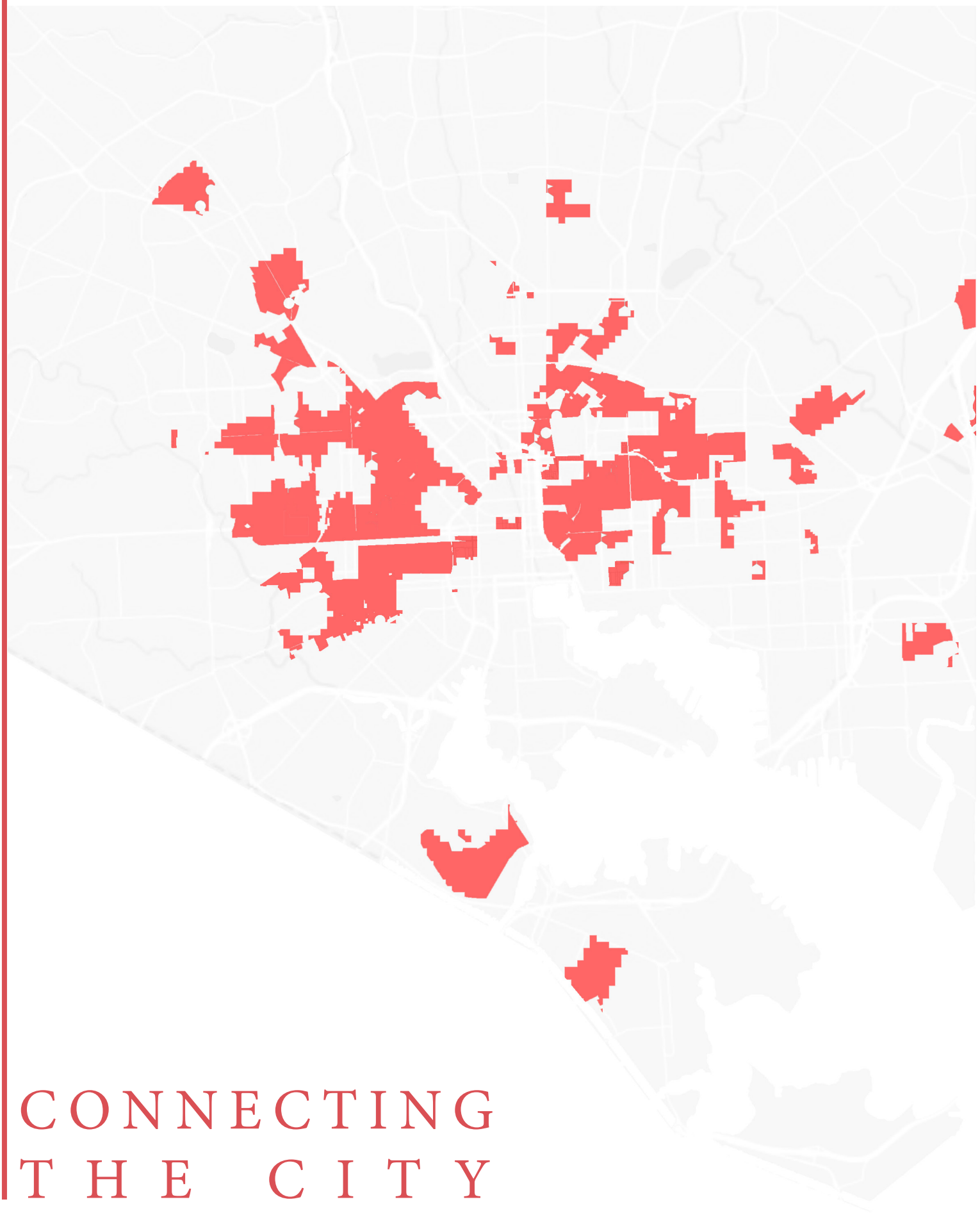


CONNECTING THE CITY

Enyi Onukwubiri

Connecting the City:
A Vertical Farm for Baltimore's Food Desert

Thesis submitted to the faculty of the Virginia Polytechnic Institute and

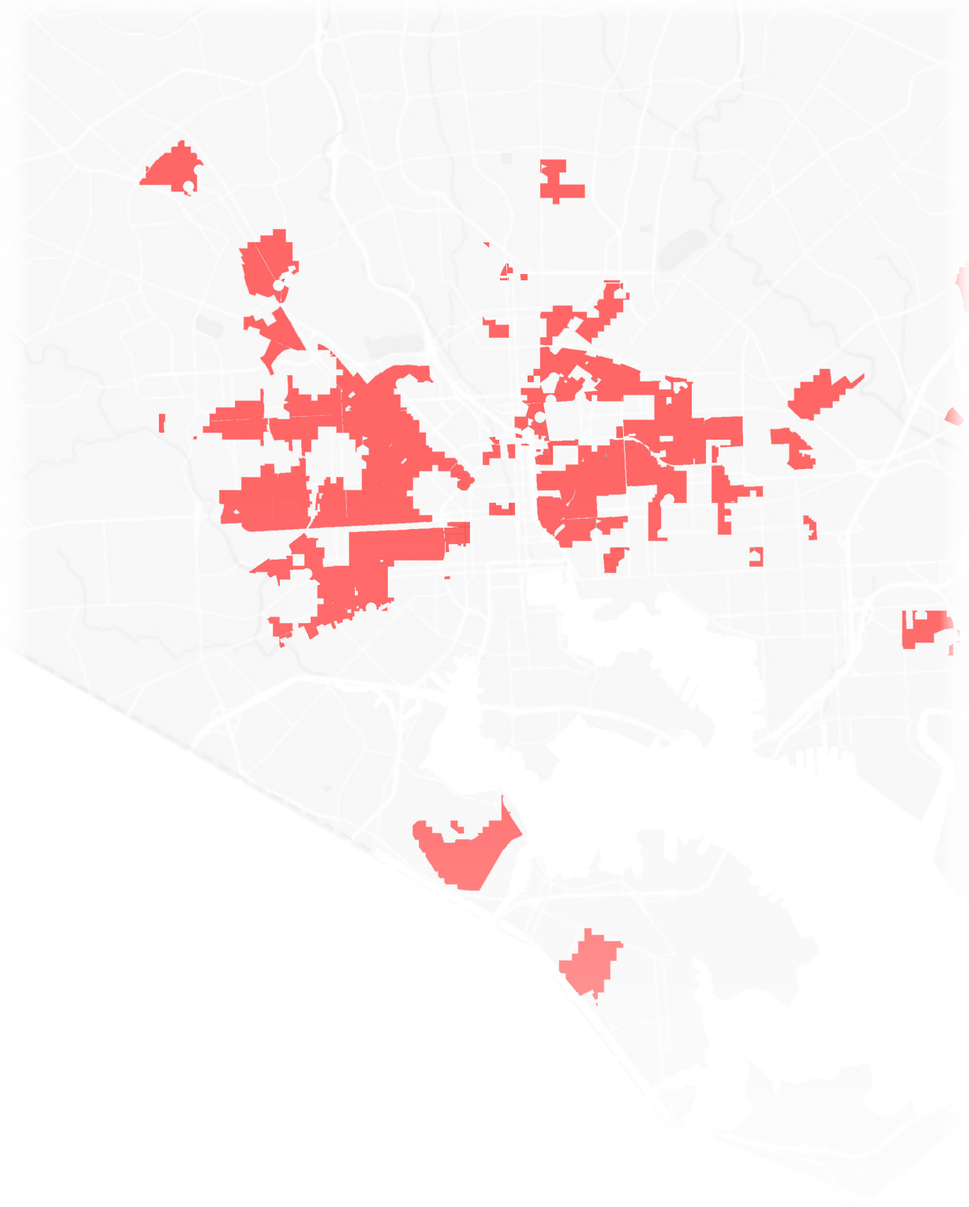
State University in partial fulfillment of the requirements for the degree of

Master of Architecture
in
Architecture and Urban Studies

Dr. Lisa Tucker, Chair
Dr. CL Bohannon
Prof. Kevin Jones

Aug 11th, 2017
Blacksburg, VA

Keywords:
vertical farm, central farm, farmland, connectivity, live, work, grow,
community, food desert, impoverish neighborhoods, Baltimore City



ABSTRACT

Nike designer Eric Agar said, “Good design is a balance between art and science -- bold expression and enough familiarity or function.” That statement is true in its own right, however I believe we should explore the boundaries of familiarities. Farming is second nature to mankind, which is why it is understandable that farming has not changed significantly in thousands of years. That lack of evolution is becoming detrimental to our rapidly growing urban population. That notion fueled the concept of this thesis.

The concept of this thesis is to use Maslow’s Hierarchy of Needs pyramid as a guide to solve human psychological needs through architecture. Maslow’s Hierarchy inspired my approach to the thesis - address the problem from the foundation. The thesis analyzes Baltimore City’s food network, and seeks a site which has the potential for several factors: site accessibility, renewable resources, solar exposure, and connecting the community. These factors serve as the basis in which to build a hybrid prototype that is able to expose people to the process of food production through a combination of traditional outdoor farming methods and indoor hydroponics in the form of a vertical farm.

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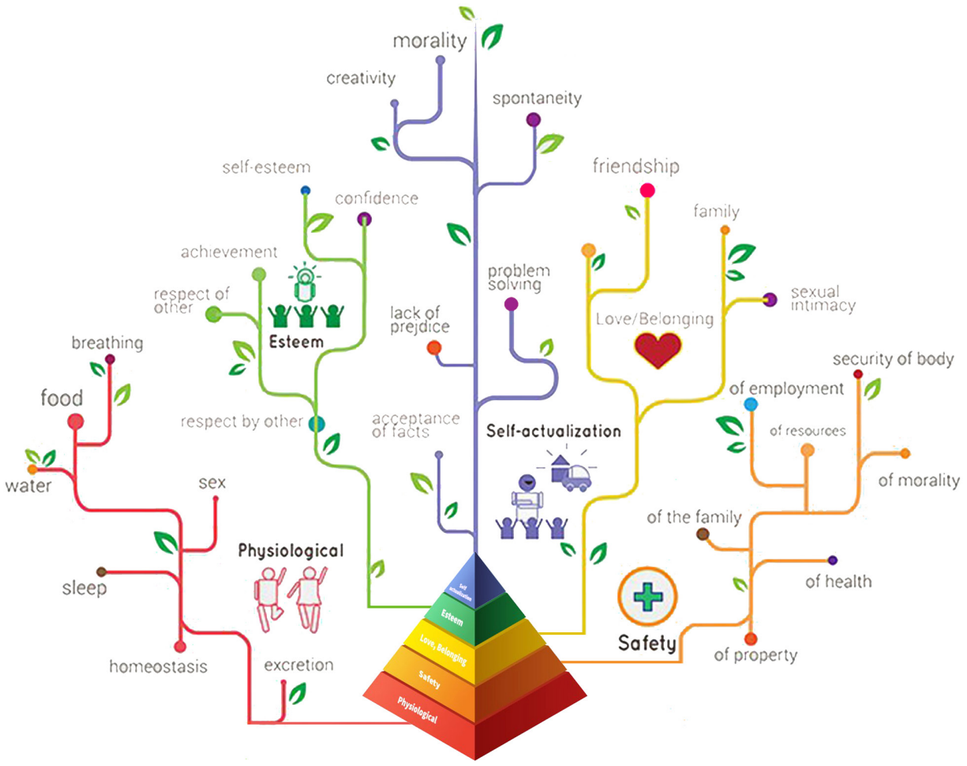
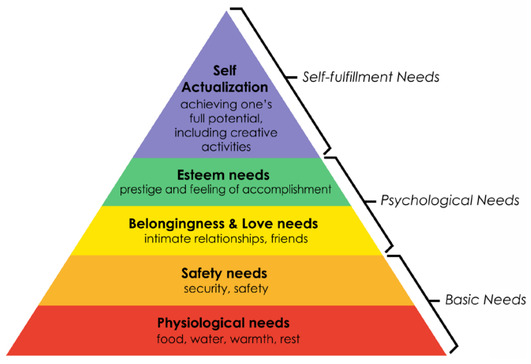
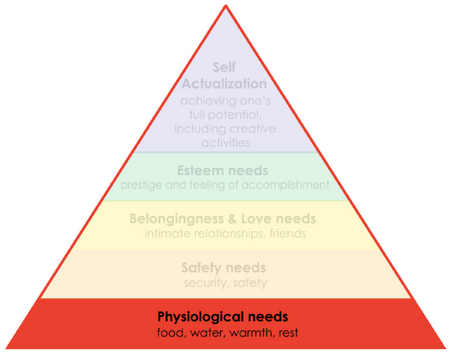
THE PARTI



MASLOW'S HIERARCHY OF NEEDS

Maslow's Hierarchy of Needs is a motivational theory in psychology comprising a five tier model of human needs, often depicted as hierarchical levels within a pyramid. Maslow stated that people are motivated to achieve certain needs and that some needs take precedence over others. Our most basic need is for physical survival, and this will be the first thing that motivates our behavior. Once that level is fulfilled the next level up is what motivates us. (McLeod, 2007) Within the Basic Needs is the Physiological Need, also known as th foundation of the pyramid. By addressing that need, I may unlock the solution to urban crisis relating to food, quality of life, educational opportunities, jobs, and greener economy.

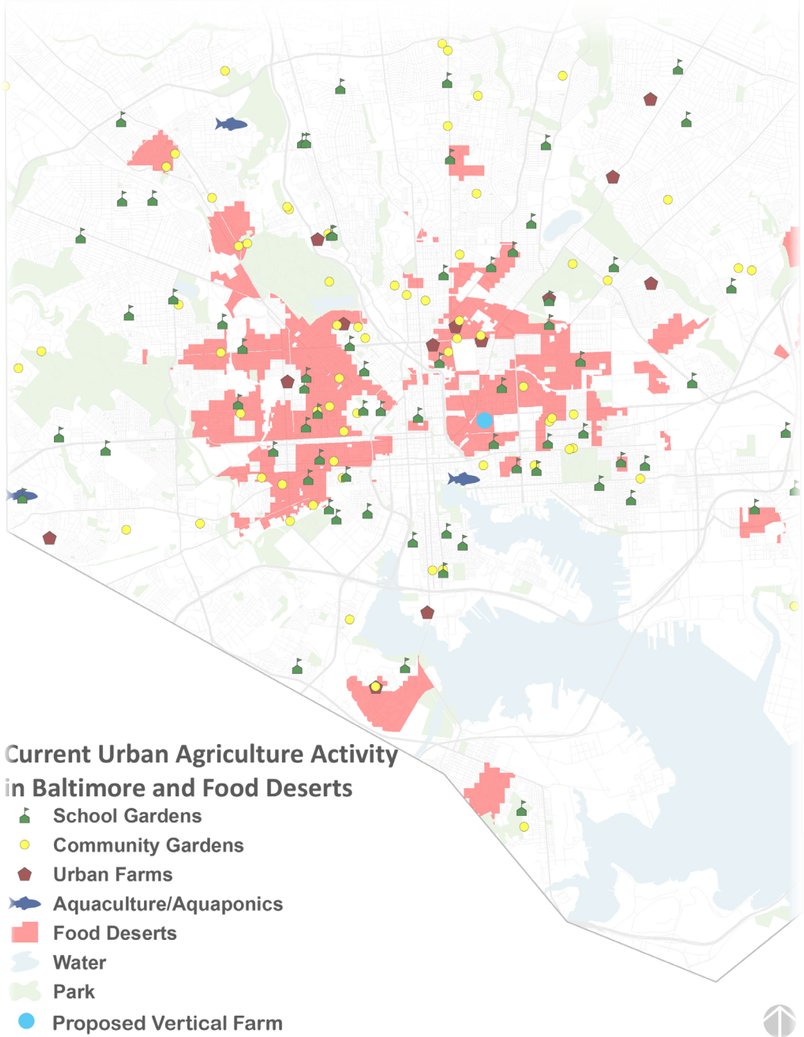


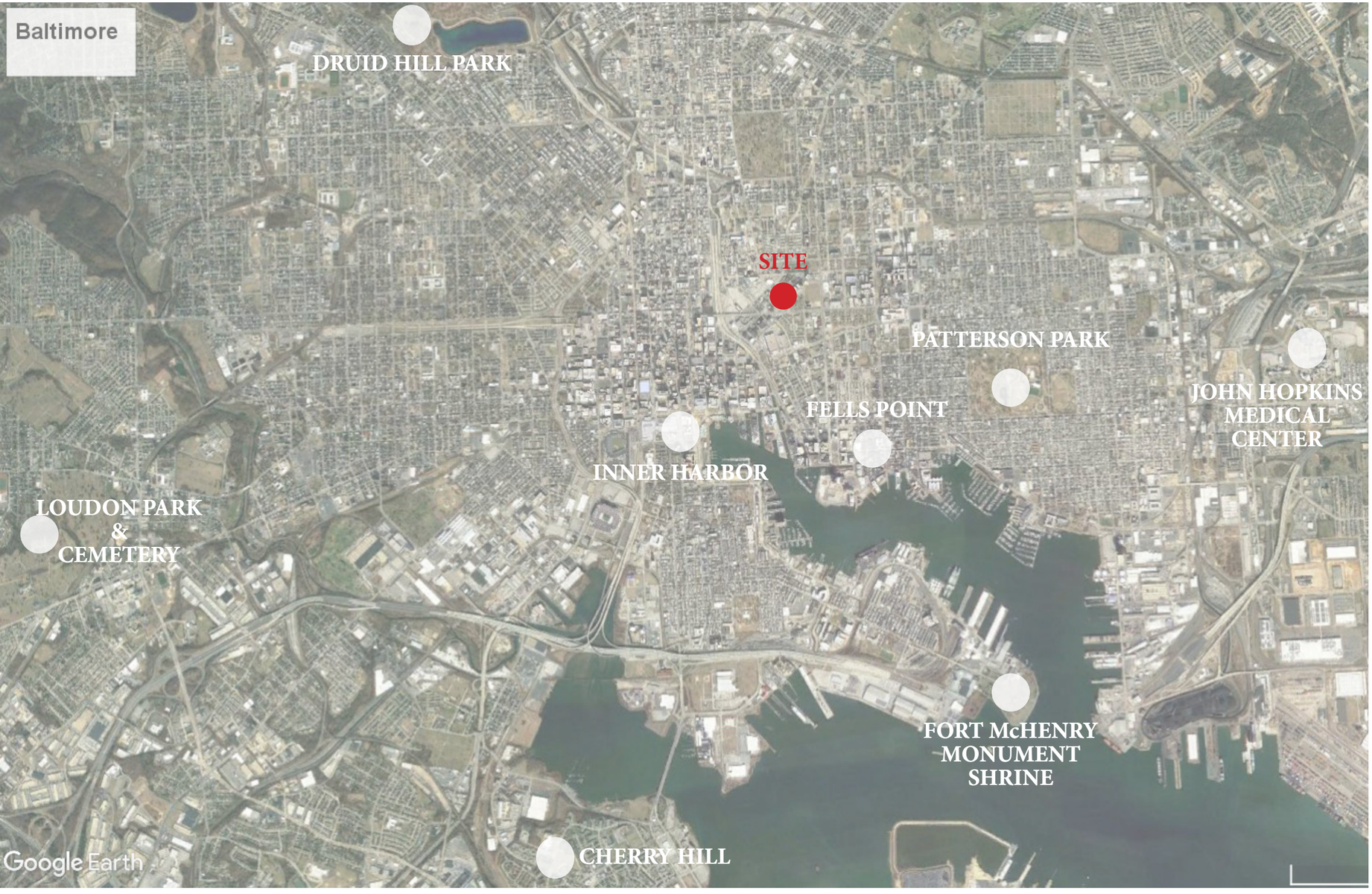


THE PROBLEM

Food Desert

By the year 2050, nearly 80% of the earth's population will reside in urban centers. Applying the most conservative estimates to current demographic trends, the human population will increase by about 3 billion people during the interim. An estimated 109 hectares of new land (about 20% more land than is represented by the country of Brazil) will be needed to grow enough food, if traditional farming practices continue as they are practiced today. At present, throughout the world, over 80% of the land that is suitable for raising crops is in use (sources: FAO and NASA). Historically, some 15% of that has been laid waste by poor management practices. What can be done to avoid this impending disaster?
(Despommier, 2010).

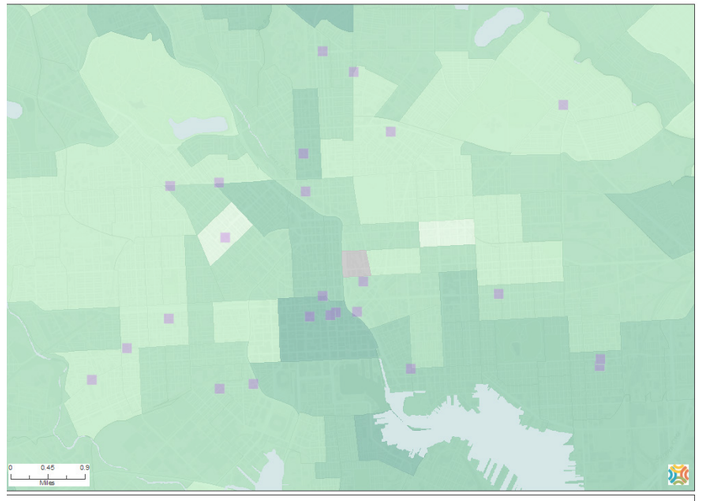




Baltimore City | THE SITE

Baltimore is the largest city in the U.S. state of Maryland, and the 29th-most populous city in the country. Baltimore was established by the Constitution of Maryland and is not part of any county. With a population of 621,849 in 2015, Baltimore is the largest independent city in the United States. As of 2016, the population of the Baltimore metropolitan area was estimated to be just under 2.8 million, making it the 21st largest metropolitan area in the country. Below is an aerial view of Baltimore's Inner Harbor; an important seaport.

Fruit



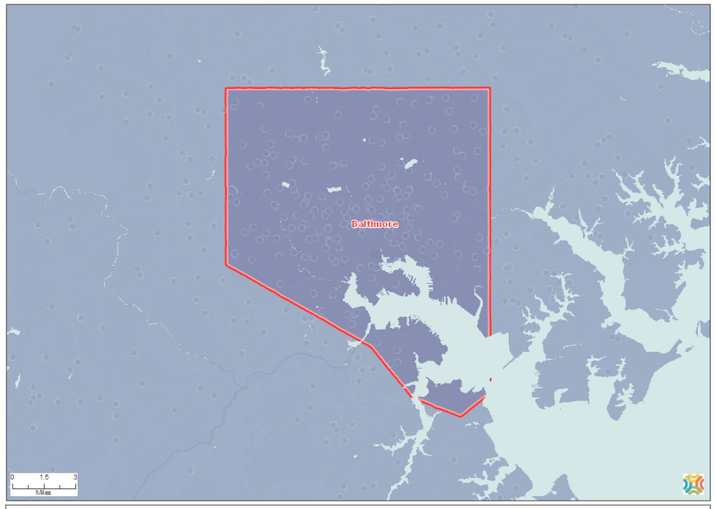
Map Legend

Federally Qualified Health Centers, POS 2016

Fruit and Vegetable Expenditures, Percent of Food-At-Home Expenditures, National Rank by Tract, Nielsen 2014
- 1st Quintile (Highest Expenditures)
- 2nd Quintile
- 3rd Quintile
- 4th Quintile
- 5th Quintile (Lowest Expenditures)
- No Data or Data Suppressed

Community Commons, 2/14/2017

Fast Food



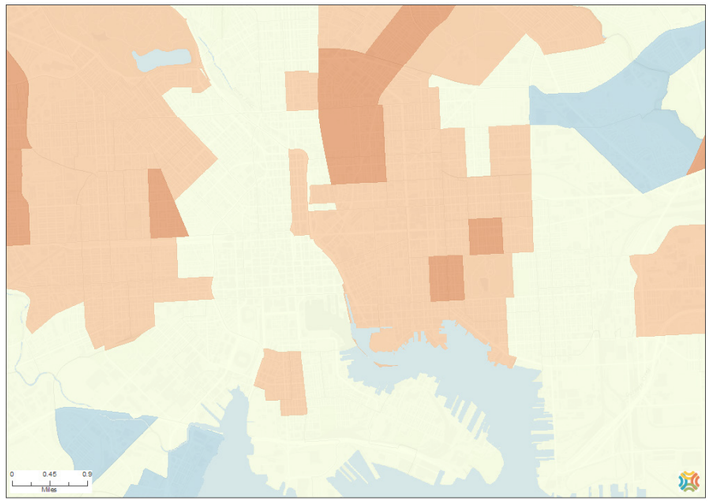
Map Legend

Public Schools, NCES CCD 2013-14

Fast Food Restaurants, Rate (Per 100,000 Pop.) by County, CBP 2014
- Over 100.0
- 75.1 - 100.0
- 50.1 - 75.0
- Under 50.1
- No Fast Food Restaurants

Community Commons, 2/14/2017

Modified Retail Food Envr

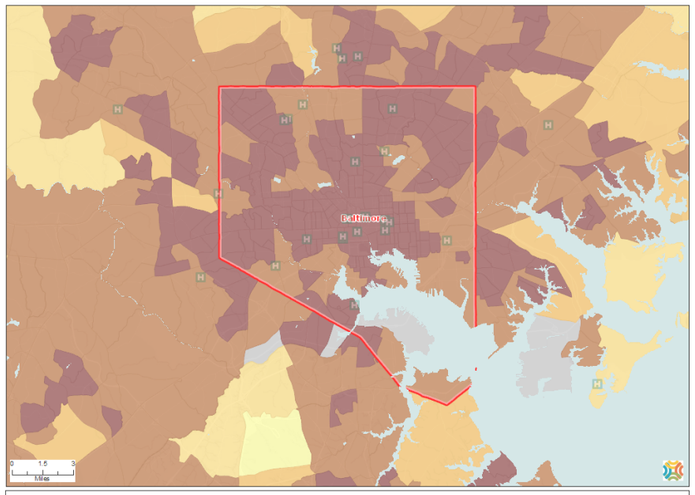


Map Legend

Modified Retail Food Environmental Index Score by Tract, DNPAO 2011
- Index Score Over 30 (High Access)
- Index Score 15 - 30 (Moderate Access)
- Index Score 5 - 15 (Low Access)
- Index Score Under 5 (Poor Access)
- No Healthy Retail Food Outlet (No Access)
- No Retail Food Outlets Present (Food Desert)

Community Commons, 2/14/2017

Population



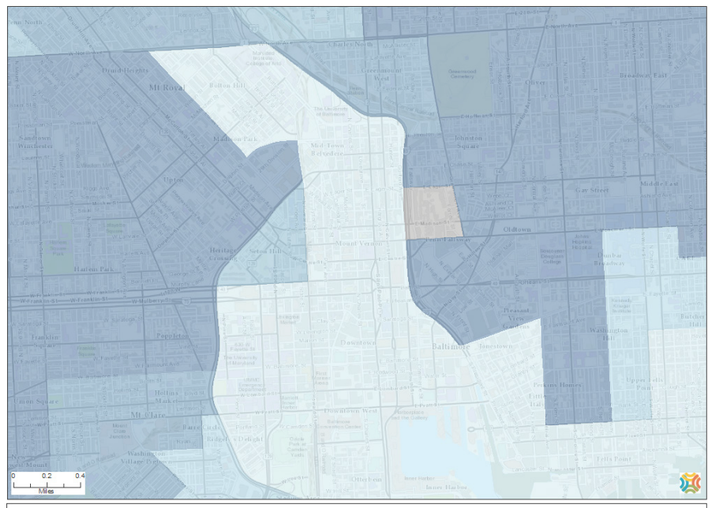
Map Legend

Hospitals, POS 2016

Population, Density (Persons per Sq Mile) by Tract, ACS 2011-15
- Over 5,000
- 1,001 - 5,000
- 501 - 1,000
- 51 - 500
- Under 51
- No Data or Data Suppressed

Community Commons, 2/14/2017

Food at Home Expenditures

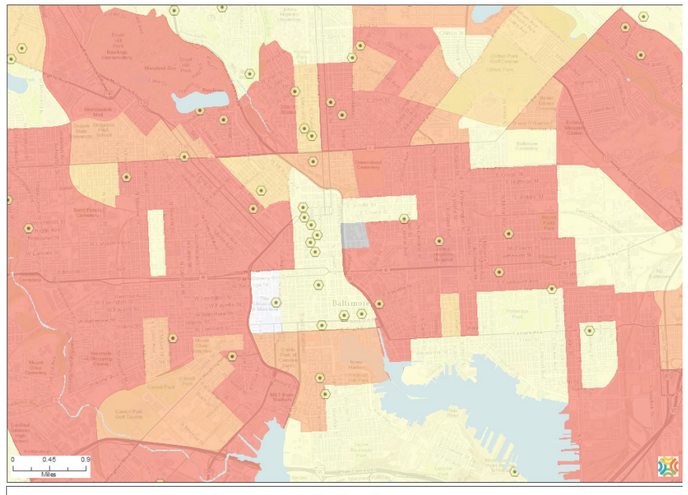


Map Legend

Food-At-Home Expenditures, Percent of Total Expenditures, National Rank by Tract, Nielsen 2014
- 1st Quintile (Highest Expenditures)
- 2nd Quintile
- 3rd Quintile
- 4th Quintile
- 5th Quintile (Lowest Expenditures)
- No Data or Data Suppressed

Community Commons, 2/14/2017

Households with Children Living in Poverty



Map Legend

Nonprofit Organizations, Youth Development, IRS 2015

Family Households with Children Living Below the Poverty Level, Percent by Tract, ACS 2009-13
- Over 25.0%
- 19.1 - 25.0%
- 13.1 - 19.0%
- Under 13.1%
- No Families with Children Reported
- No Data or Data Suppressed

Community Commons, 2/14/2017

THE SOLUTION

COMMUNITY

Focus on local agricultural solutions to de-centralize supply and increase the availability of quality food.

1 GROW FOOD LOCALLY

Build and backyard and community gardens as well as larger scale urban agriculture such as vertical farm(s).

2 DEVELOP ALTERNATIVE RETAIL OUTLETS

Farmers Markets, Public Markets, and Community Supported Agriculture (C.S.A.) Programs.

ACCESS

Increase the ease of obtaining quality food.

3 REPLACE "CONVENIENT" WITH QUALITY

Increase stocks of fruits and vegetables at corner stores or small grocery stores.

4 TRANSPORTATION

Improve transportation to grocery stores, farmer's markets, public markets, and vertical farm(s).

EMPOWERMENT

Equip individuals and families with the tools to make healthier food choices.

5 NUTRITIONAL EDUCATION

To teach nutritional information involving healthier produce and lifestyle.

THE ADVANTAGES

IMAGINE : A building that uses solar and wind energy... hydroponic methods of growing crops... Food grown, harvested, and consumed in one location.

20% of fossil fuels are consumed by tractors

The average meal travels 1000 miles

Additional farmland; 20% larger than Brasil needed

Three billion parasite infections worldwide

The urban population is growing by 80%

Food prices have increase by 22% from 2007 - 2017

Adds Energy back to the grid

Reduces dependence on fossil fuel

More control of safety and security

Eliminates agricultural runoff

Return farmland to nature

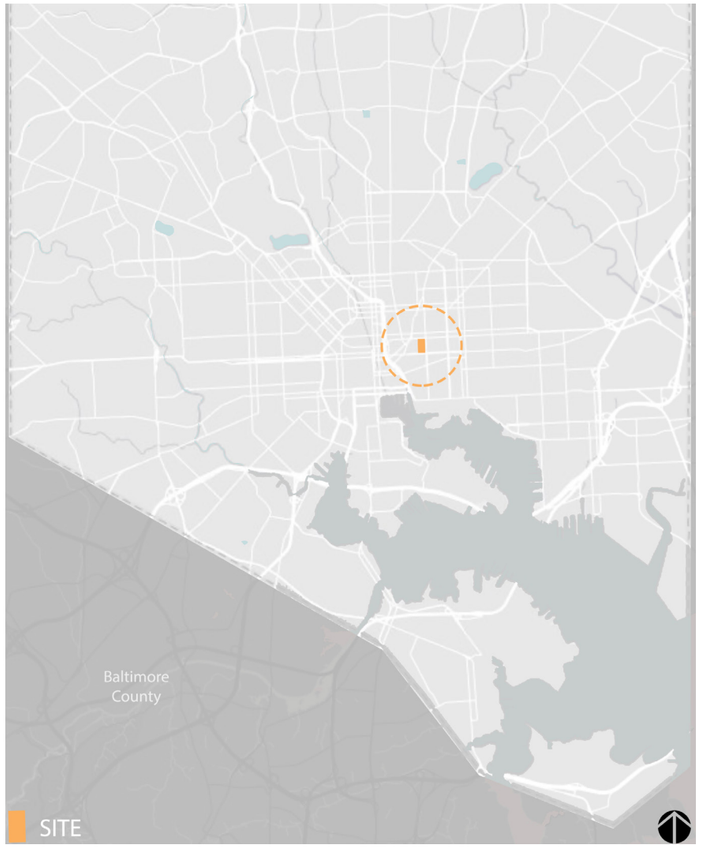
Uses 70% - 90% less water

Year round food production

No weather or pest related crop failure

All vertically grown food is 100% ORGANIC

THE SITE | Site Analysis



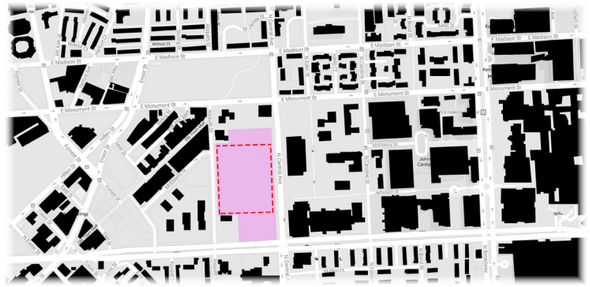
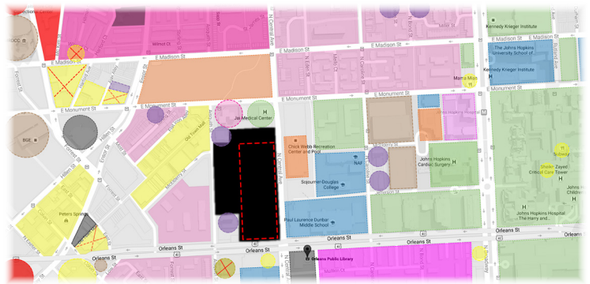


FIGURE GROUND

The figure ground shows the developments and density surrounding the site.

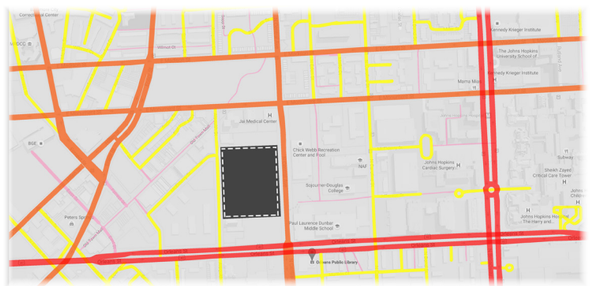
GREEN SPACE

The map shows the green spaces surrounding the site. To the north is Dunbar football field.



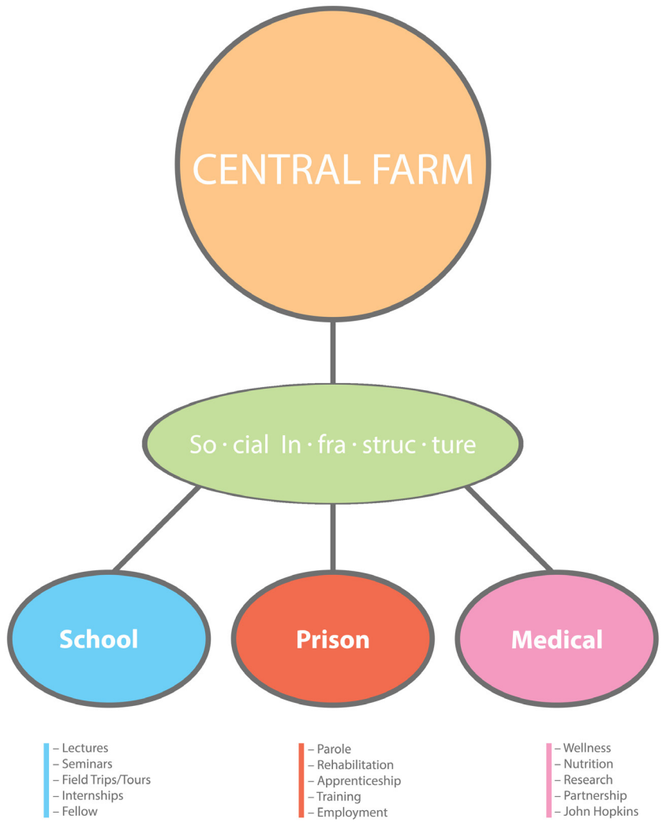
LAND USE

The social fabric is predominately residential, institutional, medical, and a few commercial.

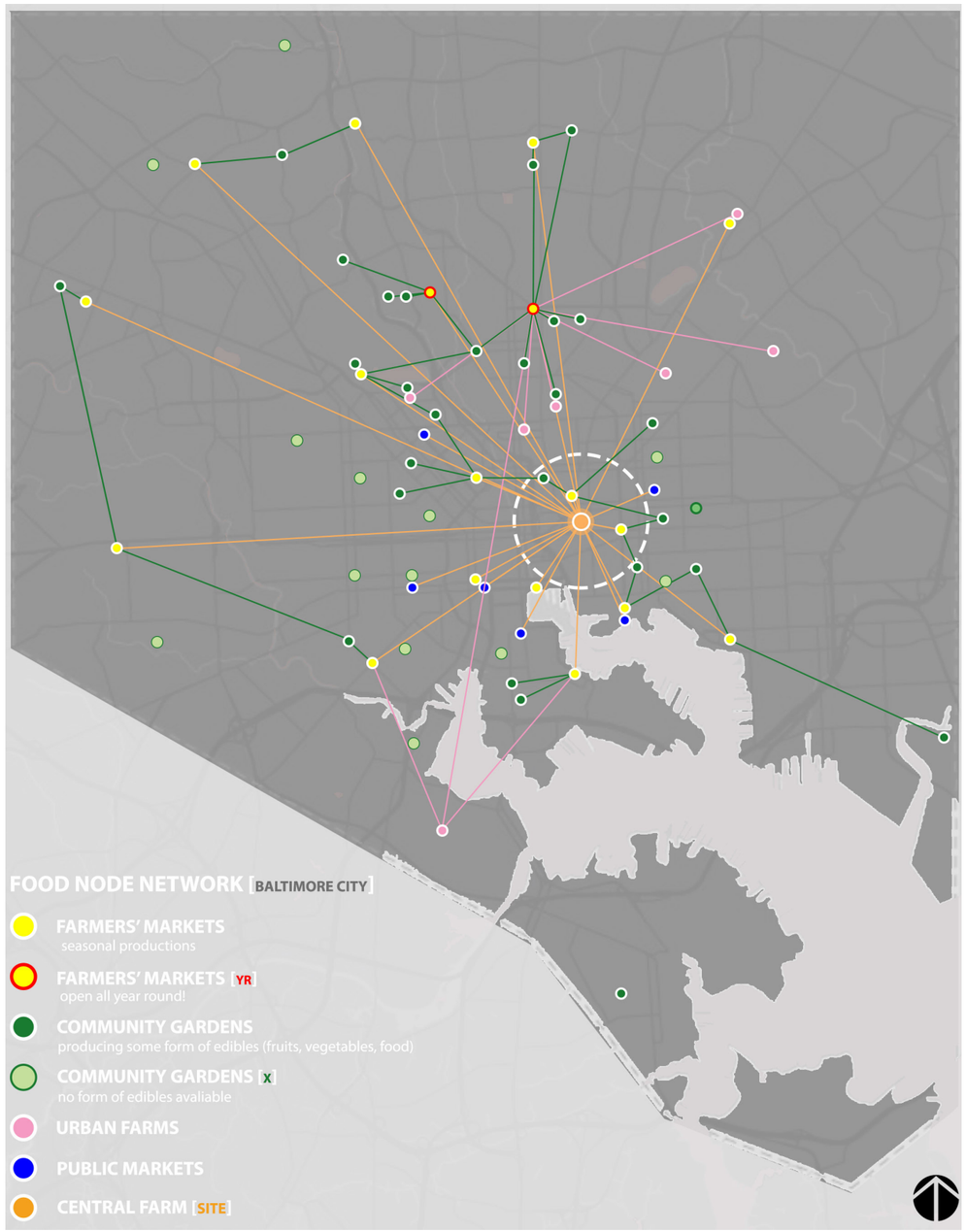


TRAFFIC FLOW

The site is located adjacent to Orleans Street (high) and Central Ave (moderate).

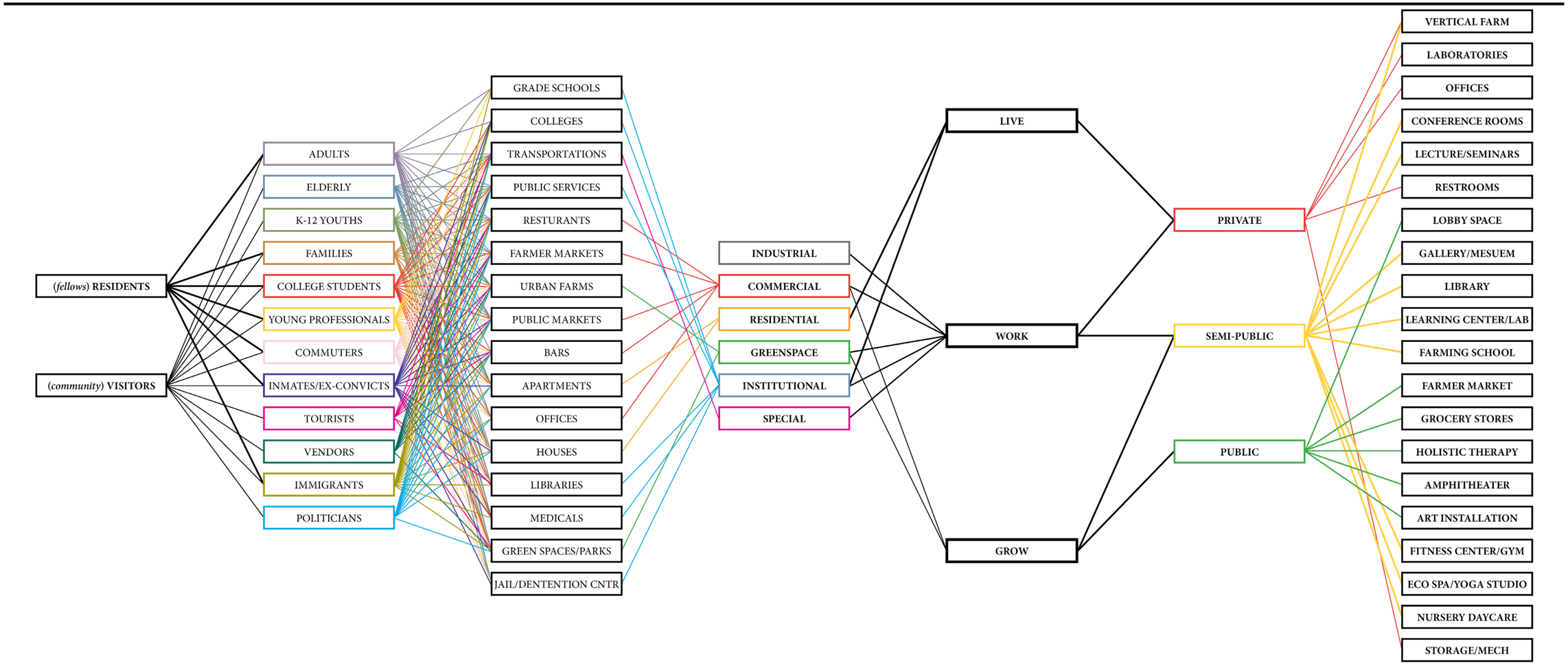


After analyzing the social infrastructures surrounding the site, it was important that I target those institutions as my primary partners. The medical and educational institutions of John Hopkins Hospital, John Hopkins University, and the John Hopkins Children's Center located to the east of the site. Potentially, John Hopkins could serve as an internship and/or fellowship program alongside the Central Farm to help with the research process. In addition, the Central Farm would serve as an educational infrastructure for K-12 students while also assisting parolees with the transition back into society. Growth through connection will enable a network of food node between.

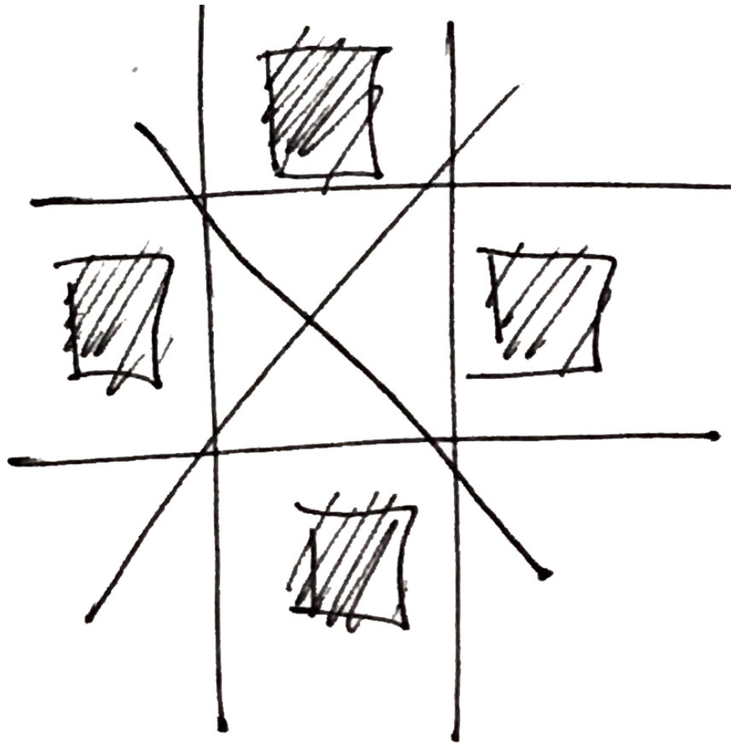


THE APPROACH | Find the Connectivity

The vertical farm will connect the city of Baltimore and the surrounding areas. But first, I wanted to understand the demographic of the occupants and the social fabric in which the vertical farm will serve. That approach led me to the programs suitable for the vertical farm.

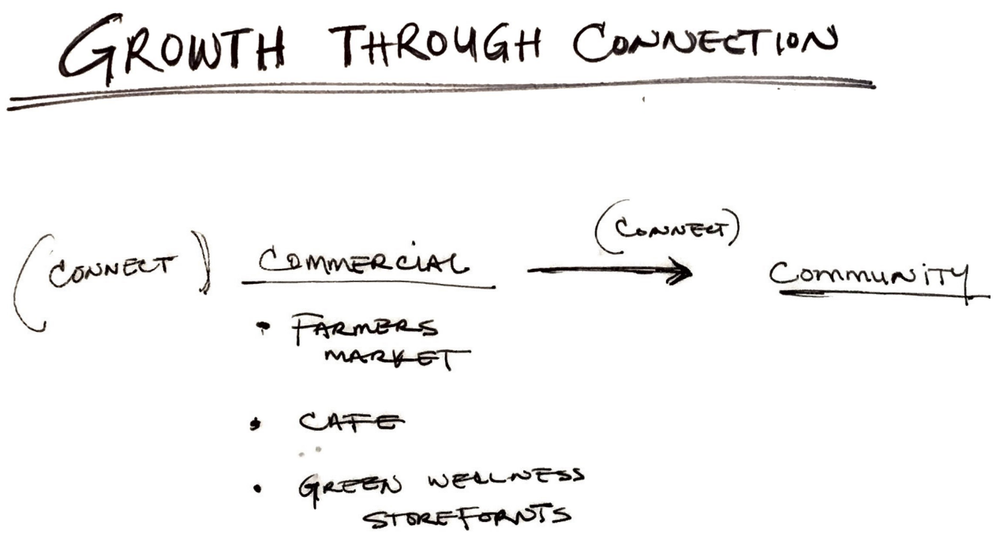


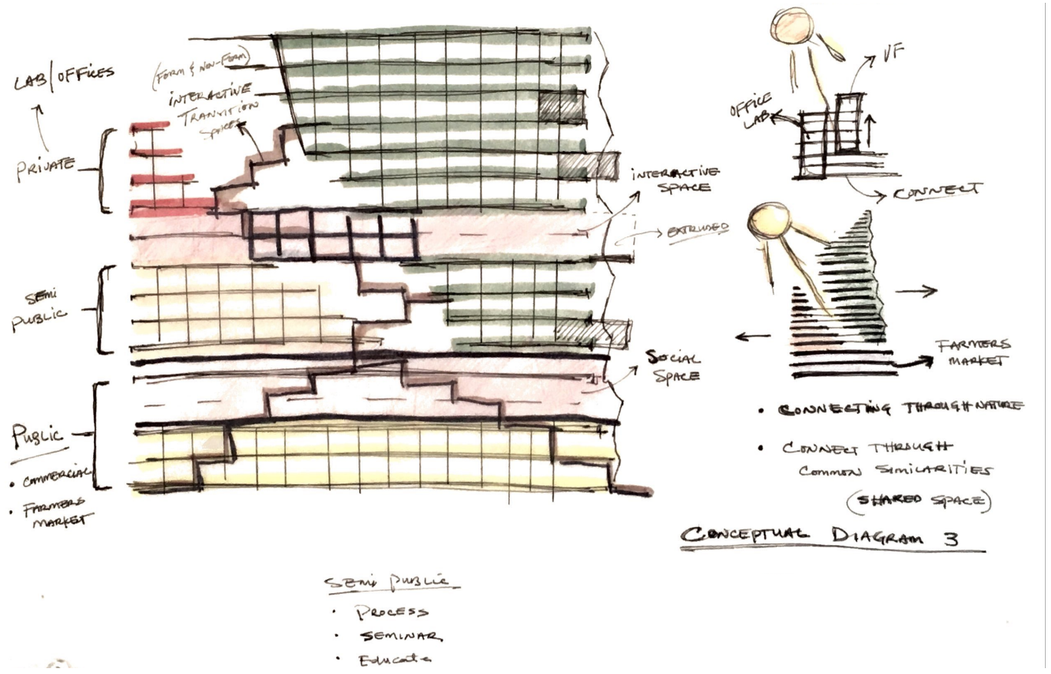
THE PROGRAM | Central Farm



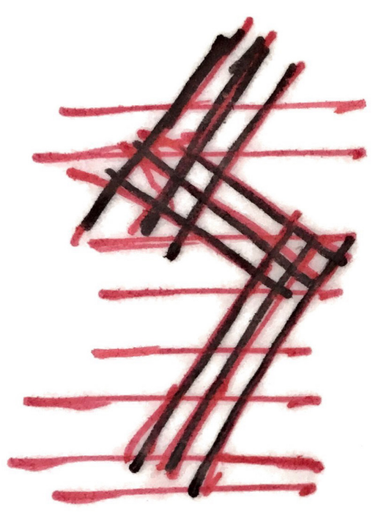
The conceptual figure diagram is my first illustration of connectivity. The hatched boxes serve multiple purpose; the concept is from a macro to a micro approach. First, I understood the social infrastructures were important, therefore connecting those institutions to the functions and program of the Central Farm is ideal. Secondly, I wanted to propose a great, but yet unfamiliar idea to the community of Baltimore City. The Central Farm will serve as a haven for the community by social and educational interactions. Finally, the programs and facilities within the Central Farm are designed as a network: live, work, grow, and community.

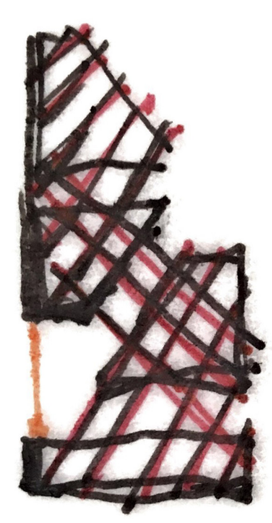
Vertical Farm	Quantity	Sq Ft	Total Sq Ft
Vegetables/Fruits	15 Flrs	10,000	100,000
Processing	1	2,000	2,000
Poultry	2 Flrs	5,000	10,000
Processing	1	1,000	1,000
Administration			
Laboratories	5	300	1,500
Offices/Meetings	10	120	1,200
Conference Rooms	2	300	675
Lecture Halls/Seminars	1	1,000	1,000
Restroom (M/W)	5	600	3,000
Multi-Purpose Space			
Lobby Space	1	3,000	3,000
Exhibition Gallery/Mesuem	1	10,000	10,000
Library	1	6,000	6,000
Organic Culinary Learning Center	1	10,000	10,000
Agric & Farming School	1	7,000	7,000
Env. Learning Lab	1	3,000	3,000
Community			
Farmer's Market	1	50,000	50,000
Organic Grocery Stores	10	500	5,000
Holistic Medical Therapy	1 (3 Op)	1,300	1,300
Amphitheater	1	2,500	2,500
Green Space - Art Installations	1	1,000	1,000
Service			
Service Core	28 Flrs	2,000	56,000
Storage	3	1,000	3,000
MECH	1	10,000	10,000
HYDRO Control System	1	2,000	2,000
BOH/Delivery Dock	1	4,000	4,000
Parking Space	1	30,000	30,000
TOTAL			324,175
Residential (Fellows)			
Studio	45	500	22,500
1 Bedroom	35	750	26,250
2 Bedroom	20	1,200	24,000
Fitness Center/Gym/Pool	1	10,000	10,000
Eco Spa/Yoga Studio	1	4,000	4,000
Nursery Daycare	1	1,200	1,200
Multi-Purpose Space	1	14,000	14,000
Service Core	10 Flrs	1,500	15,000
TOTAL			116,950
NET TOTAL			**400,000**





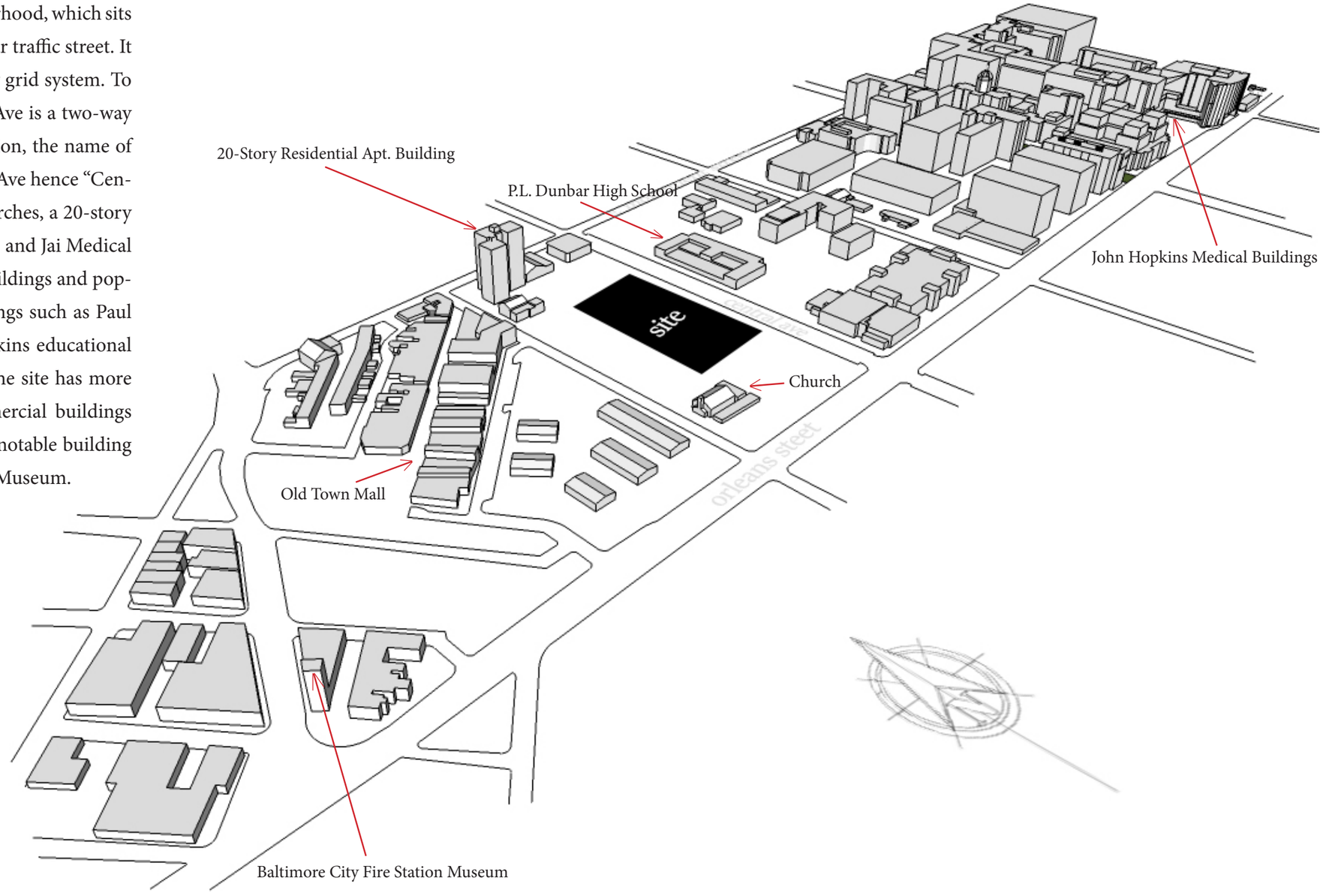
The diagrams below illustrate the motto of the Central Farm, "growth through connection" is an idea predicated on live, work, grow, and community. A concept that depends on each entity to be effective. The live section supports residents, which are predominantly researchers, fellows, and their immediate family members. The work, mostly regarded as the infrastructure, keeps the building functioning and is designed for the processing, laboratory, and administrative sectors. The grow, also referred to as the jewel, is solely intended for the greenhouse and poultry facilities. Finally, the community is the foundation of the vertical farm. The Farmers' Market and all the amenities within the site cater to the needs of the community.





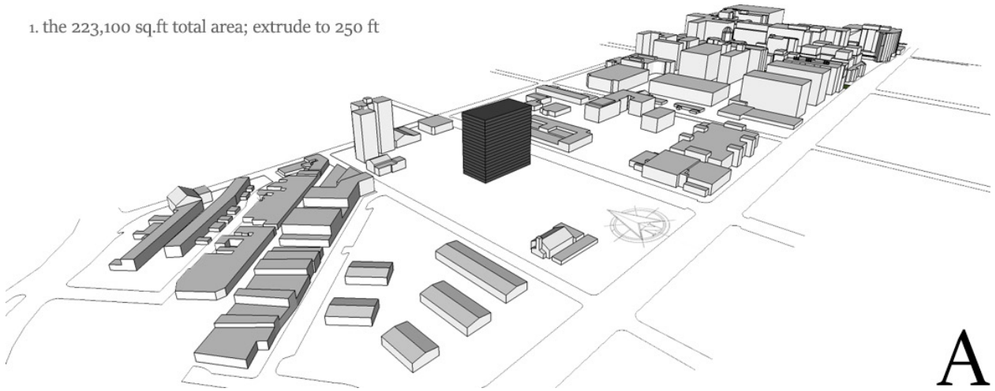
IDEA DEVELOPMENT | Site Mass

The site is located within the Old Town neighborhood, which sits north of Orleans Street, a high volume vehicular traffic street. It is also a major street within the Baltimore City grid system. To the east of the site is Central Avenue. Central Ave is a two-way moderate vehicular traffic flow street. In addition, the name of the vertical farm stems from the street Central Ave hence "Central Farm". The 10 Acre site consists of two churches, a 20-story residential apartment building, a civic building, and Jai Medical Center. East of the site is heavily dense with buildings and populated with predominantly institutional buildings such as Paul Laurence Dunbar High School and John Hopkins educational and medical buildings. Whereas, the west of the site has more open space with a few residential and commercial buildings (Old Town Mall) at roughly 3-5 stories tall. A notable building southwest of the site is the Baltimore City Fire Museum.



IDEA DEVELOPMENT | Conceptual Design I

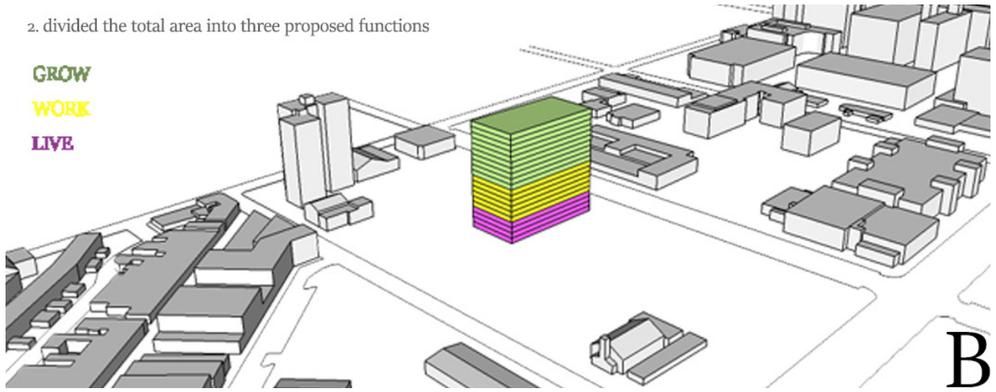
1. the 223,100 sq.ft total area; extrude to 250 ft



A

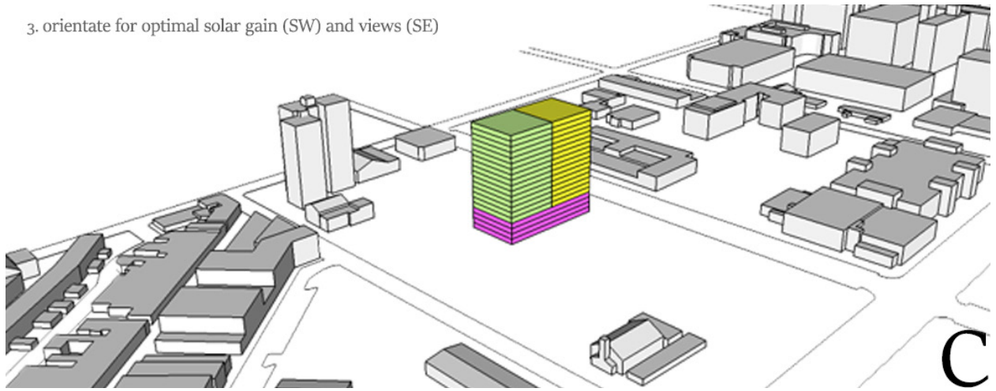
2. divided the total area into three proposed functions

GROW
WORK
LIVE



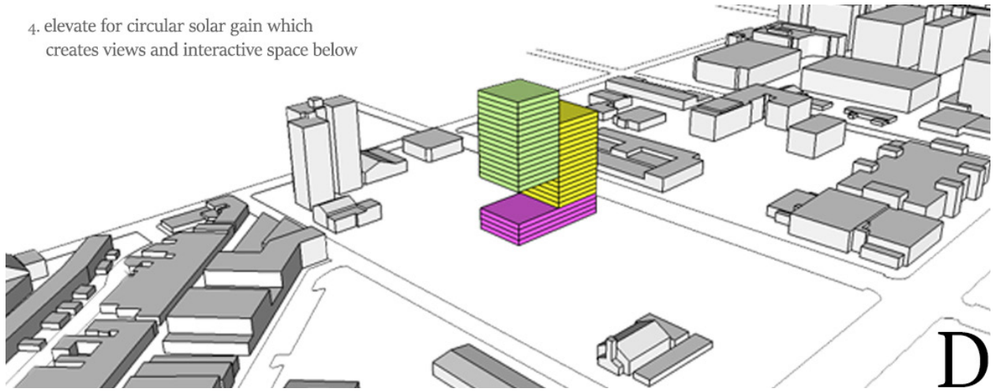
B

3. orientate for optimal solar gain (SW) and views (SE)



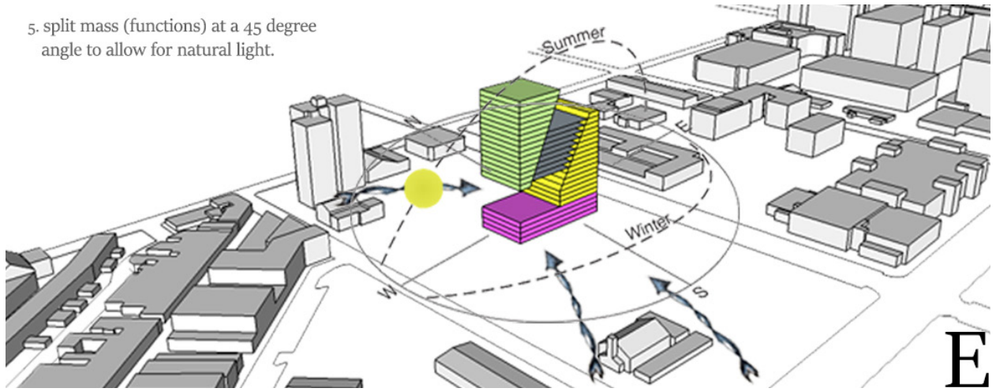
C

4. elevate for circular solar gain which
creates views and interactive space below



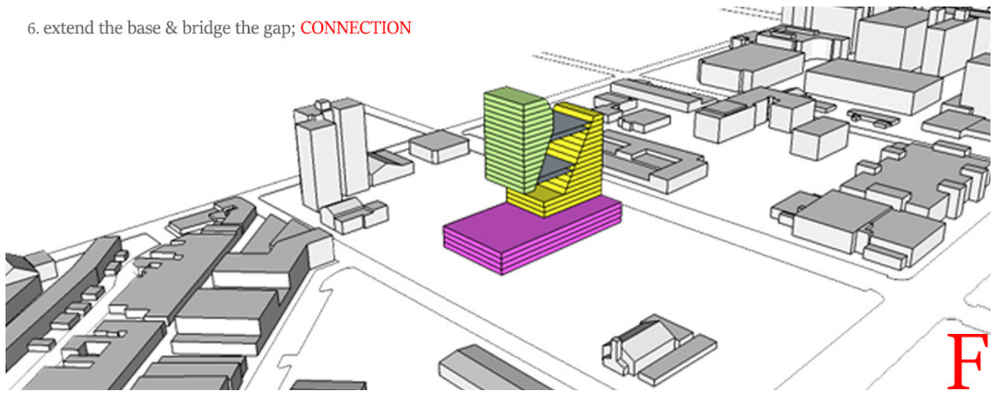
D

5. split mass (functions) at a 45 degree angle to allow for natural light.



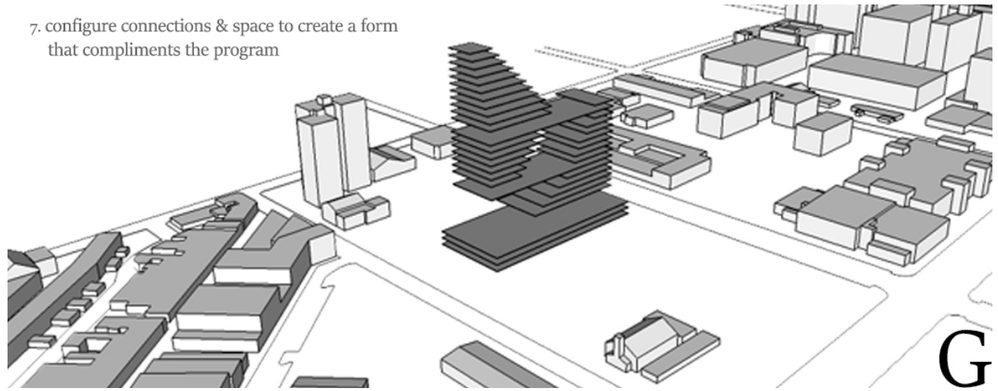
E

6. extend the base & bridge the gap; CONNECTION



F

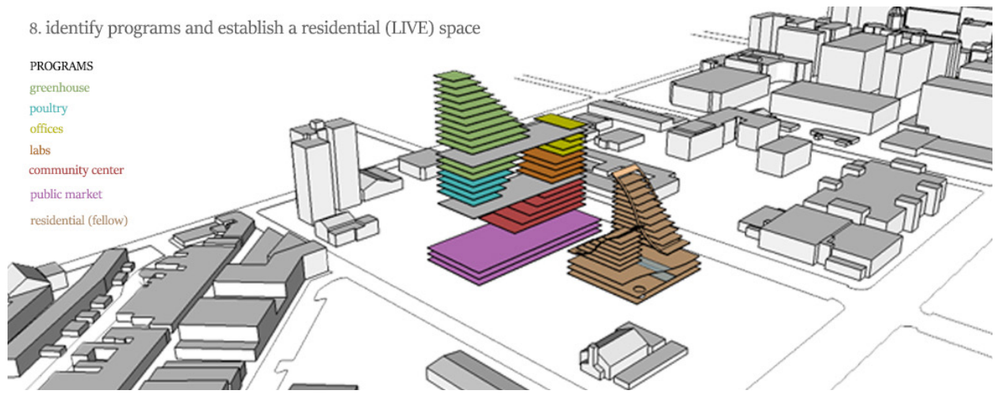
7. configure connections & space to create a form that compliments the program



G

8. identify programs and establish a residential (LIVE) space

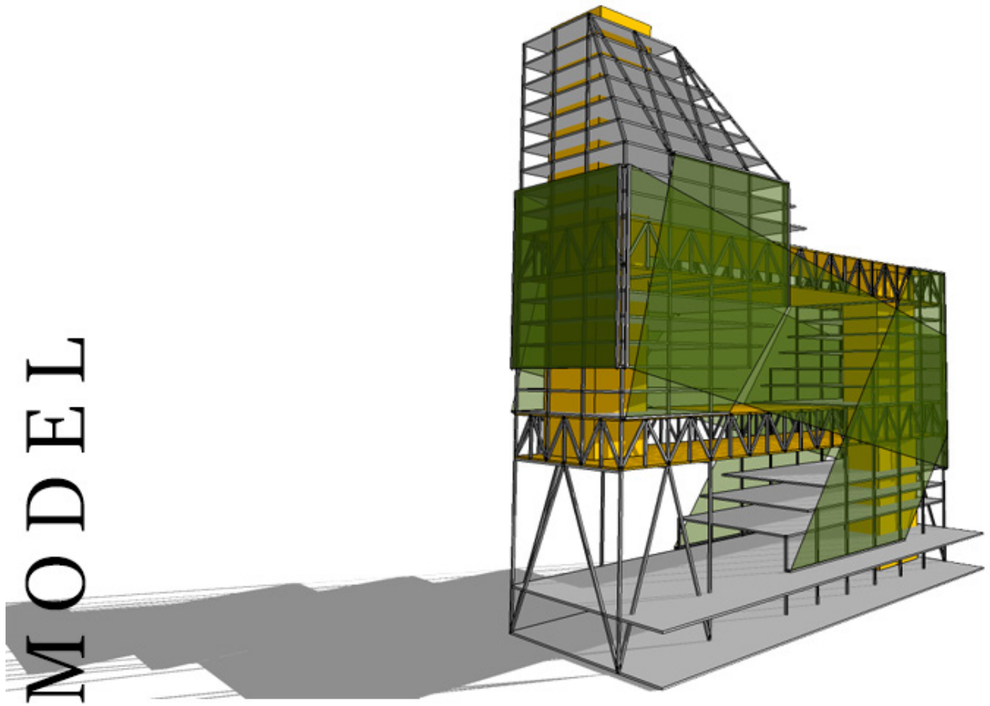
PROGRAMS
greenhouse
poultry
offices
labs
community center
public market
residential (fellow)



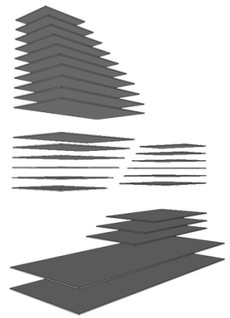
IDEA DEVELOPMENT | Conceptual Design III

After the form was configured from the solar orientation, environmental conditions, and access approach, it was important for me to construct a core. The core consists of the vertical and horizontal circulations. The vertical cores are 1,575 sq-ft concrete structures, while the horizontal concrete and steel structure are concrete slabs with rebars as support systems. Due to the large overhang, a three sided k-leg support structure was implemented. The k-leg structures are 24" x 24" concrete support columns, whereas the other support columns are 14" x 14". The shell, also known as the skin is a living solar screen with vegetation and photo-voltaic panels.

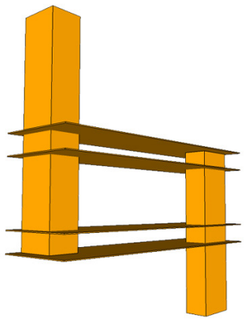
MODEL



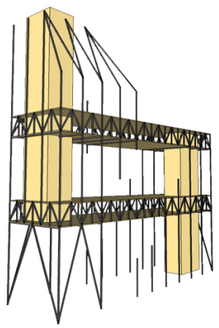
FORM



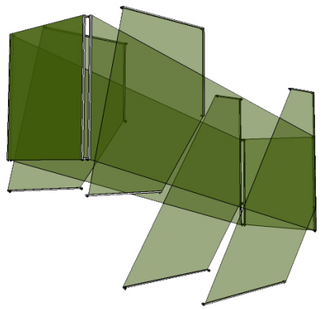
CORE



STRUCTURE



SHELL

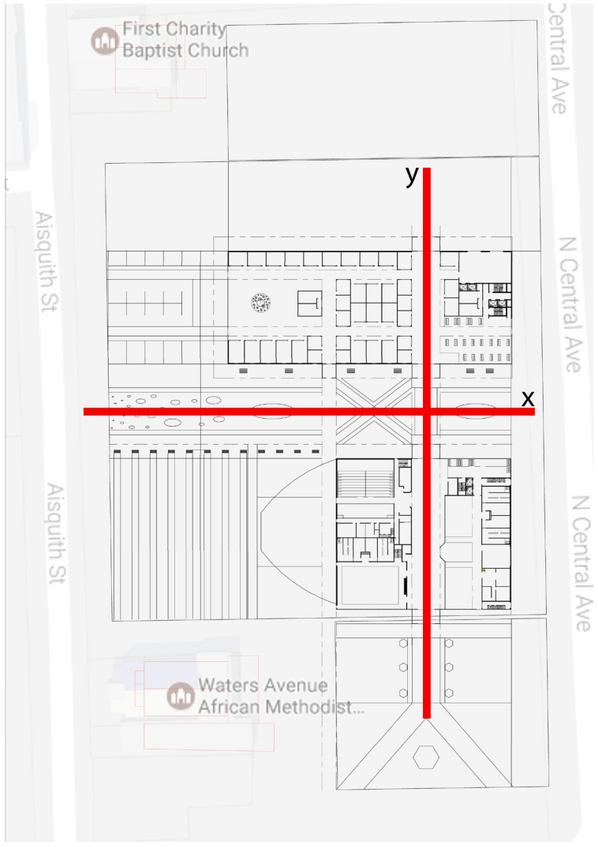


CENTRAL FARM | Site Plan

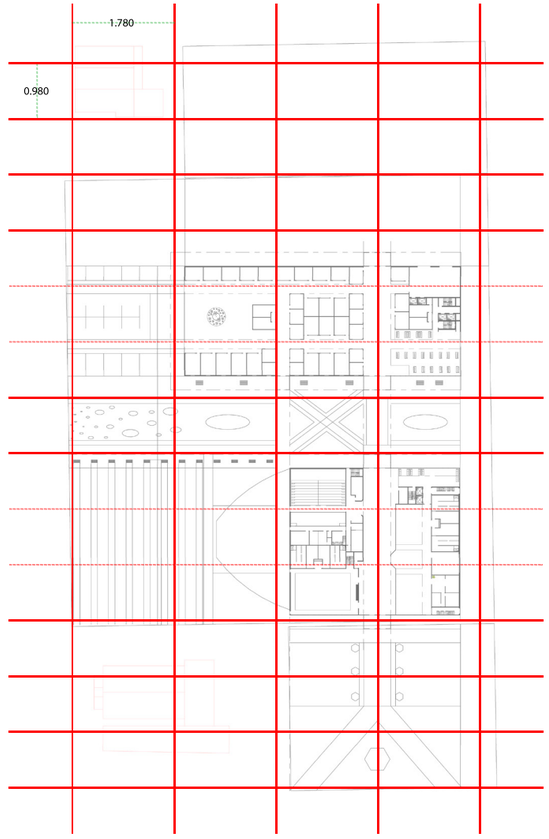
The footprint of the site is slightly over 7 Acres, therefore I thought will would be important to address the landscape conditions. My approach was to design within these 3 guidelines, environmental friendly features, access, and an socially interactive spaces. It was also important for all these guidelines to coexist together without either one compromising the existing figure ground of the block plan by addressing Baltimore city grid pattern, biodiversity, and wellness amenities. First, direct access between N. Central Ave and Aisquith Street gave me an opportunity to propose a plaza space for community interaction. Second, implementing a maze farmland and a green space between the churches helped promote an environmental friendly element. Finally, adding environmental friendly and bioretention features such as wetlands, swales, permeable pavers, indigenous trees, bioretention islands, a reflective pond, bike rack, and benches would not only benefit the sustainability of the site but it will also educate the community about bioretention. The process in which contaminants and sedimentation are removed from stormwater runoff.

Legend

1. Farmers' Market
2. Fitness Center
3. Plaza
4. Amphitheater
5. Farmland
6. Wetland
7. Sculpture Garden
8. Reflective Pond
9. Outdoor Booth
10. Green Space
11. Parking Lot
12. Loading Dock

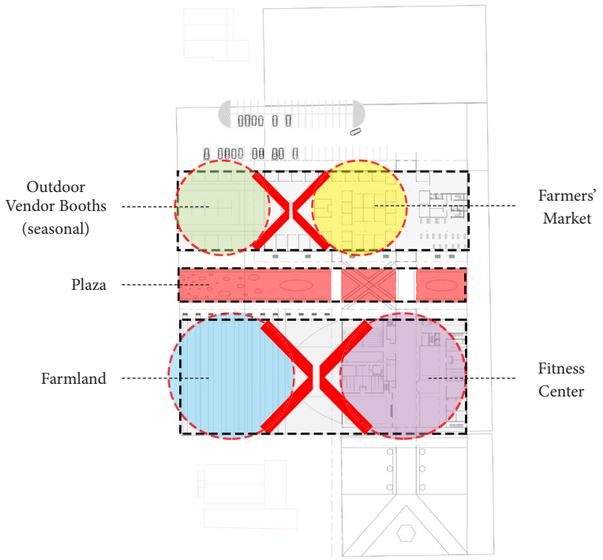


The schematic design process started with the axis. The motto, growth through connection was also prevalent in this design process. By replicating the axis of the streets within the buildings, that approach psychologically invites the pedestrians to explore Central Farm. The benefits of engaging all four streets meant I can also engage the community. In addition to the adjacent buildings, such as the churches, Dunbar High School, Orleans Library, etc.



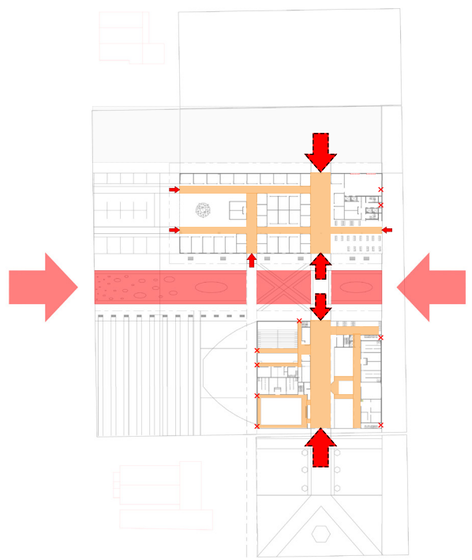
The concept behind the grid was to develop a concise plan. By replicating a similar grid format system used in Baltimore City planning, it assured me that I am aligning my access points and programs accordingly. Also, it illustrates a symmetrical design that responds cohesively to the sizes and footprints of each program. According to the grid, the columns are 100 feet apart and the rows are 50 feet apart.

Program Relations



The concept behind the program relations design is similar to the levels of needs within the Maslow's Hierarchy. Each level of needs requires complete fulfillment from the previous level. This program relation fulfillment can be found between masses, functions, and contrasting spaces. For example, the Fitness Center compliments the Farmland.

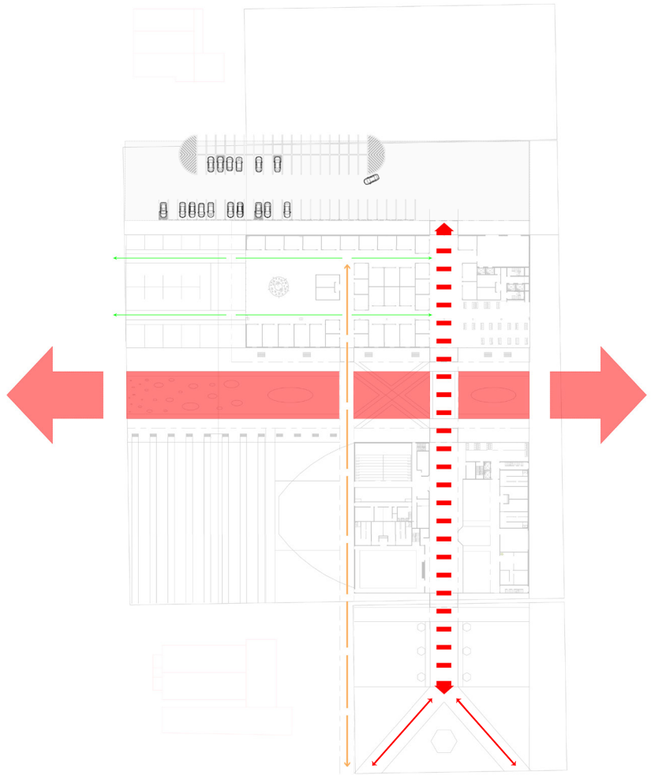
Access & Circulation



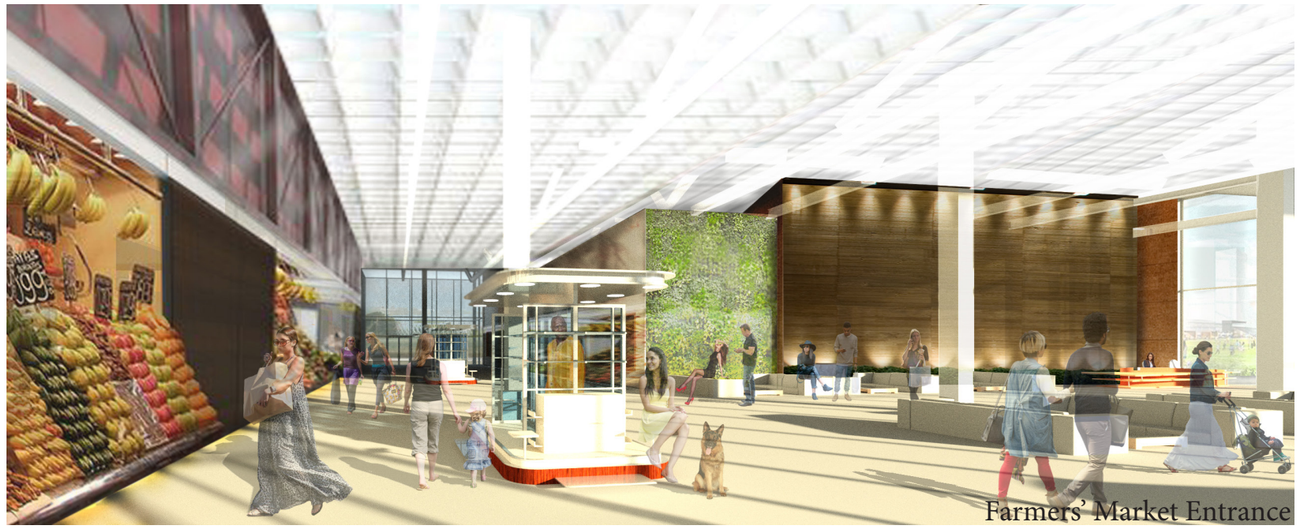
Access and circulation were just as important as program relations. The plaza is designed to function as the primary access. However, complimenting the building access to the pedestrian pathway helped facilitate the circulation. In addition, there are multiple egress doors and stairwells that led to an open space in case of an emergency exit.

Central Farm Plaza

SCHEMATIC DESIGN | Transitions



Transitional spaces are where an individual will experience all that the Central Farm has to offer. The ambiance, though is created from the features within the space, such as a living green wall for a biophilic essence, an open atrium for natural light; even the exposed structures display repetition. The idea of transition is also associated with the functions of the space; the journey from the Fitness Center to the Farmers' Market.



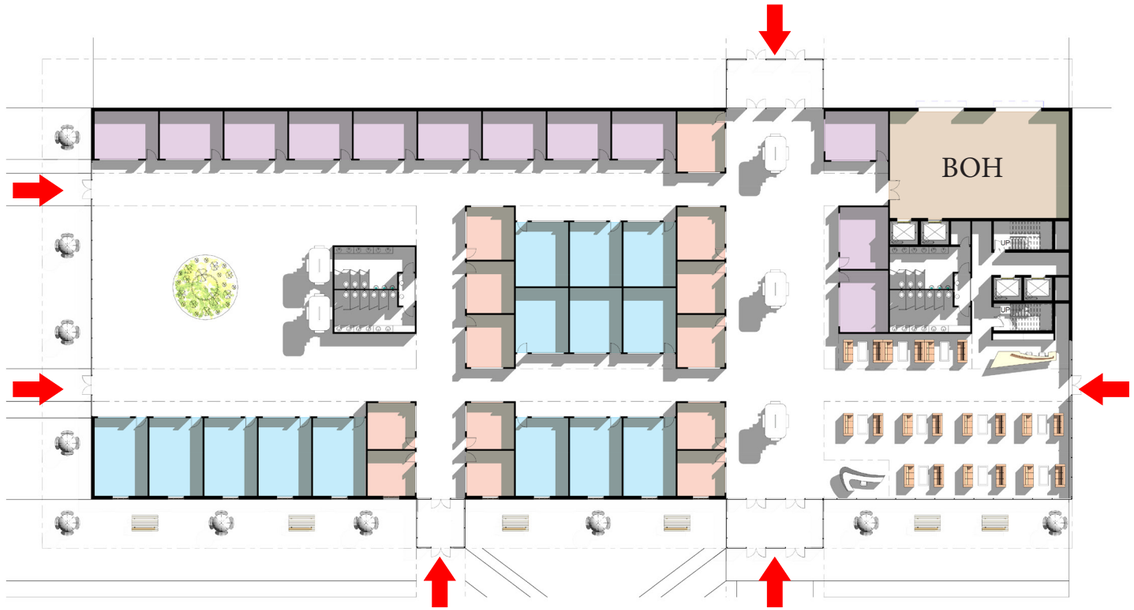
Farmers' Market Entrance

Resident Fitness Center

BIOPHILIC DESIGN

This conceptual and structural design in the Farmers' Market food court symbolizes biophilic architecture: bringing nature indoors. The presence of nature in the food court promotes the awareness for healthy food and a healthy lifestyle.

Farmers' Market Food Court



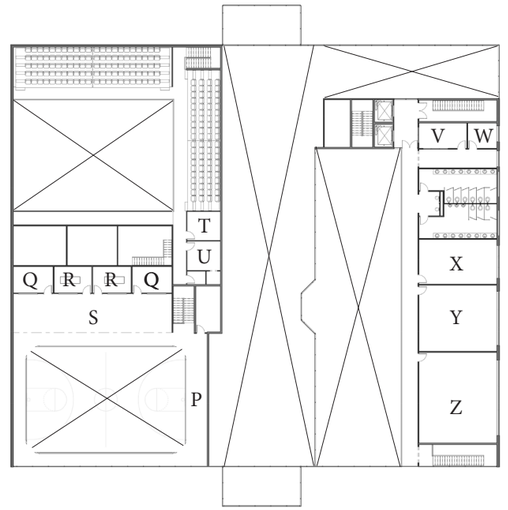
First Floor

Large Vendor (480 SqFt) Middle Vendor (300 SqFt) Small Vendor (180 SqFt)

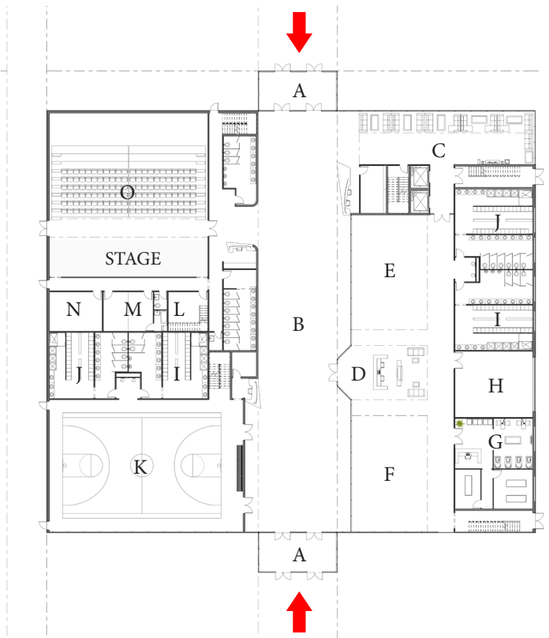
The Farmers' Market is the quintessential focus and attraction for the community. The market was intentionally designed for multiple entrances, with the primary entrance is towards the plaza. The east side of the floor plan is designed for a semi-public use, whereas the food court is intended for public consumption. This 36,000 sq-ft market hosts 14 larger size vendor units, 12 middle size vendor units, 13 small size vendor units, 5 kiosks, a food court, and multiple lounge areas inside and outside of the market.

Legend

A. Vestibule
B. Atrium
C. Resident Lobby
D. Fitness Gym
E. Cardio Equipments
F. Free Weights Area
G. Holistic Spa
H. Children Playroom
I. Men Locker Room
J. Women Locker Room
K. Gymnasium
L. Storage
M. Dressing Room
N. Rehearsal Room
O. Auditorium
P. Walk Track
Q. PT Office
R. Massage Room
S. Warm-Up/Stretch
T. Sound/Light Ctrl Rm
U. Electrical Room
V. Break Room
W. Manager's Office
X. P-Trainer Studio
Y. Multipurpose Studio
Z. Cycling Studio



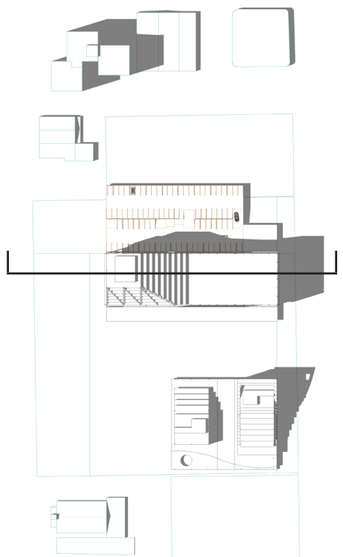
Second Floor

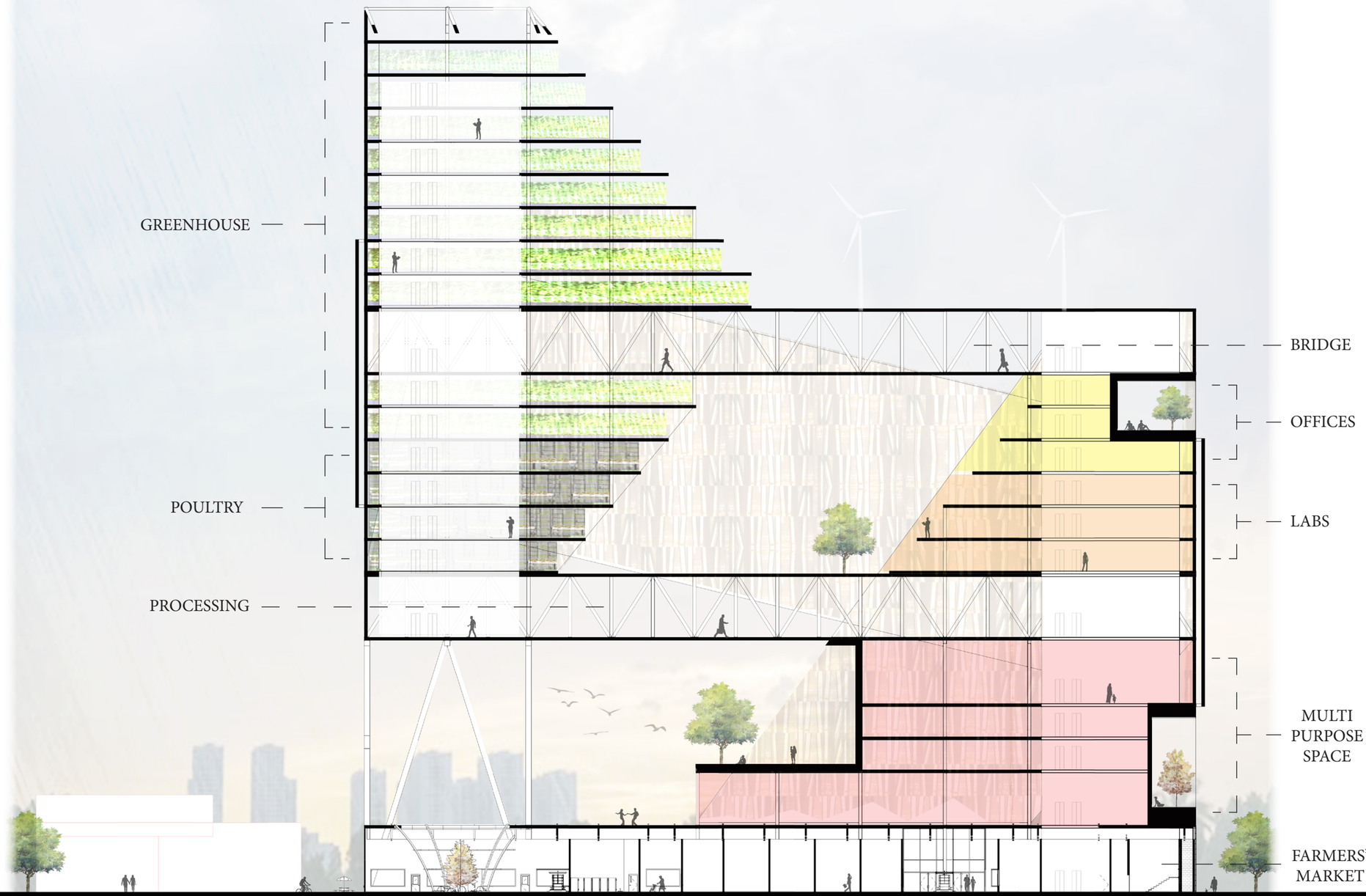


First Floor

CENTRAL FARM

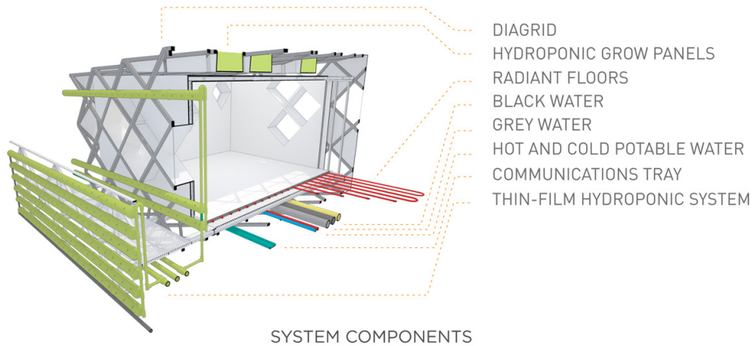
Vertical Farm Section





VERTICAL FARM | Greenhouse

The greenhouse is the jewel of the Central Farm design, peaking at a towering 300 feet high. Imagine a 2.5 acres, 13 story greenhouse that grows and produces fresh fruits and vegetables all year round through hydroponic methods. According to Farmland LP, 1 acre of indoor greenhouse produces the same crops as 4-6 acres farmland. Also, 3 acres of an outdoor farmland could feed 10,000 residents all year round, therefore Central Farm's 2.5 acre indoor greenhouses could feed 40,000-50,000 Baltimore City residents. That is over 8% of the city population.

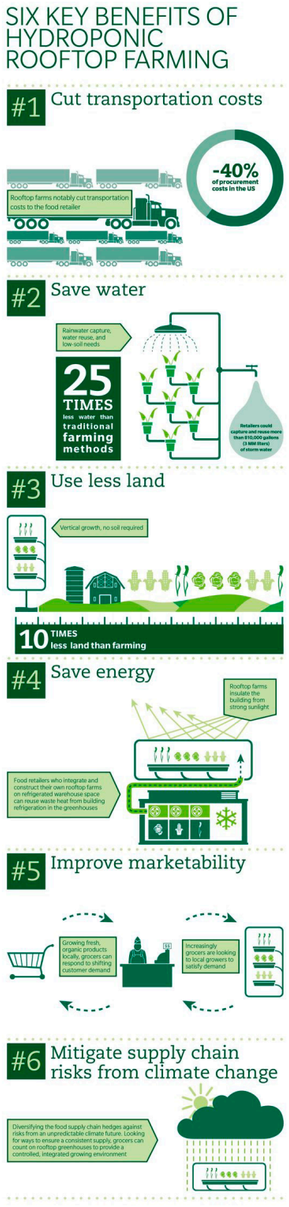


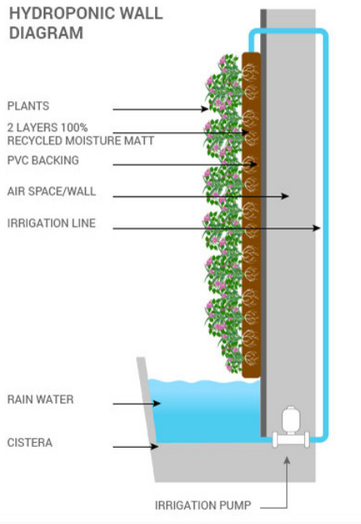
SYSTEM COMPONENTS

BALTIMORE SEASONAL FOOD

JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	OTHERS
Cucumbers	Cucumbers	Cucumbers	Cucumbers	Asparagus	Apricots	Apricots	Asian Pears	Asian Pears	Apples	Apples	Apples	Coffee
Mushrooms	Mushrooms	Mushrooms	Mushrooms	Broccoli	Asparagus	Beets	Beets	Beets	Asian Pears	Broccoli	Cucumbers	Dairy
Apples	Apples	Apples	Asparagus	Cauliflower	Blueberries	Black-eyed peas	Black-eyed peas	Blackberries	Broccoli	Brussel Sprouts	Lettuces	Eggs
Lettuces	Lettuces	Lettuces	Lettuces	Cucumber	Broccoli	Blackberries	Blackberries	Brussel Sprouts	Brussel Sprouts	Cauliflower	Mushrooms	Meat
Tomatoes	Tomatoes	Tomatoes	Tomatoes	Herbs	Cabbage	Blueberries	Blueberries	Cabbage	Cabbage	Chard	Sweet Potatoes	Wine
				Kale	Cauliflower	Cabbage	Cantaloupes	Cantaloupes	Carrots	Collards	Tomatoes	
				Lettuces	Chard	Cantaloupes	Carrots	Carrots	Cauliflower	Cucumbers		
				Mushrooms	Cherries	Carrots	Collards	Cauliflower	Chard	Kale		
				Onions	Collards	Cherries	Corn	Chard	Collards	Lettuces		
				Radishes	Corn	Collards	Cucumber	Collards	Cucumbers	Mushrooms		
				Spinach	Cucumber	Corn	Eggplant	Corn	Herbs	Onions		
				Strawberries	Garlic	Cucumber	Garlic	Cucumber	Kale	Pumpkins		
				Tomatoes	Green Beans	Eggplant	Grapes	Eggplant	Lettuces	Radishes		
				Turnips	Herbs	Garlic	Green Beans	Garlic	Mushrooms	Spinach		
					Kale	Green Beans	Honeydew	Grapes	Onions	Sweet Potatoes		
					Lettuces	Herbs	Lettuces	Green Beans	Pears	Tomatoes		
					Mushrooms	Honeydew	Lima Beans	Honeydew	Peas	Turnips		
					Onions	Lettuces	Mushrooms	Lettuces	Pumpkins	Winter Squash		
					Peas	Lima Beans	Nectarines	Lima Beans	Radishes			
					Potatoes	Mushrooms	Okra	Mushrooms	Raspberries			
					Radishes	Nectarines	Onions	Okra	Soybeans			
					Raspberries	Okra	Peaches	Onions	Spinach			
					Spinach	Onions	Pears	Peaches	Summer Squash			
					Strawberries	Peaches	Plums	Pears	Sweet Potatoes			
					Summer Squash	Peas	Potatoes	Peas	Tomatoes			
					Tomatoes	Peppers	Radishes	Peppers	Turnips			
					Turnips	Plums	Raspberries	Plums	Winter Squash			
						Potatoes	Summer Squash	Potatoes				
						Raspberries	Tomatoes	Radishes				
						Summer Squash	Watermelon	Raspberries				
						Tomatoes	Winter Squash	Soybeans				
						Watermelon		Spinach				
								Squash				
								Tomatoes				
								Turnips				
								Watermelon				

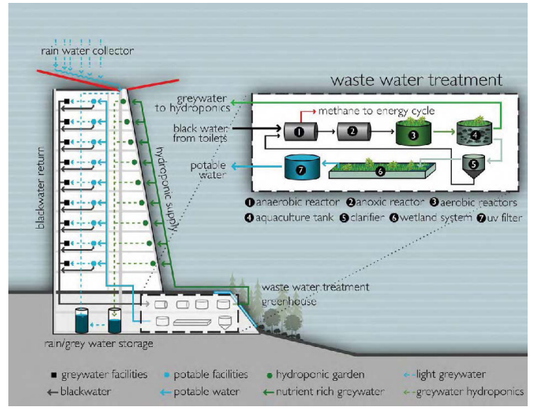
Benefits of Hydroponic Farming

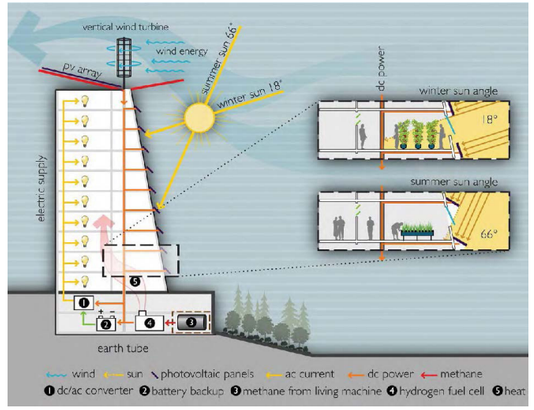


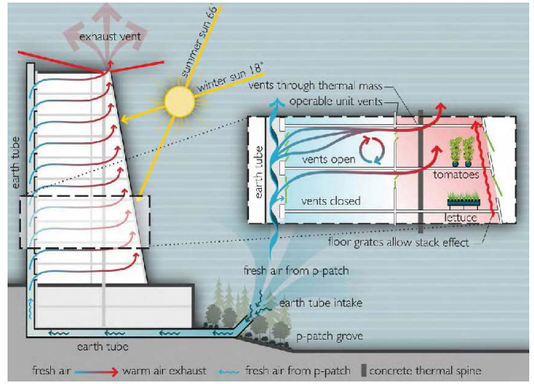


Hydroponic is a soilless farming method that enables the farmer to grow plants and crops using mineral nutrient solutions in water. However, Terrestrial plants can be grown with their roots in the mineral nutrient solution while perlite or gravel is present. Within the building, there will be two main hydroponic systems: the Nutrient Film Technique (NFT) channel system and the Bato Bucket System. The NFT system is ideal for growing leaf crops (lettuce, spinach, swiss chard, etc.) and herbs, while the bato bucket system is ideal for growing vine crops (tomatoes, cucumbers, peppers, etc.).

The Solar Life-Cycle of Hydroponic Farm

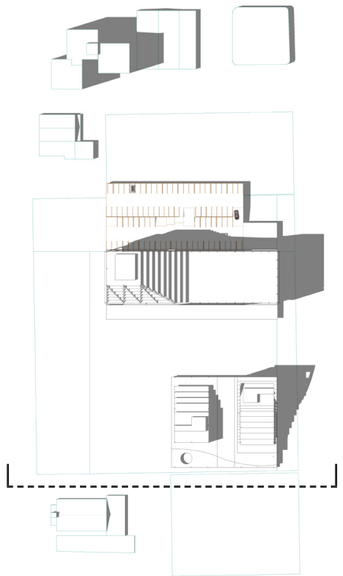


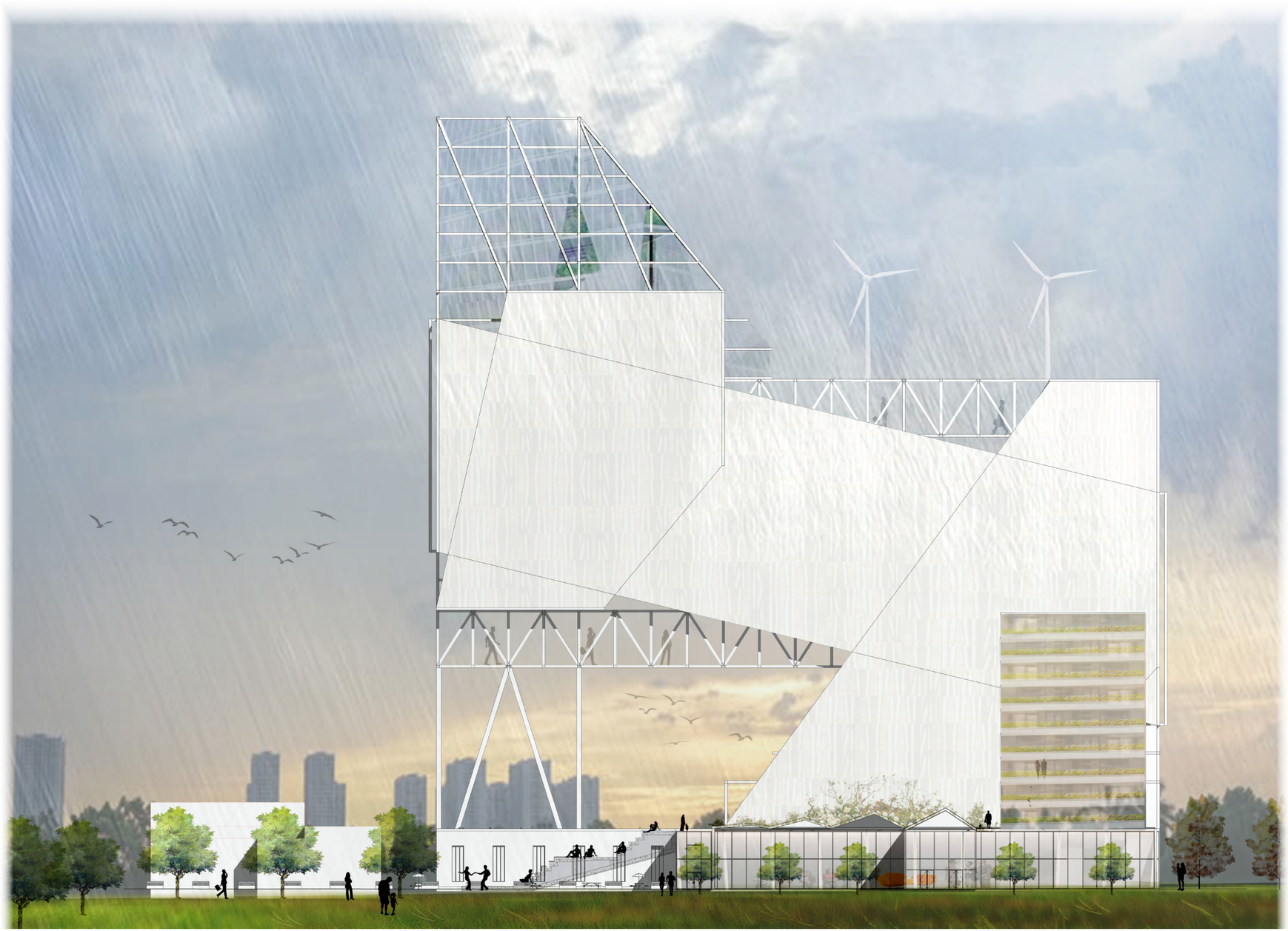




CENTRAL FARM

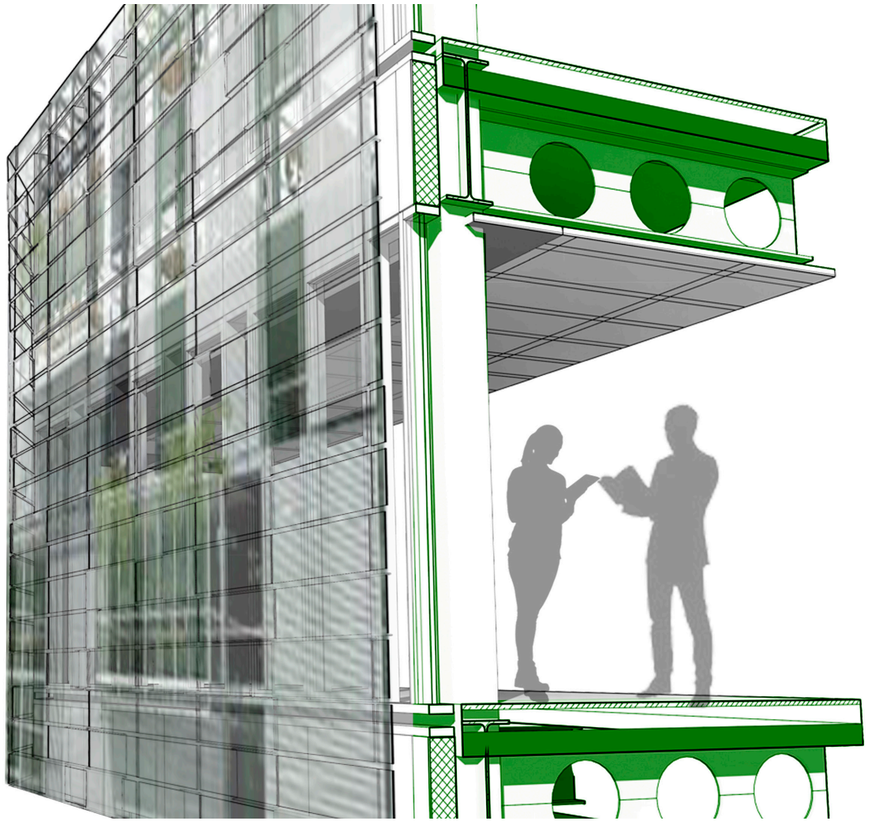
South Elevation



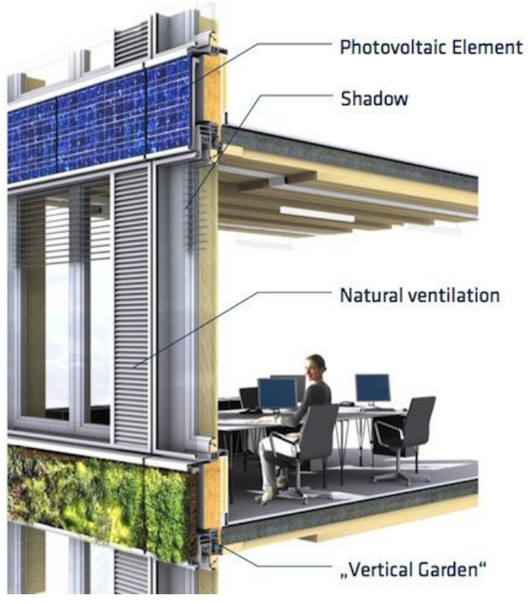


VERTICAL FARM | Living Solar Screen

The Living Solar Screen is a perforated skin made from 5mm sheet aluminum. The environmentally friendly exterior skin helps control solar radiation and illumination while giving the Vertical farm a living green facade. The pattern of the diamond-shaped cutouts varies in density according to the building's lighting, climate control needs, and atmospheric conditions.



Equipped with photo-voltaic panels, the screen will also support the growth of vines and plants on the south and west facades. The living screen infuses the interior with lots of light without causing overheating, and it also has the added benefit of quieting the interior spaces from exterior noise pollution and interior mechanical noise.



RESIDENT BUILDING

The residential building is designated for Researchers, Scientists, Farmers, and their immediate family members. The 10-stories condo accommodates 80 units with 3 apartment styles: Studio, 1 Bedroom, and 2 Bedrooms.

IMAGE CREDITS

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