Controlled Environment Agriculture Greenhouses in Alaska

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Abstract

This project investigates the economic viability of producing Controlled Environment Agriculture (CEA) in the Southwest Alaska communities of Kodiak, Dillingham, Akutan and Saint Paul. The primary objective of this research was to aggregate existing CEA greenhouse production and research in North America. Conclusions were drawn from existing empirical data to identify assumptions that were applied to conditions at the selected communities. Using those assumptions an enterprise budget was drafted to investigate operating revenue and expenses, as it applied under various models. The conclusions drawn from this study indicate that there is a high likelihood of successfully implementing a viable CEA greenhouse under the correct circumstances. Additional research is required before final determination can be made to move forward with development.

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Table of Contents

Tables

1. Introduction

1.1. Background

While Southwestern Alaska exports more food than any other region in the State, exceedingly expensive input prices for local consumption drive the cost of food, and food production, to relatively excessive levels. The region's geography, defined by mountains, encapsulated by the ocean, and expanding vast distances, imposes great difficulty in establishing efficient modes of transportation. The result is higher energy prices, which translate to expanding costs for all aspects of life in the region. The heavy reliance on outside factors to determine economic growth is a cause of great public concern. This heavy reliance on outside factors also precipitates a colony style economy, where outside money invests in local resources, takes profit and leaves. A colony style economy exports dollars and resources that could otherwise be used to develop stronger local communities, and collectively, the entire region. Due to the large expenditures required to import food, many dollars are exported, rather than circulating within the community.

The problem and obvious reason of importing food is that a challenging, cool and often wet environment is not conductive to harvesting supplies sufficient to meet local demand. The abundant resources available from the ocean are critical components of the food supply in the region; however, that resource does not meet the entire demand for food. Firsthand account from the region shows that the added effort, expense and lack of availability of quality fresh produce deters residents from consuming quantities that may otherwise be the case if a local supply was viable. The other important aspect of developing a local food supply is that dollars generated could circulate through the community and be a direct driver of economic activity.

1.1. Solution

Advances in renewable energy resources have promoted interest in developing energy inputs closer to home. With the exception of hydropower, and to a limited extent wind, renewable resources have not proven to be an effective means of reducing the cost of energy. The food and energy shock of 2008, required local leaders to be forward planning, turning an eye to the future to reduce vulnerable communities to outside factors and plans for local energy security. Southwest Alaska has an abundance of hydro, wind, geothermal, tidal and even limited potential for solar resources to provide its future energy supply. All of which are being researched in anticipation of a technological breakthrough which will create a competitive environment for those sources of energy; or another spike in the price of fossil fuels which will make alternatives a more reasonable solution.

As the potential for cheap energy expands to become more plausible, the prospect of creating a local food supply also becomes attainable. Advances in Controlled Environment Agriculture (CEA) have presented themselves as viable options for creating a food supply in an otherwise inhospitable growing environment. CEA is still an emerging technology, as computer systems have been integrated to control all aspects of the internal growing environment: Lighting, temperature, nutrients, hydroponics and air control. These variables create the potential to develop a commercial agriculture business anywhere the input prices cost less than the output potential, including indirect monetary multipliers.

The determining factors in developing a CEA greenhouse then become an analysis of those input factors: What are the heating units required to hold temperature at optimal levels, year-round? What lighting scheme will provide the perfect growing environment which leverages swing of 6 to 18 hours per day? What are the water requirements, and effectiveness of a hydroponic system? What area the equipment and technology requirements that produce an optimal output? What are the land and other rent requirements? What are the operational and capitol costs?

The output benefits need to be weighed against the potential community impact: What is annual yield, at a nutritional equivalent unit and what value can be retained for those products? What are the multiplying factors of operating and retaining profits which are recycled into the local community? What is the consumer surplus due to a reduced cost and intrinsic value for locally grown food products? How will infrastructure and labor force development affect the community?

Four communities in Southwest Alaska stand out for further investigation based on community factors: Kodiak, Dillingham, Akutan and Saint Paul. Each of these communities has the benefit of relatively narrow range of temperature deviation from those necessary for favorable growing environment. As fishing communities, each has a strong sense of individuality and community cohesion that may prove necessary to support a greenhouse capable of increasing economic activity. Kodiak has a developed logging industry which may be able to provide wood biomass competitively. Only Kodiak has a developed alternative energy sector capable of reducing costs, although each of the other communities is investigating expanding their renewable energy capacity. Akutan has recently discovered a shallow well, high temperature geothermal source, with plans for further development. Saint Paul has installed wind turbines with potential for available capacity. Dillingham is actively looking for a resource capable of weaning the region away from fossil fuels. Dillingham also has the potential for seed money to subsidize a sustainable industry in the form of the Pebble Partnership Sustainability Fund, for Bristol Bay entities.

1.2. Objective

The objective of this project will be to analyze existing empirical studies and define the Controlled Environment Agriculture greenhouse industry to draw conclusions for input costs and output potential for four communities in Southwest Alaska; this study will provide the preliminary information necessary to identify areas of strength and weakness to be identified in further analysis. Based on the success of the Chena Hot Springs model, research by the University of Alaska Fairbanks, empirical evidence supporting CEA in various regions around the world, the input potential at each of the identified communities, a cultural shift towards locally supplied food products, and uncertain outside factors affecting local economies, further research to determine the feasibility of such a project is justified. Other research Universities in the US are actively engaging CEA agriculture capable of producing higher yields with the capability to meet US demand for fresh produce; Canada has a highly developed industry of CEA greenhouses. The CEA greenhouse industry and research is important as it points to a future where Southwest Alaska will one day be able to provide its own local food supply through greenhouse produce.

This study is important as it will investigate CEA greenhouse potential in select communities in Southwest Alaska. A primary objective of this study will be to identify all measureable inputs and outputs and establish tables that calculate input costs and output potential. Beyond the importance to the communities in this study, other communities will be able to identify the information needed to update the tables with their own factors in other communities. Inefficiencies will be able to be adjusted and analyzed to see what changes will be necessary to overcome challenges to establishing an economically viable greenhouse industry. Prohibitive electric costs could be adjusted to see what price would facilitate the profitability of the greenhouse, if, for instance a new energy resource was able to reduce that price to a certain level.

A limitation of this study will be that assumptions are made based on results recorded outside of the study area. It is unlikely practical implementation in communities in this study will yield results exactly the same as data recorded in other studies. The results will be that cost benefit analysis will be based on numbers that do not necessarily accurately identify the true inputs and outputs, but rather base assumptions on national statistics and other empirical data, which may not be a direct reflection of local factors. This study will identify a number of areas for further study that will need to be addressed through additional research.

1.3. Benefits

CEA greenhouses are built to serve the highly technological and specialized purpose of mass producing agriculture with the utmost efficiency. While a typical agricultural farm produces output on an acreage basis, CEA greenhouses calculate precision input costs, and output potential on a per foot basis. This study is for researchers, entrepreneurs, and community leaders who may further investigate issues addressed in this study and move to develop a viable industry producing locally grown food supply. The results in this study can be used to identify step by step factors used determine the profitability of potential greenhouses, as well as easily reviewing areas of inefficiency. As all data has been broken into line item inputs and outputs, adjustments can be made to determine what changes would need to be required to develop an economically viable operation. These theoretical adjustments will need to be analyzed to determine applicability at the community level. The benefit of this study is to outline the initial data sets that will need to be analyzed before determining if a greenhouse industry in Southwest Alaska is an economically feasible option.

2. Community Analysis
(Community Database Online , 2010)

2.1. Akutan

Akutan is both a community and an Island at the western end of the Eastern Aleutians Borough, 35 miles east of Dutch harbor and 766 miles west of Anchorage. The community is only accessible by sea or air. The village of Akutan is comprised of about 90 year round individuals, mostly from Aleut decent, and a highly transient population of between 700 and 900 workers living at the Trident fish processing plant. Members of the City of Akutan claim that the Trident facility is one of the largest land based fish processing facilities in Alaska, if not the entire Northern Hemisphere, in terms of volume passing over its docks. Currently, all produce is shipped in through Dutch Harbor and distributed through the local store. As recorded in a personal correspondence on October 22nd, 2010 with Abe Palmer, assistant produce manager of Safeway in Dutch Harbor; they receive about 12 pallets of vegetables per week: 50 cases of tomatoes, 5 cases of cucumbers, 7 or 8 cases of peppers and 25 cases of leafy greens. Prices on that date were: $3.99 per pound of tomatoes, $2.69 each for cucumbers, $2.49 per pound for green peppers, $3.49 per pound for red and yellow peppers and $2.99 each for iceberg lettuce. Each of the above would have to be shipped and resold in Akutan for an additional premium.

The maritime climate of Akutan allows a moderate temperature variation, on average between of 32.5 degrees Fahrenheit in January and 53.4 degrees Fahrenheit in August. Wind and cloud cover is common. While the narrow variation in temperature is beneficial for controlling the internal temperature of the greenhouse, the cloud cover will require a greater supply of artificial light. The high winds may pose a challenge in designing a structure that will be able to withhold hurricane force winds during storms, and a stiff, steady breeze the rest of the time. The fishing fleet which frequents Akutan will require an additional food supply. It is unknown how local demand will compare to the national statistics used for this study of either produce with a short shelf life and high water content, or other vegetables with more sustenance and higher vitamin content. Another aspect of the fishing fleet is the fish harvested, and the waste use potential of that product. Two inputs that are valuable to a greenhouse are nutrients and heat. Although technically, fish waste has the potential to provide both of these, it is beyond the scope of this project to determine the extent that those products could be of value. Labor is a large expense for any new business venture. Akutan is a working community, where the large majority of the population is used to working 16 hour days, averaging only $8 an hour, plus overtime at the Trident processing facility. Further analysis will be required to determine if that labor structure is appropriate for the community greenhouse, but it is reasonable to assume that if employees are willing to work those hours in a fish processing facility, they would also be willing to spend those long days in a greenhouse. In addition to laborers, the community would likely need to train a specialist that could manage the highly technical aspects of environmental control and harvest.

The City of Akutan has had success in identifying a potential geothermal source of energy on City land. During the summer of 2010, wells were drilled which identified a hot, shallow source of energy. Based on that work, plans have been drafted to develop this local source of energy capable of meeting the community's energy needs for both heat and electricity. A cheap source of power that could be scaled to meet the needs of the community could have a very favorable effect on the feasibility of a CEA greenhouse.

2.2. Dillingham

Dillingham is located at the headwaters of Bristol Bay, near the confluence of the Wood and Nushagak Rivers; it lies 327 miles southwest of Anchorage. The community is only accessible by sea or air. The year round population is 2264 residents; during the summer months the population can double when the summer salmon season is under way. The population is a mix of native and non-native residents, the summer population shifts away from being predominantly native with the influx of outsiders to harvest the world's largest sockeye salmon run. Salmon is an important source food for residents of Dillingham, which is prepared and stored in the summer for year round supply. There is a local Alaska Commercial Company that distributes food to the community, and in recent years Full Circle Farms has become a popular source of fresh organic vegetables. As recorded in a personal correspondence on October 22nd, 2010 with Rae Belle Whitcome, Director of Workforce development for Bristol Bay Native Association in Dillingham: Price of tomatoes range from $3.99 - $4.59 per pound, cucumbers are $1.99 each, peppers are $2.00-$3.00 per pound and leafy greens are $2.69 - $3.29 per pound.

The climate is partially affected by the relatively warm maritime air coming off the water and the cold arctic air coming from the interior. The average temperature ranges from 14.4 degrees Fahrenheit in December to 55.0 degrees Fahrenheit in July. This variation is still relatively narrow compared to some regions of Canada that have successful implemented a greenhouse industry; although the affect of arctic air does reduce winter temperatures, which will be reflected in greater costs to maintain optimal heat in a controlled environment. Cloud cover and wind are common, but relatively more moderate than other areas of the region due largely to the arctic weather patterns balancing the maritime climate. The population potential varies, with a reported doubling of the population in the community during the summer due to the more than 2,000 salmon fishing operations and seasonal tourism. It is unknown how local demand will compare to the national statistics used for this study of either produce with a short shelf life and high water content, or other vegetables with more sustenance and higher vitamin content. Dillingham has a vast resource in salmon waste during the summer months, although less, if any would be available for year round contribution to a greenhouse operation; it is beyond the scope of this project to determine the extent that salmon waste could be of value to offset input cost for a greenhouse. A community college exists in the community that may provide the advanced labor force necessary to operate the technical aspects of the greenhouse. Many members of the community operate seasonal greenhouses. A high rate of unemployment provides slack in the market to provide the necessary labor to operate the greenhouse.

An attempt to develop a geothermal source in Naknek, a nearby community appears to be on hold indefinitely. Regionally, a shift to wean itself away from fossil fuels is ingrained in the strongly independent community culture. Plans are in place to investigate further developing the wind sector. The community college is investigating other options for generating cheaper energy with is not produced by burning imported fossil fuels. Funding opportunities are available through the Pebble Partnership to progress this research. Waste heat may be available during the summer months to offset the cost of maintaining ideal internal greenhouse temperatures; further analysis is needed to determine if this is feasible.

2.3. Kodiak

Kodiak is both a community and an Island located 252 miles south of Anchorage in the Gulf of Alaska; the community is located on the northeastern corner of the Island. The community is only accessible by sea or air. According to documentation provide by Martin Lydick, planner with the Kodiak Island Borough, there were approximately 13,062 residents living on the road system in 2009. While the population is fairly stable year round, an influx of seasonal residents and tourism boosts the population during the summer months; 2000 person cruise ships make port calls on Kodiak at various occasions from May through September. There is year round fishing fleet home porting in Kodiak. While there is a large native population, the community is predominantly non-native; subsistence activities are common, although they are conducted for entertainment as much as for food supply. Kodiak is a semi urban population where most residents shop at the grocery store for their food supply needs. As recorded in a personal correspondence on October 28th, 2010 with an associate of the produce department at Safeway of Kodiak, they receive about 36 pallets of vegetables per week. Prices on that day were $3.99 per pound for Roma and vine tomatoes, $4.99 per pound for hothouse tomatoes, $2.29 each for cucumbers, $2.69 per pound for green peppers, $3.49 for red, orange and yellow peppers, $3.49 per pound for leaf lettuce and $2.40 each for head lettuce.

The climate in Kodiak is strongly affected by the marine environment which moderates the temperature year-round within a narrow range from 29.9 degrees Fahrenheit in January to 55.2 degrees Fahrenheit in August. While the narrow variation in temperature is beneficial for controlling the internal temperature of the greenhouse, a consistent cloud cover will require a large supply of artificial lighting. Wind can become fierce at times, where hurricane force winds are common at least a few times a year, although there are generally areas that stay well protected from the strongest gusts. Kodiak's developed and stable economy should provide good data about the true demand for a quantity and variety of vegetables most conductive to an economically viable operating environment. Year round fish processing would provide a constant supply of fish waste, if that could be determined to be valuable if rendered into a useable product. The logging industry may be able to provide cheaper inputs to the greenhouse. A community college and a well defined industrial sector should be effective in providing the technical expertise to operate a greenhouse, even if some training was required. A supply of laborers is available in the community, where many work in the processing industry for less than $8 per hour, plus overtime.

A hydroelectric plant provides 70% of the electrical demand, while another 10-15% is provided by wind, and the remaining 15-20% is provided by diesel powered generators. Plans are in place to double the wind power capacity, supplying 95% of the community's power needs with renewable energy. The large supply of renewable electricity helps to insulate the community, and the potential greenhouse from spikes in the price of fossil fuels. One concern is that a greenhouse may draw such large quantities of energy that the stable, renewable supply does not have the excess capacity to meet the extra demand from a greenhouse, forcing the new energy capacity to come from fossil fuel. Producing power from fossil fuel will likely prove to be economically infeasible due to the large energy requirements of a CEA greenhouse. A well funded private industry and entrepreneurial attitude may provide funding to establish a greenhouse industry if the economics proved the project to be viable.

2.4. Saint Paul

Saint Paul is both a community and an Island located 240 miles north of the Aleutian Islands, 300 miles west of Bristol Bay, and 750 air miles west of Anchorage. The community is only accessible by sea or air. The village of Saint Paul has about 459, mostly Aleut residents and a year-round fishing fleet. As recorded in a personal correspondence on October 28th, 2010 with a clerk from the Alaska Commercial Company community store, prices are recorded as follows: tomatoes are $4.29 per pound, cucumbers are $1.70 per pound, peppers are $3.79 per pound, head lettuce is $2.99 per pound and romaine lettuce is $4.59 per pound.

The climate of St. Paul is arctic maritime. The Bering Sea location results in cool weather year-round and a narrow range of mean temperatures, varying between 22.4 degrees Fahrenheit in February and 47.7 degrees Fahrenheit in August. Natural conditions for a greenhouse are challenging, with cooler temperatures, requiring more heating inputs, and steady cloud cover will require a supply of artificial light; high winds are frequent in Saint Paul. The fishing fleet, which frequents Saint Paul, will require an additional food supply. It is unknown how local demand will compare to the national statistics used for this study of either produce with a short shelf life and high water content, or other vegetables with more sustenance and higher vitamin content. The processing of fish and the fish waste itself may provide valuable inputs for a greenhouse. Additional training may be required for staff to manage the greenhouse; laborers should be plentiful due to high unemployment and the processing industry laborers who work for $8 per hour, plus overtime.

The village corporation of Saint Paul has slack capacity in wind turbines due to a dispute with the electrical company. If this energy could be used to provide cheap electricity to the greenhouse that may prove sufficient to offset the high cost of energy produced by diesel, which is likely to prove cost prohibitive.

3. CEA Greenhouse Industry

The CEA greenhouse industry has seen substantial grown in recent years as technology has been integrated into the design, allowing for control and monitoring of all aspects of environmental control. In large part this is due to the fact that a great deal of energy and resources are used to transport vegetables, which have a perishable shelf life, resulting in substantial amount of product being wasted rather than consumed. The fact that CEA greenhouses control the environmental factors required for producing the desired output, the determining factors of production become the unit cost of inputs. Essentially, all output per square foot of greenhouse should be identical, assuming all factors of production are held equal. The effectiveness of the CEA greenhouse is the extent to which the temperature, lighting, CO_2 and nutrients can be controlled, and the costs associated with providing those ideal conditions.

The cost of controlling environmental factors is the focus of economic analysis to determine continued operation of the greenhouse. The expense of controlling the internal greenhouse environment will be the energy inputs required to grow the desired product. As defined by NASA, the law of conservation of energy and first principle of thermodynamics states; "Within some problem domain, the amount of energy remains constant and energy is neither created nor destroyed. Energy can be converted from one form to another but the total energy within the domain remains fixed" (NASA, 2010). Simply put, energy cannot be created or destroyed, only altered. What this means to a greenhouse operation is that the energy cost of creating an ideal environment for growing needs to be less than the revenue from selling the final product. While nature has proven that in the appropriate environment with the proper inputs of naturally occurring heat and light, vegetative life will grow; growers should not assume that burning fossil fuel to produce a final product is an efficient allocation of resources. In order for an Alaska greenhouse to be economically viable, the appropriate use of naturally occurring inputs will be required.

All three of the major economies in North America have a developed greenhouse industry centered on clusters of activity. Although CEA greenhouses create ideal growing conditions, seasonality of production is evolving to capture the greatest profitability. Canada reduces supply in the winter months due to the added costs of heating, and Mexico reduces effort in the summer months as the cost of cooling and controlling humidity become cost prohibitive. The US market varies its supply as well, depending on the geographic cluster of activity; the Northeast reduces supply in the winter and the Southwest reduces supplies in the summer. The effects are various growing cycles, where the most efficient supplier meets the market demand, allowing for a steady supply of year round crops (Calvin & Cook, p. 2). The effects of the greenhouse industry can are especially noticeable in the American tomato market where the profitability and productivity of the industry since the early 1990's has moved beyond a niche market, and is now fully integrated into the entire system, affecting the dynamics of the industry. This is summed up in an excerpt from a research document conducted by the USDA's Economic Research Service (Calvin & Cook, p. 63).

> *"The North American greenhouse industry is still in a state of flux, with firms trying to identify the most profitable combination of locations, technology, and marketing alliances to meet market demand in different seasons. Unfortunately, miscalculations by firms are expensive. There has been rapid turnover in greenhouses in the United States as marketers attempted to realign their supply to improve profitability. With the greenhouse tomato industry growing so rapidly and undergoing so much structural change, it is difficult to predict what the industry will look like in the near future. Even in a greenhouse, growers ignore Mother Nature at their peril. Increasingly, greenhouses are carefully situated to minimize the cost of achieving the ideal tomato growing conditions for the targeted market window."*

Even while the greenhouse industry is maturing in the United States and Canada, a great effort is being undertaken by a number of prominent universities and private industry to continue efforts to optimize efficiency and standardize production. In Alaska, the University of Alaska Fairbanks (UAF) works with the Chena Hot Springs Resort greenhouse to optimize and gain an understanding for a CEA greenhouse in an arctic environment. Due to the presence of a geothermal source, there has been success in developing a small production of agriculture. This project has yet to move beyond research and niche market; however, recent efforts are in motion to further expand capacity on campus and assess the viability of for profit business. There is hope that the research and findings prove marketable, both expanding profitability for the University and economic opportunity for Alaskans. Efforts at Cornell University in New York and University of Arizona in Tucson are conducting large-scale efforts, investigating the fringe of possibility for CEA greenhouses. Cornell University is studying the prospect of expanding CEA production to the point of providing locally grown fresh vegetables to the greater Northeast region of the US. The University of Arizona is under contract with the Department of Defense, in coordination with Raytheon Company to optimize efforts to grow produce in Antarctica; further planning exists to take that technology into space. The private industry is also expanding to meet the growing demand for technologies and products to support the greenhouse industry. A number of business exist in the US and Canada that will supply a business plan and kit which identify the local environmental conditions to consider, infrastructure to support growing and control systems that monitor internal greenhouse environment.

The following highlights findings of a Cornell University study prepared for the New York Energy Research and Development Authority: (Reinhardt, Albright, & de Villers, 2008)

- *Energy used directly in field agriculture is dominated by petroleum fuel for transportation.*
- *The price of diesel fuel already favors local production of all our field crops (and many others) because a good deal more fuel is burned to transport product to NY than is needed for production.*

- *New York's disadvantage in perishable field crops is the shortness of the growing season and the difficulty of securing market share for perishable crops on a short-term basis.*
- *We can reduce heating and lighting costs in various ways. We can use heat retention technologies more effectively, extend the duration of CO enrichment through greenhouse air dehumidification and optimize venting for temperature control, and generate electricity on site, coupled with using the waste heat and CO that comes from doing so. It may also be possible to achieve advantage by securing favorable deals with municipalities for electricity, particularly renewable energy (e.g., hydropower).*
- *A final consideration is that, whether or not more total energy is needed to grow crops out of season in cloudy northern latitudes, where market opportunity exists it will happen. It may be that, by direct marketing that avoids middlemen, market share to the grower will be sufficiently large that opportunities will always exist for local outdoor and CEA operations. Moreover, small growers may be able to survive by rapidly adjusting to changing desires of the buying public and continually develop new market product niches.*
- *If CEA production is desired in less advantageous climate zones, where it is illogical to do so from the perspective of current energy use intensity, there is all the more need to develop technologies to be more energy efficient per unit of product consumed by the public.*

The above findings are especially interesting and provide insight into opportunities that are exponentially more important in the Alaska market. The fact that the greatest energy expenditure in New York's fresh vegetable consumption is spent on supply chain activities, exemplifies the fact that Alaska is even more wasteful in its importation of food and the extent of lost perishable products. This is magnified even further in regions of Southwest Alaska where product must be flown or shipped to market. The short growing season which exists in Alaska, and the costs associated with supplying a reliable crop are woefully uncompetitive for supping a reasonable food supply for the population. An important aspect for local communities is to note that the larger supply chain and middlemen activity drain direct value that could otherwise be retained by Alaskan communities. Produced locally, the complete value of the crop could include, infrastructure development, jobs, education opportunities and the multiplying factor of money circulating through the economy. It is especially important to note the benefits will not exceed costs unless some local supply of energy is available to facilitate the growing season, either in natural heat, light or growing material and access to a reliable source of cheap power. As noted in the Cornell University study, if it is illogical to operate a CEA greenhouse at this time, efforts should be investigated to improve conditions so such an operation will become feasible. Alaska is a resource economy and creating conditions that provide more efficient power should be a matter of when and what, not if.

No comparison exists between the yields, or environmental friendliness of CEA greenhouse compared to field grown crops. As described in an economic analysis conducted by Ilaslan, White, and Langhans: (2002)

> *"In addition to higher yields and better quality production, the CEA hydroponic system has many other advantages, including a reduced need for disinfectants, decreased water consumption, more efficient use of nutrients, better control of plant development, qualitatively improved products, and more efficient use of labor. The CEA hydroponic operation is an environmentally friendly system since it eliminates the water and fertilizer runoff, and the produce is pesticide-free."*

The economic analysis goes on to conclude that even if the environmental conditions do not currently exist to operate a viable CEA greenhouse it would be in the best interest of the public if government facilitated CEA hydroponic operations. While not every project should be considered for development, positive conditions exist where socially beneficial projects are prudent in certain Alaskan markets.

Canadian Greenhouse Industry: Empirical Data

The Canadian Government records the best statistics on the North American greenhouse industry. The following tables provide an overview of that industry, and prospects for what growth potential exists in the Alaska Market. All statistics are recorded by Agriculture Canada, as recorded from the web pages:

Source: (Statistics Canada , 2010)

Table 3.1 displays a snapshot in time recorded for the years 1999 and 2009 provide less-than-optimal analysis, as 1999 was near the peak of six decades of solid growth, while 2009 was the deepest recession in seven decades; however, valuable correlations can be noted. The data displays a sharp consolidation in the industry as shown by the average square foot of each operation, typical to a growth industry as less efficient operations are acquired by larger and more competitive firms. The cluster of activity in the Canadian greenhouse industry is centered in Ontario, where the average greenhouse operation is greater than two and a half acres. Another fast growing cluster of activity is the British Colombia (B.C.) region where the average greenhouse operation is well over two acres on average. Something to note about the Ontario and B.C. clusters is that they are also in proximity to large populations that are easily accessible via through the North American Interstate highway network. This is surely an attempt to reduce transportation costs. During the time period represented, only Ontario lost value on a sales per square foot unit. This is reasonable as it experienced the largest growth, and was likely hit hardest by the recession, causing less competitive firms that were over-capitalized to fail. What is most interesting is that is the narrowing of profit per square foot. This is a reasonable observation, as the industry is maturing, and standardizing operations to maximize profit. This is also representative of the industry consolidation, where least competitive firms would fail, driving up the per unit profit for the remaining operations. In the 10-year span profits increased by 38%, an impressive growth considering these results would represent a substantial hit due to the deep recession; sales should be expected to expand in the coming years as the world shakes off the effects of the recession. The $2.35 billion in total sales represents a substantial contribution to the Canadian Economy.

Table 3.1: Greenhouse Data Comparison: 1999 to 2009

1999 Canadian Statistics

	Number of Greenhouses	Total Square Feet	Average Size: Square Feet	Average Sales	Sales per Square Foot	Total Sales
Ontario	1,355	80,218,813	59,202	$564,629	$9.54	$765,072,217
Quebec	875	24,291,163	27,761	$173,810	$6.26	$152,084,000
B.C.	650	37,336,415	57,441	$536,928	$9.35	$349,003,000
Alberta	325	7,382,318	22,715	$199,523	$8.78	$64,845,000
Canada	**3,810**	**158,123,462**	**41,502**	**$380,528**	**$9.17**	**$1,449,812,617**

2009 Canadian Statistics - All Greenhouses

	Number of Greenhouses	Total Square Feet	Average Size: Square Feet	Average Sales	Sales per Square Foot	Total Sales
Ontario	1,250	143,205,450	114,564	$1,040,032	$9.08	$1,300,041,000
Quebec	730	28,744,110	39,375	$358,153	$9.10	$261,452,390
B.C.	495	52,882,940	106,834	$1,056,814	$9.89	$523,123,320
Alberta	335	10,973,100	32,756	$346,652	$10.58	$116,128,750
Canada	**3,305**	**247,499,270**	**74,886**	**$712,052**	**$9.51**	**$2,353,334,160**

Table 3.2 displays statistics from the specialized vegetable greenhouses. Consolidation exists to an even greater degree. While only a fraction of the total greenhouses are specialized for vegetables, the total square feet represents half of the industry total. The average size of greenhouse in Ontario is nearly 8 acres, while the average sale is $ 2.3 million; B.C. greenhouses are not as large, although considerably larger than other regions, and provide the largest average sales. Sales per square foot are not as high as the total greenhouse industry, except in Quebec, although close in B.C. $ 929 million in annual sales is a substantial contribution to economic activity.

Table 3.2: 2009 Canadian Statistics - Vegetable Greenhouses

	Number of Greenhouses	Total Square Feet	Average Size: Square Feet	Average Sales	Sales per Square Foot	Total Sales
Ontario	240	81,411,390	339,214	$2,323,353	$6.85	$557,604,840
Quebec	190	8,014,680	42,183	$403,396	$9.56	$76,645,340
B.C.	105	28,256,455	269,109	$2,393,702	$8.89	$251,338,760
Alberta	N/A	N/A	N/A	N/A	N/A	$33,777,050
Canada	**645**	**122,676,605**	**190,196**	**$1,440,280**	**$7.57**	**$928,981,000**

As the graph below shows the growth in the greenhouse vegetable industry was the only one to increase total sales for year on year sales through the recession, while sales of plants and flowers fell.

Chart 3.1: Sales of Greenhouse and Nursery Products, Canada, 2004-2009

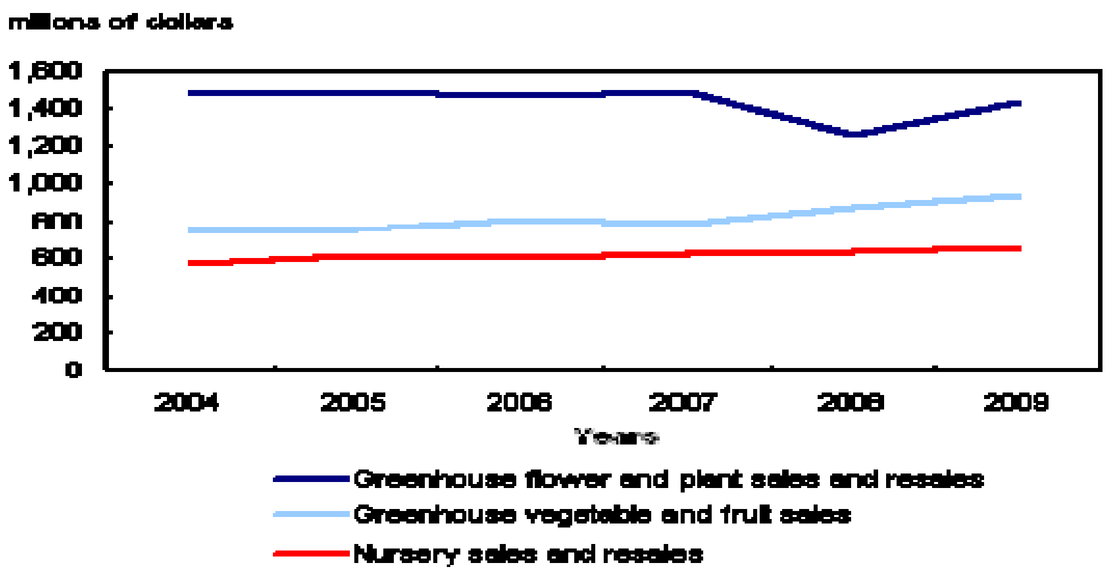

Table 3.3 breaks out the value of greenhouses specialized in flowers and plants, and those specializing in fruits and vegetables.

Table 3.3: Canadian Greenhouse Production

	Total Flower and Plant Sales	Total Fruit and Vegetable Sales	Total Greenhouse Sales
2008	$1,261,504,115	$869,971,655	$2,131,475,770
2009	$1,424,353,160	$928,981,000	$2,353,334,160

Tables 3.4 breaks up the specialized vegetable greenhouses into the four primary crop varieties grown in the Canadian Greenhouse industry: Tomatoes, cucumbers, peppers and leafy greens. These tables display dollar value and output per square foot, industry wide. Tomatoes, which are slightly more valuable per square foot, have a larger total area, than cucumbers and peppers. Lettuce, the most valuable per square foot has a substantially smaller production area. This data is contradictory to factors of production, which state that the most valuable categories will be expanded to maximize profit. Further research is required to understand the discrepancy.

Table 3.4: Comparison of Primary Greenhouse Vegetables

Canadian Greenhouse Tomatoes

	Area in Square Feet	Production in Heads	Farm Gate Value in Dollars	Dollars per Square Foot	Pounds per Square Foot
2008	51,865,500	477,412,350	383,670,290	$7.40	9.20
2009	53,510,860	507,497,465	434,018,490	$8.11	9.48

Canadian Greenhouse Cucumbers

	Area in Square Feet	Production in Dozens	Farm Gate Value in Dollars	Dollars per Square Foot	Pounds per Square Foot
2008	31,075,610	30,101,530	212,215,580	$6.83	17.44
2009	31,487,320	31,058,405	226,627,223	$7.20	17.75

**Average Dozen: 18 Pounds

Canadian Greenhouse Peppers

	Area in Square Feet	Production in Heads	Farm Gate Value in Dollars	Dollars per Square Foot	Pounds per Square Foot
2008	36,309,090	183,230,490	235,807,000	$6.49	5.05
2009	37,278,160	197,150,380	230,191,380	$6.17	5.29

Canadian Greenhouse Leafy Greens

	Area in Square Feet	Production in Heads	Farm Gate Value in Dollars	Dollars per Square Foot	Pounds per Square Foot
2008	1,666,180	N/A	20,052,775	$12.04	N/A
2009	1,975,730	20,051,570	21,993,260	$11.13	10.15

**Average Head: 1 Pound

Table 3.5 displays total dollar value of expenses for the Canadian greenhouse industry. It is important to notice that the expenses in the flower and plant industry are considerably higher than in the vegetable producers, especially the cost of materials and labor. It is worth notice that fuel expenses are greater in the vegetable greenhouses. That data appears inconsistent in that expenses for the flower and plant industry remain relatively static between 2008 and 2009 and the expenses for the vegetable industry increased by 21% in the same time period. Further research is required to better understand how those increases came about.

Table 3.5: Comparison of Operating Expenses

Total Greenhouse Producers Operating Expenses

	Plant material for Growing and Resale [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$383,308,740	$540,619,780	$52,441,300	$246,374,990	$249,577,520	$479,916,025	**$1,952,238,355**
2009	$372,921,810	$578,332,560	$61,636,242	$253,795,330	$273,780,930	$587,217,098	**$2,127,683,970**

Specialized Greenhouse Vegetable Producers Operating Expenses

	Plant material for growing [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$51,090,200	$163,168,900	$24,261,895	$136,297,006	$89,847,600	$206,319,120	**$670,984,721**
2009	$71,860,105	$203,837,940	$27,610,980	$154,104,430	$110,540,920	$285,238,990	**$853,193,365**

Specialized Greenhouse Flower and Plant Producers Operating Expenses

	Plant material for Growing and Resale [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$304,280,845	$319,475,100	$26,878,600	$96,979,850	$124,429,350	$223,913,000	**$1,095,956,745**
2009	$279,499,350	$317,331,365	$25,965,170	$86,789,910	$127,325,660	$218,067,390	**$1,054,978,845**

[1] Includes value of plants, seedlings, seeds and bulbs purchased (before sales tax).
[2] Includes seasonal and permanent labor.
[3] Electricity expenses for lighting, airflow fans and heating.

Table 3.6 displays operating expenses for the Canadian Greenhouse industry on a per foot basis. The increased cost for materials and payroll for the plant and flower industry, and the marginal increase for fuel for the vegetable are easily distinguished.

Table 3.6: Comparison of Operating Expenses per Foot

Total Greenhouse Producers Operating Expenses per Square Foot

	Plant material for Growing and Resale [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$1.63	$2.30	$0.22	$1.05	$1.06	$2.04	$8.30
2009	$1.51	$2.34	$0.25	$1.03	$1.11	$2.37	$8.60

Specialized Greenhouse Vegetable Producers Operating Expenses per Square Foot

	Plant material for Growing and Resale [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$0.43	$1.38	$0.21	$1.15	$0.76	$1.75	$5.68
2009	$0.59	$1.66	$0.23	$1.26	$0.90	$2.33	$6.95

Specialized Greenhouse Flower and Plant Producers Operating Expenses Per Square Foot

	Plant material for Growing and Resale [1]	Gross yearly payroll [2]	Electricity [3]	Fuel	Other crop Expenses	Other Operating Expenses	Total operating expenses
2008	$2.60	$2.73	$0.23	$0.83	$1.06	$1.91	$9.37
2009	$2.24	$2.54	$0.21	$0.70	$1.02	$1.75	$8.45

Table 3.6 displays the operating cash flow and ratio analysis for the Canadian and Ontario greenhouse industry. Notice the efficiency gains in the specialized Ontario region, verses the aggregated data for the entire country.

Table 3.7: Operating Cash Flow and Ratio Analysis

		Total Operating Expenses	Total Gross Revenue	Total Profit	Revenue to Operating Expense Ratio	Revenue per Square Foot	Expenses per Square Foot	Profit Per Square Foot
Ontario	2008	$980,793,510	$1,144,287,050	$163,493,540	1.167	N/A	N/A	N/A
	2009	$1,133,303,960	$1,300,041,000	$166,737,040	1.147	9.08	7.91	$1.16
Canada	2008	$1,952,238,355	$2,131,475,770	$179,237,415	1.092	$9.07	$8.30	$0.76
	2009	$2,127,683,970	$2,353,334,160	$225,650,190	1.106	$9.51	$8.60	$0.91

Table 3.8 displays the operating cash flow and ratio analysis for the fruit and vegetable greenhouse operators. A significant fall in profit is displayed from 2008 to 2009. Most of the expenses, $110.7 million of the $182.2 million nationwide increase, take place in Ontario. Further research is required to determine what caused the large variation between 2008 and 2009.

Table 3.8: Specialized Fruit and Vegetable Operating Cash Flow and Ratio Analysis

		Total Operating Expenses	Total Gross Revenue	Total Profit	Revenue to Operating Expense Ratio	Revenue per Square Foot	Expenses per Square Foot	Profit Per Square Foot
Ontario	2008	$399,938,456	$529,963,800	$130,025,344	1.325	N/A	N/A	N/A
	2009	$510,647,400	$557,604,840	$46,957,440	1.092	6.51	6.27	0.24
Canada	2008	$670,984,721	$869,971,655	$198,986,934	1.297	$7.37	$5.68	$1.68
	2009	$853,193,365	$928,981,000	$75,787,635	1.089	$7.57	$6.95	$0.62

Table 3.9 displays the operating cash flow and ratio analysis for the specialized flower and plan greenhouse industry. Margins are considerably higher compared to the vegetable industry for the years displayed. While the profitability in the vegetable greenhouses narrowed, the flower and plant greenhouses became more profitable.

Table 3.9: Specialized Flowers and Plants

		Total Operating Expenses	Total Gross Revenue	Total Profit	Revenue to Operating Expense Ratio	Revenue per Square Foot	Expenses per Square Foot	Profit Per Square Foot
Ontario	2008	$516,511,300	$614,323,250	$97,811,950	1.189	N/A	N/A	N/A
	2009	$524,406,020	$742,436,160	$218,030,140	1.416	N/A	N/A	N/A
Canada	2008	$1,095,956,745	$1,261,504,115	$165,547,370	1.151	$10.78	$9.37	$1.42
	2009	$1,054,978,845	$1,424,353,160	$369,374,315	1.350	$11.41	$8.45	$2.96

4. Optimizing Controlled Environment Agriculture Greenhouse

Developing an economically viable greenhouse industry in Alaska will require an efficient building design and components which allow users to have a high degree of control over the internal environment required for growing crops while the outside environment has proven hostel for agriculture. This section will identify: land requirements, efficiency of design, internal infrastructure, technology, temperature, airflow and materials necessary to optimize a controlled environment greenhouse. More often, data suggests a lack of effective management as a primary component of greenhouse failure; successful management and training are imperative as communities consider implementing CEA greenhouse operations. As intended this study will focus on an economically viable business plan, where a certain amount of flexibility will be required to adapting to site specific variables, but the primary scope is to identify a template for moving forward with the most optimal design.

4.1. Land and Location

The large capital cost of acquiring land and managing operating costs dictate that land and location settings are thoroughly analyzed. Land costs in rural Alaska may not be as competitive as urban areas; however, there will still be substantial costs in acquiring land. Three of the selected locations for this study are island communities, where available land is limited. Obtaining viable land, which may require a large footprint, could prove difficult on a per community basis. Location can be vital to the operating costs as proper selection may dictate cogeneration of inputs. The most obvious would be to select a location near a power source. In addition to heat, the excess use of CO2 could benefit both the greenhouse and the polluting agent, especially if future laws are enacted to tax emissions. Other large input needs are electricity, water, growing materials and nutrients than need to be considered for cost sharing. Due to excessive operating costs, without some competitive advantage from using onsite resources, a CEA greenhouse in rural Alaska will likely fail to prove economically viable.

4.2. Design Requirements

Various design options are available to fit any number of environmental factors; this study will focus on one design from which we can analyze capitol and operating costs. The *gutter connect greenhouse*, provides a number of potential benefits in that it is a fairly standard design with the capability to easily expand. *Gutter connect greenhouses* are composed of a number of "bays" or compartments running side by side along the length of the greenhouse. The interior working space can be compartmentalized to adapt sectional interior environments, or expanded to one large growing environment. It may be required that varying products and plants at various stages of growth will require different environmental factors, thus requiring the compartments to serve different functions. The roof above each bay is pitched. Recent trends have been for greenhouses to become taller to accommodate more growing space as well as ease associate with controlling a larger air mass, once the internal environment has been established. (Seginer, 1996)

Additional chambers will need to be considered for operational purposes. A loading and unloading chamber will be required for moving supplies in and out of the greenhouse. An office area should house all computer, operating and monitoring equipment, technology and supplies. The large number of utilities necessary to operate the greenhouse will require housing that is easily accessed for maintenance and troubleshooting. Restrooms, lounge, break and cafeteria facilities will be required to meet health and safety standards.

Floor design is required to maximize output potential. Drainage is required to eliminate standing water. Reflective coatings can increase lighting, minimizing lighting input, and increasing yields. In Alaska's harsh environment, consideration will be required for insulating factors to optimize heat retention and protection for fragile plant life.

4.3. Building Materials

Aluminum frames are a sturdy, cheap and durable material from which to construct the CEA frame. A number of private agents provide a "kit" which can be installed with all necessary components to operate a greenhouse. Prices can vary considerably. Consideration needs to be given to material strength which can withstand, wind, rain, snow and other variable conditions unique to an Alaskan greenhouse. Insulating factors need to weigh upfront cost against replacement and operating costs for the life of the greenhouse. Equipment requirements need to be assessed to determine that they will have the capabilities to appropriately maintain ideal internal environmental conditions on a cost per unit of output basis; a slight variation in the ability to control the internal environment can lead to considerable variation of input costs and output potential. As in any maturing industry, sourcing potential varies, and no clear standards or market leaders have been established. Prices will likely reflect quality, and business reputation may not be fully established in all circumstances; prudence in vendor selection is advised.

4.4. Water, Hydroponics, Lighting, Soil, Perlite, Composite

Water quality is of great importance to the output potential of the greenhouse operation. Maintaining levels pertaining to optimal growth are necessary for maximum growth potential. (Wilkerson D.)

Quality	Electrical conductivity (milliohms)	Total soluble Salts (ppm)	Sodium content (% Salts as Na)	Soluble Absorption Ratio
Excellent	0.25	175	20	3
Good	0.25 - 0.75	175 - 525	20 - 40	5-Mar
Permissible	0.75 - 2.0	525 - 1400	40 - 60	10-May
Doubtful	2.0 - 3.0	1400 - 2100	60 - 80	15-Oct
Unsuitable	>3.0	>2100	>80	>15

Nutrient film technique has developed as a prominent form of hydroponics, where a very shallow stream of water containing all the dissolved nutrients required for plant growth is re-circulated past the bare roots of plants, often delivered in water filled troughs. Another efficient means of supplying water and nutrients is through soilless culture, housing roots in substrates such as rockwool or perlite. Various substrates are routinely researched in attempts to increase yields and reduce costs. Local options may exist that can reduce input costs, which can be substantial.

Selection of the appropriate exterior paneling is important for efficient retention of internal environment, and also receiving maximum external natural light. Glass is an effective exterior although large panels need to be tempered to increase integrity from outside elements which could damage the structure. Glass is found to be heavy and hard to work with and potentially inefficient for retaining heat. Developments are being made in double ply glass, with a layer of air that helps to retain heat loss. In recent years some greenhouses have been constructed with, or in addition to the glass exterior, rigid clear plastic. As well as being cheaper, plastic can be constructed in layers, to develop layers of air to increase insulating capabilities. (Roberts & Giacomelli, 1993)

4.5. Airflow and Temperature Control

Maintaining an ambient temperature within the control area will require a great deal of consideration. Depending on the interior compartments size and volume, various methods need to be considered to maintain an optimal temperature year round when outside temperatures vary substantially. One primary concern in a CEA Greenhouse is to maintain an optimal temperature for growing. This will entail air temperatures at the canopy, near the roof, the plant body compromising the large interior space and the root level near the floor. A combination of piped water, forced air and fans will need to be installed at each level. As outside temperatures, products and plant lifecycles change, flexibility for optimal control will prove vital. Circulating interior air, in addition to temperature control, is responsible for mixing CO2 levels and regulating humidity; a ventilation system needs to be appropriately coordinated with fans and natural air flow. An active greenhouse will reduce availability of CO2, where increased levels, around 700 ppm have been shown to increase yields by as much as 33%. The importance of CO2 requires that levels need to be artificially increased. Burning natural gas or directing the exhaust from the heating units can be sufficient in increasing CO2. Exhaust fumes need to be scrubbed of harmful byproducts. (Tremblay & Gosselin, 1998)

4.6. Technology and Automation

CEA includes many input costs that are unnecessary for field cultivated crops, and need to be more efficient to obtain a comparative advantage. Computerize environmental control systems manage all aspects of the greenhouse in order to manipulate optimal growing conditions. Natural external environmental factors are constantly acting upon the greenhouse; light, weather and temperature swings constantly influence the defined optimal internal environmental parameters and the result of the ongoing input of the component systems acting in concert is to stabilize the internal controlled environment. Watering and fertilization are key components of a CEA greenhouse that need precise control. Fertilizer is infused in the water provided to the plants. An efficient system must capture and reuse as much of the inputs as necessary, so water and fertilizer are circulated to the plants then reused. The optimal level of water-fertilizer mixture needs to be automated to avoid variation in the nutrients the plants receive.

4.7. Management and Training

The consolidation of the Canadian greenhouse industry is proof enough that while certain operations should remain in business, market saturation has forced other operators to fail. Prudent business planning, training and management could surely hedge against failure. A Cooperative Extensions study asks the following questions of its potential greenhouse manager. The following questions address the fact that not everyone is meant to be a business owner, and specifically a greenhouse operator. Even if one posses the business capacity, special skills are required for managing a greenhouse; additional expenses of hiring specialist will need to be covered by the operating revenue. Government should investigate facilitating the local capacity to prepare prospective business owners: (Smith J. , Hewitt, Hochmuth, & Hochmuth)

> ***Are you action oriented?*** *Business people often don't have all the facts needed to make a black-and-white decision.*

> ***Are you dedicated to success?*** *Greenhouse plants must have attention every day, up to 70 hours per week or more. You, as the boss, must be prepared to commit the time and attention required, and getting the job done.*

Are you a manager? *You cannot do everything yourself if you are the boss. You must hire competent people as part of your team and give them responsibility to get jobs done.*

Are you a good planner? *A manager needs to plan for growth in the business, plan when to plant and harvest crops, and plan for unforeseen challenges such as cold temperatures in the greenhouse or crops that are not ready at harvest.*

Do you have the appropriate knowledge and experience? *There are many things you will need to know concerning crop culture, greenhouse operation, people management, sales, and the day-to-day operation of a business.*

Do you have enough resources? *You will need enough money to start and operate the business while you get established and until you can pay your own bills, and may even require additional personal resources.*

Do you have people skills? *Managing a business involves managing your time, other people's time, your customers' complaints, and your suppliers, as well as your banker, attorney, accountant, and financial planner.*

Are you flexible? *You must adapt and grow as your business grows, which will require being innovative and plan for meeting customers want, and anticipating where the market is headed in the future.*

Analyze management capabilities carefully to make sure challenges can be overcome. Not everyone is made to own a business; not everyone has all the skills needed to operate a business. Identify strengths and weaknesses to determine the viability of a greenhouse operation; identifying shortcomings during the planning phase will be more cost effective than admitting failure later in the production process.

5. Methods

5.1. Models

The methods for analyzing the possibility of Southwest Alaskan greenhouses is primarily based on empirical evidence, applied to the geographical constraints of four communities in the region: Kodiak, Dillingham, Akutan and Saint Paul. Much evidence exists from which to analyze the greenhouse industry; however, not all data can be translated to form assumptions about the operating capacity of greenhouses in the selected communities. The empirical data that is applicable to the region is ample, detailed and transferable. CEA greenhouses, by definition, control for the environmental factors for optimal vegetative growth; as long as the exterior structure and equipment are capable of maintaining the internal environment and withstanding the external environment, assumptions can be made about operations on a site by site analysis.

The obvious choice for analyzing options for Alaskan CEA greenhouses operations is to use the only operating production facility in the State, the Chena Hot Springs Resort Greenhouse. The Chena Model follows research and production conducted by the University of Alaska Fairbanks (UAF) and the Chena Hot Springs Resort, located just outside of Fairbanks. The availability of the Chena Model and the research conducted by UAF provided an operating budget, detailing capital and operating costs. Understanding the cost structure is one of the most important aspects for exporting greenhouse operations to various locations as the output can be generally maintained and costs will vary by location. Standardizing the capital and operating costs is important to understand how those costs will vary by specific operations.

Understanding the capital costs required the assumption that features which maintain a controlled environment and withstand the external environment of interior Alaska would be sufficient in Southwest Alaska. Capital costs were translated from the Chena Model, directly to reflect cost at each of the Southwest communities of interest. In order to meet the varying demand at different communities, the Chena Model needed to be standardized to a per unit basis. A standard unit was determined to be one 60 foot by 72 foot greenhouse. This allows for a predetermined cost for materials and equipment and scalability to determine heating requirements, energy usage and output potential, which can be expanded to meet the unique requirements of each community.

Operating cost will be the determining factor of the feasibility of any greenhouse operation. Community specific variations in operating costs focused on the greatest input costs: energy. The amount of electricity required was based on the usage per hour in the Chena Model; initially no assumptions were made for interpreting the use of natural light. This identified a common electricity demand, where the kilowatt rate per hour (kw/h) was applied based on community standards. The heating requirements were again based on the Chena Model, where a standard calculation for determining British Thermal Units (BTU) is calculated based on the internal area of the structure. The site specific variation is then limited to the external temperature and the cost of BTU's per hour to reach the desired internal temperature.

The first set of assumptions is based on the Chena Model, which identifies variable costs of operation, and the fixed cost of depreciation, interest and insurance; these costs were initially translated into the first analysis of site specific operations. The second set of assumptions is based on the Chena Model and adjusted the materials, labor and cash flow for interest and depreciation. The adjustments to materials were based on empirical evidence from the Canadian industry recorded in 2009. The adjustments to labor were based on separating laborers from managers, and adjusting the pay scale to reflect a low paying, entry level position. The adjustments to the cash flow were based on reducing the interest rates. The third set of assumptions was based on the Chena Model, including all previous assumptions with additional adjustments to energy costs. The adjustment to the price of electricity incorporates the inputs of natural light to reduce the requirements of artificial light. The adjustment to heating assumes that construction of the greenhouse with greater insulation will reduce the heating units required to maintain optimal internal temperature. The fourth set of assumptions was based on the Chena Model, including all previous assumptions, with additional adjustments made to additional expenses and payroll based on empirical evidence from the Canadian industry.

5.2. Expectations

As identified, output potential should be reasonably stable based on a per unit basis. This experiment operates under the assumption that greenhouse yields will be equal to those reported in the Canadian industry. Costs are assessed on a community by community basis, given the assumptions identified here. Based explicitly on the Chena Mode, it is expected that none of the communities under consideration will be feasible to operate an economically viable year round production of the given vegetables. As the project moves from the strict Chena Model to the hybrid model, based on statistics retrieved from the Canadian greenhouse industry it is expected that the Kodiak greenhouse model will prove profitable based on the given assumptions. The Kodiak greenhouse model should be further investigated to determine actual demand and revenue potential, as well as closely scrutinizing the capital and operating costs to assure figures are appropriate in a practical approach. Dillingham, Akutan and Saint Paul are not expected to prove feasible under the given assumptions with the high cost of energy inputs identified here. Further research is required to determine methods for reducing input costs at each of the communities investigated.

5.3. Data and Results

5.3.1. Capital Cost

Capital costs were assumed based on the Chena Model. A complete list of construction and durable costs needed for construction and maintenance of the greenhouse is shown in the Table 5.1. A straight-line depreciation is used. Interests are charged on the average investment, using a rate of 10%. Insurance is assumed to be 1.3% of the original investment. The following represents a single unit from which costs were extrapolated to meet size requirements unique to each community.

Table 5.1: Capital Cost – Chena Model

Construction	Original Cost	Life in Yrs.	Depreciation	Interest*	Ins.**	Annualized
Buying Property	0	100	0	0	0	0
Licenses	0	100	0	0	0	0
Greenhouse Frame (60ft x 72ft)	20,188	20	1,009	1,009	262	2,281
Warehouse & Packing Plant on site	16,600	10	1,660	830	216	2,706
Controller	5,500	10	550	275	72	897
Floor (insulation, concrete slab, paint)	9,035	10	903	452	117	1,473
Floor Heating System	1,302	10	130	65	17	212
Water Tank	1,248	7	178	62	16	257
Irrigation/Fertigation (hydroponic structure & equipment)	24,555	10	2,456	1,228	319	4,003
Electrical Installation	6,005	10	601	300	78	979
Miscellaneous Supplies	7,952	5	1,590	398	103	2,091
Labor (Const. & Equip. Install.)	13,000	10	1,300	650	169	2,119
Total Construction Cost	**$105,386**		**$10,378**	**$5,269**	**$1,370**	**$17,017**
Durables						
Roof & Walls	799	3	266	40	10	317
Plumbing Hot Water	2,835	5	567	142	37	746
Plumbing Fresh Water	356	5	71	18	5	94
Plumbing MISC	2,130	5	426	106	28	560
Extra Cooling Fans & Environmental Control	147	5	29	7	2	39
Lights	16,800	5	3,360	840	218	4,418
Other Durable Goods	850	5	170	42	11	223
Total Durable Goods	**$23,917**		**$4,890**	**$1,196**	**$311**	**$6,397**
Total Greenhouse Construction & Durables	**$129,303**		**$15,268**	**$6,465**	**$1,681**	**$23,414**
Utility hook-ups (electrical, heat)	5,000	5	1,000	250	65	1,315
Cost fresh water well & hook up	4,000	20	200	200	52	452
Total Greenhouse Investment	**$138,303**					
* Interest Rate (%) =	10.0%					
** Ins. Rate (%) =	1.3%					

Source: (Mager, 2008)

5.3.2. Demand

Per capita demand is based on the three year average of fresh vegetable consumption of US citizens between 2006 and 2008, as reported by the United States Division of Agricultural, Economic Research Service. It is assumed that demand in each of the communities represented here is equivalent to the national average. To obtain a community demand for each category, population was multiplied by the unique demand for each vegetable. Total greenhouse potential is the sum of the individual categories, which is also equal to the category sum multiplied by the community population. The *All Vegetable* category was not considered as it is beyond the scope of this study.

Table 5.2: Estimated Per Capita Consumption Based on US Average

	Akutan	Dillingham	Kodiak	Saint Paul
Population	846	2,264	13,062	459
	Per Capita Potential Per Community			
Leafy Greens**	32,116	85,945	495,856	17,424
Cucumbers	5,448	14,579	84,111	2,956
Bell Peppers	8,089	21,647	124,889	4,389
Tomatoes	16,225	43,421	250,513	8,803
Total Greenhouse Potential	**61,877**	**165,591**	**955,369**	**33,572**
All Vegetables	162,576	435,075	2,510,134	88,206

US Three Year Average Per Capita Consumption - Fresh Vegetables

Leafy Greens**	Cucumbers	Bell Peppers	Tomatoes	All Vegetables
38.0	6.4	9.6	19.2	192.2
Category Sum	73.1			

** Leafy Greens include: Cabbage, Romaine and Head Lettuce

Source: http://www.ers.usda.gov/data/foodconsumption/FoodAvailSpreadsheets.htm#vegtot

To determine the appropriate size greenhouse for community, the average yield for each category of vegetable was divided by the per capita average from Table 5.2. The average yield is based on the statistics from the Canadian industry as reported in 2009. Table 5.3 displays the size in square feet required to meet the needs of the communities investigated in this study.

Table 5.3: Greenhouse Size in Square Foot

Population	Akutan	Dillingham	Kodiak	Saint Paul	
	846	2264	13062	459	
					Pounds per Square Foot
Leafy Greens**	3,164	8,468	48,858	1,717	10.15
Cucumbers	307	821	4,737	166	17.75
Bell Peppers	1,529	4,093	23,615	830	5.29
Tomatoes	1,711	4,578	26,414	928	9.48
Total Greenhouse Square Foot Potential	**6,712**	**17,961**	**103,624**	**3,641**	
All Vegetables Per Capita Average	17,634	47,190	272,262	9,567	
Average Square Foot Production Across All Categories					9.22

** Leafy Greens include: Cabbage, Romaine and Head Lettuce

A standard unit was determined to establish individual community capacity based on demand. Size requirements, as described in Table 5.3 were divided by a single 60 foot by 72 foot unit, totaling 4320 square feet. Table 5.4 displays the Unit requirements for each community greenhouse.

Table 5.4: Greenhouse Units 60 ft. * 72 ft – 4320 Square Feet

	Akutan	Dillingham	Kodiak	Saint Paul
Population	846	2,264	13,062	459
Leafy Greens**	0.73	1.96	11.31	0.40
Cucumbers	0.07	0.19	1.10	0.04
Bell Peppers	0.35	0.95	5.47	0.19
Tomatoes	0.40	1.06	6.11	0.21
Total Greenhouse Square Foot Potential	1.55	4.16	23.99	0.84
All Vegetables Per Capita Average	4.08	10.92	63.02	2.21

5.3.3. Enterprise Budget Accounting

Capital costs were determined by multiplying the community equivalent unit by the costs determined in table 5.1 of $138, 303 per unit. Table 5.5 displays the total capital costs per community.

Table 5.5: Greenhouse Capital Costs per Community

	Akutan	Dillingham	Kodiak	Saint Paul
Population	846	2,264	13,062	459
Leafy Greens**	$ 101,308	$ 271,112	$ 1,564,164	$ 54,965
Cucumbers	$ 9,823	$ 26,288	$ 151,665	$ 5,330
Bell Peppers	$ 48,965	$ 131,037	$ 756,010	$ 26,566
Tomatoes	$ 54,771	$ 146,573	$ 845,642	$ 29,716
Total Greenhouse Square Foot Potential	$ 214,867	$ 575,010	$ 3,317,482	$ 116,577
All Vegetables Per Capita Average	$ 564,541	$ 1,510,780	$ 8,716,347	$ 306,293

Operating costs are initially based specifically on the Chena model, with the only exceptions being for the community specific inputs for heat, electricity and packaging. Table 5.6 displays the operating budget based on the Chena model.

Table 5.6: Operating Budget Chena Greenhouse Unit - 4320 Square Feet

Costs	Unit	Quantity	Price	Total Value
Pre-harvest & harvest				
Material Inputs (21)	$			$ 45,243
Accessories (22)	$			$ 1,978
Labor (2 people full time) (23)	Hours	4160	30	$ 124,800
Heat (24)	$			
Electricity (25)	$			
Int. on Op. Capital** (26)	$	$ 225,834	$ 0.05	$ 11,292
Packing & Marketing				
Custom Packing & Marketing (30)	#	9.2 / Foot	$ 0.25	
Fixed Cost				
Depreciation & Interest (31)	$	1	$ 21,73	$ 21,733
Ins. (32)	$	1	$ 1,68	$ 1,681
Total Costs				

(Mager, 2008)

Table 5.7 explains the temperature variation between each community's monthly average and the ideal internal temperature required for growing. The low end of that spectrum is 69.8 degrees Fahrenheit and the high end is 73.4 degrees Fahrenheit. (Calpas, 2001)

Table 5.7: Temperature Variation from Optimal Temperature – Low 69.8 & High 73.4 Degrees Fahrenheit

Kodiak

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Average Temperature	29.9	30.5	32.9	37.5	43.5	49.6	54.4	55.2	50	40.7	34.4	30.8	40.8
Ti - To														
	Low	39.9	39.3	36.9	32.3	26.3	20.2	15.4	14.6	19.8	29.1	35.4	39	29
	High	43.5	42.9	40.5	35.9	29.9	23.8	19	18.2	23.4	32.7	39	42.6	32.6

Saint Paul Island

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Average Temperature	26.6	22.4	24.2	28.3	35.2	41.5	46.1	47.7	44.6	37.8	33	29	34.7
Ti - To														
	Low	43.2	47.4	45.6	41.5	34.6	28.3	23.7	22.1	25.2	32	36.8	40.8	35.1
	High	46.8	51	49.2	45.1	38.2	31.9	27.3	25.7	28.8	35.6	40.4	44.4	38.7

Akutan

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Average Temperature	32.45	32.45	33.45	36.15	41.45	46.8	51.45	53.35	48.7	42.3	37.3	34.65	40.9
Ti - To														
	Low	37.35	37.35	36.35	33.65	28.35	23	18.35	16.45	21.1	27.5	32.5	35.15	28.9
	High	40.95	40.95	39.95	37.25	31.95	26.6	21.95	20.05	24.7	31.1	36.1	38.75	32.5

Dillingham

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
	Average Temperature	16.1	16.4	22.1	31.4	42.6	50.95	54.95	53.6	47.1	33.1	22.7	14.4	33.75
Ti - To														
	Low	53.7	53.4	47.7	38.4	27.2	18.85	14.85	16.2	22.7	36.7	47.1	55.4	36.05
	High	57.3	57	51.3	42	30.8	22.45	18.45	19.8	26.3	40.3	50.7	59	39.65

Table 5.8 explains the dimensions of the 60 foot by 72 foot greenhouse as described in the Chena Model. These dimensions are used to calculate the external surface area, which is required to determine heating units required to maintain an ideal internal temperature. The *Roof Area*, 6:12 pitch is a standard construction term describing 6 inches of rise to 12 inches of run; the standard coefficient for calculating the width of a building with that pitch is 1.12. *Area of Roof* area is calculated by determining the *Roof Width*: *Face* (30 ft.) * *Coefficient* (1.12 ft) = *Roof Width* (33.6 ft) * by *Wall Length* (72 ft.) * two panels (2) = *Area of Roof* 4838.4 square feet. *Area of Sidewalls* is calculated by: *Wall Length* (72 ft.) * *Height* (10 ft.) * two panels (2) = 2280 square feet. *Area of Endwalls* is calculated by: *Wall Width* (60 ft.) * *Height* (10 ft.) * two panels (2) + *Face* (30 ft.) * *Height* (10 ft.) * two panels (2) = 1800 square feet. *Total Area* is the sum of the components; 9518 square feet.

Table 5.8: Calculation of Greenhouse Unit Surface Area

Chena Greenhouse Unit - 60 ft. * 72 ft.

Roof Area	Coefficient	Roof Width	Wall Length	Wall Width	Height	Face
6:12 Pitch	1.12	33.6	72	60	10	30

Area of Roof	33.6*72*2	4838.4 sq. ft.
Area of Sidewalls	72*10*2	2880 sq. ft.
Area of Endwalls	((60*10) +(30*10)) *2	1800 sq. ft.
Total Area	Sum	9518 sq. ft.

Table 5.9 calculates the Q coefficient, heating units in British Thermal Units per hour (Btu/hr). This is a function of temperature variation, area and the heat transfer coefficient U, in Btu/hr. Areas and temperature variation are explained in tables 5.7 and 5.8. The coefficient U is given provided a level of insulating capacity found in the exterior wall structure; for calculations recorded here, U-values will equal .6 for a Twin Wall, and .4 for a Twin Wall plus an additional Energy Curtin. (Roberts E. W., 2005) The Q-value is calculated based on averages for each month based on a standard greenhouse unit of size 60 foot by 72 foot.

Table 5.9: Btu Heating Units Required per Hour - Based 4320 Sq. Ft. Unit: Optimal Temperature of 69.8 Degrees Fahrenheit

Twin Wall: U = .6

		January	February	March	April	May	June	July	August	September	October	November	December	Annual Avg.
Kodiak	Q = U * A * (Ti–To)	227,870	224,444	210,737	184,467	150,200	115,363	87,950	83,381	113,079	166,191	202,171	222,731	165,620
Saint Paul	Q = U * A * (Ti–To)	246,717	270,703	260,423	237,008	197,602	161,622	135,352	126,214	143,918	182,753	210,166	233,010	200,458
Akutan	Q = U * A * (Ti–To)	213,307	213,307	207,596	192,176	161,908	131,354	104,798	93,947	120,503	157,054	185,609	200,743	165,049
Dillingham	Q = U * A * (Ti–To)	306,683	304,970	272,417	219,304	155,340	107,653	84,809	92,519	129,641	209,595	268,990	316,392	205,883

Twin Wall + Energy Curtin: U = .4

		January	February	March	April	May	June	July	August	September	October	November	December	Annual Avg.
Kodiak	Q = U * A * (Ti–To)	151,914	149,629	140,492	122,978	100,134	76,909	58,633	55,587	75,386	110,794	134,781	148,487	110,413
Saint Paul	Q = U * A * (Ti–To)	164,478	180,469	173,616	158,005	131,735	107,748	90,234	84,143	95,945	121,836	140,111	155,340	133,638
Akutan	Q = U * A * (Ti–To)	142,205	142,205	138,398	128,118	107,939	87,569	69,865	62,631	80,335	104,702	123,739	133,829	110,033
Dillingham	Q = U * A * (Ti–To)	204,455	203,313	181,611	146,203	103,560	71,769	56,539	61,679	86,427	139,730	179,327	210,928	137,255

Table 5.10 uses the standard calculation that a gallon of "Number 2 Diesel" heating oil is equivalent to 139,000 Btu's of energy. The Q coefficient from Table 5.9 was divided into the diesel equivalent unit to obtain the required heating oil equivalent unit per hour required to maintain an optimal temperature of 69.8 degrees Fahrenheit, year round.

Table 5.10 - Diesel per Hour Based on 60 ft. * 72 ft. Unit: Optimal Temperature of 69.8 Degrees Fahrenheit

1 Gal of Fuel Oil: Btu Equivalent = 139000

	January	February	March	April	May	June	July	August	September	October	November	December	Annual Avg.
Twin Wall: U = .6													
Kodiak	1.639	1.615	1.516	1.327	1.081	0.830	0.633	0.600	0.814	1.196	1.454	1.602	1.192
Saint Paul	1.775	1.948	1.874	1.705	1.422	1.163	0.974	0.908	1.035	1.315	1.512	1.676	1.442
Akutan	1.535	1.535	1.493	1.383	1.165	0.945	0.754	0.676	0.867	1.130	1.335	1.444	1.187
Dillingham	2.206	2.194	1.960	1.578	1.118	0.774	0.610	0.666	0.933	1.508	1.935	2.276	1.481
Twin Wall + Energy Curtin: U = .4													
Kodiak	1.093	1.076	1.011	0.885	0.720	0.553	0.422	0.400	0.542	0.797	0.970	1.068	0.794
Saint Paul	1.183	1.298	1.249	1.137	0.948	0.775	0.649	0.605	0.690	0.877	1.008	1.118	0.961
Akutan	1.023	1.023	0.996	0.922	0.777	0.630	0.503	0.451	0.578	0.753	0.890	0.963	0.792
Dillingham	1.471	1.463	1.307	1.052	0.745	0.516	0.407	0.444	0.622	1.005	1.290	1.517	0.987

Table 5.11 calculates the diesel oil requirements based on a 24 hour day, using calculations based on Table 5.10, for average hourly requirements.

Table 5.11 - Diesel Oil Required for 24 Hour Day Based on 4320 Sq. Ft. Unit: Optimal Temp of 69.8 Degrees Fahrenheit

	January	February	March	April	May	June	July	August	September	October	November	December	Annual Avg.
Twin Wall: U = .6													
Kodiak	39.345	38.753	36.386	31.850	25.934	19.919	15.186	14.397	19.524	28.695	34.907	38.457	28.596
Saint Paul	42.599	46.740	44.965	40.922	34.118	27.906	23.370	21.792	24.849	31.555	36.288	40.232	34.611
Akutan	36.830	36.830	35.844	33.182	27.955	22.680	18.095	16.221	20.806	27.117	32.048	34.661	28.498
Dillingham	52.952	52.657	47.036	37.865	26.821	18.588	14.643	15.974	22.384	36.189	46.444	54.629	35.548
Twin Wall + Energy Curtin: U = .4													
Kodiak	26.230	25.835	24.258	21.234	17.289	13.279	10.124	9.598	13.016	19.130	23.271	25.638	19.064
Saint Paul	28.399	31.160	29.977	27.282	22.746	18.604	15.580	14.528	16.566	21.036	24.192	26.821	23.074
Akutan	24.553	24.553	23.896	22.121	18.637	15.120	12.063	10.814	13.871	18.078	21.365	23.107	18.998
Dillingham	35.302	35.104	31.357	25.244	17.881	12.392	9.762	10.650	14.923	24.126	30.963	36.419	23.699

Table 5.12 calculates the diesel oil requirements based on a 24 hour day, using calculations based on Table 5.11, for average daily requirements, multiplied by the community multiplier as described in Table 5.4. Annual average displays each community's, unique daily requirement of diesel fuel to maintain an optimal internal temperature.

Table 5.12 - Diesel Oil Required Based on 4320 Sq. Ft. Unit for Average Daily Maximum Community Requirements

	January	February	March	April	May	June	July	August	September	October	November	December	Annual Avg.
Twin Wall: U = .6													
Kodiak	943.760	929.568	872.800	763.996	622.077	477.793	364.258	345.336	468.332	688.306	837.321	922.472	686.335
Saint Paul	35.907	39.398	37.902	34.494	28.759	23.522	19.699	18.369	20.946	26.598	30.587	33.912	29.174
Akutan	57.219	57.219	55.687	51.551	43.431	35.235	28.112	25.201	32.324	42.129	49.789	53.849	44.312
Dillingham	220.156	218.926	195.557	157.430	111.513	77.280	60.881	66.416	93.064	150.460	193.097	227.125	147.659
Twin Wall + Energy Curtin: U = .4													
Kodiak	629.173	619.712	581.867	509.331	414.718	318.529	242.839	230.224	312.221	458.871	558.214	614.981	457.557
Saint Paul	23.938	26.265	25.268	22.996	19.172	15.681	13.133	12.246	13.964	17.732	20.391	22.608	19.449
Akutan	38.146	38.146	37.125	34.367	28.954	23.490	18.741	16.801	21.550	28.086	33.193	35.899	29.541
Dillingham	146.770	145.950	130.371	104.953	74.342	51.520	40.587	44.277	62.043	100.307	128.732	151.417	98.439

Table 5.13 displays electrical usage at the Chena Hot Springs Resort Greenhouse as Reported by Chena Hot Springs Employee on 10/27/10, as well as the individual community electrical requirements. Individual community kilowatt per hour was reported by personal correspondence with local utility companies. Community *Annual Costs* are calculated by using the community unit requirements as described in Table 5.4 multiplied by the average monthly kilowatt rate per hour, multiplied by estimated monthly usage.

Table 5.13 - Electrical Usage for 4320 Sq. Ft. Unit

Kilowatts per hour	70	Hours per day	12	Monthly Use	25,550

	Greenhouse Units Required	Average kw/hour	Monthly Use		Annual Cost
Kodiak	23.99	$0.145	612,869	$	1,066,392.06
Dillingham	4.16	$0.363	106,227	$	462,724.81
Akutan	1.55	$0.320	39,694	$	152,424.96
Saint Paul	0.84	$0.550	21,536	$	142,137.60

Table 5.14 reports statistics regarding the natural light contribution to kilowatts per hour per meter squared at each of the communities in 2005, as recorded by the National Renewable Energy Laboratory. (National Solar Radiation Data Base, 2009) As described in a personal correspondence with Eric Labbate of Climate Control Systems Inc., ideal kilowatts per hour per meter squared required for growing are 1200 kw/m. The percentage of the natural light supplied in each of the communities, on a monthly average is derived by dividing the recorded kw/m by 1200 kw/m. NOTE: Daylight hours represents time in Juneau; variation will exist for actual light in Akutan, other communities are at similar Latitude and should be comparable.

Table 5.14 – Natural Light in Kilowatts per Hour & Percentage Required for Greenhouse

	kw/m2 per Hour of Daylight				Percentage of 1200 kw/m2 per Hour			
	Kodiak	Akutan	Dillingham	Saint Paul	Kodiak	Akutan	Dillingham	Saint Paul
January	167.6	228.5	153.8	178.6	8%	10%	7%	8%
February	283.3	333.3	265.7	292.3	16%	19%	15%	17%
March	419.7	462.1	404.7	430.6	31%	34%	30%	32%
April	533.9	571.3	518.7	539.6	44%	48%	43%	45%
May	596.0	631.6	581.5	601.2	50%	53%	48%	50%
June	612.2	639.4	601.6	607.5	51%	53%	50%	51%
July	602.8	631.5	585.6	607.1	50%	53%	49%	51%
August	550.6	590.6	539.8	556.0	46%	49%	45%	46%
September	458.5	498.4	435.7	461.0	38%	42%	36%	38%
October	321.6	371.4	306.3	331.0	26%	30%	24%	26%
November	196.2	249.1	179.8	204.2	12%	15%	11%	13%
December	128.4	192.7	113.5	143.5	6%	9%	5%	7%
Average	**405.90**	**449.99**	**390.56**	**412.72**	**32%**	**35%**	**30%**	**32%**

Table 5.15 displays local retail prices as reported by personal correspondence with grocers and local government authorities as reported in October 2010.

Table 5.15 – Local Retail Prices

	Kodiak	Dillingham	Akutan	Saint Paul
Tomatoes	$ 3.99	$ 4.20	$ 3.99	$ 4.29
Cucumbers	$ 1.53	$ 2.00	$ 1.99	$ 1.79
Peppers	$ 3.49	$ 2.50	$ 3.00	$ 3.79
Leafy Greens	$ 2.40	$ 3.00	$ 2.99	$ 3.00

Table 5.16 describes the operating revenue and expense assuming figures from all previous tables. *Square Feet* represent the size of greenhouse as described in table 5.3. *Greenhouse Units* represents the number of 60 foot by 72 foot units required to meet the required capacity as described in Table 5.4. *Revenue* is a function of *Pounds* produced, as described in Table 5.2, multiplied by local retail prices as described in table 5.14. *Heating* represents the annual daily usage of #2 Diesel Heating Oil required by each community greenhouse, constructed with a Twin Wall infrastructure, as described by Table 5.12, multiplied by the reported price of Heating Oil as reported in personal correspondence with local providers in October 2010. *Electric* represents usage and average price per unit as described in Table 5.13. *Custom Packing and Marketing* is a function of total pounds of output, multiplied by a standard $0.25 cost, as represented in the Chena Model. *Variable Costs* sum all reported categories, as stated above; the additional *Material Inputs, Accessories* and *Labor* are reported by actual costs of production from the Chena Model as described in Table 5.1, multiplied by the individual community *Greenhouse Units* required for each community. *Fixed Costs* are also a function of the numbers represented by the Chena Model in Table 5.1, multiplied by individual community *Greenhouse Units* required. *Operating Revenue* is a function of *Total Revenue* less *Total Cost. Average Return per Pound of Output* is a function of the *Operating Revenue* divided by the *Pounds* of output. Based on the assumptions provided here, all models fail to prove economically viable.

Table 5.17 makes all assumptions defined in Table 5.16, with adjustments made to *Payroll*, *Materials* and *Interest Rates*. Adjustments to *Payroll* included reducing the hourly wage of *Labor* to $8 per hour and including a *Manager* with salary equal to $65,000; greenhouse units are applied for each community. Adjustments to *Materials* set the price of material equal to the Canadian industry average in 2009, as shown in Table 3.6 of *Plant Material for Growing and Resale*. Adjustments to interest rates have been adjusted down from 10% to 5%, and adjusting to all costs in the *Fixed Costs* category. Based on the assumptions provided here, all models fail to prove economically viable.

Table 5.18 makes all assumptions defined in Table 5.17, with adjustments made to *Electrical* and *Heating* requirements. Adjustments to *Electric* incorporate the use of natural light to adjust the amount of artificial light required; the average percentage of natural light was directly substituted for the use of artificial light, reducing electrical costs by the percentage recorded in Table 5.14. Adjustments to *Heating* accounted for additional insulation, reducing the U-coefficient from .6 to .4, as described in Table 5.12. Based on the assumptions provided here, all models fail to prove economically viable.

Table 5.19 makes all assumptions defined in Table 5.18, with adjustments made to *Crop Expenses, Additional Expense* and *Payroll.* Adjustments to *Crop Expenses, Additional Expenses* and *Payroll* reflect actual average expenses as recorded in the Canadian greenhouse industry in 2009, as recorded in Table 3.6. Based on the assumptions provided here, all models fail to prove economically viable.

Table 5.20 make all assumptions defined in Table 5.19 adjusted to represent operating revenue and expenses on a per foot basis. Since all categories are standardized, it becomes easy to identify variation in each of the greenhouse operations. The output revenue per square foot represents the price of vegetables at each community, as the pound per unit is held constant. The large variation in variable costs should be noted for each community; fixed costs are assumed to be the same.

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Table 5.16 – Assumes Chena Model: No Adjustments

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
Greenhouse Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	495,856	$ 1,190,053.42	17,424	$ 52,273.25	32,116	$ 96,025.61	85,945	$ 257,835.80
Cucumbers	84,111	$ 128,689.86	2,956	$ 5,290.65	5,448	$ 10,840.93	14,579	$ 29,157.46
Bell Peppers	124,889	$ 435,861.54	4,389	$ 16,632.80	8,089	$ 24,266.38	21,647	$ 54,116.52
Tomatoes	250,513	$ 999,548.28	8,803	$ 37,765.15	16,225	$ 64,738.77	43,421	$ 182,367.28
TOTAL OUTPUT & REVENUE	**955,369**	**$ 2,754,153.10**	**33,572**	**$ 111,961.84**	**61,877**	**$ 195,871.70**	**165,591**	**$ 523,477.05**
Costs								
Heating								
Annual Average Diesel Oil per Day	686.33		29.17		44.31		147.66	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		4.452	
TOTAL Annual Heating Costs	$ 811,659.69		$ 47,173.20		$ 4,695.71		$ 239,942.33	
Electric								
Annual Electrical Demand in Kilowatts	7,354,431		258,435		476,332		1,274,723	
Average kw/hour	0.145		0.550		0.320		0.363	
TOTAL Annual Electrical Costs	$ 1,066,362.42		$142,139.50		$152,426.25		$ 462,505.15	
Material Inputs	$ 1,085,246.36		$ 38,135.67		$ 70,289.27		$ 188,102.72	
Accessories	$ 47,446.40		$ 1,667.27		$ 3,073.01		$ 8,223.75	
Labor (2 people full time)	$ 2,993,584.54		$105,194.86		$193,888.57		$ 518,869.65	
Heat	$ 811,659.69		$ 47,173.20		$ 64,695.71		$ 239,942.33	
Electricity	$ 1,066,362.42		$142,139.50		$152,426.25		$ 462,505.15	
Int. on Op. Capital	$ 270,861.83		$ 9,518.11		$ 17,543.19		$ 46,947.73	
Custom Packing & Marketing	$ 238,842.16		$ 8,392.94		$ 15,469.34		$ 41,397.85	
Variable Costs	**$ 6,275,161.24**		**$343,828.61**		**$501,915.99**		**$1,464,591.33**	
Depreciation & Interest	$ 521,310.68		$ 18,318.91		$ 33,764.27		$ 90,357.32	
Insurance	$ 40,322.24		$ 1,416.93		$ 2,611.59		$ 6,988.94	
Fixed Costs	**$ 561,632.92**		**$ 19,735.84**		**$ 36,375.86**		**$ 97,346.27**	
TOTAL COSTS		**$ 7,075,636**		**$ 371,95**		**$ 553,761**		**$ 1,603,335**
TOTAL REVENUE		**$ 2,754,153**		**$ 111,961**		**$ 195,871**		**$ 523,477**
OPERATING REVENUE		**$ (4,321,483)**		**$ (259,995)**		**$ (357,889)**		**$(1,079,858)**
Average Return per Pound of Output		**$ (4.52)**		**$ (7.74)**		**$ (5.78)**		**$ (6.52)**

Table 5.17 – Assumes Previous Model: Adjustments to Payroll, Materials and Interest Rates

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
Greenhouse Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	495,856	$ 1,190,053.42	17,424	$ 52,273.25	32,116	$ 96,025.61	85,945	$ 257,835.80
Cucumbers	84,111	$ 128,689.86	2,956	$ 5,290.65	5,448	$ 10,840.93	14,579	$ 29,157.46
Bell Peppers	124,889	$ 435,861.54	4,389	$ 16,632.80	8,089	$ 24,266.38	21,647	$ 54,116.52
Tomatoes	250,513	$ 999,548.28	8,803	$ 37,765.15	16,225	$ 64,738.77	43,421	$ 182,367.28
TOTAL OUTPUT & REVENUE	**955,369**	**$ 2,754,153.10**	**33,572**	**$ 111,961.84**	**61,877**	**$ 195,871.70**	**165,591**	**$ 523,477.05**
Costs								
Heating								
Annual Average Diesel Oil per Day	686.33		29.17		44.31		147.66	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		4.452	
TOTAL Annual Heating Costs	$ 811,659.69		$ 47,173.20		$ 64,695.71		$ 239,942.33	
Electric								
Annual Electrical Demand in Kilowatts	7,354,431		258,435		476,332		1,274,723	
Average kw/hour	0.145		0.550		0.320		0.363	
TOTAL Annual Electrical Costs	$ 1,066,362.42		$142,139.50		$152,426.25		$ 462,505.15	
Material Inputs	$ 154,072.88		$ 5,414.14		$ 9,979.00		$ 26,705.02	
Accessories	$ 47,446.40		$ 1,667.27		$ 3,073.01		$ 8,223.75	
Labor (2 people full time)	$ 798,289.21		$ 28,051.96		$ 51,703.62		$ 138,365.24	
Manager	$ 1,559,158.61		$ 54,788.99		$100,983.63		$ 270,244.61	
Heat	$ 811,659.69		$ 47,173.20		$ 64,695.71		$ 239,942.33	
Electricity	$ 1,066,362.42		$142,139.50		$152,426.25		$ 462,505.15	
Custom Packing & Marketing	$ 238,842.16		$ 8,392.94		$ 15,469.34		$ 41,397.85	
Total Variable Cost	**$ 4,675,831**		**$ 287,628**		**$ 398,330**		**$ 1,187,383**	
Depreciation & Interest	$ 366,234.36		$ 12,869.51		$ 23,720.28		$ 63,478.38	
Insurance	$ 40,322.24		$ 1,416.93		$ 2,611.59		$ 6,988.94	
Interest on Depreciation	$ 81,480.19		$ 2,863.22		$ 5,277.31		$ 14,122.73	
Interest on Capital Investment	$ 262,727.34		$ 9,232.27		$ 17,016.33		$ 45,537.80	
Total Fixed Costs	**$ 750,764.14**		**$ 26,381.93**		**$ 48,625.51**		**$ 130,127.85**	
TOTAL Cost		**$ 5,426,595.52**		**$ 314,009.93**		**$ 446,956.06**		**$ 1,317,511.80**
TOTAL REVENUE		**$ 2,754,153.10**		**$ 111,961.84**		**$ 195,871.70**		**$ 523,477.05**
OPERATING REVENUE		**$ (2,672,442)**		**$ (202,048)**		**$(251,084)**		**$ (794,034**
Average Return per Pound of Output		**$ (2.80)**		**$ (6.02)**		**$ (4.06)**		**$ (4.80)**

Table 5.18 – Assumes Previous Model: Adjustments to Electrical and Heating Requirements

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
Greenhouse Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	495,856	$ 1,190,053.42	17,424	$ 52,273.25	32,116	$ 96,025.61	85,945	$ 257,835.80
Cucumbers	84,111	$ 128,689.86	2,956	$ 5,290.65	5,448	$ 10,840.93	14,579	$ 29,157.46
Bell Peppers	124,889	$ 435,861.54	4,389	$ 16,632.80	8,089	$ 24,266.38	21,647	$ 54,116.52
Tomatoes	250,513	$ 999,548.28	8,803	$ 37,765.15	16,225	$ 64,738.77	43,421	$ 182,367.28
TOTAL OUTPUT & REVENUE	**955,369**	**$ 2,754,153.10**	**33,572**	**$ 111,961.84**	**61,877**	**$ 195,871.70**	**165,591**	**$ 523,477.05**
Costs								
Heating								
Annual Average Diesel Oil per Day	457.56		19.45		29.54		98.44	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		4.452	
TOTAL Annual Heating Costs	$ 541,106.46		$ 31,448.80		$ 43,130.47		$ 159,961.55	
Electric								
Annual Electrical Demand in Kilowatts	5,037,328		175,868		311,788		887,206	
Average kw/hour	0.145		0.550		0.320		0.363	
TOTAL Annual Electrical Costs	$ 730,391.92		$ 96,727.36		$ 99,772.31		$ 321,903.18	
Material Inputs	$ 154,072.88		$ 5,414.14		$ 9,979.00		$ 26,705.02	
Accessories	$ 47,446.40		$ 1,667.27		$ 3,073.01		$ 8,223.75	
Labor (2 people full time)	$ 2,357,447.82		$ 82,840.95		$152,687.25		$ 408,609.85	
Heat	$ 541,106.46		$ 31,448.80		$ 43,130.47		$ 159,961.55	
Electricity	$ 705,665.33		$ 93,253.38		$ 95,267.46		$ 311,975.78	
Custom Packing & Marketing	$ 238,842.16		$ 8,392.94		$ 15,469.34		$ 41,397.85	
Total Variable Cost	**$ 4,044,581.06**		$223,017.48		$319,606.53		$ 956,873.81	
Depreciation & Interest	$ 366,234.36		$ 12,869.51		$ 23,720.28		$ 63,478.38	
Insurance	$ 40,322.24		$ 1,416.93		$ 2,611.59		$ 6,988.94	
Interest on Depreciation	$ 81,480.19		$ 2,863.22		$ 5,277.31		$ 14,122.73	
Interest on Capital Investment	$ 262,727.34		$ 9,232.27		$ 17,016.33		$ 45,537.80	
Total Fixed Costs	**$ 750,764.14**		**$ 26,381.93**		**$ 48,625.51**		**$ 130,127.85**	
TOTAL Cost		**$ 4,795,345.20**		**$ 249,399.41**		**$ 368,232.04**		**$ 1,087,001.66**
TOTAL REVENUE		**$ 2,754,153.10**		**$ 111,961.84**		**$ 195,871.70**		**$ 523,477.05**
OPERATING REVENUE		**$ (2,041,192)**		**$ (137,437)**		**$ (172,360)**		**$ (563,524)**
Average Return per Pound of Output		**$ (2.14)**		**$ (4.09)**		**$ (2.79)**		**$ (3.40)**

Table 5.19 – Assumes Previous Model: Crop Expenses, Additional Expenses and Payroll

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
Greenhouse Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	495,856	$190,053	17,424	$ 2,273.25	32,116	$ 96,025	85,945	$ 257,835
Cucumbers	84,111	$128,689	2,956	$ 5,290.65	5,448	$ 10,840	14,579	$ 29,157
Bell Peppers	124,889	$435,861	4,389	$16,632.80	8,089	$ 24,266	21,647	$ 54,116
Tomatoes	250,513	$999,548	8,803	$37,765.15	16,225	$ 64,738.77	43,421	$ 182,367
TOTAL OUTPUT & REVENUE	**955,369**	**$ 2,754,153**	**33,572**	**$ 11,961**	**61,877**	**$195,871**	**165,591**	**$ 523,477**
Costs								
Heating								
Annual Average Diesel Oil per Day	457.56		19.45		29.54		98.44	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		4.452	
TOTAL Annual Heating Costs	$ 541,106		$ 1,448.80		$ 43,130		$ 159,961	
Electric								
Annual Electrical Demand in Kilowatts	5,037,328		175,868		311,788		887,206	
Average kw/hour	0.145		0.550		0.320		0.363	
TOTAL Annual Electrical Costs	$ 730,391		$ 96,727		$ 99,772		$ 321,903	
Crop Expenses	$ 154,072		$ 5,414.14		$ 9,979		$ 26,705	
Additional Expenses	$ 173,686		$ 6,103		$ 11,249		$ 30,104	
Payroll	$ 137,827		$ 4,843		$ 8,926		$ 23,889	
Heat	$ 541,106		$ 31,448		$ 43,130		$ 159,961	
Electricity	$ 730,391		$ 96,727		$ 99,772		$ 321,903	
Total Variable Cost	**$ 1,737,085**		**$ 144,536**		**$ 173,057**		**$ 562,563**	
Depreciation	$ 366,234		$ 12,869		$ 23,720		$ 63,478	
Insurance	$ 40,322		$ 1,416		$ 2,611.59		$ 6,988.94	
Interest on Depreciation	$ 81,480.19		$ 2,863.22		$ 5,277		$ 14,122	
Interest on Capital Investment	$ 262,727		$ 9,232		$ 7,016		$ 45,537	
Total Fixed Costs	**$ 750,764**		**$ 26,381**		**$ 48,625**		**$ 130,127**	
TOTAL Cost		**$ 2,487,849**		**$ 70,918**		**$ 221,683**		**$ 692,691**
TOTAL REVENUE		**$ 2,754,153**		**$ 111,961**		**$ 195,871**		**$ 523,477**
OPERATING REVENUE		**$266,303**		**($58,957)**		**($25,811)**		**($169,214)**
Average Return per Pound of Output		**$ 0.28**		**$ (1.76)**		**$ (0.42)**		**$ (1.02)**

Table 5.20 – Assumes Previous Model: Crop Expenses, Additional Expenses and Payroll

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
Greenhouse Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	4.79	$ 11.48	4.79	$ 14.36	4.79	$ 14.31	4.79	$ 14.36
Cucumbers	0.81	$ 1.24	0.81	$ 1.45	0.81	$ 1.62	0.81	$ 1.62
Bell Peppers	1.21	$ 4.21	1.21	$ 4.57	1.21	$ 3.62	1.21	$ 3.01
Tomatoes	2.42	$ 9.65	2.42	$ 10.37	2.42	$ 9.65	2.42	$ 10.15
TOTAL OUTPUT & REVENUE	**9.22**	**$ 26.58**	**9.22**	**$ 30.75**	**9.22**	**$ 29.18**	**9.22**	**$ 29.15**
Costs								
Heating								
Annual Average Diesel Oil per Day	457.56		19.45		29.54		98.44	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		$ 4.45	
TOTAL Annual Heating Costs	$ 5.22		$ 8.64		$ 6.43		$ 8.91	
Electric								
Annual Electrical Demand in Kilowatts	5,037,328		175,868		311,788		887,206	
Average kw/hour	0.145		0.550		0.320		0.363	
TOTAL Annual Electrical Costs	$ 7.05		$ 26.56		$ 14.87		$ 17.92	
Crop Expenses	$ 1.49		$ 1.49		$ 1.49		$ 1.49	
Additional Expenses	$ 1.68		$ 1.68		$ 1.68		$ 1.68	
Payroll	$ 1.33		$ 1.33		$ 1.33		$ 1.33	
Heat	$ 5.22		$ 8.64		$ 6.43		$ 8.91	
Electricity	$ 7.05		$ 26.56		$ 14.87		$ 17.92	
Total Variable Cost	**$ 16.76**		**$ 39.69**		**$ 25.79**		**$ 31.32**	
Depreciation	$ 3.53		$ 3.53		$ 3.53		$ 3.53	
Insurance	$ 0.39		$ 0.39		$ 0.39		$ 0.39	
Interest on Depreciation	$ 0.79		$ 0.79		$ 0.79		$ 0.79	
Interest on Capital Investment	$ 2.54		$ 2.54		$ 2.54		$ 2.54	
Total Fixed Costs	**$ 7.25**		**$ 7.25**		**$ 7.25**		**$ 7.25**	
TOTAL COSTS per Foot		**$ 24.01**		**$ 46.94**		**$ 33.03**		**$ 38.57**
TOTAL REVENUE per Foot		**$ 26.58**		**$ 30.75**		**$ 29.18**		**$ 29.15**
OPERATING REVENUE per Foot		**$ 2.57**		**$ (16.19)**		**$ (3.85)**		**$ (9.42)**
Average Return per Pound of Output		**$ 0.28**		**$ (1.76)**		**$ (0.42)**		**$ (1.02)**

6. Discussion

The results provide clear support that a CEA greenhouse industry is in the realm of feasibility for Kodiak; assuming current conditions, CEA greenhouse industry in the communities of Dillingham, Akutan and Saint Paul, without adjusting the given set of assumptions, will likely not prove economically viable. This section will analyze the usability of the given dataset, investigate adjustments to improve efficiency and assess the community impact with alternative assumptions. Each community will be analyzed to determine a favorable set of conditions that could allow a viable CEA greenhouse industry to be established. System wide, community based input/output analysis will consider effects of establishing a CEA industry in each of the local economies studied.

6.1. Assumptions Explained

Assuming that national consumption patterns were identical to the communities selected for this study provided the best available data to determine demand parameters. Communities in this study are unique compared to the national standard and individuals are unlikely to fit exactly in to the same consumption patterns as the average American. The logistics required to supply communities in this study are far more complicated than most other regions of the US. An absence of overland interconnectivity and vast distances of separation, ensure that prices are elevated and time between harvest and consumption is expanded. In addition to price and freshness variation in each of the selected communities a large transient population is not recorded. As a counterweight to the downward pressure on consumption, the support that consumers may provide for a local food source could produce upward pressure on demand due to the strong sense of community. Greenhouse sales in the developed markets of the Canada, United States and Mexico calculate pricing and sales at wholesale values to maximize profit. A lack of pricing data at the selected communities required that assumed sales were based on the retail standard as recorded on a fixed date in October at each of the local communities. It is unknown if the optimal price which maximizes economic profits is equivalent to prices assumed in this study. Further research is required to determine the exact demand for leafy greens, peppers, cucumbers and tomatoes in the communities of Kodiak, Dillingham Akutan and Saint Paul.

Assumptions were made to the actual capitol and operating costs that should be audited for accuracy of practical implementation. All data used in this study is based on empirical evidence, and thus provides the best theoretical assumptions; this does not necessarily translate into determining factors for practical implementation. Capitol cost components yet to be investigated includes: land acquisition, shipping costs and additional cost of construction. Each of the communities discussed in this study have geographical limitations to include, water bodies, mountains, State parks and other access restrictions to developable land. Whereas shipping costs can easily be integrated into capital expenses, the lack of road access in Southwest Alaska necessitate that additional planning incorporates appropriate time and money increases. The relatively small and isolated communities investigated may have elevated construction costs for labor and/or adjustments to the construction process requiring additional materials or supplies.

Models should be assessed for practical purposes at local communities to verify actual operating expenses. Assumptions were made that controlling for variation, costs should be equivalent at any location. While the greenhouse industry is maturing, changes in operations and efficiency are ongoing; until the industry is stable, and a consistent set of standards is established, materials input, labor, energy costs and capitol costs need to be analyzed on a community specific basis by professionals knowledgeable to the greenhouse industry.

6.2. Investigating Efficiency

As energy inputs will be the largest operating expense for CEA operations, gaining efficiency on a per-until basis is likely to yield the most profitable results. Assuming that the price of diesel is not subject to subsidies, a more effective unit of energy is required to provide adequate BTU's, which maintain optimal temperature. The most common fuel for heating greenhouses in the US and Canada is natural gas. Other methods convert electricity to heat. One technology that holds promise for reducing costs is Ground Source Heat Pumps (GSHP). Because GSHP's draw the energy from the ambient warmth in the ground and water it is unknown if such a technology is appropriate in Alaska.

Efficiency gains in electricity require using local factors of generation; otherwise market factors will dictate prices with a high likelihood of variability and no means to hold costs down. The most straightforward method would be to develop a renewable source of electrical generation. This source of energy must be cost effective compared to importing another fuel source, or efficiency gains will not be met. Outside of directly converting natural resources into electricity, methods should be investigated to capture and retain more of the natural heat and light to maximize use of the free energy.

Payroll, crop expenses and operating overhead will consume most other variable costs. These items may be difficult to reduce without importing outside expertise with experience operating similar operations, or research institutions with the time and money to investigate alternative methods. Initial capital expenditures may provide improved operations through reduced labor and operating expenditure. Crop expenses should be investigated to determine usability of local resources which may be able to provide reduced cost and retain value within the community.

Huge annual expenses are afforded to cover the cost of financing and replacing capitol. Capital expenses are a major component of any CEA greenhouse, especially those located in northern climates. Outside of heating and electrical demand, depreciation is the largest expense, followed by interest on capital, based assumptions in Table 5.19. Because many components of the greenhouse, are electrical, or are made from less durable material such as glass and aluminum, the replacement costs cause depreciation to add up fast. Advances in greenhouse technology may be available to reduce the costs of common components, or extend the life of others. Many vendors are rising up to meet the demand for greenhouse kits; it is likely that a maturing market will produce reduced costs at higher quality in the future as competition increases.

6.3. Implications of Results

The determining factors of whether a CEA greenhouse industry is developed in Alaska will depend on the demand potential and the energy inputs. Due to the limitations of this analysis being conducted without special knowledge of local demand and costs structures, these results should be used to determine what further research needs to be conducted prior to practical implementation.

A greater understanding of actual demand at each community will be necessary before moving forward with construction of a greenhouse industry based on national statistics, when the likelihood that demand structure hinges on factors which differ from national assumptions. Key differences in demand may be determined due to the reduced access to fresh vegetables, and cost of moving most vegetables large distances prior to consumption. The result is that consumers are paying a higher price for products that may be of a lesser quality than consumers closer to the source. While improvements have been made in the supply of fresh produce to most communities in Alaska, a cultural adjustment may have taken hold where some residents may not be used to a reliable and cost effective source of fresh vegetables, reducing demand over time. Another factor affecting actual demand may be the culture of hard physical labor, and the energy demands necessary to supplement the lifestyle may lead to an altered local demand for vegetables from national average. As noted in Table 5.20 the output potential ranges from $26.58 to $30.75 per foot of greenhouse. There is a high likelihood that in actual production revenue may not be that great. As shown in Table 3.2, in 2009 the Canadian greenhouse industry only averaged $7.57 per square foot of greenhouse. This is largely due to the fact that Canadian Greenhouses sell product at larger volumes, not at retail prices. While it is reasonable to assume that a greenhouse whose primary market is in a isolated community could sell product at retail prices, a prudent business plan would need to identify a pricing scheme necessary for competitive pricing that maximizes profits. These demand issues should be determined through a more detailed analysis of local data.

Aside from the actual costs for electricity and heating oil, all other costs are assumed based on past empirical research regarding other greenhouse operations. The data gathered from the Canadian Greenhouse industry is comprehensive, as it represents a large data set; however, further analysis is required to determine if that data can be assumed to be accurate when applied to an Alaska model. Data gathered from the Chena Model, the base for all capitol expenses should be analyzed to further determine if that model is the most appropriate for each of the individual communities researched in this study. A greenhouse study recorded by the Government of Alberta reported total investment costs in the range of $1.54 to $2.32 per square foot of operating costs, and total capital costs in the range of $11.34 to $12.68 for various greenhouse operations. (Dey, 2001) This compares to capitol cost of $32.01 per square foot for capitol costs using the Chena Model, and using a straight-line depreciation and 5% interest, annual costs of $7.25 per square foot for financing debt. Reducing the Fixed cost from $7.25 to $2.32 as in the Canadian model, reduces total expenses by $4.93 per foot, or $21,297.60 annually for each 60 foot by 72 foot unit. In order to properly determine the actual costs associated with each greenhouse a more detailed analysis is required.

6.4. Community Impact

While an operator may think of the costs of operation, a community can think of many of those costs as a source of revenue, money retention and multiplication, investment and increased quality of life and health.

The greenhouse operations analyses determine a cost of payroll between $1.33 cents per foot of greenhouse; or $8.00 per hour for labor and a salary of $65,000 for a manager, per greenhouse unit; or $30 per hour. Paying $1.33 per foot in a greenhouse may not make sense for a small operation like Saint Paul, where this would only account for an annual salary of $ 4,843 for one person; nor can we assume that paying $2.99 million is an appropriate payroll, as is assumed in Kodiak, where a flat rate of $30 per hour is assumed, for two full time employees, per greenhouse unit. The important thing to note is that from a community perspective jobs will be created that will add to the direct supply of money circulating within the community, and any effect to increase the circulation of money supply in small isolated economies will generate a significant multiplying effect.

Infrastructure development has the potential to add a significant economic impact to a community. No assumptions were made to the multitude of infrastructure options that would likely be considered for such vastly different operations for each of the communities. Using the figures provided by the Chena Model, we assume capitol costs of $138,303 per greenhouse unit, plus a substantial annual investment to replace and maintain the operation. While a great deal of this purchase will be to outside vendors, some components will likely be sourced locally, where it is appropriate for support business to prop up the greenhouse operation. In small communities like the ones mentioned in this study, a support business may relay on a relatively small set of partners in order to stay profitable and stay in business; in such instances, the greenhouse operations may add just enough additional work to keep struggling support business operating.

The consumables, to include material inputs and power for heat and light, are cost that could affect a community in varying capacities. Keeping a large, steady supply of consumables may prove difficult for some communities with the need to import all necessary inputs. Assuming, diesel is used to generate the power, the added strain to the existing supply chains may prove more than the local carrying capacity. This may be yet another discouragement to communities researching greenhouse operations when the power source is supplied through diesel fuels. On the other hand, if a renewable source of energy was available locally, the power requirements could weigh very positively towards the development of both projects; the greenhouse and the renewable power source. As noted in Tables 5.16 to 5.20, considerable expenses are required for materials. If local supplies are available the greenhouse operation could be a boon to other development projects, but if it is required to ship materials that are not available locally, considerations should address supply chains carrying capacity to meet the input requirements.

As described by Ilaslan, White, and Langhans (2002), research supports that local government may have an economic incentive to assist with the development and operation of commercial greenhouse operations. The figures provided here show that while the accounting for a private firm reduces profits, the benefits to a community can be substantial and measurable. In addition to the measureable impacts of economic activity, local governments may also want to include the intrinsic value that such an operation could provide to a small community. Commercial CEA greenhouses may serve a sense of community pride, increase health and overall community wellness, as well become an identifying mark that could boost tourism appeal. It is beyond the scope of this study to determine a complete economic input/output analysis; however, total community impact should be assessed for final determination of project development.

The output potential for this study was limited to available data on leafy greens, cucumbers, peppers and tomatoes, other products may be more appropriate. This study has identified the need for a clear understanding of local demand; using that data, a more appropriate analysis could be incorporate products that more appropriately fit local consumption patterns, while also meeting the necessary requirements to be profitable products for greenhouse production. This analysis focused on a national per capita consumption of 73.1 pounds, the sum of: leafy greens, cucumbers, bell peppers and tomatoes; total per capita average consumption of all fresh vegetables is 192.2 pounds per person. A number of other factors would need to be analyzed before assuming greenhouse potential of 192.2 pounds per person in the community, but it is important to notice that if the entire market could be captured for all vegetable products, production could be expanded. Converting biomass to energy is still a developing market; however, with investment increasing, future efficiencies may be deemed feasible to grow energy in greenhouses where energy inputs are inexpensive. Most of the major oil companies are currently looking into applications of biomass to meet US regulations requiring a mix of ethanol into the fuel supply. Fish plants are already extracting fish oil for use in their generators. With the large demand and great expense of diesel fuel, integrating another source of fuel may prove valuable and increase the feasibility of developing a commercial greenhouse.

6.5. Improved Efficiency Assumptions

While a number of assumptions were made to determine results, further technological gains could improve the operating environment. Ground source heat pumps have been noted as one potential to reduce the cost of heating. According to a study conducted by Oak Ridge National Laboratory, a potential exists to reduce heating cost by up to 45% compared to other reasonable technology (Hughes P. J., 2008). Assuming a reduction of this magnitude is applied to the heating cost for each community, as noted in Table 6.1. Rates of renewable electricity have the potential to be substantially cheaper than current rates that incorporate the expense of burning imported fossil fuel to generate electricity. According to Kodiak Electric Association, the cost of electricity generation produced by the hydroelectric plant is about $.12 per kilowatt; which is similar to a target estimate of $.13 from the proposed Akutan Geothermal plant as reported by Raymond Mann, a consultant familiar with the project. Assuming a rate of $.12 kw/h, energy costs are further reduced as noted below. Assuming payroll as reported in the Canadian greenhouse industry may be inappropriate for the Alaska model assumed in Tables 5.17 – 5.20. Assuming that management with technical experience, works for a flat salary of $65,000 and labor at a minimum wage of $8 per hour, the adjusted payroll is displayed below. As noted, the fixed costs reported in the Canadian greenhouse industry, to include depreciation and interest costs averages $2.32 per foot. As the industry continues to mature and materials become standardized, it is reasonable to assume that costs should settle around an industry mean. A fixed cost of $2.32 is assumed below.

Table 6.1: Alternative Scenario – Reduced Heating, Electric & Fixed Costs

	Kodiak		Saint Paul		Akutan		Dillingham	
Square Feet	103,624		3,641		6,712		17,961	
# of 4320 Sq. Ft. Units	23.99		0.84		1.55		4.16	
Revenue								
Output	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars	Pounds	Dollars
Leafy Greens	495,856	$ 1,190,053	17,424	$ 52,273	32,116	$ 96,025	85,945	$ 257,835
Cucumbers	84,111	$ 128,689	2,956	$ 5,290	5,448	$ 10,840	14,579	$ 29,157
Bell Peppers	124,889	$ 435,861	4,389	$ 16,632	8,089	$ 24,266	21,647	$ 54,116
Tomatoes	250,513	$ 999,548	8,803	$ 37,765	16,225	$ 64,738	43,421	$ 182,367
TOTAL OUTPUT & REVENUE	955,369	$2,754,153	33,572	$ 111,961	61,877	$ 195,871	165,591	$ 523,477
All VEGGIES TOTAL OUTPUT & REVENUE	2,510,134	$7,530,403	88,206	$ 264,619	162,576	$ 487,729	435,075	$1,305,223
Costs								
Heating								
Annual Average Diesel Oil per Day	457.56		19.45		29.54		98.44	
Average price per Gal. Diesel Oil	$ 3.24		$ 4.43		$ 4.00		$ 4.45	
TOTAL Annual Heating Costs	$ 351,719		$ 20,441		$ 28,034		$ 103,975	
Electric								
Annual Electrical Demand in Kilowatts	5,037,328		175,868		311,788		887,206	
Average kw/hour	0.120		0.120		0.120		0.120	
TOTAL Annual Electrical Costs	$ 604,479		$ 21,104		$ 37,414		$ 106,464	
Crop Expenses	$ 154,072		$ 5,414		$ 9,979		$ 26,705	
Additional Expenses	$ 173,686		$ 6,103		$ 11,249		$ 30,104	
Management	$ 130,000		$ 65,000		$ 65,000		$ 65,000	
Labor	$ 399,144		$ 16,640		$ 16,640		$ 69,182	
Heat (24)	$ 351,719		$ 20,441		$ 28,034		$ 103,975	
Electricity (25)	$ 604,479		$ 21,104		$ 37,414		$ 106,464	
Total Variable Cost	**$ 1,813,102**		**$ 134,703**		**$ 68,317**		**$ 401,432**	
Total Fixed Costs	**$ 240,407**		**$ 8,447**		**$ 15,570**		**$ 41,669**	
TOTAL Cost		**$ 2,053,510**		**$ 143,151**		**$ 183,888**		**$ 443,101**
TOTAL REVENUE		**$ 2,754,153**		**$ 111,961**		**$ 195,871**		**$ 523,477**
OPERATING REVENUE		**$ 700,642**		**$ (31,189)**		**$ 1,983**		**$ 80,375**
Average Return per Pound of Output		**$ 0.73**		**$ (0.93)**		**$ 0.19**		**$ 0.49**

Incorporating efficiency assumptions beyond what is currently available; all community greenhouses become profitable except Saint Paul. None of the assumptions made here should be beyond feasibility as technology improves and the greenhouse industry matures. A project underway in Akutan has taken the first steps towards more efficient energy that could provide inputs necessary to develop an economically viable greenhouse industry. The defining factors to development are once again identified to be the costs of energy inputs.

6.6. Alternative Scenarios for Success – Law of Thermodynamics

To restate the First Law of Thermodynamics, energy cannot be created or destroyed, only altered. This principal is very important for proposed greenhouse operations where naturally occurring conditions are marginal, requiring a controlled environment. Without significant contribution from the local environment profitability will not likely be determined; a fact identified in this study. What was not considered was to alter the growing environment to maximize the nature supply of resources. Without an abundant supply of locally supplied power this will most likely mean making use of natural light and heat. The trade of relying on natural heat and lighting is that of efficiency; however, a slight decrease in output potential may prove profitable if adjustments to the operation focused on maximizing value. A number of such operations have been established in most regions of Alaska, and while they are effective in providing a local supply of produce for a limited time, they have not yet proved a viable option for reducing the costs or availability of food in local communities as imports are still relied on for most of the year.

6.7. Future Direction for Further Study

This study gathered a comprehensive set of available data, from which conclusions have been drawn which aim to identify strengths and weaknesses in the Alaska greenhouse model. A great deal of effort was devoted to areas of this study that need to be enhanced to determine practical application of a greenhouse industry in Southwest Alaska; the focus of which needs to identify individual community specifics. Central to further studies will be to determine the actual level of demand, products and growth potential based on various pricing models. Input prices were taken at a point in time, where a more detailed study would want to use pricing models that takes into account historical accounts, and forecasts future prices. Without reducing, or keeping input prices low CEA greenhouses will not be a feasible option; research should focus on projects which reduce long term energy costs. The development of a greenhouse industry needs to take account of local factors. Capitol costs, to include site selection and landscaping, shipping and mobilization and construction costs using local capacity, financing and permitting will all need to be included in the final business plan.

6.8. Conclusion

The results of this study provide support that a CEA greenhouse industry could be profitable in Kodiak and that input cost need to be reduced in Dillingham, Akutan and Saint Paul before economically viable operations can be established. This study also identifies a lack of information needed to adequately produce a sound business plan that local communities would require prior to implementation. It is important to differentiate greenhouses between a structure which improves environmental factors of production and Controlled Environment Agriculture greenhouses referenced in this report. CEA greenhouses incorporate a high level of engineering and technology into a production facility capable of producing yields necessary to supply all of a community's vegetable needs. The result is that a great deal of planning and capital expenditure is required to ensure that failure is averted. This report is the first step necessary to expanding year-round growing potential in Alaska.

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