INTRODUCING 500 FOODS

by

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Abstract

This paper explores a new idea-stage venture, 500 Foods. This venture plans to grow and directly market a wide variety of fresh produce using entirely different methods than those used by the greenhouse industry today, using shipping containers for the primary growing system. An overview of the agriculture industry is provided, followed by the development of a benchmark greenhouse model. The methods 500 Foods is proposing are introduced and compared to this benchmark. This is followed by an implementation plan, detailing the phases and financial metrics that 500 Foods may use on its way to reaching its objectives.

Keywords: agriculture; horticulture; olericulture; containerculture; fresh produce; greenhouse; shipping container; biochar; tomatoes; hydroponics;

Executive Summary

This paper introduces 500 Foods, an idea-stage venture exploring a new form of industrial farming that uses shipping containers. As global population growth rates continue to increase, so does the challenge of growing more food. Projections indicate that by 2050, crop yields will have to increase by 70%. While organic farming practices may provide some environmental benefits, they do not increase crop yields enough to keep pace with population growth. More sustainable and productive industrial farming methods are needed. 500 Foods is interested in methods related to fresh vegetable production.

Part 1 provides an external analysis of the agriculture industry in Canada, and more specifically the greenhouse fresh vegetable industry. Field crops yield about 10-20 tonnes of vegetables per hectare, generating farm revenue of about $0.50/kg. Greenhouse crops, primarily tomato, pepper, cucumber and lettuce crops, yield more than 400 tonnes per hectare, and generate farm revenue of about $2.00/kg. Despite the massive improvements in yield, more than 70% of greenhouse businesses are unprofitable. Applying Porter's 5 Forces analysis, a number of problem areas are identified, indicating that farmers have little power in their own industry.

In Part 2, a model of a 10-hectare commercial tomato greenhouse production business is developed. Using average revenues of $1.86/kg and average yields of 50.4 kg/m^2, this model generates gross revenues of $9,374,400 for 5,040,000 kg of fresh tomatoes that it produces each year, in a facility that might cost $25 million to construct. An analysis of how this business operates is provided. A complete business cycle is then described, and some of the limitations, particularly related to labour, are identified. Finally, a profit and loss statement is presented, where $1.81/kg of the $1.86/kg of the revenue generated is needed to cover operating and depreciation costs. A 5 kg case of tomatoes sold at retail for $23.25 would generate revenues of $9.30 for the farm business, of which only $0.25 would be profit.

Part 3 starts with an exploration of how 500 Foods plans to grow produce, following the same general approach used for the model developed in Part 2. Instead of a greenhouse, standard 40' shipping containers are used. Stacking containers and using longer growing periods potentially lead to dramatically increased crop yields. 7,500 containers can be managed on an equivalent amount of land, hypothetically producing 30,000,000 kg of fresh tomatoes annually, corresponding to $55.8 million in gross revenue. Produce can be grown consistently year-round, with no seasonal fluctuations for labour or energy consumption. At $10,000 per container, capital costs approach $100 million, more than four times the capital cost of the greenhouse for five

times the crop yield. Energy requirements using this approach are substantially higher, however, with $17 million in electricity costs accounting for 30% of gross revenue. Despite this cost, growing tomatoes using a container system can achieve returns comparable to a greenhouse model. Finding sources of waste biomass can help offset energy costs.

The latter part of Part 3 introduces the concept of growing a broader array of produce, leading to the possibility of selling produce directly to consumers through a chain of small retail stores. This creates more opportunities to offer differentiated products, moving away from the current environment of perfect competition and low supplier power, but with additional costs.

Part 4 describes a 5-phase implementation plan. *Pre-Investment* covers primarily research, with no external funding, essentially expanding upon the ideas in this paper, finding answers to all of the questions that can be answered without building anything. The Business Model Canvas for 500 Foods is also included here. *Pre-Revenue* covers primarily the setup and testing of a handful of containers to validate the key performance metrics, with a budget of about $2 million. *Pre-Profit* covers regular commercial production and retail sales, with a budget of about $15 million. *Scaling Up* covers the issues related to adding enough containers to serve the Metro Vancouver market, where just the sheer number of containers comes to about $75 million, in small $10,000/container increments. *Scaling Out* covers what might be involved in replicating this facility in other markets, potentially another $100 million per facility, depending on the size.

Finally, in part 5 we provide a summary and some conclusions about what we've learned from this exploration of 500 Foods. Comparing the greenhouse model we developed in Part 2 to the 500 Foods ideas we explored in Part 3, better key performance metrics are possible. Much higher yields for the same area (30,000,000 kg versus 5,040,000 kg) comes from stacking (container) crops and extending growing seasons. Better labour performance (0.18 hours/kg versus 0.47 hours/kg) comes from making better use of the labour available. And lower costs ($/kg) can be achieved, even when paying higher wages.

As this project has such lofty ambitions, there are likely more questions raised than answered. Ultimately, the conclusion is that more confidence in all of the material presented here will be needed before any serious investments in 500 Foods would be considered.

Dedicated to MJ Spencer 

My life has been filled with ingredients one could readily weigh.
Each measure a decision, rarely black or white, most often grey.
Little did I know, so many seasons ago, how the scale would sway.
Invisible to all, it seems as if some much greater force was in play.
Never could have dreamed how you would change my life that day.
Always in my heart, many loving thoughts of you will forever stay.

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Foreword

The world is full of interesting people. It is full of interesting ideas. It is full of interesting challenges. Some of these challenges fall under the heading of 'wicked problems' that may never truly be solved. However, many challenges are simply out there, ready to be tackled with the right combination of people and ideas. A new technology might be able to address an old problem. Expertise from one discipline might be retooled for another. An entrepreneur with a grand 'blue ocean' idea might cross paths with just the right investor. Many people have come up with ideas, connected dots, and solved problems that have made our world the way it is today. Some by chance, some deliberately, some famously and some from the shadows. Many have inspired others to do the same. Three such famous individuals have provided my inspiration.

As a young boy, I frequently watched the television show Cosmos, hosted by Carl Sagan. I am reasonably certain my younger self did not understand a great deal of the material he talked about, but his famous "billions and billions" descriptions of our universe filled me with a sense of wonder. In a way it was comforting that no matter what problems I faced, and no matter what might happen on this 'pale blue dot' we call home, it was most certainly irrelevant to the universe at large. At the same time, he would talk about concepts and ideas so vast and beyond what I could imagine that it seemed no idea was too big or audacious. Everything in the universe seemed bigger and more audacious still.

David Suzuki, on the other hand, was the host of another television show that aired around the same time, CBC's The Nature of Things. One episode in particular struck a chord that resonates with me still. He talked about how the world was going to run out of food, complete with graphs and assorted prognostications about when that would be. Decades later, his message still carries substantial weight. Fortunately, however, his timetable was off and we are all still here. To me, it instilled a sense of urgency to the problems of the world. While Carl Sagan would elaborate about the grand universe we lived in, David Suzuki provided the reality check that, most likely, we would not be around long enough to discuss it. Unless some drastic and truly ambitious changes were made, which seemed as unlikely then as now, life as we knew it would be over. Climate change seems to have usurped world hunger as the topic du jour, but world hunger is not a problem that is going away by itself.

Finally, and much more recently, Steve Jobs, the former CEO of Apple Inc., left his mark on the world in a big way. His failures have proven to be just as inspirational as his successes, and he had plenty of both over his storied career. In particular, I found his narration of Apple's

famous “Think Different” ad campaign quite impactful:

> ***Here’s to the crazy ones. The misfits. The rebels. The troublemakers. The round pegs in the square holes. The ones who see things differently. They’re not fond of rules. And they have no respect for the status quo. You can quote them, disagree with them, glorify or vilify them. About the only thing you can’t do is ignore them. Because they change things. They push the human race forward. While some may see them as the crazy ones, we see genius. Because the people who are crazy enough to think they can change the world, are the ones who do.***
>
> *(https://www.youtube.com/watch?v=8rwsuXHA7RA)*

This paper describes an idea that is, in its own small way, equal parts audacious, ambitious and impactful, certainly showing no respect for the status quo. The hope is indeed to encourage others to think differently and, perhaps, just maybe, to change the world.

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Glossary

Arboriculture	The science of growing trees.
ALR	Agricultural Land Reserve, refers to a collection of agricultural land in British Columbia designated as farmland. Parcels of land that are in the ALR are subject to various rules and limitations on their use.
BCVeg	BC Vegetable Marketing Commission.
Beefsteak	A common locally grown tomato variety.
Case	Cardboard case, what fresh greenhouse beefsteak tomatoes are typically packaged in.
Containerculture	A new term describing a subset of horticulture concerned with growing plants in a containerized system, regardless of the type of plants or the growing media used.
Crop Wire	Metal wires that are run above the crop along the length of every row in the greenhouse. Twine hung from these wires support the plants as they are trained to grow along the length of the row.
Determinate	An attribute of a particular variety of plant characterizing its ability to only grow and produce fruit for a short, fixed period of time before dying.
Dripper	Part of an irrigation system, drippers are placed at the ends of irrigation lines to limit the flow of water to individual plants.
FCC	Farm Credit Canada, the leading agricultural lender, providing loans and other financial services to Canadian farmers.
Fertigation	The method of adding fertilizers and other water-soluble chemicals to an irrigation system. This often involves large mixing tanks where solutions are carefully prepared before being applied evenly throughout a crop.
Floriculture	The science of growing flowers.
GTIN	Acronym for Global Trade Item Number. This describes a code assigned to each SKU, much like a UPC code on retail products in a grocery store. The 'Global' refers to this being a worldwide standard with strict rules about use, as this system allows for the lookup of information by anyone in the supply chain, including the final customer.
Horticulture	The science of growing plants.
Hydroponic	A method of growing plants without the use of soil. Nutrients are provided to the plant in a liquid solution or through an inert medium like perlite or gravel.
Indeterminate	An attribute of a particular variety of plant characterizing its ability to continue to grow and produce fruit repeatedly.

IPM	Integrated Pest Management. Refers to systems or a set of practices geared toward controlling pest populations, particularly in agricultural crops. Components of an IPM program work together to achieve acceptable pest levels with minimal impact on the environment using biological controls, pesticides, mechanical methods and other approaches.
ISO	The International Organization for Standardization, responsible for publishing and otherwise managing various global standards, like intermodal shipping container dimensions.
Irrigation	The method of providing water to plants, often using a network of pumps, irrigation lines, valves, manifolds and drippers to distribute water evenly throughout a growing area.
Leadhand	In the greenhouse context, this is an assistant supervisor, typically managed by and reporting to the greenhouse labour manager.
MSDS	Material Safety Data Sheet. A document that describes the proper handling procedures for a particular chemical or other material, along with information about what kinds of risks are posed by exposure to the material, safety precautions that should be taken, and any emergency procedures that would be necessary in the event of a spill.
MSW	Municipal Solid Waste. Household garbage that is typically sent to a landfill or other processing facility. This waste stream can often be processed to recover metals, glass and other recyclable materials. What is leftover after processing is usually bailed and sold as an alternative energy source, known as RDF, for energy-producing incinerator facilities.
NAICS	North American Industry Classification System. This is a coding system used in Canada, the United States and Mexico to provide common definitions of industries across these countries to make it easier to compare statistical data.
Olericulture	The science of growing vegetables.
Overpack	A case of produce is typically packed to within a target weight range. Overpack refers to the weight packed that is over this target. Overpack is undesirable as the producer does not typically get paid for excess produce packed in this fashion.
PAR	Photosynthetically active radiation. This describes light that plants can use to grow, different from other measurements, like lumens.
Plant Training	The process of tying a (vine-like) tomato plant in a way that encourages its growth along a set direction, using twine and tomato clips, with trusses angled in such a way that fruit grows below the stem.
PLU	Price Look-Up code. This is usually a four- or five-digit code on a small circular sticker, along with a logo and a barcode, used to identify different kinds of produce. These usually are placed on individual items (e.g., on each tomato) to facilitate inventory and check-out activities.
PPFD	Photosynthetic photon flux density. A unit of measurement that reflects how much light is reaching the plant, expressed in $\mu mol/m^2/s$.

PPM	Parts per million. A measure of concentration, usually referred to in this paper as the level of CO_2. Ambient CO_2 is about 350 ppm, for example.
PTI	Produce Traceability Initiative – an agreement amongst produce farmers across North America to standardize on produce labelling using GTIN barcodes, voice codes and so on.
RDF	Refuse-Derived Fuel. When municipal solid waste is processed, recyclable materials are removed. What's left is largely plastics and other combustible materials. RDF is typically used as a fuel source for energy production.
Reefer	Refrigerated shipping container.
Rock wool	A type of inert growing medium commonly used in hydroponic systems, made from blowing steam through molten rock.
RPC	Returnable (reusable) Plastic Crate (carton, container, case). These are standard (usually black) containers for packaging and shipping fresh produce of all kinds.
SKU	Stock Keeping Unit. This describes a business-specific (non-standard) identifier for a product that they manage (produce, store, use, buy, sell, etc.). For example, "Bell Pepper, Green, Large, Loose, 6 kg case" (SKU #20912G), might be managed separately from "Bell Pepper, Yellow, Large, Loose, 6 kg case" (SKU #20912Y). Any difference in variety, colour, size, package type, package weight, age, branding or other factors may result in different SKUs. More recently, GTINs have started to replace SKUs as the tracking mechanism due to their global nature.
SME	Small- and medium-sized enterprises. Businesses that employ less than 500 workers each year.
TOV	Tomato-on-the-Vine, a commonly grown cluster tomato variety, sold as an entire truss with typically four or five tomatoes still attached to the vine.
Turnaround	Term used to describe the process of cleaning out the greenhouse at the end of the growing season, removing plants and sanitizing the facility, as well as the process of setting up the greenhouse for the new crop season.
Underpack	A case of produce is typically packed to within a target weight range. Underpack refers to a shortage of produce under this target. Underpack is even more undesirable than overpack as the producer may be heavily penalized for a larger portion of their shipment if an underpack case is found during routine spot checks.

1 Introduction

1.1 The Big Idea

Farming practices have been with us since before recorded history. Over the millennia, these practices have evolved to feed, clothe and house an exploding human population. Advances in our understanding of how plants grow have led to numerous improvements in food crop yields, both in terms of quality and quantity produced per unit of arable land. It is critically important that these advances continue. One estimate suggests that the amount of land available for food production is not going to increase much beyond today's levels, and that food production on this same amount of land will need to increase by at least 70% just to keep pace with the level of population growth expected by 2050 (David J. Connor, 2011).

One potential solution to this global dilemma is to continue to develop even more intensive agricultural practices, also known as industrial farming, in order to maximize food crop yields. Investments in mechanization, labour, seed improvement programs, fertilizer and pesticide research, education and many other crop management tools have already produced dramatic improvements. Greenhouse tomato production, which we will explore more fully in Part 2, is just one example of industrial farming. In 2014, average greenhouse tomato businesses across Canada achieved crop yields of 50.4 kg/m^2, compared to just 5.5 kg/m^2 achieved from traditional field crops (Table 2: Field Crop Yields Versus Greenhouse Crop Yields).

Industrial farming is not without its problems however. The amounts of chemical fertilizers, water and energy consumed by these crops are substantially higher than traditional alternatives, and sourcing these supplies can be costly and environmentally problematic. Run-off from crops can accumulate and contaminate local groundwater and local farmland. Residue and other side-effects from pesticides, insecticides and herbicides can have an enormous impact on both the viability of the farmland available to grow crops as well as the surrounding ecosystems. For example, neonicotinoids, the most widely used class of insecticides deployed throughout the world over the past 30 years, has recently been linked to a severely declining bee population (Jeroen P van der Sluijs, 2013). As bees pollinate our major crops, this is also very problematic.

These kinds of issues have led many to endorse organic agricultural practices, focused on comprehensive soil management, all-natural fertilizers and non-chemical forms of pest control. Unfortunately, such practices, while perhaps not as harmful to the environment, result in lower

yields when compared to even traditional crops, and nowhere near the levels of production achievable with industrial farming. When considering the switch to organic practices on a global scale, local supplies of natural fertilizers also become a constraining factor. This leads to the inescapable conclusion that such organic practices alone are not going to produce enough food to meet our future needs (Connor, 2008).

The big idea is really about creating new industrial farming practices that are capable of yielding considerably more food per unit of land than even the most intensive current practices, while also reducing the environmental impact far below even the most carefully managed organic practices. A relatively new form of industrial farming has exactly this potential, using standard intermodal shipping containers as self-contained growing environments. Farmers have the ability to more precisely control all of the crop inputs in order to maximize crop yield, while the container itself acts as a protective barrier between the crop and the surrounding environment. But these benefits come with additional costs and trade-offs that need to be considered carefully.

Horticulture is the science of growing plants of all kinds. *Olericulture*, *floriculture*, *arboriculture* and *viticulture* are subsets of horticulture, referring to the sciences of growing vegetables, flowers, trees and grapes, respectively. *Organic* growing and *hydroponic* growing are also subsets of horticulture, but these refer to growing methods that use soil (organic) and that are soilless (hydroponic). Both approaches can be used to grow a wide variety of plants. We are going to use the term *containerculture* to refer to the subset of horticulture concerned with using intermodal shipping containers as growing environments, regardless of the types of plants grown and regardless of whether organic or hydroponic methods are used.

There are already a handful of businesses working to bring containerculture farming into regular practice. Freight Farms, for example, is a business that sells individual shipping containers equipped to grow lettuce and other microgreens (www.freightfarms.com, 2016), similar to Growtainer (www.growtainer.com, 2016) and others. Their customers are often small farmers who are able to sell their produce to local restaurants at premium prices year-round. In order to better understand the motivations for these kinds of businesses, and the tremendous opportunities for others, let's first cover some basic principles about how crops are grown as well as how different choices in farming practices can lead to dramatically different crop yields.

1.1.1 Crop Basics

Most crops need seven key ingredients. Seed, land, water, nutrients, carbon dioxide (CO_2), heat and sunlight. Wild crops manage to thrive without any help, year after year, so long as they

continue to have access to all of these ingredients. Farmers strive to maximize yields and minimize costs by providing an optimal balance of each key ingredient, within the constraints of their particular farming methods. We'll very briefly compare two regular farming methods (traditional and organic) alongside two industrial farming methods (greenhouse and container) to help illustrate the choices farmers might make and the yields they might achieve.

This is admittedly a contrived example, simply intended to introduce concepts we'll explore more fully later. Each key ingredient will be assigned a yield multiplier for each of the farming methods. The traditional farming method will serve as the benchmark for this illustration, with each of its key ingredients assigned a yield multiplier of 1.0x. Yield multipliers assigned to each of the key ingredients of the other farming methods reflect the potential impact of the choices available with those methods. The final crop yields are derived by combining all of the yield multipliers, and are summarized in Table 1: Comparison of Farming Methods.

Let's assume that the traditional farmer tends crops in a field, using chemical fertilizers and chemical pesticides. The organic farmer also tends crops in a field of the same size, but uses all-natural fertilizers and pesticides. The greenhouse farmer operates a greenhouse covering the same amount of land used by the traditional and organic farmers. The greenhouse farmer uses chemical fertilizers but does not use any pesticides. And finally, the container farmer naturally uses shipping containers, but these can be stacked on top of one another. The area taken up by these stacks of containers is equivalent to the area used by the other three farmers. The container farmer also uses chemical fertilizers and no pesticides, just like the greenhouse farmer.

All of the yield multipliers presented here are completely subjective, intended to illustrate the potential impact of the variability of each key ingredient for each of these farming methods. Note that we're not even going to specify what kind of crop is being grown, where it is grown, nor how much area is available to each of the farmers. In the case of the container farming method in particular, no such container farm exists at any scale, so these values are entirely hypothetical. However, we will be examining all of these details more closely, later in the paper.

For the first key ingredient, seed, lets assume that there are three types of seed to choose from. Open-pollinated seed, meaning seed pollinated by natural means (wind, insects, etc.), is relatively inexpensive, but produces consistently good yields. Heirloom seed is more expensive, comes from plants that have been around for more than 50 years, chosen for their excellent flavour, but produces typically lower yields. Finally, hybrid seed is the most expensive, produces highly uniform crops with very good yields, but ranks lowest of the three in flavour. The

traditional farmer selects open-pollinated seed (1.0x). The organic farmer and container farmer both select heirloom seed (0.9x). And the greenhouse farmer selects hybrid seed (1.25x).

For land, our second key ingredient, the planting density and growing media are the biggest contributors to yield. Let's assume that the traditional farmer and the organic farmer plant at the same density (1.0x) and in the same type of soil in both fields (1.0x). The greenhouse is able to plant at a higher density (1.25x) and uses hydroponic methods instead of soil to ensure a more controlled growing environment (1.25x). The container farmer is also using a hydroponic system (1.25x) but their containers can be stacked on top of one another, essentially overlapping crops on the same amount of land, increasing density considerably (3.0x).

Water, the third ingredient, is readily available to all of the farmers in our illustration. For the traditional farmer and the organic farmer, water is supplied to their crops using a network of porous irrigation lines running along the rows of their crops, in addition to whatever rainfall is received over the growing season (1.0x). The greenhouse farmer and container farmer use an equivalent network of irrigation lines, but use drippers positioned at the root of each individual plant to more precisely control the amount of water delivered (1.25x). The greenhouse farmer collects rainfall to reduce water consumption. The container farmer recirculates irrigation water, reducing water consumption even further, but neither of these methods, as worthwhile as they are in terms of water conservation, contribute directly to improvements in crop yields.

Nutrients (fertilizers) are the fourth key ingredient. The traditional farmer uses generic chemical fertilizers that are tilled into the soil before planting and then augmented periodically during irrigation (1.0x). For the organic farmer, nutrients come from local manure suppliers and other organic nutrient sources. These are tilled into the soil before planting and augmented periodically during irrigation, much like the traditional farmer. These natural fertilizers are somewhat less effective than the chemical fertilizers available to the traditional farmer (0.9x). The greenhouse farmer injects smaller amounts of more specialized chemical fertilizers into their irrigation system continuously (known as fertigation), adjusting every few days as needed (1.5x). The container farmer's recirculating irrigation systems, one in each container, use the same fertilizers as the greenhouse farmer. This system is continuously monitored and automatically adjusts fertilizer levels several times each day to maximize optimum nutrient delivery (2.0x).

CO_2, the fifth key ingredient, is readily available in the atmosphere, so the traditional farmer and the organic farmer do nothing – the ambient CO_2 in the atmosphere is all that is available to their crops (1.0x). The greenhouse farmer increases the level of CO_2 using the exhaust from the boilers they use to heat their greenhouse (1.5x). The container farmer increases

the levels of CO_2 to the maximum levels that the plants can effectively use throughout each day, using an automated system, with more precision than the greenhouse farmer (3.0x).

The availability of heat, the sixth key ingredient is dependent on both the location of the farm and the weather for both the traditional and organic farmers. Their growing seasons start once temperatures rise enough for seeds to germinate, and end when temperatures fall enough that their crops are no longer productive. There is little they can do to control when their growing seasons start or end (1.0x). For the greenhouse farmer, temperature can be controlled throughout the season, so they are able to plant their crops earlier and harvest later, with growing seasons limited by available light instead of temperature (1.5x). The container farmer can control temperatures even more precisely, and their growing seasons have no limitations. They can operate year-round in virtually any location with little concern for the weather (3.0x).

Finally, the availability of sunlight is the seventh key ingredient. Traditional and organic farmers are again subjected to the limitations imposed by their location and the weather (1.0x). The greenhouse farmer is subjected to the same location and weather limitations, but in the temperature-controlled greenhouse environment they can make the most of the sunlight that is available by extending their growing season and also by ensuring the plants are arranged to receive an optimal amount of sunlight relative to one another (1.5x). The container farmer supplies artificial light, and can therefore maximize the available light year-round (2.5x).

Combining all the yield multipliers (multiplying them) results in the yield improvements listed at the bottom of Table 1: Comparison of Farming Methods. Put another way, if the traditional farmer manages to harvest 1,000 kg of produce annually, the organic farmer will harvest about 800 kg, the greenhouse farmer will harvest about 12,000 kg and the container farmer will harvest about 132,000 kg, all from the same amount of land. Note that in this illustration we deliberately didn't specify what kind of produce, how much land, or anything to do with input costs (labour, energy and so on) – just the approximate yields that may be possible.

For the remainder of this paper, we'll largely consider traditional and organic methods to be equivalent (field crops). We can readily see from our illustration that greenhouse crops are expected to yield more than ten times what is achieved in field crops. Container crops are hypothetically expected to yield more than ten times what is achieved in greenhouse crops, or more than 100 times what is achieved in field crops. And higher yields still, when compared to organic crops, even when growing the same kinds of heirloom varieties. The well-known astronomer Carl Sagan popularized the phrase "extraordinary claims require extraordinary

evidence." The claim that such yield improvements are possible might seem extraordinary, particularly to farmers that have invested so much in getting their crop yields as high as they are.

Farming Method	Traditional		Organic		Greenhouse		Container	
Seed	Open-pollinated	1.0x	Heirloom	0.9x	Hybrid	1.25x	Heirloom	0.9x
Land – Media	Soil	1.0x	Soil	1.0x	Hydroponic	1.25x	Hydroponic	1.25x
Land – Density	Average	1.0x	Average	1.0x	High	1.25x	Stacked	3.0x
Fresh Water	Porous	1.0x	Porous	1.0x	Drip	1.25x	Drip	1.25x
Nutrients	Synthetic	1.0x	Natural	0.9x	Injected	1.5x	Maximum	2.0x
CO_2	Ambient	1.0x	Ambient	1.0x	Increased	1.5x	Maximum	2.5x
Temperature	Ambient	1.0x	Ambient	1.0x	Extended	1.5x	Year-round	2.5x
Sunlight	Ambient	1.0x	Ambient	1.0x	Extended	1.5x	Year-round	2.5x
Yield Improvement	**Traditional**	**1.0x**	**Organic**	**0.8x**	**Greenhouse**	**12x**	**Container**	**132x**

Table 1: Comparison of Farming Methods

To add some credibility to this illustration, we can easily compare field crop yields to greenhouse crop yields using data supplied by Statistics Canada. Table 2: Field Crop Yields Versus Greenhouse Crop Yields summarizes field crop production versus greenhouse crop production across Canadian businesses in 2014 (the latest year that data is available). Depending on the crop grown, the 12x yield improvement from our illustration might actually be too conservative.

It is also noteworthy that for tomatoes, peppers and cucumbers, greenhouses yielded more produce by weight overall than field crops, despite having only one-tenth the growing area. Note also that the yield improvement for lettuce can largely be attributed to the fact that lettuce takes only about 30-40 days to grow from seed to harvest. Field crops are limited to two or three crops per year, whereas greenhouses can grow as many as 12-14 crops per year. Cucumbers also grow fast enough to support more greenhouse crops annually than field crops.

Tomatoes, peppers, cucumbers and lettuce are the only types of produce grown in greenhouses commercially, largely because such large yield improvements are possible. Higher quality produce, along with higher production costs, mean that greenhouse crops are almost always marketed as fresh produce, where they can fetch the highest possible price. Some field crops may be marketed as fresh produce, or may be grown specifically for processing markets. For example, field tomatoes might be grown specifically for use in ketchup production, where presentation quality is much less important and handling costs can be minimized.

Validating crop yield estimates for a hypothetical container farm is considerably more difficult however, without an equivalent set of data readily available for comparison. Marketing

materials that are supplied by container businesses like Freight Farms and Growtainer do not translate well to the scenario illustrated here. For example, growing areas inside these containers are arranged so that workers can walk in and manage the crops inside. In a large-scale container farm, it is far more likely that growing areas inside containers would be maximized for plants, with no space set aside for workers at all. Containers and crops would be managed differently.

Field Crops	**Tomato (2014)**	**Pepper (2014)**	**Cucumber (2014)**	**Lettuce (2013)**
Production	272,818 t	50,493 t	52,844 t	74,821 t
Area	4,922 ha	1,936 ha	1,942 ha	3,840 ha
Yield	55.4 t/ha	26.1 t/ha	27.2 t/ha	19.5 t/ha
Yield	5.5 kg/m^2	2.6 kg/m^2	2.7 kg/m^2	1.9 kg/m^2
Greenhouse Crops	**Tomato (2014)**	**Pepper (2014)**	**Cucumber (2014)**	**Lettuce (2013)**
Production	280,291 t	130,294 t	180,294 t	17.468 t
Area	556.6 ha	495.1 ha	364.6 ha	18.3 ha
Yield	503.6 t/ha	263.2 t/ha	520.2 t/ha	954.5 t/ha
Yield	50.4 kg/m^2	26.3 kg/m^2	52.0 kg/m^2	95.5 kg/m^2
Yield Improvement	**9.1x**	**10.1x**	**19.1x**	**48.9x**
Statistics Canada – CANSIM Tables 001-0006, 001-0013				

Table 2: Field Crop Yields Versus Greenhouse Crop Yields

A small farmer that buys such a container is also most likely just going to park the container beside their existing vegetable stand, in their backyard, or wherever makes sense for their particular situation, without much consideration at all for land use on such a minute scale. And, according to the Freight Farms literature, these are frequently bought by hobby farmers who handle all the labour themselves, without hiring anyone. Any operational data that might be available from these kinds of businesses aren't going to be very useful for our needs. Therefore, we'll need to develop a different approach for validating crop yield improvement estimates and the other key performance metrics we are interested in.

1.1.2 Introducing 500 Foods

The purpose of this paper is to introduce 500 Foods, a new idea-stage containerculture venture that aspires to grow and market a variety of fresh vegetables, ultimately at a very large scale. Rather than the single container model that Freight Farms, Growtainer and others are pursuing, 500 Foods is interested in the potential to displace current farming methods with a model that uses thousands of containers in one location. At the same time, 500 Foods hopes to accomplish this more efficiently in terms of both land use and labour, more cost-effectively and

with much less of an overall environmental impact than any of the other farming methods we've discussed thus far. Our four key performance metrics are crop yield (kg/m^2), labour performance (hours/kg), cost ($/m^2) and revenue ($/kg).

It is helpful to first get a birds-eye view of what such a container farm might look like at scale. In our model, the containers are all owned by 500 Foods and they don't normally leave the facility. Although the shipping-related attributes of such containers are critically important (standard dimensions, doors, strength, etc.), it is best to think of them as providing a standard unit of compartmentalized growing volume that can be efficiently moved around the facility.

Let's consider the most common form of greenhouse fresh produce, the tomato (as per Table 2: Field Crop Yields Versus Greenhouse Crop Yields). A typical tomato variety grown in a greenhouse starts from seed in late November and grows, much like a vine, for about four months before producing any tomatoes. Around the beginning of March, flowering trusses start to appear along the primary stem each week, with a new truss developing about every 50 cm. Flowers eventually grow into tomatoes, with one truss (four or five tomatoes each) ready to be harvested each week. The primary stem can grow to as long as 10m-15m over the course of the next eight months before the plant stops producing in November, due primarily to the reduced amounts of sunlight available. Often, one plant will be allowed to grow multiple stems, thus increasing overall plant density and yield, but for our purposes, we'll just consider a simple primary stem that produces tomatoes regularly. An illustration of what this might look like can be found in Figure 1: Greenhouse Tomato Crop.

Greenhouse tomato crops produce, on average, a yield of 50 kg/m^2 of fresh tomatoes over the course of single growing season (one year). A 100,000 m^2 greenhouse would therefore be capable of producing 5,000,000 kg of fresh tomatoes. Yields during the summer months are much higher (more, larger tomatoes) than either the spring or the fall. This is an average amount, with each variety producing at different levels. Larger beefsteak tomatoes may reach yields as high as 60-70 kg/m^2, while much small cherry varieties may only reach yields of 20-30 kg/m^2.

On a container farm, let's assume that identical ISO-standard 40' intermodal shipping containers are used throughout the facility. They are primarily kept in a 100,000 m^2 storage yard, arranged in stacks that are 8 containers wide, 5 containers high and 25 containers long, for a maximum of 1,000 containers per stack. Each stack has a pair of large gantry cranes that can quickly and efficiently prioritize and move containers from these stacks to a warehouse for processing (planting, maintenance or harvesting). After processing, the cranes move the containers back to the stacks where they remain until they need to be processed again.

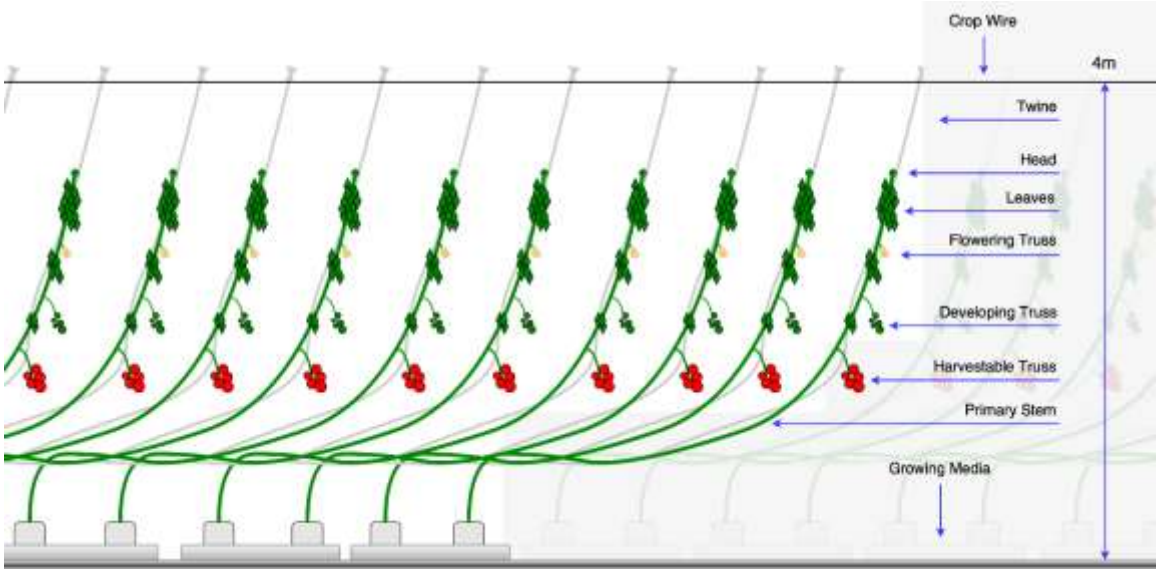

Figure 1: Greenhouse Tomato Crop

Each container of this size has an approximate internal growing area of 20 m^2. If we assume we can grow at the same density as a greenhouse (an important assumption, one we will investigate in more detail in Part 3), then we will need (100,000 m^2 greenhouse area / 20 m^2 area per container) = 5,000 containers to produce the same 5,000,000 kg of tomatoes. If somehow we could increase the density of the tomato plants growing inside the containers to twice that of the greenhouse, we'd only need half as many containers, so this is a topic of intense interest.

The tomato growing cycle would follow the same sequence of events, but would be distributed evenly across the containers over time. For example, each week 100 empty containers would be configured for a particular tomato crop and then planted with tomato seeds. These containers would sit in the stacks while the tomato plants grow, just as in the greenhouse, for the first four months. They would sit alongside all the other containers that would be planted in the same way each subsequent week. Each container would periodically be brought into the warehouse for crop maintenance. After about four months, the first batch of 100 containers would have tomatoes that are ready for harvest, so they would be brought to the warehouse for processing. The following week, the same 100 containers would be brought back again for their next weekly harvest, and the second set of 100 containers planted would be brought in for their first harvest. The week after, three sets of 100 containers would be ready for harvest, and so on until all 5,000 containers were being processed each week.

A set of 100 containers would need to be planted each week for 50 consecutive weeks to reach our target of 5,000 containers. Let's assume that every container is subsequently emptied and replanted annually on the anniversary of their first planting. There would be (4 pre-harvest

months * 4 weeks/month * 100 containers per week) = 1,600 containers somewhere in the pre-harvest stage. There would also be (5,000 containers – 1,600 pre-harvest) = 3,400 containers brought in each week for harvest. Of particular interest, however, is that growing this type of tomato crop in a container introduces the possibility of a longer crop cycle, due to not having any seasonal restrictions imposed by outside temperatures or available sunlight. This could potentially extend the harvest period from just 8 months to as long as two or three years, maybe even considerably longer, depending on the variety, increasing yields dramatically.

Just as importantly, after the initial period of planting new containers for the first time, the weekly harvest will remain relatively constant from one week to the next, indefinitely. The 5,000,000 kg of tomatoes generated annually from these 5,000 containers will arrive at a completely predictable rate of 100,000 kg each and every week (averaging 30 kg for each of the 3,400 containers that are harvested each week) for years into the future, so long as the facility continues to operate. New plants would replace old plants periodically, containers would be repaired or replaced, and individual container crops may be discarded from time to time, but on average, this level of production would be remarkably consistent. Overlapping crop cycles in this way, or even extending them, means *this is no longer a seasonal business*. All the labour activities required to plant, maintain and harvest the crop also remain relatively constant from one week to the next, making it considerably easier to attract and retain workers.

1.1.3 Approaching the Problem

Part 1 of this paper introduces the agriculture industry in Canada generally, and then examines in more detail the greenhouse industry and specifically fresh produce businesses. The intent is to determine the size of this potential market along with some insight into how to go about determining reasonable values for the key performance metrics. Although data is available for every region in Canada and beyond, British Columbia and specifically the Metro Vancouver market are the focus for this paper. Research for Part 1 has primarily involved analyzing information contained in Statistics Canada databases. This is then followed by a discussion about non-profitability, an attribute that seems to permeate the agriculture industry.

Part 2 of this paper is devoted to the development of a benchmark business model for a modern tomato greenhouse. This model describes the numerous inputs and outputs, covering labour, energy, capital and other relevant operational activities. Research for Part 2 has been based on primary observations through my own work experience over the past 20 years. In addition, I've had informal discussions with more than 20 owners, general managers, senior

growers and other key personnel working at several greenhouses operating in Metro Vancouver, Quesnel and Prince George. In particular, I've spent many years working with the people at Village Farms Canada and their local tomato greenhouses (which have a combined area of more than 500,000 m^2) in Delta, British Columbia. The intent of Part 2 is to provide a clear understanding of how these kinds of businesses operate today, what activities they perform, at what cost, with what labour, and what kind of return they might expect for their efforts.

Part 3 explores 500 Foods, using the benchmark greenhouse developed in Part 2 as the framework for the discussion.

Part 4 describes five implementation phases for 500 Foods. The first phase covers the pre-investment period, concerned primarily with business planning, developing a complete Business Model Canvas (Osterwalder & Pigneur, 2010). The second phase covers the pre-revenue period, testing hypotheses, building prototypes and validating key performance metrics. Phase three covers the post-revenue but pre-profit activities pertaining to operational efficiencies, retail sales and branding issues. Phase four describes what steps might be taken to scale up the operational model to the point where it can achieve profitability. Finally, phase five is concerned with scaling out to multiple sites

Part 5 wraps up the paper with a summary comparison of the key performance metrics we identified in Part 1. The ideas presented throughout this paper are both audacious and ambitious, with the potential to fundamentally change how fresh produce is grown. But with such a broad scope, this introduction to 500 Foods is likely to raise more questions than answers.

1.2 The Agriculture Industry in Canada

In order to better comprehend the scale of 500 Foods, we first need to get an idea as to the size of the fresh produce market that it intends to serve. In this section, we investigate the attributes and capabilities of businesses that are already serving this market, an external analysis of several databases that will help determine how 500 Foods might best position itself relative to the rest of the industry, both in Canada and abroad.

We are going to begin first with a high-level overview of businesses, both in Canada and British Columbia, that are involved in all types of agriculture. We'll then narrow the focus successively to only crop production businesses, then all greenhouse crop businesses, followed by greenhouse food crop businesses and finally greenhouse vegetable crop businesses. Along the

way we'll also gain some insight into general industry trends at each level, as well as how agriculture overall fits into the bigger picture of the Canadian economy.

We will then compare field and vegetable crop production statistics, to gain some insight into how large these segments of the agriculture sector are relative to one another, as well as a more detailed look at crop production figures. This will also help us get a better idea of the structure of these businesses, how big they are, how many employees they have, and how much revenue they can reasonably expect to generate. This information will be used extensively in the development of the benchmark greenhouse in Part 2.

A different database is then investigated, where we look at all vegetable production combined (field and greenhouse). This will help give us a better picture of the rest of the produce industry. Our comparison of the benchmark greenhouse developed in Part 2 to the exploration of 500 Foods in Part 3 is ostensibly all about commercial tomato production, but we'll also be investigating the possibility of growing many other varieties of produce. Maybe even 500 different food varieties, so getting a better understanding of the rest of the industry is important.

Canada's vegetable exports exceed one billion dollars every year, and imports are nearly three times that amount. Imports and exports of tomatoes both surpass $300 million every year as well. Understanding some of the issues around why we import and export as much as we do, and why we both import and export such large (but oddly similar) volumes of tomatoes, will help us understand a more about the global vegetable commodity market and crop seasonality.

It is difficult to get a clear picture of what amount of produce a typical Canadian, or even someone in Metro Vancouver, might consume annually or what they might spend. This is an important consideration when we start to think more about what our total addressable market might be. Combining national production with import and export data, we end up at "produce available for consumption" – Statistics Canada's way of describing this combination. Looking from this perspective, we have a pretty clear picture of what the retail market might look like.

1.2.1 Understanding the Data

Comprehensive data about the agriculture industry in Canada and British Columbia, as with all industries, is freely available online, from websites run by the Government of Canada. In particular, Innovation, Science and Economic Development Canada, in partnership with Statistics Canada, regularly publishes data on the Canadian Industry Statistics site (Government of Canada, 2014). This includes high-level information, such as the number of businesses operating in a

particular industry sector, as well as detailed analyses related to financial performance, imports and exports, and so on. This will be our primary source of data for this section. Data is from 2014, the latest year that data is available at this time, unless otherwise specified. One exception is lettuce production, for which 2013 data is the latest available.

The information presented here is organized according to North American Industry Classification System (NAICS) guidelines. Every business in Canada (as well as the United States and Mexico) is assigned a single NAICS code that describes the industry that the business primarily operates within. Complex businesses that operate across more than one industry are assigned a code that represents the majority of their business activities. Therefore, like all statistical data, this is subject to numerous caveats. The primary caveat for our purposes is that as we drill down into the data, information about more complex businesses participating in a particular subsector will become less accurate. Fortunately, farming businesses often are not very complex in this way, as we shall see, so for our purposes, this will not be a consideration.

NAICS codes are 2 to 6 digits long, depending on how granular the sectors, industries, or subsectors have been defined. Businesses are assigned a code representative of where their business falls within that hierarchy. Aggregate data can be retrieved using fewer digits of the NAICS codes. For example, NAICS code 11 represents the entire agriculture sector, referred to formally as [Agriculture, Forestry, Fishing and Hunting]. NAICS code 23 represents the [Construction] sector. A business that just operates in the agriculture industry generally, without a specific subsector focus might be assigned NAICS code 11. Most businesses, however, tend to be assigned NAICS codes that are 5 or 6 digits long. A list of all 20 top-level industry sectors can be found in Table 8: Industry Sector Statistics.

The businesses that are primarily of interest to our discussion are those growing fresh produce in a greenhouse environment. In Statistics Canada parlance, this is referred to as "grown under cover" and includes essentially all crops that are not simply grown in an open field. Glass or poly greenhouses, warehouses for vertical farming, and potentially containers and other structures are covered by this definition. To find the appropriate NAICS code for comparison, we first start with the entire agriculture sector and then search through each of the defined subsectors to find the appropriate branch of the NAICS tree to follow.

Starting with NAICS code 11 [Agriculture, Forestry, Fishing and Hunting], looking at the available subsectors gets us to NAICS code 111 [Crop Production], leaving out agriculture business related to raising livestock. Next, we get to NAICS code 1114 [Greenhouse, Nursery and Floriculture Production] which excludes all of the field crop businesses. NAICS code 11141

[Food Crops Grown Under Cover] excludes all the flower, seedling and garden centre businesses. Although this might at first seem like a good candidate for our purposes, this NAICS code is actually broken down further into NAICS code 111411 [Mushroom Production] and NAICS code 111419 [Other Food Crops Grown under Cover] which is the final definition that we're looking for. A summary of how we got to this particular branch of the NAICS tree is provided in Figure 2: Relevant NAICS Codes.

11 – Agriculture, Forestry, Fishing and Hunting
111 – Crop Production
1114 – Greenhouse, Nursery and Floriculture Production
11141 – Food Crops Grown Under Cover
111419 – Other Food Crops Grown Under Cover

Figure 2: Relevant NAICS Codes

The division of NAICS code 11141 [Food Crops Grown Under Cover] into NAICS code 111411 [Mushroom Production] and NAICS code 111419 [Other Food Crops Grown Under Cover] is more of an artifact of how NAICS codes are defined, rather than a statement about the relative importance of mushroom production versus fresh vegetable greenhouse production. The formal definition of NAICS code 111419 [Other Food Crops Grown Under Cover] is provided in Figure 3: Definition of National Industry 111419. Note that mushrooms are grown indoors (which is why they are considered a crop grown under cover) but in facilities that are completely dark – the exact opposite of a greenhouse. The business model envisioned for 500 Foods involves growing fresh produce under cover (within an enclosed shipping container) and thus would fall under this classification more than any other NAICS classification. We'll be most interested in statistics pertaining to these businesses, with the underlying assumption that they operate within the same general area that 500 Foods aspires to operate.

This Canadian industry comprises establishments, not classified to any other Canadian industry, primarily engaged in growing food crops under glass or protective cover. Example Activities: Food crops (except mushrooms), grown under cover Greenhouse tomatoes growing Herb farming, grown under cover Hydroponics crops, grown under cover Market gardening, greenhouse Seaweed grown under cover Vegetable farming, grown under cover.

Figure 3: Definition of National Industry 111419

By looking at the data available for each of the NAICS codes that led us to NAICS code 111419 [Other Food Crops Grown Under Cover], we will get a bit more of an idea about the size of the overall agriculture industry as well as the size of the relevant sectors within it. At each step, we will look at the number of businesses in each sector, the relative sizes (based on the number of employees) of the businesses that make up the sector, the level of profitability within the sector, and how the sector in British Columbia compares to the rest of Canada.

Only agriculture businesses that reported having employees are included in the summary calculations. Many businesses are owner-operated and either have no employees (the owners do not pay wages to themselves), or their workforce consists only of business owners, family, contracted workers, volunteers or part-time employees. Numerous family farms, small organic farmers, hobby farms and so on make up a substantial number of these kinds of businesses, and they are certainly worthy of consideration when it comes to competition in the marketplace. For this discussion, however, the number of these businesses are shown in the tables but have excluded from the calculations. The business model for 500 Foods involves hiring full-time employees, and deliberately has no interest in other employment arrangements.

Business size classifications for this data, and generally throughout this paper, are as follows. Micro businesses have 1-4 employees. Small businesses have 5-99 employees. Medium businesses have 100-499 employees. Large businesses have at least 500 employees. Micro, small and medium businesses (enterprises) are sometimes combined and referred to as SMEs, and are simply defined as those businesses having less than 500 employees.

Financial information, specifically businesses that report as being profitable or non-profitable, is derived from a subset of all businesses, and includes only those that report earning more than $30,000 and less than $5,000,000 in their fiscal year. There are a few important considerations with this part of the data. First, the businesses that report such financial information include all businesses, both with and without employees, so there can be more such reporting businesses than just the number of businesses that have employees. Not all businesses report this information, so the assumption is that the results are representative of the businesses that have employees.

Second, there is an assumption that outliers that are excluded due to earning less than $30,000 or more than $5,000,000 are not representative of business that have employees. Those earning more, as we shall see, are likely to be very few, and as such are not considered to be statistically significant for our purposes. Those businesses earning less than $30,000 are likely not in the business of agriculture for profit, and may consist largely of family farms or hobby farms, or those who have an agriculture business for the tax benefits it affords. Although there may be a large number of these kinds of businesses, their profitability (or lack thereof) doesn't have much bearing on this discussion. The information we are looking for here isn't really going to come from a hard statistical analysis of this part of the data, but rather from examining trends.

1.2.2 Agriculture Businesses

Starting with Table 3: Agriculture, Forestry, fishing and Hunting (NAICS code 11), we can see that this sector consisted of 48,653 businesses compared to 6,891 in British Columbia. The GDP for all of Canada in 2014 was $1.6 trillion. Agriculture accounted for just 1.6% of that amount. Approximately 21% of these businesses were employers. The ratio of the number of businesses in British Columbia versus Canada is closely related to the GDP ratio. 40.3% of businesses that supplied financial information reported that they were non-profitable.

The main observations at this highest level are that it is already apparent that this is not a very profitable sector, nor is it a particularly large sector relative to the rest of the economic activity of the other 19 sectors within Canada. All of these figures are summarized in Table 8: Industry Sector Statistics. It is interesting to note that, even though Canada is ranked seventh globally in terms of arable land (with 45.9 million hectares), and third, behind only Australia and Kazakhstan, when ranked by arable land per capita (1.31 hectares), we do not devote as much effort to agriculture (The World Bank, 2013). Australia's agriculture sector contributes 4.0% of its GDP, and Kazakhstan's agriculture sector contributes 5.2% of its GDP. Closer to home, the much larger economy of the United States had an agriculture sector that contributed 1.2% of its GDP, while Mexico's agriculture sector contributed 3.8% of its GDP.

Agriculture NAICS: 11	Non-Employers	Micro	Small	Medium	Large	Total	GDP ($ Millions)
Canada	178,538	34,536	13,857	246	14	48,653	$ 25,976
British Columbia	13,148	4,240	2,571	77	3	6,891	$ 3,649
BC / Canada %	7.4 %	12.3 %	18.6 %	31.3 %	21.4 %	14.2 %	14.0 %
https://www.ic.gc.ca/app/scr/sbms/sbb/cis/establishments.html?code=11&lang=eng							

Table 3: Agriculture, Forestry, fishing and Hunting (NAICS code 11)

Narrowing the focus from the overall agriculture industry to just crop production businesses, we get Table 4: Crop Production (NAICS code 111). The number of these businesses account for approximately 40% of the agriculture sector businesses overall (19,443 businesses in NAICS code 111 versus 48,653 businesses in NAICS code 11). Importantly, for the 23,739 businesses in this group that reported between $30,000 and $5,000,00 in revenue, 61.6% reported that they were non-profitable in 2014. Approximately 19% of businesses were employers, similar to the 21% reported in the agriculture sector overall. The number of these businesses operating within British Columbia, 11.7%, is slightly lower than the 14.2% for the entire agriculture industry, as is the ratio of non-employers, 4.4% versus 7.4%.

There are two main observations at this second level. First, other regions of Canada tend to have relatively more of these kinds of crop production businesses than British Columbia does, particularly at the smaller end of the scale. And second, that levels of non-profitability are about 50% higher than the overall agriculture industry. These may be related, implying that perhaps there is a higher per-capita ratio of hobby farms in Ontario and Quebec, for example. As a standalone data point, this isn't particularly useful, but it does start a trend, as we'll see, that indicates that a large number of businesses engaged in growing crops aren't making a profit.

Crop Production NAICS: 111	Non-Employers	Micro	Small	Medium	Large	Total
Canada	84,006	13,031	6,290	118	4	19,443
British Columbia	3,700	1,233	1,020	30	1	2,284
BC / Canada %	4.4 %	9.5 %	16.2 %	25.4 %	25.0 %	11.7 %
https://www.ic.gc.ca/app/scr/sbms/sbb/cis/definition.html?code=111&lang=eng						

Table 4: Crop Production (NAICS code 111)

Dropping down to the third level, examining non-field crops, we get Table 5: Greenhouse, Nursery and Floriculture Production (NAICS code 1114). There are no large greenhouse operations (more than 500 employees) in British Columbia and only two in all of Canada. Non-profitability is nearly the same with 58.7% of the 1,496 businesses that reported claiming that they were non-profitable versus 61.6% previously for all crops. Approximately 55% of businesses were employers. British Columbia hosts 20% of these businesses versus 11.7% previously, and these now make up a significant portion of the total businesses in Canada.

The increase in the ratio of businesses that are employers, up now to 55% from the previous level of 11.7%, indicates that more of these kinds of businesses are operating as regular businesses instead of just family farms or hobby farms. Non-profitability remains at around the same level as before, suggesting that growing crops under (in greenhouses, for example) are not significantly more or less profitable than growing crops in fields.

Non-Field Crops NAICS: 1114	Non-Employers	Micro	Small	Medium	Large	Total
Canada	2,066	877	1,574	62	2	2,515
British Columbia	403	200	287	15	0	502
BC / Canada %	19.5 %	22.8 %	18.2 %	24.2 %	0.0 %	20.0 %
https://www.ic.gc.ca/app/scr/sbms/sbb/cis/definition.html?code=1114&lang=eng						

Table 5: Greenhouse, Nursery and Floriculture Production (NAICS code 1114)

Continuing along, we next get to the fourth level of the NAICS data, Table 6: Food Crops Grown Under Cover (NAICS code 11141). This excludes all the other forms of crop

production, including tree and flower growers, turf and landscaping growers, home and garden nurseries and so on. There are no large businesses in Canada, and only five medium businesses in British Columbia. 340 businesses reported earning between $30,000 and $5,000,000 in revenue and of those, the ratio increased to 70.6% reported as being non-profitable versus 58.7% previously. Approximately 41% of businesses were employers, smaller than the previous classification, but the proportion of these businesses in British Columbia is similar to the previous classification, at 20.5% versus 20.0%.

At this level, it becomes evident that this industry has something about it that makes it less attractive to big business, with no large businesses at all and a very small number of medium businesses. The level of non-profitability, increasing to 70.6% very likely has something to do with that, suggesting that greenhouses growing food are somewhat less profitable than those growing flowers (the other large greenhouse crop). We can also observe that, generally speaking, British Columbia typically accounts for about 20%, or one-fifth, of food crops grown under cover across the rest of Canada. We will see a little later that British Columbia hosts 301 hectares of Canada's total of 1,436 hectares of greenhouse food production. The municipality of Leamington, Ontario hosts approximately 841 hectares of greenhouse vegetable production, making it the largest concentration of such facilities both in Canada and across North America.

All GH Food Crops NAICS: 11141	Non-Employers	Micro	Small	Medium	Large	Total
Canada	368	137	368	22	0	527
British Columbia	108	29	74	5	0	108
BC / Canada %	29.3 %	21.2 %	20.1 %	22.7 %	0.0 %	20.5 %
https://www.ic.gc.ca/app/scr/sbms/sbb/cis/definition.html?code=11141&lang=eng						

Table 6: Food Crops Grown Under Cover (NAICS code 11141)

Finally, at the fifth and most granular level of data, we get Table 7: Other Food Crops Grown Under Cover (NAICS code 111419). There are only three such medium businesses in British Columbia and 13 medium businesses of this type across Canada. Of the 340 businesses that reported earning between $30,000 and $5,000,000 in revenue, the ratio grew slightly to 73.3% reported as being non-profitable versus 70.6% previously. Approximately 59% of businesses were employers versus 41% previously, and this segment of the industry is represented by 17.2% of businesses located in British Columbia versus 20.5% previously.

This small bump in the non-profitability numbers suggests that growing greenhouse vegetables is slightly less profitable than growing mushrooms. The very small number of medium businesses, both in British Columbia and across Canada, suggests that the size of these

businesses might not contribute to their overall profitability – if simply being larger was a benefit, it would follow that there would likely be a larger number of them.

Other GH Food Crops NAICS: 111419	Non-Employers	Micro	Small	Medium	Large	Total
Canada	303	114	309	13	0	436
British Columbia	49	25	47	3	0	75
BC / Canada %	16.2 %	21.9 %	15.2 %	23.1 %	0.0 %	17.2 %
https://www.ic.gc.ca/app/scr/sbms/sbb/cis/definition.html?code=111419&lang=eng						

Table 7: Other Food Crops Grown Under Cover (NAICS code 111419)

From these high-level snapshots of the different levels of agriculture sector, it is readily apparent that this isn't a very profitable sector at any level, and increasingly less profitable as the focus narrows to the part of the industry that 500 Foods intends to operate within. In fact, comparing the agriculture sectors we've covered to all of the other industries in the entire Canadian economy shows that these are the least profitable, by a wide margin. Table 8: Industry Sector Statistics outlines all of the top-level sectors along with the portion of businesses reporting as non-profitable, with the agriculture sectors we've covered presented at the top of the table.

Also from this table, note that there are only two industry sectors smaller than the agriculture industry sector (based on GDP), each with a level of non-profitability that is less than half that of any of the agriculture sectors we've covered. This suggests that there isn't a direct correlation between the size of an industry sector and its levels of non-profitability, similarly demonstrated by observing that the largest sectors are also not the most profitable. In other words, being small doesn't imply non-profitability.

Looking at the rest of Table 8: Industry Sector Statistics, we can readily see (again) that the agriculture industry represented just 1.6% of Canada's total GDP in 2014. However, the number of businesses that contributed to that 1.6% was much higher, at 4.2% of all businesses. This suggests that these businesses are potentially less productive. For example, the real estate sector (NAICS code 53) is comprised of a similar number of SMEs (49,721 versus 48,639) but generates $205.9 billion. If we were to simply ignore contributions from large businesses, this means that real estate SMEs each generate $4.1 million on average, versus $0.5 million for agriculture businesses. However, this data doesn't indicate how many people are working in these businesses. While agriculture businesses aren't as productive in terms of GDP, there isn't enough detail to determine whether this is due to the businesses simply being consistently smaller, or whether the per-capita contribution is also smaller.

Industry Sector	% Reporting Non-profitable	GDP ($Billions)	SMEs	Large Firms	Size Ratio
11 - Agriculture, Forestry, Fishing and Hunting	40.3 %	$ 26.4	48,639	14	0.03 %
111 – Crop Production	61.6 %	N/A	19,439	4	0.02 %
1114 – Greenhouse, Nursery and Floriculture Production	58.7 %	N/A	2,513	2	0.08 %
11141 – Food Crops Grown Under Cover	70.6 %	N/A	527	0	0.00 %
111419 – Other Food Crops Grown Under Cover	73.3 %	N/A	436	0	0.00 %
21 - Mining, Quarrying, and Oil and Gas Extraction	20.2 %	$ 138.9	10,758	78	0.73 %
22 - Utilities	15.7 %	$ 39.5	1,443	41	2.84 %
23 - Construction	17.4 %	$ 117.4	138,657	138	0.10 %
31-33 - Manufacturing	25.7 %	$ 173.4	51,209	276	0.54 %
41 - Wholesale Trade	25.9 %	$ 92.1	61,330	58	0.09 %
44-45 - Retail Trade	26.7 %	$ 88.8	145,863	108	0.07 %
48-49 - Transportation and Warehousing	14.3 %	$ 68.6	62,104	125	0.20 %
51 - Information and Cultural Industries	17.3 %	$ 52.5	15,822	56	0.35 %
52 - Finance and Insurance	N/A	$ 111.4	42,801	158	0.37 %
53 - Real Estate and Rental and Leasing	15.7 %	$ 205.9	49,721	46	0.09 %
54 - Professional, Scientific and Technical Services	11.2 %	$ 87.1	136,023	123	0.09 %
55 - Management of Businesses and Enterprises	14.8 %	$ 11.7	12,760	193	1.51 %
56 - Administrative and Support, Waste Management and Remediation Services	13.8 %	$ 41.1	52,886	232	0.44 %
61 - Educational Services	18.2 %	$ 84.6	13,111	433	3.30 %
62 - Health Care and Social Assistance	6.4 %	$ 110.7	105,002	365	0.35 %
71 - Arts, Entertainment and Recreation	19.0 %	$ 11.3	17,014	66	0.39 %
72 - Accommodation and Food Services	34.1 %	$ 34.1	77,427	62	0.08 %
81 - Other Services (except Public Administration)	21.3 %	$ 32.6	112,667	47	0.04 %
91 - Public Administration	N/A	$ 109.4	7,795	322	4.13 %
Totals		**$ 1,637.5**	**1,163,032**	**2,941**	**0.25 %**

Table 8: Industry Sector Statistics

Before moving on to the next set of data, let's quickly summarize what we've learned from this cursory look at these agriculture businesses. Some of the areas of concern will need to be revisited once we've had a look at the other sets of data. By itself, this data doesn't really provide much insight as to why any of these conditions exist.

1. British Columbia makes up about 20% of the greenhouse industry in Canada
2. Agriculture is completely dominated by many small businesses.
3. There are no large greenhouse businesses. Understanding why this is will be important for 500 Foods, which ultimately aspires to be a large business.

4. High levels of non-profitability are an issue, particularly as 500 Foods plans on ultimately becoming a profitable business.
5. Agriculture businesses might not be very efficient, but more data is needed to clarify whether this is something more than a function of being small.
6. Non-profitability increases with more specialized crop production. This seems counter-intuitive as much of the growing infrastructure of such businesses is purposely intended to reduce this risk. Other factors may be impacting their profitability.

1.2.3 Field Versus Greenhouse Vegetable Crop Production

Data about farm activity in Canada is also tracked in the same online databases (Government of Canada, 2014). In this section we'll look more closely at the levels of production across field and greenhouse farms, along with some simple comparisons. We'll be able to use this information to determine values for some of our key performance metrics, in particular those corresponding to crop yield (kg/m^2), cost (\$/m^2) and revenue (\$/kg). Note carefully that metric units are used in these tables. Currency is expressed in Canadian dollars in all cases. Table 9: Unit Conversions shows a summary of different unit conversions that some readers may find helpful. In particular, note carefully that 10 t/ha is equivalent to 1 kg/m^2.

Unit Conversions	Metric Units	Non-Metric Units
1 hectare (ha)	10,000 m^2 0.01 km^2	107,639 sqft 2.47 ac
1 acre (ac)	4,047 m^2 0.4 ha 0.004 km^2	43,650 sqft
1 kilogram (kg)	1,000 g	2.2 pounds (lbs) 35.3 oz.
1 pound (lb)	454 g 0.454 kg	16 oz.
1 tonne (t)	1,000 kg	2,200 lbs 1.1 US tons 0.98 imperial tonnes

Table 9: Unit Conversions

Our data for this section has been compiled into Table 10: Field Versus Greenhouse Vegetable Crop Production. Please note that data in this table does not correlate directly with our previous data from businesses classified under NAICS code 111419 or to any of the other NAICS categories specifically. Businesses report this farm data separately to Statistics Canada. Some correlation is possible though, particularly for the greenhouse-specific data, as this is largely the only food crops grown under cover. Businesses growing herbs and other food under cover, other

than tomatoes, peppers, cucumbers or lettuce, but still categorized under NAICS code 111419, make up a very small portion of those businesses.

2014 Field Production	Production Area (ha)	Production (tonnes)	Production Value ('000)	Production Yield (t/ha)	Unit Value ($/kg)
Canada	99,777 ha	1,952,496 t	$ 946,053	19.6 t/ha	0.48 $/kg
British Columbia	5,483 ha	61,629 t	$ 63,809	11.24 t/ha	1.04 $/kg
%	5.5 %	3.2 %	6.7 %	57.3 %	216.7 %
2014 Greenhouse Production	**Production Area (ha)**	**Production (tonnes)**	**Production Value ('000)**	**Production Yield (t/ha)**	**Unit Value ($/kg)**
Canada	1,436 ha	590,879 t	$ 1,286,092	411.5 t/ha	2.18 $/kg
British Columbia	301 ha	124,256 t	$ 290,743	412.8 t/ha	2.34 $/kg
%	21.0 %	21.0 %	22.6 %	100.3 %	107.3 %
2014 Greenhouse Versus Field	**Production Area**	**Production**	**Production Value ('000)**	**Production Yield (t/ha)**	**Unit Value ($/kg)**
Canada	1.4 %	30.3 %	135.9 %	2,100.0 %	454.2 %
British Columbia	5.5 %	201.6 %	455.6 %	3,672.6 %	225.0 %

Table 10: Field Versus Greenhouse Vegetable Crop Production

Looking at just field production, we can see that businesses in British Columbia produce substantially less per unit of area than the rest of the country, yielding only 11.24 t/ha versus 19.6 t/ha across Canada, yet the unit value of this production is substantially higher at 1.04 $/kg. Part of the reason for this has to do with the kinds of crops businesses grow. Some crops are grown for sale directly to consumers, as is the case with fresh produce, whereas other crops are grown for sale to processing companies. These crops are of lower overall quality so they fetch a lower unit price. More produce can be harvested because the threshold for acceptance is lower. The numbers here suggest that this kind of activity is more prevalent outside of British Columbia.

Comparing greenhouse crops to field crops, we can again see that greenhouse production yields are substantially larger, more than 21x across Canada, and more than 37x across British Columbia. Please note that in the case of greenhouses, this only covers tomatoes, peppers, cucumbers and lettuce, while field vegetable crops cover a much broader array of vegetables. Considering the overall vegetable production industry, it should therefore come as no surprise that greenhouse vegetable production area represents only a very small fraction of the field production area. However, because of the focus on high-quality produce, and because of the volumes that greenhouses operate at, they collectively add more production value than field businesses. British Columbia greenhouses, in particular, contribute more than four times the production value of field crops, using just 5.5 % of the area.

We can see from Table 10: Field Versus Greenhouse Vegetable Crop Production that there were 301 hectares of greenhouse vegetable crop production in British Columbia in 2014. We also know from Table 7: Other Food Crops Grown Under Cover (NAICS code 111419) that there were 75 businesses with employees involved in greenhouse food production. Another 49 businesses also reported operating, but did not report having any employees. This means that, on average, the typical greenhouse size is approximately (301 hectares / 75 + 49 businesses) = 2.4 hectares (about 6 acres).

For our benchmark greenhouse, to be developed in Part 2, we're going to assume we have a plot of land that is 16 hectares. Given a 16-hectare plot of land, and the data from Table 10: Field Versus Greenhouse Vegetable Crop Production, without knowing anything about what kinds of vegetables might be grown, we can already determine some key performance metrics. If a field crop is planted, we might expect the entire land area would be fully planted. Using the British Columbia field production yield value of 11.24 t/ha, we might expect to grow about (16 hectares * 11.24 t/ha) = 179.84 tonnes of vegetables annually with gross revenues of about ($1.04 $/kg * 179.84 tonnes * 1,000 kg/tonne) = $183,437.

A field crop can utilize essentially all of the available land area for actual crop production as there is typically no space needed for anything else. The farmer might use a tractor to till the soil at the beginning of the season, and then plant the crop in rows covering the entire 16-hectare field. When it comes time to harvest, workers would move across the field, picking whatever vegetables were grown into small totes, which are then emptied into large bins at the edge of the property. These bins are then immediately shipped to a centralized distribution warehouse where vegetables from a number of similar farms would be cleaned, graded or otherwise prepared for sale, rather than performing this kind of work at the farm location.

If a greenhouse were used instead, the infrastructure necessary for operating the greenhouse would consume a significant portion of the available land. This would potentially include areas for packaging, greenhouse perimeter access roads, water tanks, boiler rooms, staff parking lots, offices, lunchrooms, washrooms, warehouses, loading docks and so on. Workers would be coming to the facility every day, rather than just at planting and harvest. This reduces our greenhouse to only about 10 hectares, which is the figure typically reported as the growing area, not the size of the parcel of land that the greenhouse occupies.

With our 10-hectare greenhouse situated on our 16-hectare parcel of land, using the greenhouse production yield average for British Columbia from Table 10: Field Versus Greenhouse Vegetable Crop Production of 412.8 t/ha, we would expect to produce (412.8 t/ha *

10 hectares) = 4,128 tonnes of fresh produce. Using the average price of 2.34 $/kg from the same table, we would further expect to earn gross revenues of about ($2,34 $/kg * 4,128 tonnes * 1,000 kg/tonne) = $9,659,520.

To summarize, we can draw a number of simple conclusions.

1. Greenhouses crops consistently achieve yields well in excess of 10x field crops.
2. Significantly larger capital and operating expenditures are required.
3. Some of these additional expenses are simple trade-offs to the business model. For example, greenhouses typically sort and package their own produce, delivering a higher value to the distribution channel, and claiming a higher price, compared to field crops that frequently don't perform any of the sorting or packaging activities.

1.2.4 Vegetable Crop Production

By investigating further and analyzing the underlying database used to generate the data summarized in Table 10: Field Versus Greenhouse Vegetable Crop Production, we can get a more detailed picture of individual vegetable crops. Table 11: Vegetable Crop Yields shows this level of detail. The values for greenhouse vegetables are listed separately from field crops, showing the stark differences between these two environments. For example, greenhouse tomatoes generate average revenues of $1.86/kg versus just $0.20/kg for field tomatoes.

There are a number of considerations behind why greenhouses only produce tomato, cucumber, pepper and lettuce crops. The kinds of crops that 500 Foods may ultimately decide to grow might be impacted by these considerations, so we'll quickly introduce those that are most important. Then we'll discuss some other observations from Table 11: Vegetable Crop Yields.

In order to generate higher overall unit volumes, what we've been referring to as production or yield, crops would have to be chosen that benefit significantly from the protected environment that a greenhouse provides. All four of the greenhouse vegetables do benefit from this environment. The longer growing seasons contribute directly to increased yields. Tomato plants that greenhouses use will continue to produce as long as the growing environment is favourable. This works the same way for pepper crops. Lettuce has a short crop cycle, just 30-40 days from planting to harvest, so the greenhouse environment allows farmers to iterate through many crop cycles each year. This approach works for cucumbers as well.

Most other vegetable crops would not see the farmer receive the same benefits. Brussels sprouts, for example, have crop cycles that last 120 days, and are usually harvested only once per

season (West Coast Seeds, 2016). Growing Brussels sprouts in a greenhouse might very well lead to increases in crop yields, but not likely the 10x yield improvement that these other crops achieve. Crops that can't realistically be planted at higher densities will also not create as much of a yield multiplier effect. Root vegetables are already planted at very high densities in field crop farming. Carrots, for example, are unlikely to be planted at a density that is 10x field crops.

Vegetable Crop	Type	Yield (tonnes)	Value ('000)	Unit Value ($/kg)
Tomatoes	Greenhouse	280,291 t	$ 519,960	1.86 $/kg
Cucumbers	Greenhouse	180,294 t	$ 325,905	1.81 $/kg
Peppers	Greenhouse	130,294 t	$ 408,486	3.14 $/kg
Lettuce (2013)	Greenhouse	17,468 t	$ 28,994	1.82 $/kg
Brussels Sprouts	Field	4,369 t	$ 6,059	1.39 $/kg
Carrots	Field	267,568 t	$ 91,357	0.34 $/kg
Tomatoes	Field	272,818 t	$ 55,481	0.20 $/kg
Dry Onions	Field	206,863 t	$ 74,204	0.36 $/kg
Corn	Field	209,963 t	$ 76,657	0.37 $/kg
Lettuce	Field	85,225 t	$ 69,583	0.82 $/kg
Cabbage	Field	156,795 t	$ 78,105	0.50 $/kg
Broccoli	Field	39,013 t	$ 52,201	1.34 $/kg
Peppers	Field	50,493 t	$ 40,091	0.79 $/kg
Beans	Field	50,089 t	$ 31,346	0.63 $/kg
Cucumbers	Field	52,844 t	$ 29,171	0.55 $/kg
Cauliflower	Field	28,211 t	$ 25,527	0.90 $/kg
Asparagus	Field	6,346 t	$ 24,065	3.79 $/kg
Squash and Zucchini	Field	30,123 t	$ 22,344	0.74 $/kg
Rutabagas and Turnips	Field	54,337 t	$ 21,357	0.39 $/kg
Peas	Field	51,954 t	$ 21,722	0.42 $/kg
Celery	Field	34,384 t	$ 15,183	0.44 $/kg
Pumpkins	Field	64,736 t	$ 23,194	0.36 $/kg
Shallots and Green Onions	Field	16,777 t	$ 30,301	1.81 $/kg
Radishes	Field	16,330 t	$ 11,339	0.69 $/kg
Beets	Field	29,689 t	$ 15,529	0.52 $/kg
Spinach	Field	5,610 t	$ 9,279	1.65 $/kg
Watermelon	Field	27,048 t	$ 7,255	0.27 $/kg
Leeks	Field	3,716 t	$ 7,231	1.95 $/kg
Other melons	Field	19,222 t	$ 10,205	0.53 $/kg
Parsnips	Field	9,066 t	$ 9,456	1.04 $/kg
Parsley	Field	1,455 t	$ 2,774	1.91 $/kg
Garlic	Field	532 t	$ 5,003	9.40 $/kg
Rhubarb	Field	1,286 t	$ 1,829	1.42 $/kg
Totals / Weighted Average	**Combined**	**2,405,209 t**	**$ 2,229,398**	**0.89 $/kg**

Table 11: Vegetable Crop Yields

In order for a greenhouse to generate higher overall per-unit revenues, $1.86/kg for greenhouse tomatoes instead of just $0.20/kg for field tomatoes, for example, there has to be

some differentiation that the greenhouse environment facilitates, as well as a market for that differentiation. Fortunately for greenhouse businesses, people tend to prefer produce that "looks better". We even have food standards to quantify exactly what that means, such as the "Canada Grade A Tomato" standard (Government of Canada, 2016). For these kinds of produce in particular, misshapen or discoloured produce may not even be legally marketable through normal distribution channels.

Greenhouse farmers have a substantial advantage here. The protected environment of the greenhouse and the intensive manner in which crops are managed enable farmers to grow highly uniform, and thus high quality, crops. Contrast this with typical organic produce that you might see in the supermarket which tends to look noticeably different, and not in an appealing sort of way. Increased exposure to insects, birds, weather, etc. result in higher incidences of the aforementioned misshapen or discoloured produce. Because field crop yields are so low to begin with, these farmers are almost forced to send to market whatever passes as edible.

These advantages do not apply to many other vegetables. Using Brussels sprouts as an example again, it is likely that samples taken from a greenhouse crop and a field crop would be indistinguishable to a typical consumer, if such samples were placed in adjacent cases in the supermarket fresh produce aisle. If we were to consider a more popular vegetable, carrots, the same kind of reasoning applies. A greenhouse-grown carrot would likely not differ substantially enough appearance-wise, to justify any additional expense to the consumer. Some other valuable attribute or value-added service would have to be offered to the consumer before they would consider paying more for an otherwise identical carrot. Bags of peeled and ready-to-eat baby carrots are an example of a value-added service, but there's nothing that gives a greenhouse any competitive advantage in packaging carrots in this fashion – everyone else can easily do the same.

Looking at the rest of Table 11: Vegetable Crop Yields, there are a number of other observations that will help us in understanding the overall vegetable market.

1. Canadian businesses grow in excess of 2.5 million tonnes of vegetables each year with a value in excess of $2 billion.
2. The total value of greenhouse crops is greater than field crops ($1,283 million versus $946 million), though the total produce grown is substantially less (608,347 tonnes versus 1,952,496 tonnes).
3. The greenhouse area is also substantially less (1,436 hectares versus 99,777 hectares).

4. Looking at the weighted-average unit values, just at an approximate level, $0.89/kg was the average per-unit farm gate revenue in 2014.

But this is not yet the complete picture. As a commodity that is traded globally, Canada is both an importer and exporter of many agricultural products, and fresh produce is no exception. Although we have a pretty clear picture now of what vegetable production looks like in Canada, we don't yet have much to help us understand what is causing such high levels of unprofitability or even where market pricing comes into play.

1.2.5 Vegetable Imports and Exports

Vegetable trade happens at a large scale all over the world. Canada trades a large volume of vegetables with the United States, Mexico and to a lesser degree with many other countries. Table 12: Canada's Global Vegetable Trade gives a summary of trade data for all vegetables, including dried and frozen. Net trade is presented as exports minus imports. Despite ranking so high in arable land, both overall and per-capita, Canada is a net importer of vegetables.

The trend over the past few years indicates that while the unit value of our exports is increasing, the unit value of our imports is increasing more quickly. So even though the net trade volume (by weight) is relatively constant, the net trade value is steadily decreasing. At this high level of abstraction, it is not possible to tell what specific changes are occurring between Canada and its trading partners to bring about this particular result. If such a trend were to continue, our vegetables would end up becoming less valuable relative to our trading partners.

Trade Year	Export Volume (tonnes)	Export Value ('000)	Unit Value ($/kg)	Import Volume (tonnes)	Import Value ('000)	Unit Value ($/kg)	Net Trade Volume (tonnes)	Net Trade Value ('000)
2010	729,969 t	$ 1,056,719	1.45 $/kg	1,719,015 t	$ 2,267,649	1.32 $/kg	(989,046)	(1,210,930)
2011	741,567 t	$ 1,056,265	1.42 $/kg	1,808,706 t	$ 2,359,487	1.30 $/kg	(1,067,139)	(1,303,222)
2012	736,605 t	$ 1,047,736	1.42 $/kg	1,805,517 t	$ 2,278,419	1.26 $/kg	(1,068,912)	(1,230,683)
2013	829,461 t	$ 1,297,675	1.56 $/kg	1,853,485 t	$ 2,649,137	1.43 $/kg	(1,024,024)	(1,351,462)
2014	832,151 t	$ 1,327,606	1.59 $/kg	1,860,062 t	$ 2,925,484	1.57 $/kg	(1,027,911)	(1,597,878)

Table 12: Canada's Global Vegetable Trade

More data than what is shown in Table 12: Canada's Global Vegetable Trade is available. If we take a look at just the next level of detail, filtering the import and export data to just show fresh tomatoes, the results can be found in Table 13: Canada's Global Tomato Trade. On the exports side, volumes and values are relatively constant over this period. On the imports side, we are importing tomatoes that are less expensive than what we are exporting, but that value

gap is narrowing, and we are continuing to import more and more tomatoes each year. This is an indication that our Canadian tomato businesses are not keeping pace with local demand.

Trade Year	Export Volume (tonnes)	Export Value ('000)	Unit Value ($/kg)	Import Volume (tonnes)	Import Value ('000)	Unit Value ($/kg)	Net Trade Volume (tonnes)	Net Trade Value ('000)
2010	142,773 t	$ 308,158	2.16 $/kg	193,511 t	$ 310,461	1.60 $/kg	(50,738)	(2,303)
2011	141,511 t	$ 299,533	2.12 $/kg	193,869 t	$ 321,979	1.66 $/kg	(52,358)	(22,446)
2012	139,507 t	$ 274,321	1.97 $/kg	193,587 t	$ 270,694	1.40 $/kg	(54,080)	3,627
2013	140,682 t	$ 337,072	2.40 $/kg	199,838 t	$ 310,755	1.56 $/kg	(59,156)	26,317
2014	146,792 t	$ 316,701	2.16 $/kg	213,733 t	$ 356,957	1.67 $/kg	(66,941)	(40,256)

Table 13: Canada's Global Tomato Trade

From this data, one observation is that we could be producing more ourselves – there is a market for it, but perhaps not at a price that our consumers are willing to pay. Unlike many other commodities, there is a seasonal element to growing produce that encourages trading with other regions. As each geographically diverse region enters its peak harvest season for a particular type of produce, tomatoes for example, the local price in that region will typically fall, as an economic supply/demand curve would predict. But global trade means that some of this loss can be mitigated by selling farther abroad.

Imbalances occur when peak production issues from different regions collide. The recent drought in California reduced the supply of many vegetables, raising prices substantially. Locally, cauliflower, usually priced at $20 per box, rose dramatically to $70 per box over the Christmas season this past year (CBC News, 2015). Eventually the production cycle moved on to other regions and other suppliers and the price fell back to normal. These kinds of disruptions in the trade cycle happen routinely, making the overall picture murky at best, and making it difficult to determine the viability of our own businesses.

1.2.6 Produce Available for Consumption

With the import and export data added to the mix, we at last form a complete picture of the overall vegetable industry in Canada. Statistics Canada uses the phrase "availability for consumption" to describe this particular combination of their datasets. This is intended to reflect what amounts of fresh vegetables (by weight) that are available annually, on average, for consumption by each person in Canada. Starting with production from Canadian business, imported vegetables are added and exported vegetables are subtracted. The underlying data was combined revenues from Table 11: Vegetable Crop Yields, with the results summarized in Table

14: Fresh Produce Availability. Note that this is for fresh vegetables whereas the import and export data included the broader categories of dried and frozen vegetables.

This gives us a reasonably accurate picture of overall vegetable revenues. The unit values for greenhouse vegetables (tomatoes, cucumbers, peppers and lettuce) are the weighted averages of both greenhouse and field production methods listed in Table 11: Vegetable Crop Yields. The weighted average of $0.94 is slightly higher than the $0.89 figure we came up with by averaging local production in Table 11: Vegetable Crop Yields, but reasonably close given that a much different set of underlying data was used to arrive at this number, including the impact of imports and exports.

The revenue column in Table 14: Fresh Produce Availability shows a calculation of the potential gross annual revenue for each type of produce (available kg * unit value). Metro Vancouver, with a population of approximately 2.5 million people, might therefore have a fresh produce wholesale market size of ($64.12 per person * 2.5 million people) = $160.3 million annually. Canada, with a population of 35 million, would similarly have a fresh produce wholesale market size of about ($64.12 per person * 35 million people) = $2.244 billion annually. However, these are "big" numbers that reflect quite a large number of equally large and variable assumptions.

1. A caveat defined for the underlying Availability table, is that availability "Does not adjust for losses (such as waste and/or spoilage in stores, households, private institutions, restaurants) or losses during preparation."
2. Assumes that the consumer will be willing to pay this unit value plus whatever additional costs are added by the various distributors and retailers in the supply chain that handle the produce before it reaches the consumer, regardless of whether a less expensive alternative (an import, for example) is available to them. We're going to assume for now that the "farm share" is 40% of the retail price (Kelly, 2014).
3. Assumes that the produce is always available to the consumer when they wish to purchase, regardless of season or location, in the exact quantities that they require.
4. Assumes that the consumer, on average, consumes all these kinds of produce each year, regardless of their age, ethnicity, location, dietary preferences, etc. These are averages after all, and in reality few people would consume their annual total fresh produce in anything remotely similar to these quantities.

5. Assumes that consumption and availability are exactly the same thing for the purposes of this discussion, meaning that what is available is the same was what is purchased and what is consumed, nothing is wasted in any of the transactions.
6. Assumes the average price of produce is constant over the course of the year, and that farm gate revenue estimates correspond to the market overall, including imports.

Available for Consumption	Unit Value ($/kg)	Available (kg/year)	Revenue ($/person)
Tomatoes	1.04 $/kg	8.68 kg	$ 9.03
Cucumbers	1.52 $/kg	3.61 kg	$ 5.49
Peppers	2.48 $/kg	4.44 kg	$ 11.01
Lettuce	0.96 $/kg	9.14 kg	$ 8.77
Brussels Sprouts	1.39 $/kg	0.24 kg	$ 0.33
Carrots	0.34 $/kg	6.25 kg	$ 2.13
Dry Onions	0.36 $/kg	8.52 kg	$ 3.07
Corn	0.37 $/kg	3.18 kg	$ 1.18
Cabbage	0.50 $/kg	5.64 kg	$ 2.82
Broccoli	1.34 $/kg	2.70 kg	$ 3.62
Beans	0.63 $/kg	0.85 kg	$ 0.54
Cauliflower	0.90 $/kg	2.33 kg	$ 2.10
Asparagus	3.79 $/kg	0.70 kg	$ 2.65
Rutabagas and Turnips	0.39 $/kg	1.28 kg	$ 0.50
Peas	0.42 $/kg	0.22 kg	$ 0.09
Celery	0.44 $/kg	2.98 kg	$ 1.31
Pumpkins	0.36 $/kg	3.61 kg	$ 1.30
Radishes	0.69 $/kg	0.77 kg	$ 0.53
Beets	0.52 $/kg	0.64 kg	$ 0.33
Spinach	1.65 $/kg	0.96 kg	$ 1.58
Leeks	1.95 $/kg	0.23 kg	$ 0.45
Parsnips	1.04 $/kg	0.24 kg	$ 0.25
Parsley	1.91 $/kg	0.28 kg	$ 0.53
Garlic	9.40 $/kg	0.48 kg	$ 4.51
Weighted Average / Totals	**0.94 $/kg**	**67.97 kg**	**$ 64.12**

Table 14: Fresh Produce Availability

The annual per-person total wholesale cost of $64.12 works out to ($64.12 annual wholesale cost * 4 people / 52 weeks / 0.4 markup) = $12.33/week at retail for a family of four. In reality, this would fluctuate up and down due to seasonal availability, personal preferences,

sale prices, quantity discounts and so on. For those who consume fresh produce regularly, or who shop at farmer's markets during the peak summer season, this might not seem like a very accurate dollar amount. As an individual fresh produce shopper myself, I can certainly recall weeks where I've spent more than $12 just for my own produce (one person, not four). Over the course of a year, however, this is a reasonably accurate calculation for estimating retail fresh vegetable produce revenue per week.

This will be used as one of the key metrics when it comes to the discussion about directly selling produce versus other distribution methods in Part 3. To put this weekly fresh produce purchase amount into perspective, another set of data from Statistics Canada (Government of Canada, 2016) reports that, in 2014, the annual bill for food purchased from stores was $5,718 per household, or $109.96/week.

1.2.7 Summary of the Agriculture Industry in Canada

We've covered a substantial amount of material with this external analysis, from looking initially at the $26.4 billion Canadian agriculture industry overall, all the way down to the $12.33 that a typical Canadian household might spend on fresh produce in a given week, with some key stops along the way. We've demonstrated that greenhouses have the capability to handily achieve 10x yields that are achievable with field crops. For the select crops that we grow in greenhouses, greenhouse production levels exceed field production.

In terms of costs, we determined that greenhouses are considerably more expensive to operate and maintain, and a majority of businesses, 73%, report as being unprofitable. They are further challenged by lower-priced imports, having to compete with the broader international market for vegetables, where the unit values and volume of their exports are not increasing as quickly as the unit values and volumes of imports.

On average, vegetable production generates farm gate revenues in the ballpark of $0.90-$1.00/kg across all vegetables, and in particular, $1.86/kg for greenhouse tomatoes. We learned that greenhouses can fetch a higher price for their outputs due to the higher quality produced. If we assume the farm gate value is 40% of retail prices, then the total addressable fresh produce market in Metro Vancouver is $160 million, and across Canada is $2.2 billion.

1.3 Non-Profitability

Back in Table 8: Industry Sector Statistics, we showed that agriculture businesses reported higher rates of non-profitability compared to other industries, but examining the data presented so far hasn't really suggested a reason. Greenhouses generate more revenue per unit of area and have yields far in excess of field crops so it would seem, from a distance, that this was a really good situation to be in. Part 2 of this paper will explore the various financial and operating mechanics of how a modern greenhouse business works. The main idea we want to introduce here is that non-profitability comes from two likely causes. First, on the expense side, there is significant operational risk involved in growing produce that does not have parallels in more traditional manufacturing industries. This leads to additional unexpected expenses that impact profitability. And second, on the revenue side, the markets in which these businesses operate fit the definition of perfect competition. There are numerous buyers and sellers at all stages of the food distribution channel, and none large enough to independently influence market prices. Sellers, and in particular greenhouses, are often at the mercy of market forces well beyond their control, where almost any depression in market pricing is an automatic loss to the business.

1.3.1 Operational Risks

Growing crops, even in a greenhouse, is an activity that involves a number of high-risk factors that can derail even the most carefully managed businesses. Considerable investments are made in advance to mitigate against known risks, but it is not at all uncommon for these to ultimately be inadequate, leading to further unanticipated expenses. The area we're going to investigate here are weather-related risks.. Plants are living organisms that don't always behave in expected ways, and small changes in their environment can have a dramatic impact on their ability to provide marketable produce. There are numerous other risks facing a greenhouse business, but for illustration purposes we're going to focus on just this one.

Greenhouse structures are purposely built in large part as a protected environment, where the effects of a fluctuating climate can be effectively managed. Energy curtains, venting systems, heating pipes, irrigation systems and even auxiliary lighting help provide a consistent growing environment. Data on climate conditions for a particular region is available in most inhabited areas of Canada for at least the past 50 years, if not even longer. Heating and otherwise managing an average greenhouse involves major, but largely predictable, expenses.

Unfortunately, greenhouses aren't perfect, and there are numerous risk events that impact how well they perform. Hail can destroy a greenhouse and the crops within it. Unexpectedly

high snowfalls at just the wrong time of year can literally flatten a greenhouse. Wild temperature swings can damage fruit while it is still attached to the plant. These kinds of catastrophic events aren't frequently visited upon every business, but they occur frequently enough that any farmer that has been in business long enough has most likely experienced some of them first-hand, and everyone knows someone who has. The farmer can do nothing to prevent such risk events from happening, they just have to deal with whatever the outcome is, either by closing the greenhouse for the season, or by accepting the loss, cleaning up the resulting problems, and continuing to operate. Crop insurance, and other forms of business insurance, while very costly, are necessary and really are the only option for greenhouse businesses.

Less catastrophic weather events happen more frequently. A spring season with very little average daily sunlight (overcast weather in Metro Vancouver isn't at all uncommon, after all) can slow down plant growth during the critical initial stages, often resulting in lower yields for the rest of the growing season. Lower than average temperatures can be mitigated with more heat, but if such temperatures persist for too long, the extra expense can be as costly as experiencing lower yields. These losses, either in terms of lower yields or higher energy costs, can routinely introduce an impact on the business that is beyond whatever contingency funds might have been set aside to deal with them.

1.3.2 Perfect Competition

On the revenue side of the equation, there is a different kind of risk – market pricing. When fresh produce greenhouse businesses sell their produce, it is generally to a distributor or large wholesaler, as a commercial grower is very much interested in minimizing their transaction costs so they can keep their people focused on the primary driver of their business – crop yield. Generally, this involves some kind of contract where the farmer is paid for 100% of the produce that they ship, with all of their production capacity going to one distributor. The distributor then agrees to pay market prices for their produce, as this is what the distributor will sell it for later.

One way to assess this market is with a Porter 5 Forces analysis (Porter, 2008), which describes how the various firms in a specific subsector of an industry interrelate with one another, and ultimately where the profits in the industry subsector end up. A quick Porter 5-Forces analysis is provided in Figure 4: Porter's 5 Forces. The industry we are evaluating in this case is specifically the fresh produce greenhouse industry in British Columbia.

The *Threat of New Entrants* is low. We mentioned already that the conditions for perfect competition are already prevalent, with a large number of players in the market. High greenhouse

capital costs, and a low expectation for high returns mean that there isn't much incentive for new entrants to enter the market. In British Columbia, the BC Vegetable Marketing Commission regulates many aspects of vegetable production in the province. We'll discuss them later, as 500 Foods will have to address the restrictions they may impose, but in general they have the authority to assign quotas for crop production, further limiting any threat from new entrants.

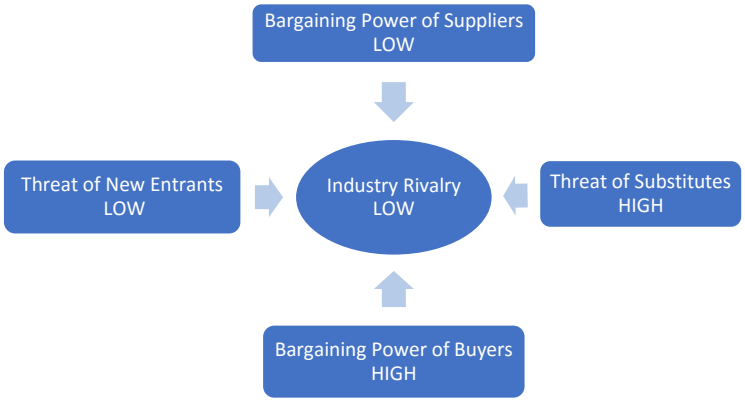

Figure 4: Porter's 5 Forces

The *Threat of Substitutes* is high. When a retailer wishes to purchase fresh produce for sale to its customers, they can choose between any number of alternatives, for which the local greenhouse business, or indirectly its distributor, is just one. Local organic producers may get a spot in the fresh produce aisle, whereas a local greenhouse producer may be easily displaced by a less costly supplier from Mexico. From the consumer perspective, if the produce they want isn't available at the price they're willing to pay, or in the format or quality they prefer, they can easily go to another store, or even just to another aisle and buy processed or frozen produce, with virtually no switching costs.

The *Bargaining Power of Buyers* is high. The customer (retailer or consumer) has many alternatives. Switching to a different produce supplier isn't difficult or costly. Being a commodity, customers will purchase less expensive produce if available, so a coordinated response to high prices occurs even when customers are acting independently.

The *Bargaining Power of Suppliers* is low. There is little they can do to offer differentiated products as they are selling a commodity – tomatoes. The cost of switching suppliers is very low. Most suppliers (greenhouses) are very small, making it difficult for them to move up the supply chain. The distributors they work with are also often smaller than the customers that the distributors sell to (like Costco, Walmart and Safeway) so even if a greenhouse could move up one rung on the supply chain ladder, they'd be in roughly the same position still.

Industry Rivalry is low. Greenhouse business generally don't market their own produce, so there isn't much direct competition across the industry. In terms of innovation, new technologies and new farming practices disperse very slowly across the industry, despite numerous industry associations that are in place to help facilitate such things, like the BC Greenhouse Growers' Association (http://www.bcgreenhouse.ca). But there are many firms, all trying to get the best possible price against their competitors, both foreign and domestic. A big wrinkle in this aspect of the 5 Forces analysis is the BC Vegetable Marketing Commission (which we discuss more in Section 2.5, about controlled markets), a regulating body that ensures that everyone plays along nicely. The end result is that greenhouses effectively don't compete head-to-head with one another in the normal sense. The agencies that distribute their products do, however, but even at that level, there isn't much industry rivalry as this is such an old and well-established market – the players generally know where they all stand.

In combination, these five forces lead to a situation where industry profits ultimately bleed away to buyers, and the suppliers are left struggling, largely unable or unwilling to either differentiate, consolidate or otherwise innovate to capture more of what little profit remains.

1.3.3 Narrow Operational Window

In many other industries, business that take on such high-risk activities to conduct their business affairs might reasonably expect to receive a greater reward for their troubles, or at the very least they will be able to pass along their cost increases to their customers along with the same markup they apply to the rest of their offerings. In Porter's model, this would mean that suppliers would have more power over their market, and would be able to extract more revenue in compensation for their high-risk efforts.

In the greenhouse industry, such risks are common across all businesses, and the costs related to mitigating them do not provide any measure of differentiation that might otherwise separate them from one another, and supplier power remains nearly non-existent. Without such power, and with such potential inherent risks, greenhouse businesses are essentially sandwiched into a narrow operational window. On the revenue side, they are bounded by market prices, set as a combination of both domestic and foreign markets. On the expense side, they are bound by the high cost of production relative to field growers, both domestic and foreign as well.

This leaves management focused almost exclusively on the perpetual hunt for cost reduction exercises. Other industries might be able to approach changes to their operations through the lens of a return-on-investment calculation. For the average farmer, any unexpected

investment or substantial expense is likely to be framed as a direct hit to the bottom line of the business. As the vast majority of these businesses are small, it is often the owners themselves who have to make the decision (essentially absorbing yet another expense). The return part of the equation, unless it happens in the current fiscal year, is often overlooked as they are often forced to make a choice that is literally coming out of their own pockets each time. This makes for generally less than ideal decision-making as there are more issues brought into the decision process than just the business itself. In MBA parlance, this means that these businesses have virtually no organizational ambidexterity – they're thinking of today, not tomorrow.

Over a long period of time, the types of people that manage these businesses tend to be considerably more risk averse, just to be able to survive in the industry. The concept of "failing forward" is nowhere to be found. Incremental innovations do occur but it is a slow process. New technologies won't be deployed until they can be proven effective elsewhere. Ironically, new technologies often can't be proven effective until they're deployed, so technological stagnation sets in. Working as a technology provider to these kinds of businesses over such a long period of time, there has definitely been this sense that "nobody wants to go first" when it comes to adopting any new technologies.

Ultimately, this overall level of non-profitability bodes very poorly for the industry. If 500 Foods is to be ultimately successful as a new food production venture, it will need to find a way to reduce the risks inherent in growing produce while at the same time it will also need to find a way to also move away from the existing perfect competition environment. The container model is intended to address the former, while developing a closer relationship with consumers, potentially through a retail chain, may address the latter.

Having just the capability to reduce the risk involved in growing produce, even at lower costs, doesn't automatically lead to more profitable businesses – the profits will still ultimately end up being drained away to the buyers in our 5 Forces model. Having just a retail operation doesn't change the situation either, as it would be competing on exactly the same terms as existing retailers. Greenhouse businesses don't sell directly to consumers because they typically only grow one or two types of produce. It would be inconceivable to have a chain of stores that *just* sells tomatoes or *just* sells cucumbers, for example. In fact, the existing supply chain came about when a number of greenhouses banded together to create a marketing co-operative known as BC Hot House, in an effort to get their produce into more stores. But instead of retail, due to their large volumes, they opted for a distribution model, selling their produce farther abroad. This has led to the situation we have now, where they have very little power.

2 Benchmark Greenhouse

With the background of the fresh produce industry well in-hand, our attention now turns to the development of a model of what an average modern commercial fresh tomato greenhouse production business looks like, herein simply referred to as "the model." Rather than developing a detailed case study of an existing business, the purpose of our model is to highlight the major functional areas of these kinds of businesses in a more general way, along with some basic assumptions pertaining to labour and operating costs. Our model will then be used as the benchmark to better understand 500 Foods, described in Part 3, with the goal of determining how well it performs using many of these basic assumptions and metrics.

To begin with, we're going to setup our model with the intent that it will be growing tomatoes, but not any specific variety. As we know from Table 11: Vegetable Crop Yields, this is the most commonly grown type of fresh produce, in greenhouses or otherwise. At such a high level of data abstraction, the allocations between varieties were not provided (beefsteak versus cherry tomatoes, for example). There are significant differences in labour input, yield and selling price for each tomato variety, but as we'll be using averages for many of these numbers, the added complexity of modeling multiple varieties wouldn't add anything useful to our model.

From here, we will first describe the site and the facility, highlighting the major components that are common in any typical fresh produce greenhouse business. Then we'll cover the basic revenue model, followed by expense estimates for labour and energy, as well as the productivity metrics and other numbers that we'll need for comparison in Part 3.

2.1 Facility

Naturally the key distinguishing feature of this facility will be the greenhouse itself. Nearly all of the activities of this kind of business would be conducted at one site, so we'll first cover the attributes of a typical site. Then we'll look at the main structures that can be commonly found at such facilities and explore some ideas as to the overall capital cost to build such a site.

2.1.1 Site Selection

As greenhouses are technically classified as farms, they meet the requirements for using farmland. In British Columbia, this means they can be constructed on Agricultural Land Reserve land (ALR). This class of land is generally significantly cheaper than other classes of land (industrial, commercial or residential) but comes with restrictions limiting what kinds of activities

can be conducted on such land. We'll assume for the purposes of our model that all of our activities will fit within these restrictions, though increasingly complex greenhouse functions pertaining to energy co-generation would normally require additional approvals. Using ALR land would most likely place such a greenhouse in a more rural setting, though this is of no particular benefit to the greenhouse itself. It could be setup in an urban area just as easily, or even built on top of an existing building, though it might be difficult to find a building of suitable size.

For our model, we'll assume that we have a 16-hectare plot of suitable rural ALR land with enough city-supplied water, electricity and natural gas for all of the operational needs of the greenhouse. We'll also assume for simplicity that we've gotten all the necessary permits, licenses and approvals to build and operate a fresh produce greenhouse at this location with whatever methods and energy technologies we choose to employ.

2.1.2 Structures

We'll assume that the greenhouse is a 10-hectare glass greenhouse. Figure 5: Benchmark Greenhouse Facility shows the layout of our model. The green perimeter reflects typical setbacks for any features constructed on any parcel of land. In this case it is 10 m wide (approximately 30 feet). Inside that, a perimeter road circles the property, needed for trucks to access all sides of the greenhouse for activities like glass cleaning and repairs. The perimeter road is also 10 m wide.

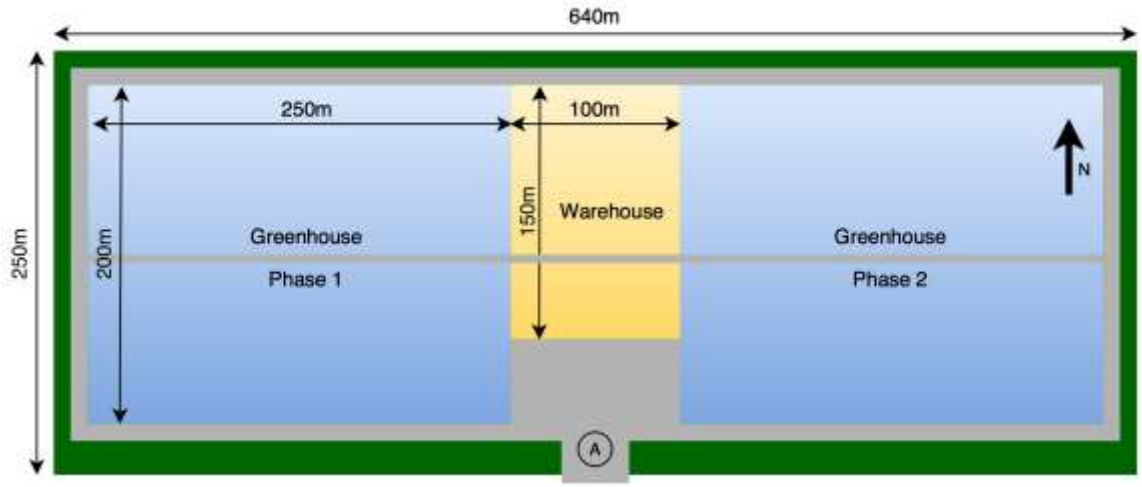

Figure 5: Benchmark Greenhouse Facility

The greenhouse area is divided into two equal but separate areas (typically referred to as phases, labelled as phase 1 and phase 2 in the diagram). This makes it simpler to manage two different crops, each with their own growing environment, and is a popular configuration for this

kind of business. Each phase of the greenhouse is 5 hectares (200 m by 250 m). There is a centre path, running across the length of the facility (from left to right in the diagram). This is where people will travel into and between the greenhouses. It is typically a few metres wide, but can vary from greenhouse to greenhouse. Figure 6: Greenhouse Centre Path shows an example of the view from the centre path of a local Village Farms tomato greenhouse, along with their Regional Manager, Dirk de Jong, providing a suitable reference for scale (Brown, 2012).

Figure 6: Greenhouse Centre Path

Either inside this warehouse area or somewhere along the outside perimeter of the greenhouse, there may also be other structures. Large heat storage tanks or cooling towers may be used to help moderate greenhouse temperatures. Large water storage tanks may be used to collect rainwater or other recirculated water. For our purposes, we'll acknowledge that these are important features for an operating greenhouse, but we'll not be concerned about them for our model as they don't require much attention in terms of labour or any other inputs, they simply form part of the overall greenhouse infrastructure.

2.1.3 Configuration

Within the greenhouse, plants are arranged in long parallel rows. Each row starts at the centre path of the greenhouse and extends 100 m all the way north or south to the far wall of the

greenhouse (to either the top or the bottom of the greenhouse diagram in Figure 5: Benchmark Greenhouse Facility). The width of all of the rows are fixed. In our model, we'll use 1.6 m as the row width. Different crops benefit from different densities, but generally once a greenhouse is constructed, the row width does not change as the extensive network of heating pipes are used as guideways for carts that run along the rows, and these heating pipes are costly to rearrange.

A row width of 1.6 m and length of 100 m give each row an area of 160 m^2. Rows are grouped together into sets of 10, and these groups are referred to as bays. Each bay is comprised of five rows from each side of the centre path (5 paths on the north side, 5 paths on the south side). With this arrangement, we will have 30 bays, each with 10 rows that are 100 m long by 1.6 m wide, in each of the two phases, giving us a total area of (2 phases * 30 bays * 10 rows/bay * 160 m^2 area/row) = 96,000 m^2 phase area.

The overall greenhouse area is 100,000 m^2 so we're going to assume further that this extra area of (100,000 m^2 greenhouse area – 96,000 m^2 phase area) = 4,000 m^2 will be assigned to the centre path running through both phases as well as the areas at the beginning and end of each phase between the first and last paths and the greenhouse walls. Whether this area is included in certain calculations will be based on whether the scope is directed at row metrics (such as productivity per row) or whether the scope is directed at facility metrics (crop yield expressed as t/ha for example). This small variance (4%) can be of some consequence, so we'll be careful to clarify which value is being used when necessary. For our model, we're trying to keep things simple, however in an actual greenhouse these numbers would be considerably more precise.

To recap, a single row is 100 m long and 1.6 m wide, for an area of 160 m^2. A bay contains 10 rows, so each bay has a total area of 1,600 m^2. 30 bays make up one phase, equivalent to 48,000 m^2. And all 60 bays in both phases add up to 96,000 m^2. The total greenhouse area under glass is 100,000 m^2 (10-hectares). The amount of area we're considering as "walking area" is the difference, 4,000 m^2. If a person were to enter the west door of phase 1 and then walk from the center path to the end of each row and back, for every row of both phases, they would have to walk a total distance of (600 rows * 100m * 2 directions) = 120 km! And that's not counting the distance walking along the centre path or between phases. Assuming an average (normal) walking speed of 5 km/hr, it would take 24 hours to walk the entire greenhouse.

2.1.4 Capital Financing

Our model greenhouse is a 10-hectare facility, equivalent to 100,000 m^2 of greenhouse space. In Section 1.2.3, we reported that the cost to build a modern greenhouse was about

$250/m^2, equivalent to $2.5 million/hectare or $25 million for a facility of our model's size (Mirza, 2007). Another estimate from a large greenhouse operator, having recently constructed a new facility, reported that it was about $1 million per acre (Magruder, 2013). This also works out to about $250/m^2 or around $25 million for our facility. These two numbers, despite coming from vary different sources, are surprisingly consistent. This doesn't paint a complete picture of the variability in cost for such a project, but this is a reasonable enough approximation.

First, we're going to assume that after 20 years, the greenhouse will have depreciated to a value of $5 million, using a straight-line depreciation of $1 million per year. The Canada Revenue Agency considers greenhouses to be a Class 6 asset, with a depreciation rate of 10% (Government of Canada, 2015). Over the same 20-year period, this depreciation method would result in the greenhouse having a residual value of about $3-4 million, roughly equivalent for our purposes. After 20 years, the greenhouse will still be quite usable, but the owner isn't going to be able to sell it for anything close to $25 million. Over time, greenhouse structures age, glass transmissivity may be reduced (scratches from excessive cleaning, for example), heating pipes start to corrode and burst more frequently, and in general it starts to become more expensive to maintain and less efficient (sometimes even less safe) to operate. At the same time, new greenhouse designs, more integrated features and yield-enhancing technologies are introduced (higher roofs, pressurized air systems, better glass systems leading to better light transmissivity, energy curtains, etc.), often making old facilities less attractive when starting new businesses.

Second, we're going to assume that the entire capital cost is going to be financed by the owner taking out a business loan, amortized over the same 20-year period. Let's also assume that the loan rate is a very favourable 3% (roughly the current prime rate in Canada). This means that the business will pay $138,649 per month, or $1,663,793 per year, to finance this expense. The monthly interest would be $34,483 and over the lifetime of the loan the total interest would be $8,275,856. We'll also assume that all payments are made with neither penalties nor prepaid payments, and that this amount doesn't fluctuate for any other reason over the period the business is operating. In reality, this amount would likely get refinanced numerous times as interest rates changed and as the asset depreciated. A good year might well see this loan paid off more quickly, and a series of less profitable years might see this loan extended further. A separate operating line of credit would be established to handle routine business expenses.

2.2 Revenue

In this section we are going to make some estimates that relate to the overall revenue generated from our benchmark greenhouse. There are many external variables that can impact the potential revenue, most notably the current market prices for tomatoes. For this discussion, we're going to assume the averages from Part 1 apply to our model where possible, and we'll make some reasonable estimates about production capacity where necessary.

Referring back to Table 10: Field Versus Greenhouse Vegetable Crop Production, we know generally that greenhouse production for all fresh produce in British Columbia averaged 412.8 tonnes per hectare, equivalent to 41.28 kg/m^2. The type of produce grown can have a pretty substantial impact on the ultimate yield attained. Breaking out the data summarized in Table 10: Field Versus Greenhouse Vegetable Crop Production to show the individual types of produce results in Table 15: Greenhouse Production Yields.

Commodity	Area (hectares)	Volume (tonnes)	Value ('000)	Unit Value ($/kg)	Yield (kg/m^2)	Revenue ($/m^2)
Tomatoes	556.6 ha	280,291 t	$ 519,960	1.86 $/kg	50.4 kg/m^2	93.74 $/m^2
Peppers	495.1 ha	130,294 t	$ 408,486	3.14 $/kg	26.3 kg/m^2	82.58 $/m^2
Cucumbers	364.6 ha	180,294 t	$ 325,905	1.81 $/kg	49.4 kg/m^2	89.41 $/m^2
Lettuce (2013)	18.3 ha	17,468 t	$ 28,994	1.66 $/kg	95.5 kg/m^2	158.53 $/m^2
Total	**1,434.6 ha**	**608,347 t**	**$ 1,283,345**	**2.11 $/kg**	**42.4 kg/m^2**	**89.46 $/m^2**

Table 15: Greenhouse Production Yields

From here, we can see that tomato production yields are a bit higher than average, and that it is primarily the lower pepper production yields that bring the overall average greenhouse production yield figure down. For our greenhouse then, let's assume that we are an average producer and that we can readily achieve 50.4 kg/m^2. Let's also assume that we generate revenue at the same rate as everyone else, and that we earn $1.86/kg for everything we ship. Note that the world record holder for greenhouse tomato production in 2002 achieved 75 kg/m^2 so we're in the ballpark of what a typical greenhouse might reasonably expect to achieve (BC Greenhouse Growers Association, 2016).

In Table 14: Fresh Produce Availability, we learned that average tomato consumption across Canada was 8.68 kg per person. If our model 10-hectare (100,000 m^2) facility can produce 50.4 kg/m^2 annually, for a total of 5,040,000 kg/year, then each square metre of greenhouse space is sufficient to supply, on average, (50.4 kg/m^2 / 8.68 kg/person) = 5.8 people. A single row of tomatoes (100 m) could supply 580 people. The entire facility could be capable of supplying the

tomato consumption needs of 580,000 people, or just under a quarter of the population of Metro Vancouver's 2.5 million residents.

Conversely, to supply 2.5 million people would require the equivalent of (((2.5 million people * 8.68 kg/person) / 50.4 kg/m^2) / 10,000 m^2/ha) = 43 hectares of greenhouse space, a little more than four of our model facilities. Supplying Canada's entire tomato needs would require (((35 million people * 8.68 kg/person) / 50.4 kg/m^2) / 10,000 m^2/ha) = 603 hectares, or about sixty facilities that are the same size as our model facility.

The gross revenue from our benchmark greenhouse is simply (50.4 kg/m^2 * 1.86 $/kg * 100,000 m^2) = $9,374,400. Let's assume that we ship everything that we grow, and that we don't get anything back or charged for any waste produce in our contribution to the supply chain. Let's also assume that we ship to a local distributor at their expense and that we aren't concerned with any currency or distribution issues beyond getting the produce into trucks at our loading docks.

2.3 Expenses

In this section we'll cover virtually all of the costs that a modern commercial fresh tomato greenhouse production business might experience during a typical year. The general scope of our expenses start with growing tomato plants from seed, starting in November. Then setting up the greenhouse and growing the plants throughout the spring. Harvest starts around March. In our model we will package and ship tomatoes all the way through to November. Coming up with estimates for all of the activities will also require some explanations along the way about what activities are being performed, and what other operational costs are needed to support those activities. There are many details, so we'll have to tackle them a section at a time.

First we will come up with some estimates for how much our model will spend on labour, which we will further subdivide into three categories. Management staff, greenhouse workers and packaging workers each have distinct roles and responsibilities. We'll cover some of the basic functions of each group along with some idea as to the related payroll costs.

Then we'll tackle the question of how much it will cost to heat the facility. Different heating systems, average daily temperatures and the market price of energy will be the main drivers of the energy expense for our model. For simplicity, we'll be outfitting our model with a standard boiler that uses natural gas. We'll make some assumptions about what that might look like from an operational perspective and the kinds of trade-offs that are possible.

Finally, we'll look at some other variable costs to the business, beyond just labour and energy, and then present an overall breakdown of expenses in the form of a profit and loss statement. We'll also come up with more key performance metrics that we can use in Part 3.

2.3.1 Management Staff

Management staff are paid a regular salary, work the same number of hours each week, generally take a few weeks of vacation time each year, and are paid reasonably competitive wages for their work, much like any typical office worker in any other industry. The rest of the workers, both greenhouse workers and packaging workers, are paid hourly, work seasonally with much longer shifts over the summer months, receive vacation pay in lieu of time off, and are paid very low wages for what is considered unskilled labour.

We'll assume that management salaries as reported here reflect the "fully burdened" cost to the business, meaning that it includes all the businesses' expenses, including WCB, EI, CPP, payroll taxes, vacation pay and other benefits. We'll assume three management tiers, starting at the top with a salary of $100,000 for the most senior person on staff. The next tier will be paid $75,000. And the third tier will be paid $50,000. These are deliberately just ballpark numbers, and would work out to something like a $40/hr, $30/hr and $20/hr hourly rate for each tier. This assumes a typical 40-hour work week, 50 weeks a year.

The organizational chart for our benchmark greenhouse is presented in Figure 7: Greenhouse Org Chart. The General Manager is the only person in the top tier, earning $100,000. Making up the middle tier are the senior managers in charge of the growing, facility, greenhouse, packaging, and administration departments, respectively. Each of these senior managers has two direct reports that round out the rest of the management team.

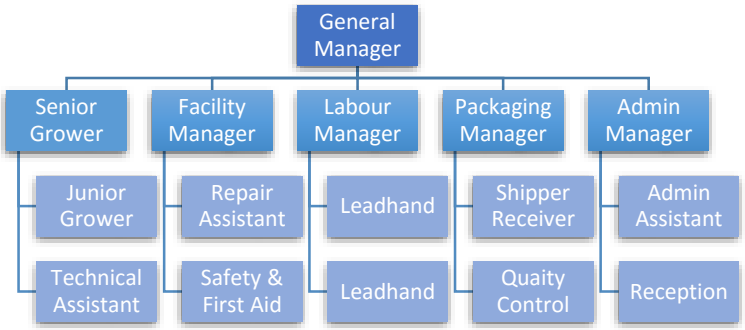

Figure 7: Greenhouse Org Chart

All of these roles are summarized in Table 16: Management Roles, with the salary amounts and a calculations showing the salaries as a percentage of gross revenue (based on $9,374,400) and unit cost (based on $1.86/kg). The pie chart shows the summary by department.

Group	Role	Salary	% Rev	$/kg
Executive	General Manager	$100,000	1.1 %	0.020 $/kg
Farmer	Senior Farmer	$75,000	0.8 %	0.015 $/kg
	Junior Farmer	$50,000	0.5 %	0.10 $/kg
	Technical Assistant	$50,000	0.5 %	0.10 $/kg
Facility	Facility Manager	$75,000	0.8 %	0.015 $/kg
	Repair Assistant	$50,000	0.5 %	0.10 $/kg
	Safety & First Aid	$50,000	0.5 %	0.10 $/kg
Greenhouse	Labour Manager	$75,000	0.8 %	0.015 $/kg
	Leadhand #1	$50,000	0.5 %	0.10 $/kg
	Leadhand #2	$50,000	0.5 %	0.10 $/kg
Packaging	Packaging Supervisor	$75,000	0.8 %	0.015 $/kg
	Shipper/Receiver	$50,000	0.5 %	0.10 $/kg
	Quality Control	$50,000	0.5 %	0.10 $/kg
Admin	Admin Manager	$75,000	0.8 %	0.015 $/kg
	Admin Assistant	$50,000	0.5 %	0.10 $/kg
	Reception	$50,000	0.5 %	0.10 $/kg
Total	**16 Positions**	**$975,000**	**10.4 %**	**0.19 $/kg**

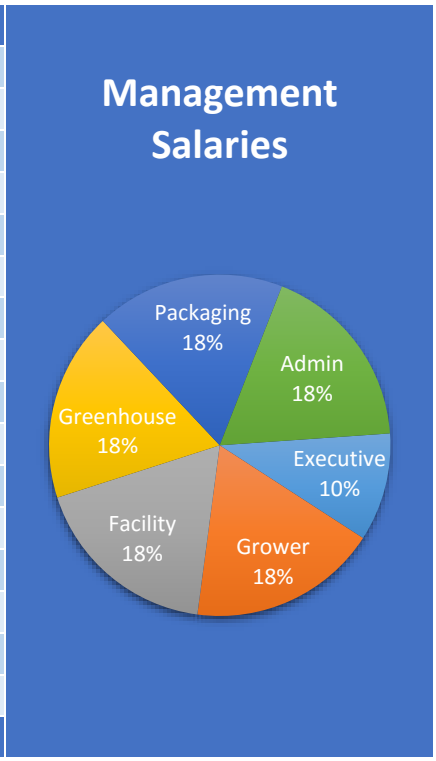

Table 16: Management Roles

2.3.2 Greenhouse Labour

Greenhouse labour covers the workers that are maintaining the crop under the supervision of the Greenhouse Labour Manager and Leadhands, and ultimately under the direction of the Senior and Junior Growers. This is the largest single cost to any greenhouse business, and will be the largest single cost in our model as well. One rough rule of thumb for an annual greenhouse labour budget is that it should be about a third of the annual gross revenue. Another estimate is that it should take about 7.5 workers per hectare of greenhouse to maintain a tomato crop. These and other approximations make many assumptions about the cost of labour or the productivity of labour, and sometimes both. The number of variables make this a very difficult question to answer with any kind of precision. An estimate for all greenhouse labour is provided in Table 17: Greenhouse Labour Activities. Given our gross revenue figure of $9,374,400, the total for greenhouse labour comes in at 34% of gross revenue, pretty close to our rough approximation of one-third. Put another way, of the $1.86 that the greenhouse receives for each kilogram of produce, $0.63 of that amount can be attributed strictly to the cost of greenhouse labour.

Activity	Hours / Row	Weeks	Cost	Hours/m²	$/m²	% Rev	$/kg
Picking	2.0	32	$ 576,000	0.384	$ 5.76	6.1 %	0.11 $/kg
Plant Training	1.0	44	$ 396,000	0.264	$ 3.96	4.2 %	0.08 $/kg
Pruning	1.0	44	$ 396,000	0.264	$ 3.96	4.2 %	0.08 $/kg
Deleafing	1.0	44	$ 396,000	0.264	$ 3.96	4.2 %	0.08 $/kg
Truss Work	1.0	38	$ 342,000	0.228	$ 3.42	3.6 %	0.07 $/kg
Lowering	0.5	32	$ 144,000	0.096	$ 1.44	1.5 %	0.03 $/kg
Other	2.0	52	$ 936,000	0.624	$ 9.36	10.0 %	0.19 $/kg
Total	**212,400 hours**		**$ 3,186,000**	**2.124**	**$ 31.86**	**34.0 %**	**0.63 $/kg**

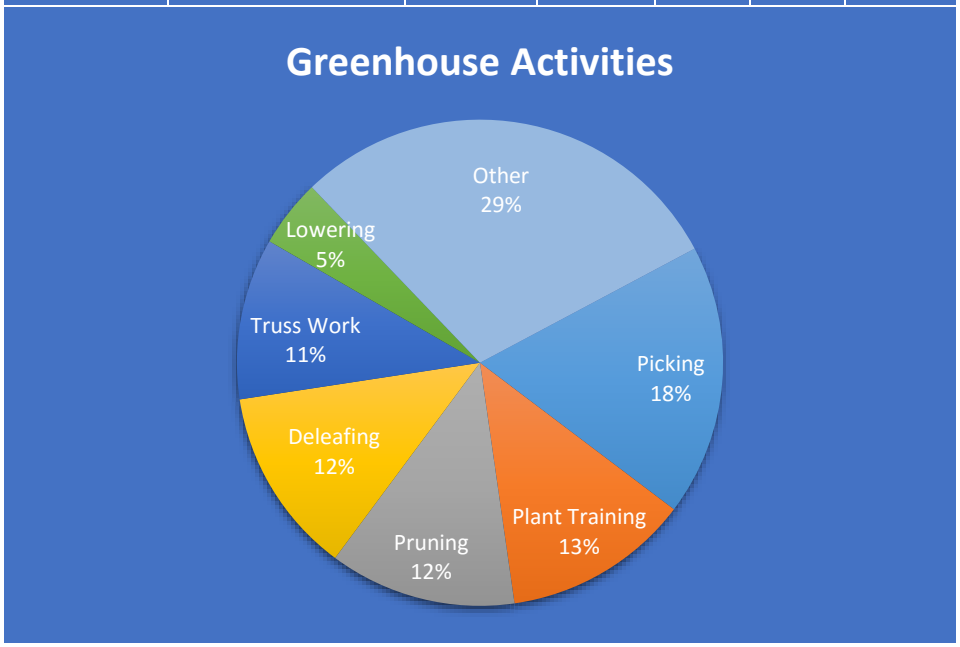

Table 17: Greenhouse Labour Activities

2.3.3 Packaging Labour

Calculating an expense for packaging labour is a considerably simpler undertaking, compared to estimating greenhouse labour. Tomatoes come from the greenhouse in plastic totes. The packaging department is tasked with converting this stream of tomatoes into something that is ready to be sold. There are workers that do the actual packaging, working on a packaging line, typically a set of conveyors that have tomatoes in totes arriving at one end from the greenhouse, and packaged tomatoes leaving at the other end. Table 18: Packaging Labour Expenses shows a summary of the packaging labour we've covered in this section. Figure 8: Case of Tomatoes shows what a typical 5 kg case of TOV tomatoes looks like once it has been packaged.

Role	People	Weeks	Cost	Hours/m^2	\$/m^2	% Rev	\$/kg
Transport	1	32	\$ 23,040	0.015	\$ 0.23	6.1 %	0.005 \$/kg
Stacker	1	32	\$ 23,040	0.015	\$ 0.23	4.2 %	0.005 \$/kg
Packaging Line	11	32	\$ 253,440	0.169	\$ 2.53	4.2 %	0.050 \$/kg
Shipper	1	32	\$ 23,040	0.015	\$ 0.23	4.2 %	0.005 \$/kg
Box Maker	1	32	\$ 23,040	0.015	\$ 0.23	3.6 %	0.005 \$/kg
Cleaner	2	32	\$ 46,080	0.031	\$ 0.46	1.5 %	0.009 \$/kg
Total	**26,112 hours**		**\$ 391,680**	**0.261**	**\$ 3.92**	**4.2 %**	**0.078 \$/kg**

Table 18: Packaging Labour Expenses

Figure 8: Case of Tomatoes

2.3.4 Energy

As with estimating greenhouse labour costs, coming up with an estimate for the energy cost for our model is complicated by many factors. Estimates vary widely over what the average cost of energy should be, anywhere from 5% to 25 % of the gross revenue figure. It is commonly thought to be the second largest cost to a greenhouse business, but this isn't the kind of figure that is readily discernible to anyone outside of the business. This section covers a bit more of the detail of how this cost is incurred and why, and which variables can have an impact on the final total annual energy bill. Note that the cost of heating the greenhouse far outweighs the cost of electricity for the rest of the business, including all the pumps, conveyors, office equipment and so on. When we discuss energy, it is generally a discussion just about greenhouse heating.

Let's assume that our greenhouse is 4 m tall and constructed as an industry-standard gutter-connected greenhouse. The volume of air in the greenhouse (both phases) that needs to be heated is (500 m length * 200 m width * 4 m height) = 400,000 m^3. There is an additional volume of air in the top-most section of the greenhouse, in the peaks between the gutters, and a little less volume in the greenhouse in general because of the volume of air otherwise taken up by people, plants and posts, but this is a good approximation for our purposes.

Large boilers are very efficient at heating water, but a 10-hectare greenhouse is an incredibly large volume of air to try and heat using heating pipes. Even the most efficient heating pipe arrangement is likely to lose a lot of energy along the way. There is also more than 120 km of heating pipes, as a heating pipe loops around each row of the greenhouse. The approximate volume of water moving through these pipes can be calculated using the formula for the volume of a cylinder, $V = \pi d*l$. A typical heating pipe for our model 2" in diameter (5cm). The volume of water in these pipes can therefore be calculated as (π * 0.05 m * 120,000 m) = 18,849 m^3.

There are various references for calculating heating costs including (Shaw, 2001) or (Khosla, 2007) but finding a simple formula that is applicable to our simple model has been a challenge. The basic inputs are that we need to heat 400,000 m^3 of air using 18,849 m^3 of hot water against an outside temperature differential. Let's assume that we need to be able to have the capacity to raise the temperature of the circulating water by one degree Celsius per hour to maintain the temperature of the greenhouse for a long and cold winter day.

The Khosla reference suggested that a boiler would be sized to approximately 80-100 HP per acre, which, for our 10-hectare facility, would be in the range of 1,976 HP to 2,470 HP. There are three more considerations. First, we need to heat the warehouse, which is another

150,000 m^2 (3.7 acres) which would add a range of 296 HP to 370 HP. Second, boilers are never 100% efficient. Depending on cost, age, maintenance and other factors, a highly efficient boiler in peak operating condition is only 85% efficient. So if we need 2,229 BHP for the greenhouse and we add the average of the range in BHP for the warehouse, and our boiler is 80% efficient, we will require a total boiler capacity of ((2,229 + (296 + 370) / 2) / 0.85) = 3,203 BHP. Third, boilers can be run at lower capacities than they are rated, but typically only come in maximum fixed sizes. In our case, for redundancy, we'd also like to have two boilers. That way, in non-critical periods, one boiler could be taken out of service for maintenance. Splitting into two, we would end up with one 1,500 BHP boiler, and one 2,000 BHP boiler, for a total combined capacity of 3,500 BHP. This value can also be expressed as 124 GJ/h.

Also referencing Khosla, there will be about 230,000 cubic metres of natural gas consumed per acre. If we continue with the area of the greenhouse plus the area of the warehouse, we have a total of 115,000 m^2, so we can expect to consume 6,532,000 cubic metres of natural gas annually, equivalent to 249,913 GJ. If we were to run the boiler system at its maximum capacity of 124 GJ/h all year, this would consume (124 * 24 * 365) = 1,086,240 GJ. If we were to run it at 50% capacity for 12 hours a day and six months of the year, this would consume (124 * 0.5 * 12 * 6 * 30) = 133,920 GJ. Neither scenario is particularly likely, but the energy consumed seems to be consistent with the idea that the boiler will be operating whenever the outside temperature is less than the set point, and that we are not wildly off with our assumptions. The maximum use for one day would peak at (124 * 24) = 2,976 GJ.

FortisBC, the local supplier of natural gas to businesses, charges different rates for different classes of customers. In our case, we're in a category that uses more than 5,000 GJ per month, referred to as Rate Schedule 7 (FortisBC, 2015). Under Rate Schedule 7, the monthly connection charge is $887.00. The delivery charge is $1.296 per GJ. And the consumption charge is $1.702 per GJ. This brings the total annual bill to the following.

($887.00*12) + ($1.296*249,913) + ($1.702*249,913) =
($7,044) + ($323,877.25) + ($425,351.93) =
$ 756,273.18 or an average cost of $3.03/GJ after delivery charges.

Expressed as a portion of gross revenue, this works out to about 8%. Now, for such a large single and simple cost to the business, this is hardly an exhaustive exploration of the realities of this particular transaction. One would expect a general manager to spend some considerable time and effort ensuring that they are getting the most from their heating system, that it is sized appropriately, and that they've done everything they can to ensure its efficiency.

The two main learning points from this discussion of energy expenses are that energy is a substantial expense to the business, worth exploring and understanding in great detail for any stakeholder of such a business, and that this is a major risk to the business if it is not managed carefully. As a commodity, the price of natural gas is currently low enough for our purposes in the benchmark model to make these assumptions and move on.

2.3.5 Other Expenses

With the major expenses of labour and energy covered, there are a handful of other expenses. While not as large individually, these are going to be important considerations for this type of business and will need to be contemplated in any kind of alternative business plan.

Tomato Plants

2.3.5.1 Due to the nature of the business cycle, greenhouses generally don't grow tomatoes directly from seed themselves. Industry practice is for the greenhouse to buy the seed and then have a separate plant propagation company grow the seeds into young plants. Once they've reached a certain height, they are placed in the greenhouse. This ends up being a significant expense to the greenhouse.

Plant propagation often also involves grafting. This is a process where two tomato plants are grown. One variety is chosen for its rootstock – qualities that give it excellent root systems and protection from various root-related diseases. The second variety, known as the scion, is chosen for its fruit. These two seeds are planted at the same time and once they've reached a certain height, the scion plant is grafted onto the rootstock to create a plant with the desired fruit but a better root system than that variety would have naturally. This has become commonplace practice and the economic benefits of this process have been studied (Cary L. Rivard, 2010).

The result is that there is a cost of seed to the greenhouse, and then a cost to produce these transplant seedlings that incorporates the labour and time (and growing energy) to produce the plants that are delivered to the greenhouse. The number of plants needed will be largely a function of how dense the crop will be. We already know that the rows are 1.6m apart, leaving enough room for workers to walk up and down between the rows of plants. For planting density, without too much emphasis on a specific variety, plants will be spaced 0.5m apart, or 200 plants per row (Susannah Amundson, 2012). For 600 rows, this means that we'll need 120,000 plants to complete our crop. Note that as rows are 1.6 m wide, this is a planting density of 1.25plants/m^2 but that plants can grow multiple stems, so this density can be increases substantially.

The Rivard paper suggested that the cost of the scion seed was about $0.05/seed and the cost of the rootstock seed was about $0.30/seed. Grafting was only about 90% successful. And the cost of producing these transplants in Canada was estimated at $2.00 each before the cost of seed. To get 120,000 plants we will then need (120,000 / 0.90) = 133,333 transplants at a combined price of (0.05 scion seed + 0.30 root stock seed + 2.00 transplant cost) 2.35 each, for a total plant cost of $313,332.55, equivalent to $3.13/m^2 or $0.062/kg.

Nutrients

2.3.5.2 Plants extract nutrients from their environment in order to grow (University of Arizona, 2000). The main delivery mechanisms available to the farmer to supply these nutrients are by adding CO_2 to the air around the plants, and by adding fertilizers to the irrigation water using a practice known as fertigation. Sixteen elements used in high concentrations are carbon, hydrogen, oxygen, nitrogen, phosphorus, potassium, calcium, sulfur, and magnesium. Plants get their supply of carbon from CO_2 in the air, which is increased above regular atmospheric norms using the excess CO_2 produced by the boiler. In addition to the elements used in high concentrations, seven additional micronutrients that plants need are iron, chlorine, manganese, boron, zinc, copper, and molybdenum. These are all fed to the plants using a variety of fertilizer salts formulations.

Numerous publications (and opinions) on nutrient delivery can be found in the literature (Jones, 2004), though finding references that report annual costs in any meaningful way are elusive. Looking at the costs reported in (Alberta Agriculture and Forestry, 2001), a we can estimate $5.70/m^2, or a total of $570,000 across our 100,000 m^2 facility. Over the course of the year, $4.75 in fertilizers are supplied to each of the 120,000 plants.

According to (Welles, 2005) tomato greenhouses in British Columbia consume 0.8 m^3 of water per m^2 of crop, so we'll be needing 80,000 m^3 of water over the course of the year. According to the rate tariffs for the Corporation of Delta's water service bylaw (Corporation of Delta, 2016), there is an annual fee of $200 plus $0.74/m3 for the first 8,000 cubic metres per quarter and $1.25/m3 for every cubic metre after that. This means that the fees will add up to ($200 + 4 * (8,000*$0.74 + 12,000*1.25)) = $83,800/year.

Adding the cost of water to the cost of nutrients brings this expense category up to $653,880 annually, 7.0% of gross revenue, $0.13/kg and $6.54/m^2.

Greenhouse Materials

2.3.5.3 Greenhouse workers make use of a number of consumables while working on the crop throughout its productive life. At the beginning of the crop season, a spool of twine on a metal hook is hung from a wire run along each row near the top of the greenhouse, known as the crop wire. Various clips are used to attach the twine to the primary stem of the plant as well as to support the weight of the tomatoes on the truss. And the growing media that the plants grow their roots in is another consideration.

Miscellaneous other costs include disposable gloves, sanitation supplies, replacement knives and clippers used for pruning, and various other consumables used throughout the crop cycle, adding up to about $0.10/plant. Combined, this is yet another expense that is difficult to determine exactly, but this is a small per-plant expense. Adding up the cost of the twine ($0.50), the cost of the clips ($0.20), the cost of the growing media ($1.00) and miscellaneous cost ($0.10) gets us to an even $2.00 per plant or $240,000 in total for the crop.

Packaging Materials

2.3.5.4 Tomatoes in our model are packed into 5 kg cardboard cases and then shipped to the distributor. If we ship 5,040,00 kg annually, this means that we'll be needing 1,008,000 cardboard boxes to ship them in. Each of these boxes will also need a label and a box liner, a plastic indented sheet that the individual tomatoes are placed in to prevent them from moving around and bumping into one another inside the case. Individual tomatoes will have a PLU sticker, and pallets of tomatoes will also need to be wrapped and labelled again.

Prices per-box can vary based on order quantities, delivery charges, and box printing designs (colour, logos or other markings). For now, let's assume that each case costs $0.75, each label applied to the outside of the case costs $0.03, the liner inside costs $0.05, and PLU stickers are less than $0.01 each, maybe an average of $0.05 for all the tomatoes in the case. Damaged boxes, glue, pallet labels, and pallet wrap also add a little to the per-case cost, say $0.02 per case,
2.3.5.5 for a total of $0.90/case. Packaging materials overall then cost ($0.90/case * 1,008,000 cases) = $907,200. This works out overall to about 9.7% of gross revenue, $0.18/kg and $9.07/m^2.

Insurance

There are many kinds of insurance that are needed for this kind of business. Regular business insurance, insurance against damage to the greenhouse structure from weather as well as

crop insurance to cover losses due to unforeseen circumstances. Insurance for the workforce (WorkSafeBC in our model example) was included as part of the wage structure.

According to (Alberta Agriculture and Forestry, 2001), greenhouse insurance for their tomato crop was listed at $1.83/m^2 or a total of $183,000 for our model greenhouse. The biggest factor in determining an insurance coverage amount is naturally the value of what is being insured. In our case, we're going to be insuring the value of our crop at close to $10 million and the value of the greenhouse at $25 million. What portions and amounts are covered within those umbrellas, and the actual risks covered relative to the timing of the event (crop loss in October versus crop loss in June, for example), and the history of the business' past insurance claims are likely to have an impact on what the actual expense might be.

Department Budgets

2.3.5.6 Finally, we're going to assign an operating expense budget to each of the departments in our model greenhouse, and just a rough idea as to what kinds of things that might be covered. The general principle is that if you have a group of people doing a bunch of different tasks, they will, from time to time, depending naturally on the people and the tasks, have other expenses that the business will incur.

2.3.6 Expense Summary

Table 19: Expense Summary gives a summary of all of the expenses we've covered along with some simple per-unit calculations based on our previously claimed figures for gross revenue of $9,374,400, growing area of 100,000 m^2, crop yield of 5,040,00 kg and per-unit revenue of $1.86/kg or $9.30/case. The capital finance cost discussed in 2.1.6 is included here as well, to give a complete picture of what the cash outflows for the model greenhouse look like.

Although it may seem rather contrived that these expenses total the same as the gross revenue, ($9,374,400 - $9,375,159) = ($759) - a negligible loss, this is often the reality of the greenhouse business as we've discussed. The margins of error on all of these expenses, and on the gross revenue figure, are sufficiently large enough that whether the business makes money or not is likely not to be known until well after the last tomato has been picked. Considering the impact of the depreciation of the facility on the overall financial model, the benchmark greenhouse actually loses money each year.

Expense Summary	People	Expense	$/m2	$/kg	$/case	% Rev
People	**118**	**$ 4,552,680**	**45.52 $/m²**	**0.903 $/kg**	**4.517 $/case**	**48.6 %**
General Manager	1	$ 100,000	1.00 $/m²	0.020 $/kg	0.099 $/case	1.1 %
Growing Dept.	3	$ 175,000	1.75 $/m²	0.035 $/kg	0.174 $/case	1.9 %
Facility Dept.	3	$ 175,000	1.75 $/m²	0.035 $/kg	0.174 $/case	1.9 %
Greenhouse Dept.	3	$ 175,000	1.75 $/m²	0.035 $/kg	0.174 $/case	1.9 %
Packaging Dept.	3	$ 175,000	1.75 $/m²	0.035 $/kg	0.174 $/case	1.9 %
Administration Dept.	3	$ 175,000	1.75 $/m²	0.035 $/kg	0.174 $/case	1.9 %
Greenhouse Workers	85	$ 3,186,000	31.86 $/m²	0.632 $/kg	3.161 $/case	34.0 %
Packaging Workers	17	$ 391,680	3.92 $/m²	0.078 $/kg	0.389 $/case	4.2 %
Energy		$ 756,273	7.56 $/m²	0.150 $/kg	0.750 $/case	8.1 %
Tomato Plants		$ 313,333	3.13 $/m²	0.062 $/kg	0.311 $/case	3.3 %
Nutrients		$ 653,880	6.54 $/m²	0.130 $/kg	0.649 $/case	7.0 %
Packaging Materials		$ 907,200	9.07 $/m²	0.180 $/kg	0.900 $/case	9.7 %
Greenhouse Materials		$ 240,000	2.40 $/m²	0.048 $/kg	0.238 $/case	2.6 %
Insurance		$ 183,000	1.83 $/m²	0.036 $/kg	0.182 $/case	1.9 %
Department Budgets		$ 105,000	1.05 $/m²	0.021 $/kg	0.104 $/case	1.1 %
Expenses Subtotal		**$ 7,711,366**	**77.11 $/m²**	**1.530 $/kg**	**7.650 $/case**	**82.3 %**
Capital Financing		$ 1,663,793	16.64 $/m²	0.330 $/kg	1.651 $/case	17.7 %
Total		**$ 9,375,159**	**93.75 $/m²**	**1.860 $/kg**	**$9.301 $/case**	**100.0 %**

Table 19: Expense Summary

2.4 Profit and Loss

Table 20: Greenhouse Profit and Loss Statement summarizes this cycle into a Profit and Loss statement. In the final section, we're recording the interest paid on the capital financing expense, not the principal, and we're reporting depreciation of our facility at $1,000,000. This leaves a net profit in the business of $249,241. In reality, the depreciation on the facility isn't paid out of the business chequing account, but $1,250,000 is paid towards the capital finance principal. Naturally, how much of the principal is paid back each year may well be a function of much capital is available to the business. We're also not calculating any taxes for our model or for the new business. There are many considerations for agricultural tax planning, all of which are beyond the scope of this paper.

As an illustration, every 5 kg case of tomatoes is sold for ($1.86 $/kg * 5 kg/case) = $9.30. After passing through various distributor and retail markups, the consumer ultimately pays ($9.30 wholesale / 0.4 supply chain markup) = $23.25. From the Profit and Loss statement, we can see that ($0.05/kg profit * 5 kg/case) = $0.25/case is generated as profit by the greenhouse.

Annual Profit & Loss	Dollars	$/m^2	$/kg
Gross Revenue	**$9,374,400**	**93.74 $/m^2**	**1.86 $/kg**
Tomato Sales (5,040,00 kg @ 1.86/kg)	$ 9,374,400	93.74 $/m^2	1.86 $/kg
Cost of Goods Sold	**$ 6,448,366**	**64.48 $/m^2**	**1.28 $/kg**
Greenhouse Workers (average: 85)	$ 3,186,000	31.86 $/m^2	0.63 $/kg
Energy (Natural Gas)	$ 756,273	7.56 $/m^2	0.15 $/kg
Tomato Plants (net 120,000 plants)	$ 313,333	3.13 $/m^2	0.06 $/kg
Nutrients	$ 653,880	6.54 $/m^2	0.13 $/kg
Greenhouse Materials	$ 240,000	2.40 $/m^2	0.05 $/kg
Packaging Workers (average: 17)	$ 391,680	3.92 $/m^2	0.08 $/kg
Packaging Materials	$ 907,200	9.07 $/m^2	0.18 $/kg
Gross Margin	**$ 2,926,034**	**29.26 $/m^2**	**0.58 $/kg**
% of Gross Revenue	31.2 %	31.2 %	31.2 %
Sales, General & Admin Expenses	**$ 1,263,000**	**12.63 $/m^2**	**0.25 $/kg**
Sales (Managers + Expenses)	$ 0	0.00 $/m^2	0.00 $/kg
Admin (GM, Managers + Expenses)	$ 310,000	3.10 $/m^2	0.06 $/kg
Growing (Managers + Expenses)	$ 210,000	2.10 $/m^2	0.04 $/kg
Greenhouse (Managers + Expenses)	$ 175,000	1.75 $/m^2	0.03 $/kg
Packaging (Managers + Expenses)	$ 175,000	1.75 $/m^2	0.03 $/kg
Facility (Managers + Expenses)	$ 210,000	2.10 $/m^2	0.04 $/kg
Insurance	$ 183,000	1.83 $/m^2	0.04 4/kg
EBITDA	**$ 1,663,034**	**1.66 $/m^2**	**0.33 $/kg**
Interest	$413,793	4.14 $/m^2	0.08 $/kg
Taxes	$ 0.00	0.00 $/m^2	0.00 $/kg
Depreciation	$ 1,000,000	10.00 $/m^2	0.20 $/kg
Amortization	$ 0.00	0.00 $/m^2	0.00 $/kg
Net Profit (Loss)	**$ 249,241**	**2.49 $/m^2**	**0.05 $/kg**

Table 20: Greenhouse Profit and Loss Statement

2.5 Controlled Markets

Our model greenhouse, at least if it operates within British Columbia, is generally not simply able to start operating and selling its tomatoes to whomever it wants. Rather, it is subject to regulation by the BC Vegetable Marketing Commission (http://www.bcveg.com). Their role is to facilitate marketing activities across a number of greenhouse crops, including tomatoes, peppers, cucumbers, as well as various other vegetables, including peas, beans, corn, broccoli, brussels sprouts, cauliflower, cole crops, and strawberries, potatoes, carrots, rutabagas and others.

The Commission does this in part by controlling who can perform different roles in the industry. Producers (greenhouses and farms) must register with the Commission, including paying fees and agreeing to the Commission's terms, after which they are assigned quotas that determine what kinds of crops they are allowed to grow, and what growing area they can use. A handful of processing companies are similarly registered with the Commision. These companies (17 are currently listed on the Commission's site) are only allowed to buy produce from the Producers. They take produce and, well, process it into other products (as with our usual example, turning tomatoes into ketchup). Wholesalers are another group that need to be registered with the Commission. They are also only allowed to buy from registered Producers, and the Commission manages an extensive list of customers that are only allowed to buy from Wholesalers, thus controlling a large part of the market.

Fortunately, there are two exemptions that are relevant, listed in the Commission's Consolidated General Order (BC Vegetable Marketing Commission, 2014). First, exemptions are granted to greenhouse farmers (producers) that market solely to consumers via direct sales through their farms or local markets. There is a limit of 60 lbs of greenhouse produce per consumer for regulated produce. There are other provisions for "direct manifest sales" where BCVMC will supply a list of customers which are not eligible for such direct sales. Second, there is an exemption for "certified organic" farmers which may be applicable for certain types of produce. It may also be that 500 Foods falls outside the jurisdiction of BCVMC if it pursues primarily crops that are not regulated, or if it produces only value-added products (effectively becoming a processor in their view. Meeting with the Commission is on the short-term to-do list.

Although the typical large commercial greenhouse produce farmer isn't currently concerned with the sales and marketing of its produce, there is the potential for these businesses to capture a larger share of the value chain if they're willing or able to participate in it, either through direct selling or other means. A big part of the plan for 500 Foods is to exactly that, greatly shortening the path that produce travels to get to the consumer in the first place.

3 500 Foods

In Part 2, we developed a model of what a modern greenhouse business looks like, complete with a profit and loss statement and key performance metrics. In this part, we're going to explore 500 Foods, a new idea-stage that hopes to achieve comparable results, but using a completely different route to get there.

We're going to discuss in general terms what 500 Foods looks like, following the same order and structure we used in the model. This is a different farming system entirely, so we'll need to be sure that we've accounted for all the same revenue and expense amounts, and related activities, that the model covered.

Finally, we'll explore a different angle on marketing, an activity that is largely absent from our model. In order to capture more value (to get to a position of power from the quick 5 Forces analysis we did previously), we're going to take a different route to market – ultimately via direct sales to consumers through 500 Foods-owned retail outlets.

3.1 Facility

Using the same 16-hectare plot of land that we used in the model, Figure 9: 500 Foods Facility shows what a container farm might look like at scale. Each little coloured rectangle represents a stack of 5 containers. In this configuration, instead of a 10-hectare greenhouse, we've got approximately 10-hectares of containers along with some room to move them around. With 8 stacks, each 8 across by 5 high by 25 long, along with some extra room to move them around, let's assume that we have space for 7,500 containers operating at full capacity.

The containers themselves are standard 40' refrigerated containers, each requiring power to operate while sitting in the stacks. The cost of such a container, used, from local suppliers, based on various quotes, was about $7,500. The cost to outfit the container with the necessary shelving, irrigation lines, computer controls, and water tanks is about $2,500, bringing our total cost for a container to about $10,000 or $75 million for all the containers in the facility.

A pair of gantry cranes will be needed for each stack of 1,000 containers, at a cost of about $800,000 each, or about $13 million for the facility. These fully-automated cranes move containers from the stack to the warehouse at the right of the diagram, where they are processed (planted, maintained or harvested) before being placed back in the stack.

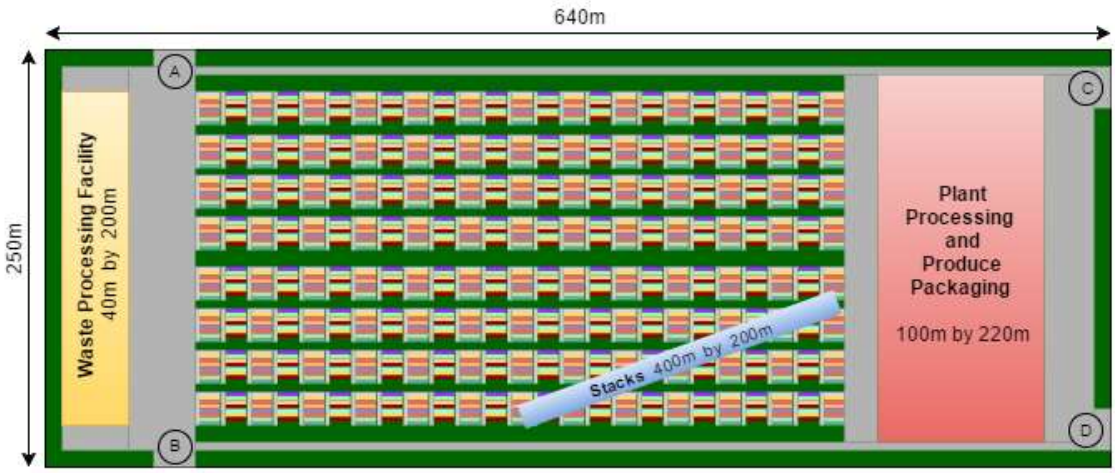

Figure 9: 500 Foods Facility

If each container is processed once per week, and the facility operates around the clock, this means that two gantry cranes from one stack have to deliver one container every ((7 days * 24 hours * 60 minutes) / 1,000 containers) = 10 minutes. Developing an algorithm to optimize this delivery will be an important activity. It is likely one of the cranes will deliver containers to and from the warehouse, while the other optimizes how the containers are arranged in the stack. Properly managed, containers could be delivered at twice this rate, one container every 5 minutes.

The two warehouses, one for processing containers and packaging fresh produce, and one for processing waste, would have a significant cost as well, but for our purposes, we're going to assume this is half the cost of the overall model greenhouse, or about $12 million. This gets us to a total facility cost of ($75 million containers + $13 million cranes + $12 million warehouses) = $100 million, or about four times the $25 million that our model greenhouse might cost.

Using the same capital finance model we used previously, despite the unlikelihood of being able to secure a traditional $100 million business loan, we would end up with a payment of $554,596 per month, or $6,655,152 per year, and a monthly interest payment of $137,932. At four times the capital expense, we'll also assume depreciation will be $4 million per year instead of the pervious $1 million per year. Logistically, however, the bulk of the assets are in containers, which would be recycled or replaced during normal use, so the depreciation in reality might look very different than what it might be for a greenhouse.

3.2 Revenue

For revenue, let's assume we're still growing the same tomatoes and selling them in the same way, earning $1.86/kg. To calculate how many kilograms of tomatoes we're able to ship from our 7,500 containers, we're going to have to make a few key assumptions.

First, the growing area of a container is the internal dimensions of a container minus whatever space is needed for equipment. For our purposes, and for simplifying the math a little, we'll assume that the growing area of a container is 2 m by 10 m or 20 m^2. Containers are a little bigger than that, so we're erring on the small side here.

Second, we're going to assume that we can grow two sets of plants in this volume. Imagine cutting the container in half, so that it is only about 1m tall instead of 2 m tall. Each half (bottom half and top half) could support a separate set of plants, thus doubling the growing area to 40 m^2. The reality of this is a little more complicated, but the idea is that, along with extra lights and extra irrigation lines, this level of plant density can be achieved in a contained volume.

Third, we're going to assume that the original crop yield of 50.4 kg/m^2 is going to be increased to 100 kg/m^2 due to having an unlimited amount of light and a potentially significantly extended growing season, no longer restricted by weather or available sunlight, and by specifically selecting tomato plants that have the highest production yields.

Overall, this means that we should be able to produce (100 kg/m^2 * 40 m^2) = 4,000 kg per container, or (7,500 containers * 4,000 kg/container) = 30,000,000 kg annually. Using the same figure for farm gate revenue of $1.86/kg, we can generate gross revenues of (30,000,000 kg * 1.86 $/kg) = $55.8 million annually, from a facility expected to cost $100 million. For comparison, the model greenhouse was expected to produce 5,040,00 kg, worth $9,374,400 annually, from a facility expected to cost $25 million. In Section 3.5.2, we'll briefly investigate the potential for earning more revenue, but for now we'll assume that we're selling our produce into the same market, for the same prices, as the greenhouse model.

3.3 Expenses

The following diagram (Figure 10: 500 Foods Departments) presents a high-level functional overview of 500 Foods, showing each of the departments. A key feature of this overview is that this is potentially a closed system. We'll briefly cover the labour requirements of each department to get an idea as to how the overall expenses relate.

An important difference here, however, looking at this level of overview, is that there is the potential for this business to operate almost as an entirely closed system in terms of energy and waste. If enough external biomass can be brought into the facility (food waste, yard waste or even construction waste redirected from local landfills) the biochar reactors would in theory be able to produce enough electricity to power the entire facility. Similarly, waste from the facility itself (either plant material like leaves, or waste produce from packaging) would immediately be sent to the biochar reactors for recycling, generating electricity instead of landfill material.

Management would be responsible for all functional areas except for growing, packaging, as these other operations are generally fully automated or use very few staff.

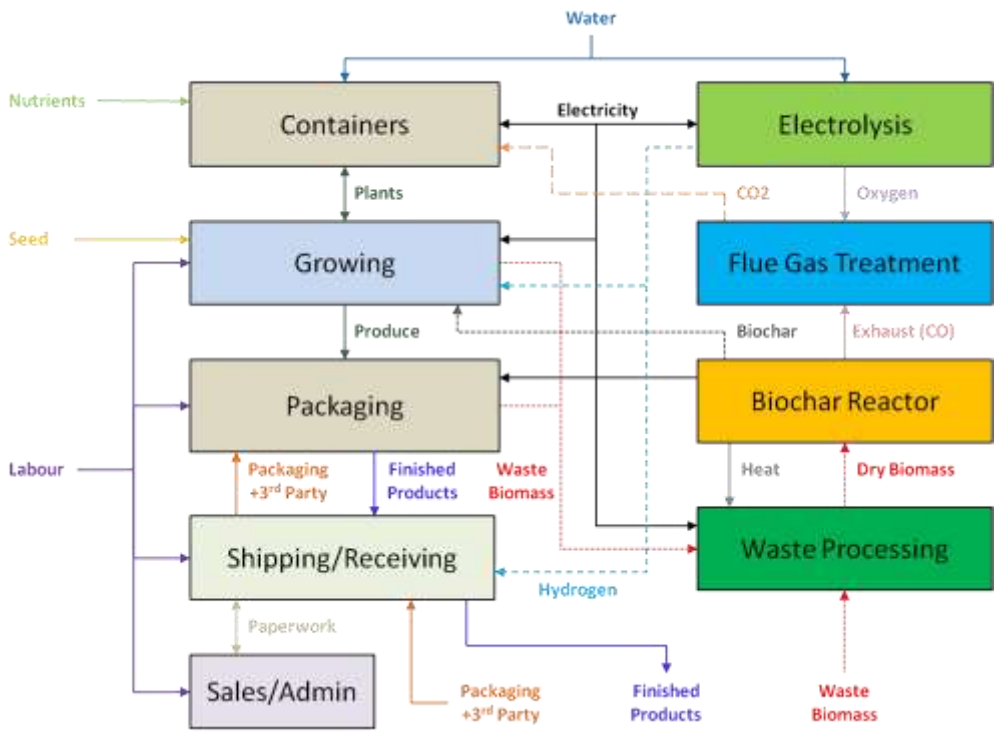

Figure 10: 500 Foods Departments

3.3.1 Management Staff

The hierarchy for 500 Foods would more closely match a typical business, with typical titles and typical roles. As a larger business, not as many responsibilities would be assigned to any one individual, so naturally the management team would be somewhat larger in comparison. Also, we're going to assume that they are paid competitive wages (c-suite at $200,000, everyone else at $100,000), twice what they make in the greenhouse, and that there are twice as many people working at the lower tiers. Using the same rough organizational chart as before, we get

Figure 11: 500 Foods Org Chart, with a combined labour cost of (6 * 200,000 + 20 * 100,000) = $3.2 million.

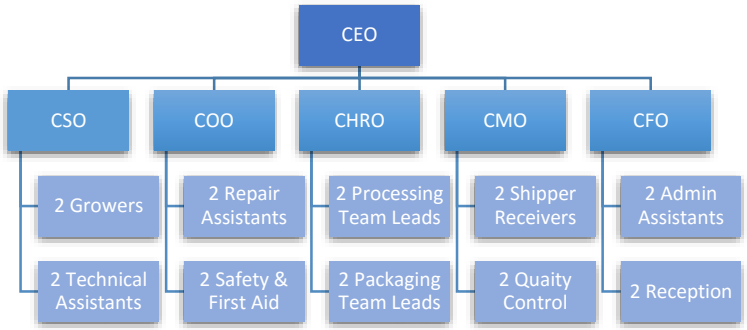

Figure 11: 500 Foods Org Chart

The roles of CEO, COO and CFO would be similar to traditional roles in any modern business. The CSO role refers to "Chief Science Officer" and is the equivalent to the senior grower role from the greenhouse, largely responsible for the plants that are growing inside the container. The CHRO role refers to "Chief Human Resources Officer" and is the combination of both the Greenhouse Labour Manager and the Packaging Manager roles, responsible ultimately for all non-management staff. CMO refers to "Chief Marketing Officer" responsible for working with the CSO to determine what to grow, as well as how best to package and sell the produce that comes out of the facility.

3.3.2 Containers

Referring to Figure 10: 500 Foods Departments, the container function represents the containers sitting in the stacks. As such, there is no labour component to consider. There is an operational expense, discussed in Section 3.3.5, covering the cost of energy to move containers with gantry cranes. The COO role would be responsible for ensuring the smooth operation of the cranes, but as they are largely automated, this is ideally not going to consume any operational costs other than energy and container maintenance, covered by the management team.

3.3.3 Processing

This is the function that deals with processing the container contents. Either planting new crops, performing various maintenance activities, or harvesting produce from the plants, or some combination of all three. On average, each container may be brought in to the warehouse once per week for processing, where a team of workers performs a list of tasks identified by the CSO. For example, in the 37th week after a container is first planted, it might be brought in to be

picked as well as deleafed. Each container, for each week, might have a different set of activities that need to be performed. Containers in the stack can be addressed in a random-access fashion. Their next processing times would be scheduled individually, and processed in priority order with the option to retrieve containers in exceptional circumstances (repairs, etc.).

The team works much like a team at an Indy 500 pit stop might work. A container is brought in, and workers perform all the necessary steps as quickly as possible, and then the container is sent out, with a new container taking its place, with its own new set of processing steps. For our purposes, we're going to assume that there are four workers doing the processing, one worker supervising, and one worker loading and unloading. We covered earlier that we can deliver one container from each stack every 10 minutes. If we use teams of six for each stack, that means each team has 10 minutes to process a container, leaving 10 minutes for unloading and loading each container as well as some extra time to allow for delays in container handling. Let's also assume that we pay all these people twice what they were before, or $30/hour.

In total, to process 7,500 containers, we would need 10 minutes of labour for each of the six workers, or one hours' labour for each weekly visit the container makes. This works out to ($30/container * 52 weeks * 7,500 containers) = $11,700,000 annually, also close to four times what the greenhouse model used. In terms of the number of workers, we'd need a team of six for each stack, and either three shifts for each stack or room for more than one team to work on one stack. This works out to a similar amount (6 people/team * 3 shifts * 8 hours/shift * 8 stacks * 365 days * $30/hour) = $ 12,614,400, which is the number we'll use as it more accurately reflects the true cost of labour (breaks and so forth) that just looking at processing times doesn't capture. If we assume a typical worker works 8 hours/day for 50 weeks/year (2,000 hours) then our processing teams will have a total of about 210 people.

3.3.4 Packaging

For packaging labour, we'll assume to be the same as the greenhouse model, as the job is essentially the same. Tomatoes arrive via a conveyor from the processing area and need to be shipped out in the same way, so using the final tally of $0.078/kg for labour, packaging 30,000,000 kg, we'd be looking at about $2,340,000 for packaging labour. Staffing this department will require about 39 people.

3.3.5 Energy

The cost of energy in a container farm relates to three separate functions. Lighting the containers (which indirectly heats them), cooling the containers (lighting them creates too much heat), and moving the containers. These all require electricity, so let's assume that we buy power from BC Hydro at the large customer rate, averaged at $0.06/kWh. Ultimately, if we produce enough electricity from our biomass reactors, these cost would be reduced substantially.

Lights for the containers would be supplied with LED lights, with a separate set of lights for each shelf in the container. As we've specified that we expect to have two shelves in the containers that we're using to grow tomatoes, we'll thus need two sets of lights. In order to replace sunlight, we'll need to have enough LEDs to produce the same amount of light for each set. PAR (photosynthetically active radiation) describes the type of light that plants can actually use, and corresponds to several wavelengths of light, in the range of 400nm to 700nm. By itself, PAR doesn't tell us very much, but by measuring how much PAR reaches the plant, we get another value, known as PPFD (photosynthetic photon flux density) that we can use for determining how much light we are providing, measured in $\mu mol/m^2/s$. For our location, a PPFD range of 500 to 2,000 $\mu mol/m^2/s$ might cover the sunlight we receive year-round.

In order to generate that much light with LEDs, strip lights could be used. If we accept that a given LED strip uses about 10 watts per metre, and can generate about 25 $\mu mol/m^2/s$ per metre, and we want to deliver an average of 1,000 $\mu mol/m^2/s$, we'll need about 40 strips, each 10 m long, for each shelf. Combined, (10 watts/m * 10 m/strip * 40 strips * 2 shelves/container) = 8,000 watts per container. If we further assume that we're going to run the lights 12 hours each day, then (8 kWh * 12 hours * 365 days * $0.06/kWh) = $2,102 per container or $15,768,000 annually.

Cooling the containers is a more difficult question. The 8,000 watts expended to generate light will also generate some amount of heat. How much will depend on how quickly air is circulated, what the outside temperatures are, and how much is dissipated through the container itself, as well as how efficient the cooling system is. Running a fan may cool the container significantly enough throughout much of the year, whereas actively cooling the container may be required at other times. If we adjust the timing of the lights so that they are on mostly at night, with cooler outside temperatures, let's say that we can get a per-container cooling cost of 1 kWh for 12 hours per day, for six months of the year. This amounts to (1 kWh * 12 hours * 180 days * $0.06/kWh * 7,500 containers) = $972,000.

Gantry cranes each consume about 40kWh to operate, and as they operate year-round, our fleet of 16 cranes will consume (40 kWh * 16 cranes * 24 hours * 365 days * 0.06 $/kWh) = $336,384. This assumes that the cranes are running continuously, and that this level operation is both sufficient and necessary to move enough containers through the processing facility. It may be that one crane of each stack sits idle for part of the day if the algorithm is efficient enough, for example, or that some containers don't need to be processed as quickly or as often.

Combining the cost of lighting ($15,768,000), the cost of cooling ($972,000) and the cost of moving ($336,384) we get a total energy cost of about $17,076,384, more than twenty times the energy cost of our greenhouse model. However, the variables that impact this cost are very different than greenhouse energy costs. It would largely be the same, independent of weather, location or time of year, variables that cannot be controlled. Cooler outside temperatures would actually reduce the amount of energy needed to cool the containers, rather than the reverse situation that the greenhouse finds itself in. Variables that could be now controlled include day length, light intensity, operating temperatures, or number of container moves.

Offsetting this cost, the main principle behind the biochar reactors is that waste biomass, from the facility itself or from external sources, could reduce this energy bill. If we assume that each processing step of a container produces some average nominal amount of biomass waste, say 25 kg, the facility itself will produce (25 kg * 52 weeks * 7,500 containers) = 9,750 tonnes of biomass annually, or about 1 tonne per hour. A biochar reactor (or a set of biochar reactors) that are configured to process one tonne per hour of biomass will produce about 50,000 kWh in electricity per day, which amounts to about $1 million in energy savings over the course of a year (Carbon Zero Project, 2016). Many of the largest greenhouses in Vancouver are now operating co-generation facilities, and a biochar reactor fits this model very well (no harmful byproducts).

Sourcing alternate supplies of waste biomass would therefore result in further energy cost reductions. To reduce the energy bill to zero, the facility would have to take in an additional 15 tonnes per hour (375 tonnes per day) of waste biomass. For comparison, Metro Vancouver produces more than 800 tonnes of food waste each day, or 300,000 tonnes annually. Other sources of waste biomass include waste from forestry operations, waste from housing demolition and construction, and waste from other greenhouse businesses.

Further energy reductions can also be found in optimizing the lighting systems of each container, the largest cost. Different lighting programs may be used (less than 12 hours per day overall, or maybe cycling the lights, with longer days but at lower average intensity). More efficient lighting systems are also possible, depending on how the power for lights is converted

into the 12V that these kinds of lights need. Let's assume that we're using biochar reactors and that we get some biomass from external sources, reducing our final energy bill to $15 million.

3.3.6 Other Expenses

Like the greenhouse model, there are a number of other directly comparable expenses that 500 Foods would incur, for all of the same reasons. If we collectively just include the costs for plants, nutrients, processing materials, packaging materials, insurance, and department budgets, based on product shipped, we get a total cost of $0.477/kg or $14,310,000.

3.3.7 Expense Summary

Table 21: Expense Summary gives a summary of all of the expenses we've covered along with some simple per-unit calculations based on our previously claimed figures for gross revenue of $55,800,000, the same growing area as the greenhouse, 100,000 m^2, crop yield of 30,000,000 kg and the same per-unit revenue of $1.86/kg or $9.30/case. The capital finance cost discussed previously is included here as well, to give a complete picture of what the cash outflows for the container farm looks like.

Expense Summary	People	Expense	$/m2	$/kg	$/case	% Rev
People	275	$ 18,154,400	181.54 $/$m^2$	0.605 $/kg	3.03 $/case	32.5 %
Management	26	$ 3,200,000	32.00 $/$m^2$	0.107 $/kg	0.54 $/case	5.7 %
Processing	210	$ 12,614,400	126.10 $/$m^2$	0.420 $/kg	2.10 $/case	22.6 %
Packaging	39	$ 2,340,000	23.40 $/$m^2$	0.078 $/kg	0.39 $/case	4.2 %
Energy		$ 15,000,000	150.00 $/$m^2$	0.500 $/kg	2.50 $/case	26.9 %
Tomato Plants		$ 1,860,000	18.60 $/$m^2$	0.062 $/kg	0.311 $/case	3.3 %
Nutrients		$ 3,900,000	39.00 $/$m^2$	0.130 $/kg	0.649 $/case	7.0 %
Packaging Materials		$ 5,400,000	54.00 $/$m^2$	0.180 $/kg	0.900 $/case	9.7 %
Processing Materials		$ 1,440,000	14.40 $/$m^2$	0.048 $/kg	0.238 $/case	2.6 %
Insurance		$ 1,080,000	10.80 $/$m^2$	0.036 $/kg	0.182 $/case	1.9 %
Department Budgets		$ 630,000	6.30 $/$m^2$	0.021 $/kg	0.104 $/case	1.1 %
Expenses Subtotal		**$ 47,464,400**	**474.64 $/$m^2$**	**1.582 $/kg**	**7.92 $/case**	**85.0 %**
Capital Financing		$ 6,655,152	66.55 $/$m^2$	0.222 $/kg	1.11 $/case	11.9 %
Total		**$ 54,119,552**	**551.20 $/$m^2$**	**1.804 $/kg**	**$9.03 $/case**	**97.0 %**

Table 21: Expense Summary

Compared to the greenhouse expense summary, this is slightly more profitable, with expenses consuming only 97% of revenues rather than 100%. There are more variables here, and a variation of just a few percent in the expenses of any category could wipe out this advantage.

However, it is also important to note that there are fewer risks in this scenario – fewer unknowns about the weather and about crop performance, in particular.

3.4 Profit and Loss

Table 22: 500 Foods Profit and Loss shows the final tally using the container approach. In this case, while every 5 kg case of tomatoes is sold for the same ($1.86 $/kg * 5 kg/case) = $9.30 as was done in the greenhouse model, 500 Foods will retain a slightly larger amount of $0.09/case instead of $0.05/case.

Annual Profit & Loss	Dollars	$/m^2	$/kg
Gross Revenue	**$55,800,000**	**558.00 $/m^2**	**1.86 $/kg**
Tomato Sales (30,000,00 kg @ 1.86/kg)	$ 55,800,000	558.00 $/m^2	1.86 $/kg
Cost of Goods Sold	**$ 42,554,400**	**425.54 $/m^2**	**1.42 $/kg**
Processing Workers (average: 210)	$ 12,614,400	126.14 $/m^2	0.42 $/kg
Packaging Workers (average: 39)	$ 2,340,000	23.40 $/m^2	0.08 $/kg
Energy (Electricity)	$ 15,000,000	150.00 $/m^2	0.50 $/kg
Other Expenses	$ 12,600,000	126.00 $/m^2	0.42 $/kg
Gross Margin	**$ 13,245,600**	**132.46 $/m^2**	**0.44 $/kg**
% of Gross Revenue	23.7 %	23.7 %	23.7 %
Sales, General & Admin Expenses	**$ 4,910,000**	**49.10 $/m^2**	**0.16 $/kg**
Management (Staff + Expenses)	$ 3,830,000	38.30 $/m^2	0.13 $/kg
Insurance	$ 1,080,000	10.80 $/m^2	0.04 $/kg
EBITDA	**$ 8,335,600**	**83.35 $/m^2**	**0.28 $/kg**
Interest	$1,655,184	16.55 $/m^2	0.06 $/kg
Taxes	$ 0.00	0.00 $/m^2	0.00 $/kg
Depreciation	$ 4,000,000	40.00 $/m^2	0.13 $/kg
Amortization	$ 0.00	0.00 $/m^2	0.00 $/kg
Net Profit (Loss)	**$ 2,680,416**	**26.80 $/m^2**	**0.09 $/kg**

Table 22: 500 Foods Profit and Loss

3.5 Non-Profitability

With a comparable production system in place, our attention turns to the non-profitability issue we identified in Section 1.3. The two areas we focused on, operational risks (weather, impacting expenses) and perfect competition (low supplier power, impacting reveneue), are just a subset of the problems facing the greenhouse industry. A more thorough analysis of the industry will be necessary, and should be completed as part of the first phase of any implementation plan. In this section, we'll revisit how 500 Foods intends to overcome these two problems in particular.

3.5.1 Operational Risks - Weather

Using shipping containers, where the business fully controls the growing environment, the impact of weather is very much reduced, with colder temperatures actually bringing a net benefit to the business, due to reduced container cooling costs, rather than an unpredictable added expense. Containers are meant to survive harsher environments than any greenhouse, like being lashed to the deck of a ship pitching to and fro in a tropical storm in the middle of an ocean somwhere, and isn't going to be impacted by any amount of rain, hail or snow.

3.5.2 Perfect Competition

Because the growing environment is so highly controlled, it is now almost a trivial matter to *grow a wide variety of vegetables*, rather than just tomatoes. So the business can actually do a great deal more to differentiate its offerings relative to its peers in the greenhouse industry, and thus break away from this model of perfect competition.

The approach we're going to consider here would be to setup a 500 Foods retail chain, where all the produce grown by the facility is sold directly to consumers. This brings a number of benefits that could be used to help market the stores to future customers:

1. Produce could be picked the same day it is available in the store, so it would be as fresh as simply going to any farmer's market or on-farm store.
2. Higher valued products could be created from the existing supply of fresh produce, including soups, salads or sandwiches, displacing food processing companies.
3. If hydrogen created from the biochar reactors is used to fuel trucks that transport produce from the facility to these retail outlets, the entire operation could be carbon-negative, meaning that the business takes in more CO_2 than it produces.
4. Using the model of a typical pizza franchise, home delivery would be an option.
5. Other complementary high-value items (salad dressings, teas, etc.) could also be sold through the same chain of stores, becoming a one-stop shop for people who prefer a vegetarian diet.
6. Less overall food waste would result from having the ability to send any waste material anywhere in the process back to the biochar reactor to generate energy.

Each (very small) retail store might be modelled after another similar retail business, perhaps Subway. The major expenses for a typical retail outlet might be $10,000/month for rent,

and (6 full-time people at $30/hour) = $30,000 in labour, to operate the store 8am-midnight, 7 days per week. A total of $40,000/month in expenses would then have to be covered.

Using our retail example from Section 1.2.6, a family of four spends $12.33 per week on fresh produce, of which $4.93 goes to the farm and $7.40 goes to everyone else which, in this case, would still be 500 Foods. To cover $40,000 in expenses, such a store would need ($40,000 / 4 weeks / $7.40/customer) = 1,351 transactions on average each week to break even. If the store were to be open 7 days a week for 16 hours each day, this works out to 12 transactions/hour.

Using tomatoes as the stand-in for produce generally, this means that each transaction would be for ($4.93/$1.86/kg) = 2.65 kg of tomatoes. The retail store would need to sell a total of 14,324 kg of tomatoes each month, or 171,882 kg of tomatoes each year, to recover its costs. If the facility could theoretically produce 30,000,000 kg, it would be enough to stock (30,000,000 kg / 171,882 kg/store) = 175 stores or (175 stores * 1,351 customers) = 236,425 customers visiting these retail stores each week, or about 10% of the population of Metro Vancouver.

For comparison, Subway has more than 400 stores in British Columbia, employing 4,000 people in more than 100 different communities. With only one store per 11,000 residents, they claim to be nowhere close to reaching market saturation (Vancouver Sun, 2013).

This analysis gives us an idea of what transaction volume is needed to break-even on the retail model. More detailed analyses of the kinds of produce that could be grown and distributed in such a way, as well as the many different types of value-added products (soups, salads and sandwiches), would be needed to determine how profitable this approach ultimately could be. Value-added products would be sold for a higher margin, and complementary products could also be sold for additional revenue. By capturing not just the next rung of the fresh value chain, but the entire value chain, some degree of supplier power might be possible, and therefore a considerably more profitable business could result.

3.5.3 Other Risks

There are certainly other risks facing a greenhouse, and other risks facing 500 Foods. For example, an extended interruption in the supply of natural gas to a greenhouse on a cold April day would be a big issue that would require a well-tested contingency plan. Similarly, an extended power outage at 500 Foods would also be problematic. This paper has introduced just two of these areas, but a full exploration of many other areas would be critical in assessing the feasibility of the project overall.

4 Implementation

In order to realize the objectives of 500 Foods in any reasonable amount of time, significant funding will be required which will most likely come in the form of venture capital. However, it is unlikely that even the most motivated investor would fund the full project as outlined based strictly on the contents of this paper, so a number of stages are envisioned. Each stage covers a particular problem area or question that is key to moving forward to the next stage. This section outlines five distinct stages, each an order of magnitude larger than the last.

Phase 1 is concerned with pre-investment activities. Developing a fully-developed business plan, well beyond this introductory paper, will be the primary focus of this phase. Developing some additional pieces that don't require capital, such as the container scheduling algorithm, will also be conducted in this phase. The end goal of this phase is to secure an initial round of $1.5 million in venture funding, sufficient to fully deploy Phase 2. Ideally Phase 1 work would be complete within six months.

Phase 2 is concerned with pre-revenue activities. The primary focus will be around deploying a test set of five containers to validate the key performance metrics outlined in this paper. There isn't really a question of whether fresh produce can be grown this way, it certainly can. We are more interested in determining the precise capital and operating costs of these test containers, as well as a better idea as to the initial yields for specific types of produce in this environment. Phase 2 work would be complete within one year, with the end result being a set of five containers that produce a predictable amount of produce, with a clear understanding of costs.

Phase 3 is concerned with post-revenue but likely pre-profit activities. A much larger facility will be required, something on the order of the 16-hectare site discussed throughout this paper. Moving containers will also become an issue, so this is where gantry cranes enter the equation. At the beginning of this phase, we'll be already producing a small amount of produce from the first 5 test containers, but will reach 100 containers by the end of this phase, expected to take about a year. Ideally, containers would be added initially at a rate of one per week. By the end of this phase, containers would be being added at a rate of two per shift (six per day), and the resulting produce from 100 containers would be generating predictable revenue for the business.

Phase 4 is concerned with scale, both in terms of the facility and in terms of profitability. With all the planning up to this point, scaling up should be straight-forward with the addition of more containers, more workers on more shifts, more gantry cranes, more retail outlets and more opportunities to start to capture additional value with the rest of the elements of the complete

plan. The primary goal of this phase is therefore to be profitable across the entire business. This introductory paper, in fact, describes what 500 Foods might look like at the end of Phase 4. Continuing at a rate of 6 containers per day, it would take about another 3.5 years to get to the 7,500 containers we've been exploring in this paper.

Phase 5 is concerned with scaling beyond this first facility. Growth should be predictably linear – more containers processed should be directly proportional to the revenue being generated. Locating suitable markets, and the investment funding required to establish a 500 Foods presence in them, will be the main activity in this phase which can continue indefinitely.

4.1 Phase 1: Pre-Investment

Starting a brand new venture in today's business environment can be a challenging task, and all the more daunting if venture capital is part of the business plan. 25 years ago, the internet ushered in a new era of information and entirely new markets, new business models and even new tech-savvy investors. The end result of the innovation in the venture startup space is that entrepreneurs don't have to do all the work themselves.

The BCIC Venture Accelerator Program was undertaken as part of this project in part to network with like-minded entrepreneurs starting new ventures of their own, along with mentors connected to the larger Vancouver investor community. The VAP program focused a great deal of attention on the Business Model Canvas, with a particular focus on customer discovery. The BMC for 500 Foods can be found in Figure 12: 500 Foods Business Model Canvas. Beyond the BMC, a considerably more comprehensive 500 Foods business plan will be developed.

In addition to business planning, several smaller projects that don't require significant capital will also be developed further. The gantry crane algorithm for container processing will be formalized. Software to manage container activity schedules and collect data will be developed further. Labour management software already in use in other greenhouse business will be adapted to better suit the needs of this venture. Presentation, marketing and branding materials will be developed further.

The latter part of Phase 1 will be more focused on approaching potential funding sources, including various government programs, angel investors and venture funds. The final goal of Phase 1 is to raise $1.5 million to fund Phase 2.

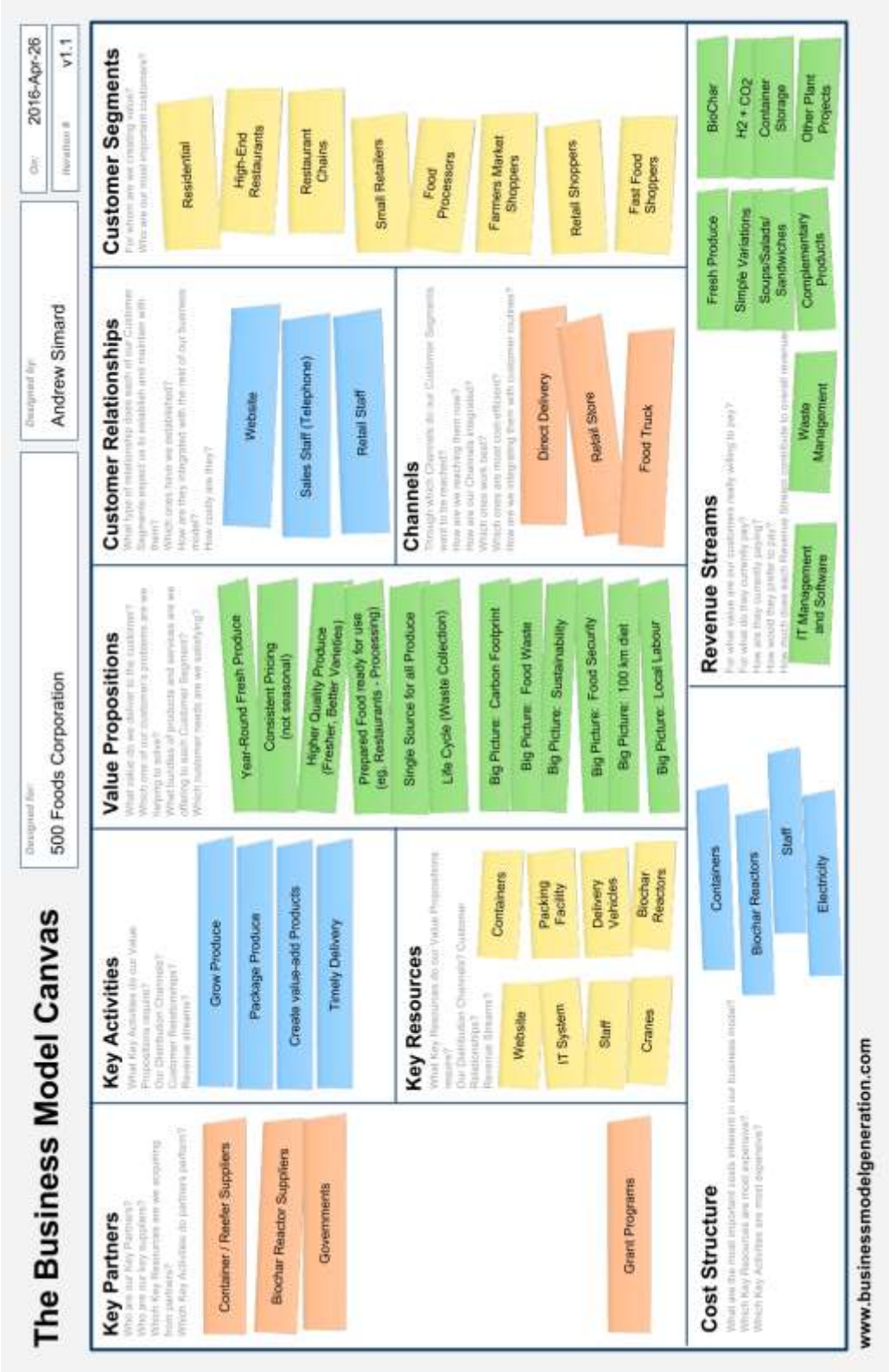

Figure 12: 500 Foods Business Model Canvas

4.2 Phase 2: Pre-Revenue

Phase 2 is focused primarily on the development of a test facility, a 5-container version of the 500 Foods facility outlined in this paper. The goal of this phase is to develop a more accurate understanding of the costing model for the containers (both capital and operating expenses) as well as to more fully develop some supporting infrastructure. While all this testing and development is going on, very little, if any, produce will be grown for sale. All of these efforts are geared towards preparing for commercial production that is to start in Phase 3.

4.2.1 Facility

Ideally, the venture would operate out of an industrial park-style unit, perhaps 10,000 sqft., with a loading dock equipped with five bays. Each bay would have a container parked at it for the duration of this phase. Warehouse space would be needed in to construct the growing support systems that will be used in the containers. Warehouse space would also be needed to test processing activities. Facility labour would primarily be just one person doing the construction and managing the containers, essentially a scaled down version of the Facility department. For our purposes, we'll assume everyone is paid a full-time wage with benefits, averaging out to $75,000 each.

4.2.2 Container Prototypes

Several containers will need to be acquired (leased or purchased) and different configurations of the internal growing environment will be built. This plan calls for five containers, one with just one growing layer, supporting plants up to 2 m tall. Two could be configured with two growing layers, supporting plants up to 1 m tall. And two more could be configured with three growing layers, supporting plants up to 65 cm tall. Each configuration would be equipped with a different number of lights, and thus have a different power utilization model, as well as different irrigation and fertigation requirements.

These containers, as prototypes, would cost a bit more ($15,000 instead of $10,000) to account for the extra sensors and various trials that will be necessary to figure out how to best manage crops. Once some of these parameters are known, and we've got a better handle on what designs work best, we can optimize this aspect of the containers, and we won't need nearly as many sensors for new containers. Ultimately, we'll be able to determine more precisely the actual capital and energy requirements to deploy a larger number of these containers.

4.2.3 Crop Development

Once the container prototypes are ready, it will be time to start testing various crops. Tomatoes, peppers, cucumbers and lettuce to start, but trial a variety of produce, figure out some initial parameters, setup system to record growth data (photos, measurements, automation, etc.). Start testing/verifying/improving crop templates. Some processing activities will be required as well. This is the miniature version of the growing department, needing two people. One to do the planning, and an extra pair of hands to do the work on the crop.

This will give us a more complete and repeatable recipe for what it takes to grow each of the crops that we test, and set us on a path to further refine and improve yields from these crops as we grow more instances of each. This will also generate the data to help validate the rest of our key performance indicators – those pertaining to crop yields and labour performance.

4.2.4 Mock Storefront

There are two purposes for this project. First, the idea is to get started on the branding side, getting an idea as to what is important for the appearance and content of the stores – what draws in customers, what do they want to see on the shelves, what kinds of shelves, etc. The idea is to invite designers to submit their ideas for a traditional retail store design.

Second, the idea is to sort out some of the other aspects of the retail store design. Point-of-sale systems (checkout register, scale, software, etc.) will be needed just as in any grocery store. This is also where various refrigeration tests can be performed, testing shelf-life and product longevity in different packages, as well as finding packaging that works, labelling systems, and seeing how close we can get to the zero-waste goals that we have.

The goal is to be ready to actively sell produce at the end of Phase 2.

4.2.5 Develop 3D Model Facility

In order to help visualize how the facility in Phase 3 might operate, this project is tasked with developing a 500 Foods Simulator. This will include an interactive 3D model of the facility, suitable for planning the design of the actual facility. The simulator will also allow us to test some of the algorithms that have been developed in Phase 1, particularly those related to container management (ordering the containers, digging out containers from the bottom of a stack, that sort of thing) and how processing will work when scaled up. This will be used to also explore how best to optimize growth in Phase 3, such as metrics to determine when to add cranes.

4.2.6 Modified Atmosphere Packaging System

500 Foods intends on using an innovative (though not entirely new) system of packaging fresh produce in a modified atmosphere packaging system, prolonging the shelf-life of virtually all types of fresh food, including meat, vegetables, fish, and so on. At this stage, we intend to develop this system further to optimize packaging for the kinds of produce that we wish to offer.

We hope to determine what the optimal best-before dates are for a variety of SKUs, along with more precise packaging parameters. For example, cherry tomatoes are picked at a specific stage or colour. The expected room-temperature shelf-life might be 7 days. Using modified atmosphere packaging for a 300 g SKU, where the packaging film has no perforations, the shelf-life might be extended to 12 days. Perhaps with 150 perforations it can be extended to 21 days.

Costs for this project are primarily related to the machine itself. It replaces the air inside a package with a modified atmosphere – typically different levels of nitrogen, oxygen and CO_2. Then it seals the package with a film. A different machine is then needed to perforate the film in a specific way, to allow the exchange of gases. Combined with a scale and a labelling system, the end result is a small production line with fresh produce entering at one end and ready-for-sale product at the other. These kinds of machines are offered for sale by several vendors.

4.2.7 Administration

Underlying these projects will be a substantial amount of administrative work, software development and of course just the paperwork needed to run a business. Expenses related to utilities, computers, office supplies, in addition to the tools and materials needed for operating even a small crop production facility will be significant.

4.2.8 Phase 2 Summary

Combined, these all add up to $745,000, summarized in Table 23: Phase 2 Implementation Budget. At the end of the project, we would have a pretty accurate set of data to validate all the operational aspects of the 500 Foods business model in operational terms, as well as a head-start on crop-research for a number of different crops. From the point of view of a prospective investor (say, a venture fund) there isn't really an exit stage here. This is more of a test to ensure that everything works as advertised before investing a larger sum for Phase 3. This kind of transaction might be managed through a relationship between an angel investor and a venture fund, or through a venture fund directly, but the 'value' at this stage is in the validation of the larger Phase 3 plan.

Phase 2	Budget
Manager (1 person)	$ 75,000
Facility Lease @ $10,000/mo.	$ 120,000
5 Containers @ $15,000/ea.	$ 75,000
Facility Manager (1 person)	$ 75,000
Crop Development (2 people)	$ 150,000
Mock Storefront	$ 25,000
3D Model	$ 25,000
Modified Atmosphere Packaging	$ 75,000
Administration Staff (1 person)	$ 75,000
Everything else (heat, power, IT)	$ 50,000
Total	**$ 745,000**
With 100% Contingency Fund	**$1,500,000**

Table 23: Phase 2 Implementation Budget

4.3 Phase 3: Pre-Profit

Phase 3 is focused on setting up the minimal operational skeleton of 500 Foods as we've outlined in this paper. The includes the development of an actual operational container facility as well as establishing the first retail store. While Phase 2 was generally concerned with what was inside the containers, Phase 3 is now concerned with what is happening outside the containers.

4.3.1 Facility

In this phase, we'll need enough space for 100 containers and the ability to move them around with gantry cranes, so we'll be looking for a larger facility with additional loading dock bays to handle processing more containers simultaneously. Ideally, we'd end up in a facility that could also be expanded all the way through to the end of Phase 4 without having to move again.

Biochar reactors will be part of this phase so we can properly evaluate its operational performance, specifically looking at its energy production capacity. There is more money allocated to this than the cost of the biochar reactor, in part because this is a larger unknown. Systems to capture and process flue gases, for example, or a component to convert heat to electricity, may all be highly desirable. Figuring out which parts to add first, or what will generate a better return for our investment dollar, will need to be considered carefully. One or two biochar reactors would be installed by the end of Phase 3, with a clear understanding of the operational parameters and capital costs needed to expand further. Work on sourcing alternate biomass supplies will also begin once the reactors come online.

4.3.2 Processing and Packaging

With ultimately 100 containers to process each week, the team working on processing will need to grow a bit more, to ten people. It will take them awhile to get up to speed, particularly the speeds needed to make 500 Foods a profitable reality. Some additional infrastructure will need to be setup – conveyors and bins and that sort of thing – to help facilitate the increased productivity that we're after. Like processing, packaging will need more people (five) and more infrastructure. Packaging materials, labelling systems, scales and so on.

4.3.3 Retail

Once we've consistently got enough crops producing (maybe after six months) and we've got our packaging line operating efficiently, we'll need to setup a store. Leasing a location and outfitting it with the designs we came up with in Phase 2, as well as setting up an operational Point-of-Sale system is going to cost quite a bit of money, particularly for the first store. The store lease is likely to be about $10,000/month anywhere within the Vancouver city limits. We'll set the budget at about $250,000 just to open the doors, with the idea that this is ultimately going to happen later in this Phase rather than immediately at the outset.

4.3.4 Phase 3 Summary

In total, this adds up to just under $10 million, with the detailed breakdown shown in Table 24: Phase 3 Implementation Budget. At this stage we're basically all set and operating, adding containers regularly and increasing the amount of produce available to the retail store. We've done all the work necessary to produce and sell regularly, and have all of the operating information to continue, with a clear picture of where Phase 4 will take us. With our 100 containers, we should be on-track to generate about $1 million in revenue at the start of Phase 4.

From the investor's perspective, this business should now be on a specific linear trajectory, making a set amount of money relative to the number of containers it has, along with a specific formula of how much additional capital is needed to increase revenues by a particular amount. For example, 1,000 containers might add $10 million in revenue, but require an additional 20 workers and $10 million in capital. The resulting formula, assuming that it is profitable and skewed in the right direction, should be sufficient to attract either a larger investor to buy out the smaller venture fund or angel investor, or sufficient to attract a buyer for the business. Potential buyers could include large retail stores, a business like Amazon, or perhaps a

government agency looking to secure a guaranteed food supply for a particular population (northern communities, for example).

Phase 3	Budget
Manager (1 person)	$ 75,000
Facility Lease @ $50,000/mo.	$600,000
100 Containers @ $10,000/ea.	$ 1,000,000
Gantry Cranes (two)	$ 2,000,000
Facility Team (5 people)	$ 375,000
Processing Team (10 people)	$ 750,000
Packaging Team (5 people)	$ 375,000
Biochar Reactor Prototypes	$ 2,500,000
Administration Staff (3 people)	$ 225,000
Conveyors and Equipment	$ 1,000,000
Retail Store	$ 250,000
Everything else	$ 250,000
Total	**$ 9,400,000**
With 50% Contingency Fund	**$ 15,000,000**

Table 24: Phase 3 Implementation Budget

4.4 Phase 4: Scaling Up

Phase 4 is simply focused on increasing the capacity for all facets of 500 Foods, adding more containers, more processing capacity, more biochar reactors, more retail stores, and more staff to support the operation and move it towards profitability. The trajectory at this stage is expected to be linear, with continued growth possible so long as investments in capacity continue.

The end of Phase 4 is really what this paper has been exploring. Table 22: 500 Foods Profit and Loss describes what the end of the last year of Phase 4 might look like. Adding six containers a day, it will take nearly 3.5 years to reach that level of activity, but it will also take time to build out the retail infrastructure and gain the efficiencies we need to be profitable.

The capital requirements for this phase should be predicate, as outlined in the example in the last section. To add another 7,400 containers will require $74 million, and the extra gantry cranes would cost $12 million. But these can all be added incrementally. It may even be feasible to fund part of the growth of this phase using the proceeds of the business. For example, if we can source enough low-cost (or no-cost) waste biomass to reduce our energy expenses, there may be sufficient funds to grow the business organically (pun not entirely intended).

4.5 Phase 5: Scaling Out

This last phase of the implementation is really just about duplicating the 500 Foods facility in another location, to serve another market. Determining where to develop the next site (or multiple sites) will be the initial focus. Such a facility could be built nearly anywhere, though to capture the most value initially, the approach would likely to expand to areas where fresh produce is unavailable for the longest periods throughout the year, while also having a large enough regional population to support a facility large enough to benefit from such scale.

Unlike greenhouse businesses, synergies between different 500 Foods sites could be significant. Sharing containers that are already producing harvests could help a new facility generate revenue immediately, for example, regardless of when it starts operations. And the very nature of global shipping means that a network of such facilities could literally span the globe.

If venture funds are still wrapped up in the business at this point, we'll need to find an exit strategy, either via an appeal to public markets or by finding a large corporate buyer. We mentioned a few previously, but at this stage there may be other interested parties as well. Particularly foreign governments concerned about local food security. As an operating company with a predictable rate of return, the business itself becomes a commodity, ready to be bought and sold just as readily as the produce it grows.

5 Conclusions

The intended purpose of our exploration of 500 Foods was to determine whether a new form of industrial farming could improve upon existing methods currently employed today. With the growing need to increase crop yields beyond what we can currently achieve, we need alternative solutions, but we also need to be more mindful of the impact industrial farming can have on the environment. The containerculture methods that 500 Foods hopes to employ seem to be able to accomplish these goals, while also addressing some of the problems facing the fresh produce greenhouse industry.

Let's first consider our four key performance metrics: crop yield (kg/m^2), labour performance (hours/kg), cost (\$/m^2) and revenue (\$/kg). Looking at the profit and loss statements and the underlying data from both the greenhouse model (Table 20: Greenhouse Profit and Loss Statement) and from our container exploration (Table 22: 500 Foods Profit and Loss), we can now draw some direct comparisons.

In terms of crop yield (kg/m^2), the container model is ahead of the game, as using the same amount of land, we're producing 30,000,000 kg instead of 5,000,000 kg. This is largely attributable to simply stacking containers on top of one another, but also due to increases in yields from having more control over the growing system. Being able to grow year-round also means that the growing season can be arbitrarily extended for some crops, increasing yields further.

For labour performance (hours/kg), we know from the greenhouse model that we needed 118 people, at an average of 2,000 hours per year, to produce 5,040,000 kg, which works out to 0.047 hours/kg. In the container model, we needed 275 people, at an average of 2,000 hours per year, to produce 30,000,000 kg, which works out to 0.018 hours/kg, more than twice the performance. This can be attributed largely to how labour is managed. Using the team approach, with a small group processing each container once per week, less time is spent processing the containers than is spent by individual workers walking up and down greenhouse rows. More direct support and supervision may very well lead to higher quality work as well.

Overall cost (\$/m^2) is naturally much higher, given how more expenses are needed per unit of area. If we consider the overall cost instead as a function of production (\$/kg) we see that the expenses are slightly lower (\$1.804/kg versus \$1.860/kg) even though wages were doubled for 500 Foods versus the greenhouse model. The biggest change overall is that the cost of energy is substantially higher, due to having to provide light and cooling for all of the containers. If

enough biomass could be sourced, however, the facility could theoretically be a net producer of electricity, using it as a source of revenue rather than an expense.

Revenue ($/kg) was set to the same amounts for both models initially, as we had first envisioned 500 Foods as a tomato production facility. In Section 3.5.2, we expanded this by suggesting that a retail chain of stores could be used to sell a broader array of produce that 500 Foods would be able to grow. This has the potential to capture the entire share of the revenue stream, moving away from the position of nearly zero supplier power, in the 5 Forces model.

Beyond key performance metrics, the main operational risk identified for greenhouse businesses, weather, is largely a non-issue. Containers can be used to grow produce year-round, and colder temperatures actually help reduce the cost of cooling them. Extended overcast periods have no bearing on container production, nor do any other weather-related risks.

All of this comes at a much larger capital expense, and with a potentially much larger energy bill. While sourcing additional waste biomass can help with the latter, finding venture funding, or funding of any kind, will be a key activity at this early stage.

Further development and refinement of all of the concepts covered so far, as well as expanding our scope to look more closely at all the potential risks, will be critically important if 500 Foods is to advance beyond the pages of this paper.

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