Fordhamopolis 7.0

The Future of Sustainable Urban Infrastructure

May 2023
Ecology for Designers

Designed by: Laurel Applegate, Ryan Chen, Katelyn Figueroa, Jack Kelly, Anthony Lekakis, Amelia Medved, Grace Nelson, Erin Newton, Isabela Pizarro, Samantha Roberts, Shamia Rahman, and Genesis Yi

A special thanks to our professor, Dr. Dickson Despommier, for his wisdom and support.

Table of Contents

Introduction

1. General Challenges

Rapid, anthropogenic Climate Change

One of the most significant issues facing our planet is rapid, anthropogenic climate change. Although earth's climate and atmospheric conditions have changed before, the increase in average global temperatures which we are experiencing right now are unprecedented in the speed of change. Additionally, the scientific consensus is that this warming is anthropogenic, meaning that the atmospheric conditions are caused by human activity.

The extraction and combustion of fossil fuels adds greenhouse gasses to the atmosphere; these trap heat from the sun and warm the atmosphere. Since the Industrial Revolution, humans have extracted coal, oil, and natural gas and burnt them for energy, a process which releases greenhouse gasses including carbon dioxide, methane, and nitrous oxide. Currently, our systems are dependent on extraction and emission, because fossil fuels power most of our electricity, industry, and transit.

In combination with the emission of greenhouse gasses, humans are responsible for widespread deforestation. Since the Agricultural Revolution, humans have cut down upwards of 3 billion trees and converted forested land to land for development, construction, and agriculture. Humans have had an impact on many kinds of ecosystems, including deserts, plains, and oceans; however, our destruction of forests has significant impacts on climate change because forests and trees sequester atmospheric carbon. As humans at once emit greenhouse gasses and destroy the natural processes which remove greenhouse gasses, we harm the planet's ability to maintain a stable, life-supporting climate.

Urbanization

The fact that the majority of humans will live in urban centers within the next half century means that humanity needs to rethink their home. As of now, cities are leeches on the world: sucking up tremendous quantities of natural resources and wreaking havoc on the natural world as they drain it of its natural resources in order to keep themselves afloat. As these "leeches" expand, as more and more humans choose to live in cities, humanity needs to redefine this relationship it has with the planet, especially when it comes to the design of the city. Cities need to be able to at the very least sustain themselves, and at best give back to the environment. The new city needs to be able to harvest its own water, generate its own energy, grow its own food, and sequester its own carbon. The new city needs to be able to mimic a forest.

Pros and Cons: Density Creates Less Sprawling Development

Areas that are densely populated today use a relatively small amount of land when compared to rural populations. This allows for less land to be altered in order for humans to live on it. Large amounts of people can live in dense urban areas today with high standards of living while also not needing too much land area. For example, 26,403 live in a single square mile in New York City on average, while in rural areas a single family may take up a square mile and alter the land to their needs. In this way, dense, modern cities are somewhat ecologically friendly because of the fact that they can support a large population without the need of thousands of acres of land. Though supporting millions of people in a city that constantly emits carbon dioxide and other pollutants can have detrimental effects to the environment. Cities today are often dependent on cars, inefficient energy sources, and gas/oil. Furthermore, the amount of waste these cities produce is astronomical, this waste simply being put into landfills or bodies of water. The food supplying most metropolitan areas comes from all over the world, this and other factors making them dependent on a variety of outside sources. There are many problems that modern cities pose to the environment, while they can be beneficial in some ways. Fordhamopolis will tackle these problems and become a city that coexists with the environment rather than harm it, especially as a densely populated urban city.

Resource Consumption and Environmental Destruction

Current cities operate within a system that is unsustainable for long term survival. Systems import goods using energy intensive processes and export monumental amounts of waste. Infrastructure built from unsustainable material, such as cement, emits massive amounts of carbon and disconnects people from their home environment. Waste that is exported out of the city is allotted to landfills or burned at incinerator sites, and then released into the atmosphere –oftentimes in a more dangerous state of matter than before. Accordingly, communities located in close proximity to incinerator sites experience disproportionately higher health issues, i.e., cancers, asthma, and other related issues. Ultimately, the facade, so easily digestible in the urban environment, that all goods are at people's disposal and that all waste merely 'goes away,' is precisely the ideology that fuels rapid anthropogenic climate change. Thus, to reinvent the traditional city, Fordhamoplois 7.0 must simultaneously reinvent ideology. So forth, Fordhamopolis 7.0's principles will prioritize reconnecting residents with nature and its ecological cycles.

Fordhamopolis 7.0 challenges issues related to resource consumption and environmental destruction by configuring all designs based on the gaia hypothesis: Life on earth creates the conditions for life on earth. Present cities are disconnected from such ideology and currently function dysregulated from the natural flow of ecology. Cities are structured around an economy centered around exponential growth. Moreover, such economic growth is solely dependent on the accumulation of capital –sustained by exploiting people and natural resources. The Anthropocene has revealed the issues with such a socioeconomic system, i.e. rapid climate change and environmental desecration. Humans must evolve out of such systems to ensure long-term survival. Fordhamopolis 7.0 sets the precedent for an effectual society that sustains all life on Earth.

1. Mission of Fordhamopolis

One of the key philosophies of Fordhamopolis is that we need 'redundancy which leads to resilience which leads to long-term sustainability'. Redundancy is an observation of how nature works–aim to mimic it. Having redundancy allows for backups to be in place in case of emergency. Each pillar addresses redundancy by implementing myriad ways of meeting the needs of each pillar. For example the food production pillar has multiple ways of producing food, both in-door and out-door, to ensure there is always a method of growing food in the event of catastrophe or malfunction. Our renewable energy pillar utilizes multiple forms of energy harnessing to prevent power outages if one system fails.

Fordhamopolis strives to be a completely self-sufficient city, which leads to a number of benefits. A self sustained city is a concept where a city is designed to meet its essential needs within the city boundaries without the need for help from outside sources. The many advantages for a self sufficient city is as follows:

1. Resilience: A self sufficient city is more resilient to external or environmental disruptions, such as natural disasters or global supply chain disruptions. Because they produce their own food, energy, and other essential resources – there is a reduced dependence on other resources, leading to resilience.
2. Environmental sustainability: A self-sufficient city can work to prioritize sustainable

practices and waste management. This can promote more environmentally friendly systems. In an ecosystem, everything is connected and will produce no waste – by mimicking this as a self sustaining city, we will be more sustainable.

3. Food Security: Due to the resilience stated above and local food production, there will be increased food security for the citizens of the city.
4. Community engagement: There will be a stronger sense of community as everyone will work together to help keep the city running. A stronger community will lead to better systems of management and overall community attitude.

Fordhamopolis will mimic a hardwood forest ecosystem, which naturally operates with zero waste. Like a forest, it will sequester carbon, store and utilize rainwater, convert sunlight to create its energy. Forests are extremely resilient ecosystems. Trees have survived three major extinction events, and they work together to establish and sustain richly biodiverse forest ecosystems. Forests also have the capacity to sustain, and even regenerate themselves naturally. As established in the Hubbard Brook experiment, a clear-cut forest ecosystem will regenerate itself without significant intervention. Gradually proceeding through stages of reorganization, aggradation, and transition, the forest establishes a resilient steady state.

3. Governance structures

Law and Policy

Fordhamopolis 7.0 is an opportunity to construct a political system that aligns with nature. The current socioeconomic and political systems in place are the forces that are driving the Anthropocene. Therefore, Fordhamopolis will be holistically democratic. Mimicking ancient Greece, but ensuring total inclusivity, Fordhamopolis' governmental system will be a direct democracy. The system will prioritize and nurture an egalitarian society, of which *all* residents share equal power. The details of such a system are as follows:

I. All residents can and will vote on issues independently.
   A. Fordhampolis will provide a phone application that uses facial and fingerprint identification for a secure voting system.
   B. Residents can vote starting at 18, and can only vote once.

II. Agencies will act only on behalf of decisions made by voters.
   A. Will not be elected officials.

III. All major issues will be voted on by the people. This includes:
   A. Court cases
   B. Political topics
   C. Immigration/Emigration
   D. Any other issue pertaining to the livelihood of Fordhamopolis' residents.

Given the population of the city, 100,000 residents, luckily, direct democracy as a governmental system is very feasible to attain. However, it is notable to mention that such a system may be more difficult to mimic in a city with a larger population. Enforcement agencies will be responsible for creating and implementing policies that residents vote on. Larger, more powerful managerial positions will be decided based on a vote as well. Additionally, the people can choose to enact a vote in the event that a political leader is either corrupt, or not enforcing regulations at the integrity of the people.

4. Waste Management

We will manage waste in a closed loop system by addressing the three main ways the city will produce organic waste. Food, fecal, and urine waste will be used to the fullest extent to replenish the nutrients of our farms. We will talk about the systems we intend to use to structurally manage the waste of the city.

5. Food Management

Current food systems are unsustainable in environmental practice but also social practice. The ever increasing separation between humans and the land contributes to environmental degradation and human isolation. Our food production pillar uses sustainable farming practices while increasing public participation in food systems. This will guarantee equitable food distribution and better social planning.

6. Public Transit

The transit system will be managed by the Toledo Intracity Transit System (TITS), who will be responsible for maintenance of the transit system.

A hybrid system of trains and trams will be employed to ensure that each area of the city is equally accessible to everyone. Much like the Citi bike system here in NYC, Fordhamopolis would rely heavily on a free biking system, which would be carbon neutral and be the main mode of transportation within the city, as the city would only be about one square mile large.

In terms of energy for the transit system, every method of transportation will be powered by renewable energy. Buses and trams will be electric, with solar panels on their roofs allowing them to be completely self-sufficient, powered by clean energy. Furthermore, trains will also be electric. Because the train system will be underground, they will not be powered by solar, instead they will utilize the excess energy generated from micro roof turbines, solar, hydro and more from other sources throughout the city. Use of rollerblades and Heelys to move around will be encouraged, as well as any other personal electric vehicle like scooters or bicycles, as long as the users wear helmets.

Unlike most other metropolitan transportation systems, our intra-city transportation system runs on free renewable energy, meaning it costs almost nothing to operate once built, besides upkeep. This will be paid for by those who made the construction of the city possible.

7. Population Growth Management

a. How do we manage the growth of the city?

Population growth will be primarily managed through education. It is proven that women that have been able to receive an adequate sexual health education, as well as general education, are less likely to have more kids. Furthermore, if the population does happen to grow due to immigration, Fordhamopolis will expand in all areas to fit these people.

b. How do we manage education?

Every citizen in Fordhamopolis will receive the same education, none having a better education than others. Higher education will always be an option for citizens, and it will also be free to encourage people to learn as much as they can. In schools, especially middle and high school, the environmental sciences will be one of the main focuses of the schools. It is important that students not only understand Fordhamopolis, but also why it was created.

8. The Four Pillars

The city proposed in Fordhamopolis 7.0 will sustain 100,000 residents with infrastructure holistically designed to align with nature's ecological cycles. Specifically, Fordhamopolis 7.0 is centered at the current location of Toledo, Ohio, in the United States, which is 83.83 square miles. In Fordhamopolis, the main priority of the city's infrastructure, the socioeconomic system, and residential culture will encompass nature. We have split the main entities of the city's design into four pillars: Carbon Storage, Food Production, Rainwater Harvesting, and Renewable Energy, respectively. While broken down into sections to best conceptualize the city dynamic, ultimately, the four pillars intertwine, creating an optimal, cyclic, independently run city. Each pillar is listed as followed:

Carbon storage will be accomplished through reforestation of the land surrounding our city. We will use sustainable, carbon storing building materials throughout the construction of Fordhamopolis 7.0, including cross laminated timber. This material selection will be supported by the reforesting and subsequent management of the forest. Additionally, we have included plans to reintegrate the forest ecosystem into the Great Black Swamp, which formerly existed in the region.

Food production in Fordhamopolis has many layers. Our system addresses farming practices, social impacts, and waste management. Through a closed loop system we will be able to be self-sufficient without creating any waste that leaves the city and without causing significant harm to other ecosystems through imports. Additionally, our 8 farming sectors were strategically chosen to create redundancy and foster community involvement. It'll restructure our relationships with each other and the earth.

Rainwater harvesting will be the main methodology for Fordhamopolis 7.0 to acquire water. Designs nurture a decentralized, local approach to obtain water, using rainwater collection tanks to sustain the water necessities of each building respectively. Self-sufficiency will be pertinent, as local residents will be incharge of systemic upkeep of their own water systems. Nonetheless, Fordhamopolis 7.0 will also sustainably extract water from local sources, such as Lake Erie and the Detroit River. Ultimately, Fordhamopolis 7.0's water structure will be a balanced, hybrid system of rainwater harvesting and noninvasive, cyclic irrigation.

Renewable Energy will be powered by solar, wind, and hydropower for Fordhamopolis. These sources of energy will be completely carbon neutral and will have no impact on the surrounding environment. Fordhamopolis will be located where Toledo, Ohio is, making it optimal for hydroelectric power due to its proximity to Lake Eerie and the Maumee and Ottawa Rivers. Solar panels as well as micro turbines will be placed on top of buildings as well as other areas that receive a lot of sunlight, all of these combined creating a surplus of energy. Everything that requires energy in Fordhamopolis will be powered by one of these sources which are all located within Fordhamopolis, making it entirely self-sufficient and clean.

Pillar I: Carbon Storage

What is Carbon Sequestration?

Carbon dioxide is a naturally occurring greenhouse gas that holds heat energy in the atmosphere. Carbon sources add CO_2 to the atmosphere while carbon sinks remove CO_2 from the atmosphere. ***Carbon sequestration*** is the process by which carbon dioxide is removed from the atmosphere and stored in natural or artificial sinks, such as forests, oceans, soils, or geological formations.

The goal of carbon sequestration is to mitigate climate change by reducing the concentration of CO_2 in the atmosphere, which is the main greenhouse gas responsible for global warming. Atmospheric carbon has helped create the conditions for life on earth, but current levels of atmospheric carbon, emitted by the burning of fossil fuels, are driving a rapid increase in global temperatures.

There are many different ways to sequester carbon dioxide, including natural and artificial methods. Natural carbon sequestration occurs through photosynthesis, which converts CO_2 into organic matter through the growth of plants and trees. This organic matter can be stored in soil or biomass for long periods of time. Artificial carbon sequestration includes methods such as carbon capture and storage (CCS), which involves capturing CO_2 emissions from industrial processes, compressing it, and storing it underground in geological formations or in the ocean.

Carbon sequestration can help to slow down the rate of global warming and reduce the impact of climate change. However, it is not a solution in itself, and needs to be combined with other efforts to reduce greenhouse gas emissions and transition to a low-carbon economy.

How Does Carbon Sequestration Mitigate Climate Change?

Carbon sequestration is important because it can help mitigate the impacts of climate change by reducing the concentration of greenhouse gases in the atmosphere. Greenhouse gases, such as carbon dioxide, trap heat in the atmosphere and contribute to global warming. The increased concentration of greenhouse gases in the atmosphere is mainly caused by human activities, such as burning fossil fuels, deforestation, and land-use change.

Carbon sequestration provides a mechanism to remove carbon dioxide from the atmosphere and store it in natural or artificial sinks, such as forests, oceans, soils, and geological formations. This helps to offset the emissions of greenhouse gases, and reduce the net amount of carbon dioxide in the atmosphere. By reducing the concentration of greenhouse gases, carbon sequestration can help slow down the rate of global warming and mitigate the impacts of climate change, such as sea-level rise, more frequent and severe weather events, and loss of biodiversity.

In addition to mitigating climate change, carbon sequestration can also provide co-benefits, such as improving soil quality, enhancing biodiversity, and supporting sustainable agriculture and forestry practices. Carbon sequestration can also create new economic opportunities, such as through the development of carbon markets and the use of carbon credits.

Overall, carbon sequestration is an important tool for addressing climate change and building a sustainable future. While it is not a solution in itself, it can complement other efforts to reduce greenhouse gas emissions and transition to a low-carbon economy.

Overview of Carbon Sequestration Methods

Architects and planners can choose materials which sequester carbon dioxide and store it in the built environment. They can also include green roofs and walls which use plant life to actively sequester carbon as they photosynthesize, or create designs which incorporate artificial carbon capture technologies. Finally, the reuse and adaptation of existing structures is considered a carbon sequestration technique. Here is a brief overview of these various options.

Building materials: Certain building materials, such as wood, bamboo, and straw, are renewable and have a low embodied carbon footprint, meaning they require less energy to produce and emit fewer greenhouse gases during their production. Using these materials in construction can help sequester carbon in buildings.

Carbon-negative materials: There are also emerging building materials that are specifically designed to remove carbon dioxide from the atmosphere. For example, a company called Blue Planet has developed a method for producing building materials, such as concrete, that absorb more CO_2 during production than they emit.

Green roofs and walls: Green roofs and walls involve the installation of vegetation on building surfaces, which can help sequester carbon through photosynthesis. They also provide other environmental benefits, such as reducing urban heat island effects, improving air quality, and providing habitat for wildlife.

Carbon capture technologies: Some buildings are equipped with carbon capture technologies that capture CO2 emissions from heating, ventilation, and air conditioning (HVAC) systems and store them in building materials or underground. For example, the Bullitt Center in Seattle uses a geoexchange system to capture CO2 from its HVAC system and store it underground.

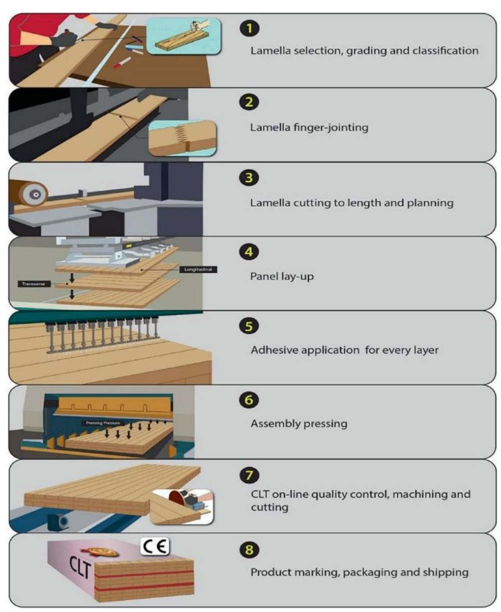
Retrofitting buildings: Retrofitting existing buildings with energy-efficient technologies, such as insulation, efficient lighting, and renewable energy systems, can help reduce their carbon footprint and contribute to carbon sequestration.

Fordhamopolis 7.0 Carbon Sequestration Methods

What is CLT?

The environmental performance of Timber has many advantages as a potential construction material within mass construction. Building green has been a large importance within the construction industry focusing on the environment and carbon emissions. Timber construction will be very important to the future of sustainability with it at the forefront of every design. Timber possesses numerous environmental characteristics that allow it to be considered as a renewable and sustainable building material. WIth proper harvesting of trees as a construction material, we can remove carbon from the air and attack the leading indicator of global warming.

Cross Laminated Timber (CLT) also known as massive or mass timber is an engineered wood panel that is capable of performing at the same level of other building materials such as concrete or steel. The material itself is extremely versatile and can be used in the construction of an entire building or a specific element. Because of its versatility it seems more favorable as opposed to other expensive or scarce materials, which involve skilled labor hours, and intricate design concepts. Because CLT is wood, it has caused many hesitations from owners, putting CLT on the back burner.



CLT is manufactured through an extensive process, with few key distinguishing steps that distinguish CLT from other timber building materials. CLT panels are arranged in a lattice pattern and checked for any defects in order to ensure the integrity of the panel itself. The panels are then arranged in layers oriented 90 ° from the previous. CLT panels are built with an odd numbers of layers in order to give the panel directionality A bonding agent is then placed on and between the layers and pressed together with pressure in order to ensure a tight bond. The panels are then again checked for quality control and packaged to ship.

Building Typologies

In regards to Fordhamopolis we will be using CLT in order to develop three different types of buildings: multi-family homes, medium mixed use structures, and large skyscrapers. Each of these structures are based off of existing CLT buildings around the world. We chose to use this for multiple reasons, one being the high strength to weight ratio which makes it a strong and durable building material that can support heavy loads especially when used for large numbers of people.

The small multi- family homes will have a design based on Fraser/Livingstone's mass-timber tenement style housing. The original development is located in the southside of

Edinburgh. It has a structural timber frame with exposed wood on the interior walls. Each structure could house a total of 5 residents per home. In total we anticipate building 8,000 of these buildings which would have a lancover of 100 m² per building and a total land area of 800,000 m². These buildings would house 40,000 of our residents.

The medium mixed-use buildings are designed based off of C.F. Møller Architects Kapstaden Tall Timber Building. The original development is located in Sweden and is the tallest mass timber building in the district of Kajstaden. The entirety of the building consists of CLT, including the walls, joints, balconies, and stairwells. The 9 story building would consist of a commercial space located on the ground level. In addition to that it consists of about 32 units of various sizes, housing roughly 50 residents per building. We anticipate 600 of these buildings with a total Land area of 498,000 m² and housing up to 30,000 residents.

The large skyscraper is inspired by White Arkitekter's Sara Kulturhus Center which is located in Skellefteå, Sweden and is one of the world's tallest timber buildings to date. The skyscraper consists of exposed wood on its walls, stairwells, and ceilings. The 75, tall skyscraper would consist of 20 stories and house roughly 250 residents per building. Fordamolpolis would consist of 120 of these buildings covering a total Land area of 168,000 m² and housing 30,000 residents. The skyscraper would also be used as an office building as well.

Advantages of CLT as a Building Material

By utilizing CLT as our main building material we can use it not only for its very effective structural properties but also its safety and serviceability characteristics. CLT is sound retentive due to the thickness and density of the material. This allows it to be very sound retentive as opposed to a normal stud wall, which could be ideal especially for residential space. Fire resistance is also an additional benefit of using CLT panels. CLT panels are less flammable than traditional wood building materials, due to its thick panels and the layering of the grains. This causes the panels to char as opposed to simply burning through completely. The thickness of these panels can also increase thermal performance and energy efficiency because it decreases overhead costs for owners and less of a need to have a central heating or cooling system running all year round. Some tests have shown that CLT panels are 10 times less conductive than concrete and almost 400 times less conductive than steel. This again is due to the density of the material creating a tight building material. The overall construction of CLT buildings also has a unique advantage since it is fabricated off site, making installation quick and easy. This calls for a less need for workers when building the actual structure but does provide more jobs for the construction of the CLT panels themselves. The cost efficiency of the material is very attractive to owners.

The costs are not only economical, but ecological as well. Overall building materials account for 11% of greenhouse gas emissions, with the production of one ton of cement resulting in about one ton of carbon dioxide. The manufacturing of CLT emits less carbon. Forests themselves are carbon sinks and trees remove the carbon dioxide from the atmosphere and transform it through photosynthesis. When a tree is used for building purposes it continues to store carbon within the structure. Because CLT is made of wood it can store carbon during the building's lifetime. Some research has shown that a hybrid, mid-rise CLT commercial building could provide a 15%-26% reduction in global warming potential, depending on the design of the building.

There are still a lot of advancements to be made in CLT however because of some drawbacks if not maintained correctly, but it continues time and time again to be a great alternative building material than traditional construction materials. Mass Timber and CLT construction is the basis of the construction of Fordhamopolis in order to combat carbon sequestration and surround the residents with a natural building material.

Mycelium and Hemp-Lime Insulation

In order to move towards a goal of low-energy buildings in which less energy is spent on temperature regulation, it is important to choose the most appropriate insulation. While there are currently insulations like expanded polystyrene, phenolic board, and rock wool which provide great insulative properties, these options have negative environmental impacts due to being non-biodegradable, having a high carbon footprint, and/or having little recyclability. By choosing carbon negative insulation options, it is possible to work towards both goals of low energy usage and carbon sequestration.

In the case of CLT construction, there are specific needs for its insulation. It is recommended in all climates that rigid external insulation (as opposed to flexible and/or internal insulation) be used with CLT. Placing insulation externally of the CLT panels allows for continuous insulation whereas internal insulation must break at the intersection of floors or internal walls to external walls or the roof structure. External insulation reduces these gaps and thus reduces thermal bridging, allowing for more effective thermal insulation. External insulation also provides a protective barrier for CLT, shielding it from the extreme temperatures which can cause damage via expansion and contraction of the CLT. External insulation can also regulate the humidity alongside the temperature to which the CLT is exposed, ideally keeping it in a slightly warm and dry state to reduce potential for microbial growth. It is also recommended that the insulation be mildly permeable to water vapor. While exposure to water should be avoided and mitigated, it is inevitable that the wood panels will come in contact in its lifespan. Insulation which is lightly vapor permeable allows the moisture to be wicked away and evaporate instead of holding the moisture in contact with the CLT where it can promote microbial growth and damage the panels.

One material that aligns with the needs of CLT insulation is mycelium. When dried, mycelium offers properties similar to polystyrene, a commonly used external insulation, so much so that it has already been implemented as a commercial alternative to polystyrene packaging. The tangled hyphae structures create many pockets of air, resulting in a lightweight material with great insulative properties. These hyphae are made up of carbon and sequester a large amount as they grow. Mycelium insulation is inexpensive to produce and can be produced easily in mass quantities indoors with little energy required. It is produced by growing a mushroom variety on a pasteurized substrate, which can utilize agricultural waste like seed hulls and husks which would otherwise have little use. Edible mushrooms are often a byproduct of the production process. After the growing process, the mycelium is dried and heated to a high temperature to stop microbial and eliminate further fungal growth. Mycelium can be used in many different applications, like faux leather and floor tiling, and the substrate composition can be altered to suit these different uses. The mushroom species can also be selected in combination with the substrate composition to create the needed qualities for insulation. Mycelium also boasts a naturally high fire resistance and only chars when exposed to flame, requiring no fire treatments.

In conjunction with mycelium, hempcrete, or hemp-lime, can be used as a protective finish. Hemp not only sequesters carbon as it grows, but it also helps to repair depleted soils. While limestone does emit carbon dioxide the production process to create lime, these emissions are reabsorbed as it sets, making it a carbon neutral material. Hemp-lime provides a waterproof finish while still being water vapor permeable, allowing the insulation and CLT underneath to breathe. The material is fully biodegradable and can be reused or broken down to be recycled. Hemp-lime is also resistant to mold, pests, and fire, making it a strong defense barrier for the insulation and CLT.

Although further research must be done to assess its interaction with water and how varieties and substrates can be tailored to produce optimal results, mycelium offers promising benefits of carbon sequestration, agricultural waste utilization, insulative properties, adaptability, and fire resistance. The combination of mycelium insulation and hemp-lime with the additional properties of CLT will help us build Fordhamopolis towards the goals of carbon sequestration and low-energy usage.

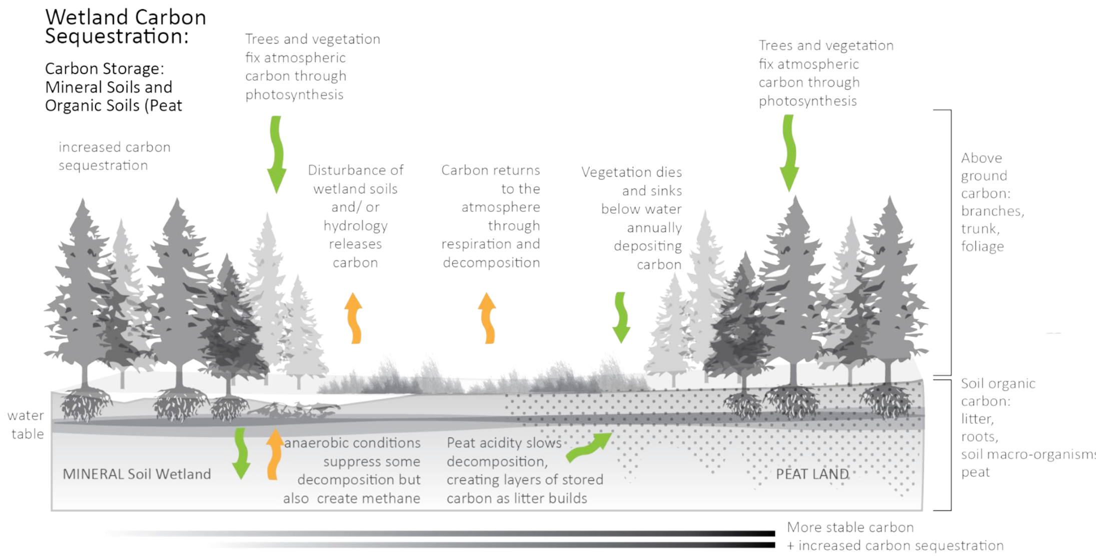
Reforesting the Black Swamp

Part of our early research included getting to know the geographic context of Fordhamopolis 7.0, which will be placed on the current site of Toledo, Ohio. Toledo was built at the delta of Maumee River on the western end of Lake Erie. Importantly, the city is within the Great Black Swamp ecosystem, which used to be a dense, frequently flooded hardwood forest. In the 19th and 20th centuries, the swampland was drained and turned to agricultural land.

Both the trees and bogs of this ecosystem would be extremely effective carbon sinks. Our intention is to not only reforest the surrounding land but to reflood the wetlands of the Black Swamp. That way, the swamp itself as well as the trees would remove carbon dioxide from the atmosphere and naturally store it.

Wetlands sequester carbon by slowing the decomposition of vegetation. As forest vegetation such as leaves, branches and other dead organic material fall to the ground and begin to decompose in a wetland, the decomposition process is anaerobic, which keeps carbon stored in the soil. In peat wetlands, this carbon sequestration process is even more stable, because the acidity of the soil builds many layers of organic material.

Soil carbon is highly present in wetland soils. In the United States, freshwater inland wetlands have been found to store up to ten times as much carbon as tidal wetlands and marshes (Nahlik and Fennessy, 2016). Reforesting the Black Swamp has the potential to sequester significant levels of atmospheric carbon, both in the trees and in the wetland soil.



The restoration of the Great Black Swamp will also aid our city in building resilience against flooding and sea level rise. The location of Fordhamopolis is on Lake Erie, which is part of the North American Great Lakes system. The Great Lakes are expected to rise in water level by half a meter by 2050, which is anticipated to drive coastal flooding. By returning the forest to a wetland, the forest will be able to accommodate floodwaters and divert flood impact away from the urban settlement (including housing, streets, infrastructure and more, which would otherwise be at risk for destruction).

Floodplain management has become an increasingly popular urban resilience planning strategy because it allows water to flow freely rather than always forcing it into manmade infrastructure. Floodable plazas, parks, fields, and forests have been designed to accommodate water and allow it to flow away from other areas of the city. For example, Aranzadi Park, a floodable forest park in Pamplona, Spain, was designed to accommodate the river’s regular flood pattern.

This way of managing floods is less resource and energy intensive than dams or floodwalls, along with allowing for carbon sequestration in the soil. It also resonates with the urban ecological history of the location. In the case of Aranzadi Park in Spain, residents expressed less fear of flooding, and began to think of it as a natural ecological process that is part of the life of their city.

In Fordhamopolis 7.0, the restoration of the Great Black Swamp will allow for an improved, deeper relationship between city residents and the regional ecology. The swamp, as well as the Great Lakes, was formed by glacial retreat during the last Ice Age. The land is extremely flat in the region. Because of the decomposition process that was supported by the wetland, the swamp's soil was also very nutrient rich. As a result, European settlers chose to deforest and drain areas of the swamp to convert to farmland, although eventually the soil would prove not very well suited to agriculture.

Today, organizations such as the Black Swamp Conservancy have campaigned to protect and restore areas of the swamp, both for reforestation of the region but also to improve the water quality through the swamp's filtration capacity. This strategy is a response to toxic algae blooms in the river and lake which have been a chronic threat to Toledo's water supply. Although our Fordhamopolis 7.0 plan includes alternative rainwater harvesting infrastructure, we recognize the importance of protecting the region's water for resource and recreational purposes. The reforestation of the Black Swamp will also support residents of Fordhamopolis to safely spend time along the river and waterfront of their city.

Major tree species that are native to the Fordhamopolis region are walnut, maple, cottonwood, ash, elm, and giant oak. We plan to sustainably manage the forest and grow these tree species alongside species of pine, hemlock, spruce, and fir, which have been found to be more suited to CLT manufacturing (Redmore, 2022). By combining native tree species with CLT-suitable species, we will reforest the area surrounding the city in a way that will enhance and restore native biodiversity.

Pillar II: Food Production

Introduction

Author of *Fate of Food*, Amanda Little, sheds light on the impact food has on the environment. With food production using up 71% of our water usage and one-third of our land usage, it is truly astoundingly painful to know that Americans waste enough food to fill a 90,000 seat stadium everyday with 30% of food waste generated by individual households. Current agricultural systems are extremely inefficient and lead to intense soil degradation and erosion, eutrophication, and extreme water usage. Due to these detrimental prospects of our current food production systems, our team aims to solely use sustainable agriculture in our food production. Sustainable agriculture can be described as the practice of growing food or other crops within a city or urban area, using environmentally sustainable methods and technologies. This type of agriculture aims to provide a local, decentralized source of produce, reduce the environmental impact of food production and transportation, and increase food security within urban communities.

With this in mind, the task of the food production team is three fold. Firstly, we must change the techniques currently used in farming practices (largely pioneered by large agribusinesses) to mimic our ecosystems. Secondly, the social and cultural aspects of food consumption must shift towards a less indulging mindset and towards a more communal and healthy one. Lastly, although the ultimate goal is to become zero waste, we must develop ways to return *all* of our waste back to the soil. Our food production system will be a cyclical multidimensional system that would not only revolutionize production methods but also rethink our interaction with food. These three goals of the urban agriculture team will aid in creating a sustainable production system that will supply nourishment for all citizens. Our utilization of sustainable agricultural practices will provide food security, environmental sustainability, and social equity to our community.

In this section, we will explore the importance of nutritional diversity, highlight our 8 sectors of food production, and finish off with our plans for waste management and the social aspects of sustainable agriculture. We will also discuss the significance of creating sustainable and diverse sectors to address the relationship between food production and societal health. Through our research, we hope to discover a stable framework for environmentally sustainable agriculture that can be used both by our Fordhamopolis society and future sustainable civilizations.

The 8 Sectors

As exemplified by the COVID-19 food supply shortages that devastated cities that relied on global imports for food, dependency on global supply chains can create an unstable supply of food for communities. Decentralizing food systems and focusing more on localized farming can combat this unstable foundation, and has been proven to be beneficial in a number of ways for communities. (Manning). With localized production, cities will be able to have accessible food supplies, have a stronger foundation for possible disasters, and provide better food security for their inhabitants. Through examining this study, our team made the ultimate decision to create 8 different sectors of our farms rather than one large location — providing that stability and accessibility our community will need. We also wanted to provide a deeper connection between the community and food production. With the 8 locations of the Fordhamopolis farms, locals will be able to visit our locations easily, as well as feel more connected with the food that they consume.

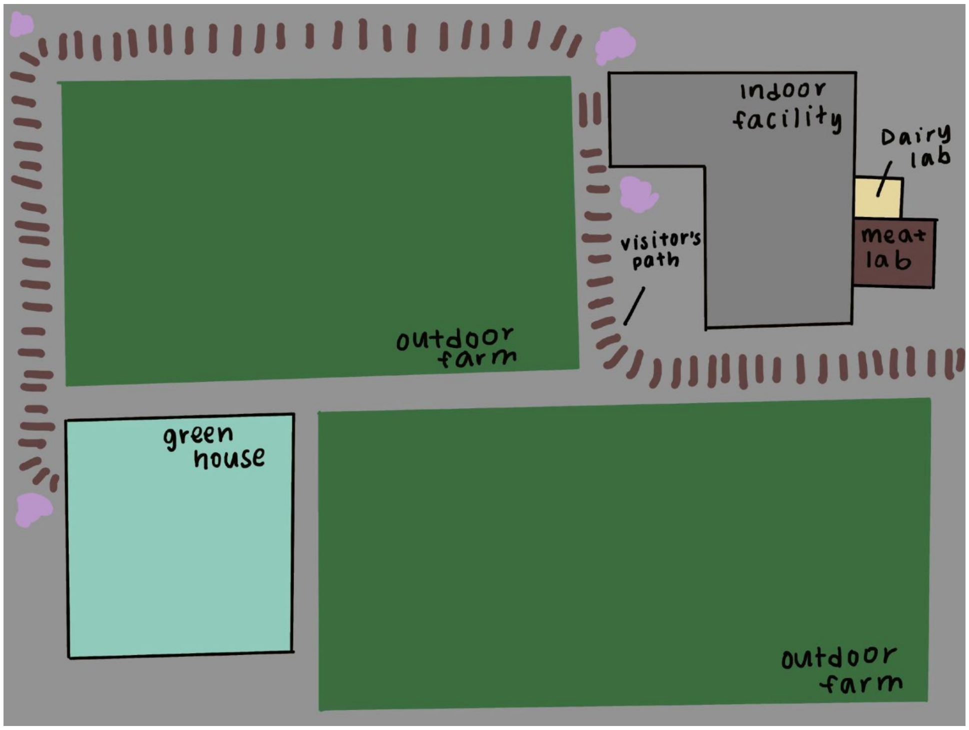


Fig. 1 — The Layout of Each Sector

For Fordhamopolis' agriculture and food production, we will possess a total land area of 2,100 acres at our disposal, allowing each location to operate on 262.5 acres. The farm layout will be standardized across all sectors, each featuring a greenhouse, indoor section, and outdoor area. (Fig. 1). Our indoor farm will primarily focus on cultivating lab-grown proteins, along with a diverse range of microgreens, herbs, and aromatics that thrive in controlled conditions. Additionally, our composting facility will be located within our indoors section. In our outdoor area, we will prioritize crops that are challenging to nurture indoors. This will include field crops, fruit trees, and berries, that will thrive better within the open environment. As for the greenhouse section, produce such as tomatoes, cucumbers, peppers, and an assortment of leafy greens will be grown. The greenhouse provides the ideal conditions for such crops to flourish, ensuring optimal growth and productivity. All of the crops produced through each farm will deliver their crops to the location's nearest grocery, and because we will have 8 different sectors equally scattered throughout the city — transportation to deliver the produce will be minimized.

Calculations

The dietary statistics of 2020-2025, as detailed by the U.S. Department of Agriculture and the U.S. department of Health and Human Services, it is recommended for the average U.S. adult to consume around 2,000 calories per day. From those 2,000 calories, 1.5 to 2 cups of fruit, 2 to 3 cups of vegetables, and 13.5 servings of grains are recommended to promote a healthy diet for an average adult. (USDA).With that in mind, the following calculations (reference Equations 1-6) detail the amount of food that our farm will need to produce in order to sustain our population of 100,000 people, per month.

Equation 1 — Calculating the amount of produce needed a day for one adult.

$$(2\ cups\ of\ fruit/1\ day)\ +\ (3\ cups\ of\ vegetables/1\ day)\ =\ 5\ cups\ of\ produce\ a\ day$$

Equation 2 — Calculating the amount of produce needed per month for one adult.

$$(5\ cups\ of\ produce/1\ day)(30\ days)\ =\ 150\ cups\ of\ produce\ a\ month\ per\ person$$

Equation 3 — Calculating the amount of produce needed for a population of 100,000 people.

$$(150\ cups\ of\ produce/1\ person)(100,000\ people)\ =\ 1.5\ million\ cups\ of\ produce\ per\ month$$

At least 1.5 million cups of produce will be needed per month in order to sufficiently feed the Fordhamopolis population while following the HHS and USDA guidelines.

Equation 4 — Calculating the amount of grains needed a day for one adult.

$$(13.5\ servings\ of\ grains/1\ adult)(1\ day)\ =\ 13.5\ servings\ of\ grains$$

Equation 5 — Calculating the amount of grains needed per month for one adult.

$$(13.5\ servings\ of\ grains/1\ day)(30\ days)\ =\ 405\ servings\ of\ produce\ a\ month\ per\ person$$

Equation 6 — Calculating the amount of grains needed for a population of 100,000 people.

$$(405\ cups\ of\ produce/1\ person)(100,000\ people)\ =\ 40.5\ million\ cups\ of\ produce\ per\ month$$

At least 40.5 million servings of grains will be needed per month in order to sufficiently feed the Fordhamopolis population while following the HHS and USDA guidelines.[1]

[1] *All calculations are approximations.*

The Indoor Facility - Aeroponics

As stated previously, our indoors section will be growing microgreens, herbs, and aromatics — produce that require a more controlled environment in order to grow. After reading through different case studies, our group came to the conclusion that the use of aeroponics will be the best choice in order to grow the crops indoors. Aeroponics is a variety of agriculture that had gained popularity in the late 1990's, when the National Aeronautics and Space Administration (NASA) began looking into aeroponics as a possible option for growing crops in soilless environments. (Keller). The term aeroponics, directly translates to "working air", as this form of agriculture relies on the use of air to deliver mist to the plant's roots. By adopting the use of aeroponics, we will eliminate the need for traditional soil-based cultivation for these specific crops — thereby maximizing our space efficiency and resource utilization. Aeroponics systems are also extremely water efficient, using 95% less irrigation than plants that are grown traditionally in soil. (Barth). Additionally, because aeroponics systems are fully enclosed, there will be a lack of nutrient and fertilizer run-off to nearby waterways — eliminating the possibility of water pollution. Furthermore, the closed loop system will allow for any excess water to be collected and recycled, as aeroponics systems have a water-collection apparatus that closes the system and loops the water through (See Fig. 2). The produce sector for the indoor facility will be divided into designated growing areas in order to ensure sufficient space between each section for easy access, implement the use of vertical space in order to maximize the number of produce grown in an area, and group crops with similar grow requirements.

The benefits of an indoor sector is the ability to develop specific controlled environments for different crop groups. For example, various microgreens of broccoli, radish, mustard greens, and micro basil can all be grown under the same type of environment; therefore, will be placed in the same section of the facility. Our farming system will grow the produce using light foam for the seeds placed on lightweight trays that will easily stack and make use of the vertical space (see Figure 3).

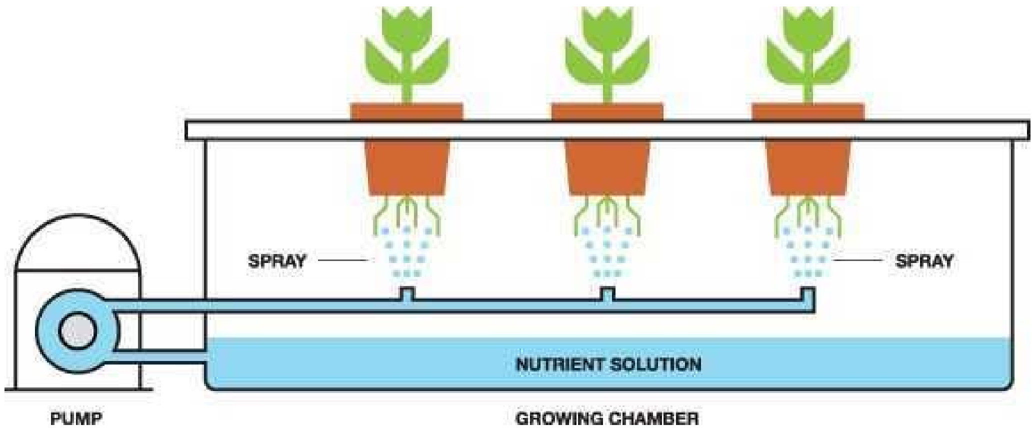


Figure 2 – Diagram of a Basic Aeroponics System.

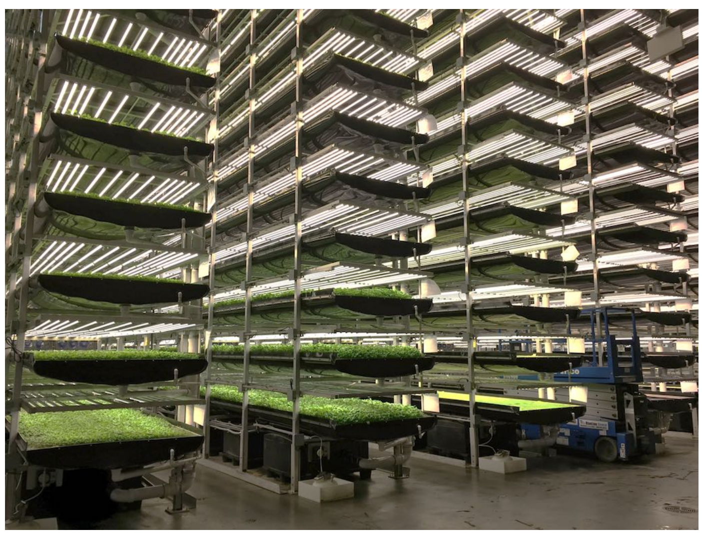


Figure 3 – Stacked Tray Example From Aerofarms.

Indoor Facility - Meat Production

When we were first developing our agriculture techniques we failed to consider the nutritional need for individuals who need meat to stay healthy. Lab grown meat has gained a ton of traction in recent years with many people debating how safe or legitimate it is. While more research needs to be done on efficiently and safely producing lab grown meat, we thought it was worthwhile to implement lab grown meat in our city's food system. The process of cultivating lab grown meat is relatively simple in theory; however, in practice there are many details to consider. Firstly, small tissue samples need to be extracted from live or dead animals. Many types of stem cells can be extracted from these tissues with myogenic satellite cells being the most preferred for meat cultivation–however other types of cells can be used as well. The cells are then placed into bioreactors that feed the cells a growth serum mixture of proteins, fats, hormones, vitamins, minerals, and water. Since it is not currently possible to cultivate whole cuts of meat, the ingredients will vary depending on the part of the meat that is being cultivated (skin, muscle, fat, or bone). The final step is scaffolding to form a structured piece of meat. (Ching).

It is estimated that a single tissue sample can cultivate approximately 1000 kg of meat in just 2 to 8 weeks. (Ching) According to the United States Department of Agriculture Dietary Guidelines recommends 23 to 33 ounces of meat intake per person every week. (Dietary) If every single person in our city of 100,000 people consumed around 30 ounces of meat every day we would need approximately 187,500 pounds of meat every week. Last year, the California based company Good Meats announced the beginning of constructing the world's largest meat cultivation facility in the United States. It will have ten bioreactors that are 40 feet tall and can hold up to 250,000 liters and claims to produce 30 million pounds of meat every year. (Leffer) (Ramirez) This would be the equivalent of 2,207 square feet taking up as little as 0.000024% of the space designated for food production in our city. With a facility of this size, we could produce the entire city's meat needs for more than three years.

The environmental, social, and health benefits of lab grown meat would be immense. Our current animal agriculture methods are inefficient due to the fact that 36% of crop production is used for animal feed and only 55% of it is directly consumed by humans. (Cassidy) Animal agriculture accounts for 15% of global greenhouse gas emissions and contributes to biodiversity loss, eutrophication, and deforestation. Lab grown meat would reduce land and water usage by 99% and 96% respectively. (Ching) Not only would lab grown meat reduce our environmental impacts, it would also prevent the human rights abuses to indigenous peoples around the world that are often the victims of land grabs that lead to their displacement and destruction of their livelihoods. Additionally, cultivating meat without the slaughter would reduce the atrocious conditions of factory farming and be far more ethically sound in the treatment of non-human animals. The citizens of our cities would be able to meet their nutritional needs without the guilt of environmental destruction, human rights abuses, and non-human animal abuse.

Indoor Facility - Dairy Production

To continue the conversation of the consumption of animal products, we have also considered dairy products. Although dairy is not necessary to meet our nutritional needs, it is a huge part of our food culture–the United States loves cheese and ice cream. Cow’s milk is also used to produce baby formula for people who have children and are unable to lactate. The solution? Cow-free milk.

To produce cow-free milk we need to produce whey protein–the protein found in cows. The DNA sequence of this protein is readily available and is 3-D printed using synthetic nucleotides. It is then mixed with micro-floral that adopt the whey DNA where they multiply before being fermented with sugar, vitamins, and minerals which create the actual whey protein. The whey protein is treated like a normal ingredient to create all sorts of dairy products. (Can Lab-Grown) The company Perfect Day, who is pioneering this endeavor, claims that their process uses 91% to 97% fewer greenhouse gas emissions, 60% less energy, and 99% less water. (Houser) Utilizing this method to produce dairy products would be revolutionary in reducing the harm associated with traditional dairy farming practices.

However, it is crucial to keep in mind that transitioning dairy production methods is not the only solution. According to a study conducted by the USDA, “The average American consumed 667 pounds of dairy on a milkfat basis in 2021 versus 539 pounds in 1975 when data was first established.” (American Dairy) This massive consumption growth of dairy products is not only unnecessary to our nutritional needs but also contributes to the growth of the harmful and inhumane dairy industry. Part of our solution is also changing our relationships with food and changing the way we interact with it which we will get into later.

Outdoor Facility - Three Methods

We decided on three methods of farming our produce and microgreens for the outdoor portion of our farm: Permaculture, Crop Rotation, and Regenerative Gardening. Unlike traditional agricultural techniques, the permaculture approach will enable us to produce large yields and high production levels. Instead of fighting nature, we will cooperate with it and leave the bulk of the work to it. The idea of permaculture is to collect resources like solar energy and rainwater to reuse over and over. We can use the many renewable resources found in nature and combine the following techniques with the prevalent permaculture ideology. First, provide a separate section for each crop to get along with its neighbors. Second, use trees in farming practices to boost soil fertility and biodiversity. Third, companion planting is growing two or more beneficial plant species together, such as plants that fix nitrogen and plants that need nitrogen. Lastly, crop rotation helps keep the soil healthy and prevents the buildup of pests and diseases. Finally, natural predators and repellents are used instead of chemicals to control pests. Numerous fruits, including those that are simple and fast to grow, like tomatoes and cucumbers, will be produced using this technique. Permaculture farming aims to maintain a thriving ecosystem while creating a self-sufficient and sustainable food production infrastructure.

Crop rotation, the most popular technique for growing vegetables in agriculture, should be considered next. We grow vegetables in varied places yearly to avoid the buildup of pests and illnesses and let the soil resupply the various nutrients each crop requires. A three-year rotation, for instance, is used in several popular crop rotation plans where the property is divided into three fields. A cereal crop (like wheat, corn, or barley) is grown in one field, a legume crop (like peas or beans) is grown in another field, and a third area is either left fallow or planted with a cover crop. This approach uses rotation to divide the land into seven fields, each growing a different crop in a planned sequence. This technique produces good crops of corn, wheat, potatoes, etc.

Finally, by focusing on replenishing the nutrients in the soil, regenerative gardening improves soil health, agricultural yields, water resilience, and nutrient density while also enabling our plants to capture and store carbon from the atmosphere in the soil. Regenerative gardening emphasizes improving the health of the soil while eliminating the usage of synthetic fertilizers and pesticides. Various plants in the garden sustain one another and provide wildlife with a habitat that mimics the natural environment. Regenerative gardening methods can be used to grow nuts, herbs, fruits, and vegetables. Vegetables like peppers, squash, and berries are some examples of common crops grown using this technique.

The Greenhouses

We intend to put eight greenhouses into operation for our outside farming. The best greenhouses for growing crops all year round are those that are diffused with coverings. The most significant advantages will come from a greenhouse built with a clear side covering and diffused roof covering. Another important consideration for the greenhouse throughout the summer is UV protection because sunlight eventually degrades plastic. The greenhouse framework and glazing should be UV-treated for the most extended possible lifespan; when building greenhouses, we look for UV-certified materials. Our greenhouse covers feature an exterior UV coating that must always be kept safe. The greenhouse's covering material will be durable enough to withstand potential risks in our farming area without breaking. The covering will withstand falling branches if we plan to grow trees nearby. It will have enough impact strength and resist hail and other storms. The greenhouse roof will be sturdy enough to withstand any occasional winter snowfall that we may have Our greenhouse will, include traditional peaked roofs, hexagons, and geodesic domes. The shelving inside will be arranged to work with our planting style and kind. For seedlings and establishing starter plants, shallow shelves work best; for mature plants, greater shelf spacing is required, and overall this is an excellent way for us to grow our microgreens and other herbs all year.

Community

What we've identified as a fundamental factor for our food system is the idea of community. Sure, we can have aeroponic farms in every building and mass produce it so anyone can access it; but, if we are really going to make significant environmental and social change that fundamentally shifts our relationship with the earth we need to be able to *work together*. The 8 different sections of our farms are meant to facilitate human to human interaction and human to earth interaction. One can think of it as a large community farming initiative that aims to achieve the benefits of community gardening on a much larger scale. Part of our goals with our food system is reducing our intake of meat and animal products and increasing the consumption of nutritious foods. Studies have shown that community gardens for youth and adults have led to an increase in the consumption of more fruits and vegetables. (Freedman) Our farms aim to achieve this goal through educational programs all around the city that would be a requirement of our school curriculum as well as open access to all citizens to help with the farming process. Full time managers, educators, and farmers would be the foundation of these programs. The curriculum includes nutritional science, agricultural techniques and practices, artistic and spiritual projects to build connections with mother earth, as well as environmental sciences. Managers are in charge of facilitating relationships across the city, ensure access to the farms for schools and all other citizens, and promote participation. These programs work to increase nutritional knowledge, aid families in meal planning, and foster better environmental attitudes.

Other studies on community gardening determined that they, "successfully bring together people of different races and other people who would not normally socialize [and] found that the multiple social processes (e.g., mutual trust, reciprocity) fostered during participation translated into situations outside of the community garden setting, and other studies found that the relationships formed led to a stronger overall sense of community…" (Freedman) The current state of our societies is evermore isolated, bigoted, and hopeless which has largely contributed to fatalistic attitudes about the environmental crisis–we cannot afford to repeat the mistakes of the past. Our farms would serve to heal these wounds and mitigate future social crises by acting as a community epicenter. It'll create reciprocal relationships. It'll know the people. It'll create the foundation of a democratic system and prevent individuals from exploiting corruptive power. However, to ensure accessibility, neighborhoods in the city would have direct public transportation routes to our farms. This is so that all citizens have the opportunity to participate in the community.

Waste Management and Compost

Sustainable food management depends on reducing food waste; however, managing food waste has several challenges. The approaches listed below are the most effective in our setting. Composting is a natural process that converts organic waste into nutrient-rich soil. Every week, a trash collection vehicle will pick up compost from each community's composting facilities and transport it to be reused using the following composting techniques. The first type of composting is food composting. In addition to enhancing soil health and lowering the demand for chemical fertilizers, it is an efficient approach to reducing food waste. Another type is anaerobic digestion, which turns organic waste into fertilizer and methane. As biogas has the potential to be a renewable energy source, this method of managing food waste is sustainable. Although the two may have a similar meaning, there are several variances. The most significant difference between the two is that composting creates a stable, prosperous soil procedure called compost. In contrast, anaerobic digestion turns liquid and solids rich in nutrients into a mixture of methane and carbon dioxide through the bacteria transformation in organic wastes, including animal feces, food scraps, and water waste.

Composting toilets at first encounter seems repulsive, but so does everything else we haven't tried. For our city, we will be using active composting toilets. The toilets look pretty similar to your standard flushable toilet but instead they don't use water to transport the waste into a sewage system. Rather a large compartment located at the bottom is used to hold the waste. Once there is waste in the compartment, a carbon rich substance, like sawdust, is added on top to prevent odors and begin the decomposing process. Active composting toilet systems sometimes have a fan and heating system to further reduce odors and also create adequate conditions to compost. (Vartan) However, in order to centralize our composting facilities we would need the infrastructure to efficiently collect the waste. We were inspired by a container based composting sanitation pilot program started last year in Santa Cruz, California. The households participating in this pilot program individually collect their secretions into sealable composting toilets that are then picked up on a weekly basis and transported to a centralized facility. (Hattis) Although this program has just started, we believe Fordhamopolis is the perfect place for a large-scale program like the one in Santa Cruz. Every residential unit in our city would have a sealable active composting toilet installed in their bathrooms. Every week the household would remove the container, transport it to their building's waste collection site–just like we take out the garbage–where they will be picked up and transported to a central facility. Cleaned compartments would be reinstalled and used until the next pick up date. The composted fecal waste then can be used as fertilizer in our outdoor farms and in-door greenhouses.

Aeroponics *need* fertilizer because of the lack of soil nutrients. Phosphorus and nitrogen fertilizer, however, is commonly sourced through mining. Although aeroponics use of fertilizer is much more efficiently used than traditional monocrop farming methods, it's still important to consider other ways of sourcing fertilizer. Human urine is a huge untapped resource of nitrogen and phosphorus. Human urine accounts for 1% of waste water but accounts for 80% of the nitrogen and 50% of the phosphorus. (Simha) In fact, using human urine as fertilizer is an ancient practice that is being resurrected by people in Asia and Niger. (Koumoundouros) Scientists are working on ways to turn human urine into solid fertilizer through a process called alkaline urine dehydration. The technique involved raising the pH of the urine by using calcium or magnesium hydroxide so that as it goes through a heating chamber, only the water is evaporated and the nutrients are left behind. (Simha) Fordhamopolis can tap into the ancient potential by also including separate toilets in bathrooms for urine only. The urine would be transported via sewage systems and used to create fertilizer for our aeroponic farms.

Conclusion

Our food production plan addresses multiple angles of interest and issues. We've tackled the unsustainable practices of current methods of agriculture by utilizing new technologies and forgotten farming practices. We've looked at the social aspect of urban agriculture through the implementation of educational and social programs as well as the strategic physical placement of our farms. Lastly, we've addressed the three main ways the city would produce waste and how we can not only mitigate them from landfills, but also utilize them for food production by creating a closed loop system. It is our hope that all cities can look at the issue of food production and waste management through these three lenses.

Pillar III: Rainwater Harvesting

Water Harvesting

Water is perhaps the most essential resource for all life forms. Pure, safe, access to water is arguably, and legitimately, a natural human right. The Anthropocene has led to a war on water, as clean sources dwindle, people and nations are mobilizing to compete for freshwater access. The ongoing issues of water insecurity are multifaceted at the global and local levels. Globally, rapid climate change and agriculture are manipulating entire ecosystems, causing water to dry up in places that have never before experienced droughts, and to overpour into places not formally equipped for such high levels of precipitation. Locally, point and nonpoint pollution runoff, toxins, and inefficient irrigation systems are contaminating and extracting clean water at much faster rates than water can recycle back into ecology. The current societal methodology of water extraction and accessibility is underdeveloped and unsustainable. The goal of Fordhamopolis is to reorient society's water system to run efficiently, sustainably, and in line with the planet's water ecological cycle.

Fordhamopolis 7.0 is in a unique position, as the chosen location was meant to be a challenge –to emphasize how sustainable cities can be implemented in a diverse range of environmental conditions. Residing, hypothetically, at the current location of the city Toledo, Ohio, Fordhamopolis 7.0 rests on the shores of Lake Erie, the smallest, shallowest, and arguably most contaminated of the Great Lakes. While Fordhamopolis has the distinct advantage of being located next to this great natural resource, it is important to take note of the complications and disadvantages that Lake Erie will contribute to our city. To understand these limitations, we must first understand Lake Erie.

Compositionally, Lake Erie gets its water from three sources. Approximately 80% of Lake Erie's water comes through the Detroit River, a 28 miles river that stretches from Lake St. Clair to Lake Erie. At this juncture, it is important to note that much of the land that encloses the Detroit River is urbanized. As a result, water pollution is high. The Detroit River has a long history of shipping and industrialization and in the 1950s, 60s, and 70s, served as a dumping ground for toxic materials and pollutants. In 1987, the river was given the designation of an *Area of Concern* by the Environmental Protection Agency. As of 2019, The Environmental Protection Agency (EPA) estimates that there are still between three and four million cubic feet of toxic sediment in the river and despite a concerted and aggressive effort to clean up, it is estimated that the river will still contain an unsafe level of toxins beyond the year 2025.

In addition to the Detroit River, Lake Erie gets another 11% of its water from precipitation in the form of rainwater or snowfall. Beginning in 1998, researchers and scientists of the NOAA Rise Team began noticing sharp declines in water levels. In a seventeen year span following this notice in the decline of water levels, Lake Erie experienced warmer temperatures, low ice levels, and increased amounts of evaporation. The state of Lake Erie again began to drastically fluctuate in 2014, when water levels increased. As a result, water temperatures decreased and ice coverage increased. Lake Erie's water problems do not stop there.

Excessive phosphorus pollution induced by agricultural runoff has led to the overgrowth of thick, often poisonous algae mats, which then leech into the public's water supply. Algae threats harm ecosystems, and the freshwater supply of an estimated 12 million people in the United States and Canada combined. Even more, algae can persist for weeks in the summer because of wind and/or water currents that run eastward through the lake. Almost each new year record-setting algal blooms and associated "dead zones," i.e. oxygen depleted areas created when algae die, are documented along Lake Erie.

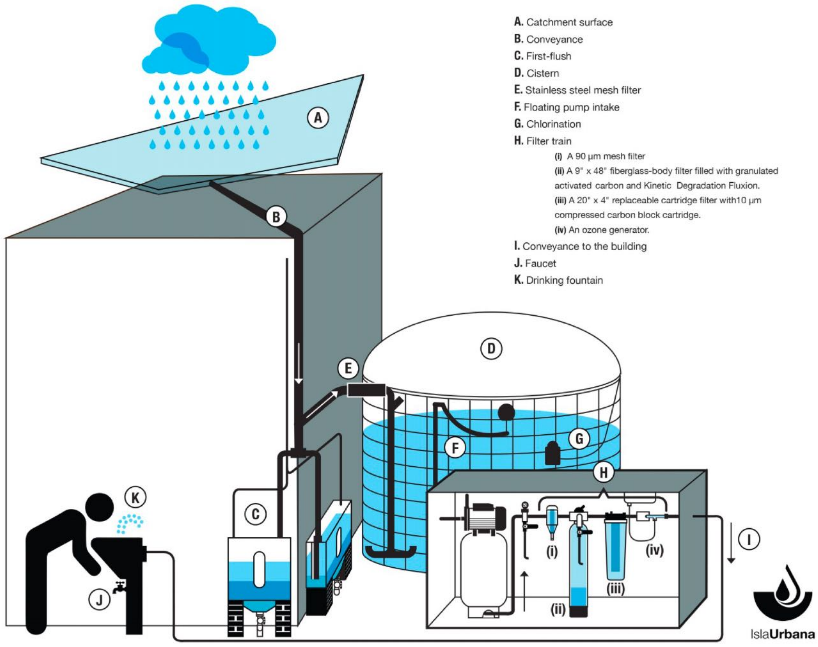
The issues of both the Detroit River and Lake Erie exemplify the need for Toledo to metamorphosize its current water system. Fordhamopolis 7.0 hopes to create a feasible, sustainable water system that removes itself from the anthropogenic spiral currently fueling the freshwater crisis. By instilling a decentralized, cyclic water structure, Fordhamopolis 7.0 residents will be free from fear of water contamination and of the economic costs associated with water complexities.

One of the most effective and sustainable ways to harvest water is through rainwater capture. This is simply a method of collecting all the rainwater in any given season, cleaning it through a filtration system, and then piping it for use throughout a house or municipal building for any water necessities. Because rainfall precipitation occurs in most environments, it is easily feasible to establish in most locations. Thus, the concept of rainwater harvesting can be mobilized and/or copied in most city designs.

Humans currently demand and use inordinate amounts of water, especially in the western world, to fulfill unrealistic lifestyle needs. Such misuse has led to a planetary dysregulation from the natural water cycle, which has led to decreased freshwater accessibility, and increased contamination. Water contamination is a major global problem; it is both a public health and economic crisis. For instance, in Toledo, in 2014, over half-million city residents lost water access because of severe contamination wrought from agricultural pollution runoff. Disorganized governmental systems are not equipped to handle such swift and problematic water contamination issues, leading to contention with victimized communities and an overall health crisis.

Rainwater harvesting alleviates the overcomplexities of water politics, and is a more efficient and sustainable water source. Even in locations, like Toledo, that lack an overt supply of rainwater precipitation, a balanced system that incorporates rainwater harvesting will optimize water management. Accordingly, rainwater harvesting will be the primary method of water capture in Fordhamopolis 7.0. The system will build off of itself, accumulating more water as time goes on. Such a closed system will be able to, ultimately, fulfill the cumbersome water needs asked by most of the western world.

The method of rainwater capture is fairly simple. This is a system that will capture, divert, and store rainwater for later use. The collection of rainwater most commonly occurs on rooftops and gutters, as the water trails off and diverts into a storage system for filtration and cleaning. This system can also be implemented on other buildings, such as offices, and/or buildings specifically designed for rainwater capture. Rainwater collection tanks will be situated on the rooftop of every building, structured to scale relative to each building's perimeter size. The water will first enter the collection tank, will be diverted into a cleaning/filtration tank, and then piped for use, or diverted again into a reservoir system located beneath each building respectively.



The filtration of the water depends on the water's final destination. Water delegated to plumbing and agricultural needs will undergo a less intensive filtration system than water allotted for consumption. Accordingly, the filtration system is robust as the water gets used for many different commodities that include sinks, showers, and tap water. Non-intensive water purification can often occur in a two-step process.

First, the water must be properly filtered to remove any solid particulate matter. Secondly, the water will be exposed to UV light for total purification –killing any harmful microorganisms or viruses. Post UV filtration, the water will be free to consume. After the water is thoroughly cleaned it is then diverted into a storage tank, where it will sit until the household is in need. Notably, the rainwater harvesting system is particularly unique as it is managed by the user. Thus, Fordhamopolis 7.0 residents will be required to learn about self sustaining water management and to operate their own water system at times. Nonetheless, the upkeep of the rainwater harvesting system is minimal, and will likely provide a joyous connection to nature.

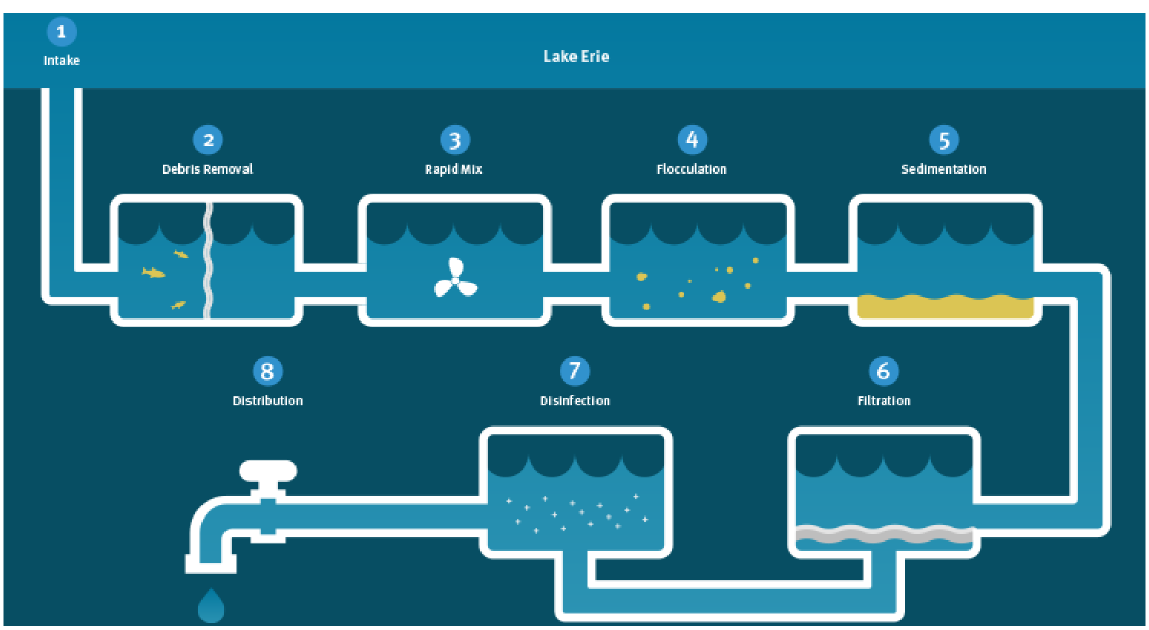
Applying this rainwater harvesting system to Fordhamopolis we must take into account the levels of rain the area of Toledo, OH receives on a yearly basis, as well as the square footage Fordhamopolis will inhibit. The city of Toledo, OH receives approximately 33.5 inches of rain a year. The city of Fordhamopolis is approximately 27,878,400 square feet or 1,466,000 meters squared. Researching both of these facts allows for our team to estimate exactly how much rainwater can be gathered yearly in Fordhamopolis and then be able to adjust how much water will need to be gathered in other areas in order to sustain the entire city.

The amount of water secured from any given area can be calculated by the formula: 1" of rain multiplied by 1 square foot will give the storage tank approximately .623 gallons of water. Taking those figures and applying them to Fordhamopolis, we will be able to capture around 1,594,072 gallons of water per day or 581,836,147 gallons of water per year.

While this is a large amount of water to contend with, the city of Fordhamopolis inhabits 100,000 people. Each multi-family house needs around 5,800,000 gallons of water per day, medium mixed-use buildings will need around 10,500,000 gallons of water per day, and large skyscrapers will account for around 52,500,000 gallons of water per day. Overall, the needed water in Fordhamopolis will be approximately 68,960,000 gallons per day. This means that rainwater harvesting will only account for around 2.3% of the water consumption within Fordhamopolis.

Although the rainwater capture system is fairly simple, it does rely on how frequent rain comes to any given area. So in this way the entire system can be unreliable. Due to this factor, and to the low level of rainfall the area of Toledo, OH receives yearly, our team has looked at several other water capture systems to include within Fordhamopolis as well.

Another system that we will seek to utilize is that of Lake Erie itself. We will seek to create a decentralized, renewable, long term treatment system that will be able to supply clean water for the residents of Fordhamopolis. At this moment in time, the system for water treatment in Lake Erie is a fairly centralized, eight step process. (See diagram below.) We will seek to establish several additional water treatment intakes in the lake to create a decentralized system of a multitude of options. By making this system redundant, our aim is to create a long term, resilient methodology, which will lead to the long term survival of our city. Our ethos remains the same throughout all approaches to Fordhamopolis 7.0, especially with regards to Lake Erie. Our long term goal is to create an equitable city, where environmental consciousness is at the utmost forefront of our society. With this in mind, we will seek to live in conjunction with nature, with Lake Erie. We must begin to shift our notions and beliefs about natural resources. We are not the only species that depend on the lake, and as so, we must endeavor to do no harm to it and its supporting ecosystem.



Our goal for Fordhamopolis' long term water sustainability will not neglect the great natural resource that is Lake Erie. In order to be able to take full advantage of Lake Erie, our team will undertake the task of combating the various pollutants that often render the lake unsafe for any use. It is important to note that according to the EPA, Lake Erie is more directly impacted by urbanization and industrialization than any of the other Great Lakes. Our team wants to change this existing view of Lake Erie. Yes, the Lake provides incredibly important services to the surrounding economies, generating an estimated $12.9 million in annual revenue, but we have reached a point where dollars and cents must come second.

The contamination of Lake Erie is very much a humanitarian crisis. Our efforts, longterm, will be to effectively change the entire Lake Erie region, shifting the perception and placing the value of the region well beyond the financial uses. We believe it possible to create a more sustainable and equitable Lake Erie, while also maintaining its status as a major stream of revenue for the people surrounding the lake. Moreover, the health defects brought on by Lake Erie's contamination will neutralize any economic gain acquired agriculturally.

Fordhamopolis 7.0 will be open to innovative, feasible technologies to help reduce Lake Erie's algal pollution. For instance, creative inventor Rob Falken, stationed out in California, extracts toxic algae and manufactures it into foam used for sneakers and/or yoga mats (see diagram below). His company, Bloom, has helped reduce the pollution effects of agricultural runoff in California, in a noninvasive, profitable, and sustainable way. Fordhamopolis 7.0 is highly interested in endeavors like Rob's, that develop materials in alignment with nature. Moreover, specific to Fordhamopolis 7.0's water, the filtration process will result in abundant algae left-over from Lake Erie's irrigation. Therefore, mobilizing such algae to recycle back into the city's ecological system is pertinent. It is likely that many materials will be made out of leftover algae, which will help reduce the overall pollution contamination of Lake Erie itself.

Overall, there are many different ways of water harvesting that create safe and sustainable ways to live. Although our team was only able to research three options, there are many more that can create similar lifestyles. Creating a sustainable water source, while time consuming at the beginning, creates an invaluable resource for years to come. This is an easy way to create a sustainable lifestyle for those living in Fordhamopolis.

Pillar IV: Renewable Energy

Introduction

Energy is an incredibly important aspect to any city existing today for transportation, communication, food production, and more. It is essential for everyday, mundane things as well, such as lighting and technology. Not only does Fordhamopolis require a significant amount of energy, it also is in need of sources of energy that are reliable, renewable, and harmless to the surrounding environment. Fuel such as gas, oil, and coal have been destructive to the earth in a way that has never been seen before modern humanity. The heating of the planet is almost entirely a result of using sources of energy that only harm the environment rather than be neutral or beneficial. There continue to be global issues concerning the availability and scarcity of oil and gas, and many people are not able to afford to power their vehicles anymore as a result. It is now important that cities today adapt and take advantage of clean energy which is renewable as well as harmless to the environment. Thus, Fordhamopolis will be powered solely by renewable energy. This city will use solar power, hydroelectric power, and wind power as its main sources of energy. These forms of energy generation are the most fitting of Fordhamopolis's location of Toledo, Ohio, as it has a mix of sun and wind, as well as it being next to multiple sources of moving water. Fordhamopolis will be powered sufficiently while also causing no harm to the natural world, providing every citizen with clean and efficient energy while having a storage surplus.

Solar Power

Solar energy is extremely versatile because the methods of harvesting solar energy are vast, with new technologies being developed constantly. Fordhamopolis will harness a wide array of these technologies, using traditional photovoltaic (PV) cells on rooftops as well as transparent solar cells in place of all windows and organic solar cells on the sides of buildings. Because virtually the entire building will be covered in some form of solar panel, the larger the building is, the more energy the building will generate. Green roofs will be on the top of every building for various reasons but also because plants growing near solar panels enable those panels to absorb more energy. Not only is this energy versatile, it's also powerful. The developers of the transparent solar cells, which only absorb wavelengths of the electromagnetic spectrum that we can't see such as ultraviolet and infrared, so as to not hinder visibility whatsoever, estimated that their technology could provide more than a quarter of the energy demands of a building (MIT). This is also an estimate that relies on the current designs of buildings with many small windows spaced close together, but the transparent solar technology works best when the panels are very large because of their low efficiency, so they would best be used in passive heating arrays; arrays that, once built, would increase the efficiency of the solar panels even further because passive heating arrays would reduce heating costs for the buildings where they would be installed, which would be all of them, or as many of them as possible (Dept. of Energy). This energy saved on heating would make the building more energy efficient because it would use that saved energy towards something else, reducing total energy costs even further. It is also clear that our chosen location for Fordhamopolis VII, Toledo, Ohio, is a prime candidate to produce a tremendous quantity of solar energy because Ohio currently generates 14,400 kWh of energy through solar power a year (Wikipedia).

Hydropower

Hydroelectric power is harnessed through the natural currents that flow through bodies of water such as lakes, rivers, and rain water. Hydropower is one of the most efficient means of energy harvesting and has the potential to power a majority of Fordhamopolis' energy grid.

Currently, hydroelectric power makes up 31.5% of the United States' renewable energy grid, and 6.3% (some estimates stating as much as 7%) of the country's total energy ("Hydropower Basics," energy.gov). Hydroelectric power can be harnessed through multiple methods, the main ones established being impoundment (dams), diversion (rivers), and pump storage reservoirs. (Pump storage reservoirs utilize water stored underground at separate levels of elevation. As stated by the Office of Energy Efficiency and Renewable Energy, "PSH acts similarly to a giant battery, because it can store power and then release it when needed.") Each of these methods utilizes the water's currents to spin turbines, which in turn, produces electricity. Another important benefit of using pump storage method is its ability to keep water cool during the summer, and warm during the winter. The stored water can be used as a building's thermostat, which allows immense amounts of energy saving in the long run.

Hydropower can also be generated through the piping of individual buildings. By harnessing the energy produced by water moving through the plumbing. Arup estimates that turbines in the public water system in Hong Kong could power 6,000 households, or a population of about 24,000. In skyscrapers, the water in pipes is put under high pressure to ensure consistent supply throughout the structure. The high pressure on the lower floors is released with valves, providing an opportunity to harness otherwise wasted energy by attaching a generator ("Making a Building's Water System into a Hydroelectric Plant," McMillan, Alex).

Toledo, Ohio is an ideal location for harvesting energy through hydropower due to its proximity to Lake Eerie and the Maumee and Ottawa Rivers. The abundance of nearby waterways provides the perfect opportunity for multiple hydro-turbine plants that will provide sufficient electricity to the Fordhamopolis Energy Grid.

The main drawback of using hydroelectric power is the danger it poses to freshwater species during its generation. Hydropower methods such as dams act as an obstacle for fish, preventing them from moving between their natural feeding and spawning grounds. In turn, this has the potential to majorly disrupt their life cycles, as well as an area's overall aquatic biodiversity (“Ecosystems and Fish,” NHA). Unfortunately, due to the lack of understanding on how exactly dams impact fish populations, as well as the limited knowledge on migration routes, and spawning/feeding grounds of freshwater fish, it is hard to determine the exact consequences of this form of hydroelectric generation. According to Rafeal Schmitt, a researcher for the Natural Capital Project, dams have already wiped out many Salmon species in North America, and greatly contributed to the extinction of the Chinese paddlefish in the Yangtze River. In this same vein, the secondary drawback of using hydroelectric power is that decimated aquatic populations can cause shortages of food for people who rely on those species for sustenance (Ecosystems). However, despite these drawbacks, hydroelectric technology has come a long way in recent years, and sustainable developments in the technology have mitigated the impact on freshwater ecosystems.

Wind Power

Wind turbines act as an incredibly efficient and versatile resource for renewable energy. Because they do not require an incredibly large and empty area to function, they can be placed on top of tall buildings in the city relatively close together. This allows for a greater amount of energy because of the ability to multiply the amount of turbines placed on a rooftop. Furthermore, thanks to their versatility, micro turbines can also be placed on top of miscellaneous things throughout the city such as street lamps, traffic lights, and more while these objects completely produce their own power. This takes away the need to transmit energy in most cases, as many entities that require energy to function will be powering themselves rather than receiving energy from an outside source. With the energy being received from hydro power, buildings and other energy requiring objects throughout the city will be assisted by wind power for a variety of different things as a result of its efficiency and versatility.

Compared to larger, commercial wind turbines, micro turbines generate a very low level of sound. The average sound level for a micro turbine is 43 decibels, which is lower than an air conditioner, its sound level being 50 decibels. This makes it less bothersome to the residents of the buildings, allowing them to have a source of energy on their rooftops that is barely noticeable. With multiple turbines on the top of a building, they are able to generate around 11% to 15% of the building's annual energy demand. Thus, they are a versatile source of energy that can be placed where needed and also used when needed. Wind turbines will not be the only source of energy for Fordhamopolis, but they are an optimal source of energy for a portion of what the city will need. Because Fordhamopolis finds itself in Toledo, Ohio, the wind speeds will not be fast enough year round. Micro wind turbines require an average wind speed of at least 9 mph, while the average wind speed in Toledo ranges from 7.8 mph in August and 12.9 mph in January. The best way to utilize the wind speeds in the winter would be for the use of miscellaneous objects as well as additional energy storage for backup or during the warmer months when the wind speed is much slower. It is now necessary to have other sources of energy not only because of the lack of efficiency the turbines will see during the warmer months, but also to have a system that makes use of multiple sources of energy instead of relying on merely one source.

Energy Saving Methods

Considering the fact that Fordhamopolis is a city containing 100,000 people, it will inevitably require a great amount of energy to function. Though the sources of energy listed above are incredibly efficient, useful, and sustainable, it is still important to consider saving energy when it is not needed. An example of this that will be implemented in Fordhamopolis is a limit on the amount of hours per day lights can be on in domestic buildings, as well as all commercial lights during the night. Wasting energy through leaving lights on when not needed is a problem that lingers in the majority of cities today and consumes a very high amount of energy that is not needed. During the hours when it is dark and visibility is limited, street lamps and other necessary sources of light will remain on so that citizens may live safely and comfortably. In all other cases, if an area, business, etc. is not being used or occupied, a source of lighting is not necessary therefore it will not be used. Another important factor to understand is the typical overuse of lighting in spaces such as classrooms, supermarkets, and other public spaces, which is caused simply when there are too many lights in one space. In order to combat this, Fordhamopolis will account for how many lights are needed to create a productive atmosphere that doesn't cause eye strain, reducing the amount of light, and thus energy, that can be built into the infrastructure.

Furthermore, educating citizens about energy saving methods in their homes will also be important. With a limit to the amount of hours per day, or another limit of the same nature such as the amount of kWh of energy that can be consumed every day, citizens will begin to implement this into their everyday lives thus becoming more conscious of the amount of energy they use. Integrating energy saving methods such as this will allow Fordhamopolis to be completely run by renewable energy with an additional storage, making the city's energy supply infallible.

Energy Saving Through CLT

CLT, or Cross-Laminated Timber, is the building material of choice for Fordhamopolis, because it is able to sequester carbon and save energy. The typical energy demands of the average 28,000 square foot office building come out to about six million kWh per year. If this same building was made of CLT, the building would consume only four million kWh per year, saving about two million kWh a year, about the same amount of energy generated by 6,000 solar panels every year, assuming average energy outputs (Xi'an and Harbin, Liu et. al).

Powering Transportation

Fordhamopolis's public transit system will include public transportation such as trains, trams, buses, bikes and other personal transportation items. The trains will be completely underground, making it necessary to use a source of energy outside of solar or wind. Thus, trains will be powered by the excess energy from the hydropower system as well as the excess energy buildings produce. Everything in the train will be powered by these sources, including lights, cooling, and mobility. Concerning trams and buses, these methods of transportation will be powered by solar panels placed on the tops of buses. This will allow them to be independent of other sources of energy, not needing an outside power source to function. During times when solar energy is not optimal, there will be places where buses are parked to charge their batteries. This is also where the solar panels will collect energy, though they may also collect energy while running, all of this to ensure that they will have enough to continue through all necessary routes and stops. Trams will be powered in the same ways as buses, as they will be above ground street cars allowing for more options of transportation so the people of Fordhamopolis will have no need for a personal car. Furthermore, personal vehicles, such as bikes, motor scooters, and more that may require energy in order to function will be charged with the excess energy from their respective building or household, thus taking energy from Fordhamopolis's power grid. This means that this energy will be completely clean and renewable and no emissions will be spent for these vehicles.

Numerical Calculations

CLT Reduction Calculation:

34.35% energy saved averaged across two Chinese cities (Liu et. al).

- Energy consumption increases due to increased cooling costs of CLT are absorbed by solar screens, other efficiencies of CLT, and rooftop gardens
- Annual avg. energy consumption of office building = 2.09kwh/m^2 (twinview)
  2.09kwh/m^2*.6565 (CLT efficiency reduction) = 14.54kwh/ft^2=1.35kwh/m^2
  1.35

Conversion Key:

- 1 Gigawatt=1 million kilowatts
- kw=kilowatt
- kwh= kilowatt-hour
- 1 megawatt=1,000 kilowatts

Building Demands (CLT Adjusted):

- Multi Family: 1.35kwh/m^2 (energy demanded per square meters) *100m^2 (area of single building) =135kwh/yr
- Medium Mixed Use: 1.35kwh/m^2 *830m^2 =1120.5kwh/yr
- Large: 1.35kwh/m^2 *1400m^2 =1890kwh/yr

Solar Generation:

Pv Sizes:

- Residential Size Photovoltaic Cell: Area: 1.65m*.99m=1.6335m^2
- Commercial Size Photovoltaic Cell: Area: 1.98m*.99m=1.9602m^2
- PV Cell Energy Generation: (building areas from “building typologies” doc)

  Multi family: 100m^2 (building area) /1.6353m^2 (size of one solar panel) (a1 solar) =61 panels x 300W (watts) (forbes) =18,345W=18kw/yr
- Medium Mixed Use: 830m^2/1.9602m^2 =423 panels x 300W =127,027W=127kw/yr
- Large: 1400m^2/1.9602m^2 =714 panels x 300W=214,263W=214kw/yr

Transparent Cells:

- They estimate that using coated windows in a skyscraper could provide more than a quarter of the building’s energy needs without changing its look.
- More than a quarter=approx. 30%
- Multi family: 135kwh/yr (annual energy demand) * .3 (transparent cell reduction)=40.5kwh/yr
- Medium Mixed Use: 1,120.5kwh/yr* .3=336.15kwh/yr
- Large: 1,890kwh/yr* .3=567kwh/yr

<u>PV Cell Aggregate:</u>

- Multi family: 18kwh/yr (total solar output per building of this type)*8,000 (number of units of this type)=144,000 kwh/yr
- Medium Mixed Use: 127kwh/yr*600=76,200kwh/yr
- Large: 214kwh/yr*120=25,680kwh/yr
- Sum: 245,880kwh/yr

<u>Transparent Cell Aggregate:</u>

- Multi family: 40.5kwh/yr (transparent cell energy production) *8,000bldg (number of buildings of this type) =324,000kwh/yr
- Medium Mixed use: 1,120.5kwh/yr *600bldg =627,300kwh/yr
- Large: 567kwh/yr*120bldg=68,040kwh/yr
- Sum: 1,019,340kwh/yr

<u>**Total Solar:**</u>

1,019,340+245,880=1,265,220kwh/yr

<u>*Hydro Generation*</u>

<u>Adding Turbines to Public Water System:</u> Power 6,000 homes (times):

- 135kwh*6,000=810,000kwh

<u>Tidal Barrages:</u>

- 23,000kwh (Farhadzadeh et al.)

<u>*Wind*</u>

<u>Turbines on Roofs:</u>

- 1,100-1,300Mwh/yr: 1,200,000 kwh/yr (CTCN)

<u>***Total Required Energy of All Buildings:***</u>

Multi Family: 800,000m^2(total area of all buildings)*1.35kwh/m^2(energy requirement per square meter)=1,080,000kwh/yr

Medium mixed use: 498,000m^2*1.35kwh/m^2=672,300kwh/yr

Large: 169,000m^2*1.35kwh/m^2=226,800kwh/yr

Total Sum=1,979,100kwh/yr

Total Energy Generation:

Solar: 1,265,220kwh/yr

Wind: 1,200,000kwh/yr

Hydro: 833,000kwh/yr

Sum: 3,298,220kwh/yr

Total Net Energy:

3,298,220kwh/yr(energy generated)-1,979,100kwh/yr(energy required)

=1,319,120kwh/yr excess

Bibliography

Pillar I: Carbon Sequestration

Ahmed, A.A.Q., Odelade, K.A., Babalola, O.O. (2019). Microbial Inoculants for Improving Carbon Sequestration in Agroecosystems to Mitigate Climate Change. In: Leal Filho, W. (eds) Handbook of Climate Change Resilience. Springer, Cham. https://doi.org/10.1007/978-3-319-71025-9_119-1

Alday Jover Architecture. "Aranzadi Park." https://www.aldayjover.com/en/component/articulo/?idcategoria=17&idarticulo=251.

Appels, F. V., Camere, S., Montalti, M., Karana, E., Jansen, K. M., Dijksterhuis, J., Krijgsheld, P., & Wösten, H. A. (2019). Fabrication factors influencing mechanical, moisture- and water-related properties of mycelium-based composites. *Materials & Design*, *161*, 64-71. https://doi.org/10.1016/j.matdes.2018.11.027

Chevallier, C., Eandi, M., & Kalika, S. (2018, October 31). Producing mycelium insulation – Critical Concrete. Critical Concrete. Retrieved April, 2023, from https://criticalconcrete.com/producing-mycelium-insulation/

Cho, H. M., Wi, S., Chang, S. J., & Kim, S. (2019). Hygrothermal properties analysis of cross-laminated timber wall with internal and external insulation systems. *Journal of Cleaner Production*, *231*, 1353-1363. https://doi.org/10.1016/j.jclepro.2019.05.197

Crespell, Pablo, and Sylvain Gagnon. "Cross Laminated Timber: a Primer." FPInnovations, fpinnovations.ca/media/publications/Documents/clt-primer.pdf.

Dehn, F., & Kotan, E. (2021, September 14). Evaluation of Physical Properties of Mycelium-Based Bio Composites for Use As Facade Insulation Material. Research Square. https://doi.org/10.21203/rs.3.rs-860965/v1

Douglas, B., & Karacabeyli, E. (2013). CLT Handbook: Cross-Laminated Timber. Forintek Canada Corporation.

Evans, Layne. (2015). Cross Laminated Timber – Taking Wood Buildings to the Next Level. Sponsored by reThink Wood, American Wood Council, and FPInnovations.

HempLime. (2022, September 6). Healthy Materials Lab. Retrieved May, 2023, from https://healthymaterialslab.org/material-collections/hemplime

Jones, M., Mautner, A., Luenco, S., Bismarck, A., & John, S. (2020). Engineered mycelium composite construction materials from fungal biorefineries: A critical review. Materials & Design, 187, 108397. https://doi.org/10.1016/j.matdes.2019.108397

Minnesota Board of Water and Soil Resources. "Carbon Sequestration in Wetlands." https://bwsr.state.mn.us/carbon-sequestration-wetlands.

Nahlik, A. M. and M. S. Fennessy. (2016). "Carbon storage in US wetlands." *Nature Communications* 7. https://www.nature.com/articles/ncomms13835.

NGC Testing Services for American Wood Council. (2012). Fire Tests of Building Construction and Materials – Cross-Laminated Timber and Gypsum Board Wall Assembly (LoadBearing). Retrieved from http://awc.org/pdf/codeofficials/2012/NGC-CLT-Report.pdf

Redmore, Lauren. (2022). "Mass Timber and Other Innovative Wood Products In California: A Study of Barriers and Potential Solutions to Grow the State's Sustainable Wood Products Sector." https://www.researchgate.net/publication/359427316.

Shoot, Brittany. "This Startup Is Harvesting Wild Algae to Make Your Next Pair of Sneakers." *Smithsonian Magazine.* https://www.smithsonianmag.com/innovation/startup-harvesting-wild-algae-make-your-next-pair-sneakers-180960872/

Taylor-Foster, J. (2014, February 09). Insulation Grown From Fungi. ArchDaily. https://www.archdaily.com/473052/insulation-grown-from-funghi/52ee2e62e8e44e981a000104-insulation-grown-from-funghi-image?next_project=no

Pillar II: Urban Agriculture

"American Dairy Consumption Achieves a Record in 2021." *Dairy Foods RSS*, 30 Sept. 2022, www.dairyfoods.com/articles/95908-american-dairy-consumption-achieves-a-record-in-2021.

Barth, Brian. "How Does Aeroponics Work?" *Modern Farmer*, 19 Oct. 2018, modernfarmer.com/2018/07/how-does-aeroponics-work/.

"Can Lab-Grown Dairy Give Us A Cow-Free Future? | Lab-Grown | Science Insider." *YouTube*, YouTube, 5 May 2022, https://www.youtube.com/watch?v=dIQLqI3Yoqk. Accessed 10 May 2023.

Cassidy, Emily S, et al. "IOPscience." *Environmental Research Letters*, 1 Aug. 2013, iopscience.iop.org/article/10.1088/1748-9326/8/3/034015/meta.

Ching, Xin Lin, et al. “Lab-Based Meat the Future Food.” *Science Direct*, 11 Nov. 2022, www.sciencedirect.com/science/article/pii/S2666765722001508#bib0109.

“Composting or Anaerobic Digestion?” *Compost Crew - Good to Grow*, 4 Sept. 2020, compostcrew.com/composting-or-anaerobic-digestion/.

“Crop Rotations.” *Rodale Institute*, 15 Dec. 2020, rodaleinstitute.org/why-organic/organic-farming-practices/crop-rotations/#:~:text=Crop%20rotation%20is%20the%20practice,combat%20pest%20and%20weed%20pressure.

Manning, Lauren. “Decentralizing Food Production Offers Serious Benefits, New Study Shows.” Sacred Cow, 20 Dec. 2020, www.sacredcow.info/blog/decentralizing-food-production-offers-serious-benefits.

Freedman, Darcy, and Carrie Draper. “Review and Analysis of the Benefits, Purposes, and Motivations Associated with Community Gardening in the United States.” *Taylor & Francis*, 10 Apr. 2010, www.tandfonline.com/doi/full/10.1080/10705422.2010.519682.

Gbbg. “5 Ways to Start Regenerative Gardening for Better Soil Health.” *Green Bay Botanical Garden*, 29 Sept. 2020, www.gbbg.org/regenerative-gardening-for-soil-health/.

Hattis, PK. “Composting Waste Pilot Project Gets Nod from Santa Cruz County Supervisors.” *Santa Cruz Sentinel*, 18 Oct. 2022, www.santacruzsentinel.com/2022/10/18/composting-waste-pilot-project-gets-nod-from-santa-cruz-county-supervisors/.

Houser, Kristin. “Growing Milk Proteins without Cows - or Their Greenhouse Emissions.” *Freethink*, 5 Oct. 2021, www.freethink.com/energy/milk-proteins.

Leffer, Lauren. “Cultured Meat, without the Slaughter, Is Slated to Get a Big Boost.” *Gizmodo*, 27 May 2022, gizmodo.com/good-meat-beyond-burger-meat-vat-cultured-meat-just-1848980404.

Keller, Michelle. “Aeroponics - What Is It & Why Is It Important?” Living Greens Farm - Locally Grown Food & Fresh Salad Greens, www.livinggreensfarm.com/blog/what-is-aeroponics#:~:text=The%20term%20aeroponics%2C%20meaning%20%E2%80%9Cworking,mist%20to%20the%20plant’s%20roots. Accessed 11 May 2023.

Koumoundouros, Tessa. “A Large-Scale Experiment Used Human Pee to Fertilize Crops. Here’s What Happened.” *ScienceAlert*, 23 June 2022, www.sciencealert.com/researchers-tested-large-scale-use-of-human-pee-as-fertilizer-and-here-s-what-happened.

Ramirez, Vanessa Bates. “The World’s Biggest Cultured Meat Factory Will Soon Be Built in the US.” *Singularity Hub*, 10 Aug. 2022, singularityhub.com/2022/06/01/the-worlds-biggest-cultured-meat-factory-will-soon-be-built-in-the-us/.

Sayner, Adam. "Permaculture Farming: The Ultimate Guide and Examples." *GroCycle*, 9 Nov. 2022, grocycle.com/permaculture-farming/.

Simha, Prithvi, et al. "We Found a Way to Turn Urine into Solid Fertiliser – It Could Make Farming More Sustainable." *The Conversation*, 13 Sept. 2022, theconversation.com/we-found-a-way-to-turn-urine-into-solid-fertiliser-it-could-make-farming-more-sustainable-148877.

"Types of Greenhouses." *NSW Department of Primary Industries*, 1 Jan. 1970, www.dpi.nsw.gov.au/agriculture/horticulture/greenhouse/structures-and-technology/types#:~:text=Classification%20of%20a%20greenhouse%20is,%2C%20Sawtooth%2C%20Skillion%2C%20Tunnel.

USDA, "Current Dietary Guidelines." Dietary Guidelines for Americans, 2020-2025 and Online Materials | Dietary Guidelines for Americans, www.dietaryguidelines.gov/resources/2020-2025-dietary-guidelines-online-materials. Accessed 11 May 2023.

USDA, "Dietary Guidelines for Americans." *United States Department of Agriculture, 2020-2025*.

Vartan, Starre. "How Does a Composting Toilet Work?" *Treehugger*, 4 Apr. 2022, www.treehugger.com/how-to-use-a-composting-toilet-5190290.

Solar:

https://www.energy.gov/energysaver/passive-solar-homes

https://www.google.com/url?q=https://energy.mit.edu/news/transparent-solar-cells/&sa=D&source=docs&ust=1682034024693598&usg=AOvVaw2IHlXNafmN-wGWArZ0MYkh

Hydro

https://www.energy.gov/eere/water/hydropower-basics#:~:text=Hydropower%2C%20or%20hydroelectric%20power%2C%20is,of%20total%20U.S.%20electricity%20generation.

https://www.nytimes.com/2013/12/13/realestate/commercial/turning-a-buildings-water-system-into-a-hydroelectric-plant.html

https://www.hydro.org/waterpower/why-hydro/clean-and-sustainable/ecosystems-fish/

Calculations

Liu, Ying, et al. "Assessing cross laminated timber (CLT) as an alternative material for mid-rise residential buildings in cold regions in China—A life-cycle assessment approach." *Sustainability* 8.10 (2016): 1047.

https://www.twinview.com/insights/benchmarking-commercial-energy-use-per-square-foot

https://www.forbes.com/home-improvement/solar/how-much-power-does-a-solar-panel-produce/

https://a1asolar.com/4-differences-between-commercial-and-residential-solar-power/#:~:text=Size%20%E2%80%94%20On%20average%2C%20commercial%20solar,78%20inches%20by%2039%20inches.

https://www.nytimes.com/2013/12/13/realestate/commercial/turning-a-buildings-water-system-into-a-hydroelectric-plant.html

https://research.bangor.ac.uk/portal/files/18561400/Lake_Erie_Energy_032017_Nomarkup.pdf

https://www.ctc-n.org/technologies/building-integrated-wind-turbines#:~:text=Micro%20wind%20turbines%20are%20suitable,axis%2C%20also%20known%20as%20HAWTs.

https://energy.mit.edu/news/transparent-solar-cells/

Wind

attainableHOME. (2022a, May 30). *How much noise do small wind turbines make?*. Attainable Home. https://www.attainablehome.com/how-much-noise-do-small-wind-turbines-make/#:~:text=A%20small%20wind%20turbine’s%20estimated,a%20refrigerator%20(40%20dB).

attainableHOME. (2022b, July 9). *Small wind turbines: How fast must the wind blow?*. Attainable Home. https://www.attainablehome.com/small-wind-turbines-how-fast-must-wind-blow/

Galbraith, K. (2003, September 3). Assessing the value of small wind turbines. *The New York Times*.

Mitigation. (n.d.). *Building-integrated wind turbines*. Building-integrated wind turbines Climate Technology Centre & Network | Tue, 11/08/2016.

https://www.ctc-n.org/technologies/building-integrated-wind-turbines#:~:text=Micro%20wind%20turbines%20are%20suitable,axis%2C%20also%20known%20as%20HAWTs.

Pendle UK. (n.d.). *Fact sheet 1: Micro/small wind turbines*. pendle.gov.uk. https://www.pendle.gov.uk/download/downloads/id/6476/fact_sheet_1_microsmall_wind_turbines.pdf

US DOE. (2016). *Combined heat and Power Technology Fact Sheet Series: Microturbines*. energy.gov. https://www.energy.gov/eere/amo/articles/microturbines-doe-chp-technology-fact-sheet-series-fact-sheet-2016