

Fordhamopolis 2.0

An exemplar of humanity living in balance with nature

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Introduction

Cities today are faced with the problems brought on by climate change. Extreme weather, rising sea levels, increasing ocean acidity, unpredictable precipitation, and more have to be confronted by cities and their residents. As the Earth's state worsens and more climate refugees are forced to move from their homes, more people are expected to migrate to cities old and new, which will create unforeseen challenges for urban political systems. Furthermore, cities are major drivers of climate change, as they contribute to a large portion of greenhouse gas emissions given their substantial concentrated populations. Cities require energy to power the technology that their residents are accustomed to, and this energy historically has come from burning fossil fuels. They also require large swaths of land to produce food for their inhabitants, and this food is shipped from far away, emitting carbon dioxide into the atmosphere. Given that cities cover land with impermeable cement and building materials, they trap heat and must contend with floods caused by heavy rainfall. Due to their contribution and vulnerability to climate change, cities and their residents have a duty to do what they can to slow down climate change for future residents of their city and of the Earth. The authors believe that cities can both minimize their impact on the environment while maximizing individual and community well-being. As such, we created Fordhamopolis to tackle the problems presented by climate change and to set an example for current and future cities.

The city proposed in this report has been created with the intention of sustainability and autonomy for a population of 100,000 residents. Fordhamopolis is located south of the Firth of Thames in New Zealand, taking up twenty square miles between the Piako River and the Waihou River. The Coromandel Forest lies to its east. Within the 20-square-mile radius of Fordhamopolis, there will be conscientious efforts to fight climate change in all aspects of city

life. All urban systems in Fordhamopolis are modeled on natural systems through biomimicry. The authors believe that nature holds its own technological solutions for sustaining life, for it has done so for millions of years before humans came along. Fordhamopolis plans to create a balance between the quality of life of its residents and the quality of its surrounding environment. Self-sufficiency, environmental awareness, and well-being are at the core of Fordhamopolis, for the city will be entirely autonomous.

Fordhamopolis' primary value of 'do no harm' is followed in terms of energy, water use, food, carbon sequestration, and transportation. Green energy sources such as geothermal energy, solar energy, and wave energy will make up Fordhamopolis' grid. New Zealand's climate and natural resources facilitate the generation and storage of green energy. New Zealand also receives enough rainfall for residents of Fordhamopolis to use rainwater for their toilets, heating and cooling systems, vertical farms, and even drinking water. As Fordhamopolis strives for sustainability, every building will produce food primarily through aeroponics. Multipurpose parks will not only encourage interaction with the natural environment but will also grow large fruit and nut trees. All of the buildings in Fordhamopolis will be multi-use and will be built using mass timber frame construction. The city will foster the regrowth of the timber harvested by planting as many trees as it cuts down in order to sequester carbon. Finally, keeping carbon dioxide emissions and community well-being in mind, Fordhamopolis will promote the use of transportation such as light rail transit, bicycles, and walking. The following report details the authors' vision for a sustainable city for 100,000 that is autonomous in terms of energy production, water use, food production, building materials, and transportation.

Energy

In the wake of climate change and an increased prevalence of severe weather events, the city of the future will need to be largely self-sufficient. Contemporary urban centers require huge amounts of resources to sustain themselves. Other sections of this paper will focus on the massive amount of food and water that it takes to support a high-density population. Obviously, the landmass required for the development of a city's food supply greatly outsizes the city; but more overlooked is the amount of energy required for the production of food and the transportation of both food and water. Just as Fordhamopolis must be self-sufficient in its food production and water collection, it must be self-sufficient in its energy production as well.

Contemporary methods of energy production have clear negative impacts on the environment. Frankly, the burning of fossil fuels is abysmal, but even renewables have an environmental cost. The transition away from a fossil fuel-based energy production system to one based on renewables is a net-positive action. However, our evaluation of the impacts of such alternatives must be candid and honest. Thus, while Fordhamopolis will run entirely from renewable energy sources, the least environmentally impactful course of action would be to greatly curb energy consumption. The most obvious way to reduce the city's collective need for energy is to decrease its demand for energy. Importantly, Fordhamopolis will greatly reduce its demand for electricity through greater efficiency in all areas. By employing smart-tech, lighting and appliances will not use excessive energy when not in use. Building construction will employ high-insulation materials and environmentally conscious design in order to achieve the greatest possible degree of heating efficiency. The easiest way to reduce a city's energy consumption is to demand less consumption of its residents. However, the most ethical way to reduce a city's energy consumption is to reduce its energy waste.

This brings into discussion a crucial valuation of our city's priorities. The overarching goal of Fordhamopolis is to "do no harm" to the environment. However, the city must not sacrifice the comfort of its residents. A balance must be struck between living comfortably and doing no harm; Fordhamopolis must exist in harmony with nature in all aspects of its existence, especially energy. Thus, it will employ an approach of biomimicry wherever applicable. In a certain sense, Fordhamopolis' energy grid will be largely analogous to the constitution of an old-growth forest; every building will be independent and self-reliant, but will also be tied into an underlying grid, thus supporting all other buildings. Each building will aim to be energy self-sufficient but interconnected, and off-site production will provide energy for spaces which require power and are yet incapable of producing their own.

This system of socialized urban energy can be easily compared to nutrient sharing in the natural world. Consider a small forest or grove with several hundred trees. Each tree is independent; it collects water through its roots and absorbs sunlight through its leaves. It is a closed system in the sense that it can support itself in ideal growing conditions. Yet it is intimately related to other trees amongst it. Through root proximity and a subsurface layer of mycelium, healthy adult trees possess the ability to transfer nutrients to younger, weaker trees. This is a system of socialized energy embodied in nature. It ensures the wellbeing of trees growing in less-than-ideal conditions at no significant cost to those already grown. Fordhamopolis' energy grid will replicate this strategy in order to attain a maximum level of energy efficiency.

The energy of Fordhamopolis can thus be broken down into three main parts: first, energy-independent photovoltaic buildings; second, geothermal building heating; third, wave and offshore wind power. The overarching system of socialized energy ensures that no energy is

wasted and that no single production center is operating at full capacity, thus guaranteeing energy security even in abnormal weather or extreme circumstances.

Practically all sunlight-exposed external facades in Fordhamopolis will incorporate photovoltaic technology. Opaque photovoltaic cells will conspicuously mask the exterior of the timber frame buildings comprising the city. All building windows will be lined with translucent photovoltaics. Every building will thereby generate electricity when exposed to sunlight. The urban design will constitute blueprints which will maximize buildings' exposure to sunlight, ensuring the greatest possible utilization of photovoltaic energy capture.

Certain buildings will require large amounts of electricity, while others will not. Vertical farms, for example, will use a great deal of energy for lighting and related agricultural processes, while other buildings may require practically no electricity at all. Most buildings will be multi-use: residential, agricultural, and commercial all in one. But certainly, buildings will have different energy demand/production ratios. This highlights the importance of building interconnectedness. Buildings will also be fitted with high energy storage capacities. They will generate energy during sunlit hours, disperse it amongst other buildings where needed, and store extra energy for nights and periods of heavy cloud cover. In addition to socialized energy sharing, all buildings and public spaces will be linked to off-site energy wave and wind power farms for supplemental and backup energy.

Related to the topic of energy is building heating, which can pose a significant environmental problem. Electric heating greatly adds to general energy demand and oil or natural gas heated buildings contribute to adding atmospheric carbon dioxide. Fordhamopolis will be fossil-fuel free, and crucially, very little electric energy will be spent on building heating. The city will be in a prime location for the utilization of geothermal heat, which will provide the vast

majority of city-heating. The energy demand from summer air-conditioning will also be greatly reduced through the use of geothermal temperature, which remains constant year-round. The North Island of New Zealand is one of the most geothermal-rich areas on the globe and geothermal sources already account for a significant part of the nation's heating and energy. Fordhamopolis will utilize this to the natural gift to its fullest potential.

Water

Water is vital for all forms of life. Without clean and safe drinking water, life on Earth would cease to exist. Humans use a tremendous amount of water for other tasks too, such as gardening, showering, washing dishes, flushing the toilet, et cetera. Most of the time, water is overused. Humans' misuse of water has slowed the natural renewal process of the hydrologic cycle, creating a strain on the Earth's available freshwater supply. Although the amount of water on Earth will always remain the same, since water continuously works its way through the hydrologic cycle (Figure 1), humans need to conserve water because each stage of the cycle takes a different amount of time to complete. In other words, groundwater does not necessarily replenish itself as soon as it is pumped out of the Earth. The amount of time it will take for that groundwater to refill is not always definite. Therefore, it is important for humans to manage their water intake and output.

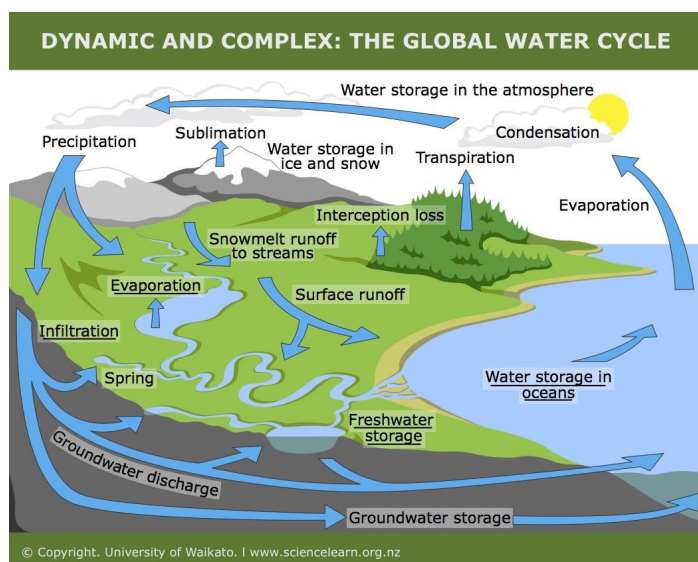


Figure 1: Hydrologic Cycle¹

Exploiting natural resources such as groundwater not only disrupts the hydrologic cycle and prevents its ability to replenish itself, but it also poses health and safety threats to humans as well. For instance, Bangladesh is currently facing the greatest mass poisoning in history due to the contamination of groundwater by arsenic. The country has been obtaining and transporting water via tube-wells since the 1940s, and the deterioration of the wells throughout the years has led to the development of deadly concentrations of arsenic. Not only this, but the installation and design of the deep-tube wells throughout the country have led to cross-contamination, which spreads the arsenic to other aquifers and water supplies.² An estimated 20 million people in Bangladesh still rely solely on these arsenic-laced water supplies and risk long-term health effects such as neurological diseases, cancer, and death. Although this crisis is still ongoing, the

¹ “Dynamic and Complex: the Global Water Cycle,” *Science Learning Hub*, www.sciencelearn.org.nz/image_maps/36-dynamic-and-complex-the-global-water-cycle.

² Smith, Allan H, et al., “Contamination of Drinking-Water by Arsenic in Bangladesh: a Public Health Emergency,” *World Health Organization*, 2000, [www.who.int/bulletin/archives/78\(9\)1093.pdf](http://www.who.int/bulletin/archives/78(9)1093.pdf).

strategies that have been suggested to mitigate and prevent further damages should be considered to be the forefront of future water technologies, such as rainwater harvesting.

Current work towards solving the global water crisis will lead to improved collection and distribution methods. However, water infrastructure will continue to resemble its contemporary counterparts. Due to the ease of collection and cost efficiency, communities that rely on traditional water sources like aquifers, other groundwater sources, and fresh surface water in rivers, lakes, and reservoirs will continue to do so. Freshwater reserves like these are becoming extremely precious, but in some areas, they remain to be far more accessible than other more technologically advanced water collection methods.

Since most of the world's cities rely on freshwater from rivers or aqueducts, elaborate pipeline systems must be built in order to transport water into the city. However, there are many drawbacks to these pipeline systems. For one, these pipelines are extremely laborious to implement, as well as expensive to build and maintain. Establishing these pipelines also damage natural ecosystems and displace many animals who lose their habitat in this process. On the other hand, there are many communities around the world who rely on state-of-the-art technology to provide water for their people. In the future, more communities will follow in their footsteps and shift towards more sustainable water systems. For example, cities can use desalination water treatment plants to supplement their water needs and some may even turn to atmospheric harvesting methods. In Fordhamopolis, we propose that the city relies on the harvesting of rainwater as an efficient and sustainable source of water.

Rain collection is evidently the lowest impact method of water collection. Extracting fresh water from local lakes or from the groundwater creates a great amount of stress on regions which depend on that water. Moreover, desalination efforts can be highly polluting through the

creation of toxic brine. Rainwater is a resource that has not been effectively utilized, especially in many modern cities around the world. For the most part, rainwater goes into storm drains as runoff instead of being made use of. Neglecting the benefits of rainwater is especially wasteful in cities that use a combined sewer system. In these systems, a single water treatment plant is responsible for storing rainwater runoff, domestic sewage, as well as industrial wastewater. From here, all of the wastewater is treated and then released for human use or into a body of water. However, if there is heavy rainfall, the excess water overflows and goes directly into a nearby water source untreated. This can be both damaging to the ecosystem of the nearby water source since it will be flooded with polluted and untreated water, and in addition, is a waste of fresh water. In order to prevent this from happening, Fordhamopolis will shift to a more efficient water treatment method where water, sewage, and waste will be managed in a self-contained system. By making these systems closed, which means we are constantly recycling water within the system, the water can also be preserved more easily.

The location chosen for Fordhamopolis in New Zealand has plenty of year-round rainfall. The area has an average of 1170 millimeters (46.063 inches) of rainfall each year and Fordhamopolis has a total area of 20 miles squared. By using an online calculator, it is determined that a total of 16,000,667,730 gallons fall onto Fordhamopolis every year. This is a huge amount of water that is going unutilized. By collecting a portion of this water we would be able to meet all of the freshwater needs of Fordhamopolis. An average person requires two liters of water to drink each day. Thus, for a 100,000 person city we need 73,000,000L (19,284,560 gallons) of water. This is only a mere 0.13 percent of the water that falls onto Fordhamopolis. In general, the average person uses about 90 gallons per day for various needs. This is a total usage of 3,285,000,000 gallons per year for 100,000 people. This number is 21 percent of

Fordhamopolis' rainfall. Therefore, it is completely possible to have all the freshwater used in Fordhamopolis to come from the rain that falls on the city.

In order to collect this rainfall, Fordhamopolis will have rainwater collection systems on the rooftop of every building. Rainwater harvesting is a simple solution to ensure that a given household always has an ample supply of water. What is particularly good about this method is that it is managed by the user. A household is only responsible for collecting the amount of water necessary for that household to function. In this sustainable city, each building will be responsible for collecting the amount of water necessary for that building's inhabitants to function. In other words, no water will need to come from an external source. We will not be collecting all of the rainwater, but aim for well over the required 21 percent needed for average human activities. The amount of water each building collects will vary depending on the type of building and its use. For example, an apartment building will likely require more water than a commercial building. Rainwater can be collected from roofs and then redirected into rain barrels or cisterns, either above ground or below ground, indoors or outdoors. The water could be used immediately or stored for later use. It could also be used for a wide variety of tasks: drinking, irrigation, heating and cooling, even groundwater recharge. Therefore, the buildings will be able to collect and store freshwater for its own inhabitants.

Fordhamopolis will not only use rooftops to help harvest rainwater, but they will also collect surface runoff that can occur due to the implementation of non-porous sidewalks and roads in the city. This water is usually wasted, simply going into storm drains and nearby water sources. An excessive amount of rainwater can often cause flooding in major cities because of this, so collecting this runoff not only contributes to the water supply but can also help mitigate flooding as well as help reduce water pollution and soil erosion. Therefore, the implementation

of water collection from the rooftops and runoff could alleviate many problems associated with conventional water sourcing.

The WaterShed House (Figure 2) is one example of a structure that successfully captures and stores rainwater. The design of this house mimics a watershed: a given area where all the water that falls into that area drains off and collects into the same place, like into a lake or into a river. In a similar way, all the precipitation that collects on the inward sloping roofs drains off into a common outlet, where it is then stored and used for a number of purposes. Bermuda's white stepped roofs (Figure 3) serve a similar function. The steps slow down heavy rainfall to help the gutters collect water and store it in a tank under the house. The white color reflects ultraviolet light from the Sun, which helps purify the water. Thus, like the WaterShed House, these homes are entirely self-sufficient in terms of their water consumption. Ultimately, self-sufficiency is important because it encourages people to conserve. When people manage their own water system in their own home, they acquire a certain responsibility that they would not have if their water supply came out of a pipe. For instance, people who collect their own water, but do not conserve it, would probably go thirsty, as they are only allotted the small amount they collect. Water from an external source, on the other hand, just keeps flowing. Therefore, it is harder for people to gauge how much water they actually use. People who manage their own water supply would probably only allow one cup to brush their teeth, whereas people who do not physically see the source of their water would surely leave the tap running.



Figure 2: WaterShed Houses allow their inhabitants to collect and utilize their own water supply.³



Figure 3: Bermuda's white stepped roofs are efficient in collecting rainfall for later water use.⁴

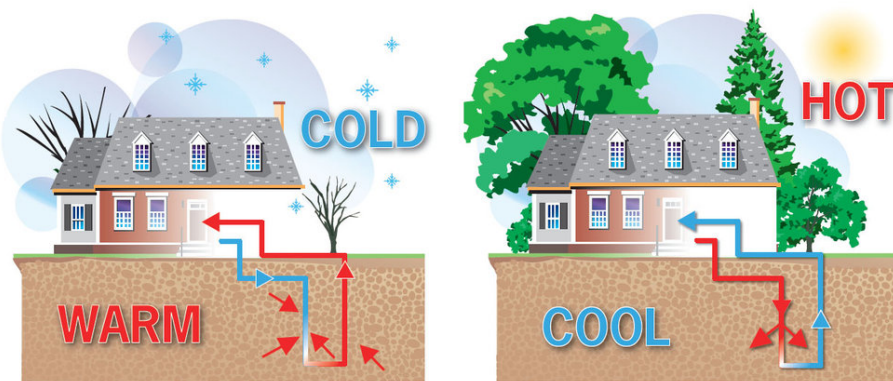
There are many ways in which rainwater can be used in Fordhamopolis. In order to be consumed the water must be purified. Since rainwater is relatively pure, the treatment system required is fairly simple. Purification of rainwater can be achieved in two steps. The first is

³ Pham, Diane, "University of Maryland's WaterShed Solar Decathlon House Takes First Place In Architecture!" Inhabitat Green Design Innovation Architecture Green Building, September 29, 2011, accessed March 28, 2019, <https://inhabitat.com/university-of-marylands-watershed-solar-decathlon-house-launches-into-first-place/>.

⁴ Low, Harry, "Why Houses in Bermuda Have White Stepped Roofs," BBC News, December 23, 2016, accessed March 28, 2019. <https://www.bbc.com/news/magazine-38222271>.

filtration, which is used to remove any particulate matter found in the water. The second step requires UV light in order to kill any microorganisms. After this process, rainwater can be considered safe to drink.

There are also many uses for water which do not require water purification. Greywater from baths, sinks, laundry machines, et cetera. will be used to flush toilets (after which it will be treated, purified, and returned to the water system as drinkable) and for buildings' heating and cooling systems. Buildings will have water flowing through a system to manage indoor temperatures. In the winter, the water pumped down into the earth will absorb stored heat from the ground, and an indoor unit will compress the heat to the desired temperature and distribute the air throughout the building.⁵ In the summer, the water in the system will pull heat from the building and carry it underground to cool before it re-circulates the building. These geothermal HVAC systems will use significantly less energy than typical systems, thus saving Fordhamopolis energy costs. The city is located in an area suitable for such direct heat use systems, therefore it is important that Fordhamopolis takes advantage of its benefits.



⁵ Cheney, Sarah, and Jay Egg, "10 Myths About Geothermal Heating and Cooling," *National Geographic*, April 24, 2018, www.nationalgeographic.com/environment/great-energy-challenge/2013/10-myths-about-geothermal-heating-and-cooling/.

Figure 4: This diagram portrays how water pumps can be utilized to warm and cool houses using Earth's natural heat⁶

The use of rainfall collection systems in Fordhamopolis is extremely beneficial to the city because it does not require the expensive and laborious importing of water from outside the area, which also conserves energy. It also increases water security since there is a constant collection and conservation of water, allowing the people of Fordhamopolis to achieve a more sustainable and water-conscious lifestyle.

When we think of water, we tend to think about how we utilize water on an individual level, such as for showering and drinking. However, we cannot overlook the fact that the food and agriculture industry are the largest consumers of water, requiring over one hundred times the amount humans go through for personal use.⁷ To minimize the energy and water used to contribute to these industries, Fordhamopolis will rely on rainwater as the main source of water to these farms. The American Heart Association recommend that adults eat no more than 170 grams of animal protein per day, and the American Institute for Cancer Research recommends eating no more than 510 grams of red meat per week. At Fordhamopolis, eating meat is not prohibited, however, it is encouraged that people eat more lean meats such as chicken or fish, and limit intake of red meat as much as possible since those are the major sources of water consumption in the animal industry.

If we estimate that every adult in Fordhamopolis consumes 85 grams of a lean meat such as chicken per day, that accounts to 3,102,500 kilograms of meat a year, for a population of 100,000. It is estimated that for every one kilogram of fresh poultry such as chicken, 6 cubic

⁶ Ziolo, Larissa, "Geothermal Heating & Cooling System," accessed in April 2019, <https://www.airmccoy.com/blog/2017/4/17/geothermal-heating-cooling-system>.

⁷ "Water Treatment Solutions," Lenntech Water Treatment & Purification, accessed in April 2019, www.lenntech.com/water-food-agriculture.htm.

meters of water will be required. To produce the amount of poultry needed for Fordhamopolis per year, 18,615,000 cubic meters of water will be used. This equates to approximately 4,917,562,755 gallons of water per year. Although this is a large majority of the total rainfall amount in the city, it is important to note that this is assuming that every person in Fordhamopolis follows this diet. Since Fordhamopolis, however, is an environmentally conscious city, it is likely that its members will follow a diet that consumes meat less frequently than once per day. There will also likely be a large population of vegetarians and vegans, which decreases this energy and water requirement significantly.

Studies show that the average carnivorous American consumes about 4,000 gallons of water per day in order to supply their meat-eating diet. If we assumed this diet for those in Fordhamopolis, this would amount to a staggering 146,000,000,000 gallons of water a year, over nine times the amount of rainwater that falls onto the city. A vegan diet, however, requires only about 300 gallons of water per day, and this reduces Fordhamopolis' water footprint to only 1,095,000,000 gallons a year.⁸

Water plays a pivotal role in nature and encompasses all aspects of modern society. On an individual level, we use water for drinking, bathing, cleaning, and more. On a broader scale, we use water as a major contributor in animal and agricultural production, without which our society could not be sustained. We use water in all facets of daily living, but we must remember that it is a precious resource. Our overuse of water has led to the exhaust of natural ecosystem functions, which can lead to depletion of habitats, as well as flooding and pollution. These factors can even present unprecedented health threats to humans as well. In Fordhamopolis, the preservation of water is at the forefront, and the harvesting and collection of water are executed

⁸ Robbins, John, "Diet for a New America: How Your Food Choices Affect Your Health, Your Happiness, and the Future of Life on Earth," *HJ Kramer*, 2012.

in a way that is economically and energy efficient and preserves the integrity and value of the life-sustaining substance. Through the implementation of a rainwater harvesting system, as well as more effective ways to treat and store water, we can minimize the impact of our water use. Fordhamopolis also deploys clever and environmentally friendly ways to utilize water to conserve energy in unique aspects of daily living, such as heating and cooling homes.

Food

This section will address Fordhamopolis' autonomous urban food system. It will explain where food comes from in nature, and how the city aims to mimic that circular process. Then, it details the environmental degradation that occurs from current food production in industrial agriculture. This section addresses the inefficiency of growing crops to feed to animals that are eaten by humans. Next, this section explains how Fordhamopolis' food system will be a closed loop so nothing goes into a landfill. It then explains the average nutritional requirements and details how aeroponics and aquaponics will be used to produce food for residents. Finally, this section describes how the food system will be used to promote mental health and foster community in Fordhamopolis.

In nature, all food ultimately comes from the sun. The sun's rays are absorbed by plants' chloroplasts and turned into glucose through photosynthesis, which provides energy for the plant to live and grow. Plants also require carbon dioxide, water, and various micronutrients such as hydrogen, calcium, magnesium, etc. to produce glucose. The rest of the food web relies on consuming photosynthesizing plants for its energy. Primary consumers are usually small animals that eat an entire plant, such as a deer eating grass, or that may eat seeds or other parts of the plant, such as small birds do. Then, secondary consumers, such as snakes, eat the smaller

animals, and the secondary consumers are preyed upon by larger animals such as hawks.

Nutrients thus cycle through the food web, and fungi and bacteria break down dead organisms to make nutrients available to plants to use from the soil. Plants and fungi are therefore the most remarkable parts of nature's food system, for plants create energy for all other organisms, and fungi make nutrients available to all other organisms.

To feed the 7.7 billion people on Earth,⁹ human food systems are largely industrialized and unsustainable. One-third of all arable land on the planet is currently dedicated to food production in some manner. A lot of this land was cleared of its natural vegetation, which had sequestered carbon and thus reduced the impact of greenhouse gases on global temperatures. 11 percent of Earth's total land is used to grow crops, and around one-quarter is pastureland for grazing animals.¹⁰ Animal agriculture is especially harmful to the earth due to its inefficiency. Crops must be grown to feed animals, but those crops could be used to produce food for humans. Furthermore, animals require incredible amounts of water in addition to the irrigation water applied to fields to produce their feed. Cows, for example, require around ten gallons of water *each day*.¹¹ Cattle contribute a large amount of carbon dioxide emissions, with the average U.S. citizen's beef consumption accounting for 1,984 pounds of carbon dioxide emitted annually.¹² Agriculture itself produces greenhouse gases, particularly when food and agricultural inputs are transported around the world before they reach their final destination. Animal agriculture also

⁹ "Current World Population," *Worldometers*, accessed in April 2019, www.worldometers.info/world-population/.

¹⁰ "Earth's Land Resources," *Annenberg Learner*, accessed April 2019, www.learner.org/courses/envsci/unit/text.php?unit=7&secNum=2.

¹¹ "Water Requirements of Livestock," *Ontario Ministry of Agriculture, Food and Rural Affairs*, accessed April 2019, www.omafra.gov.on.ca/english/engineer/facts/07-023.htm#2.

¹² "Animal Agriculture's Impact on Climate Change," *Climate Nexus*, 23 Apr. 2019, accessed April 2019, climatenexus.org/climate-issues/food/animal-agricultures-impact-on-climate-change/.

contributes to erosion, nitrogen pollution, and to the global phosphorus footprint. Due to the environmental degradation and inefficiency of animal agriculture, Fordhamopolis will not raise animals for consumption. The only exception will be a limited amount of fish, which will be produced through aquaculture.



*Figure 5: Industrial Agriculture*¹³

On top of the large quantities of land cleared for food production, industrial agriculture harms the environment in several different ways. Fertilizers that are applied to supply nutrients to crops are often over-applied. This means that fertilizer is often dissolved in water which it pollutes. When fertilizers end up in streams, lakes, rivers, ponds, and other bodies of water, they can cause eutrophication: the excess nutrients create algal blooms, which eventually die and are decomposed by aerobic bacteria. These bacteria use up all the oxygen in the water, leaving the fish and other water life to essentially suffocate. When fertilizers end up in drinking water

¹³ “Hidden Costs of Industrial Agriculture,” *Union of Concerned Scientists*, accessed May 1, 2019, www.ucsusa.org/food_and_agriculture/our-failing-food-system/industrial-agriculture/hidden-costs-of-industrial.html.

supplies, they can have harmful public health effects. Industrial farms also tend to over-irrigate, wasting a precious natural resource. Other chemicals are applied on farms, such as pesticides and herbicides. These chemicals can have unintended impacts on the ecosystem, for they can travel from farms to other areas and harm living things elsewhere. In addition, these farms rely on monocultures, which means that they grow one variety of the same crop on a large plot of land. This reduces the natural biodiversity that allows life to thrive on Earth despite dramatic events that harm a few species. Agriculture also contributes to erosion, for plowing destabilizes land. Soil is another valuable natural resource that is being lost due to industrial agricultural practices. Finally, the current food system generates a huge amount of waste. Food is processed and then packaged, and the packaging breaks down over thousands of years in landfills. This not only contributes to methane production but also is an unnecessary use of land. Urban populations are only continuing to increase, so we must find ways to sustainably feed cities by producing food indoors. We must use less land to produce our food, eliminate animal agriculture, diminish our reliance on mined or industrially produced chemicals, reduce the amount of water, and conserve soil.

Given that nature does not have an output into which it can throw away nutrients or other resources, Fordhamopolis will not waste nutrients. Nature's food system is a closed loop, with fungi and other decomposers at the end stage to break down other living things to recycle their nutrients. Our city will similarly recycle all nutrients that come from food by composting inedible parts of plants, using limited amounts of aquaculture, and by treating and reusing human waste in the food production process. The composting process is one that actually occurs in nature. In an urban food system, food waste and scraps are collected in industrial bins, and with

an adequate ratio of brown organic material, like dead leaves, twigs, and manure, green organic material, like lawn clippings, food scraps, et cetera, water, and oxygen, the bacteria already present on organic material begins to decompose it. Depending on the size of the compost pile, the types of materials, the surface area, and the number of times the pile is turned, the composting process can finish in three months.¹⁴ Our knowledge of the composting process is relatively limited, and the authors suspect that technology will be developed to speed up and improve the composting process. Furthermore, we imagine that the soil resulting from compost can be turned into a powder or liquid to be applied to plants as their nutrient sources. Currently, the majority of the nutrients applied during agricultural production come from fertilizers, which, in addition to their eutrophication and pollution potential, are mined or industrially produced. Both of these processes are not sustainable, for they use vast amounts of energy and contribute to greenhouse gas emissions. The soil produced from composting will also be applied to trees and other plants grown outdoors. Therefore, Fordhamopolis will recycle all nutrients used in food production.

Human waste can also be recycled through the food system. This technology is still in development and it lacks scientific research as of this writing, but the authors hope that human waste can be composted or otherwise treated and applied to plants during growth. This practice may seem controversial or disgust-inducing, but the whole process will be electronically monitored to ensure that any potentially dangerous microbes are killed. Human waste is simply nutrients that our bodies cannot digest, but they are essential to life and plants can use them.

¹⁴ “The Composting Process,” *Composting in the Home Garden*, accessed on May 1, 2019, extension.illinois.edu/compost/process.cfm.

Reusing human waste as an input for food production closes the nutrient-cycle loop, mimicking nature's efficient recycling of nutrients.

The United States' Department of Agriculture recommends that humans consume around 1600 calories daily, depending on their age and other factors. People over the age of nine require 1600 calories to maintain their weight, and some adults may require up to 3,200 calories per day.¹⁵ A balanced diet of 1600 calories daily includes two cups per day of vegetables from a variety of subgroups—dark green, red and orange, legumes, starchy, and other vegetables—one and a half cups of fruits per day, five and half ounces of grains, twenty two grams of oils, and five ounces of protein per day. Protein in Fordhamopolis will come from plant sources, such as beans, legumes, nuts, and seeds. As mentioned, there will be a small amount of fish produced through aquaculture, but the fish will be taxed to disincentivize its consumption. The goal is to eventually phase out fish production as citizens adjust to a plant-based diet. If meat could be manufactured in labs in a sustainable fashion, it would be considered as a source of protein. This technology is still in its infancy, however, and there have been no studies into its large-scale feasibility nor calculations about the resources it would consume. If this technology were found to be sustainable and feasible, the meat produced would be taxed to cover the expenses of creating facilities to produce meat.

As previously mentioned, a limited amount of fish will be produced through aquaponics, which is a combination of hydroponics and aquaculture. Aquaculture is the practice of raising fish indoors, and hydroponics is a crop production technology in which plants roots are

¹⁵ As per USDA 2015-20 recommendations.

submerged in a tank of nutritious water. In aquaponics, fish live in the water and plants get their nutrients from fish waste while simultaneously filtering the water. The system also fosters beneficial bacteria that break down the ammonia from fish waste, which is toxic to fish and useless to plants, into a form of nitrogen that plants can take in. Finally, composting red worms also live within this system, and they break down the solid waste and decaying plant matter.¹⁶



Figure 6: Aquaponics system¹⁷

The vast majority of food for Fordhamopolis will be produced indoors and underground, in vertical farms. Vertical farms grow food indoors with artificial light that can be kept on to maximize plant growth. Indoor farming allows more precise control of the environment to maximize plant production. Storms, unpredictable precipitation and temperatures, animals and insects, and seasons no longer inhibit crop growth. Aeroponics is the food production technology that we will employ in Fordhamopolis. It was developed by NASA in researching possibilities

¹⁶ “Aquaponic Gardening: Growing Fish and Vegetables Together,” *Mother Earth News*, accessed on May 1, 2019, www.motherearthnews.com/organic-gardening/aquaponic-gardening-growing-fish-vegetables-together.

¹⁷ Bernstein, Sylvia, “Managing PH in Aquaponic Systems,” *Maximum Yield - Your Modern Growing Resource*, published on July 22, 2017, www.maximumyield.com/managing-ph-in-aquaponic-systems/2/1208.

for growing food on other planets, and studies have shown that crops grown aeroponically can grow up to 33 percent faster than hydroponically-grown crops within the same timeframe. To grow crops aeroponically, seeds are placed in a grow tray to germinate. Soil is not needed, for nutrients are applied through nutrient solutions that are specifically tailored to each crop. This is an efficient use of nutrients that can encourage fast plant growth. Once germinated, plants' roots are exposed to the air and they can be misted with a solution of water and the chemical nutrients they require to grow. This method of growing and watering plants is extremely efficient at using water: it can reduce water usage by up to 98 percent (as compared to industrial agriculture).¹⁸ Any excess water can be recycled from plant to plant, for aeroponic trays have water-collection apparatuses that cycle the water through the system.



¹⁸ Dunbar, Brian, "Progressive Plant Growing Is a Blooming Business," *NASA*, accessed in April 2019, www.nasa.gov/vision/earth/technologies/aeroponic_plants.html.

Figure 7: An Aeroponics System¹⁹

In addition to its efficiency, trays of plants can be stacked on top of each other to maximize space usage. Potted plants such as strawberries, eggplants, and avocados can be arranged in three dimensions so that excess water can drip from one plant to water the one below it.²⁰ Any piping involved in aeroponic grow systems can be made out of bamboo, which is a strong natural material. Bamboo does not rot in water, it grows quickly, and it can be harvested at the diameter of choice.²¹ This is one sustainable option for materials other materials such as PVC that are produced in resource-intensive ways.



Figure 8: Hydrostackers Growing Strawberries²²

Every building's core will be a vertical farm, and each building will produce the majority of the food required to feed the residents of that building. This brings food directly to the consumer, and city residents will be able to pick their own produce (as visible below). Close

¹⁹“AeroFarms Technology.” *AeroFarms*, aerofarms.com/technology/.

²⁰ Despommier, 203.

²¹ Despommier, 204-5.

²²“Vertical Hydroponic Growing Systems,” *HydroStacker*, accessed in April 2019, www.hydrostacker.com/.

proximity to plants will foster a healthy and creative environment for Fordhamopolis' residents. Given that each building might grow slightly different food products, there will be market days during which citizens can purchase food from other buildings. Residents will thus have access to a variety of foods to meet their taste and cultural preferences. There will be an option for residents to participate in food production and/or distribution in exchange for food shares. This work-share system will not be required as we acknowledge that there will be some individuals who physically cannot participate in this form of labor, but the option will be available for those who are able.



Figure 9: Nature indoors²³

Crops that require a lot of space to grow such as food tree crops (i.e. fruit and nut trees), squash, and corn will be grown underground and in public spaces such as greenbelts and other

²³ Block, India, "Precht's The Farmhouse Concept Combines Modular Homes with Vertical Farms," *Dezeen*, published on March 07, 2019, accessed March 28, 2019, <https://www.dezeen.com/2019/02/22/precht-farmhouse-modular-vertical-farms/>.

parks. The underground space below buildings will be utilized to produce a lot of the protein and fruit plants for each building, and these foods will be brought to points within the building for residents to buy. Fruit and nut trees in public spaces will add a natural feel to remind citizens of the natural environment all around them, and harvesting fruits and nuts can serve as a communal, recreational activity. Thus, humans will interact directly with their provisioning environment, living out the principle of human ecology. Fordhamopolis' food system is designed to encourage citizens' direct involvement in the production and harvesting of their food, and classes will be provided about home gardening to encourage citizens to keep small gardens of herbs and plants within their homes.

Fordhamopolis' food system is modeled off of natural systems in that it recycles all nutrients, water, and other resources. This occurs through technologies such as composting and aquaponics. Aeroponics will be used to produce the majority of food crops, and the diet will be mostly plant-based. Crops will be grown in the center of buildings so that every resident has access to fresh food and can participate in their own food production. Some food plants that take up a lot of space, such as fruit and nut trees, will be planted outdoors in public parks and community gardens. On top of food crops, trees and other plants will be scattered throughout the city to add visual effects as well as the added benefit of carbon sequestration, which is explained in the following section.

Carbon Sequestration

All buildings in Fordhamopolis will be made of mass timber. In other words, wood will be the primary load bearing structure of our buildings. Timber is a renewable construction

material that can be replenished through forestry management. For instance, for every one tree harvested, ten more can be planted. If we cut down an entire forest to create our city, then we could plant a forest double in size in its place. Once Fordhamopolis is built, the regrown forest will be left alone since the wood would no longer be needed.

Environmental sustainability is only one benefit of mass timber construction. First of all, mass timber is fire resistant. Exposed mass timber chars on the outside and forms an insulating layer protecting interior wood from damage (Figure 10). During a fire resistance test, a 5-ply cross-laminated timber subjected to temperatures exceeding 1,800 degrees Fahrenheit lasted about three hours and six minutes (building codes only require a two-hour rating).²⁴



Figure 10: Mass Timber is Fire Resistant²³

Additionally, mass timber construction is cost-efficient, as buildings are 25 percent faster to construct than their concrete counterparts due to the fact that the weight of a mass timber building is one-fifth that of a concrete building, which means it does not require as large of a foundation.²³ Having wood-based construction would provide cost-effective, durable, and more importantly sustainable alternatives to common construction materials like concrete, fiberglass,

²⁴ “4 Things to Know about Mass Timber,” *Think Wood*, published on May 14, 2018, accessed March 28, 2019, <https://www.thinkwood.com/news/4-things-to-know-about-mass-timber>.

and steel. Cross-laminated timber is the most widespread secondary wood product application in mass timber engineering. The concept itself is not far from plywood or corkboard, the only true difference being the lack of veneer layers. Cross-laminated timber contains only lumber and adhesive, and are stacked perpendicularly in order to maximize surface space and ensure adequate strength for industrial use.

There are also health-related benefits to mass timber construction since exposure to the natural environment positively impacts human well-being. It is proven that the visual presence of wood indoors significantly reduces stress levels, increases productivity at work and leads to faster recovery for patients in hospitals.²³

When considering the building metrics regarding our city, we had to develop a rubric regarding our desired height limitations, and the function of our buildings. We decided that the maximum height for a building in our city would be twelve stories, a minimum of five stories, and have a medium height of nine stories. Each building would be of multi-function, take for example a residential living complex also having vertical farms with an open market as its lobby. This would allow residents to cultivate their own food, and engage in social settings when going to other buildings to retrieve foods their complex does not grow. In developing the idea, we've come up with approximate metrics to reflect a rendering of what a potential building in Fordhamopolis could look like.

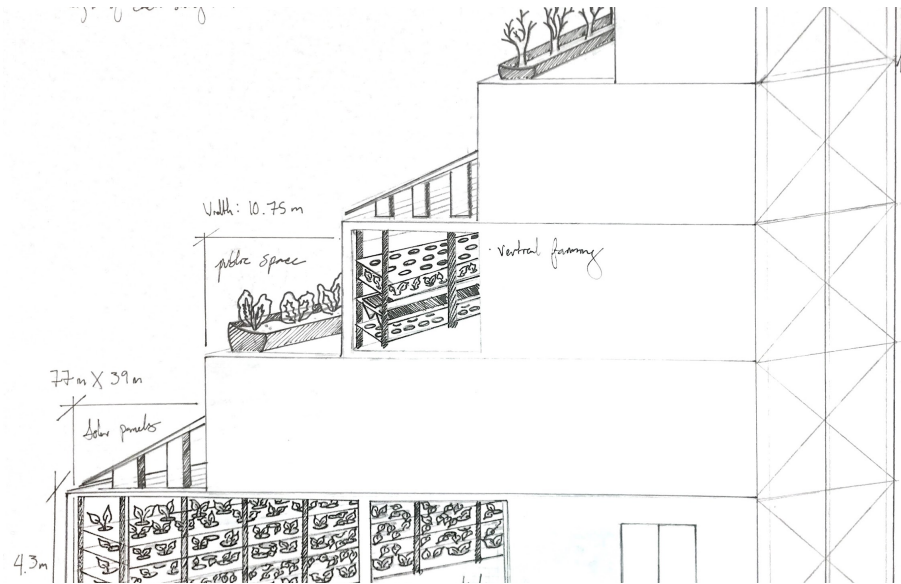


Figure 11. Courtesy of Hailey Arango

The sketch depicts a multi-use residential complex at our minimum height of five stories. The height of each story would be 4.3 meters and would incorporate public space, apartments, open food market, and solar panels. Our interest lied specifically within photovoltaics. Photovoltaics is the branch of technology concerned with the production of electric current at the junction of two substances. Photovoltaic devices generate electricity directly from sunlight. This happens by means of semiconductors. Materials like thin-film PV, are much more budget-friendly and are somewhat of a reinvented, but more experimental version of what a solar power would essentially provide.

The principle behind both types of solar panel, both solar photovoltaic and solar thermal is in all actuality the same. They absorb raw energy from the sun and use it to create usable energy. In solar photovoltaic systems, this is through the creation of electricity, whereas thermal systems are used directly for heating water or air. A great example of a Fordhamopolis-esque proposal would be Gregory Kiss' idea of the 2050 city. To quote his introductory paragraph,

“photovoltaic generation area is used as the most universally available form of renewable energy”.²⁵

By taking both geothermal and solar energy options in consideration, you can compare the pros and cons and come down to the following conclusion: both will provide you with a sustainable outcome. Solar thermal technology is more space efficient than its solar PV counterpart. This should be easy to implement on our apartment buildings, as it would take up only partial room on the rooftops. However, photovoltaics have an incredibly long lifespan, especially when compared to solar thermal technology.

With our city, I certainly believe that photovoltaics is the way to go. PV's are incredibly efficient in the summer. New Zealand's average climate temperature is 61 °F. While temperate during the year, its summers are considered subtropic, and therefore, it would be ideal to implement photovoltaics over solar thermal energy.

Referencing the concept we have come up with, the solar panels themselves would be 77 inches by 39 inches spanning the width of 10.75 meters. The positioning of the solar panels would be at a 45-degree angle and would be placed on the levels containing vertical farms. The addition of photovoltaics harnessing solar energy through semiconductors adds to the energy potential of the building and ensures the sustainability of its clientele. The following sketch goes into a bit more detail depicting what the detailed outcome of the building would look like.

²⁵ Kiss, Gregory, et al, “The 2050 City,” *International Conference on Sustainable Design, Engineering and Construction*, 2015.

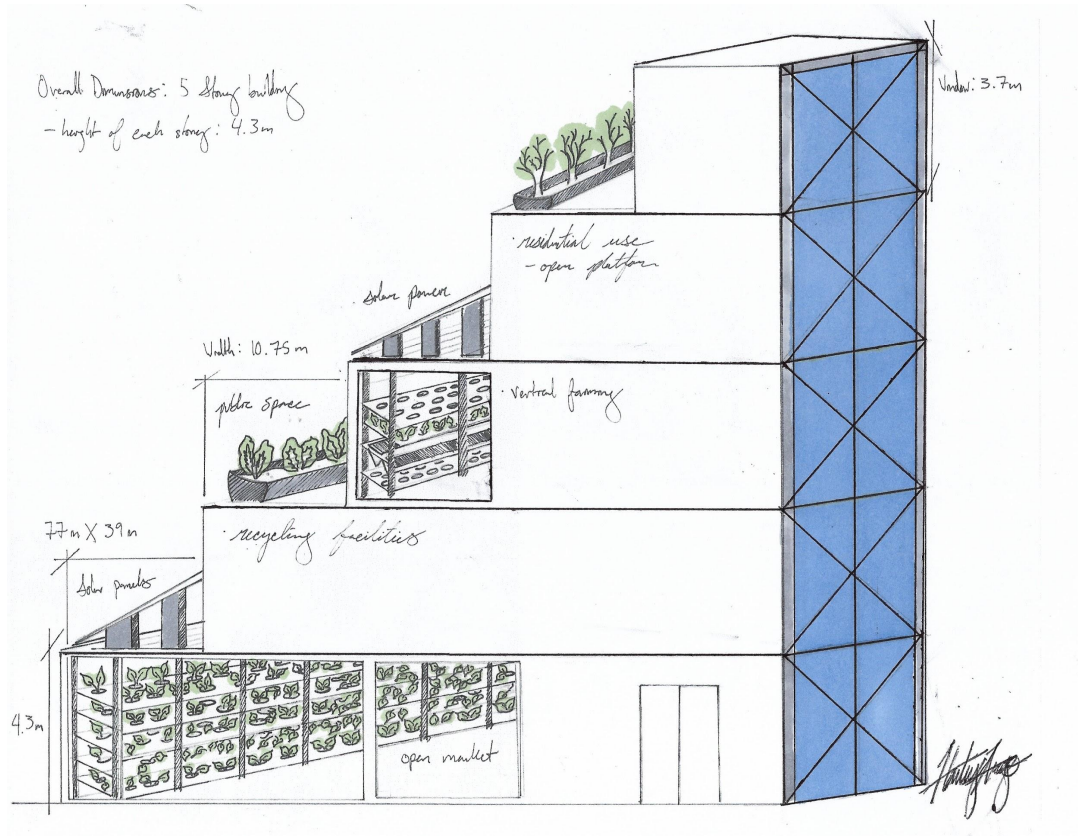


Figure 12. Courtesy of Hailey Arango

The number of trees on Earth is extremely important to maintain because trees are responsible for taking carbon dioxide out of the atmosphere and replacing it with breathable oxygen. Carbon dioxide directly contributes to the greenhouse effect, as rising CO₂ concentrations cause the planet to heat up. In other words, the increasing conglomeration of greenhouse gases present in the atmosphere means that more solar radiation is trapped within the atmosphere, causing the Earth's temperature to rise (Figure 13). Thus, more trees mean that more carbon dioxide will be taken out of the atmosphere, so global warming—and all its effects—will become less of a threat.

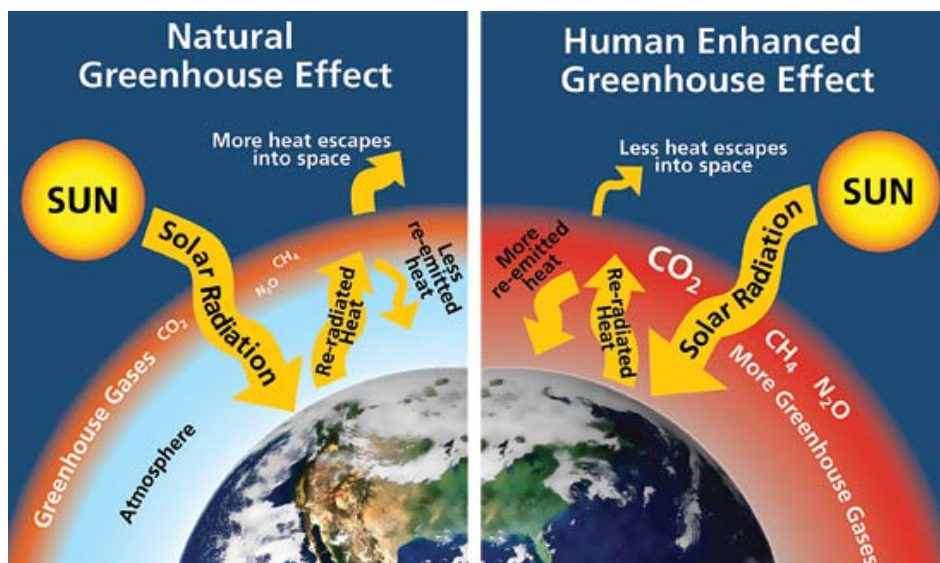


Figure 13: Greenhouse Effect²⁶

A tree can absorb as much as 48 pounds of carbon dioxide per year.²⁷ Thus, a forest of 100 trees could sequester approximately 4,800 pounds of carbon dioxide per year. Earth's original six trillion trees would have been able to sequester around 2.88 trillion pounds of carbon dioxide per year. Given that, on average, 2.57 million pounds of carbon dioxide are emitted into the atmosphere every second—and there are 31,536,000 seconds per year—about 81 trillion pounds of carbon dioxide are emitted into the atmosphere every year. Although the amount of carbon dioxide sequestered by six trillion trees would not outweigh the amount of carbon dioxide emitted by humanity in any given year, carbon sequestration does take at least some carbon dioxide out of the atmosphere, even if it is just a small fraction of the total amount. Additionally, planting three trillion trees (since there are already three trillion trees in existence) sounds like an arduous task; nevertheless, it is a good goal to strive for. Even if we fall short of this number, our work would not be in vain, as any additional trees at all will benefit the environment greatly.

²⁶ "Carbon Dioxide, Methane, Nitrous Oxide, and the Greenhouse Effect," Land Trust Alliance, accessed April 25, 2019a <http://climatechange.lta.org/get-started/learn/co2-methane-greenhouse-effect/>

²⁷ "Tree Facts," NCSU, accessed March 28, 2019, <https://projects.ncsu.edu/project/treesofstrength/treefact.htm>.

Moreover, this replanting does not have to happen instantaneously; rather, it can gradually occur over many, many years.

Whilst brainstorming, we also considered alternatives from cross-laminated timber. Cross-laminated timber is often sourced from softwoods and rarely sourced from hardwoods. Due to our location, and considering the small population of 100,000 citizens, sourcing lumber from softwood is not a pressing issue, however, could we source our materials from bamboo? Bamboo has been used as a building material for scaffolding, bridges, and housing structures, but not in the same application that laminated timber requires. The internal structure of the bamboo is heavily rhizome-dependent allowing it to grow significantly faster than most other plant species. The climate most suitable for the production and cultivation of bamboo is in Southeast Asia and South America.

Thus, in addition to planting hardwood trees—for the aforementioned building and reforestation purposes—Fordhamopolis will also plant bamboo to aid in carbon sequestration. According to the Guinness Book of Records, bamboo is the fastest growing plant in the world.²⁸ Therefore, bamboo farming is a rapid, and simple, way to sequester carbon from the atmosphere. According to Dr. Hans Friederich, Director General of the International Bamboo and Rattan Organisation (INBAR), because bamboo is a grass plant, it grows back very quickly after it is cut down, which makes it one of the most ideal plants for sequestering carbon at a rapid rate. Bamboo can reach full maturity in one to five years, whereas hardwood trees can take up to 40 years to grow to maturity.²⁵ Thus, bamboo can better keep up with the annual amount of carbon dioxide emitted into the air by humans. Moreover, the bamboo plant is particularly hardy, and

²⁸ Esipisu, Isaiah, “Bamboo—the Magic Bullet to Rapid Carbon Sequestration?” IPS-Inter Press Service, published on December 12, 2018, accessed April 27, 2019, <http://www.ipsnews.net/2018/12/bamboo-magic-bullet-rapid-carbon-sequestration/>.

therefore, it is relatively low maintenance. It also makes its own antibacterial compounds, so it does not require pesticides.²⁹

There are a variety of ways to cultivate bamboo into building material. Typically, bamboo is worked by splitting, shaping, and bending. Bamboo is split into halves, then split again into quarter sections (Figure 14). Approximately a maximum of eight segments can be retrieved to use as canes, strips or battens. The shaping of bamboo requires a rectangular structure to be placed around the bamboo and alter its natural circular shape into a cubelike fixture (Figure 15). The bending of bamboo can be executed only freshly cut pieces by heating the plant above the average temperature of 150 °C and allowing it to dry. Once cooled and dried, it will maintain the desired shape.

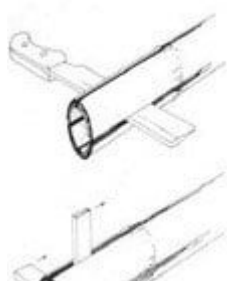


Figure 14: Splitting bamboo

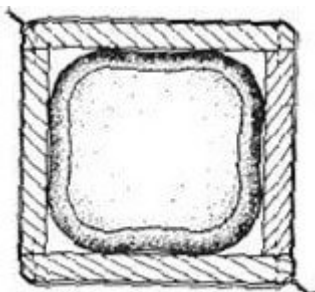


Figure 15: Shaping bamboo

Apart from the processing of bamboo, in order to use this resource as a building material, the implementation of a structural frame technique, most often used in standard timber frame

²⁹ “Bamboo,” *Headstart Publishing, LLC*, accessed April 28, 2019, <https://www.profitableplantsdigest.com/bamboo/>.

designs (Figure 16). The only conflict posed with bamboo as a material in an industrial setting is its inability to serve as a foundation. When in contact with a moisture-laden surface, the bamboo itself will catalyze the decomposition process. However, once laminated and processed chemically, the chances of fast decay are lessened. The only feasible option to serve as alternatives to direct bamboo contact with the ground would be to fix the bamboo with rock footings to allow added structural support without the fear of damage to the foundation.

Column Section

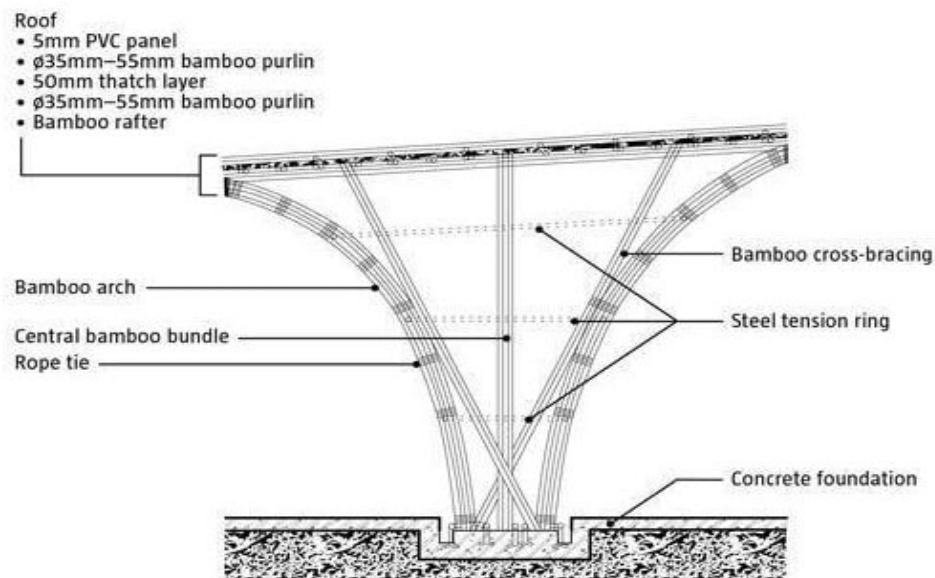


Figure 16: Structural frame technique³⁰

Not only can atmospheric carbon be absorbed by living plants, but it can also be stored within the building fabric. In other words, the act of carbon sequestration is not diminished when the tree is cut down. For instance, because Fordhamopolis will utilize mass timber as a primary building material, carbon will be stored within the structure of its buildings. Thus, the amount of

³⁰ “Bamboo as a Building Material - Its Uses and Advantages in Construction,” *The Constructor*, published on December 06, 2016, accessed May 02, 2019., <https://theconstructor.org/building/bamboo-as-a-building-material-uses-advantages/14838/>.

carbon stored by trees will double, as it will remain stored in the trees harvested for building material and it will also be sequestered by the new trees planted to replace the harvested trees.

One cubic meter of timber building material stores approximately one metric ton—equivalent to about 2,205 pounds—of carbon dioxide.³¹ Therefore, depending on how many buildings are in any given city, and depending on how tall those buildings are, a city made solely of mass timber constructed skyscrapers could store a significant amount of carbon dioxide simply by existing, as the timber's sequestration of carbon dioxide is a natural occurrence that happens on its own: no additional energy or effort is required.

Similarly, carbon stored in bamboo will remain in the plant even after it is cut down and repurposed. There are various different uses for bamboo. For instance, bamboo can be used for making drainage pipes, shipping containers and even wind turbine blades, among other things (Figure 17). Bamboo could also be used to accent Fordhamopolis' mass timber buildings, as it can be made into furniture, tiles or door and window frames—in essence, bamboo would replace anything that is hardwood: hardwood furniture, hardwood floors, et cetera. By replacing hardwood with bamboo, production time would significantly decrease, as bamboo plants regrow and can be harvested at a much quicker pace than hardwood trees.

³¹ Duncheva, Mila, and Robert Hairstans, "What Is Mass Timber Construction?" *A&DS Materials Library*, published on May 17, 2018, accessed March 28, 2019, <https://materials.ads.org.uk/what-is-mass-timber-construction/>.



Figure 17: Bamboo Blade Wind Turbine³²

Not only are bamboo products environmentally friendly, but they are also durable, long-lasting and easy to install and maintain. Bamboo is harder than most hardwoods, so many bamboo flooring options can last upwards of 50 years if maintained properly.³³ Additionally, bamboo is termite resistant and the cost is generally less than that of hardwood.³²

Expanding forests and restoring existing forests is just one way to remove carbon dioxide from the atmosphere. Like trees and plants, soils also naturally store carbon. For instance, the carbon that plants absorb during photosynthesis remains in those plants when they die. Then, when the plants decompose in the soil, the carbon subsequently becomes stored in the soil as well and remains there. The Intergovernmental Panel on Climate Change (IPCC) estimates that soil carbon sequestration could remove between 2 and 5 gigatons of carbon dioxide a year by

³² Shury, John, "Researchers Develop Lightweight Composite Wind Turbine Blades," *Composites Media Ltd.*, published on October 5, 2016, accessed on April 27, 2019, <https://www.compositestoday.com/2016/10/researchers-develop-lightweight-composite-wind-turbine-blades/>.

³³ "Bamboo Flooring vs Engineered Hardwood: What You Need to Know," *BuildDirect*, accessed on April 28, 2019, <https://www.builddirect.com/learning-center/flooring/engineered-hardwood-versus-bamboo-flooring-what-you-need-to-know/>.

2050.³⁴ However, the world's power plants released approximately 32.5 gigatons of carbon dioxide in 2017.³³ Although the annual soil carbon sequestration estimate does not quite compare to the amount of carbon dioxide released into the atmosphere per year, in conjunction with the carbon stored in trees, other plants and building materials, this estimate will increase, getting closer to the total overall atmospheric amount.

Building soil carbon is not only beneficial for reversing the effects of global warming, but it is also beneficial for soil health and crop yields. Minimal tillage, cover crops, crop rotation and leaving crop residues on fields are all ways to increase carbon in soils.³³ Composting is another way to improve crop yields, while at the same time storing the decomposing organic matter's carbon content in the soil.

Furthermore, bioenergy with carbon capture and storage (BECCS) is another way to sequester carbon from the atmosphere. BECCS is the process of using biomass for energy. Basically, it burns plants and captures the carbon emissions before they are released back into the atmosphere. It then stores this carbon that the plants previously absorbed either underground or in long-lived products, such as concrete, thus providing long-term carbon storage (Figure 18). The IPCC projects that BECCS could remove between 0.5 and 5 gigatons of carbon dioxide per year.³³ Additionally, the National Academies of Sciences, Engineering and Medicine estimates that afforestation and reforestation, along with soil carbon sequestration and BECCS, could altogether capture and store up to 10 gigatons of carbon dioxide globally.³³ To absorb and store enough carbon to make a global impact, however, energy crops would need to be planted over massive amounts of land. Thus, to minimize land competition for living and other food

³⁴ Cho, Renee, "Can Removing Carbon From the Atmosphere Save Us from Climate Catastrophe?" Columbia University, published on November 27, 2018, accessed April 28, 2019, <https://blogs.ei.columbia.edu/2018/11/27/carbon-dioxide-removal-climate-change/>.

production purposes, it would be important for Fordhamopolis' crop area to grow upwards in vertical farms, rather than horizontally outwards.

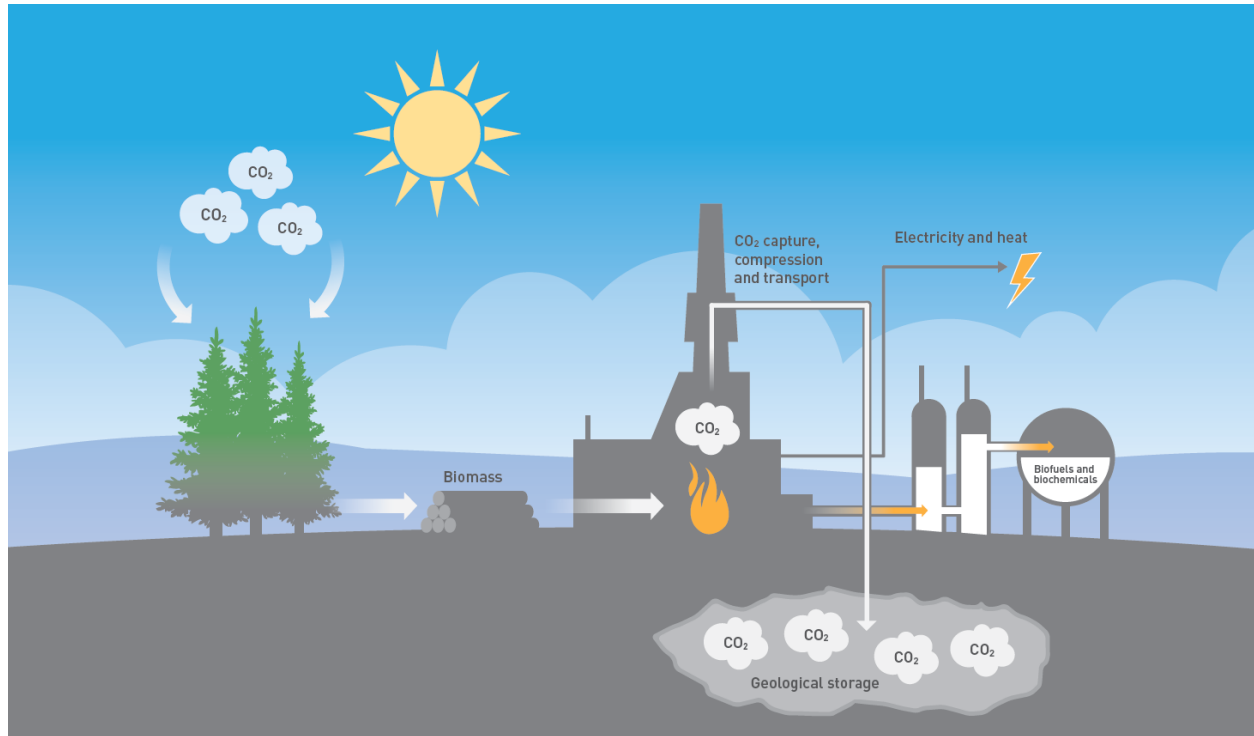


Figure 18: Production of Bioenergy with Carbon Capture and Long-term Geological Storage³⁵

Seawater capture is also a viable option for carbon sequestration. It involves extracting carbon dioxide from seawater, rather than from the air. The world's oceans cover approximately 70 percent of Earth's surface and contain roughly 93 percent of the planet's carbon dioxide.³⁶ With around 38,000 gigatons, the world's oceans contain 16 times more carbon than the land and the air combined.³⁵ Because Fordhamopolis is located on the Firth of Thames, a large bay connected to the Hauraki Gulf, which subsequently leads to the Pacific Ocean, it is ideal for seawater capture devices. Although seawater is considerably heavier than air, as stated

³⁵ Benjaminsen, Christina, "Removing CO₂ from the atmosphere," *SINTEF*, published on February 11, 2016, <https://www.sintef.no/en/latest-news/removing-co2-from-the-atmosphere/>.

³⁶ Parry, Daniel, "NRL Receives US Patent for Carbon Capture Device: A Key Step in Synthetic Fuel Production from Seawater," *U.S. Naval Research Laboratory*, published on October 3, 2017, <https://www.nrl.navy.mil/news/releases/nrl-receives-us-patent-carbon-capture-device-key-step-synthetic-fuel-production-seawater>.

previously, it is more concentrated with carbon, which makes it ideal for gathering the most amount of carbon with the least amount of work.³⁷ While carbon in the ocean does not directly contribute to climate change, by reducing the carbon dioxide concentration of seawater, the water will begin to draw in more carbon from the air in order to regain balance. Thus, seawater capture indirectly contributes to the removal of carbon from the atmosphere.

Given all these methods of carbon sequestration, the simplest and most efficient proves to be avoiding carbon dioxide emissions in the first place. Fordhamopolis will not contribute any carbon dioxide to the atmosphere that is not already part of the planet's natural carbon cycle, in accordance with its belief to do no harm. Any carbon sequestration methods that it implements would merely be to reduce the existing emissions already in the atmosphere. Therefore, eventually, these tactics will not be needed, once the Earth's atmosphere returns to its natural level of greenhouse gases. While it is unclear how long this healing process will take, it is essential for Fordhamopolis to implement these carbon sequestration methods in the meantime, and to set a "green" example for other cities in order to accelerate the process.

Transportation

What will intercity transportation look like a hundred years from now? In a small tech-forward city like Fordhamopolis, transportation infrastructure will be a modern take on traditional transit systems. Visually, infrastructure will be familiar to contemporary audiences; rail and automobile corridors will connect the city. However, how the transit system within it operates will differ dramatically. Overall, Fordhamopolis will have an integrated, multimodal transit system that will heavily rely on autonomous vehicles that are efficient and accessible to

³⁷ Mulligan, James, Gretchen Ellison and Kelly Levin, "6 Ways to Remove Carbon Pollution from the Sky," *World Resources Institute*, published on September 10, 2018, <https://www.wri.org/blog/2018/09/6-ways-remove-carbon-pollution-sky>.

all residents; this system will supplement a human-centric urban plan that fosters walkability and easy personal access to most residents' needs. Fordhamopolis is a living city, facilitating many services to its residents through its overall design. One of the main functions of the built city will be to move people around it; the physical form fosters this by following the New Urbanism design movement.³⁸ This practice began in the late twentieth and early twenty-first centuries and has yet to be applied to many cities the size and scale of Fordhamopolis.³⁹

As a New Urbanist city, Fordhamopolis will strive for egalitarianism and reflect this goal through its embrace of mass transit over that of the individual. This shift is centered around the successor of modern rail and walkable communities. Communities will center around significant areas of a neighborhood with transit stations situated at the center for easy access, no farther than a five-minute walk away from any one point. Streets will mostly be used to connect people through walking and technology-aided personal transit like bikes and scooters. Personal automobiles will be relegated to back roads and not allowed into central gathering areas.

The following section will further dive into the implementation of this design strategy in Fordhamopolis, beginning with personal transit and later expanding on both inter- and intra-city mass transit.

I. PERSONAL TRANSPORTATION

Fordhamopolis will foster many possible ways of personal travel, that is, travel which can be accomplished on foot or by the aid of simple technology like a bicycle. As far as transportation goes, walking is an obvious mode of travel as well as one that is both good for the environment and for the health and well-being of humans. While it is true that humans produce carbon dioxide

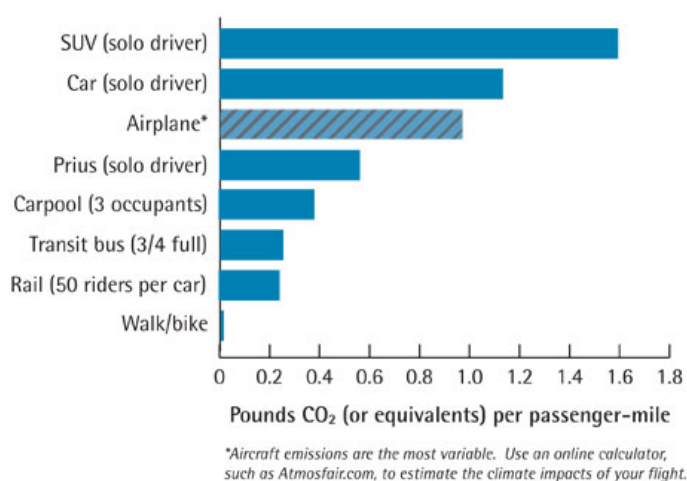
³⁸ "New Urbanism: Creating Sustainable Communities," *New Urbanism*, accessed April 28, <http://www.newurbanism.org/newurbanism.html>.

³⁹ Steuteville, Robert, "25 great ideas of the New Urbanism," *Public Square, a CNU Journal*, published on October 31, 2017, <https://www.cnu.org/publicsquare/2017/10/31/25-great-ideas-new-urbanism>.

through breathing while walking, it is much less than any other form of transportation (Figure 19). Walking is easy to do especially for short distances, like those in the downtown area or on the way to the closest light rail stop or bike share location. Walking every day can lead to stronger bones, reduced risk of heart disease and stroke, better balance, and more.⁴⁰ This contributes to the goal of Fordhamopolis to create a sustainable city where residents are cared for.

Figure 19: CO2 Emissions per Passenger-mile⁴¹

The next option for personal transportation at Fordhamopolis is bicycles. Looking to Figure 19, biking is right next to walking in terms of carbon dioxide emissions; therefore, biking upholds Fordhamopolis' core value of sustainability. However, the actual ownership of a bicycle must be sustainable in terms of money as well.



According to James D. Schwartz, the average American in 2019 who commutes on a bicycle spends \$350 a year to own and maintain their bicycle which is comparatively little compared to other means of transport.⁴²⁴³

⁴⁰ "Walking for Good Health," *Better Health Channel*, Department of Health & Human Services, published on June 30, 2015, www.betterhealth.vic.gov.au/health/healthyliving/walking-for-good-health.

⁴¹ Williams-Derry Clark, "Planes, Trains, and Automobiles," *Sightline Institute*, published on February 8, 2008, <https://www.sightline.org/2008/02/08/planes-trains-and-automobiles/>.

⁴² Schwartz, James D, "Americans Work 3.84 Minutes Each Day To Pay For Their Bicycles 59," *The Urban Country*, www.theurbancountry.com/2011/05/americans-work-384-minutes-each-day-to.html.

⁴³ This number came from a few assumptions, the first is that the bicycle costs around \$1,500 and the second is that a new bicycle is bought every five years. In 2019, the daily cost of owning a bicycle for someone making \$21.90 per hour is equivalent to financial compensation of 3.84 minutes of work. Schwartz believes that this is a fair cost for a bicycle.

In Fordhamopolis, the distance from the city center to its furthest border is about 8.75 miles. This distance may be a lot to walk but is doable on a bicycle. The limits of a person's biking skill vary from person-to-person but recent research suggests that six to ten miles are considered "doable" to the average bike commuter (Figure 20).⁴⁴ Within Fordhamopolis, commuting to work on a bicycle is very realistic in terms of both money and distance. Additionally, bicycles with motors as well as electric scooters and boards are popular and promoted by the city to aid commuters. Residents who do not want to take public transit and want to have their own personal mode of transportation are thus recommended to bike. Bike trails are available all over Fordhamopolis for both commute and leisure and streets accommodate and protect bikers with dedicated paths.

Distance (miles)	Difficulty
0 - 5	Easy
6 - 10	Do-able
11 - 15	Hard
16 - 20	Very Hard
21 - 25	You Cycle How Far?!
25 - 30	Nutter
30 +	&%6*£^^!

Figure 20: Biking Distance to Difficulty Levels⁴⁵

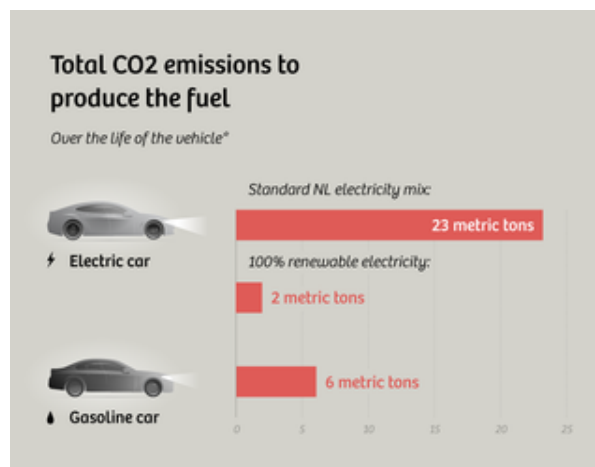
Fordhamopolis' other main form of personal transportation is the electric car. Despite a focus on mass transit, personal automobiles will be an integral part of the city. Electric cars can be used to get around most of Fordhamopolis, excluding the downtown which is zoned exclusively for pedestrians, as well as to get to and from other cities and towns. Despite a similar use to today's, cars in Fordhamopolis one hundred years from now will be nearly

⁴⁴ McLeish, Mike, "How Far Is Too Far to Bike to Work?" *Mobility Lab*, published on February 27, 2017, mobilitylab.org/2017/02/27/how-far-bike-work/.

⁴⁵ Ibid.

unrecognizable. Cars, referred to as ‘autos’ to further differentiate them from their contemporary counterparts, are entirely automated and connected to one another through the successors of 5G internet. When personal transit is needed, a smart, self-driving ride-sharing service will provide transportation.

These autos are completely electric in an attempt to be as environmentally friendly as possible. In response to concerns in the early twenty-first century, Fordhamopolis will ensure that all electric cars will be charged by energy sourced by renewable sources.⁴⁶ At the 2019 production level, the lithium battery of an electric car can produce up to 74 percent more carbon dioxide than that of a conventional car.⁴⁷ While electric cars produce a lot of carbon dioxide emissions during production, they produce less than half the amount of carbon dioxide for fuel (Figure 21). Fordhamopolis believes that the production of electric cars will produce fewer greenhouse gas emissions.



⁴⁶ Davidson, F. Todd, et al., “Is America’s Power Grid Ready for Electric Cars?” *Citylab*, published on December 7, 2018, <https://www.citylab.com/transportation/2018/12/americas-power-grid-isnt-ready-electric-cars/577507/>.

⁴⁷ “Lithium Batteries’ Dirty Secret: Manufacturing Them Leaves Massive Carbon Footprint,” *Bloomberg/IndustryWeek*, published on October 17, 2018, www.industryweek.com/technology-and-iiot/lithium-batteries-dirty-secret-manufacturing-them-leaves-massive-carbon.

Figure 21: CO2 Emission for Fuel Production⁴⁸

As modern studies suggest, automobile ownership will be very low and most community members will take part in an auto-share program.⁴⁹ Instead of keeping autos on personal property, fleets of AI-equipped personal vehicles will exist on the peripheries of cities, waiting to be called for a ride. After they complete their trip, autos will automatically fulfill another ride request or return to a station in the outer ring of the city. The stations will maintain and electrically charge the autos. While the city recognizes the importance and precedence of public mass transit, personal automobiles operate as an inconspicuous part of Fordhamopolis that accommodates outstanding needs. Visiting cars as well as any privately-owned personal automobiles can be stored in underground parking garages; electric charging ports will be available at each parking garage. By allowing residents of Fordhamopolis to maintain autos, the city allows residents to have a comprehensive level of mobility within the city as well as to travel to other cities and towns.⁵⁰ Fordhamopolis wants its residents to feel free.

II. INTRACITY TRANSPORTATION

Mass transit will be championed in this city of the future and the city will be designed around the idea of integrating accessible and efficient public transit measures. Fordhamopolis public transportation set-up will follow a fairly conservative trajectory based on the trends in the early twenty-first century. At its size of 100,000, the city is not populous enough to support a

⁴⁸ Verkade, Thalia, “Why electric cars are always green and how they could get greener,” *The Correspondent*, published on July 14, 2017, <https://thecorrespondent.com/7056/why-electric-cars-are-always-green-and-how-they-could-get-greener/741917761200-afaa6e5d>.

⁴⁹ Edwards, Jim, “Carpocalypse now: Lyft’s founders are right – we’re in the endgame for cars,” *Business Insider*, published on March 3, 2019, <https://www.businessinsider.com/carpocalypse-cars-automobile-sales-data-us-europe-2019-3>.

⁵⁰ Furthermore, commercial vehicles will be entirely automated. Like other vehicles, they will be an unnoticeable part of the city with all important delivery routes located in a ring around the urban area. In dense areas, special underground commercial corridors will be built to directly connect to businesses.

light rail system similar to modern subway systems.⁵¹ Instead, an above-ground system resembling light rail and bus rapid transit will be implemented. This light rail system, referred to as the metro, will connect all central areas to each other. All metro cars will be completely automated and arrive at each stop every two minutes.

The infrastructure will be built seamlessly into the large multi-use streets; this is already exemplified in many European urban areas (Figure 22). Metro lines will be integrated enough that they form a grid-like pattern, densely covering the city. Express routes will have stops every half-mile, and local stops will be every one-thousand feet. As Fordhamopolis is set back from the main body of water, the Firth of James, there will be an express metro line that connects the central city to the harbor community.



Figure 22: Rail is integrated into a walkable street in the historic center of Bordeaux, France.⁵²

To remove any socio-economic barriers of use, all public transit modes in Fordhamopolis are free to all, further integrating mass transit into everyday life. Every resident effortlessly

⁵¹ Florida, Richard, "The Relationship Between Subways and Urban Growth," *Citylab*, published on June 2, 2016, <https://www.citylab.com/transportation/2016/06/the-relationship-between-subways-and-urban-growth/485006/>.

⁵² Lee, Anna, "Tram running through the historic center," *Anna Lee in Italy*, published on January 3, 2014, https://ilmondoatavola.files.wordpress.com/2014/01/img_0910.jpg?w=1166&h=694.

utilizes mass transit; it is easy to use, highly accessible at every location within the city, and does not incur a fee.

III. INTERCITY TRANSPORTATION

As previously mentioned, Fordhamopolis wants to foster efficient travel between neighboring cities. Fordhamopolis does not have any communities adjacent to it's nearest metropolitan neighbors or Auckland and Wellington are and is 68 miles and 352 miles away, respectively.⁵³

Forhamopolites have the option to use more traditional electric cars to visit other communities. As of 2019, electric cars can take anywhere between twenty minutes to over twenty hours to charge depending on battery size and type of charger and, once charged, can travel around 100 miles.⁵⁴⁵⁵ These rates are on track to improve dramatically in the next one hundred years. With this charge, residents can easily drive to Auckland; further distances may depend on charges mid-trip. Fortunately, apps like Power Trip will help drivers find the closest charging station (Figure 23).

⁵³ *Google Maps*. <https://www.google.com/maps>.

⁵⁴ "FAQ," *Plug-In Hybrid & Electric Vehicle Research Center*, accessed in May 2019, phev.ucdavis.edu/about/faq-phev/.

⁵⁵ *Ibid.*

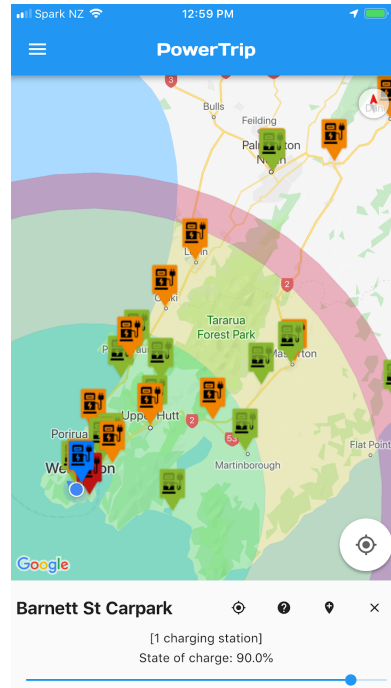


Figure 23: Power Trip App⁵⁶

However, the fastest method to travel between cities will be by heavy high-speed rail and its successors including a hyperloop. Hyperloop infrastructure will have grown substantially and experienced varying degrees of success; the North Island Hyperloop will connect Auckland to Wellington with consecutive stops in Fordhamopolis, Tauranga, Rotorua, the shared Napier and Hastings metropolitan area, and Palmerston North, with two spurs to cities adjacent to Auckland, Whangarei to the north and Hamilton to the south. The hyperloop will take the hours-long journey between some of these cities and shorten the trip to minutes in length.

Residents of Fordhamopolis who want to adventure outside of New Zealand's North Island are encouraged to leave from the Auckland Airport. The Auckland Airport is about an hour and fifteen minutes driving from the center of Fordhamopolis or connecting via the hyperloop. Because of its small population of 100,000 Fordhamopolis does not plan to build an

⁵⁶ Magnusson, Sigurd, "NZ Electric Car Guide," *Leading The Charge*, accessed in May 2019, www.leadingthecharge.org.nz/nz_electric_car_guide.

airport.⁵⁷ While there are efforts to reduce aviation-created greenhouse gases, the city recognizes the incredible environmental impact of air travel and persuades against it by not having a commercial airport; aviation is the cause of four to nine percent of the total human impact on climate change.⁵⁸⁵⁹ Fordhamopolis is working to create a direct high-speed rail connection with the international airport in Auckland.

The next hundred years will see a worldwide push to improve mass transit which will lead to more efficient intercity and intracity transportation. Future communities will all have multimodal transit grids, supported by modes of transit appropriate for the city's population and density. Fordhamopolis will be one of these communities that has a fully comprehensive transportation system. In Fordhamopolis, transportation takes a people-first approach, prioritizing actual human travel, whether by machine or on foot, over the movement of big cars and other privately-owned vehicles. Fordhamopolis champions equitable, accessible, and sustainable transit.

Conclusion

Whilst in the pursuit of a self-sustaining city, our vision of Fordhamopolis incorporates the factors we feel are needed to live the best quality of life. Giving careful consideration to energy, water, food, carbon sequestration, and transportation, we have supplied well-researched alternatives that provide significant long-term benefits and ensure we stick by our motto of *non nocere* which translates to “do no harm”. Hypothetically, a city centered around the theme of

⁵⁷ Florida, Richard, “The Surprising Math Behind Airports and City Size,” *CityLab*, published on May 25, 2012, www.citylab.com/transportation/2012/05/surprising-math-behind-airports-and-city-size/854/.

⁵⁸ “Airport Carbon Accreditation,” *Airports & CO2 Results*, www.airportco2.org/airports-across-the-world.html#region-asia-pacific.

⁵⁹ “Air Travel and Climate Change,” *David Suzuki Foundation*, published in 2017, davidsuzuki.org/what-you-can-do/air-travel-climate-change/.

biomimicry would lessen the negative impact of our heavily industrialized reality and allow for nature to live alongside us, rather than constant competition for inhabitancy.

Having the citizens of Fordhamopolis live within their means, rather than above, and understand the value of their resources encourages the following generation to hold their habitat in high-esteem. Within our modern-day society, it may seem as if we are doomed, being subjected to natural disasters and worsening climate change, however, this should motivate us to become savvy regarding pressing the environmental issues and analyze what lifestyle changes need to be made to help make a positive change to our planet.

The Fordhamopolis ideology aims to create upward trends geared toward the betterment of the environment. The global climate crisis wouldn't be just a matter of time. We could avoid the issue at all costs by starting now and working our way up. The initiative is increasing, however, execution is key. 100 years from now, we'd learn to treat our habitat with kindness. It is extraordinarily selfish to continue living beyond the earth's resource capacity. We are robbing our future generations of the simple luxuries we enjoy on a daily basis.

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