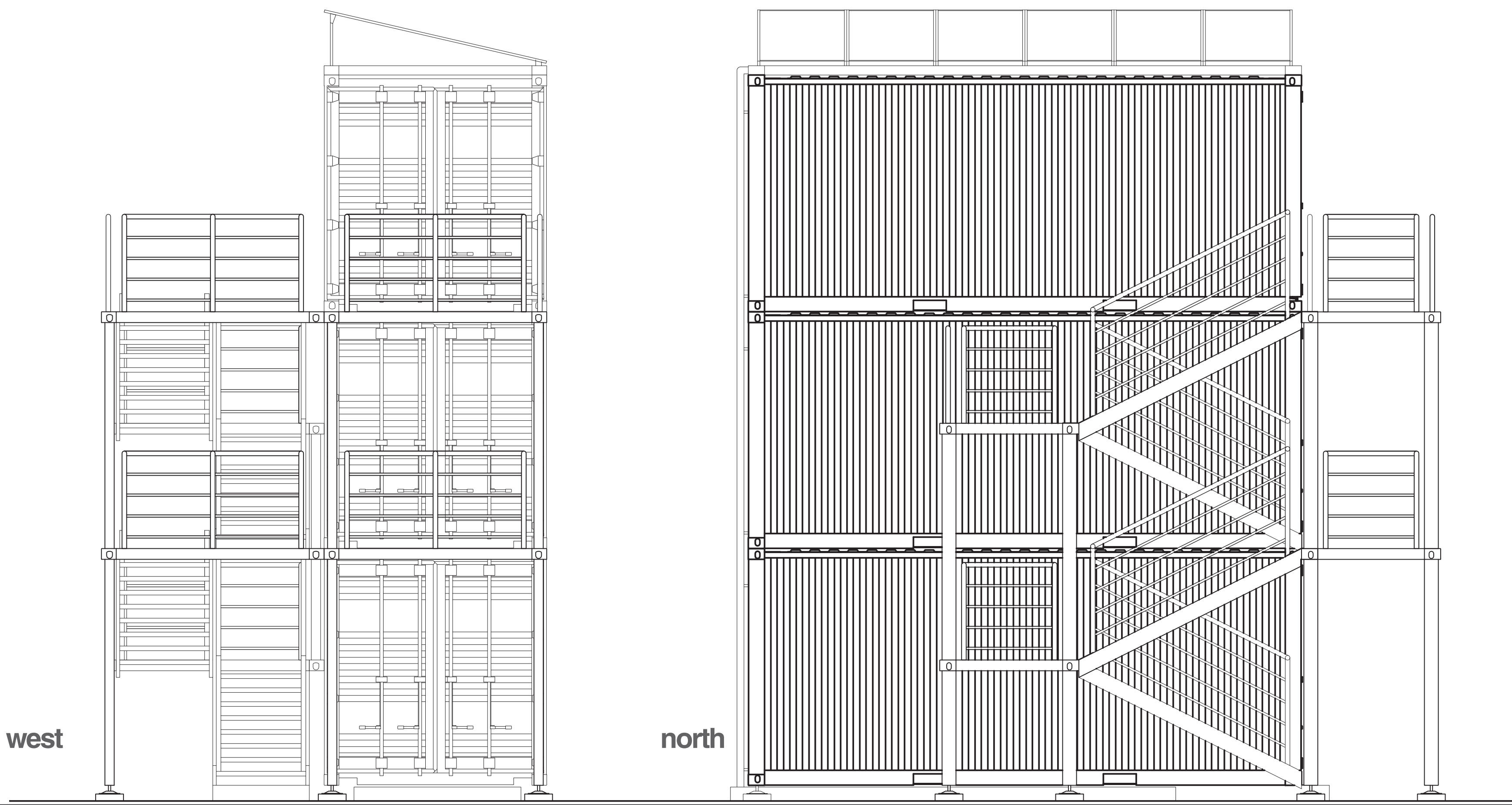
plan + south elevation





schematic design.

stacked container tower elevations



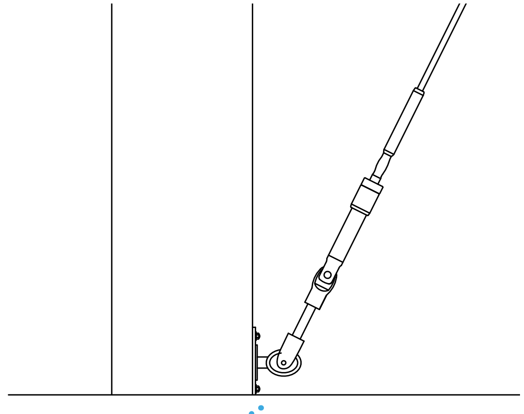
structural concepts

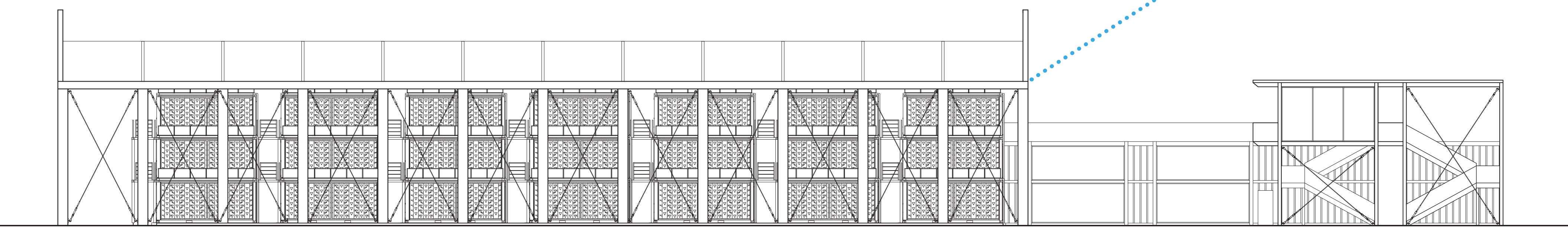
open-air concept

preserve existing building character

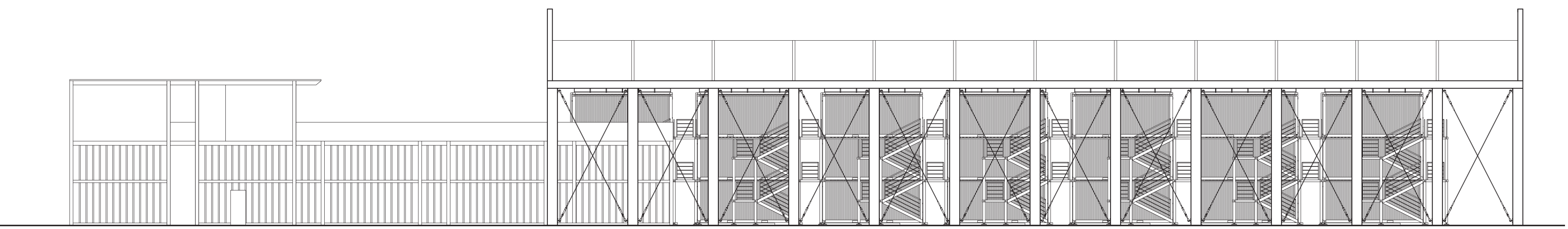
complementary new construction + community space on rear parcel

steel cable connection detail to
existing concrete column





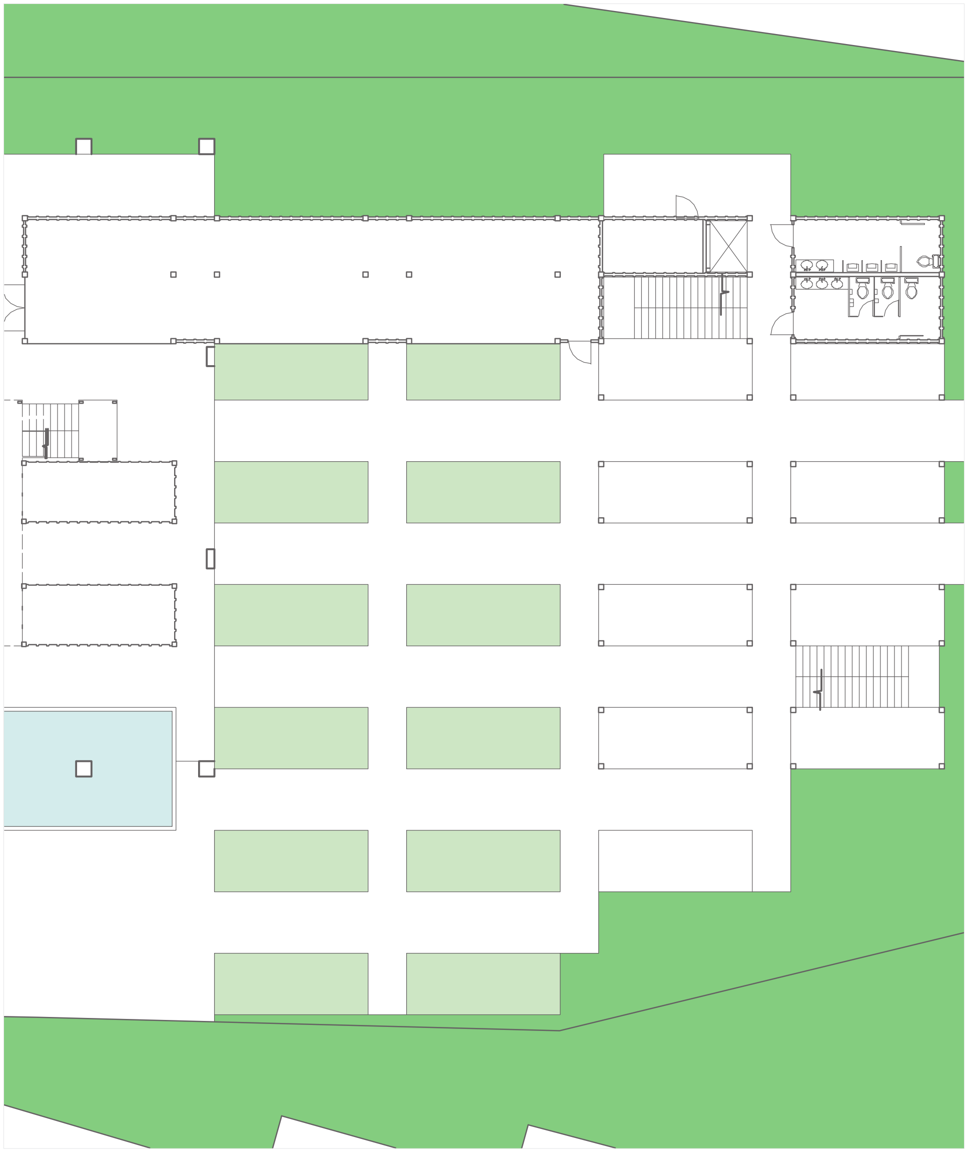
south elevation



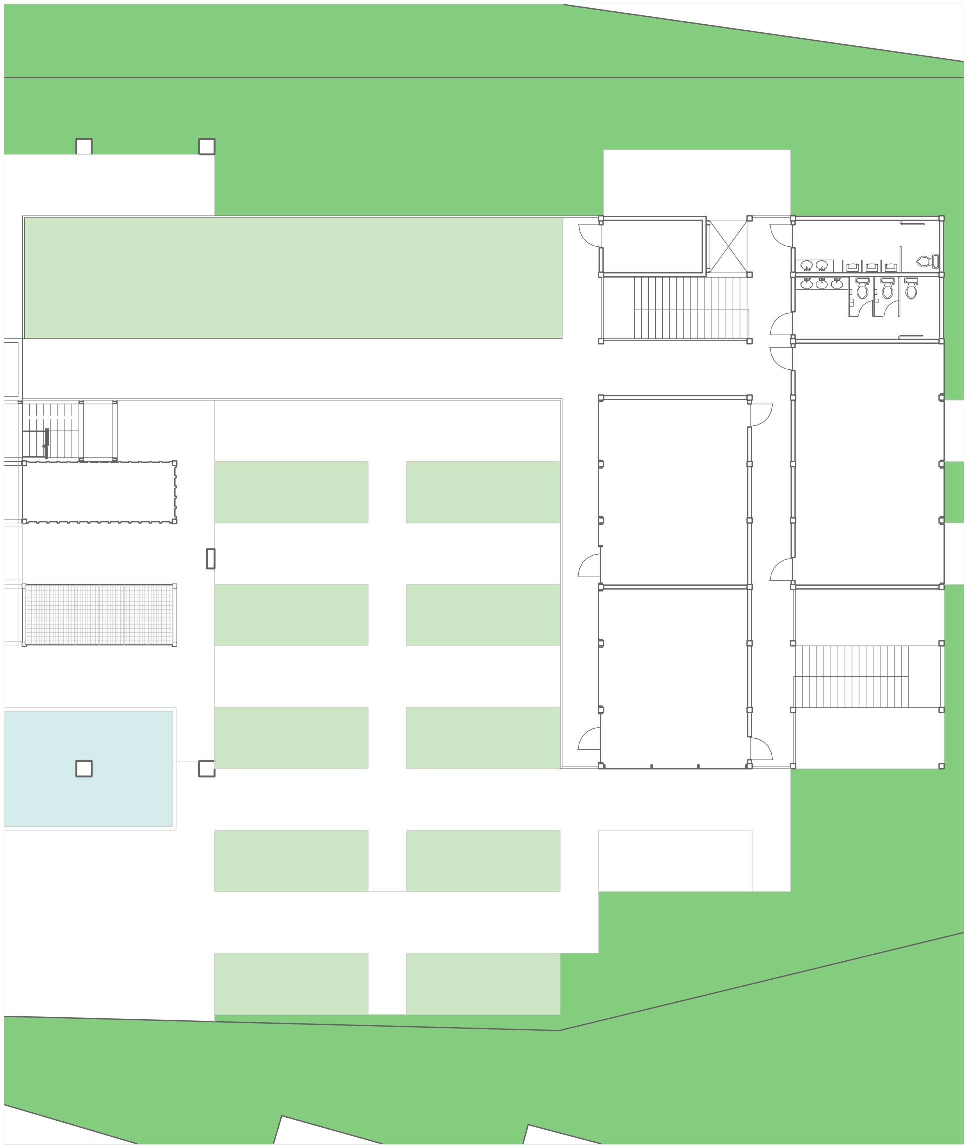
north elevation

schematic design.

new construction



ground floor plan



3rd floor plan

- extensive adaptive reuse strategies
- evaporative cooling effects
- south side water collection pool
- solar energy collected through tower arrays
- green roof tray technology
- repurposed materials

happy farming.

thanks.

Design Model 6

Grafted Vertical Farm by Chris Wilkins and Jared Moore

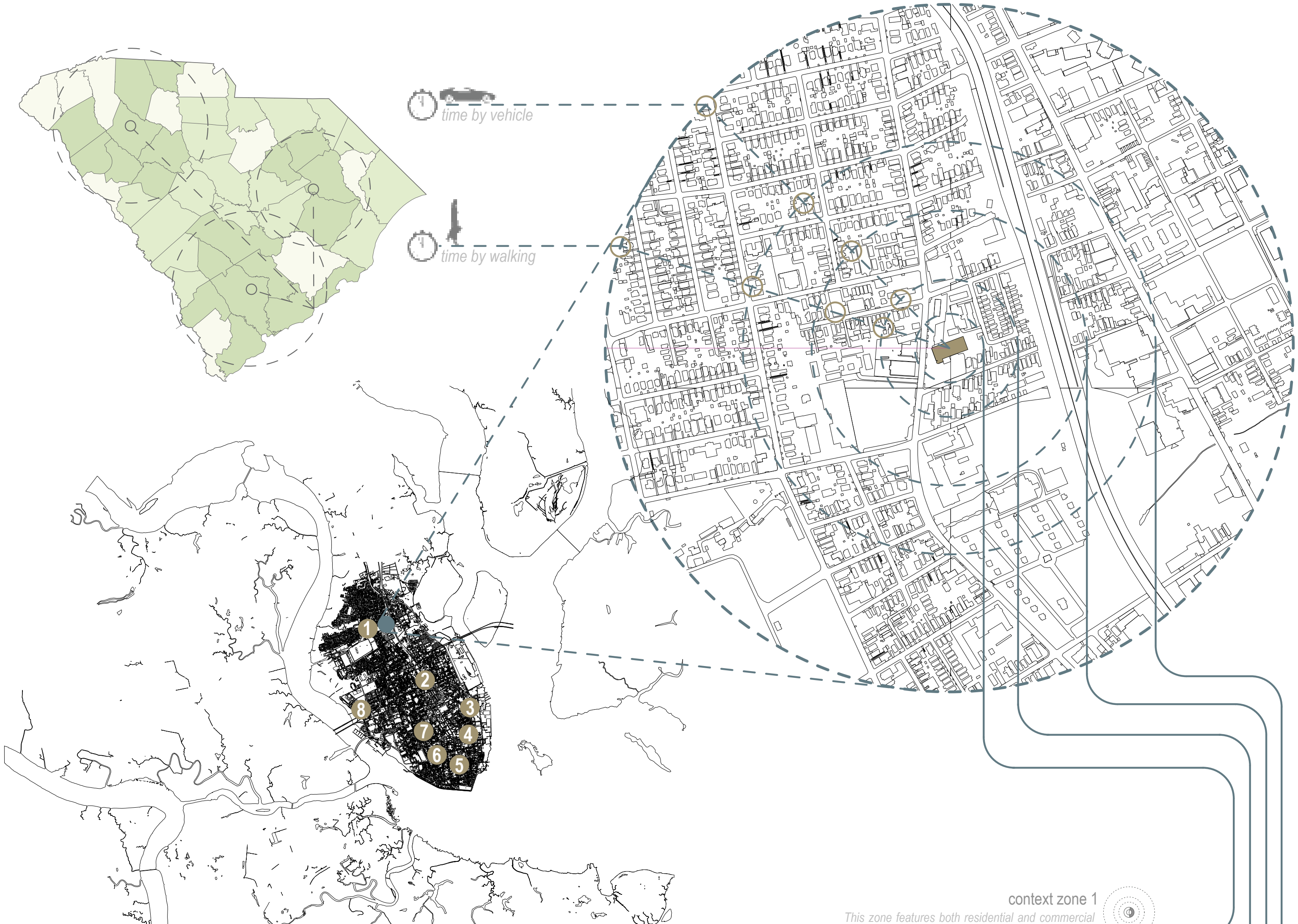
Design Summary

A major design focus for our project is to integrate the vertical farm within the local community, and for the building to serve as a community center. Our design strategy is centered around the idea of grafting. The project examines how to graft the new vertical farm with the existing structure.

GRAFTED VERTICAL FARM
GROW. COOK. EAT.

Grocery & Markets

- Food Lion 1
- Piggly Wiggly 2
- Harris Teeter 3
- The Vegetable Bin 4
- Bull Street Market 5
- Queen Street Grocery 6
- J & W Grocery 7
- President Market 8



surrounding green space

This map shows the existing green space within the surrounding context of the site. A major goal for the vertical farm is to influence and teach the community on how to make and manange their own urban gardens.

transportation + food resources

The main transportation networks for the vertical farm site include I-26 as a major connection to the rest of the state, and Huger Street as a main connection to downtown Charleston.

context zone 1

This zone features both residential and commercial program. The only other food resource is in this zone.

context zone 2

This zone features a large amount of residentail program and undeveloped land. It is also the first zone to include interstate I-26.

context zone 3

Zone 3 features many residential structures as well as two of the restaurants within the surrounding context of the vertical farm site.

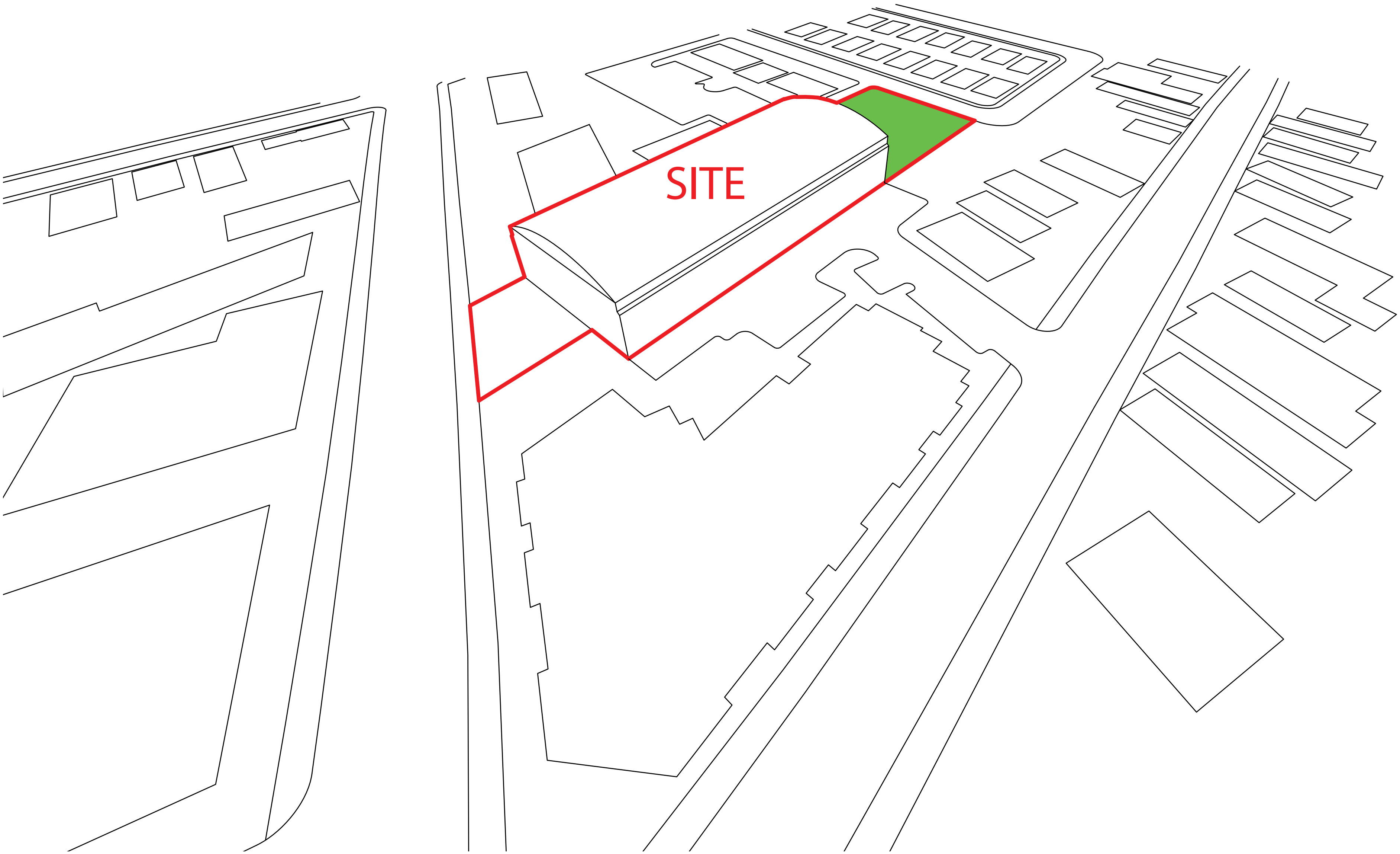
context zone 4

This zone is mainly made up of residential program. The zone makes a concept of a vertical ideal for its current location.

GRAFTED VERTICAL FARM

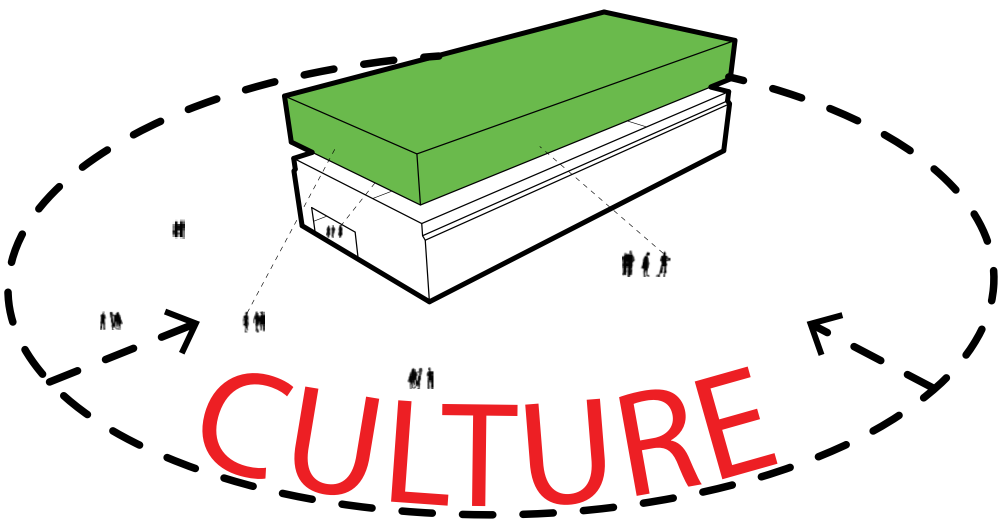
GROW. COOK. EAT.

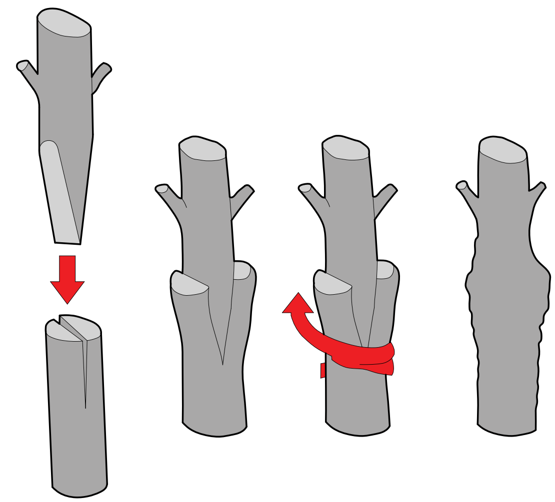
SITE | DESIGN | STRUCTURE | FLOOR PLANS | SECTION | ENVELOPE | FARMING



GRAFTED VERTICAL FARM
GROW. COOK. EAT.

SITE | DESIGN | STRUCTURE | FLOOR PLANS | SECTION
ENVELOPE | FARMING



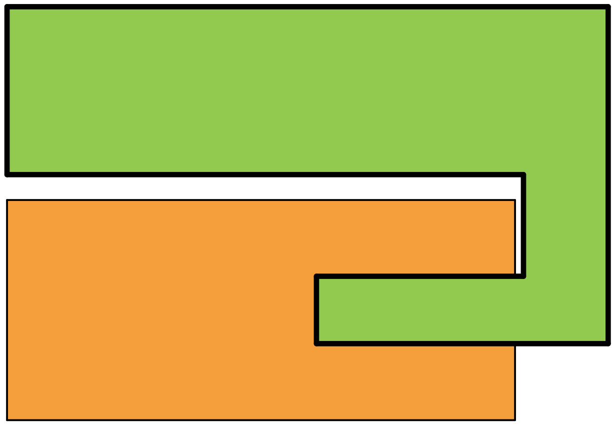


CONCEPT

A major design focus for our project is to integrate the vertical farm within the local community, and for the building to serve as a community center.

GRAFTING

Our design strategy is centered around the idea of grafting. The project examines how to graft the new vertical farm with the existing structure.

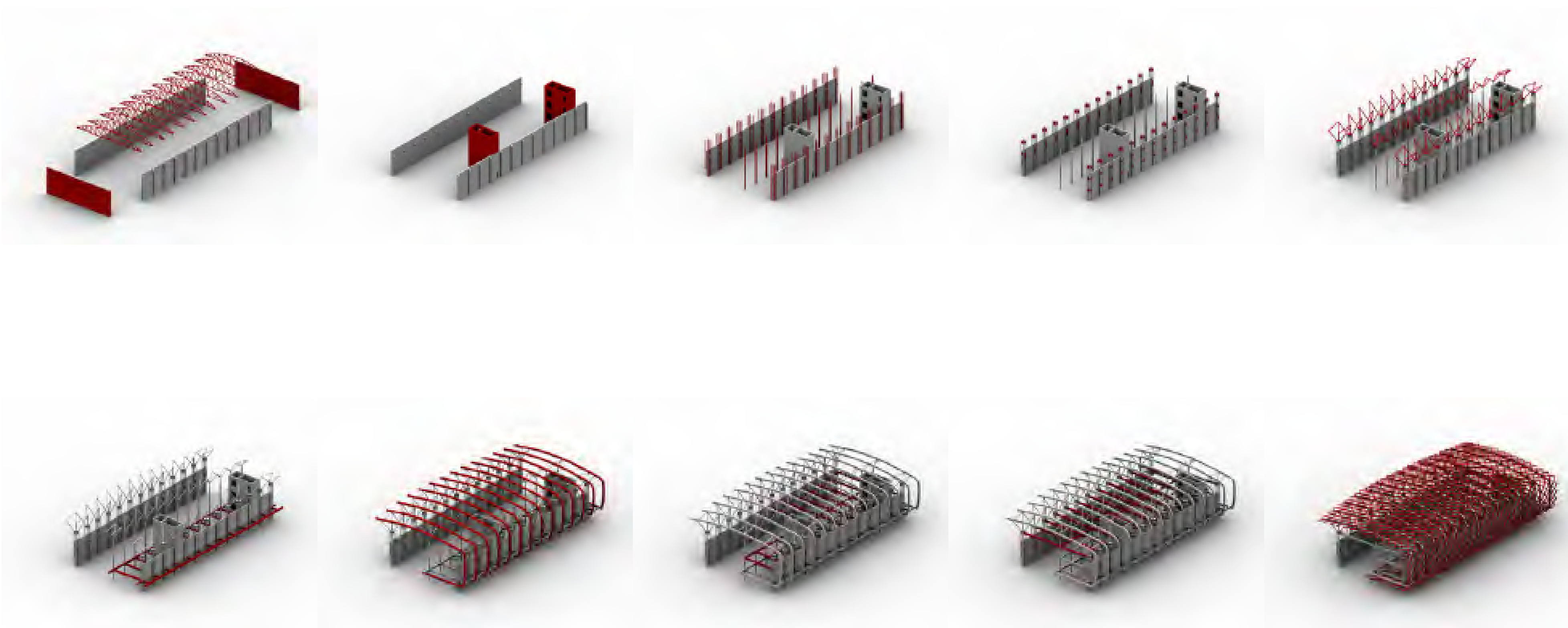


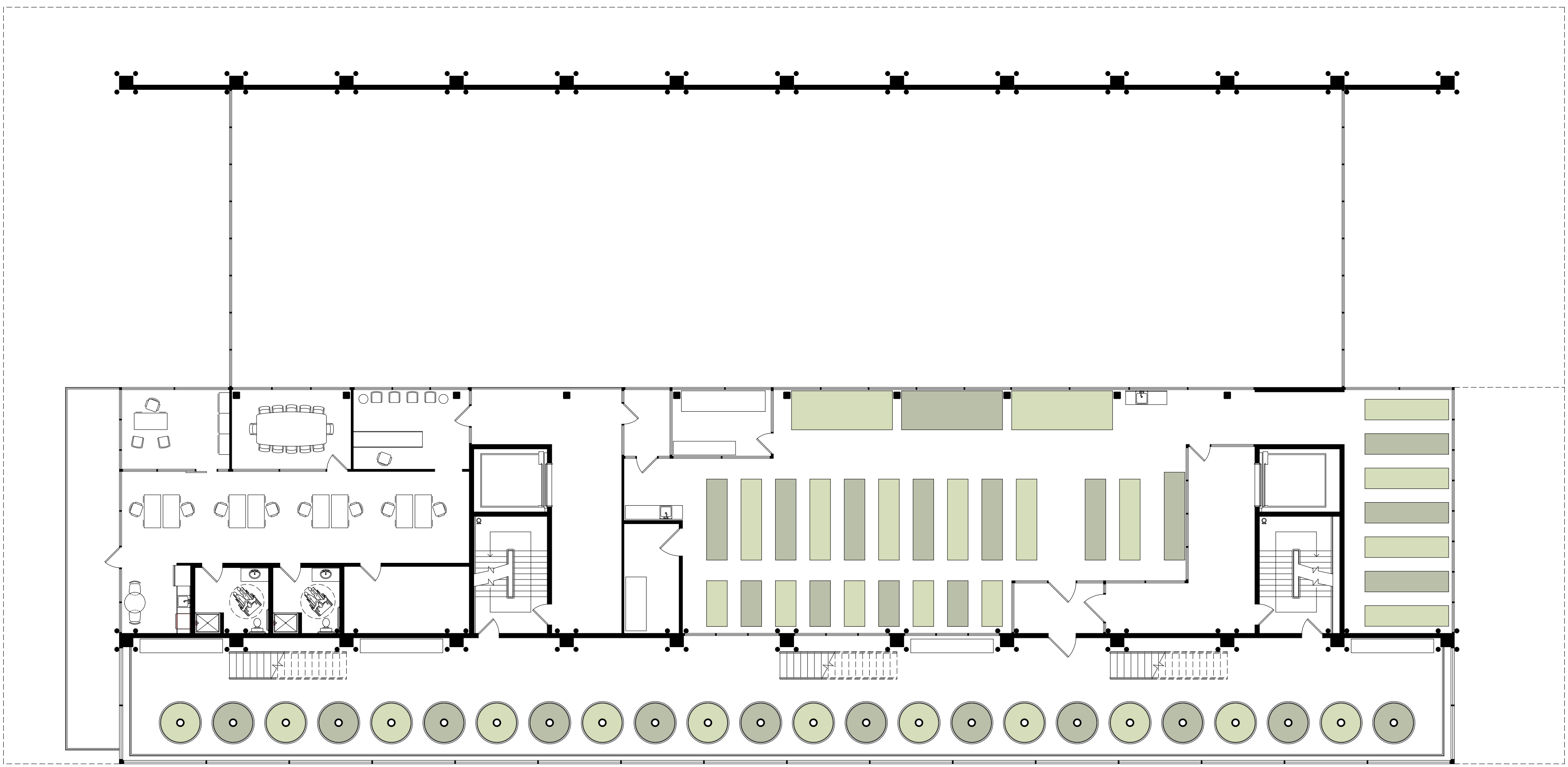
GRAFTING 1.0

The initial graft worked well with using the existing structure, but still created a boundary between the cultural and farm programs.

GRAFTING 2.0

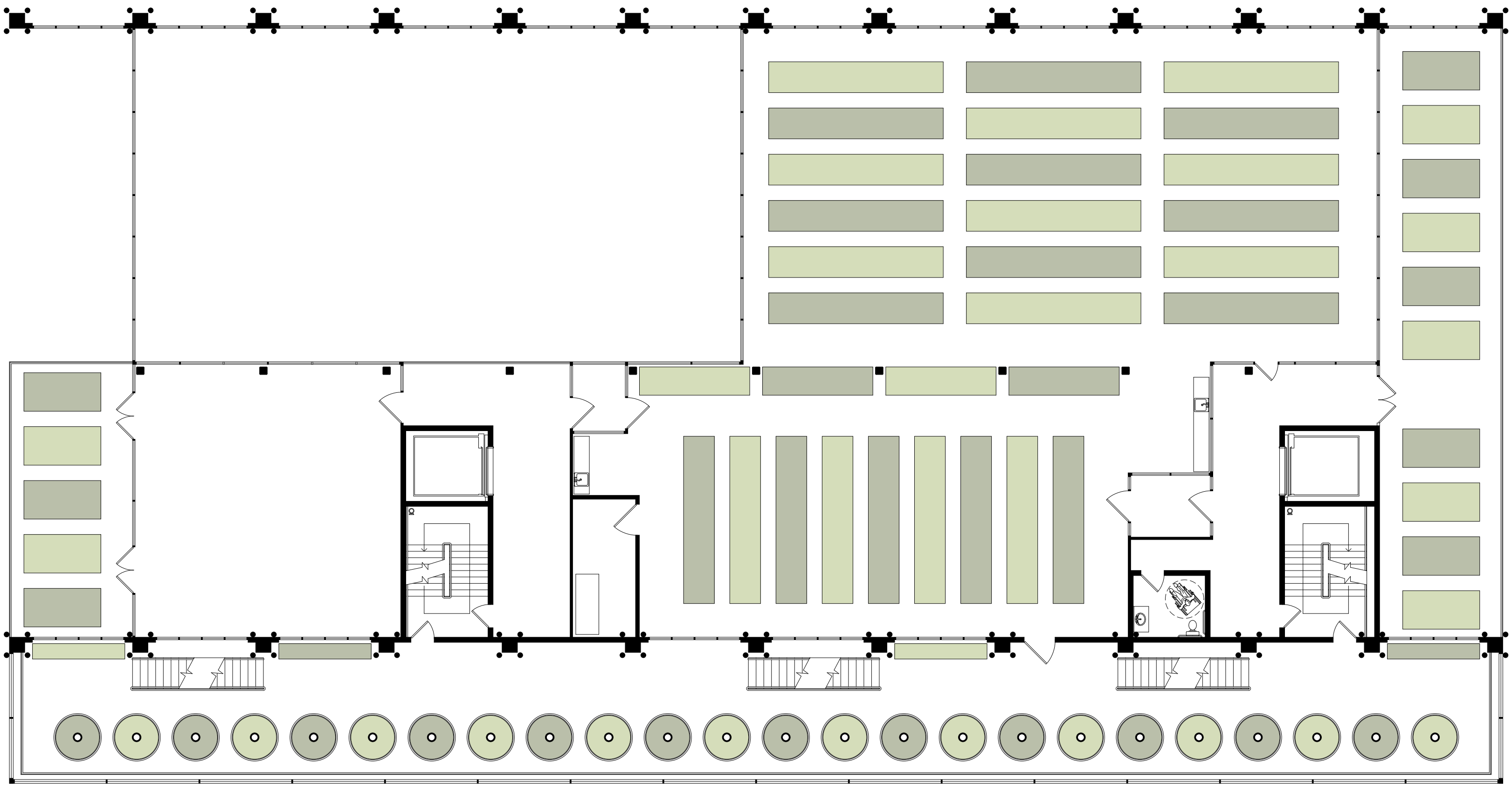
The second iteration of the grafting process begins to mix both of the programs and provide maximum transperency for the vertical farm.



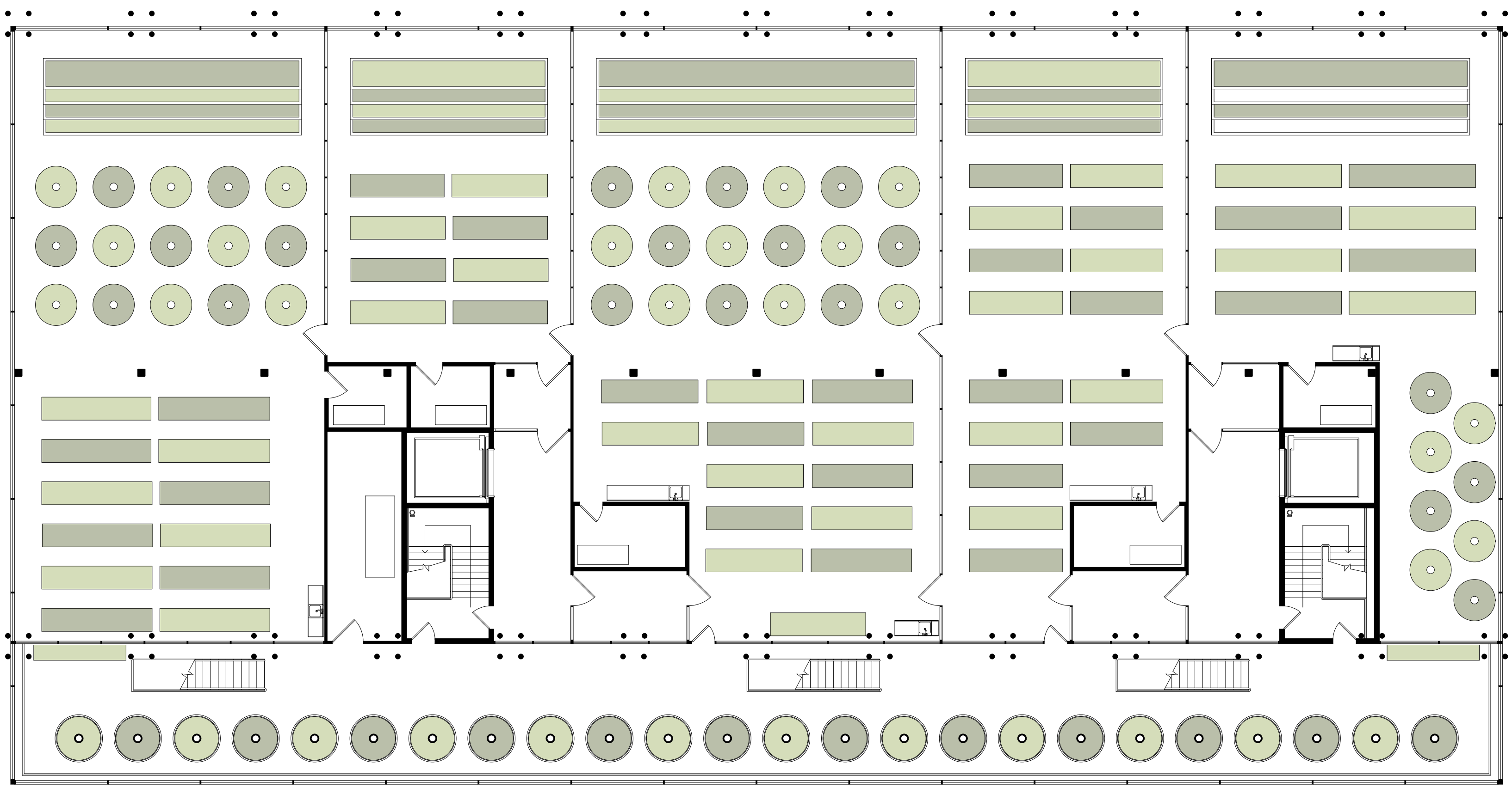


GRAFTED VERTICAL FARM
GROW. COOK. EAT.

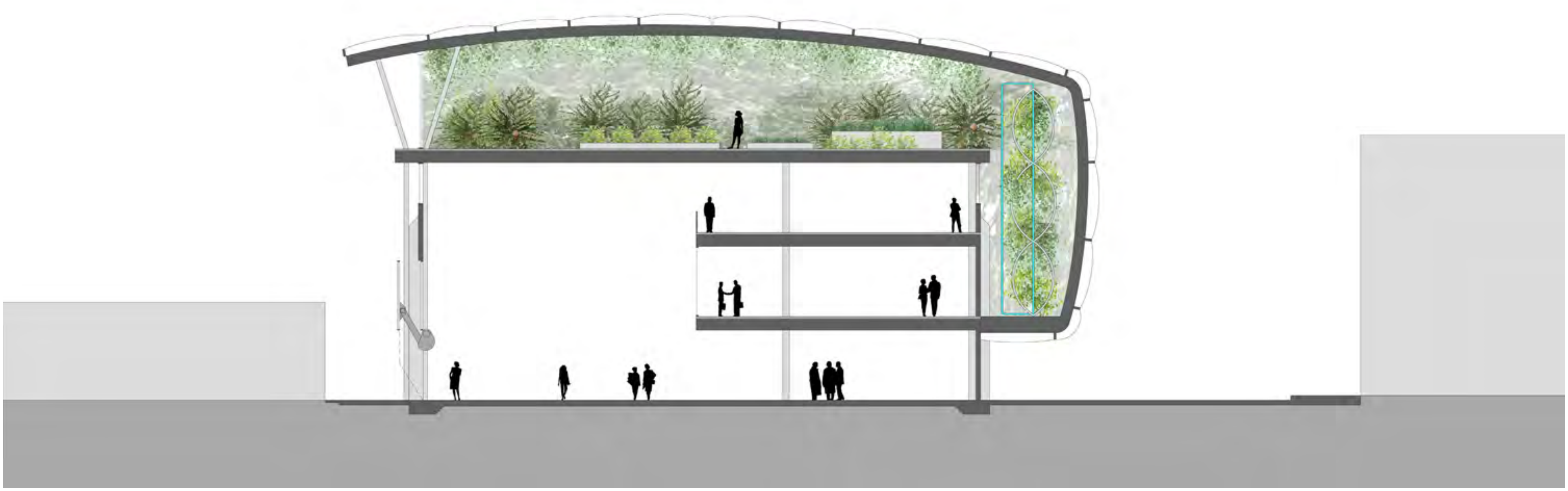
SITE
DESIGN
STRUCTURE
FLOOR PLANS
SECTION
ENVELOPE
FARMING



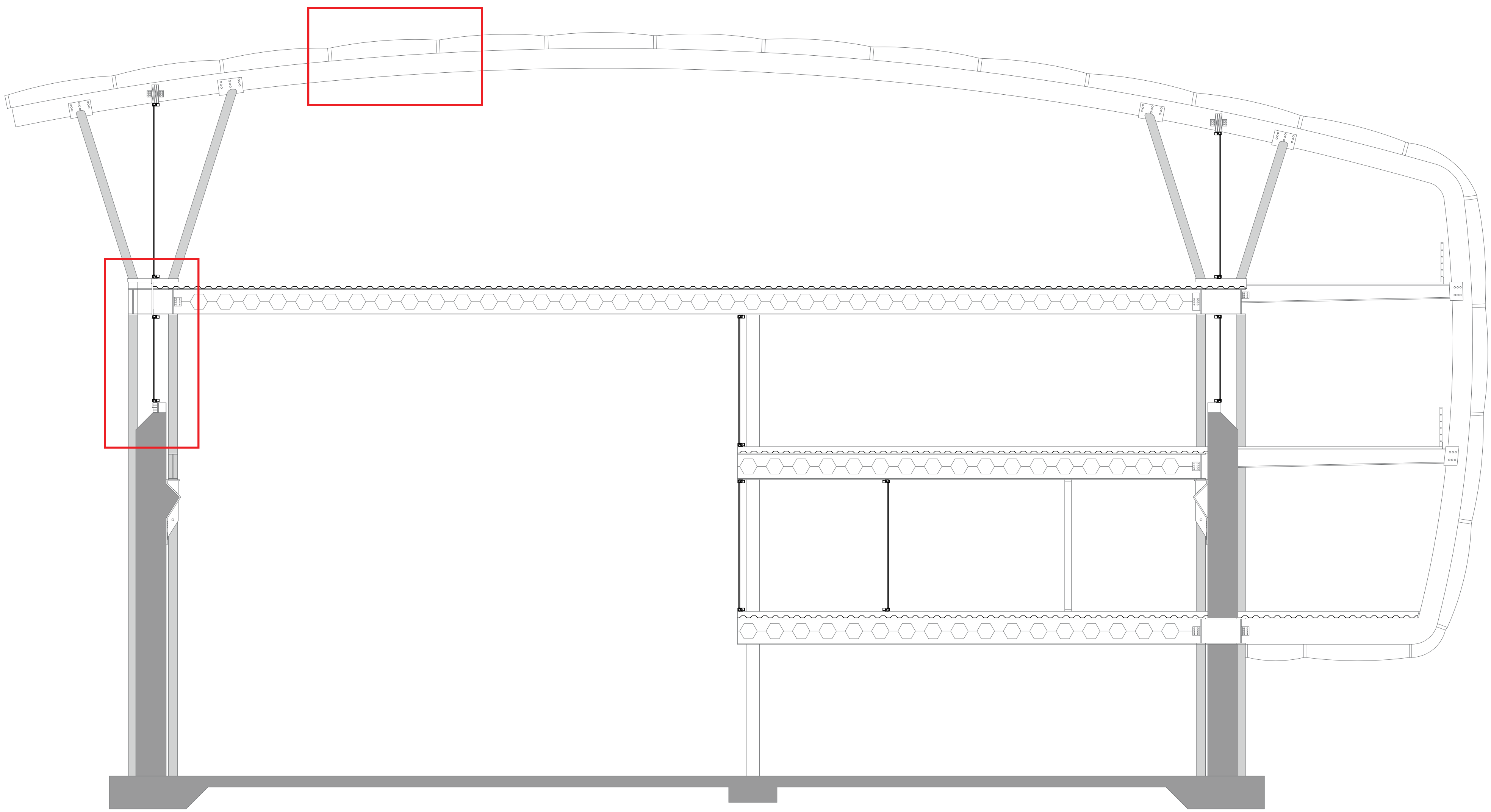
GRAFTED VERTICAL FARM
GROW. COOK. EAT.



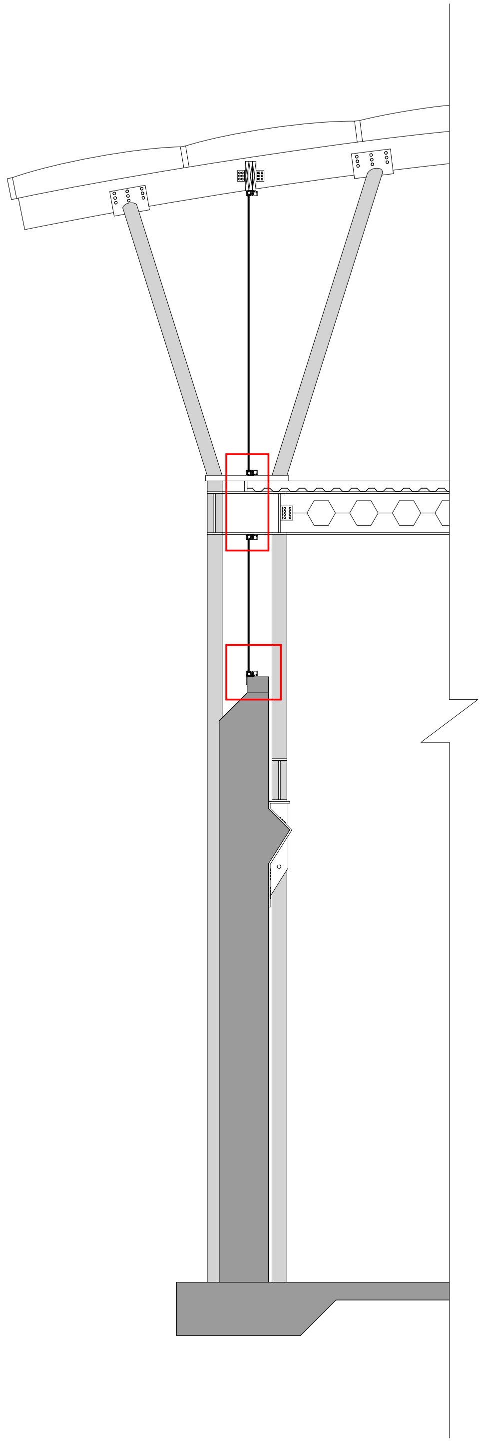
GRAFTED VERTICAL FARM
GROW. COOK. EAT.

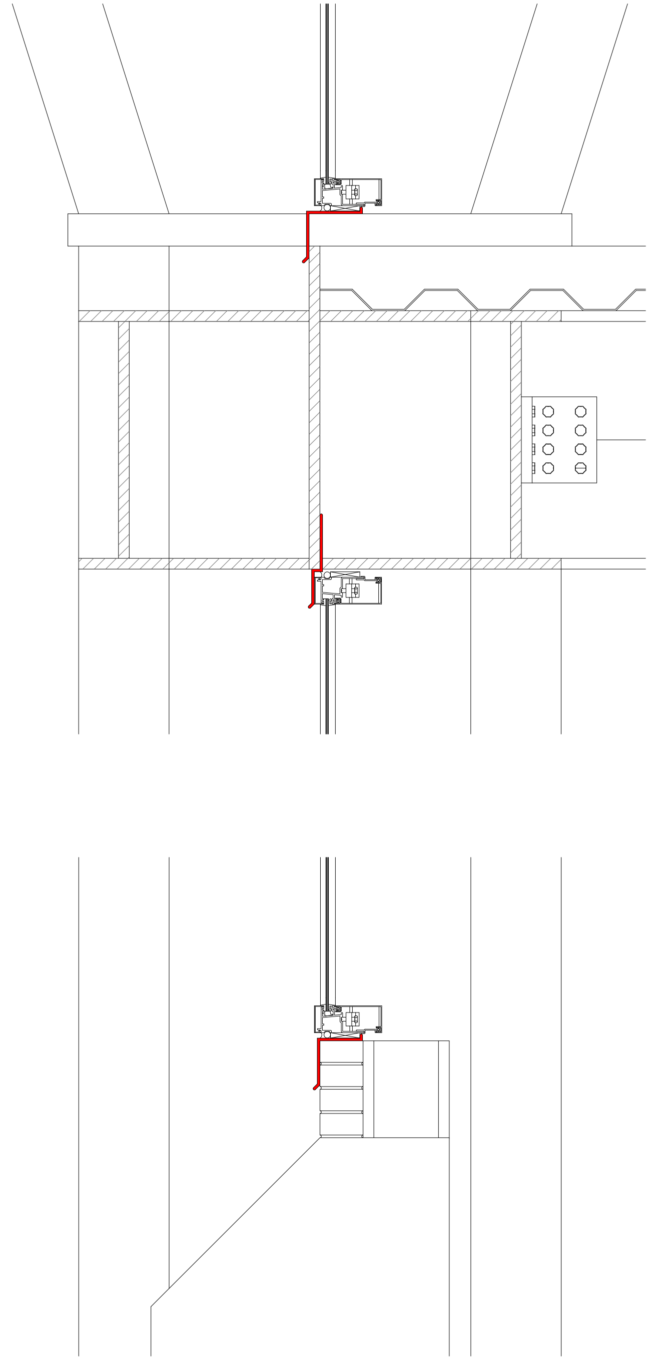


GRAFTED VERTICAL FARM
GROW. COOK. EAT.

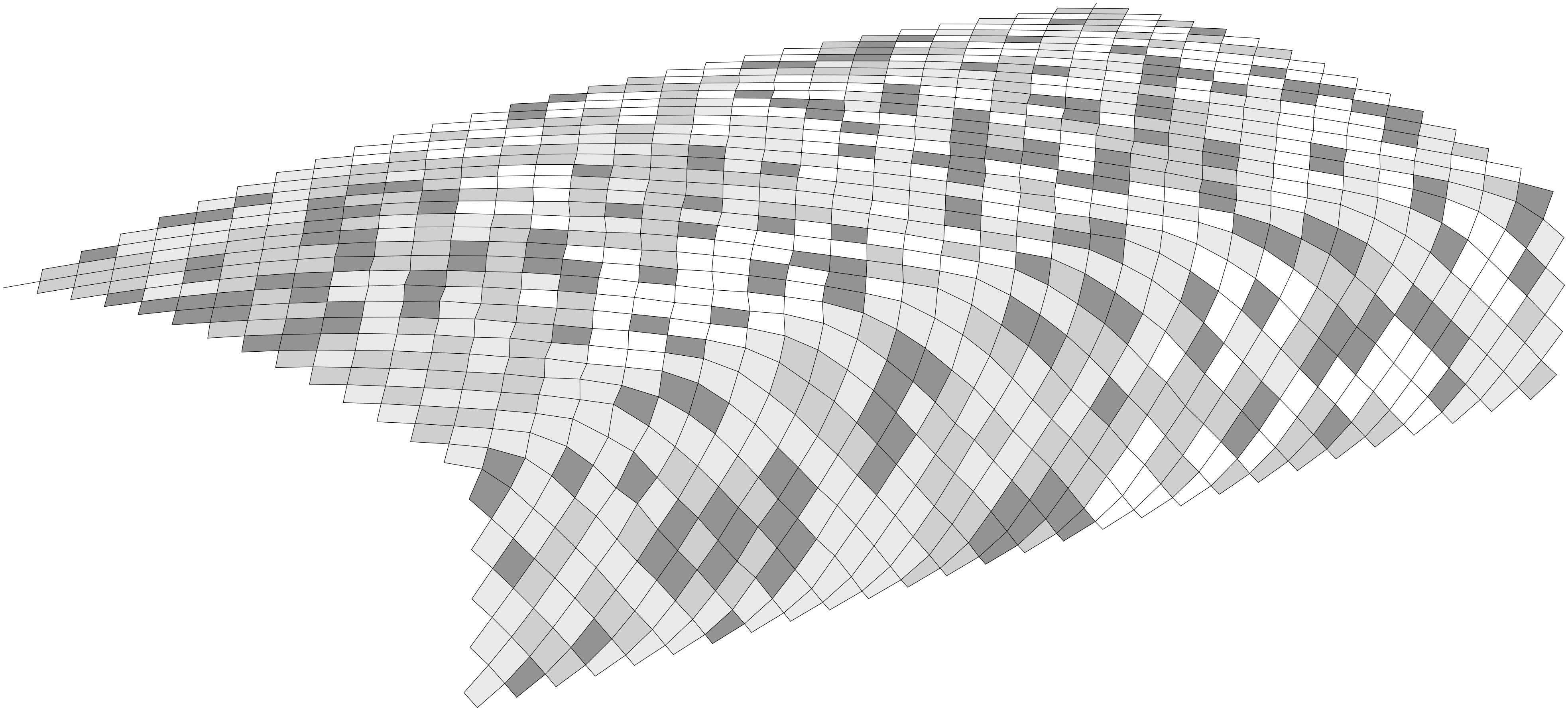


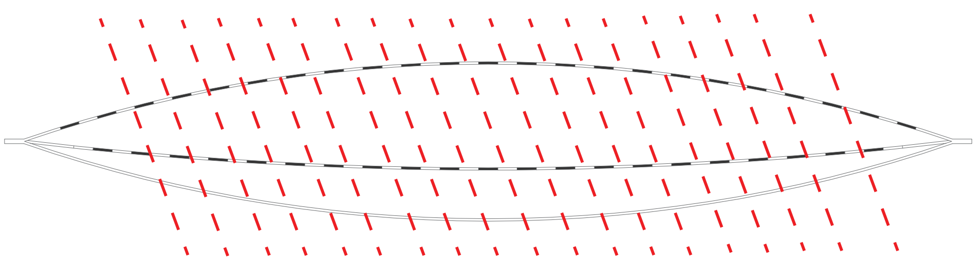
GRAFTED VERTICAL FARM
GROW. COOK. EAT.

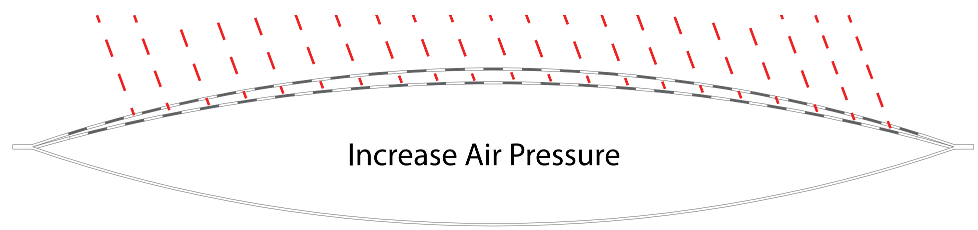




GRAFTED VERTICAL FARM
GROW. COOK. EAT.

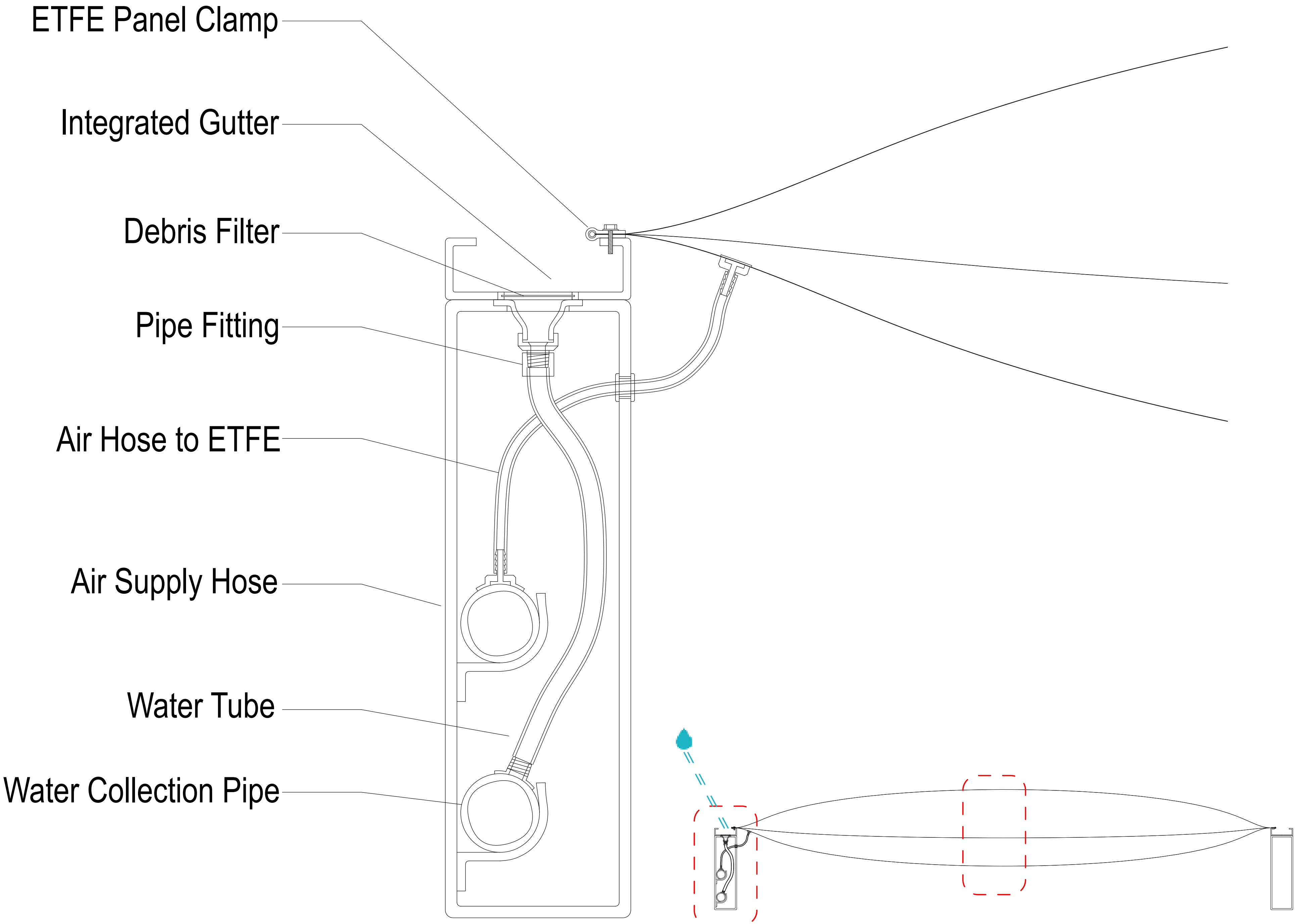


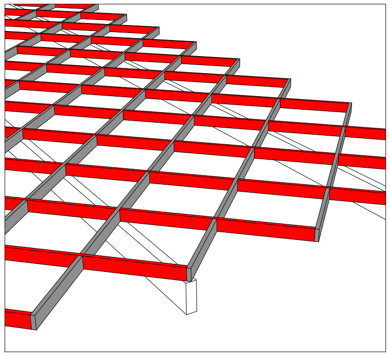


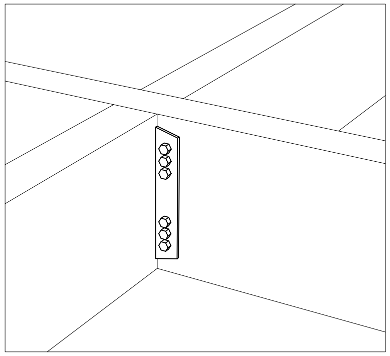


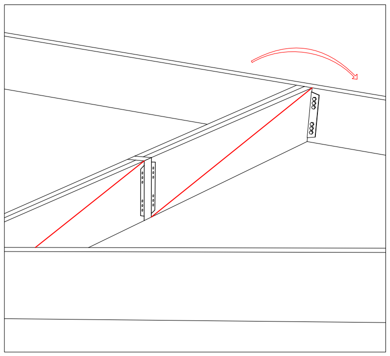
GRAFTED VERTICAL FARM
GROW. COOK. EAT.

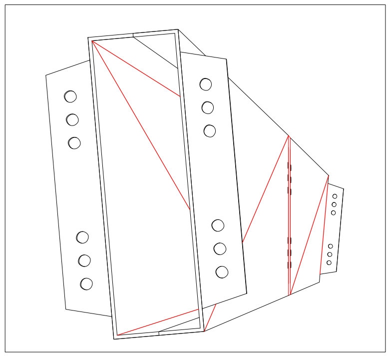
SITE
DESIGN
STRUCTURE
FLOOR PLANS
SECTION
ENVELOPE
FARMING

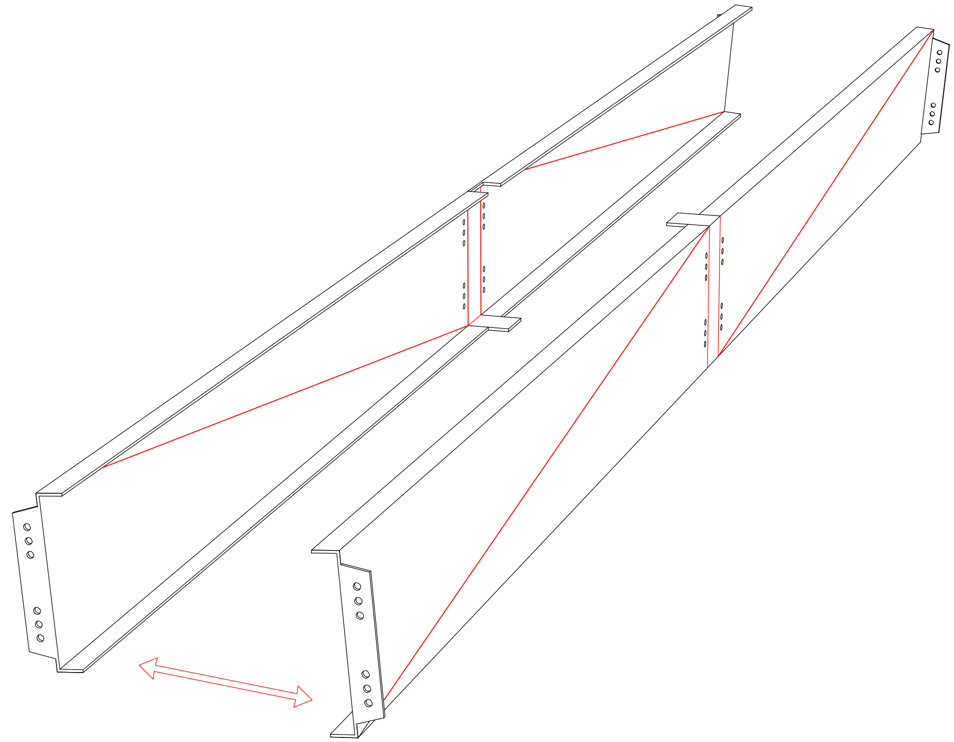

ETFE Panel Clamp
Integrated Gutter
Debris Filter
Pipe Fitting
Air Hose to ETFE
Air Supply Hose
Water Tube
Water Collection Pipe

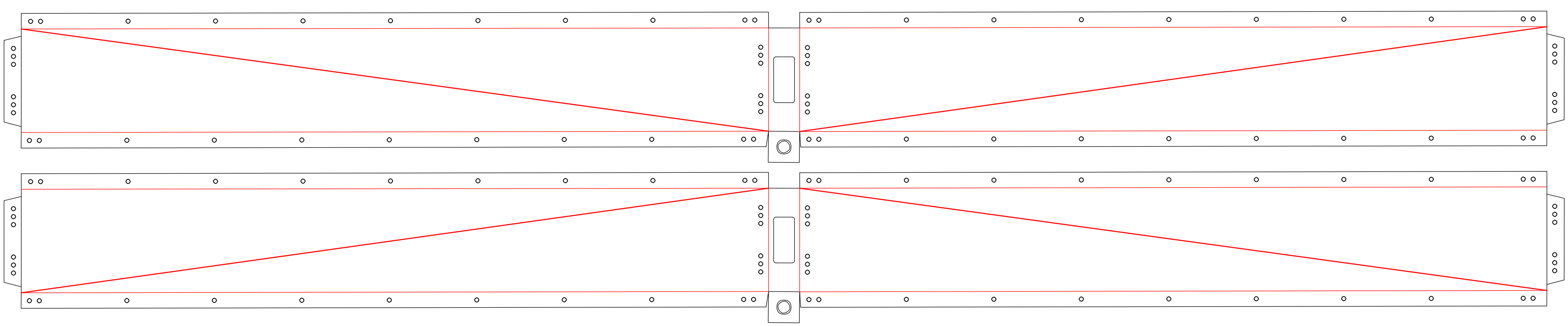






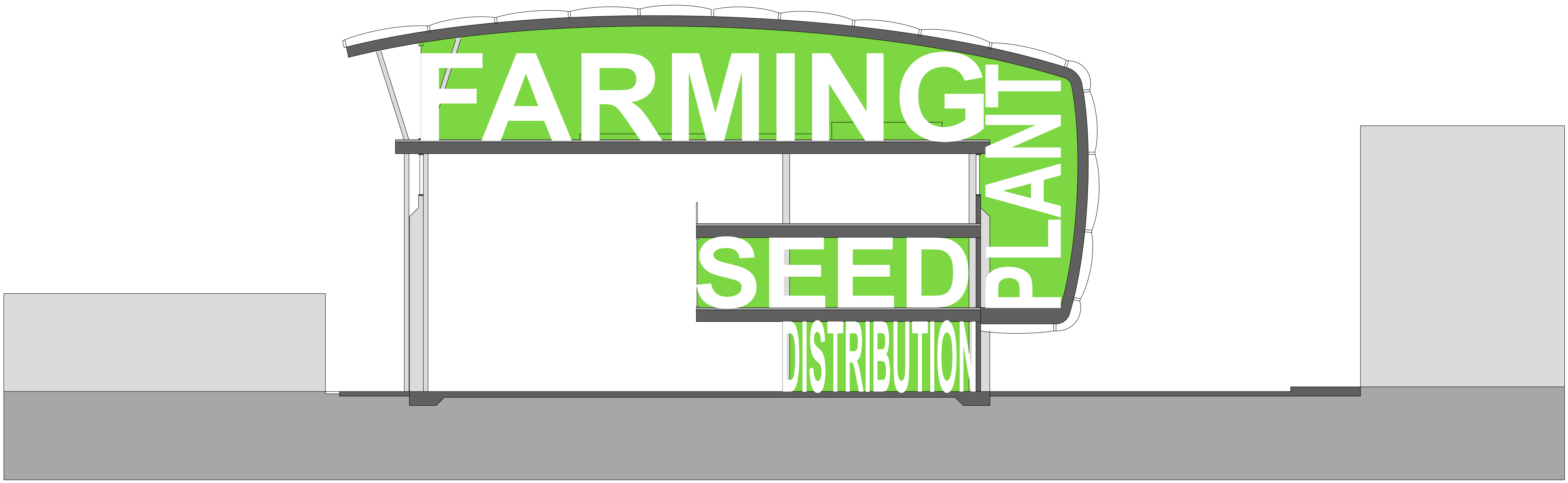






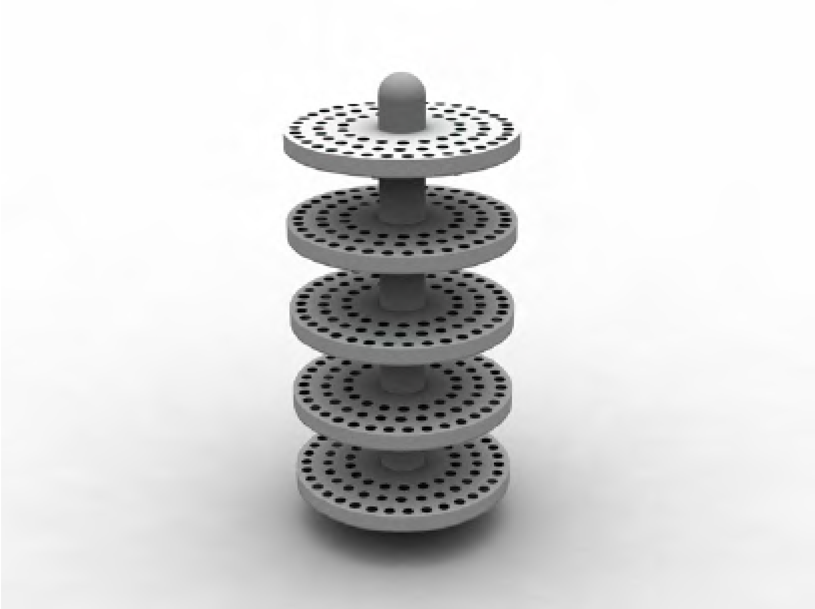
GRAFTED VERTICAL FARM
GROW. COOK. EAT.

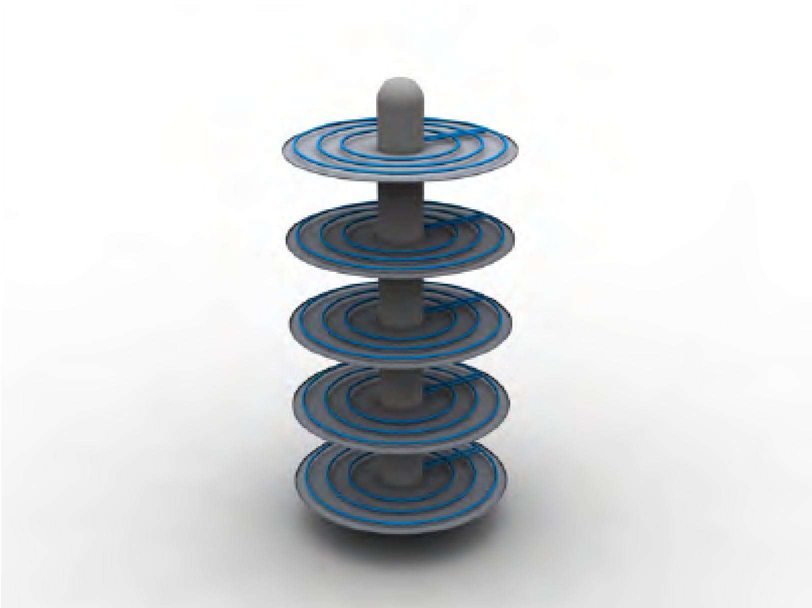
SITE
DESIGN
STRUCTURE
FLOOR PLANS
SECTION
ENVELOPE
FARMING

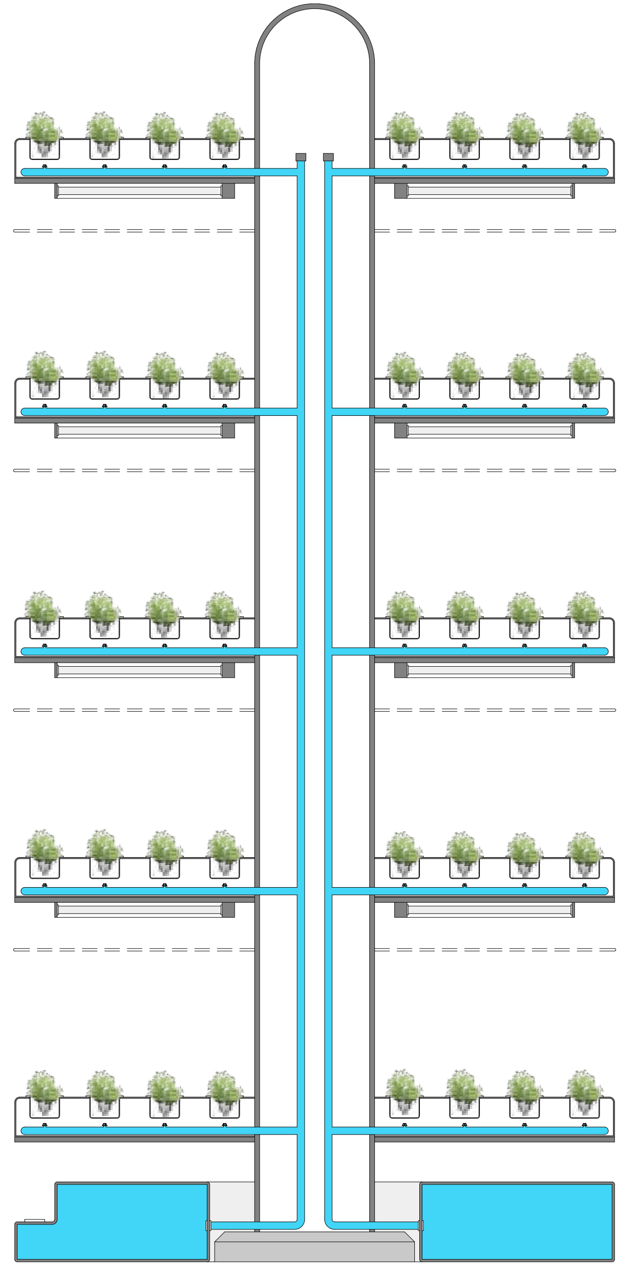


GRAFTED VERTICAL FARM
GROW. COOK. EAT.

SITE
DESIGN
STRUCTURE
FLOOR PLANS
SECTION
ENVELOPE
FARMING



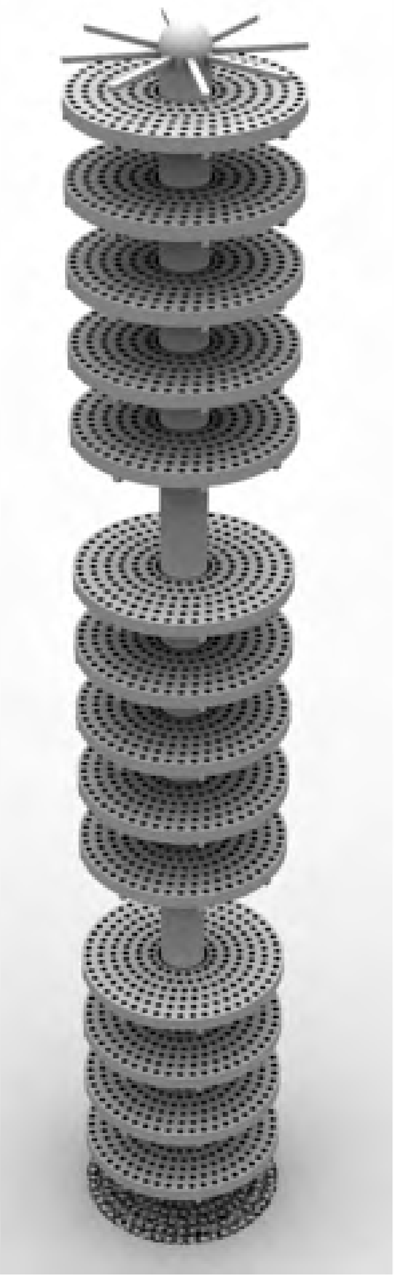


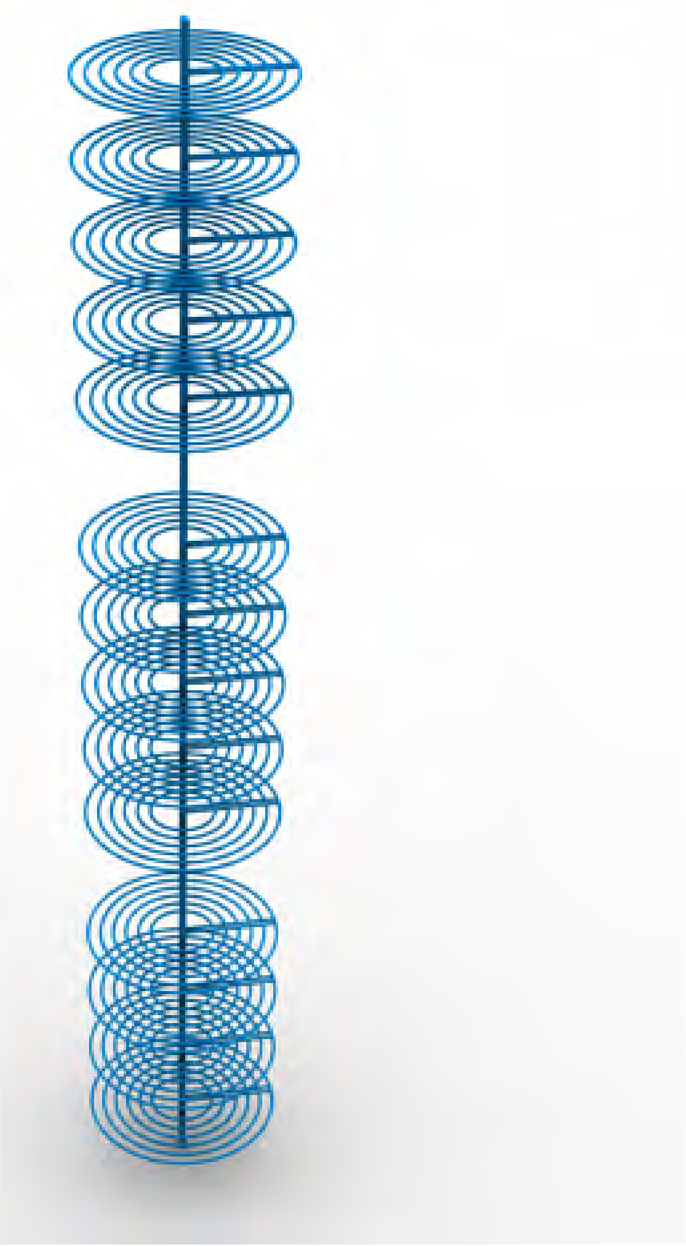


GRAFTED VERTICAL FARM
GROW. COOK. EAT.

SITE | DESIGN | STRUCTURE | FLOOR PLANS | SECTION

ENVELOPE | FARMING





Design Model 7

White Forest by Heather Zhang and Johnhoon Ahn

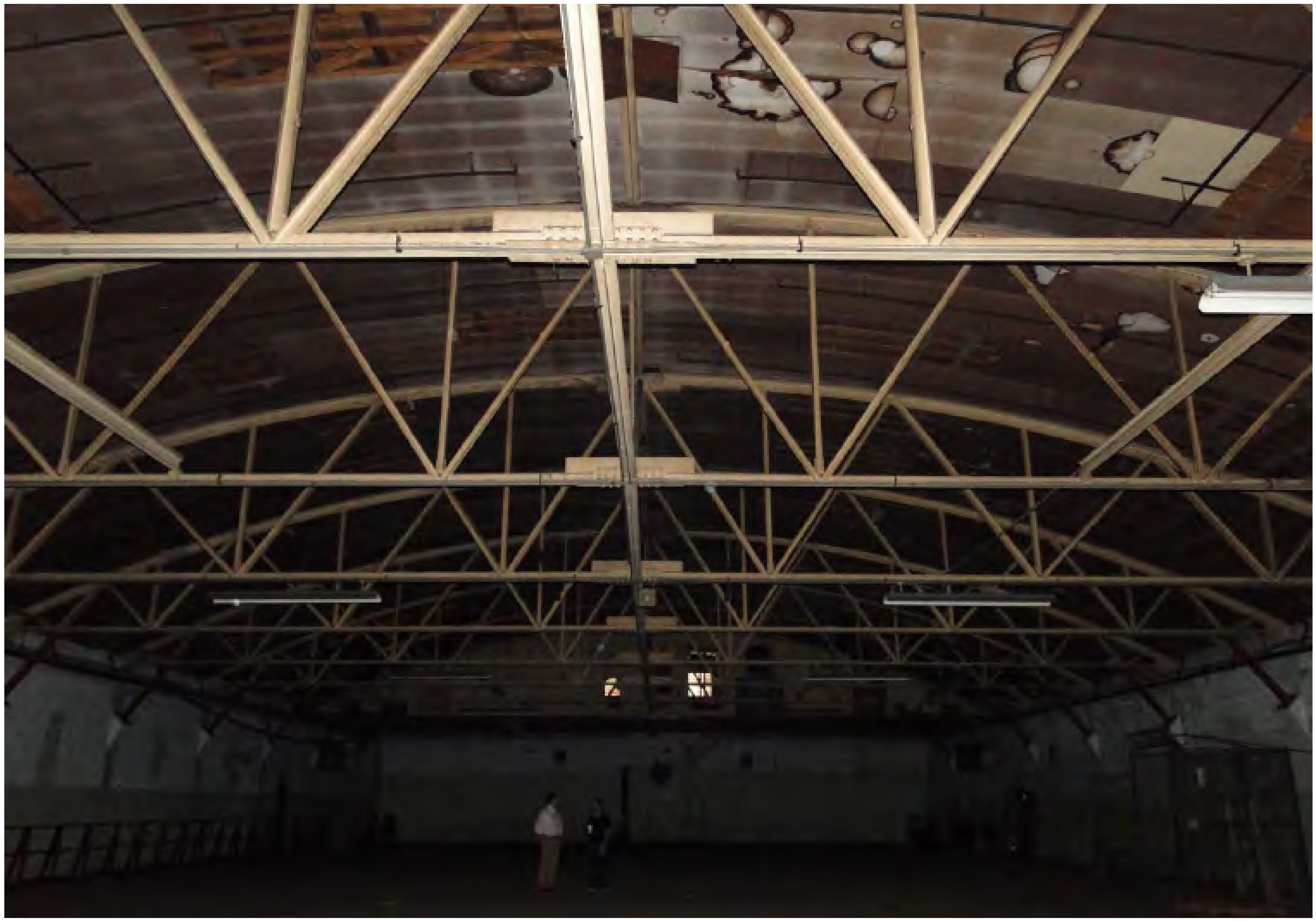
Vertival Farm
White Forest

Heather Zhang+Johnhoon Ahn

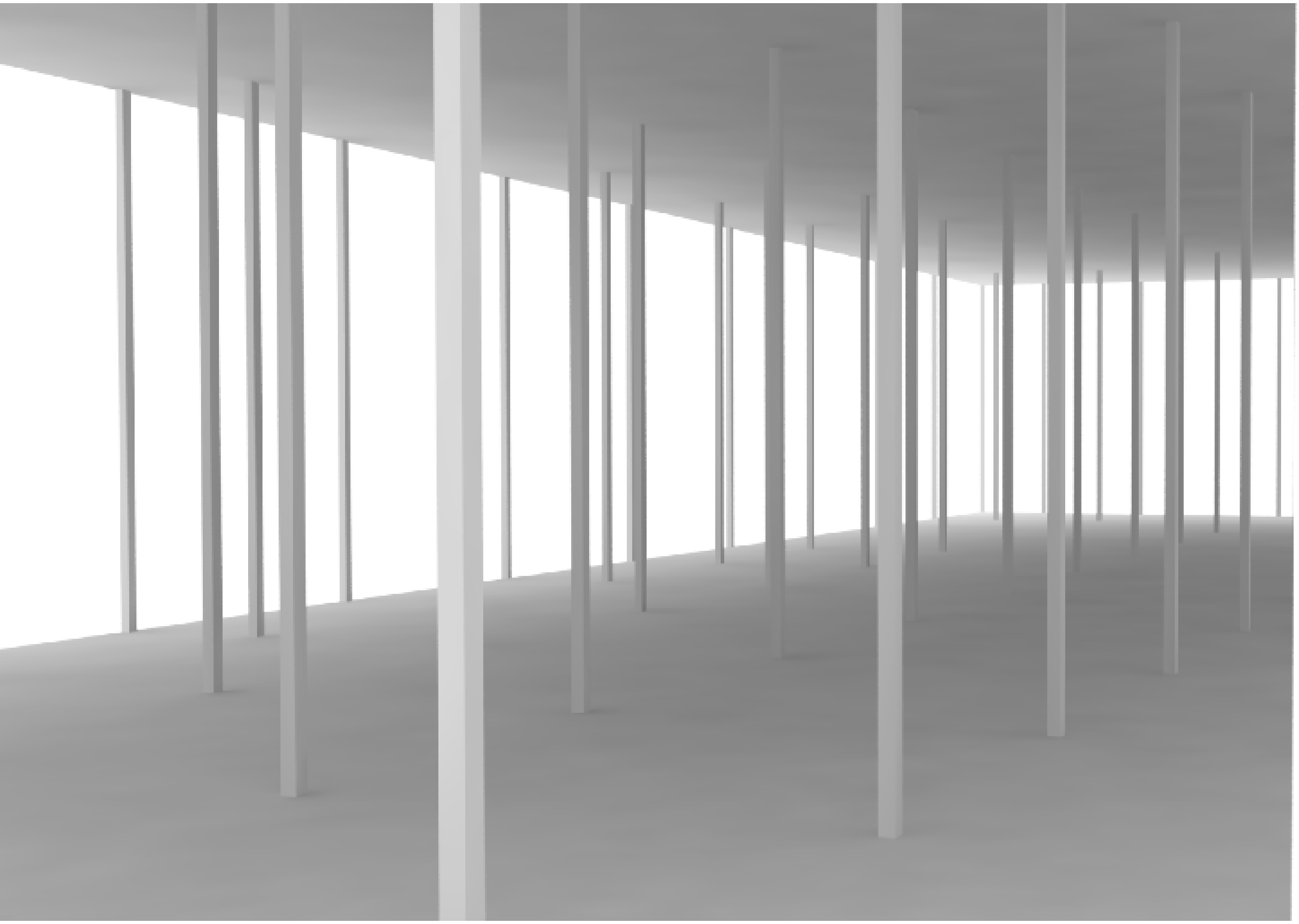
Vertival Farm
White Forest

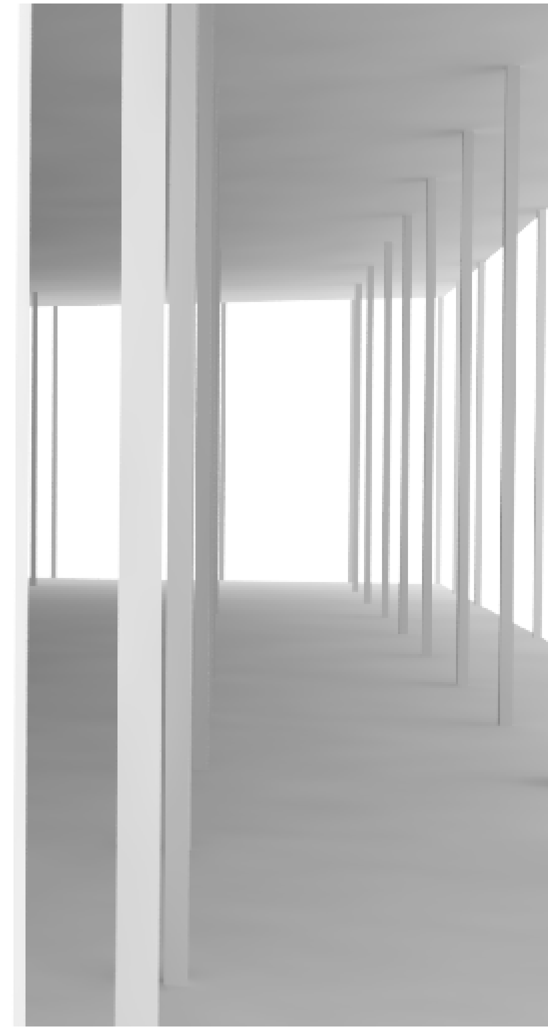
Heather Zhang+Johnhoon Ahn


PORT CITY
PAPER CO
HANDICAPPED
UNITED

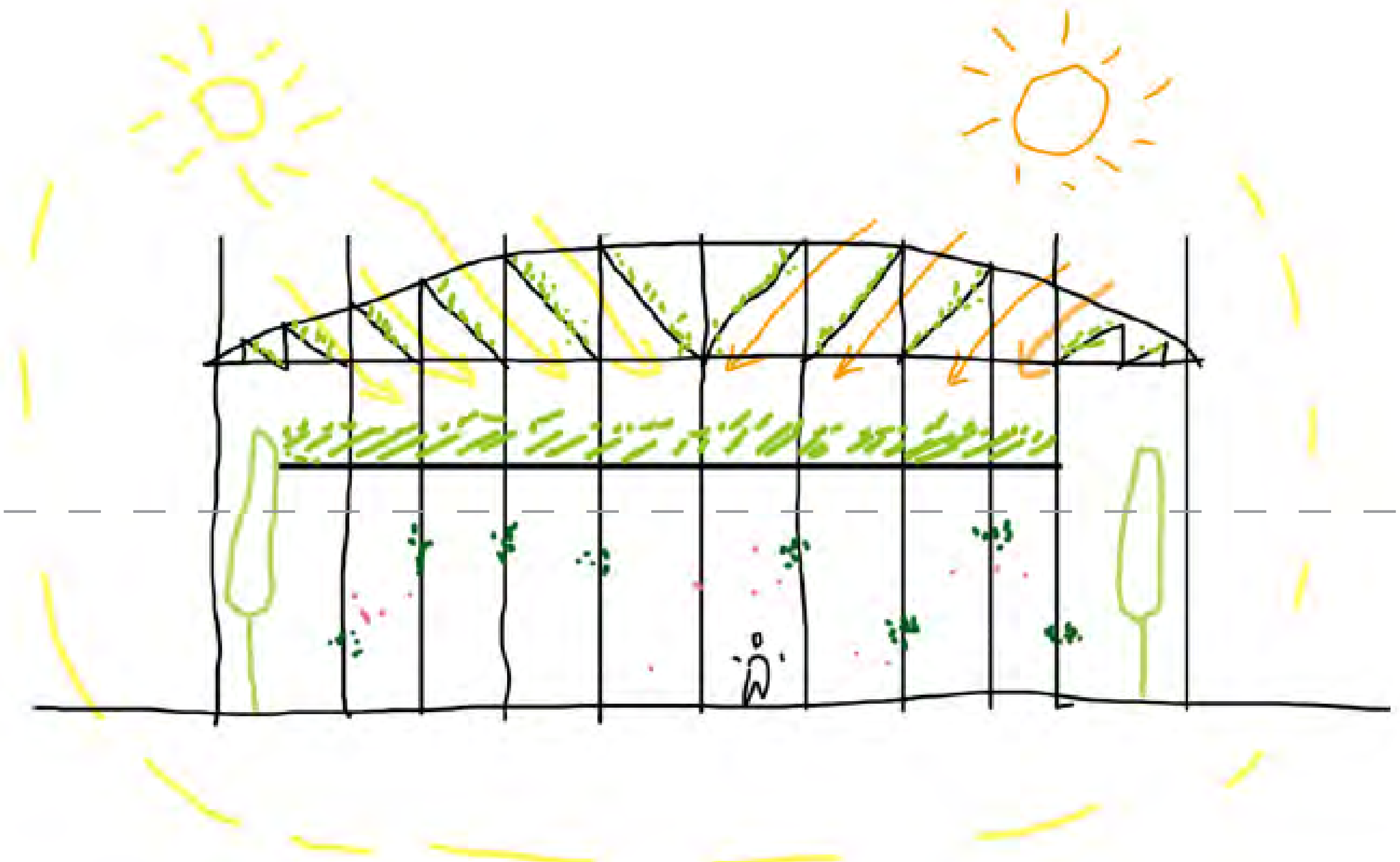


Concept





Concept



Productively Farming

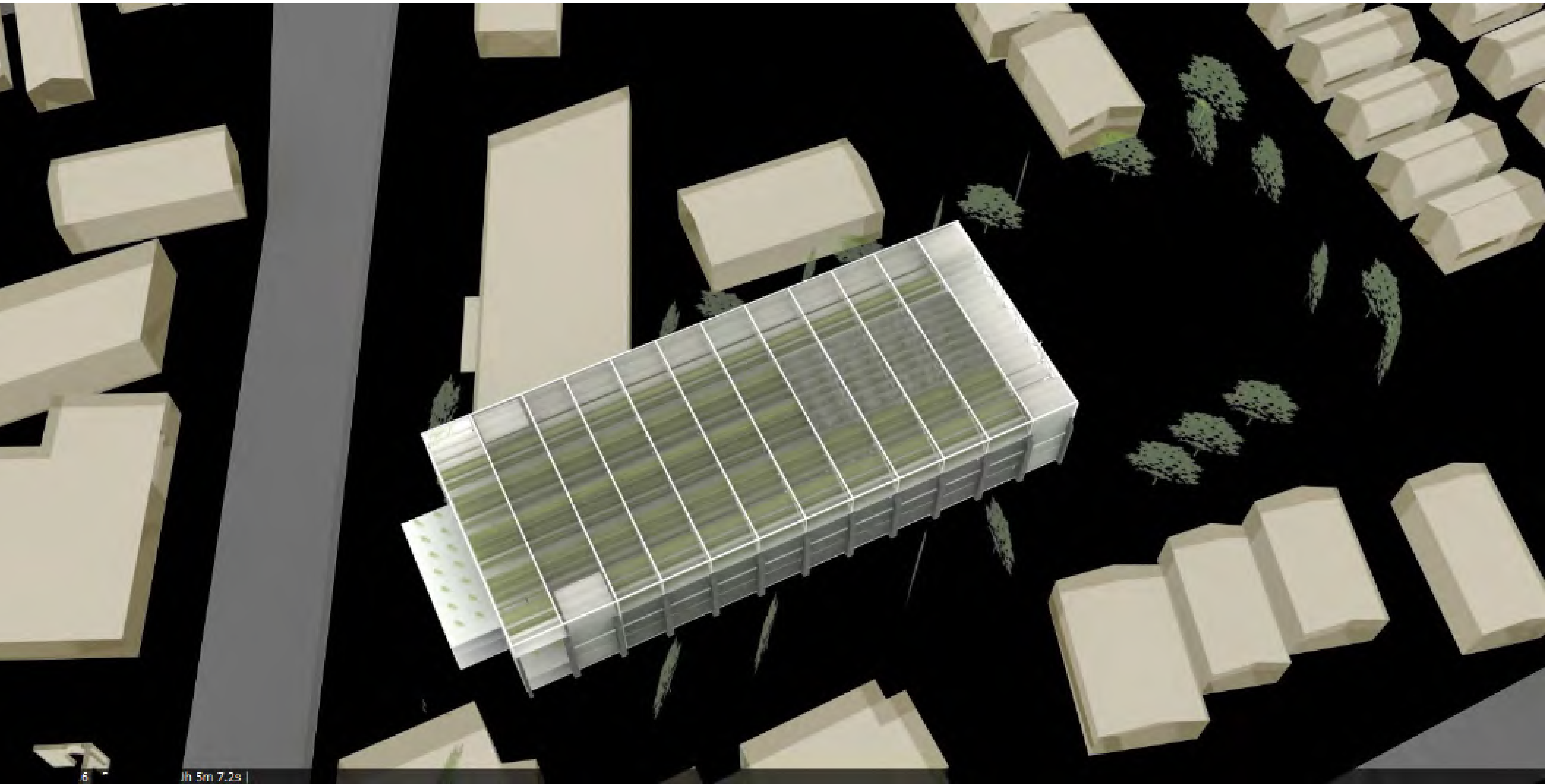
Visitor's Farming

Vertival Farm
White Forest

Site Plan

Vertival Farm
White Forest

Perspective



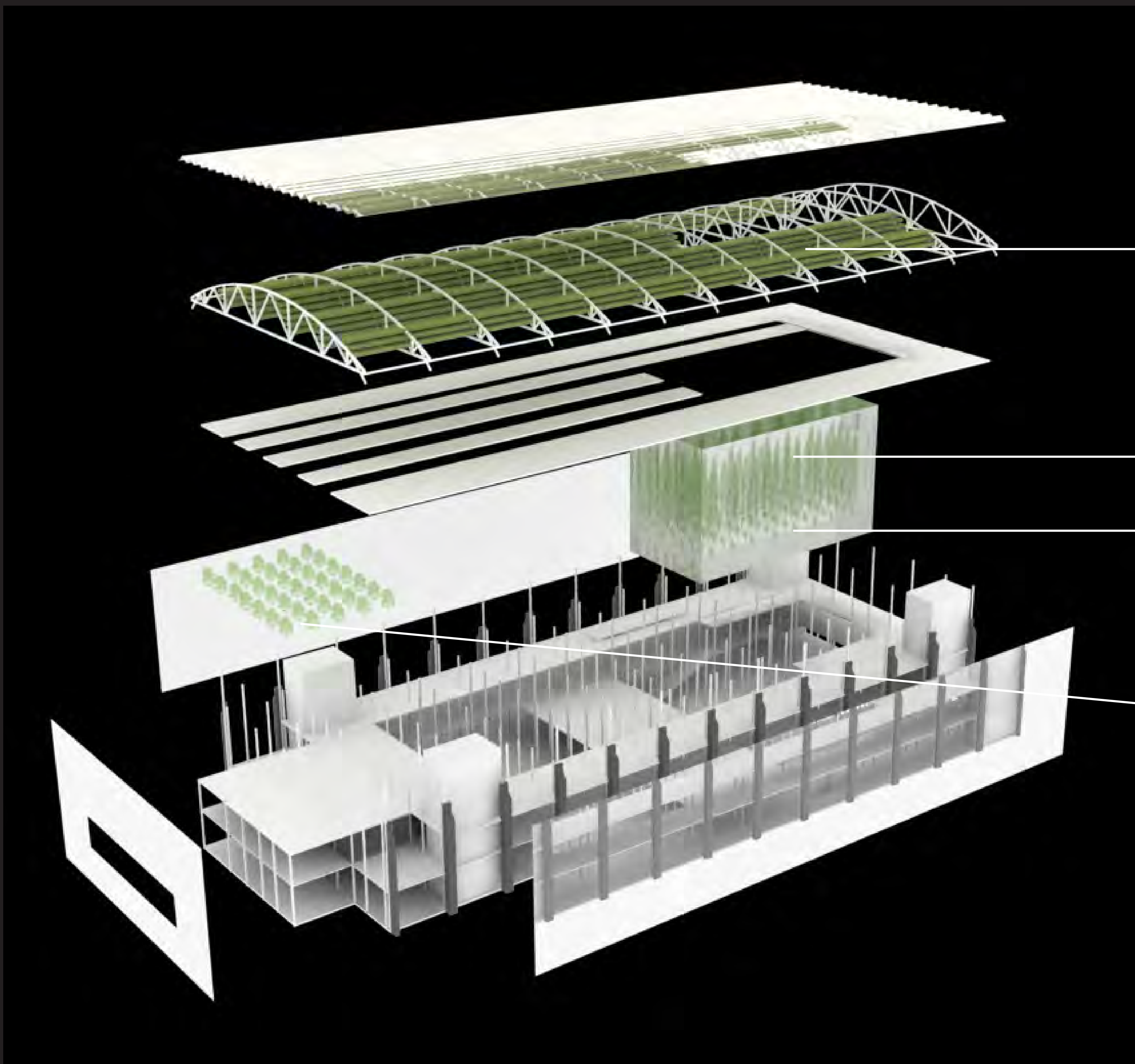
Vertival Farm

White Forest

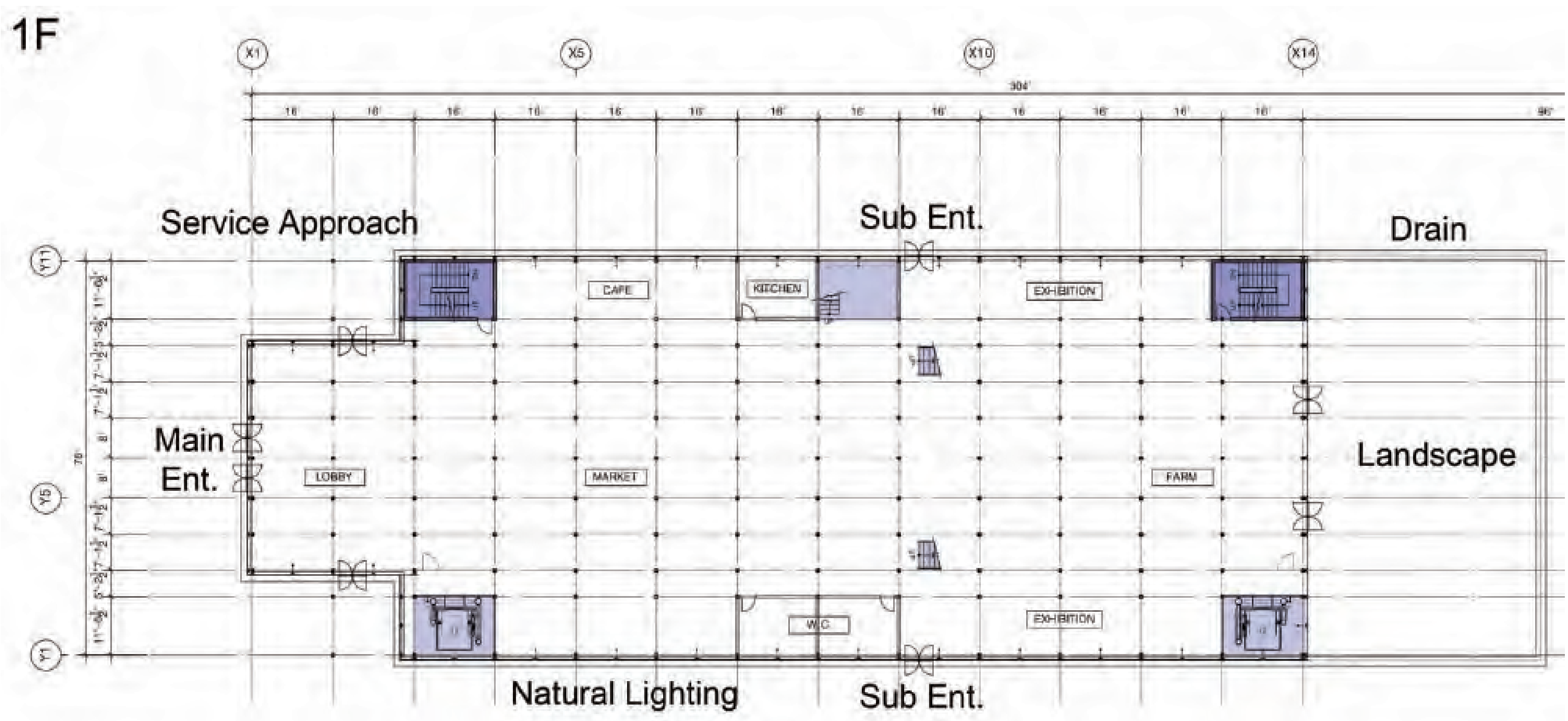
Layout

Vertival Farm

White Forest

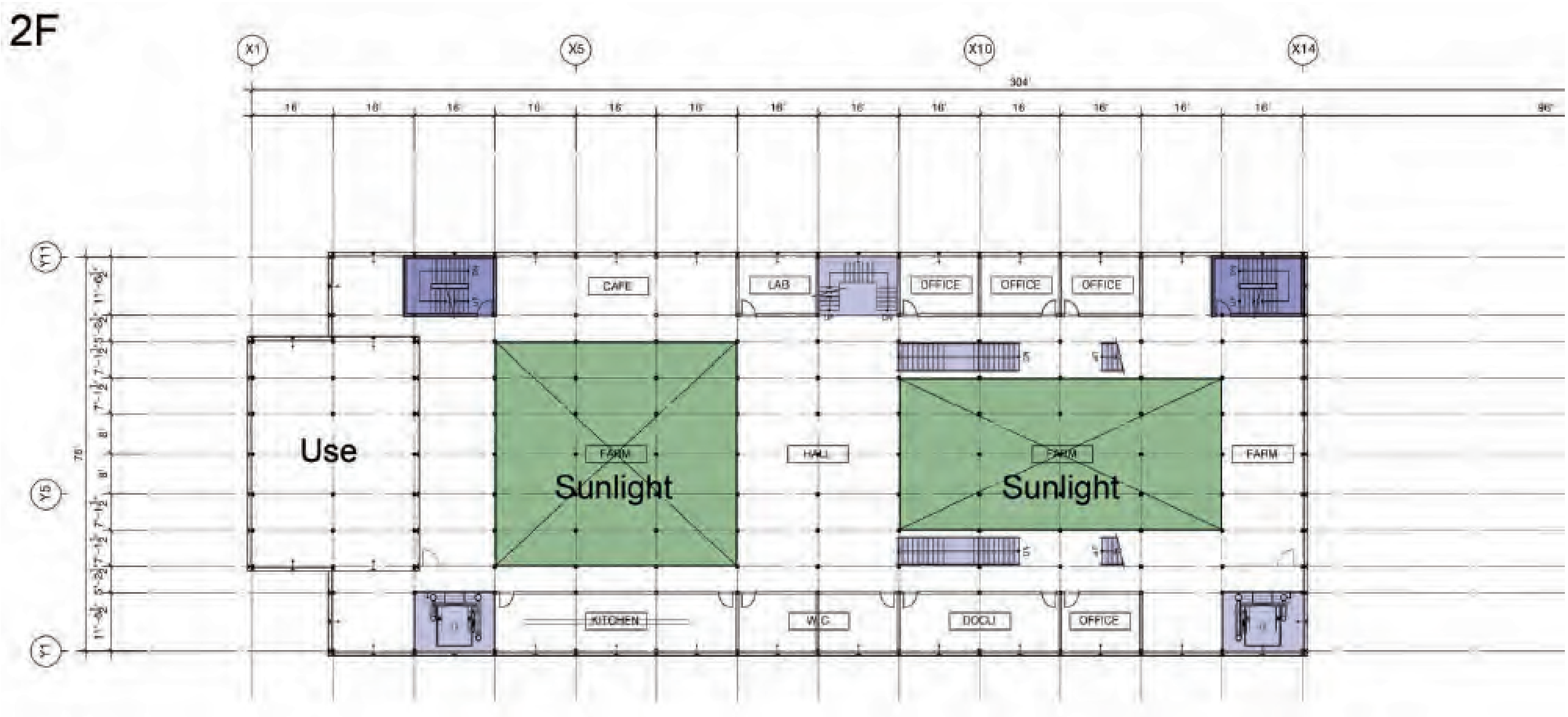


Plan


1F
X1
X5
X10
X14
304'
Y11
Y5
Y1
Service Approach
Sub Ent.
Drain
CAFE
KITCHEN
EXHIBITION
Main Ent.
LOBBY
MARKET
FARM
Landscape
W.C.
EXHIBITION
Natural Lighting
Sub Ent.

Vertival Farm
White Forest

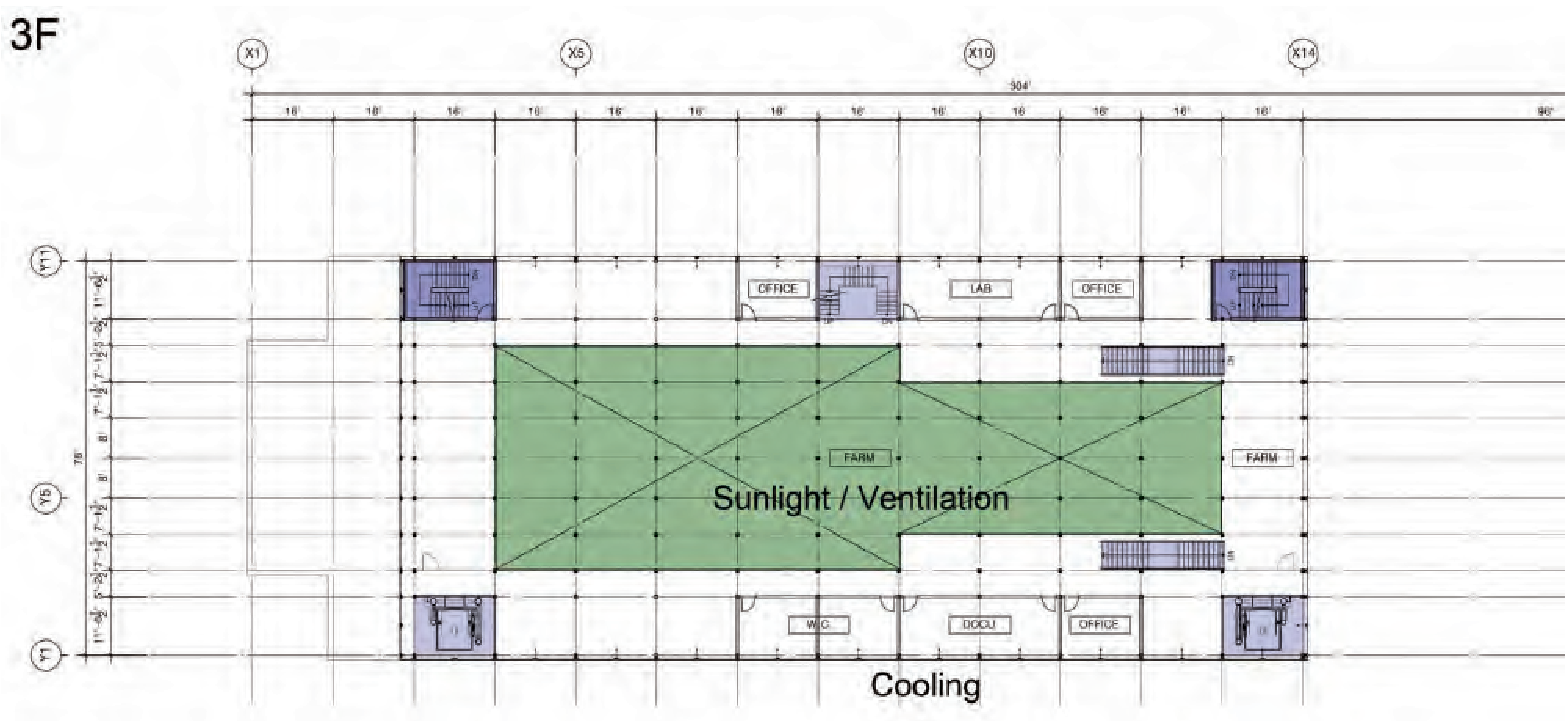
Plan



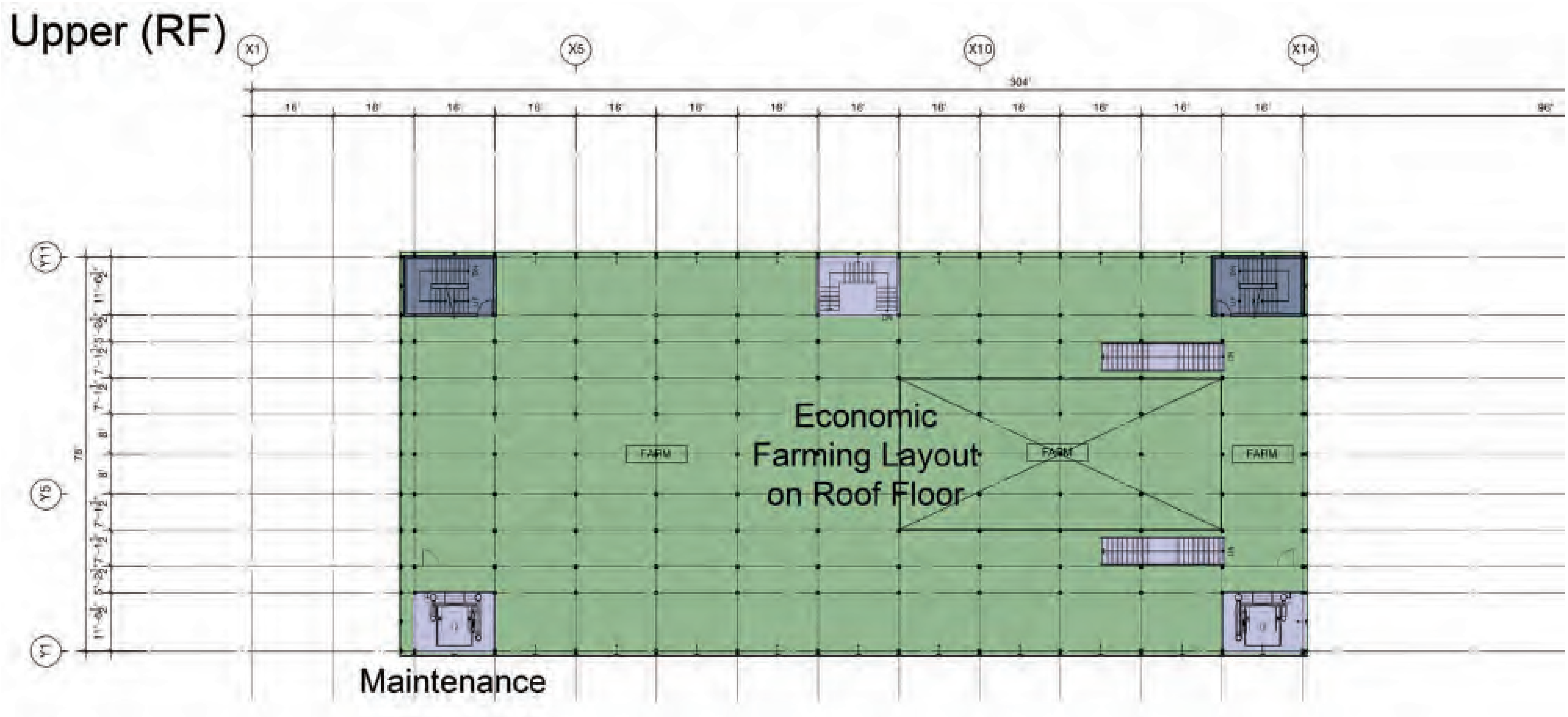
Vertival Farm
White Forest

Plan

3F



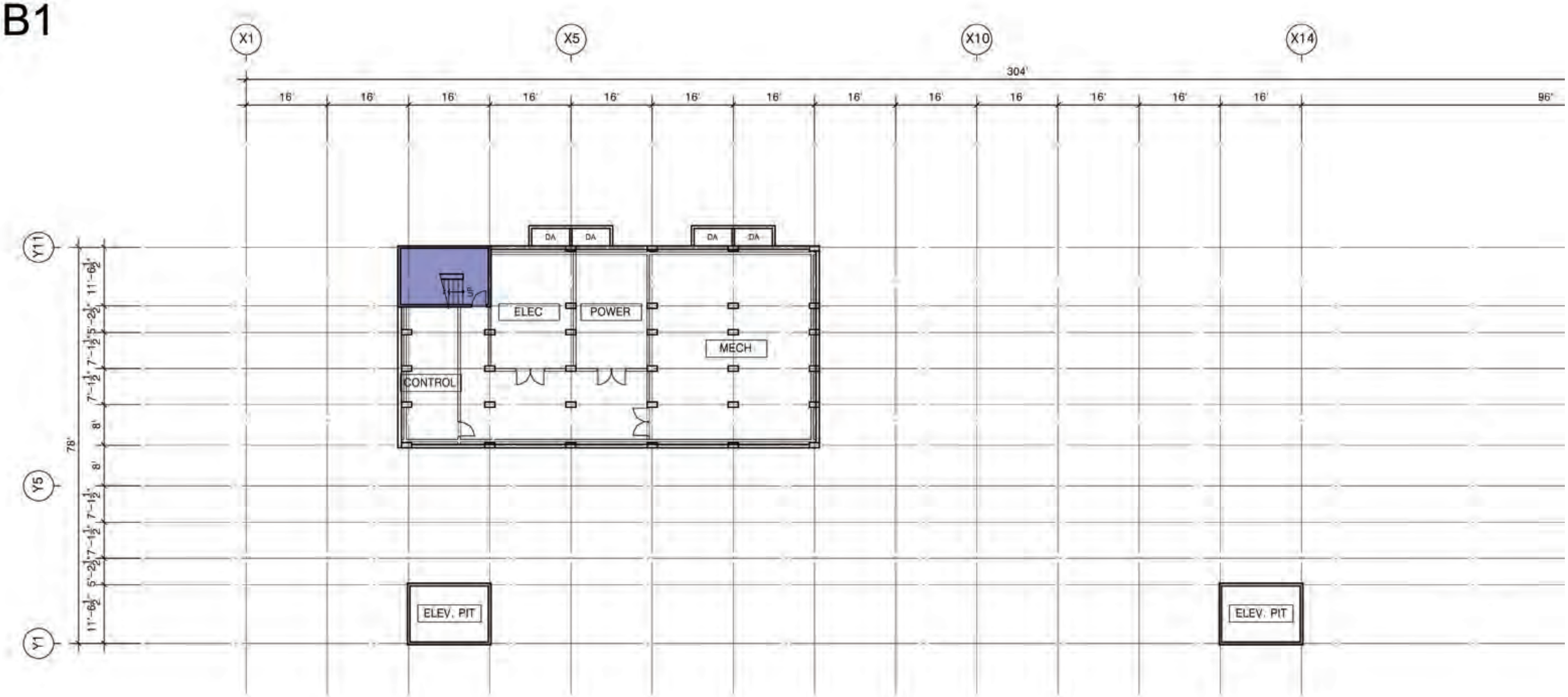
Plan


Upper (RF)
X1
X5
X10
X14
304'
16'
96'
Y11
Y5
Y1
76'
FARM
FARM
FARM
Economic Farming Layout on Roof Floor
Maintenance

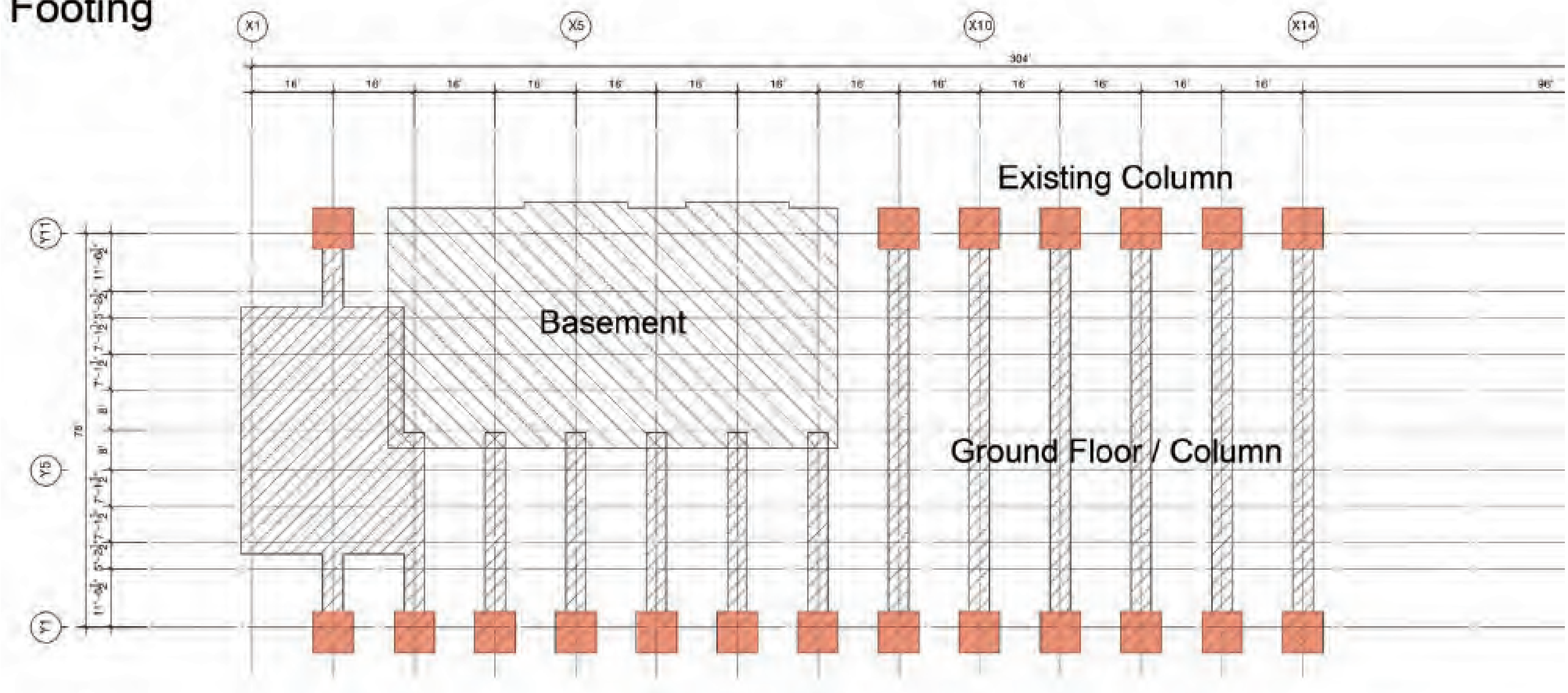
Vertival Farm
White Forest

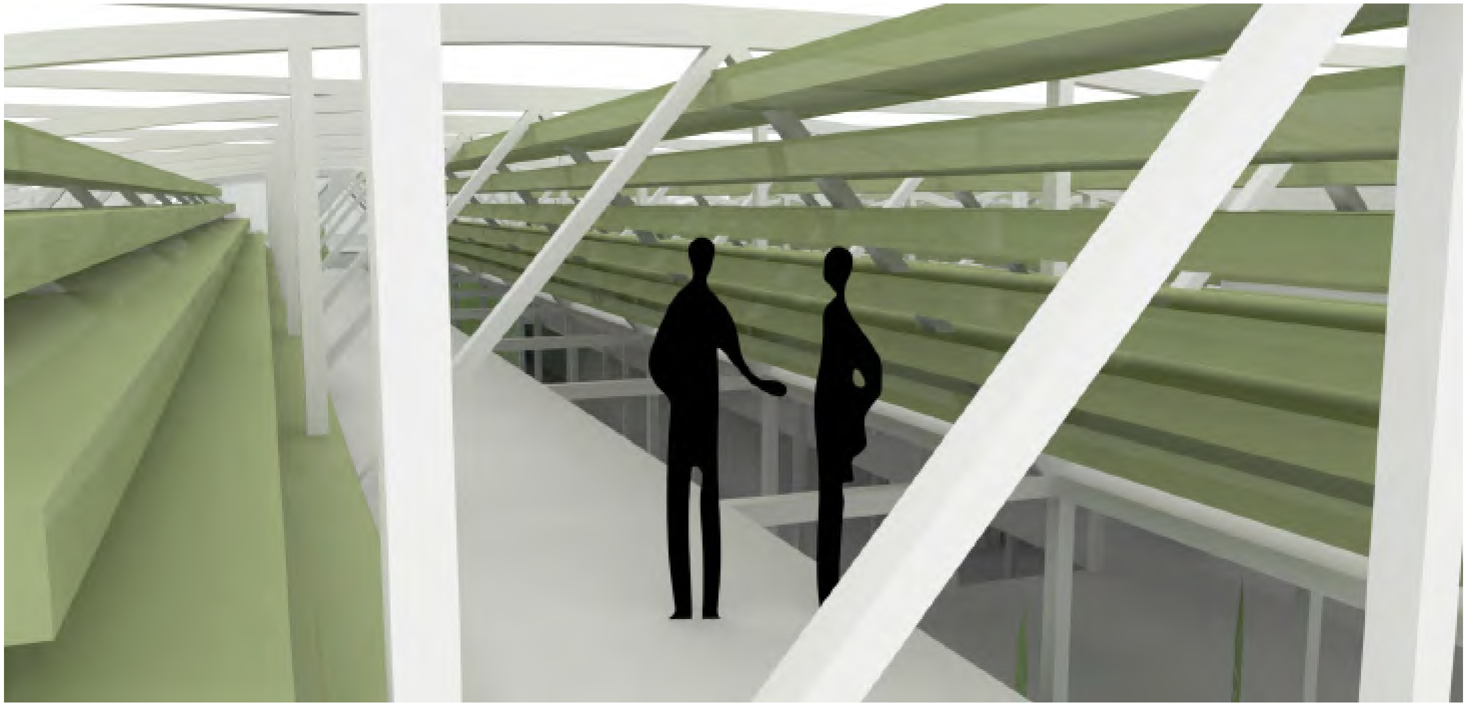
Plan

B1



Footing

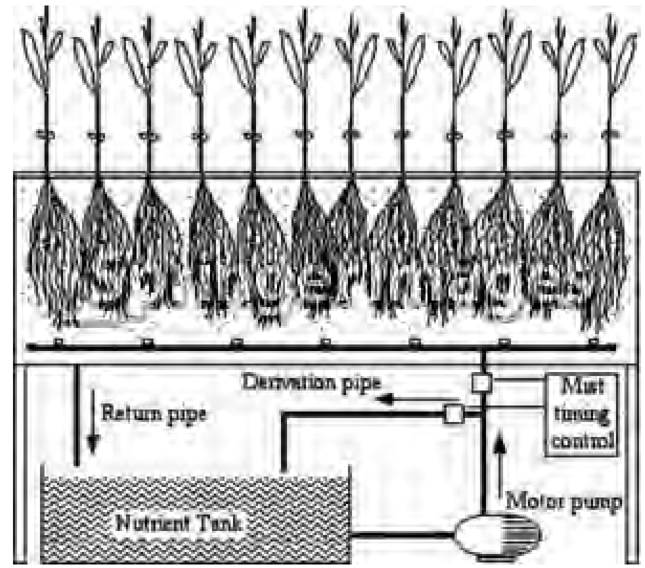

X1
X5
X10
X14
304'
16'
96'
Y11
Y5
Y1
Existing Column
Basement
Ground Floor / Column



Hydroponics

Broccoli, cauliflower, cabbage, cucumbers, tomatoes, peppers, strawberries, and other small fruits

Vertical farming



Aeroponics

White Forest

Facade

Vertival Farm

White Forest

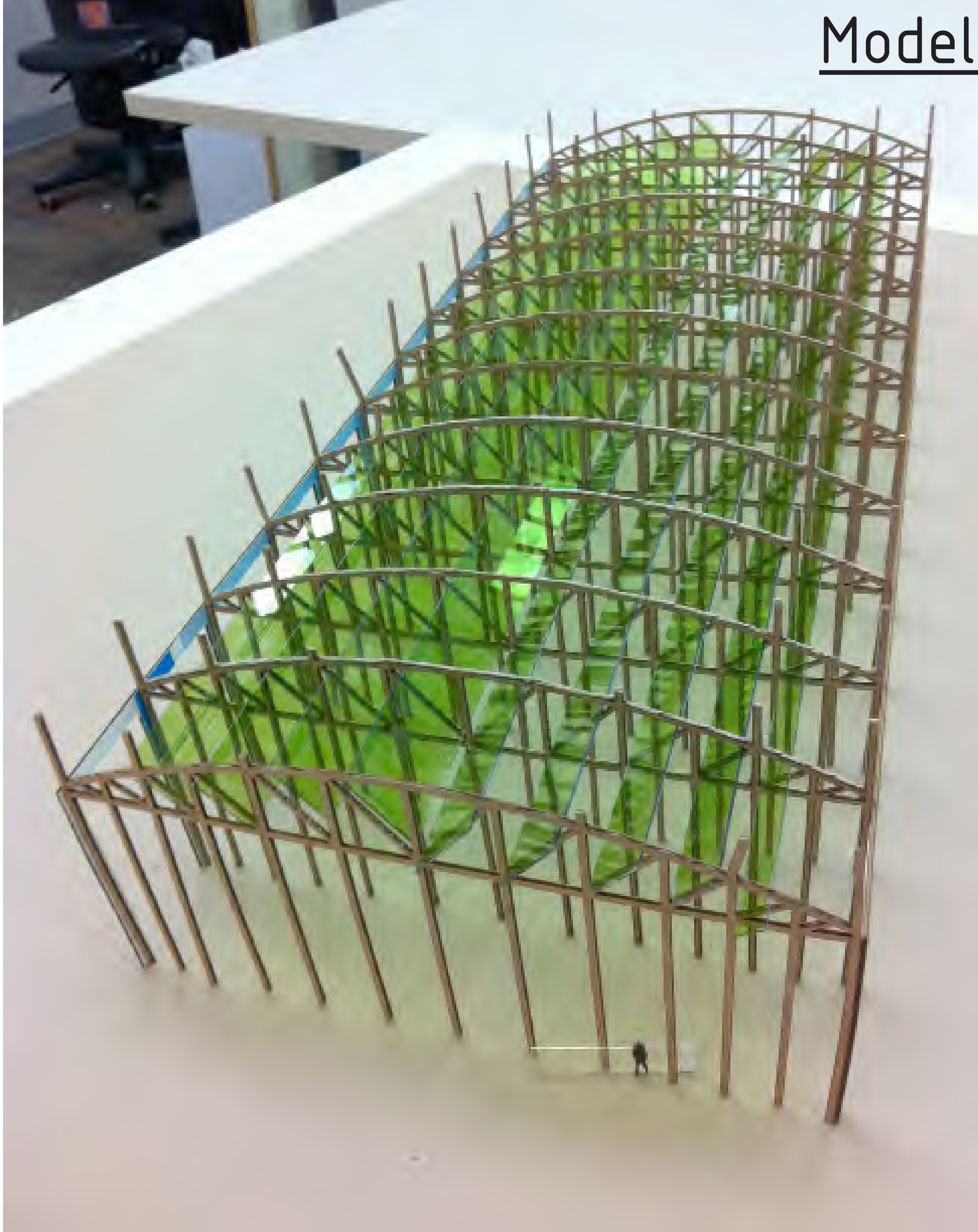
Street view

View from the libary

Vertival Farm

White Forest

Model



ACKNOWLEDGEMENTS

Clemson University's Institute of Applied Ecology wishes to recognize and thank the faculty, students, City of Charleston and charrette participants for their involvement in the Charleston Vertical Farm Design Feasibility Study.

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