

# FORDHAMOPOLIS

*“Nature has all the answers, so what is your question?”*

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## DEFINITIONS

Bio-Mimicry- Man-made systems, infrastructures, and other creations that mimic networks in nature.

Sustainability- What gets put into the environment by humans = What gets taken out of the environment by humans.

Ecosystem- A complex community of interacting diverse organisms in their physical environments.

Biodiversity- Variety of life in an ecosystem to ensure the ability to bounce back from any disaster (a.k.a, resiliency).

Resiliency- The ability to come back from a catastrophe.

Redundancy- Building a system/infrastructure multiple times to act as “back-ups”.

## **MISSION**

Fordhamopolis will be a two square kilometer city with a population of 200,000 people located on President's Island on the outskirts of Memphis, Tennessee (Appendix A). The mission of Fordhamopolis is to create an eco-city that utilizes ideas of resiliency, redundancy, and bio-mimicry to not only help the environment, but also provide a successful model to encourage other cities around the world do the same. Memphis might not be the most obvious location on which to design an ecological city that does no harm, but if Fordhamopolis can succeed in Memphis, Tennessee, our hope is that the city can then prevail anywhere around the world. Systems in nature have been able to survive through adaptation since the creation of our planet. It is therefore important for future cities to look at these natural systems so that they can consistently adopt modern technological advances that do no harm. Fordhamopolis will be an example for future cities to come, and proves that a city such as this one can be built anywhere and can adapt to any environment.

## LOCATION

President's Island sits quietly along the Mississippi River on the southwest Memphis. Ironically, President's Island is not actually an island, but a peninsula. The island was converted into a peninsula in the 1940's when a dam was constructed in response to frequent flooding. This plan, known as The Flood Control Act of 1946, closed the Tennessee Chute and created a deep-water harbor, McKellar Lake (Association, n.d.). Still, major flood concerns have prevented the development of farms, businesses, and residencies. In fact, nearly 3,500 acres of the peninsula are flood plain. However, President's Island is an ideal location for maximizing hydroelectric energy. Much like in the 1940s this area will soon undergo a major change. The Port Commission is planning to horizontally build up the industrial area with dredge material. This plan will have the potential to negatively impact the river by increasing pressure on the levee walls. Contrarily, Fordhamopolis will sit on a structurally built-up hill in such a way that there is no environmental degradation.

The permeable ground system will be designed with and inspired by nature, by mimicking the Earth's layers of rock that imperfectly stack and allow movement and water flow. This helps protect and preserve the natural water table (Aquifers and Groundwater, 2016). The gradual changes of the city and the environment can be accommodated by its structure because it works in modular units that can be aggregated (Appendix B).

## **GREEN SPACES**

Fordhamopolis will ensure multiple green spaces within the city's borders, such as parks and community gardens, to promote environmental care and support good mental health and well-being of the residents. Though we will be a technologically advanced town with a plethora of complex innovative systems, we will reiterate the importance of having natural landscapes for everyone to enjoy and socialize in. Therefore, the roofs of every building and infrastructure will be put to use as public green areas, if not covered with solar panels. These public green areas will include community gardens and public parks. The community gardens are great projects that teach families how to grow food and allow people to become connected via food and communicate more. The parks will be areas of open space where residents can walk, sit, play, eat, and enjoy the calmness and the wonders of nature within the busy city. This is discussed further in the food section. The streets of Fordhamopolis will be designed to encourage pedestrian usage. In addition to creating a better psychological environment for our citizens, this will promote better physical health for individuals. This is discussed further in the transportation section.

## **SOCIETY**

The residents of Fordhamopolis will be adapting to a life closer to their local environment. The city residents will be taught about ecologically friendly practices and encouraged to change their daily habits from what the typical American is known for: consuming excessive amounts of meat, overusing disposable items, wasting items that can be reused and

recycled, and becoming technology obsessed and detached from nature. Fordhamopolis residents will be rewarded for transitioning to a diet of only small amounts of meat and having an extremely minimal carbon footprint. Reducing, reusing, and recycling are huge here, and citizens are rewarded for such practices. Rewards come from our newly established government system that promotes positive actions instead of punishing transgression. Fordhamopolis is a true democracy, where people's votes are all taken under consideration regarding anything from the next artist for be hired for a mural to our next government officials. The voting is done through an unhackable computer system that is connected to every adult resident's phone. When officials want feedback, residents will get a popup that asks for their opinion. The vast majority of the city is satisfied more often than not with the way the city runs, and if complaints are made, they are reviewed immediately by a team of elected officials who will come to a decision on whether or not the complaint is of enough priority to be voted on by the residents. Also, our residents will be very knowledgeable on where their food comes from and how that food is grown. Great relationships will be built between the people and their growers from the vertical gardens. Dr. Despommier mentions that:

Government support at the academic level for encouraging the development of more crop-diverse applications for vertical farming (e.g., grains and root vegetables), increased manufacturer buy-in for making available more innovative, cheaper indoor growing systems, more consumer awareness regarding the food safety and security issues of outdoor versus indoor farming, and greater political support for establishing vertical farming inside the urban landscape, if properly implemented, would jump-start a movement toward establishment of the eco-city, the "holy grail" of urban cultural



evolution. (Despommier, 2017, p. 316).

Residents of Fordhamopolis will also be allotted a certain amount of free water and energy. If people use less than the standard, then they will be given a stipend, whereas if they go above the limit of free resources they will have to pay for the extra gallons and watts they consume.

We will make this information accessible to every citizen, similarly to how the voting system will work on everyone's phones. Everyone will, at any time, be able to access statistics that refer to how large their water, waste, and energy footprints are, as well as how well the city is performing as a whole. Citizens will also already have a general idea about how much they are consuming due to the educational system's emphasis on the importance of conservation of all resources.

## ENERGY

Per capita energy consumption in the United States is 313 million Btu or approximately 91,731.2 kWh in 2011 (US Energy Information Administration, 2017). That is, all of the energy used in the US per person is 91,731.2 kWh. If our energy usage per capita is the same, our total energy needs would be 18.346 billion kWh for our population of 200,000; however, we will likely use less due to energy efficient design and technology. The average individual electricity consumption in the US is 10,812 kWh (US Energy Information Administration, 2016). Our city will obtain all of its energy from ecologically friendly sources, without pollutants or causing other environmental disruption. Additionally, we will produce extra energy, some of which will be stored in case of emergency or power system failure. The rest will be sold to Memphis and other cities at a lower price than energy from fossil fuels to provide revenue for the city, energy for other communities, and encourage the use of environmentally friendly energy sources.

Clean energy from the city will power everything in it, including the vertical farms, transportation system, recycling plant, and other municipal systems. Additionally, an allotment of energy will be provided to each citizen of our city free of charge. This allotment will be calculated to be comparable with the national average (10,812 kWh of electricity annually per individual), adjusted for the more energy efficient technology of our city. It will be gradually reduced annually to encourage energy saving habits. Additional energy will be available for purchase, but this standard minimum will be free for all.

The following section lists each of the types of energy that will be utilized in our city and details the respective technologies. As new technologies are invented, there will be exciting chances for further improvements and expansion.

## **Geothermal**

Geothermal will be the main source of energy for our city. The specific energy output will have to be calculated after the bedrock has been surveyed, but geothermal energy has a tremendous capacity. The Geysers geothermal plant in California creates enough energy for 725,000 homes, and the potential for geothermal energy output is infinite (Choi, 2008; Blodgett, 2014). There are multiple options for geothermal energy production: flash steam, binary cycle, and enhanced geothermal systems (Geothermal Research Council, n.d.). At Memphis, a binary cycle system may be the best option for a few reasons. Binary cycle systems use hot water from the ground to flash boil an organic compound with a low boiling point, which then creates steam to turn a turbine (Office of Energy Efficiency and Renewable Energy, “Electricity Generation,” n.d.). The first benefit to this type of system is that binary cycle systems require a lower temperature to be reached. At Memphis, the depth to temperature gradient is steep, meaning that one would have to drill much farther to reach the temperatures necessary for flash steam systems. Binary systems work with a ground temperature of about 100° C, which is present roughly 6 km deep at Memphis (Renewable Energy World, n.d.; Annenberg Learner, 2017).

The other benefit of the binary system is that it is a closed loop system, which means that there are no emissions in gas or liquid form (Office of Energy Efficiency and Renewable Energy,

“Geothermal FAQs,” n.d.). The water from the ground flows through a loop, meaning once it has lost some heat in the process, it will flow back down. This is important because it replenishes the supply, making the system more sustainable; other geothermal wells in the past have depleted their water, meaning they have had to pump water back in or retire the well (Choi, 2008). Using a binary system would avoid this complication.

This type of binary system technology may have to be combined with a new technology, the enhanced geothermal system (EGS), depending on the permeability and moisture content of the bedrock below our city (Geothermal Research Council, n.d.). An evaluation of the specific site will be necessary to determine if this modification is necessary. Whether or not this additional component must be implemented, geothermal energy will help power our city.

### **Plasma Arc Gasification**

Plasma arc gasification will be another source of energy for Fordhamopolis (see Appendix C); this system will incinerate solid waste – even medical or hazardous waste – at extremely high temperatures (4000°C to 7000°) to create 800 kWh of energy in a gas form and 400 lbs of solid “rock residue” for every 1 ton of solid waste (Circeo, n.d.). Based on our population’s waste production, this will generate 8 billion kWh per year (Circeo, n.d.; see Waste section for more details). This would be 46.3% of our total energy budget (or more, due to our energy efficient technology use). The gas can then be used, stored, or sold depending on the current energy needs of the city. The solid residue can be used to build roads and other things (Woodford, 2017). There are, however, still some concerns about the long-term safety of the

materials produced by this process (Woodford, 2017). Therefore close monitoring of the system and testing of the products may be necessary, as well as judicious use of the solid material (i.e. in roads rather than homes or hospitals). A system to capture the gases produced and use them productively would also be necessary. This potential future risk could make some resistant to the use of such technology.

The plasma arc gasification equipment would be placed in the underground industrial space beneath the city. This would shelter it, protecting it from wear and tear caused by the elements. It would, however, again require a carefully designed and maintained safety and ventilation system. The scale of the system would be largely dependent on the amount of waste available. Due to waste reduction policies within the city, as well as reuse and composting practices, most waste may already be taken care of in other ways. However, if desirable, we could process waste from other places, such as Memphis, providing the city with more energy and an additional source of revenue. This scale could also be changed in fairly small increments. There are plasma arc gasification units that operate in the back of flatbed trucks (Woodford, 2017). Therefore, the minimum unit size for this technology is small and the operation can be tailored to the needs of our city if they change.

## **Hydroelectric**

Free flow hydroelectric turbines will produce additional energy. These turbines turn slowly, so they will have minimal impact on fish and other aquatic life (Richard, 2008). There are different turbine designs that require different minimum water speeds (Siciliano, 2017;

Treehugger, 2008). The Mississippi River flows at 1.8 mph at the headwaters and 3 mph at New Orleans, but speeds for specific points in the river are not available online (National Park Service, n.d.). Exact water speeds in each section of the river will have to be tested to determine which turbines should be placed in which locations in order to optimize energy production. Ideally, a combination of types of turbines will allow for the greatest amount of energy to be utilized, as well as building internal redundancy into the hydroelectric system to protect against any potential flaws or vulnerabilities in either particular type of turbine. Once exact water speed, placement, and numbers have been determined, the energy production of this resource can be calculated. For reference, a project in the Lawrence River in Ontario using this type of technology generates enough electricity for 11,000 homes and a project in the East River generates over 6 times this amount, or enough for over 51,000 homes, given the same energy budget per household (Richard, 2008; Verdant Power, n.d.). Therefore, hydroelectric turbines could provide enough energy for roughly a quarter of our city's homes if it is on the same scale as the project in New York. Given our location surrounded by water, it may be even more.

## **Solar**

Solar energy will serve as a supplemental source of energy, rather than as a main source. To stay inside the 2 km<sup>2</sup> parameters – and allow sunlight through for quality of life and sanity – we thus need additional power sources. Nevertheless, redundancy is the key to resiliency, so having solar energy as a component will only strengthen our city.

Memphis gets about 1700 kWh/m<sup>2</sup> annually (Solargis, n.d.). New step-cell solar panels

have an efficiency of 35% - and cost less to produce than previous solar panels (MIT News Office, 2016). Given these numbers, if our eco-city had the same per capita requirements as the US as a whole, we would require 154.17 m<sup>2</sup> of solar panels per person in order to meet their energy needs, so 30.843 km<sup>2</sup> for a city of 200,000 – far greater than our 2 km<sup>2</sup> footprint. Additionally, only a certain percentage of a city can realistically be topped with solar panels; some light must be let through to the people and plants below. If we say a quarter of our city can be covered with these panels, so half a square kilometer, it would generate just under 300 million kWh annually, which is less than 2% of the annual per capita energy budget.

We will place step cell panels on the roofs of the tallest buildings in the city, such as the vertical farms, and all other buildings that do not have gardens or other green spaces on the roofs. Additionally, they will be used in awnings and other structures for shade, such as above seating at parks and other public spaces. Finally, roofs with gardens will also incorporate a moving solar strip to capture some solar energy while still allowing a large portion of the light through so most plants can be grown. It would also provide some shade for people who will sit among their rooftop gardens. This moving solar strip would be essentially a ¼ portion of a dome that tracks the sun and follows it to remain at the optimum angle to capture energy. This is based on technology often used in solar panels that tilt to follow the sun, which were in turn based on natural phenomena, such as sunflowers (Linak, n.d.).

Some additional solar energy would also be captured through transparent solar cells in windows. These cells can reach an efficiency of up to 10% (Stauffer, 2013). This technology could also be applied to other surfaces besides windows; in fact, it can be invisibly applied to all surfaces (Stauffer, 2013). However, if there are plants behind these windows, the light absorbed

by the panels would have to be replaced using LEDs, but this would be necessary in much of the vertical farm regardless of the window material (see Food section). The transparent panels also have a relatively low efficiency and vertical windows receive a lower amount of solar energy to be absorbed (as compared to rooftops). For these reasons, transparent solar cells will add to our energy budget, but only by a small margin.

We will also utilize solar roadways. These roadways not only capture solar energy, but can also be used for LED signage on the road that can be changed when necessary, can include heating elements to melt snow and ice to maintain safe driving conditions, and have numerous other potential benefits and uses (Solar Roadways, n.d.). Normally, these roadways are made of glass, but we will use recycled transparent plastic (Solar Roadways, n.d.; Wrenn, 2012). This way the roads will be safer and more adaptable, will produce energy, and will provide a productive new life for previously used plastic.

## **Nuclear**

Nuclear energy does not pollute through emissions like fossil fuels do (Nuclear Energy Institute, n.d.). However, the big problem with nuclear energy is the spent fuel rods; these waste products are still dangerously radioactive and take a very long time to become inert (Biello, 2009). Since Oak Ridge nuclear facility is already nearby, a way to harness this energy, increase its sustainability, and reduce this waste will be through pyroprocessing. Pyroprocessing is a way of “recycling” used nuclear fuel rods to extract much of the remaining energy (Palmer, 2015). It is not a completely efficient process, and thus leaves behind its own high level nuclear waste,



albeit a much smaller amount than was originally put in to the system (Palmer, 2015). Our city will negotiate a deal with Oak Ridge through which they will construct a pyroprocessing facility or convert an existing power plant into one capable of this process. We will use the energy from this recycling process, thus giving us a net reduction in nuclear waste.

### **Kinetic Energy**

We will also get energy through kinetic energy production. This can be done in a number of ways. One exciting technology that we will incorporate is gathering kinetic energy produced by footsteps. This is being used today in places with heavy foot traffic to generate electricity, and we will use it in a similar manner (CleanTechies, 2015; Shadbolt, 2015). The pavement in our marketplaces, sidewalks in busy areas of the city, public transportation hubs, and other busy pedestrian areas will utilize this technology. They could even be potentially incorporated into the roadways to capture the energy of cars and other vehicles (CleanTechies, 2015). We will test whether these can be used in addition to solar roadways and, if not, roads will be analyzed to see what sections can gather more energy from which technology. Additionally, gym equipment and playgrounds can all also be equipped to generate energy (ReRev, n.d.; Hamblin, 2014; Markham, 2011; Henderson, 2011). Exercise equipment will feed directly back into the home or gym in which they are located. Children's play will generate energy that will go back into the city grid to be used. It is difficult to determine exactly how much energy this will produce, but as technology progresses, it will only increase. In fact, MIT recently created a device that has increased the efficiency of this technology by 100 times (Cotter, 2011).

## **Energy Storage**

Our city will also store some of the excess energy it produces, both to balance the uneven production of some of our technologies (i.e. solar that only produces energy during the day) and to be used in case of some emergency with the systems of energy production. Energy storage will utilize several different kinds of technology in order to again encourage redundancy and resiliency. To achieve this using a combination of grid-scale batteries, superconducting magnetic energy storage, and electrochemical capacitors (Center for Sustainable Systems, University of Michigan, 2016; McKenna, 2011; Energy Storage Association, 2017).

## **FOOD**

Fordhamopolis will be known for its local food culture. Traditional agriculture can no longer serve an eco-city such as Fordhamopolis due to the lack of horizontal space (2 km<sup>2</sup> for the entire city itself), and the city's desire to decrease food kilometers, the transportation of food from distant farms and factories, on each piece of produce. It is explained in Dr. Dickson Despommier's book "The Vertical Farm" that the United States Department of Agriculture estimates that 50% of our crops planted on US soil never reach the plates of the consumers from a number of factors; including droughts, floods, spoilage, pests, and diseases. The situation is even worse on a global scale where nearly 70% of the planted crops never reach the harvesting stage (Despommier, 2010, p. 26-27). Considering rapid climate change, and how this has a great possibility of worsening within the next century, urban agriculture must therefore be adopted and integrated into our city. To do so we must build our greeneries based on a vertical platform. This is what we call a vertical garden.

Traditional farming can only feed about 1000 people – plant and animal based foods – with one square mile or 2.59 square kilometers of land. Growing food outside, for most crops, takes 10 to 20 times the acreage it does to grow them inside (Despommier, 2010, p. 154). Indoor farming can also routinely produce some crops every 35 days year-round rather than seasonally (Despommier, 2017, p. 316). Due to our current advanced technologies, any type of plant can be grown in the vertical farm's specially controlled conditions, which offers far more biodiversity and opportunity than traditional farming. Because of this, Fordhamopolis will have two vertical

gardens supplying the city's residents with a vast majority of their food. Located at the northern and southern parts of what was once known as President's Island will be North Garden (NG) and South Garden (SG), which will grow about 80% of the produce consumed by city residents within its borders. This will leave 20% to be imported in from ethical and wholesome food producers across the country, primarily in the midwest near Tennessee to further reduce our carbon footprint, keeping in mind that the imported goods with the highest footprint will mostly consist of meat. Each vertical garden will employ hydroponic and aeroponic processes, making year-round growth instead of seasonal growth a possibility.

The average American in 2014 consumed around 1996.3 pounds of food annually (quora.com, n.d.). On average, this means that 5.47 pounds of food are consumed a day, which translates to around 2,700 calories a day. If Americans consume around half of those pounds in fruits and vegetables and Fordhamopolis is producing 80% of food in the city, then 1,597 lbs must be cultivated within our 2 km<sup>2</sup>. It is important to know that the national average of food consumed is different than the typical diet our residents of Fordhamopolis will adopt, due the fact that fruits and vegetables will be a heavily relied upon source rather than meats and processed foods and drinks like soda.

To achieve these numbers, North and South Gardens will have to be utilized to their complete maximum. For example, Professor Colin Cathcart (2017) of Fordham University explained that New York City, all 5 boroughs, is 787.36 square kilometers (304 miles squared) with 8.5 million people. To feed each individual resident, 43.43 square kilometers (5.5% of the land) will have to be dedicated to growing food. If Fordhamopolis is only 2 square kilometers (0.77 square miles) with 200,000 people, that would mean that 0.11 square kilometers of space

will have to be put aside for our vertical farms. We decided for our gardens that the base of our hydro-plant will take up 0.7 square kilometers and the aeroponic garden will be 0.4 square kilometers. It is possible to increase each garden's surface area to offer better resilience and a high possibility of consumption and exportation; however, for numbers sake, we will use these two sizes to provide examples on how much food can be grown in limited urban space sizes.

Our farms will be maintained very diligently by a team of Fordhamopolis farmers. The facility will offer its own LED lighting systems, an affordable product in recent times, and its own operation equipment to keep the lighting of the room very controlled, and offer the ability to adjust conditions to optimize biological and physical requirements for each plant. Other necessary factors that affect plant growth, including air pressure, temperature, bacteria, moisture, lighting and dust, similarly established in Toshiba's high-tech growing rooms (qz.com, n.d.) will be monitored as well. The mentioned technologies use "significantly less water hydroponics = 70%; aeroponics = 95% than traditional outdoor farming, which uses over 70% of the available liquid freshwater on Earth" (2017, p. 316). One can often repurpose abandoned buildings for vertical farm projects, but in this case we will be building Fordhamopolis from scratch, allowing for our farm towers to be custom built, which makes them more cost effective in the future. Our new farms will be built with materials recycled from rock residue created from our plasma arc gasifier (see Waste section) to ensure that we are utilizing all our materials to their maximum efficiency.

## **Hydroponics**

Since Fordhamopolis is on a hill with its upward area facing north and lower area down south, our hydroponic practices will be located in South Garden where water is more readily available. To understand hydroponics, one must know that all plants require only 16 elements. Potassium nitrate is considered a sufficient addition for maximum growth along with manure, “a traditional farming practice thought to be required as fertilizer, while aiding in making soil more tillable.” Both of these prized traditional farming practices are not essential for optimal plant nutrition (2017 p. 317). For our farms, we will be using continuous-flow solution culture (CSC), which in our case will specifically be the nutrient film technique (NFT). The basic idea is that nutrient solutions will be constantly flowing past roots of plants placed in regularly spaced out holes, which are special fiber-filled containers. This is easier to automate than static solution culture because sampling and adjusting temperatures and nutrient concentrations can be done in a large storage tank that will serve thousands of plants. NFT uses very shallow streams of dissolved nutrient-rich water to circulate bare roots within a watertight thick root mat, which develops in the bottom of the channel and has an upper surface that, although moist, is in the air (Hydroponics, n.d.). Because our farms will have multiple layers of growing beds, we will use a shallow PVC pipe that’s angled to allow passive flow between one pipe to another by the forces of gravity alone (2007, p. 317). The gravity pushes the roots downstream, rather than downward as the plants mature. Oxygen is abundantly supplied to plant’s roots to keep them healthy and clear of rotting. A downside to this system, even though all three requirements for healthy plant growth are being met at the same time using this technique, is that if a power outage were to perhaps occur, then the plants will experience massive challenges considering the very limited amount of room for buffering against interruptions like this one. This can be solved by installing

generator systems throughout the farm. They also promote density limitation due to the configuration of growing systems and are labor-intensive to harvest, but harvesting will provide many jobs to Fordhamopolis and each person on the job will be specially trained to collect efficiently and correctly.

### **Aeroponics**

In North Garden, aeroponic methods will be more of the focus. As stated in Despommier's article, "Aeroponics utilizes a fine mist of nutrient-laden water created by its passage through a pressurized nozzle that is then directed toward the enclosed root system of the plants" (2017, p. 319). It uses 70% less water than hydroponics, but still delivers the same amount of nutrients to the roots. Aeroponic systems follow a simple growing procedure. A large, long tub is filled with a nutrient solution and a submersible pump is fitted with a PVC tube that has portals cut into it to accommodate holders of seedlings of various types. The pump delivers a stream of nutrient solution up into the hollow body of the pipe. When it reaches the inner surface of the sealed top, a specially engineered contour disperses the stream, converting it into a mist that then brings the nutrients to the roots that are hanging inside the PVC cavity, and allows for oxygen to be taken in by the roots as well. The main advantage of aeroponic is obviously the decreased need in water, and its ability to grow high densities of grains like wheat and microgreens due to recent advances in nozzle designs that have improved the reliability of the system for creating the spray and eliminating the past issue of clogging. (2017, p. 319). A common disadvantage that will be seen with urban farming is the limited number of space available for plants to be grown. This worry typically occurs more so with reconstruction

projects, not new ones. So, considering we are making new vertical farm skyscrapers, this should not be an issue.

These farms will be a closed-loop cycle ecosystem that excessively manages everything within the vertical farm with no need for outside components. Another special trait of this farming method, unlike traditional methods, is that “Vertical farming produces locally grown food without the use of herbicides or pesticides in a clean environment that permits harvesting and sales without the need to wash the plants before packaging and shipping” (2017, P. 321), an evident plus especially with the further water reduction. Vertical farms also end the run-off issue, one of the main water polluters our current waterways experience, which excessively comes from traditional agriculture practices.

### **Aquaponics**

One addition to the hydroponic system is the opportunity for aquaponics to exist. Aquaponics is the idea of using NFT to circulate bacteria-laden water, a byproduct from the complex system of freshwater fish farming, to serve as a nutrient solution for the edible plants. Fish are first fed pellets of compressed vegetable material, so that their feces contain the essential nutrients needed for the plants in a bacteria form. After the bacteria dies and then lyse, they release the stored elements within them into the water, which are then taken up by the plants for their survival. Once these plants remove the nutrients from the water, it becomes purified and is then released back into fish tanks for reuse. Because other bacteria like the volatile compound ammonia, will come about from the fish naturally, which does not support plant well-being, it will first pass through a biofilter that is colonized with specialized bacteria the converts it



enzymatically into plant-friendly nitrates and nitrites (2017, p. 321). While this system is more challenging to operate, the benefits that will come from it when erected properly are more than worth it.

The reasoning for the aquaculture at South Garden, sitting comfortably adjacent to the Mississippi River and Lake McKellar, is due to the desire for fish not native to the local waters, along with other instances of overfishing higher concentrations of pollutants that exist in fish from human river exploitation purposes. Native fish to the area include catfish, striped bass, white bass, and sauger (tn.gov, n.d.). Fish plays huge part in the Fordhamopolis diet considering our location. But even though we have ample access to major water sources, one must keep in mind that wild fish now consist of many toxins. Mercury has played a huge role in the limiting of fish consumption in past years due to smokestack emissions, however, the fish grown in our aquaponic system will be born within the garden and not taken from the river or lake to distinguish the dangerous mercury counts underneath the scales. The native fish can be grown in the farm along with other species like shrimp, lobster, tuna, etc. Because these additional species are invasive, the storage of such creatures must be kept under strict conditions to make sure none escape and take over the River's extensive ecosystem.

## **Calculations**

Now let's talk numbers for such processes proposed. Starting first with the hydroponic garden, let's pretend we are only growing tomatoes (to make calculations easier to grasp). To grow this vegetable we will be using multiple panels that extend 50 meters long and reach a height of 10 meters. (See Cathcart's drawn example of a simple set of vertical panels in

Appendix D.) Tomatoes typically grow 1.8-3.7 meters tall, so in this case we will assume each grows 10 feet, which means that there will be 3 pots stacked on top of each other to meet the 10 meter standard. If each plant takes up 2 feet for width and a 3 foot gap exists between pots, then each panel will have 41 columns with 3 rows of pots. This equals 123 plants. If each plant produces 66.12 pounds of tomatoes (30 kilograms) then an entire panel will produce 8,132.76 lbs. One given red tomato offers around 81 calories, keep in mind the average daily caloric intake for an American is 2,700 calories, therefore, one panel will produce around 658,753.56 calories. That is enough to feed 244 people every day. However, let's say that each person in Fordhamopolis consumes 2,500 calories a day. The 200,000 residents would then need to consume 500 million calories a day, so one panel offers 0.13% calories needed for everyone in the city every 24 hours. If a tomato plant in a hydroponic system takes around 60-90 days (let's assume in this case it is 75 days) (Shaun, [hydroponicsgrower.org](http://hydroponicsgrower.org)), then we would get 4.9 full yields of tomatoes or 3,205,933 calories each year from a single panel. For one year, we would need to have 56,926 panels of tomatoes to feed everyone in the city for one year.

For aeroponics, let's grow potatoes using the same calculation system and the same panel size. If our russet potatoes grow 10 inches tall about that means that there will be 39 rows of trays since 10 meters is 393.7 inches. 50 meters would be 1968.5 inches, and if we decide to separate our plants by 36 inches, then we will be able to hold 54.7 plants across each tray. This would sum up to 2,153.54 potato plants a panel. Assuming that each plant produces 10 potatoes, and each russet potato weighs about 0.375 lbs (6 ounces), then each plant will offer 3.75 lbs or 807.58 lbs per panel. Russet potatoes typically are 169 calories, so each panel will produce 363,948.26 calories. That will mean that 0.7% of the Fordhamopolis population will be fed each

day by one potato panel. In aeroponic systems, potatoes take 70-90 days to mature (we will use 80 in this calculation) (Cornell Chronicle, 2014, [potatopro.com](http://potatopro.com)); therefore, every panel can be harvested 4.6 times a year offering 1,674,162 calories. To feed every resident in one year, we would need 111,111 panels of russet potatoes.

Knowing how much can be produced from one panel of tomatoes and potatoes in hydroponic and aeroponic systems, we can now see how many panels North and South garden can store. As mentioned earlier, South Garden (hydro) has a base of 0.7 km<sup>2</sup> or 700,000 m<sup>2</sup>. If the height of each floor is 11 meters tall, and the length and width (assuming the garden base is a square) is 836.6 meters long, which is about the same size as ten blocks in midtown Manhattan (Pollak, 2006, [nytimes.com](http://nytimes.com)). With our 50x10 meter panels, we can place 16 panels along the width of the building, and 209 panels along the length, considering that we keep each panel 1 meter apart on the length and 4 meters apart along the width. This will allow each floor to have 3,430 panels or 2,259,564,236 calories of red tomatoes 4.9 times a year. North Garden (aero) will be 4 km<sup>2</sup> or 400,000 m<sup>2</sup>. Assuming that each floor is also in a square with 11 meter high walls and the same size panels with the same distance apart, the width and length will be about 632.4 meters long (7.86 Manhattan blocks), which means we will be able to have 12.4 panels along the length and 158.1 panels down the width. The 1960.44 panels will generate 713,498,727 calories of potatoes 4.6 times a year. Depending on how many floors we will decide to have, we can feed our residents with tomatoes and potatoes with no problems at all. Of course our gardens will not only provide tomatoes and potatoes, but also other greeny plants, nuts, fruits, beans, etc.

## **Meat**

Along with all this growable produce, Fordhamopolis will offer meat as well. Consuming large amounts of cows, pigs, chickens, and turkeys will be promoted in the city as a great harm to the world, especially the cattle industry, in an effort to lower the demand for such products. Because of Fordhamopolis's size, we cannot raise such creatures on city grounds for the people that still would like to be omnivores. It is estimated that the average American in 2014, consumed around 58.7 pounds of chicken, 50 pounds of beef, and 40 pounds of pork (ers.usda.gov, n.d.). For 200,000 residents, that would entail we would need 29,740,000 pounds of chicken, beef, and pork imported each year. This is an astronomical number, which is why we will be striving for promoting a more vegetarian based diet for Fordhamopolis residents using our vertical gardens and campaigns exposing the great negativities of the livestock business, an action consistently and almost unanimously ignored by large companies and environmental groups today (Cowspiracy, 2014). Therefore, depending on meat necessities, these 29.7 million pounds of imported meat will be far less. Our meat that we will import won't be from industrialized factory farm situations, but rather from smaller-scale profit farms that raise meat in an ethical way (grass-fed with no antibiotic use). Other specialty items will also be imported into the city as well, like chocolates and spices.

## **Green Spaces**

Our city will also have a vast green space for smaller community garden projects and parks for enjoyment. In the parks, there will be native fruit providing plants such as apple trees,

pears, plums, mulberries, cherries, and peaches (Lockwood, n.d., p. 2). Community gardens will consist of multiple veggies and fruits like strawberries for residents of Fordhamopolis. During cooler seasons, community gardens can be brought inside and converted into vertical walls, which is a garden that stands up on one of its sides against vertical structure, unlike a horizontal, traditional garden. These walls can be placed within homes and in commercial business headquarters to be used as aesthetic and practical additions. Smaller plants like herbs, peppers, and lettuce can be grown for residential use using these walls. They are also great teaching tools for children to understand how gardening works and where their food comes from. In addition to these walls, rooftop greenhouses will also be fitted on skyscraper buildings for even more crop growth, which will utilize the solar strips (see Energy section). The crops grown here are smaller scale produce as well to ensure that the people of the buildings can care for them without constant assistance of the city's main growers who spend the majority of their time in SG and NG.

Fordhamopolis will have multiple open-air marketplaces for city residents instead of traditional grocery stores most Americans are accustomed to. It will become a social event, where residents can go and pick up their "vertical shares" from the gardens, and meet the growers who produced the food and other residents who are buying the same produce. This will enable the people of the city to be far more advanced and commutative about where food comes from, and further motivate better urban farming technologies for the betterment of the global society considering that, "By the year 2050, nearly 80% of us will be living in cities." (2017 p. 315). The city will be scattered with little pop-up shops for specialty items, such as organic dog and cat food, which typically consume enormous amounts of water in industrialized systems,

that pet owners of the city produce for their nonhuman loved ones.

Working toward this style of living will not be for everyone, but because food is such an essential part of people's lives, a transition for a better appreciation for our food won't be too difficult to achieve.

## **WATER**

Fordhamopolis will strive to be a water independent city by employing a closed water management system. Only 4% of all water on our planet is freshwater, and 1% of it clean enough to drink (Water Questions & Answers, 2016). Therefore the city will waste no water by constantly recycling and reusing its water, grey or black. Since the average American uses roughly 90 gallons of clean water a day, Fordhamopolis and its residents will need 18 million gallons of clean water filtered and distributed each day (Water Questions & Answers, 2016). We will strongly emphasize the importance for ourselves and our environment the rarity of fresh water within our natural resources.

### **Permeable Structure**

Not only will the city recycle water, but it will protect and maintain the natural water system and aquifers. The man-made hill that Fordhamopolis is built on is a structural system that emulates the naturally occurring ground. There are a multitude of benefits achieved by the permeable structure, which will ultimately allow for the water table level to fluctuate more naturally (Aquifers and Groundwater, 2016). While the permeable structure allows rainwater to travel downward and recharge the aquifers, it also allows space for more water systems and tanks to be installed without disturbing the natural layers of the Earth. It is as if a basement is being built for the city. The permeability of the structure is imperative given the weight that this structure bears. In order for Fordhamopolis to do no harm, the structure distributes weight to prevent weighing damage to the ground water systems, as impermeable built-up structures in

cities around the world have done to the water table level (Aquifers and Groundwater, 2016). There is strength in its structure, but the permeable ground does not compact the natural rocks (Aquifers and Groundwater). This structural aspect can be understood in the example of a honeycomb (Anker, 81, 2010). These characteristics are crucial to the accessibility of the groundwater.

This permeable grounding allows water to move fluidly through layers of rock. This is achieved by the grain and spaces of crevices of the built ground. This design has been inspired by Earth's soil and bedrock, and that will allow for the natural movement of water to be restored that is seen in nature (Aquifers and Groundwater, 2016). This design also maintains the division between the unsaturated zone and saturated zone (Aquifers and Groundwater, 2016). However, the system can be built up higher in response to sea-level rises and flooding dangers because it is modular (Aquifers and Groundwater, 2016). The system avoids the forceful impact water has on impermeable cities and architecture (Aquifers and Groundwater, 2016). The permeability of the structure would potentially allow for flood water to enter the system, without damaging the existing life in the city (Aquifers and Groundwater, 2016).

### **Sourcing the Water**

It is important that this structure allows Fordhamopolis to access the saturated level, or the "sub-basement," to obtain the required amount of water in the startup of the city. However, there are serious risks at hand when Earth's aquifers are pumped. In Earth's bedrock, a natural pressurized system takes place (Aquifers and Groundwater, 2016). There are natural pressures that can be a useful tool that pushes water upward, potentially without the need for a pump



(Aquifers and Groundwater, 2016). The permeable rock structure allows technology that works in this way and carefully pressurizes the aquifers, working in nature's horizontal motion and not man's vertical, life-sucking pumps. The speeds of pumping can not only damage a single aquifer, but decrease the water table level and dry out other aquifers (Aquifers and Groundwater, 2016). Fordhamopolis' horizontally moving pressure system works more quietly and peacefully than the disruptive pumping (Aquifers and Groundwater, 2016).

The basement and the sub-basement space that this system Fordhamopolis has adopted allows for Earth's natural systems to operate at a much more peaceful level than most current systems allow it to. Over time, this system will allow the water table to be regulated and maintained at a proper level. In terms of the city's redundancy, this system will work with the water recycling systems to provide a backup supply of water. If necessary, the city will be permitted to access groundwater without the concern of the rate of recharge (Aquifers and Groundwater, 2016).

Fordhamopolis will not be reliant on rainwater collection as a primary source of water, in order to maintain the natural water table of Memphis. The city's architecture will employ angular roofs that direct the water down and into the ground to feed the city's greenery and, of course, recharge the water table. In the event of flooding, the rainwater can be re-routed and stored in basins. Fordhamopolis values water and chooses to plan its storage and usage accordingly.

### **Filtration & Backup Systems**

The main system used in the city to clean the water is a water filtration system located underground on the south end of the city. Our filtration plant will be responsible for recleaning

90% of the city's used water. As discussed in the waste chapter, used water will be sent through one of the many underground tunnels that eventually connects to the filtration plant. There, the wastewater will undergo membrane filtration which removes pathogens, reverse osmosis which removes ions, molecules and large particles from drinking water, and finally UV Disinfection which disables the ability of bacteria and viruses to reproduce. (Bill and Melinda Gates Foundation 2017). Any sludge material gathered from the purified water will go straight into the city's plasma arc gasifier, where it will be burned and made into energy (see Waste for more information). By examining this process in the natural world, this system will emulate a natural system in a three-stage water purification process through the use of technology. The purified water will then be processed through a treatment plant that will result in safe and desirable drinking water. The water will go through a technique known as coagulation, which is when a chemical is added to produce positive charges to neutralize negative charges. This process makes it easier to remove particles because they become larger. The water will also go through an additional filtration cycle and finally a disinfection process to ensure that all pathogenic microorganisms have been eliminated (Bill and Melinda Gates Foundation 2017). This purified waste water will be redistributed to residential and irrigational needs throughout the city. People residing in Fordhamopolis city can be reassured that the water quality is as good as, if not better, than bottled water. In addition, the water filtration system will also be in charge of routinely monitoring and testing the water for inorganic contaminants that could cause concern for the residents of the city. Employees at the water treatment plant will also test for turbidity to determine and ensure the consistent effectiveness of the filtration system. All buildings will be

equipped with backflow protection to ensure that the the city's filtration system cannot be contaminated as a result of backflow.

If our water filtration system gets backed up or forced to shut down for repairs, the city can store used water temporarily. In our hollow plastic roads (more about our plastic roads can be seen in the waste chapter). Clean water can be stored in underground reservoirs that are not only underneath our city, but underneath buildings and residential complexes as well. These underground reservoirs are built and sized in consideration with the permeable structure of the land, and of course the capacity they should hold. The remaining 10% of our liquid waste will be sent through a separate chute that sends the used water into living systems (see Appendix E) incorporated into our buildings and vertical farms that clean it naturally through the use of plants and their roots.

Densely populated areas, unsurprisingly, have high water use patterns, so water recycling and filtration is imperative to the upkeep of the hydrologic cycle. In order to reduce the city's participation in an unsustainable water filtration process, a Living Machine can be used to filter and treat the city's run-off by surrounding the city with a band of Living Machines (BlueKey, n.d.). It will act almost as a barrier for contaminated stormwater run-off. Filtered water can be used for either toilet flushing/irrigation or direct flow back into the ecosystem by allowing the water to pass through the Machine and then be released. Water is polished by filtering and disinfecting it. Online sensors monitor the quality of the water consistently (BlueKey, n.d.). There are two types of Living Machines- Hydroponic and Tidal Flow Wetland. Typically indoors, a Hydroponic Living Machine functions through flowing water entering a series of aerated tanks set underneath a diverse plant set. The roots of the plants provide microbial

population growth, attracting beneficial insects and other organisms. A sheet of “light-weight expanded shale aggregate” sits on top of the plant set rack, acting as a natural biofilter and bacteria colony to “remove any residual odor compounds.” The Tidal Flow Wetland Living Machine design incorporates biomimicry to a more sophisticated degree. It creates a contained, continuous tide, comparable to a wetland ecosystem, through a series of gravel-filled basins. After nutrients and solids are removed through just one tidal cycles, water comes out of the system clean enough to drink (BlueKey, n.d.).

Guilford County middle and high schools in Greensboro, NC incorporated a Hybrid Wetland Living Machine. They chose to use their machine to filter all the water collected from the campus for irrigation and aquifer recharge. The schools saw over \$2 million in water savings, were able to source 100% of the water required for toilet flushing from treated rooftop rainwater and enjoyed year-round green athletic fields, even in drought. They also took advantage of the on-site educational opportunities, using their Living Machine as a “living-laboratory for biology, chemistry, and environmental science classes.” (BlueKey, n.d.). Furman University in Greenville, SC chose a Tidal Flow Wetland Living Machine to help exceed LEED requirements for its Charles H. Townes Center for Science building. The university mines wastewater from the campus sewer into a primary settling tank from which it is pumped into the Living Machine for treatment and UV disinfection (BlueKey, n.d.). This will enable the city to reap the additional benefits of reductions in water purchasing, water pollution and the city’s overall water footprint. It will also boost greenery and aesthetic. It provides Fordhamopolis with an important reusable resource and puts less stress on the reservoirs from which the city draws its water supply.

## Vertical Farming Water Usage

For calculating the amount of water needed for tomato growing in the hydroponic system, I will be comparing it to a more modern and widely accepted irrigation technique known as drip irrigation. In a traditional drip irrigation system for tomatoes, the plants are usually separated 20 to 25 inches apart from each other within a single acre. If an acre is 43,560 square feet, then each side of the acre would be about 208.7 feet long. If each tomato plant takes up about 2 feet on its own and has 2 extra feet of space between plants, then up and down there will be 52 plants, or 2,704 plants for the acre. Tomato plants require about an inch of water a week (Coolong, 2007-12, slide 30), and in an acre that would be equivalent to around 13,500 gallons of water a week or 1928.57 gallons a day. For our imaginary acre, let's imagine that we are using the modern style of agriculture, drip irrigation, which is 30-65% more efficient than traditional methods of agriculture, and is commonly used around the world to grow tomatoes and potatoes. For our calculations let us suppose that our drip irrigation was 40% more efficient than traditional practices. It is also estimated that hydroponics is 70% more efficient than traditional practices (Despommier, 2017, 316). Subtracting the two, the water saved would be 30%, which would mean that one panel in the vertical garden for tomatoes requires an initial 162 gallons, keeping in mind that one panel is only 12% of the area of an acre. This water would be recycled in our living machine the vertical garden provides, along with in aquaponic systems. One must keep in mind that around 7% of this water can be lost each day due to leakage and evapotranspiration (Baptista, 2014, para. 5). If these externalities within the urban farm do perhaps occur, a panel would need around 11 gallons of water to be replaced each day. A floor of tomato panels (still

using the 3,430 panel calculation) would need 555,669.72 gallons of water initially. If 7% of water does escape, then 38,897.88 gallons will have to be supplied to the South Garden daily.

On the other hand, North Garden, calls for even less water than the southern hydroponics brother. Russet potatoes require around 1-2 inches of water (Your, 2017), for this I will make that 1.5 inches. This measurement is equivalent to 20,250 gallons a week or 2,892.86 gallons per day. Still using drip irrigation, we will be comparing the 40% water efficient rate to the 95% efficient rate of aeroponics (Despommier, 2017, 316). This comes to 1,301.07 gallons of water needed in what would be an acre of aeroponics, but considering that our panels only take up 12% of space that an acre does, aeroponics in our system will consume 156.22 gallons a panel, with a daily loss of around 10.94 gallons if following the loss 7% rate. For an entire floor, using the 1,960.44 panels found in the food chapter, 306,259.94 gallons would need to initially be consumed and then recycled, which leads to an additional 21,447.21 gallons a day.

We will also include an aquaponic system in our hydroponic garden. Most of the water will be filtered through our living machine and other filtration processes; however, we will also include aquaculture to exist at South Garden for another natural filtering process and breeding ground. The most commonly raised fish in aquaponic systems are by percent tilapia (69%), ornamental fish (43%), catfish (25%), other aquatic animals (18%), perch (16%), bluegill (15%), trout (10%), and bass (7%)” (Love, 2015). It is said that about 1 fish needs 5-10 gallons or a one pound fish needs 1 square foot of water a day. For example, 16 feet squared is equivalent to 16 pounds of fish, which can recycle 80-112 gallons of water (we will use 95 gallons in our calculations). So if for hydroponics we need to recycle 555,669.72 gallons of water for one floor filled of panels, then that would require 18.46 million pounds of native fish to be required to

filter 109,608,896 gallons of water for an entire floor of 3,430 panels (Berstein & Lennard, 2017).

### **Water Budgeting**

A water footprint measures the amount of H<sub>2</sub>O that is needed to vitalize a certain product, crop or lifestyle. It can be used to place proper worth on water, which has been greatly undervalued throughout history, extending the fair trade movement to include ecosystem services in product pricing. It is also useful for understanding the true worth of water as a natural resource. The footprint calculation incorporates both direct and indirect usage of water and “includes water consumption and pollution throughout the full production cycle from the supply chain to the end-user” (Water Footprint Network, 2015- 2017). Understanding the implications of each city’s water footprint is the reason Fordhamopolis has initiated a city-wide water budget. Not only is water budgeting an important practice for the Earth’s water supply, but also for the city’s water supply. Fordhamopolis’ water budget is crucial to the essence of a closed water management system, and making sure all people understand that the water supplied is a relatively fixed number.

The water budget refers to “the interplay between storage of water in the system, flux of water through the system, and human and ecological uses of water (WaterSense an EPA Partnership Program, 2017).” The best way to ensure that the natural order of an ecosystem remains in check is to minimize disturbances to it. Members of the Fordhamopolis community must be vigilant and responsible with their water use practices in order for this new management system to function properly. Because water is an important resource, more than another commodity for purchase, it should be treated as such. Water budgeting can be employed within

buildings and facilities to reduce the stress put on this closed water management system. One way that this can be carried out is by installing water-efficient toilets throughout all buildings. Toilet flushing “account[s] for nearly 30 percent of an average home's indoor water consumption.” The national limit on the amount of water permitted per flush is 1.6 gallons; modern water-efficient toilets have cut down a full flush to 1.28 gallons per flush (gpf). Dual-flush toilets provide an alternate short flush option that uses less than 1 gpf. The full flush is intended for solids and the short flush is intended for fluids. The average American household of 2.58 people can save up to 13,000 gallons of water each year using water-efficient toilets. Fordhamopolis will ensure that all restroom facilities are equipped with water-efficient toilets (WaterSense an EPA Partnership Program, 2017). Installing other water-efficient appliances such as laundry machines and controlled-flow faucet fixtures can also reduce water use.

The citizens will follow these regulations to ensure that the technology Fordhamopolis has employed has the capacity to provide for everyone and more in the case of emergencies. Thus, Fordhamopolis would achieve the water independence it strives for. The best way to ensure that the natural order of an ecosystem remains in check is to minimize disturbances to it. A large part of that involves maintaining the water budget of the Lower Mississippi-Memphis Watershed, ensuring that the flow of water in and out of the watershed remains balanced.

Our city will set a “water cap” for each member of society at 75 gallons a day per person. It will be monitored by the amount of water used within a household and the amount of residents in that household. There will be monetary penalties for going over the cap and monetary reimbursements via tax return for staying under the cap. Guests can be registered and their costs can be deducted from a household’s water use via tax return.



## **WASTE**

Fordhamopolis believes waste, within the city and in general, should primarily be reduced, then reused, then recycled if possible, and then finally made into energy if there is no other possible way of managing it. In essence, our city will mimic nature, insofar that it will make use of all its waste. This includes all municipal solid waste such as hazardous waste, medical waste, inert waste, food waste and plastic waste.

### **Automated Vacuum Waste Chute System**

Whereas most current cities have single trash cans located throughout the town, Fordhamopolis will have groups of three waste receptacles instead of one. One for trash sent to the Plasma Arc, one intended for biodegradables that are then sent to the city's composter, and the third for recyclables. The purpose of three trash cans rather than one is to reuse/recycle any waste the city can, and then incinerate the rest in order to create energy that can be used and stored for the residents of Fordhamopolis. These three trash cans will not only be placed locally throughout the town, but in private buildings, homes, and offices. In addition, in order to save labor and the congestion of garbage trucks periodically driving on our streets, our city will use an automated vacuum waste collection system, which uses a pneumatic system to effectively transport all the trash from the three cans into their respective systems through high speeds in tunnels that run throughout the city underground (Russell, 2010). Current vacuum systems are in place within areas of only a few square kilometers, which can therefore be efficient for Fordhamopolis's two square kilometer city (Russell 2010). Using biomimicry, our vacuum waste collection system is modeled after tree branches, where each chute combines into other chutes

that then become the three main chutes attached to the plasma arc gasifier, the recycling system, and the city composter. This redundancy of multiple chutes makes it possible for the city to fix the tunnels if they get clogged or broken. If a chute gets waste stuck in it, Fordhamopolis will shut it down and take away the three above ground trash cans in order to unclog it. Waste will not pile up within the city if this happens, since residents can throw out their trash in the next most convenient trash can. However, to prevent this from happening, our city will mandate a size limitation on the waste that can be put into the trash cans and sent through the chutes. This will prevent residents from throwing out large items, such as furniture they wish to get rid of, into trash cans that could then get stuck in the chutes (Litter collection with vacuum technology, 2008) (See Appendix F). More on disposing of large items, municipal or not, will be discussed later in the chapter.

## **Litter**

Unfortunately, where there are humans, there is often littering. It should be expected that Fordhamopolis will see trash littering the streets, parks and other local areas, although we will make an effort to reduce this through education and encouraging proper waste disposal. Some biodegradable trash will probably litter the streets, which must also be taken care of due to our plastic roads and sidewalks inability to break down these materials. Since our city won't have garbage trucks collecting the trash due to our automated vacuum collection system, Fordhamopolis will instead have weekly garbage cleanup devoted to cleaning the city of its litter. On a set day each week, city garbage men will go around the two km squared city and clean up all litter and trash that is around the town. They will collect the litter from roads, parks, and

sidewalks, divide them by type of waste, and then send it into their respective waste systems. Curb suction chutes that absorb litter and send them into the city's underground vacuum chutes were considered an option during the construction of our city, however this system can be harmful and wasteful as it would have sent all the litter into the plasma arc gasifier, including recyclables. In addition, the city garbage men will also be in charge of picking up large pieces of waste that residents cannot get rid of through the trash cans in the town. Residents can go online and request waste pick up, whether it is municipal solid waste, recyclable materials, or biodegradable waste, where garbage men will then pick it up, break them apart, and send it to their respective systems.

### **Plasma Arc Gasification**

Some waste that is not reduced, reused or recycled by the city will be fed into the Plasma Arc Gasification System located in our city, such as the hazardous and medical waste. As described in the energy chapter, this carbon-filled trash will be converted into synthesis gas that will then be turned into energy for the city's use (Gasification Syngas, 2017). The rubbish trash chute will send all the trash through the tubes straight into the plasma arc gasifier. According to statistics, the average American creates up to 1 million pounds of municipal solid waste each year (How much do Americans throw away?, 2015). However, since Fordhamopolis reuses most of its trash, only 10% of the average American trash will be sent into the plasma arc gasifier. Therefore, the average citizen of Fordhamopolis will submit roughly 100,000 pounds of trash into the plasma arc gasifier per year, which will emit 800 kWh and 400 pounds of rock residue for every 2,000 pounds of trash (Circeo, n.d.). By these numbers, the plasma arc gasifier will

therefore be able to provide the city with eight billion kWh of clean energy each year. Energy that is created and not used can be stored for later use or purposes. In addition, the rock residue created by the plasma arc gasifier will be collected and reused by the city for creating and fixing all the infrastructures within the city such as roads, buildings, and residential complexes. However, according to these numbers, the average Fordhamopolis citizen will create 20,000 pounds of rock residue each year, which will be more than the city can use. As a result, our city will export much of the rock residue created by the plasma arc gasifier. Again, redundancy is a key factor in the construction of Fordhamopolis. Therefore, the city will not have just one plasma arc gasifier, but rather four in case one or more fail. Since plasma arc gasifiers today can be as small as a flatbed truck, Fordhamopolis will not waste much space for having four of these systems underground within the borders of the city (Plasma Assisted Gasification, n.d.) (See Appendix C).

## **Composter**

The next chute will transport all biodegradable trash through the tunnels and into the city's composting machine. The above ground composter uses an automated turner to mix all biodegradable materials with used water and urine from the residents to create natural soil and fertilizer for landscaping purposes such as the city's green spaces and gardens. In addition to leftover biodegradable foods and other foods that have gone bad/not sold in the markets, Fordhamopolis will also have a chute connecting the vertical farms to the city composter. This will also allow the farmers to make use of plants, fruits and vegetables that cannot be sold by converting them into soil that will go back into the environment. The soil created will be

distributed throughout the city, first to public parks, gardens, and green spaces, and then to individual residential areas and buildings where it is needed/wanted. To mask the smell created during composting, natural perfumes are mixed in with the biodegradable materials in the composter such as moss, coconut water/oil, vanilla, citruses, coffee beans, mint leaves, etc. Since the vertical farms will produce fresh food each day and week, much of the trash collected in the city will be biodegradable leftover food scraps, which can and will be composted. Therefore, the city will produce more soil and fertilizer than it can put to use. An exporting system will be put into place, where the leftover fertilizer that does not go back to use into the city will be sold and transported in an efficient manner to neighboring cities and towns.

## **Recycling**

The city will also focus on redirecting much of its waste back into daily systems for it to be reused by the people and the city itself. Therefore, the third chute will transport all recyclables, such as glass, paper, cardboard, metal, plastic, and textiles into a system that sorts them, cleans them, and reprocess them into new materials that can be used again by the city and its residents. Recycling not only reduces the amount of raw materials needed to make products for the residents of Fordhamopolis, but also lowers the number of greenhouse gas emissions in the production of constantly making new materials. For example, used office paper will be recycled and sent to the recycling plant that will renew the used products as clean paper and send them back for manufacturing and redistribution. Some plastic waste will also be recycled by the city, such as for our roads, infrastructures, and household products. Plastic roads can be made with recycled materials that only take days to make, rather than months, are much lighter, and

will last three times longer than roads that are made of concrete. Our plastic roads will not only be made of plastic, but are solar paneled plastic roads that produce energy as well (more can be read about this in the energy chapter). In fact, plastic roads are also created hollow, so that water may be stored within them (plasticroad, 2016). This is exceptionally beneficial for Fordhamopolis since it's located in Memphis, an area prone to flooding. It will also provide a backup system for our city in case our water filtration system gets clogged, since the plastic roads can not only store clean water, but dirty, used water as well until it can be cleaned.

Though plastic is efficiently recycled in our city, plastic bags are discouraged in Fordhamopolis. All stores, markets and restaurants will not offer plastic or paper bags to their customers, but will have reusable bags on sale at a very low cost. In addition, plastic bottles will not be sold within the city. Since the city has banned plastic bags and bottles, the local government will distribute 200,000 reusable bags and bottles to the residents of Fordhamopolis for free. Additional bags and bottles will be on sale at an affordable cost throughout the city in local markets and stores. Therefore, if residents of Fordhamopolis wish to purchase items or liquids, they are required to bring their own reusable bottles and bags, or purchase new ones at an affordable cost.

Fordhamopolis also encourages its residents to resell certain materials and products, in order to promote full material usage to save more before we have to recycle any waste. Examples of these materials include electronics and industrial materials, such as certain metals and leftover building items. Other companies and individuals would be willing to buy these items for their own use, rather than have the city waste the labor and energy in recycling these materials.

Residents can sell their leftover materials or used goods to markets and companies, where customers can buy them at a discounted price.

## **Water Waste**

Fordhamopolis will also efficiently take care of all its used water. 90% of liquid waste, such as used water and urine, will be sent to the water filtration system located within the city's borders. This will take care of all types of water used by the city, including gray and black water (water mixed with sludge and waste). Using biomimicry again, a tunneling system modeled after tree branches will connect all sinks/toilets to the water filtration system. Using gravity, since our city is located atop a manmade hill, our city will naturally send used water and urine through the tunnels, downward and into the filtration system. The remaining 10% of the city's liquid waste will be sent to living machines located in our vertical farms via a separate vacuum chute system. These living machines, explained more in the water chapter, can essentially take used water and filter them through live beings such as plants. No living organisms are harmed and no pollution is emitted. The clean water can then be put into use in fish tanks and for watering plants such as the ones in our vertical farms. Since Fordhamopolis is home to two vertical farms that will grow foods hydroponically and aeroponically in a technologically advanced setting without the use of pesticides, agricultural runoff will not be an issue to deal with- the world's current main source of pollution. This will save the city time, labor, and energy from capturing and filtering water contaminated with chemical substances. In addition, rather than using clean water for the city's composting machine, used water, such as bath/sink water and urine, will be used in the composter to create the natural soil. Not only is this more beneficial for the biodegradables in the

composter and for the soil created, but no clean water will be wasted where it is not needed (More on the filtration system and living machines can be seen in the water chapter).

Composting toilets will also be an encouraged idea for our city, where certain public toilets will have human waste fed into the environment that will be beneficial with its natural nutrients. This saves the city energy and power to put human feces into the plasma arc gasifier while also helping the environment naturally. Composting toilets will not be put into buildings or residential areas, but rather in public areas such as parks. Again, natural perfumes such as moss, coconut water/oil, lemons and vanilla beans will be used to mask the smell created.



# TRANSPORTATION

Having reliable and efficient transportation and infrastructure is highly relevant to creating an ideal city. Our transportation system will support the motto of Fordhamopolis by being sustainable, reliable, and redundant, as well as accessible to all its residents.

Like the other systems that make up our city, the transportation system in Fordhamopolis will be as integrated and interconnected as possible into the city's other systems, mimicking the resiliency and efficiency of nature. There are many ways to do this. An examples includes connecting transportation to both the energy and waste management systems. Transportation needs energy to run, and so these two systems are already very closely tied together. The physical space taken up by the transportation systems, for example bus shelters, train stations, and even the space covered by tracks, can be installed with solar panels wherever appropriate. In addition, there are many technologies that utilize the movement of vehicles to regain some of their energy. This will be implemented wherever possible. The Waste Management and Transportation systems are also very intimately tied, as waste has to be transported in order for it to be managed.

## Vehicle

America has historically been a very car-centric country in terms of its transportation. Fordhamopolis will break this tradition. Private cars will not be encouraged, or even allowed in Fordhamopolis, except in rare cases. There are many reasons that private car ownership is not

encouraged in Fordhamopolis. For one, it's no secret that vehicular emissions are harmful to both human health as well as the health of the environment. According to the Union of Concerned Scientists, more than half of Americans live in areas that do not meet federal air quality standards. Breathing polluted air causes respiratory ailments such as bronchitis and asthma, and increases the risk of more fatal diseases such as cancer. (UCS, n.d.) Emissions from transportation account for more than a quarter of the greenhouse gas emissions in the US, a huge percent of which come from cars and trucks (EPS 2017). These emissions are causing larger scale ecological problems as well as disease. Global warming is also a huge issue. There is an incredible amount of debate surrounding this issue, but the hard facts are that the temperature of the earth is rising, and that an increase in greenhouse gasses is contributing to the hole in the ozone layer. Rising sea levels and increase in severe weather are just two consequences of global warming if steps are not taken to reverse carbon emissions (EPA, 2017). In addition, cars provide a very real threat to the safety of pedestrians and other drivers. In 2015, there were over 35,000 deaths from car accidents in the US alone (IIHS, n.d.). Besides just improving the safety of the city, having fewer cars on the streets will make them more enjoyable for pedestrians in general.

The few cars that are used in Fordhamopolis, for uber and rentals, will be electric. There are various options for electric cars, some better than others. We have already mentioned that transportation is a leading cause of carbon emissions in the US. When talking about electric cars, it is important to note that the only sector that beats transportation in greenhouse gas emission in the United States today is electricity creation (UCS n.d.). So just converting to electric car technology is not enough on it's own. It merely shifts the problem instead of solving it. However, by changing the ways in which we get our electricity (see section on energy) and by

utilizing strategies such as ridesharing and increased public transportation to reduce the number of vehicles in use, these problems are easily combatted. Additionally, electronic car manufacturing has a significant environmental impact, as it uses rare harmful metals and lithium batteries. However, once created, these elements can be recycled and reused (Wade, 2016). Fortunately, the companies that are on the forefront of creating electric vehicles, such as Tesla, are already very environmentally focused. Tesla already recycles every battery pack that is returned to them, and plans to do even more in the future (Wade, 2016). At their worst, electric cars can be just as harmful to the environment as cars that run on gasoline. However, at their best, they have the potential to leave little to no footprint at all.

As an alternative to private car ownership, in Fordhamopolis there will be an abundance of ride sharing options that are similar to Uber and Lyft. In addition, there will be private carshare rentals that work more like Citibike than any currently existing car rental services. Modern equivalents would be services like Zipcar, which just require a membership and allow cars to be checked out by the hour. However in Fordhamopolis this system would be much more accessible and much more mainstream. TerraformOne have a couple of interesting designs for stackable electric cars which take up very little space when parked and would be ideal for this sort of car-sharing system. Not only would these stackable electric cars be ideal for reducing the gasoline emissions of our city but would also significantly reduce the huge amounts of space needed for parking. Often in cities, it's hard to see cars parked on the street as much of a space issue (as opposed to looking at a suburban mall parking lot that stretches endlessly into the horizon). However, these small spaces add up. In New York City, there are an estimated 146,000 parking spaces in the Manhattan core. At 50m<sup>2</sup> a space, that's almost 1.5km<sup>2</sup>, an area more than

half the size of Central Park. In the entire US, there are estimated to be as many as 2 billion parking spaces. If this number is accurate, then the combined size of these spaces would be larger than the entire state of Massachusetts (Public 2011).

These stackable cars would reduce this number significantly, by taking up less space individually, as well as lessening the need for private vehicles, and by extension, lessening the need for places to park them (Joachim, n.d.). Just like Citibike, the electric cars could be checked out of any terminal and returned to any terminal. These would be placed at frequent intervals throughout the city. Larger rentals, more similar to the car rental services we use today, would also be available for events such as moving, or going on vacation outside the city. Additionally, there will be free places to park cars outside the city-for both visitors to the city and residents of the city who still wish to own cars- but a permit will be needed to drive them on the streets of Fordhamopolis at any time.

### **Self-Driving Technology**

Self-driving car technology is being developed and put to work worldwide, from South Korea to The United States. For example, South Korea has permitted Samsung's self-driving Hyundai on the road, with artificially intelligent sensors and computers (Hawkins, 2017). In Las Vegas, BMW has also impressively revolutionized the automobile-commute with their prototype (Findling, 2017). The advances and benefits seen in these examples, and others in development, will be utilized in Fordhamopolis to ensure safe and feasible transportation for all citizens.

Although there are some examples of self-driving vehicles in existence today, it must be

considered that this technology tests the comfortability of the majority of people. A study in The United Kingdom, The United States, and Australia on the question of living with this new technology states this. Specifically, for the United States, it has been recorded that:

“Respondents in the U.S. expressed greater concern about riding in self-driving vehicles, data privacy, interacting with non-self-driving vehicles, self-driving vehicles not driving as well as human drivers in general, and riding in a self-driving vehicle with no driver controls available (Schoelette, 2014).”

This information on the people’s attitude toward this technology has been considered in the transportation technology of Fordhamopolis. Since the study has also shown that many people are optimistic about what this technology can do for them, it has been put to its best ability in this city.

However, if implemented, there are studies that show that self-driving systems, if implemented across an entire city, would be a vastly safer and more efficient way to get people where they are going. Even though technological glitches are inevitable, human beings cause a much higher percentage of accidents through reckless driving, driving under the influence, and just general human error (Montenegro 2015). With this in mind, the systems of Fordhamopolis will be built with the option to switch to a self-driving system across the board should the technology become even more reliable than it already is and should the idea of trusting control of personal vehicles to technology be more widespread and trusted.

All of Fordhamopolis’ systems will have self-driving technology, but still have a seat for

the driver. The experience of driving will be similar to that of the BMW. To keep traffic moving, the vehicle displays countdowns to the next green light on the dashboard to keep drivers ready to go. Once the automobile is on a highway or expressway, at the flip of a switch, the driver can release from the wheel and let the car cruise on at a constant speed. This technology allows public transportation to operate on timely schedules and set prices. While this technology is advanced, it is not entirely perfected and thus requires a driver to oversee it. Glitches are inevitable in technology, as are errors in human nature, that this technology has been programmed upon. However, the driver will serve to mediate between unfamiliarity between the passengers and this new technology. In this way, Fordhamopolis will build a widespread, new level of comfortability with this technology.

It is important to note that all private vehicles will be of the same technology and function, as a common fear with this technology is its relationship to other vehicles without these functions. In fact, it is safer and more efficient if all vehicles are operating according to the same program to avoid the miscommunication of vehicles.

All transportation will connect to a network in order for all drivers to communicate. Alerts, updates, or messages will appear on the dashboard and be read aloud. This is extremely important in the case of emergencies, to clear the street and alleviate stress. For instance, in the case that an ambulance needs to hurry through the street, the vehicle's occupants will be notified by the system, and be prepared for its artificial intelligence to conveniently maneuver itself. Thus Fordhamopolis integrates its transportation system with artificial intelligence, compactivity, and eco-friendliness. The implementation of self-driving vehicles has been influenced by the common American feelings towards the technology, and the excellence achieved by

existing examples.

## **Bicycle**

Bike sharing would be another very common way to travel around the city, the majority of which would take place on raised, above street level bike paths similar to ones they have in Copenhagen and in Eindhoven (Visit 2017). This would make it safer for both bikers and pedestrians, and also allow bikers to get where they are going faster and more efficiently. Bike sharing would be included in the charge for public transportation, with an added deposit should something happen to the bike.

## **Pedestrian Scale City**

The lack of private cars in the city will allow for a more pedestrian and bike friendly city. The streets will be built to a more narrow human scale rather than at a scale for traffic, similar to many medieval European cities. They will be tailored for pedestrian and tram usage, making driving a car a more inefficient way to get around the city. This will further reinforce people to use public transportation to get around, as well as make the streets a nicer place to be. Urbanist Jane Jacobs was a strong advocate for a network of connected pedestrian spaces, calling them "an intricate and close-grained diversity of uses that give each other constant mutual support, both economically and socially." Two cities that have great examples of these kinds of spaces are Venice (which is almost entirely pedestrian owing to the canals being less than ideal for traffic) and Copenhagen, which has made a conscious effort in recent years to reduce traffic, convert

streets and parking lots to pedestrian walkways and plazas, and maintain a sense of human scale on the streets (New Urbanism, n.d.).

The health benefits attached to a pedestrian-oriented city extend further than just having cleaner air. Not only will there be fewer fumes, but since people will be walking and biking more, they will get more exercise and lead a generally healthier lifestyle. In fact, there is an almost two year gap in life expectancy with respect to urban vs non-urban lifestyles in America (Stephens, 2014). So not only will this pedestrian emphasis make the city feel like a nicer place to be a citizen, it will also greatly improve the physical and mental health of all its residents.

### **High Speed Trains**

At its longest edge, our city is only 2.5 km long, meaning that it would only take an hour to walk the entire length of the city. However, even though our city is small, we will have a high speed train in place. At first this train will be used just for intercity transit, as well as for transportation to the surrounding Memphis airports. Hopefully the message of “do no harm” will catch on, and more people will move to Fordhamopolis. In this case, the high speed train will be ready to connect areas of the city as it grows.

There are a few options of advanced train technology that could be used for this train, some that exist and some that are still currently being developed. Our city will opt for the most efficient and fastest option. One currently existing train system is the bullet train. The trains are electric, with each carriage working as a self propelling unit, or EMU. The first, and most successful example of a bullet train was in Japan. Built in the 1940s, the system has expanded



throughout the country. These trains use a combination of technologies, including an aerodynamic nose to achieve speeds of up to 200mph (ACPR, n.d.).

Another contemporary example is the Maglev train. Maglev trains, or magnetic levitation trains, were developed in 2004 and have been implemented in mostly in Shanghai and other Asian cities. These trains can get up to higher speeds as the magnetic technology works by levitating them above the track, eliminating the drag that other trains deal with. In addition the magnets work to propel the train at high speeds. Currently Maglev trains hold the world record speed for trains, at 375 mph.

An even faster system is the Hyperloop, which is still in development and is being worked on by great minds such as Elon Musk and Shervin Pishevar. The Hyperloop, if implemented successfully, will be even faster and more efficient than the previous two options. This closed loop system eliminates most of the drag that is the main source of energy loss in the Maglev train system. The initial tests and analysis of this system boasts that the top speed of the Hyperloop could reach 760 mph. All three of the aforementioned systems are faster and more efficient than normal trains, and any could be properly implemented in Fordhamopolis. However, should the Hyperloop technology be fully developed in the near future, it will definitely be the fastest and most efficient option. Although in the current day the reality of this project seems easy to call into question, the project has an incredible number of people involved in the business, science, design and technology stages of this project , and has an ambitious goal of moving passengers by 2021 (Hyperloop One, 2016).

## Mass Transit

On a smaller scale, our mass transit will be a combination of trams and busses. Both of these systems work on a similar scale, and there are pros and cons to both methods of transport, which is why we will have both in place. Trams are more comfortable and more reliable when on an isolated track instead of among traffic. Busses on the other hand, are more adaptable to changes in traffic and accidents, as well as being quicker. Both are good options for Fordhamopolis and both can be run electrically. One clean-energy bus that is currently in use is the *Mercedes-Benz Ciatro G BlueTec Hybrid Bus*, a 4 electrical wheel bus with hub motors and automotive lithium ion batteries. The bus also generates energy in the course of braking (Daimler, n.d.).

Fordhamopolis would have one more form of public transportation- an urban gondola system that would have stops both on the street level as well as stops from the tops of skyscrapers and other high-rise buildings. While this type of transportation is most often seen in ski resorts- there are many examples of it being used as a reliable form of public transportation around the world, especially in mountainous areas. One very successful example of this is the Metrocable in Medellin, Colombia (Dale, 2010). Another contemporary example is the Roosevelt Island Tramway in New York City. Other raised cable transportation systems have been proposed in major US cities such as Chicago and Austin (Sisson, 2016). Although this system will by no means be the fastest way for the citizens of Fordhamopolis to get to their final destinations, the urban gondola will provide scenic views of the city and be a tourist attraction as well. As well as being incredibly space and energy efficient when compared to light-rail alternatives, this method of transportation is also flood-resistant, as the cars are raised far above

the level of the street. Another very flood resistant method of transportation would be solar powered water taxis. So far this technology has been tested in Paris, in the form of the “Sea Bubble” that floats two feet above the water (Mailonline, 2016). At the current moment, Fordhamopolis lies a short distance from the water, but since our area is prone to flooding, these taxis may become more of a necessity as global sea levels rise.

With busses, trams, rental cars, bikes, and gondola, our city will have more than enough transportation. Having so many options to choose from will ensure that should one system fail, there will always be another option for people to turn to. Access to these transportation methods will be a mandatory expense for every citizen, making it intuitive for every citizen to use public transportation. The cost of a monthly transportation pass would be a bill like heating or electricity, and would give them access to every form of public transportation without exception.

### **Non-Pedestrian Subway System**

One system that is seemingly missing from this description of Fordhamopolis is a subway system. However there would actually be a subway system in this city, but it would not be for pedestrian use. Our streets are built for people, and so they will not be sent underground to be transported from place to place. Rather, the underground system would be used for utilitarian purposes that usually take up valuable street and road space. One such use for the subway system would be for deliveries, eliminating the need for trucks of any kind to ever enter Fordhamopolis. The system would be fairly elaborate, and connect to the basements of buildings wherever possible in order to make delivery easier. This system would also be utilized as the main system

of removing waste from the city- so there will never have to be trash piled up on the streets waiting to be picked up. Both garbage collection and deliveries clog up the streets and blocking both traffic and pedestrians. Moving this less desirable utilitarian activity belowground will make the streets and the city as a whole a much nicer place to be. The only above ground components to this system will be on-call waste removal trucks that will be available should any citizen have a larger pieces of trash, such as furniture or old electronics.

In this way, the transportation system will be fundamentally linked with the waste removal services of the city. Fordhamopolis will have a sophisticated pneumatic system to allow for fast and efficient transportation of trash that will connect to the subway system at collection points if necessary. This is discussed further in the waste section.

## CONCLUSION

The design of Fordhamopolis considers, “Who are we to destroy the planet’s creations?” (Wilson, 2010). Fordhamopolis will model how a man-made built environment can do no harm to the natural Earth. Ecosystems contain different living components, each with different functions that give the system strength and resiliency. The array of technology that Fordhamopolis will utilize achieves this as nature does along with the contribution of each person in the community. Our thought process throughout this report has been to establish the most sustainable, efficient city ever created with new technologies in place today. Appendix G reveals how we went about designing this city using visuals, without any prior knowledge of ecology and newly innovative technologies today.

However, there are some drawbacks in certain systems that need more research and adjustments in order to be efficiently operable if placed in the real world. All our systems placed underground need to be in proper contained spaces with regulated air pressure not discussed in this paper. Plasma arc gasifiers are known to emit some harmful pollutants into the atmosphere, such as methane, so certain precautions must be taken in order to control this. Nuclear waste pyroprocessing is very expensive and does not get rid of all the waste, so this definitely needs more research if used today. Hyperloop trains are also currently not in use as they are still being developed, so again, further information needs to be looked at in order to move forward with these trains in reality.

Regardless, the systems and infrastructures described in this report are mostly used around the world today, and can therefore be utilized not only in Memphis, but in any city.

## APPENDIX

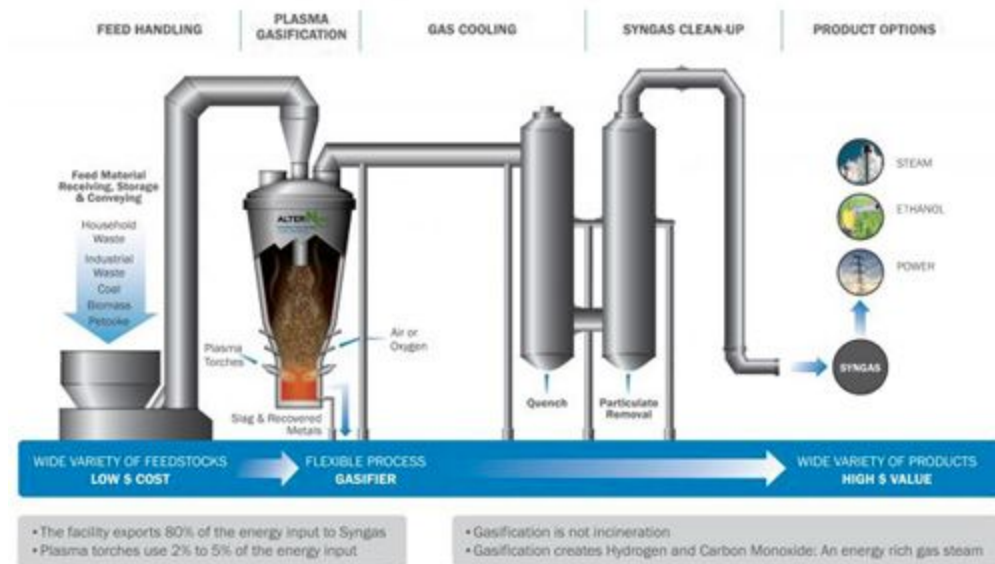
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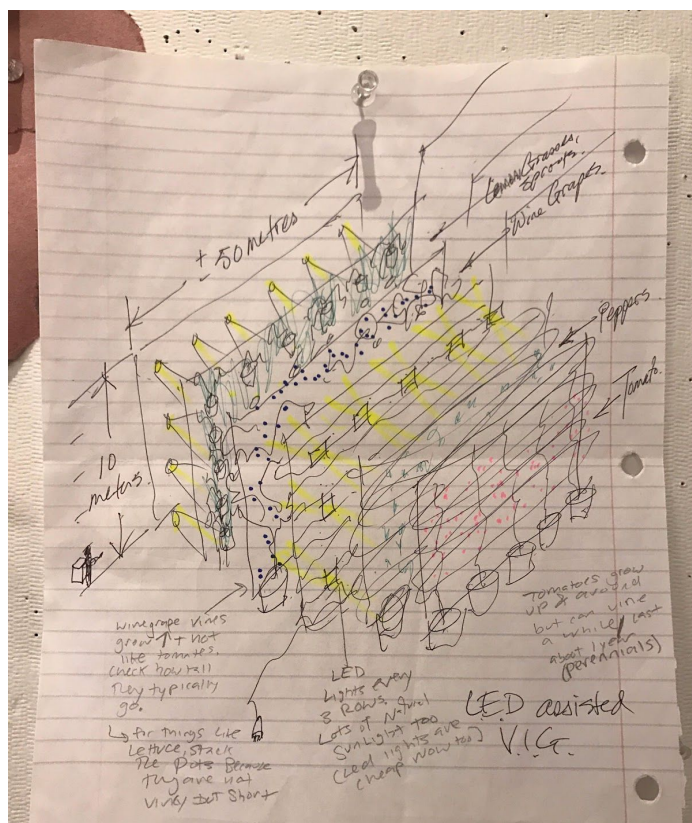
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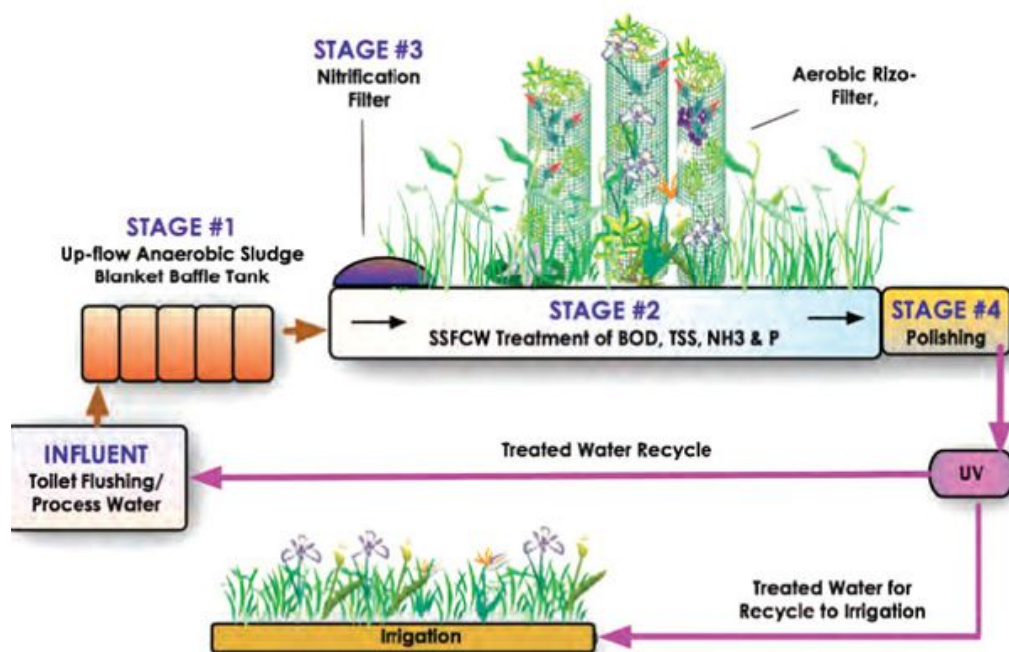


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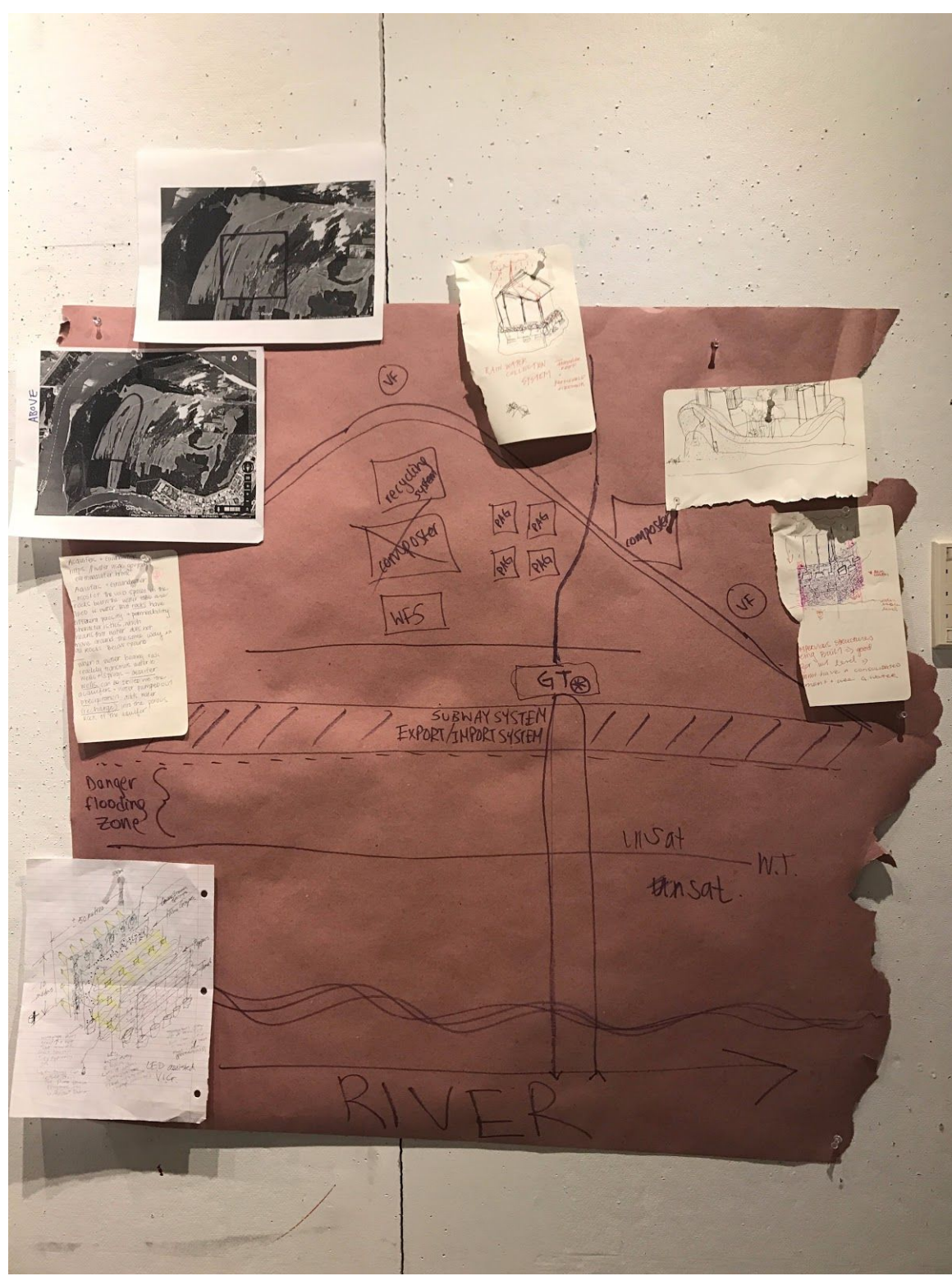


F.





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