FEEDING THE FUTURE - TECHNOLOGY, PLANNING, AND SOLUTIONS FOR AN URBAN WORLD

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ABSTRACT

The present global system of food production and distribution relies on practices and technologies that are decades, or even centuries old. In an increasingly urban world, the growth of food many thousands of kilometers from where it is consumed, while using massive amounts of energy to transport it, is simply no longer sustainable. Using the latest food production technologies in or near urban centers will save staggering amounts of water, energy, and cost. This will contribute to a far healthier and secure food source for the world's population. I will demonstrate that a combination of technological Internet of Things (IoT) aids to traditional farming, urban 'vertical' food production using hydroponic and aeroponic technologies, modern aquaculture, and a sustainable planning approach to the urban metabolic flows of food, water, energy, and waste is a superior system by far for the needs of the modern world. By the examination of existing, best practice projects and the specific data from these efforts, I will show the positive implications of this plan's implementation in terms of increased food efficiency, dramatic savings of resources, financial, food security, and the implications for communities by adopting these practices. The conclusions will prove a more than 90% savings in water used, a 30% boost in food production during the farm-to-table process, and a dramatic lowering of the embedded carbon footprint from today's food production systems.

Acknowledgements

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TABLE OF CONTENTS

LIST OF ABBREVIATIONS

IoT: Internet of Things

AI: Artificial Intelligence

BI: Business Intelligence

SDG: Sustainable Development Goal

GDP: Gross Domestic Product

PPP: Public Private Partnerships

BOOT: Build Own Operate Transfer

kWh: Kilowatt-hour

CHAPTER 1 - INTRODUCTION

Food and water security is the oldest and greatest challenge humankind has ever faced. Every continent, every race, and at every income level, people have felt the fear of hunger at some point in history for a variety of reasons, both natural and man made. We see that the world is inherently unpredictable, where everything from disease to conflict of any scale can easily bring everyday life to a halt. Unfortunately, this includes food production, resource management, as well as the global import and export process. A new critical issue, which runs in parallel and will indeed have a greater impact on overall food security than any global political situation, is how to make the farming process more sustainable in our current world which has been ravaged by both humans and nature. This includes the latest issues caused by climate change and pollution. With the increase of urbanization, the producing, storing, and managing enough food sustainably in all these areas is imperative.

I will be focusing on more urbanized areas, seeing as how combating food insecurity has become a much greater priority in the last decade or so. In addition, as I mentioned above, urbanization is sweeping the globe, with flocks of people migrating to more desired cities with the continued idea of greater opportunities for work and personal life. As developing countries advance, and developed nations continue to grow, an ever larger portion of the global population seeks long term opportunities in urban areas. One example of this migration is in the United States, where, despite there being substantial amounts of habitable land in much of the country, the majority of the American population prefers urban areas. These urban areas now account for 80% of the entire US population, as well as most zones classified as, "… densely populated for commercial and nonresidential uses" (census.gov, 2020). Therefore, an urban solution brings benefits in a highly efficient manner to the greatest proportion of humanity. Some countries simply don't have enough space for farming and agriculture using traditional methods. For example, Singapore, a country that is only 734.3 square kilometers, has a finite amount of space to farm for a population of 5.5 million. In Japan, only 12% to 20% of the land is arable for the population of 125.7 million (OECD, 2019). This stress creates an unsustainable dependency on external food supply chains, which can quickly become undependable. The issue of global food trade also comes into play, where food is shipped to these urban countries from thousands of miles away. Some of the most common countries known for their exports include Guatemala, Chile, Peru, Costa Rica, and Brazil, which supply many different foods that seem common to find in one's grocery stores, including chocolate, bananas, avocados, coffee, and more (Peasley, 2023). Sustainable urban food production will solve these problems, and more, for a majority of the world's population. Can these urban solutions be used globally? In many cases, yes, these solutions can be applied to city planning, the development of new residential areas, and even in retrofitting older community infrastructure. The main applicability at the present time is in urban areas, and I will focus on those solutions.

I hypothesize that current food systems can be replaced by a scalable cooperation of traditional agricultural methods augmented with Internet of Things (IoT), artificial intelligence (AI), and business intelligence (BI) driven techniques working together with hydroponic and aeroponic solutions, large scale and decentralized urban farming, as well as aquaculture. These systems above working in a metabolic loop (which are systems tied together to promote circularity, much like the metabolic system of the human body), allow for resource recovery and reuse. Although centering on food circularity, I will also examine the food systems' integration into other urban metabolic flows such as water, energy, and waste. I will present plans for the financing of these solutions, both in new urban centers through incentive systems, as well as funding these applications in older urban areas through equity release by retrofitting large, dated infrastructure with modern, compact solutions. I will show the benefits of such a major change in the thinking of long term, sustainable food production solutions as compared to present methods and outcomes. These new technologies, polices, financial models, and practices are a way to massively benefit populations globally over many plannable and measurable United Nations Sustainable Development Goals (SDGs).

When we can solve the problem of hunger, societies can work to put a greater amount of energy and resources toward other pressing global social objectives. Once the issue of food in urbanized countries is solved, their finances and resources can be utilized and focused more effectively on helping other countries in need. We could potentially provide aid to those countries that have their own unique issues with food growth and starvation. Other countries that may suffer from disease or from the negative impacts of a conflict, can also benefit. But no one can work for social and societal betterment if they are thirsty and hungry, and this is true for any country, no matter its economic status. I believe that we can use modern technology to achieve this effectively and sustainably. Though the question remains, **"How do we best use the latest technology, planning, and finance options to create meaningful sustainable food production options for our future?"**

By tying in all these aspects of specific needs, existing solutions, and future growth, I will prove my answer empirically and with real world examples in a suggested project structure.

CHAPTER 2 - ADDRESSING THE PROBLEM

2.1 The Facts

The current situation surrounding food security, scarcity, and waste are at the core of global tension today. At present, 56% of the world lives in urban centers and this is forecast to grow to 70% by 2050 (The World Bank, 2023). As of now, 72% of all global fresh water is used up in traditional agriculture, and 70% of all food products are shipped to urban centers which, in turn, generate 80% of the world's GDP (Fujs, Hashiwase, 2023). The traditional food production system, while still used in any country with access to arable land, has become inefficient, leads to massive amounts of waste, and has proven inadequate to feed an increasingly urban world with a fast-growing global population. Furthermore, producing crops in a low tech fashion and then shipping them many thousands of miles adds greatly to energy use, pollution, and carbon output.

The research shows that for urban population centers, pre-planned, locally centered, metabolically implemented food production provides a better degree of security, sustainability, and efficiency than traditional farming and distribution. All this is leading to a positive social impact on the population, therefore creating the 'knock-on' effect of being able to address additional pressing social issues, with a more efficient use of water and energy resources. Populations today move to, and will continue to shift to urban environments. Currently, 95% of all food globally still comes from soil and is grown many thousands of miles away from where it is consumed. With 33% of the earth's soil already severely degraded, and estimates of as high as 90% being degraded by 2050, this needs to be addressed as one of humankind's greatest challenges (UNDRR, 2020). These two trends overlapping literally create a deep existential threat to survival on Earth. Many modern solutions have been developed and are now in use in various projects worldwide, generating usable data and conclusions. I will primarily be looking at quantitative research and data from the overwhelming amount that has come into the sustainability and farming scenes over the last 15-20 years.

2.2 The General Knowledge

I will not be focusing on qualitative data, as much of this subject (while being highly relevant and important) is not a subject typically investigated or thought about by your average citizen. Rather than examining opinions, I focused on a fact-driven paradigm-shift in the sector. I come to this conclusion based on the current direction of the overall food production industry, as well as factual experience from my data gathering thus far. In addition, at various points in my life, I have personally visited hubs of technology and development in several of the countries I will examine. I will bring together what I have personally witnessed, and available data. An example of this was a series of interviews I conducted for my own interest during the course of my studies as a whole; about people's general knowledge of high tech farming and their opinions about it. These people were all from different countries that currently have strong ties to agriculture. I was curious to see how willing they, as individuals, would possibly be to the idea of urban farming practices. Some of these countries include Taiwan, Denmark, Mexico, and Guatemala. Approximately half of the participants had little to no general knowledge of the subject, while the other two were only aware because they had an educational background in the subject. Therefore, be attaining proven quantitative data, the results will present themselves in the most empirical and usable ways in hands-on projects.

Chapter 3 - Main Concepts

The three main concepts that I will be looking at in this research are food production, sustainability, and technology. As I mentioned above, I believe food production deserves its own slot of importance due to its significance as a basic human necessity. Sustainability is a necessity to look at in today's modern world as a protective measure for our Earth, and our people, to continue to live long and healthy lives. Technology offers a new platform of solutions, and is the bridge between the present problem and our desired solution. Within the last 20 years, new technology solutions in this sector have boomed, but have only been implemented on a limited or country-specific scale, largely due to an over-reliance on conservative solutions. These innovations have been introduced into traditional agricultural practices, creating totally new segments in food production. This has even become a catalyst for many young people when choosing a field of study, from engineering to computer science, drawing them to new high tech food production careers.

Tying together the topics of food and sustainability is 'which' foods to focus on growing at larger scales. The questions now are: Which foods can be grown effectively and nutritiously for people, with minimal negative environmental and financial impact, and which foods have smaller embedded carbon footprints, but can still feed a population on even the largest of scales? This could likely mean focusing less on certain meats for the time being (which have a high carbon footprint), and focusing on foods that can be staples of diets, such as greens, root vegetables, fruits, some seafoods, and even nutritional supplements to continuously provide the recommended basic nutrients for people, regardless of their location.

Connecting technology and food are the high-tech farming practices I previously mentioned, as well as augmenting traditional farms with the latest technologies. These are revolutionary new types of food production that have many added benefits while having the need for new skills, as well as new investments. They can enhance job markets for farmers, take up less space, continue to offer well-paying jobs for a larger part of the populace (including younger workers who have a higher knowledge of technology), and constantly yield multiple, large harvests of food. All this in comparison to the unpredictability of traditional farming due to events ranging from natural disasters, displacement of resources (like water), and an aging farming population that only gets more pronounced each year. Some other common global issues that are caused from traditional farming can be solved with new technology, like deforestation, biodiversity loss, dead zones, irrigation problems, pollutants, and soil degradation (United States Geological Survey, 2019).

The ties between the topics of technology and sustainability are the critical examinations of what kind of farming technology and equipment are causing the most harm to our planet and the food industry, and how best to adapt or replace these practices. Large machines, enormous fields, massive use of pesticides and herbicides - is this really the best way to continue? In no aspect of life socially, politically, or technologically, can society stay stuck in the past. Not changing in this sector is the intellectual human equivalent of insisting on land lines as the only form of telecommunication, therefore missing out on the benefits that cellular and internet-based communication have brought society.

Bringing together solutions in food production, technology, and sustainability, I propose using real world production examples, as well as financial models for funding. We can learn to use more sustainable methods in farming, architecture, interconnectivity of systems, all to produce what we need. With new methods, teachings, and science, we can have nations grow more of their food independently instead of having to rely on unsteady trade. By introducing an efficient logistics system that will lead to reduced amounts of massive food waste and carbon release, these solutions will promote considerable food security, allowing populations to thrive, even in times of conflict, pandemics, and global uncertainty. Granted, all locations can not grow all crops at all times of the year, but a critical increase in sustainability planning means more efficiency on the local, regional, and global levels, meaning that only in some limited cases do foods need to be shipped farther distances. This will also allow our land to heal, bringing the opportunity for natural growth, increased biodiversity, and species regeneration, while still giving the people what they need in terms of nutrition, food security, and independence.

Chapter 4 - Projects in the Works

4.1 Currently Applied Technology

I will examine available projects, new technologies, and their success stories. For example, but not exclusively, the Singapore '30 by 30' plan, Daiwa Agri-Cubes (Food Cubes), and the ECO1 vertical farming project in the UAE, among many others. These are all fantastic examples of modern technology utilizing high tech farming methods on both a large and small scale, from feeding a neighborhood to feeding a city. All also have been in use now for the last decade or so, and therefore have many concrete writings on the process, the results, and any improvements needed. I will use their real-world conclusions and methodology.

Most of these examples above use vertical farming, which was first invented in 1999. I believe this is the step that must be taken for countries to have their own food sovereignty, and not have to worry about food insecurity any longer. Vertical farming's real value lies in its water consumption. Researchers estimate vertical farms can use up to 99% less water than traditional farms, depending on what system they use. These farms can produce up to 500 tons of leafy greens yearly in as little as an acre and a half (Marsh, 2023). As the technology advances with us, these vertical farms have become more efficient and more energy saving. One of the largest issues people are concerned about with vertical farming is energy consumption, but already some facilities are beginning to run on purely renewable energy. Since indoor vertical farms are completely sealed off from the outside environment, there are virtually no pests. As a result, there is rarely any need for pesticides or herbicides. Vertical farms also have a much lower overall CO_2 output by 67% to 92% when compared to greenhouses (Naus, 2018). The difference between field crops is even greater. Vertical farms tend to use either hydroponic or aeroponic technologies. Hydroponic crops are grown indoors using water as the substrate with the plants being suspended in water full time. Aeroponic being a technique where the crops are grown indoors, in dry racks with their roots exposed. Of the two, aeroponic is more costly, but by far saves the most energy and water, as well as makes the growing process the most secure and controllable. Aeroponics allow for very specific and accurate use of water and nutrients, producing a crop in such a plannable manner that even crop color, size, and amount per plant can be pre-chosen (Living Green Farms, 2023).

An important aspect to the overall planning of urban food production is the selection of what to grow, in what way, and for what percentage of the overall food needs of the community. Hand-in-hand with vertical farming and IoT innovations in traditional farming is the use of aquaculture. Not only can aquaculture account for much of the protein needs of the community, it can do so in a far more efficient way than traditional open water fishing. Today, the largest portion of the aquaculture market focuses on carp, mollusks, salmon, and crustaceans, although many other aquatic foods can be raised in such a way, including seaweed and algae (Dynamic Pro Research Insights, 2023). In the case of Singapore, aquaculture is one of three main methods of growth that is a key part of the '30 by 30' food security plan. In Japan, world leaders in innovation (such as Mitsui) are investing millions of dollars into aquaculture solutions. They are anticipating that the transition from fishing to aquaculture will have as much innovation and global benefit as the transition from hunting and gathering food to growing food did 12,000 years ago. Currently, already almost half of the seafood eaten today is grown using aquaculture and this will grow to 65% within the next five years (European Commission, 2021). The next challenge to address with aquaculture, as with the transition to urban food production, is planning locally. At present, most aquaculture products, aside from a few countries, are not consumed locally; they are shipped long distances at great cost in energy and carbon footprint, plus subjecting the product to spoilage and waste. As a positive local planning example, Singapore has invested more than $50 million USD into aquaculture research as well as established investment funds for aquaculture companies, and even single family ventures to tap financial resources (Singapore Food Agency, 2023). The next phase of aquaculture seems to be not the farming of fish, but the farming of aquatic life for multiple uses (this mainly means algae). Present technologies can easily refine algae into foods, as well as nutritional supplements and fuels (Chitose Bio, 2024). The Japanese company, Chitose Bio, is one of the global leaders in this field and operates research facilities and algae farms in Japan, Singapore, and throughout Asia. When we include the latest developments in aquaculture with high tech vegetable and fruit production, we see that urban local food production is the future of communities fulfilling their nutritional needs. I have personally visited the Chitose Bio headquarters outside Tokyo and witnessed their team's efforts in creating food and food supplements, and even jet fuel from algae grown in facilities in Japan, Malaysia, Singapore and Thailand.

4.2 Global Success Stories

Being one of the smallest countries in Asia, Singapore has long struggled with food production and growth despite also being one of the richest countries in the world. It is an island city-state where only approximately 1% of the land is set aside for farming and agricultural purposes. That still means over 90% of all of Singapore’s food is imported, and that process can be easily slowed or halted by conflict, pandemics, or even a slow harvest season. That is why Singapore created the '30 by 30' initiative that began back in 2019. Singapore's '30 by 30' plan is for the country to be responsible for growing 30% of its own food and for locally producing 30% of its nutritional needs by 2030. Using vertical farms as mentioned above, including projects like Singapore's Edible Garden City and GroGrace, these methods of food growth have been proven especially productive. A much smaller amount of land is used (nothing bigger than the average high rise footprint) to produce 10 to 15 times more food than traditional farms. These farms primarily utilize multi-story LED lighting and recirculating aquaculture systems, but with plans to transition into utilizing solar power in the near future. (Singapore Food Agency, 2023)

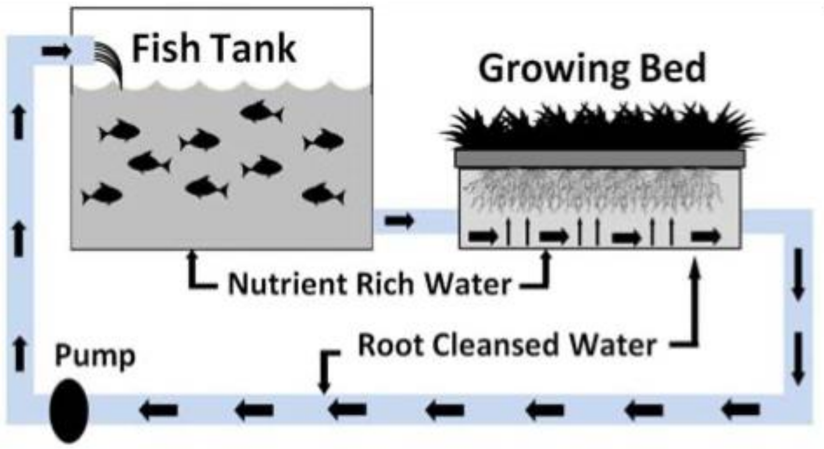

Figure 1: Aquaponics graphic illustration (North Carolina Agricultural and Technical State University, 2016)

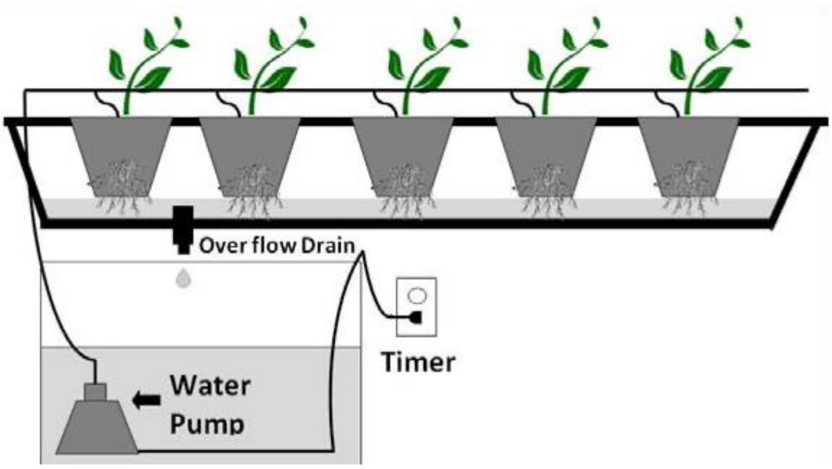

Figure 2: Hydroponics graphic illustration (North Carolina Agricultural and Technical State University, 2016)

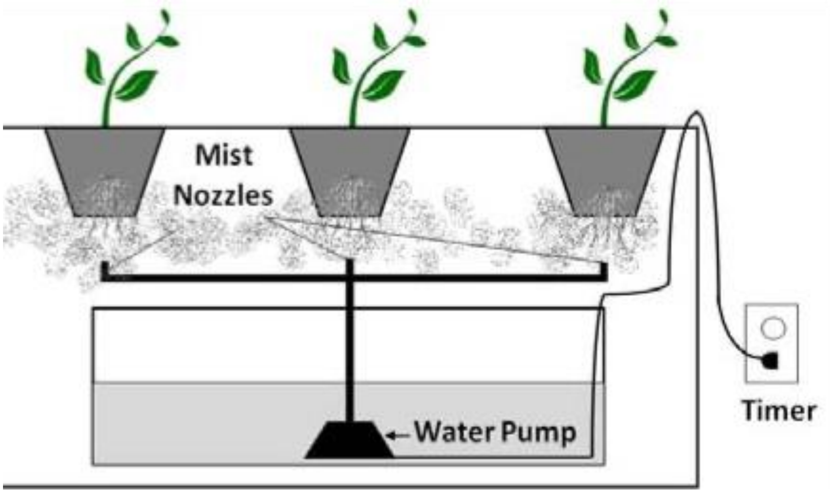

Figure 3: Aeroponics graphic illustration (North Carolina Agricultural and Technical State University, 2016)

Using these methods of vertical farming, farms like GroGrace can produce up to 33 tons of leafy greens each year in a building four stories high taking up no more space than 650 square meter footprint. With these new setups in place and more food readily available, food insecurity is slowly being wiped away and new opportunities arise. These include teaching opportunities (which is a highlight in Singapore's Edible Garden City), where workers and teachers bring young students and children from all over the country to teach them about nutrition, the benefits of different foods, and vertical farming. It is also an important element of Singapore's sustainable food success story that there is a realization that long term planning is needed, as well as a focus on technology and infrastructure. I lived in Singapore for seven years during the final stages of this independence plan, and saw the importance of this multi-faceted approach they used legislation and policy, relying heavily on public education about the importance of the issue, implemented price driven solutions, and a large investment in research and development of the specific issue of water; and now food independence. I saw that policies can not succeed alone. Sustainability also takes new technologies, the manufacturing of items needed, research, and finance (Y, 2021).

As mentioned in my introduction, only about 12% to 20% of the land in Japan is arable for its population of 125.7 million. These numbers are subject to constant change due to the unpredictability of an aging farming population, natural disasters, and a nation whose primary dietary needs consist of rice and many different fruits and vegetables. Due to these factors, many companies like the Daiwa Food Group are consistently working on new initiatives and projects to feed the population of Japan and maintain a consistent string of reliable food growth. From this came the invention of the 'Daiwa Food Cube', also known as the 'Agri-Cube', in 2012. Japan is no stranger to growing fruits and vegetables within controlled environments to create the best product in looks, size, and taste, as we have seen from the 'Yubari "King" Melon', 'Ruby Roman Grapes', or their $20 apples, though these foods are at the moment too expensive for the average local. Thus, the Daiwa Food Group created the 'Agri-Cube' to ensure the best quality of fruits and vegetables for all citizens. The Daiwa Food Cubes in Japan only take up 16 by 8 feet worth of space, cost $70,000 USD for initial construction, and can grow approximately ten thousand servings of fruits and vegetables each year at an operational cost of about $4,500 USD per year for neighborhoods. These 'Food Cubes' require little maintenance, working on a hydroponic system, with the option of solar panels and air curtains (machines that generate a wall of air which separate two environments) as other cost effective and energy saving options (Daiwa House Group, 2023). Currently, the 'Food Cube' can grow up to 23 individual plants in its singular, closed environment, including various fruits, leafy greens, and root vegetables. The 'Food Cube' has been placed in various neighborhoods, complexes, and food industry areas, capable of feeding up to ten full households, or even filling up markets, stores, and providing for various restaurants. A truly scalable and sustainable solution able to scale up from one city block to an entire urban district (Daiwa House Group, 2023).

The United Arab Emirates is another country that is struggling with food insecurity, but for different reasons than Singapore and Japan. In the UAE, despite the size of the country, there is very little water and arable land. A consequence of that is having to import just as much food as other urban countries, up to 90% and over. But with all the readily available land, there is an opportunity to expand on the ideas of vertical farming on a much grander scale. As such, they have now created the 'ECO1'. This is the largest vertical farm in the world at 330,000 square feet and using 95% less water than a traditional farm (Hall, 2022). Located near Dubai World Central, the 'ECO1' vertical farm can produce approximately one million kilograms of high quality, leafy green vegetables annually with a daily output of 3,000 kilograms of vegetables a day, and plans continual annual increases in capacity. The facility mainly grows leafy greens. The facility also tests new nanoparticle technologies that allow nutrients to be retained better in small amounts of water and sandy soils, plus develops ways of using solar power for its electricity needs (Hall, 2022). To advertise their success in this venture as well, many of the greens grown in this building are served to passengers on the Emirates airline, and stores are now selling this specific brand of vegetables in stores.

CHAPTER 5 - FINANCING OF URBAN HIGH TECH FOOD PRODUCTION

In terms of the financing of new, urban food production facilities, it is clear that there are cost effective ways that urban centers (regardless of their location or economic status), can either transition to new circular food production solutions or affordably build new ones. Whether they are built in existing developed areas, or in new cities and newly built areas, any community can affordably and efficiently finance this transition to circular solutions. Specifically, I will focus on options for both new and existing cities. For old cities, financing through the equity released by replacing and retrofitting large, outdated facilities. For new cities, I will highlight the use of Build Own Operate Transfer (BOOT) to pay for urban food production.

Examples have shown that the redevelopment of land freed by the use of modern technologies with far smaller footprint can pay for new facilities including water, energy, and food production. In some cases, in very high land value areas such as Japan, China, and the Netherlands, the funds generated by this practice actually exceed the cost of the new facilities. Specific examples of this include the 'Biopolus Hungary' design of new water treatment infrastructure for communities in Tokyo and Kitakyushu, Japan. In one project, the footprint of the original water facility was 39,500 square meters. This facility, (originally built at the edge of the city limits when it was first constructed), has in the recent decades of development ended up occupying what is now valuable land for development. The new design would, depending on the design choice of the city, cover only 6% to 17% of the original site (Biopolus, 2019). The city can therefore choose to sell or develop the remainder of the land for its financial benefit. In this example, even in the most conservative case, more than 30,000 square meters of space would be available for sale or redevelopment. The value of this land, even in average locations and market conditions, is more than $215.6 million US Dollars. In more desirable, riverside, waterside, or strategically placed areas, this value can be 5–6 times this amount (Kaneko, 2023).

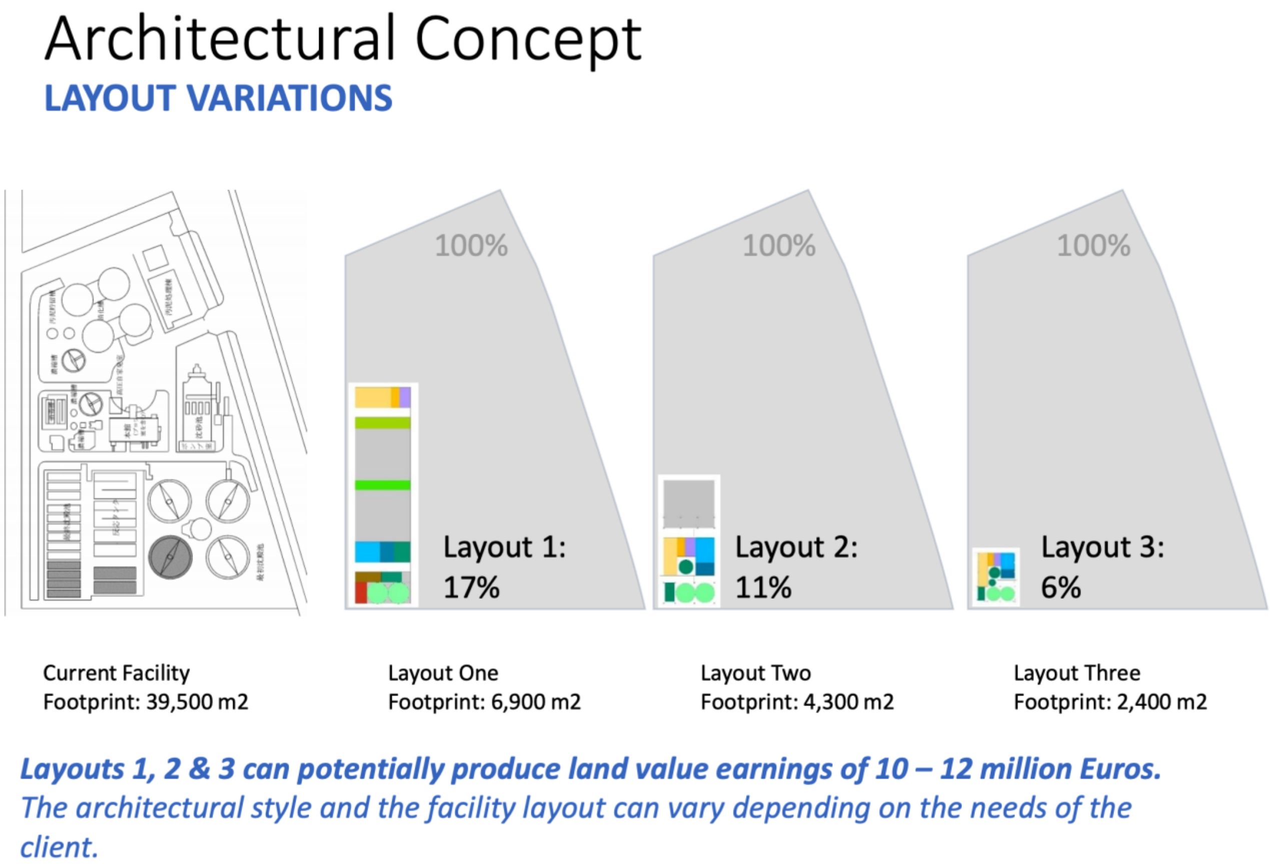

Figure 4: Architectural concept of current Kitakyushu Treatment Center and layout proposals to minimize carbon footprint. (Biopolus, 2018-2019)

So, we see that the funds released from such a new redevelopment can more than pay for a modern urban food production system and leave a great deal of funds for further development, such as healthcare, housing, schools, or other urban infrastructure such as power generation or water re use. With the average cost of 1,000 square meters of growing space in vertical farms at $970,605 USD (iFarm, 2023), a modern urban food production facility of 5,000 to 10,000 square meters (at minimum) will be built with funds left over for the city or municipality. China, The Netherlands, Singapore, Japan, Denmark, the United Kingdom, and many others fit these criteria and are ideal candidates for this financing option. In these locations, the value of commercial and resident real estate development is far higher than the cost of new urban food production centers and other modern infrastructure.

In new areas, the practices of Public Private Partnerships (PPP) and Build Own Operate Transfer (BOOT) for cities to pay for new urban food production, without having to pay out of their own budgets, is another forward thinking option. Private technology companies build the facilities for the cities at little or no cost, in exchange for a fixed production fee for a given number of years. After that, the ownership is transferred to the city or population group that will use the facility long term. This practice is especially useful in urban areas that were established long ago and have high growth at present.

In most BOOT options, the city, municipality, or national government agrees with the technology provider on a contract to be paid to operate the new facility for some agreed amount of time. The technology provider company is paid by the government for the successful operation of the facility, in this case a ‘food production facility’, for the agreed number of years at an agreed cost. After the agreed time expires, the ownership and management of the facility is passed to the government from the private company. In return for this, the private company agrees to build the food production facility at no initial cost to the purchasing government. In other words, there is no financial impact on the government to build the facility. Instead, the cost of the facility has been ‘spread-out’ over many years, making it easier for the purchasing city or government to pay for new high tech food production. These BOOT type of agreements are usually used in complex projects with high value, and are especially good at giving the purchaser access to more modern, more expensive, innovative technologies they would otherwise not be able to afford or only be able to afford at significant risk (Kirat, 2023). In most cases, the term that the builder owns and operates the facility for a fee is between 10 and 25 years. This term also allows both the builder and the eventual owner to agree on fixed costs, upkeep and continuous improvements of the facility, as well as be able to plan in detail who pays for what throughout the transaction (Faiz, 2018). In most cases, the technology company will not pay the entire cost of the construction and maintenance of the facility, but they will finance the amount through a bank or financial investor. This practice is generally seen as a 'win-win' for both partners. This structure works much the same way as putting any personal large purchase on a credit card to be able to them pay it off a bit at a time. Yes, it makes sense, and yes, you still need to pay attention to the level of the fees. Ideally, when a community can put both these financing ideas into their plans, the cash from an equity release can pay for major infrastructure updates overall, such as urban food production. When the technology provider is then paid through a BOOT plan, this means the community can use its funds effectively to have a maximum positive impact over time.

CHAPTER 6 - ADDRESSING POSSIBLE NEGATIVE REPERCUSSIONS

Of course, there can be no new innovation or ventures without some challenges. 'Vertical farming' as a concept and the methods it uses have often been heavily criticized or put into question. Some fear whenever there is an innovative technology that could or will be implemented in such an important sector of human living, like food growth and distribution. Vertical farming has been criticized for being extremely high energy, unlikely to be able to grow some dietary staples (like corn and wheat), and can create crops that are typically more expensive (Ogden, 2019). However, studies show that vertical farming tends to use a *fraction* of the water field farms use, even 95% to 99% less. According to Chief Marketing Officer of AeroFarms, Marc Oshima, *"That leads to 390 times more productivity per square foot than a commercial field farm growing the same crops. It also eliminates extreme weather risks, since everything is indoors and climate controlled,"*. Energy in the form of electricity is in fact used instead of sunlight for the crops, plus for cooling of the growing area. This energy can be generated from sustainable sources such as solar and geothermal (iFarm, 2023). In addition, with urban food production, the crops are consumed locally. Therefore, the energy is saved that would regularly be used to transport and cool food if traditional farm and transport methods were used.

Another challenge that arises is the human aspect in vertical farming. Job requirements are much different than in traditional farming, including the need for more technical experts and those that have a background in the field of engineering, biological sciences, or even computer sciences. A key component in vertical farms is, according to TechBrew, *"LED lamps, HVAC air-conditioning systems to circulate and control the temperature, water-filtration systems to circulate and purify the water used to hydrate or mist plants, and, in* *some cases, a closed-loop system of fish habitation and waste management to gather nutrients from fish and turn them into fertilizer for plants."* This has created a system where vertical farms use approximately 38.8 kWh per kg of produce crops compared to traditional greenhouses that average 5.4 kWh per kg (McDonald, 2022). As this is also a newer technology that has only been present and slowly implemented in the last 20 to 25 years, many countries and companies do not quite have a grasp yet on the technology, or how to manage it for a large scale endeavor.

Another constant concern that looms over many is, "What will happen to the current workforce within traditional agriculture?" With modern technology and some artificial intelligence being used in this traditionally human-powered field, there are an estimated 85 million jobs that may be displaced by 2025 due to a labor division between humans and machines, according to the World Economic Forum (World Economic Forum, 2020). Many of these jobs include what could be considered entry level manual labor and routine jobs. This could make things more difficult for anyone wishing to enter the workforce with anything less than a college degree. It is sometimes said, that locally sourced high tech food sources would negatively disrupt the global food production infrastructure put into place during the globalization that followed the Cold War. In other words, those farmers from poor countries who produce large amounts of basic food crops which are then shipped all over the world, would lose out to high tech local vertical farms, as would the transportation infrastructure used to move the food to consumers. In truth, the foods produced in high tech vertical farms are short life cycle leafy greens, tubers, legumes, herbs and even seedlings for trees and medicinal plants (IGS Vertical Farms, 2023). The most often traditional farmed, slow-cycle crops such as wheat, oats, millet or sugar beets are not farmed in vertical farms, therefore this sector of farming would be left largely untouched globally. In terms of global food logistics, the global shipping industry has seen an annual compound growth of plus or minus 5% for many years, so the impact of less food being shipped globally would have limited effects on the industry (UN Trade and Development UNCTAD, 2023). In truth, this industry is being targeted as one of the leading generating or greenhouse gases in any case, so a limited reduction in food shipped will likely produce only positive outcomes.

CHAPTER 7 - SOLUTIONS

There is no positive development without challenges. While these fears are valid; socially, economically, and scientifically, there have been leaps in working to solve any challenges that arise involving these innovative technologies. Vertical farming and the projects revolving around modern food production are the future of feeding urbanized cities, countries, and perhaps parts of the entire world. Like most issues surrounding energy usage, vertical farming is not left behind when attempting to come up with alternatives and utilizing their energy usage in the most sustainable way possible. According to Deane Falcone, the Chief Scientific Officer at the Massachusetts based indoor farming company, 'Crop One', improvements in LED lighting have enabled, and will continue to enable, more energy efficient growing cycles over time. *"They do consume a lot of electricity. And so, that is something that everyone is tackling, including us. One of the ways in which we do it is to increase yield. If you increase the amount of crop product with a given amount of electricity, the more you increase the yield, the better that energy-efficiency equation becomes,"* Falcone said. The improvements Falcone has mentioned here follow an observation called the Haitz law, which says that cost per lumen per LED light decreases ten times every decade, while the amount of light generated increases by 20 times (McDonald, 2022). And while not able to yet completely convert to solar power, many companies are either partly utilizing solar power as a main energy source, while some companies, like the Daiwa House Group that created the Daiwa 'Agri-Cube', have created a model of the cube that does run on solar power as a more primary source of energy.

When factoring in costs and costs spread out in each sector, one area that will drastically improve is the subsequent reduction of CO_2 emissions that come from less of a need to import as much food as we currently are. There is also the point of reduced labor costs, less spent on herbicides and pesticides, and on fertilizer that is manufactured from natural gases, which lead to fewer nitrous oxide emissions, and the promise of a full harvest at a much faster and more reliable rate when compared to the rates of traditional farming (Grunwald, 2023).

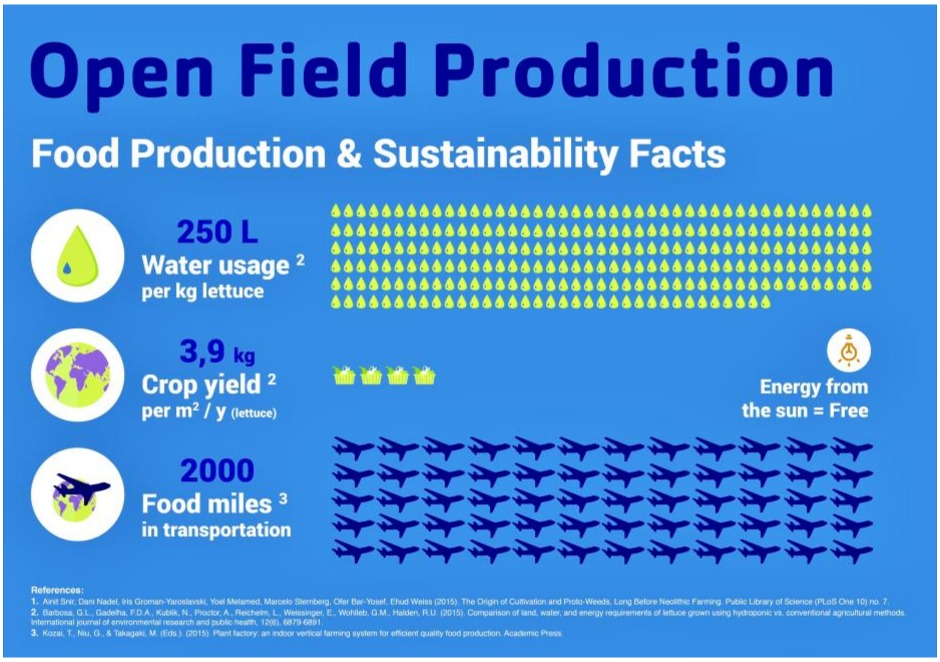

Figure 5: Food production and sustainability facts involving water, crop yield, and transportation facts surrounding traditional, open field farming, (EIT Food, 2018)

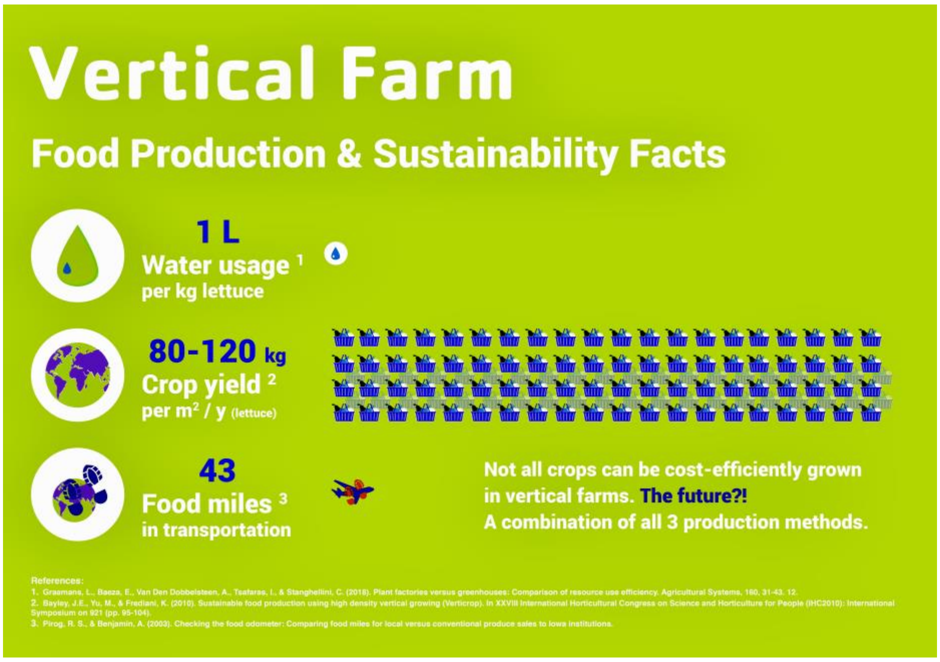

Figure 6: Food production and sustainability facts involving water, crop yield, and transportation facts surrounding high tech, vertical farming, (EIT Food, 2018)

As for job security, technology will not “steal everyone’s jobs”. In fact, according to the same World Economic Forum journal mentioned above, this shift into new technologies will mean approximately 97 million more job openings, more ‘jobs of the future’, to be precise. While work with repetitive tasks may and can be replaced with computers and different modern machinery, many more engineering, business, biological science, and computing fields will open up for the current generation entering the workforce - all of these being in the current top ten most popular college majors globally (Orduña, 2021). Another change that will arise from shifting to vertical farming is the overall relief the current farming population will feel. In the European Union, for every farm manager under 40, there are three aged 65 or older. In Japan, the average age of a farmer has now risen to 68.4 years. This trend is seen globally, where the average age of farmers focusing on agriculture only keeps increasing yearly without enough young people going in to fill the roles associated with these hard, manual labor jobs with truly little incentives like good pay or the promise of a consistent, healthy harvest (Henriques, 2019). One other reason why younger people are no longer choosing to go into this field is because of the promises of ‘jobs of the future’ should they go to college and, as I listed above, many students choose to major in a field that is deemed to have more work opportunities in the future, such as engineering and the sciences.

CHAPTER 8 - CONCLUSION

By tying in all these aspects of specific needs, existing solutions, and future growth, we can clearly see that in almost all cases, some form of urban food production adds to resource savings, food security, and increased circularity. Let us be clear about what these advances are, and what they are not: They are not ways to cover 100% of the food needs of any given urban location. They are not being put in place to replace more traditional forms of agriculture. These innovations, like any innovations before them, are to reform in a positive manner the system that came before it. With continued population growth and an increase in the rate of urbanization, agriculture can no longer rely on techniques developed many hundreds of years ago. Just as the telephone is no longer an item bolted to a wall with a long curly wire emanating from it, food production must also adopt a 'cellular' approach with each 'cell' corresponding to an amount of people. When we view the challenge in this way, modern urban food production fits perfectly into the metabolic flow model of cities, where food, energy, water and needed items are taken to a 'cell' of the population and waste is taken away. (Eberlein, 2018) With the implementation of the latest in vertical food production, aquaculture, and IoT based aids for traditional agriculture, urban centers can locally, sustainably, and with a remarkably high degree of food security, produce 20% to 30% to 50% of their own foods or more (Fu, Fath, Daigo, Zhang, Deng, 2022). Communities can also effectively fund these developments without negative budgetary impact, as well as continue to innovate in this sector as their needs change. Changes in population up or down, in population location, and in the technologies applied to food production can all be planned and accounted for. This gives the billions who live in urban centers today a far more safe, sustainable, and equitable life in food terms. In addition, the urban food production boom that comes directly from this stems from the very human need to adapt. No industries or societal sectors have changed at the same rate. If we examine the rate of innovation in communications, it is far greater than the transportation industry today. This was not always the case, as we went from animal drawn carriages to moon landings just a century ago, all in a time when electronic communication was largely accomplished by only one source… the telephone. So, really, what we are discussing is the natural progression of certain industries. The technology, best practices, financial solutions, and the desire is now in place for sustainable urban food production to be the next paradigm shift in global societies.

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