UNDERSTANDING SUSTAINABLE NORTHERN GREENHOUSE TECHNOLOGIES FOR CREATING ECONOMIC DEVELOPMENT OPPORTUNITIES AND SUPPORTING FOOD SECURITY

FINAL REPORT

Submitted to:

AGRICULTURE AND AGRI-FOOD CANADA

JUNE 2013

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ACRONYMS

AAC	Annual Allowable Cuts
AAFC	Agriculture and Agri-Food Canada
AAFRD	Alberta Agriculture, Food and Rural Development
AAI	Aboriginal Agriculture Initiative
AANDC	Aboriginal Affairs and Northern Development Canada
ACC	Aboriginal Capital Corporation
AFIs	Aboriginal Financial Institutions
AGGP	Agricultural Greenhouse Gasses Program
BC	British Columbia
BiOs	Biomass Opportunity and Supply
CAEEDAC	Canadian Agricultural Energy End-Use Data and Analysis Centre
CCAB	Canadian Council for Aboriginal Business
CHP	Combined Heat and Power
CIIF	Community Infrastructure Improvement Fund
CO	Carbon Monoxide
CO_2	Carbon Dioxide
CSA	Canadian Standards Association
EANCP	ecoENERGY for Aboriginal and Northern Communities Program
EDC	Economic Development Corporations
EPA	Environmental Protection Agency
EPDM	Ethylene Propylene Diene Methylene
FIRE	Finance, Insurance, Real estate, Rental and Leasing
FOB	Freight on Board
GHG	Greenhouse Gas
Gj	Gigajoules
GSHP	Ground Source Heat Pump
H2S	Hydrogen Sulphide
HID	High Intensity Discharge
HPS	High-Pressure Sodium
IRR	Internal Rate of Return
LEDs	Light Emitting Diodes
MH	Metal Halide
NACCA	National Aboriginal Capital Corporation Association
NAN	Nishnawbe Aski Nation
NFT	Nutrient Film Technique
NOx	Nitrogen Oxides
NPV	Net Present Value
NWT	Northwest Territories
OMAFRA	Ontario Ministry of Agriculture, Food and Rural Affairs
%ROA	Percentage Return on Assets

ORC	Organic Rankine Cycle
PAR	Photo-Synthetically Active Radiation
PTO	Power Take-Off
PV	Photovoltaic
RH	Relative Humidity
SDTC	Sustainable Development Technology Canada
SINED	Strategic Investments in Northern Economic Development
SOM	Simple Output Multiplier
SPI	Strategic Partnerships Initiative
TOM	Total Output Multipliers
USDA	United States Department of Agriculture
VOCs	Volatile Organic Compounds

EXECUTIVE SUMMARY

Introduction

As identified in the Request for Proposal, the goal of this study is "to provide a better understanding of the interrelationship among critical success factors… that contribute to a sustainable northern greenhouse that uses biomass as an alternate energy source. With this understanding, informed decision making can be made for a financial investment in a community's business model that best meets their expected outcomes for economic development and possibly matches a financial investor's model." This is to be undertaken through "a comprehensive background study on greenhouse production for northern/isolated communities, including greenhouse design components, technologies, management, marketing, and most importantly cost/benefit analyses. This report will highlight current knowledge and identify information gaps which will provide AAFC (Agriculture and Agri-Food Canada) and partners greater capacity to make well informed decisions when reviewing northern greenhouse project proposals in various locations across Canada. This research will focus on the technologies suited for northern latitudes and remote/isolated regions of the country and should consider the overall social, economic and environmental sustainability factors."

To accomplish this, Agriteam Canada Consulting Ltd. has designed a study methodology to identify what integrated greenhouse models might fit in the context of northern and remote communities given the existing resources, economic, socio-cultural and other factors. Agriteam has utilized a multi-sectoral team to undertake the study that includes expertise in greenhouse vegetable production, community engagement, economics, biomass, and environmental engineering. The methodology utilized includes:

- Extensive review of secondary sources;
- Field consultations with five northern communities in Saskatchewan and the Yukon;
- Field consultations and phone interviews with greenhouse enterprises in Saskatchewan, northern Manitoba and the Yukon;
- Interviews and cost quotations from greenhouse and biomass technology suppliers;
- Phone interviews with experts in relevant fields; and
- Wholesale and retail price data gathered from both private and government sources.

Literature Review

The literature review undertaken on northern food production found little in the way of scientific data on greenhouse production in northern Canada and Alaska. There are some research reports on prototypes (Chinese solar models) and small-scale experiments but very little in the way of actual scientific assessments that can guide decision making as it pertains to northern greenhouse development. Scandinavia (Finland in particular) does have an existing greenhouse industry at 60-65 degrees north but there are key differences that limit the applicability of production techniques to northern Canada including: 1) a greater population base and higher population densities which support crucial economies of scale; and 2) a milder climate that reduces heating costs.

When looking more broadly at the greenhouse literature in Canada and other countries, the impact of and sensitivity to energy costs is a key factor affecting the economic viability of northern greenhouses. The utilization of biomass or other heating sources to reduce heating and energy costs in the north is identified as a potential option to improve the economic viability of northern greenhouse enterprises depending on proximity to the resource and available infrastructure.

Compilation of Best Practices and Technologies for Northern Greenhouses
A range of greenhouse and other growing technologies exist that could be used within the north. These greenhouse systems lie on a continuum separated by differences in both technological complexity and costs which are crucial in identifying appropriate technologies for northern communities. In addition, however, it must be noted that there are other simpler, cheaper and less risky options such as outdoor market gardens which can produce storable root crops (potatoes, onions, carrots, etc.) and which are already in existence in the north.

Table 1: Comparison of Different Greenhouse Systems

Greenhouse Systems		Description/Pros and Cons
High-tunnel style greenhouse		• Single covered poly on simple hoop structure. • Low-cost and low-tech making them a good fit for communities with limited skills in greenhouse production. Viable skill level for an experienced but not formally trained grower. • All year production is not possible as it simply extends the season an extra month. • Productivity is very low due to poor environmental controls.
Stand-alone greenhouse		• Double-poly covering on engineered steel structure. • Variable levels of technology as can range from lower-tech soil-based production to high-tech soilless production with environmental controls similar to gutter-connected greenhouses. • Required skill levels vary with technologies utilized

Gutter-connected greenhouse		• Highly productive and capable of year-round production. • Proven Canadian technology. • Costlier and high-tech. • High skill level required to utilize which will be difficult to find in the north.
Chinese-style solar greenhouse		• Energy efficient which is of key importance for the north. • Mid-range productivity due to variable climatic conditions within greenhouse. • Still in prototype phase and capital costs are too high at present to be viable. • No proven commercially-viable models available.
Insulated plant factory		• Costly and high-tech. • Holds potential to reduce energy costs with light-emitting diodes (LED) lighting. • Economics in the north still need to be proven but they hold potential. • This type of greenhouse may not meet with northern communities visions for self-sufficiency and re-learning of skills.

There are major differences in greenhouse production systems between low- and high-tech production systems, and their associated productivity. In the commercial greenhouse industry, soilless production in raised troughs with high-tech climate and fertigation systems is the norm as opposed to simple in-ground soil-based production techniques in low-tech greenhouses.

Greenhouse technology is continually evolving with a number of new technologies having the potential to reduce energy consumption. Energy consumption is a crucial issue for northern greenhouses given their heating and lighting costs during winter which exceed greenhouse requirements in more southern climates. Low energy LED lighting technology does appear to be on the verge of transforming the greenhouse industry but may be a few years from full commercial acceptance – though this is expected to happen very soon. Technologies that are able to reduce energy costs, such as insulated plant factories, although not technically a greenhouse, hold definite promise in this regard but need to be proven to be commercially viable and/or technologically appropriate for remote, northern communities, although this technology is advancing quickly. Chinese solar style models also work toward the key goal of reducing energy costs but their economics look poor at the present until their capital costs can be reduced. It must be stated, however, than northern communities are in no position to test or experiment with commercially unproven technologies if their greenhouses are expected to be sustainable.

In terms of agronomics, almost any crop can be grown in a greenhouse. The real question, however, is which crops can be economically grown to ensure the commercial viability of a greenhouse enterprise. Tomatoes, cucumbers, peppers and lettuce account for the overwhelming majority crops grown in greenhouses, both globally and in Canada, because they produce the most revenue per square meter based on both price and yield. Woody and herbaceous plants, such as tree seedling production, also provide opportunities to simplify production and reduce operating costs as they utilize less heat and require less labour and less rigorous fertigation techniques.

Biomass may also provide an opportunity to reduce energy costs which is one of the key economic barriers to greenhouse development in the north. A number of viable biomass alternatives exist but the key for northern greenhouse development is to find locations offering a competitive advantage through access to a sustainable biomass resource. For larger-scale operations this will be dictated by the available infrastructure which will need to be located close by. Location close to lumber mills to use waste stock, pellets mills or other large-scale sources of cheap or waste biomass are viable alternatives. There are also opportunities to reduce energy costs by tying greenhouses in with district heating systems. In all of these cases, the viability is very site-specific and dependent on technology, feed stock and sustainability. The economic potential of biomass needs to be assessed on a site-specific basis.

Important advances are being made in other renewable technologies (solar, solar thermal, etc.) which can potentially be integrated into different greenhouse technologies. Others such as geothermal offer opportunity on a site-specific basis. Although there is promise with these emerging renewable technologies, more applied research is generally needed before these are ready for utilization by northern communities on a commercial basis.

Resources

Human resources are one of the key constraints to northern greenhouse development. It is crucial that communities and/or entrepreneurs establish greenhouse systems with a level of complexity that matches the level of available skills and experience. Low-tech greenhouse systems (high-tunnel style greenhouses and lower-tech stand-alone greenhouses) can be operated by an experienced greenhouse labourer, or an experienced gardener, who will run the operation and supervise labourers. Larger-scale gutter-connected systems with modern commercial technologies will require a combination of appropriate university training plus relevant industry experience. Smaller-scale versions of higher-tech systems, either gutter-connected or higher-tech stand-alone systems, can be operated by experienced growers with either formal training (diploma or higher) or those with an extensive agricultural background.

So how do northern communities acquire both the skills and experience to do this? Training will obviously be required in many cases but there are a number of northern aboriginal communities that have sufficient experience to develop greenhouse enterprises as they have either: 1) vegetable production experience within community greenhouses or also potentially if they have extensive market gardening experience; and 2) experience working in other types of greenhouse operations such as tree seedling production.

For northern communities with no or limited greenhouse expertise, or who need to improve their production expertise, a northern greenhouse training program may need to be developed unless training can be undertaken through existing programs. This program needs to include hands-on training as well as the opportunity to receive ongoing mentoring and networking with other producers in the field given the isolated locations. Olds College does have an existing online/videoconference curriculum that has been used for training in market garden and high-tunnel greenhouse production with a number of First Nations in Alberta.

Communities will, however, need to assess whether it makes sense for them to move directly to commercial greenhouse production. A first, simpler and easier step will be to gain expertise through commercial market gardening and/or through the development of small-scale community greenhouses. Once communities gain experience in vegetable production, whether outdoor market gardens or non-commercial greenhouses, they can then begin to move further up the development ladder to actual commercial greenhouse production. Acquiring this experience may be a long-term process for communities and individuals that will take a number of years for communities that have little or no greenhouse production skills. The overall process of moving to commercial greenhouse production will depend on the level of experience in greenhouse production and how quickly the needed skills and experience can be acquired.

For any communities or entrepreneurs looking at larger-scale, higher-tech greenhouses, it will likely be necessary to import labour unless highly skilled and experienced greenhouse growers can be found in the area. Otherwise, productivity levels and economic performance will likely not be sufficient to ensure the long-term viability and sustainability of the enterprise. However, specialized greenhouse vegetable growers are in demand and salaries in the industry start above C$100,000 plus benefits in the south. This presents a further economic problem in the north as the fixed costs of lead growers generally require much larger-scale greenhouses (10 acres plus) which is larger than what can generally be developed in the north. Most smaller-sized modern commercial greenhouses are operated by an owner/operator who has an acceptable combination of training and greenhouse experience.

Each community will need to review what competitive advantages and limitations, such as human resources, it faces in developing a northern greenhouse enterprise. Plans will need to be developed to capitalize on key resources – such as proximity to low-cost energy sources such as forest product mills/operations and district heating systems within a community.

Location and access will also play an important role in shaping greenhouse development. Year-round road access communities, especially further south, will face much more competition from imported products although access to inputs, specialized support and training will be much easier. For more remote communities, the high vegetable prices are a major advantage, but accessing inputs, training and other specialized support will be difficult.

Communities

The interaction between the community and the greenhouse venture will be a critical success factor for a northern greenhouse venture. In particular, it is crucial to understand what northern communities seek to achieve from greenhouse development as well as how governance and leadership will strengthen or weaken the likely economic performance of the greenhouse venture.

Based on the community consultations conducted with northern aboriginal communities, three main themes were evident in the communities' goals for greenhouse development:

1. Improved health, wellbeing and diet;
2. Increased affordability of foods and food security; and,
3. Increased independence and self sufficiency.

Profitability was not the primary objective in any of the communities the study investigated. Break-even or "profitable enough" models that also met other community objectives, including employment, were the norm. There was also a high level of interest from various community groups willing to support a greenhouse by contributing volunteer labour in exchange for fresh food. This model would build food security with labour being exchanged for food vouchers which would support poorer members of the community who have the greatest food needs.

These are isolated observations and should not be taken as being representative of all northern communities. There are likely to be many other communities in which profit is the primary objective for a greenhouse enterprise. It is clear, however, from research (the Harvard Project on American Indian Economic Development) in First Nations communities that having multiple objectives is a major barrier to successful economic development. For communities interested in a greenhouse enterprise, profitability should be the dominant objective, with employment and other goals as a beneficial outcome, rather than the other way around. However, placing a high importance on the members of the community is the norm for many First Nations communities; therefore, community goals are likely to be listed as a top priority for many communities interested in a greenhouse project. Communities who seek limited or break-even profitability may need to consider non-commercial options for greenhouse development as it is less likely that a commercial greenhouse will succeed in this context.

The research also indicates that communities with Economic Development Corporations (EDCs) or economic development departments operating independently from the politics of Band Councils will be better equipped to be successful as they make independent decisions based on the needs of the business, whereas communities with internal economic development bodies will be very heavily influenced by the political election cycle.

To ensure long-term commitment, it is recommended to look for champions and leaders that are not part of the municipal staff. Committed local entrepreneurs will be motivated to see the project through to completion and ensure long-term sustainability. Once a champion or a set of champions have been determined, a succession plan and long-term success of that plan can be considered.

No matter where the project leadership comes from within the community, it is important that civic leadership, the Band Council and the Chief be approached and consulted first. It is equally important that the rest of the community be engaged throughout the entire process to ensure buy-in from the community.

Marketing

Market demand will be shaped by location. In larger centres, or in areas with a larger percentage of southerners living in the north, a wider range and higher volume of vegetables can be sold with per capita consumption similar to national averages. Despite this, however, the very small population bases in the north, which are very dispersed, will put limits on market demand for individual greenhouses. This will inhibit modern, large-scale gutter-connected greenhouses from achieving significant economies of scale in many cases. Even for the largest population centres and areas in the north, populations are small and dispersed compared to similar areas in Europe at northern latitudes with greenhouse vegetable industries.

Per capita consumption in more remote First Nations communities will likely be shaped by local economic, social and cultural factors. The most popular vegetables appear to be primarily root crops (potatoes, onions, carrots), although some greenhouse vegetable crops (tomatoes and pepper) are also consumed. Vegetable consumption is low compared to the national averages. If new foods are to be introduced, they need to be seen as coming from within the community and programming will be needed to support the uptake and acceptance of the foods to overcome a lack of understanding on nutritional knowledge and cooking skills. This points to the need for a broad and holistic programming approach if the ultimate goal is to improve diets and health in the north rather than just support the development of commercial greenhouses.

Given the market size and demand across the north, there are a number of different market opportunities available for northern greenhouses. Larger-scale greenhouses will have to sell most of their vegetables at the wholesale level while smaller-scale greenhouses can sell predominantly to the retail market in their community (and will need to sell at retail prices in order to survive). For mid-sized greenhouses (approximately half an acre), a split of wholesale and retail sales will most likely be viable.

In certain areas, such as around larger centres in the Yukon and Northwest Territories (NWT), there are opportunities to capture higher revenues through sales at farmer's markets or at the greenhouse itself to high income consumers, or at least to consumers willing to pay higher prices for locally produced or organic products. In more remote communities it is highly doubtful that this is possible.

Looking beyond greenhouse vegetables, there are other market opportunities and strategies which are used by existing greenhouse growers to increase the commercial viability greenhouse enterprises:

- Integrating the greenhouse with a market garden. This strategy is utilized by many existing greenhouse enterprises in the north. This allows the enterprise to offer a wider range of products including root crops. This strategy may be necessary for the owner/operator of a small-scale greenhouse venture to attain economies that provide a reasonable return to their investment of capital and labour.
- Bedding plants are also a large and profitable market as some studies have shown them to be more profitable than greenhouse vegetable production. The majority of existing commercial greenhouses in the north utilize bedding plants as their primary business at present. Some have now begun to branch out into vegetable production as their skills have increased with greenhouse production. This is an option that should be reviewed by all potential greenhouse enterprises.
- Although it is very location-specific, there is interest from both mining and oil sands companies with large camps to purchase products, such as greenhouse vegetables, from First Nations communities or even partner with them in a greenhouse enterprise.
- Tree seedling production requires less energy, less labour and is less technically complex than greenhouse vegetables which are all positives for northern greenhouses. There are existing First Nations communities that have production contracts for seedlings with nearby mills for reforestation. In this arrangement the mill provides the seed and agrees to purchase a set number of seedlings at an agreed upon price.
- There are also a number of examples in British Columbia (BC) of First Nations communities working on contract with mining companies to provide native species for environmental remediation.

Economics

The study has developed and tested a series of financial models covering full life cycle accounting costs for currently feasible northern greenhouse models that could be developed within the identified study zone. The greenhouse models cover:

- A range of different technologies (high-tunnel, stand-alone and gutter-connected greenhouses as well as Chinese solar greenhouses) ranging from low-cost, low-tech small-scale greenhouse to higher cost and higher-tech greenhouses.
- The returns to scale according to greenhouse size for both small and large market opportunities.
- The economic returns to year-round versus seasonal production.

Based on a series of assumptions, probabilities and a range of estimated costs and revenues, the different greenhouse models are projected to achieve the following Net Returns and Percentage Return on Assets (%ROA) with no subsidization of capital costs. %ROA measures the economic efficiency of the investment.

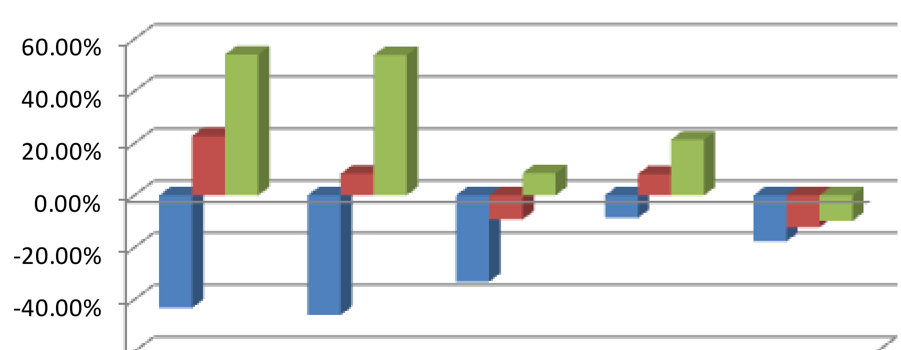
Table 2: Projected Net Returns and Return on Assets for Different Greenhouse Systems on Key Operating Metrics-Based on Probability of Achieving Low, Mid and High-Cost and Revenue Estimates

Greenhouse System	Size (m^2)	Months in Operation Per Year	Net Returns ($)	Net Returns ($)/ m^2	%ROA
High-tunnel (5 X 278m^2)*	1,394 (5 GH)	4-6	$14,595	$10.46	12.52%
Stand-alone (5 X 278m^2)*	1,394 (5 GH)	8-10	$18,695	$13.41	9.18%
Gutter-connected (3 acre)	12,140	9-10	$132,958	$10.95	9.29%
Gutter-connected (3 acre)	12,140	12	$284,109	$23.40	13.64%
Gutter-connected (0.5 acre)	2,023	9-10	-$24,152	-$11.93	-2.54%
Gutter-connected (0.5 acre)	2,023	12	$24,239	$11.98	7.31%
Chinese solar	150	7-8	-$20,938	-$139.58	-12.98%

**Note: Returns were much lower for single high-tunnel operations (278m^2) so what is shown in the above table is the most optimistic scenario but expansion is possible given the low-costs involved and limited labour required. Returns for a single stand-alone greenhouse were similar to the data above due to increased labour costs and contributions to management and labour within the %ROA calculation.*

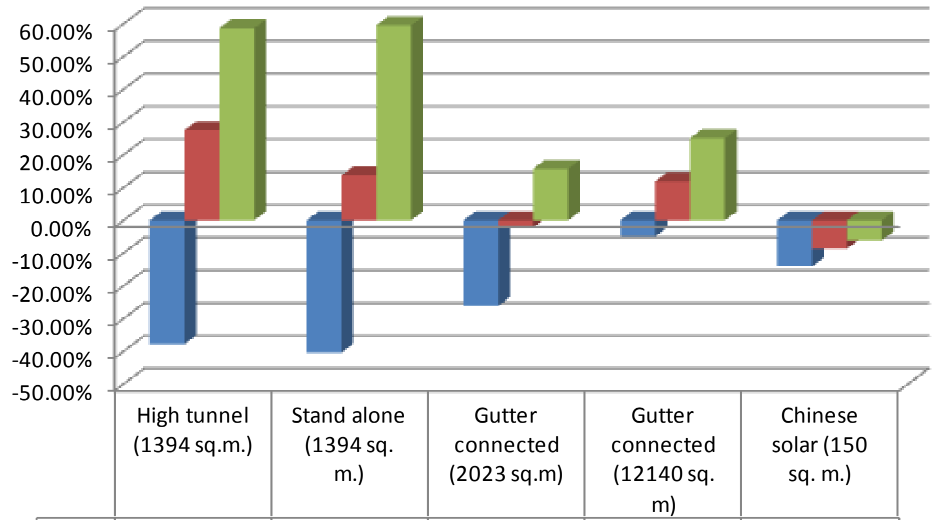
The modeling however indicates that there are a wide range of returns from unacceptable to positive for the different greenhouse models depending on size (economies of scale), key cost and revenue factors. The following figures illustrate the projected variability of %ROA for both subsidized (50% capital subsidy) and unsubsidized scenarios.

Figure 1: %ROA (Unsubsidized) for Low, Mid and High Estimates for Different Greenhouse Systems



	High tunnel (1394 sq.m.)	Stand alone (1394 sq. m.)	Gutter connected (2023 sq.m)	Gutter connected (12140 sq. m)	Chinese solar (150 sq. m.)
Low	-43.23%	-45.97%	-33.17%	-8.63%	-17.66%
Mid	22.84%	8.25%	-9.26%	8.22%	-12.26%
High	54.10%	53.83%	8.53%	21.39%	-9.78%

Figure 2 %ROA (Assuming 50% Capital Subsidy) for Low, Mid and High Estimates for Different Greenhouse Systems



	High tunnel (1394 sq.m.)	Stand alone (1394 sq. m.)	Gutter connected (2023 sq.m)	Gutter connected (12140 sq. m)	Chinese solar (150 sq. m.)
Low	-37.77%	-40.42%	-26.13%	-4.94%	-14.10%
Mid	27.54%	13.70%	-2.15%	11.90%	-8.68%
High	58.67%	59.54%	15.71%	25.07%	-6.13%

The variability clearly indicates that the models may only be successful given certain factors, with the exception of the Chinese solar model which does not appear viable at all. From an economic perspective the key cost and revenue factors are:

- *Price:* Achieving higher prices will be a crucial factor for northern greenhouses. The high revenue estimates assume both high prices and high productivity.
- *Productivity:* Strong management to achieve higher productivity will be a similarly important component as productivity is also a key driver of overall returns.
- *Energy costs:* Energy use and heating costs in particular will be critical elements in the economic viability of a northern greenhouse venture. The challenge for an individual greenhouse enterprise will likely be in finding the appropriate balance between the capital costs and reduced operating costs of heating systems that provide greater efficiencies and reduced energy use.

Other key findings from the economic analysis are:

- There are opportunities for smaller-scale greenhouses to be profitable if they can maximize price and/or productivity.
- There needs to be modest expectations for low-cost and low-tech high-tunnel greenhouses but they have an opportunity to be successful. In areas with high food prices or if high productivity can be achieved, these may be feasible, especially if there is an opportunity to expand over time

to achieve economies of scale, and if the owner takes payment in profit rather than salary (or combines their operation with an outdoor market garden).

- The opportunities for larger-scale commercial gutter-connected greenhouse systems will be dependent on finding effective balances between year-round production, large-market size and accessing higher wholesale prices. Overall however, the smaller population sizes in the north are a limitation on the overall profitability of this model, as are the human resource requirements.
- Subsidizing capital costs obviously improves the profitability and returns of different greenhouse enterprises, providing greater resiliency to withstand potential shocks.
- There generally are economies of scale within each model. However, as price is a key driver of positive returns in the models, a key benefit for smaller-scale operations is being able to sell produce at retail prices. Smaller-scale greenhouses may achieve competitive returns compared to larger-scale greenhouses if they can achieve higher prices (retail versus wholesale) and pay an operator out of profit. This may allow them to compete with lesser efficiency and/or productivity than larger-scale systems.
- Within commercial greenhouse operations, it does appear that there are positive returns from year-round production where this is technologically possible (higher-tech systems).
- The long-run survival of the greenhouse enterprise will require the capacity of the operators to withstand unplanned events with adverse effects on the facilities, the productivity performance and the economic performance. A key critical success factors is the ability to recover from these events which include having access to sufficient capital to replace damaged facilities, being able to make investments to replace technologies and systems that have either worn out or have become obsolete and being able to adapt to changing market requirements in order to retain market share.

Conclusions

Based on the completed analysis, the four most important factors that needed to be considered in the successful development of sustainable northern greenhouses are:

1. The skills and experience required to successfully run a viable and sustainable commercial greenhouse in the north.
2. Governance issues in First Nations communities.
3. Achieving high price and/or productivity levels.
4. Energy costs and usage which are magnified in northern greenhouses given heating and lighting requirements in the cold and dark winter in northern latitudes.

Successful greenhouses will have strategies for addressing these as well as other issues. However, there is no one single approach or model that will ensure success for all situations. Individual greenhouse enterprises will need to identify strategies that correspond to their own situation, optimize competitive advantages and overcome disadvantages.

Matching Complexity to Skills and Experience
In assessing the viability of different models of northern greenhouses, the human resources available to an individual greenhouse enterprise will be a critical success factor. Higher technology greenhouses will require skilled and experience growers who then can build the skills of local labourers.

Communities who already have experience with either market garden or smaller-scale greenhouse vegetable production are likely to be better prepared to move forward to more complex greenhouse models and production technologies than those without this background. This will be a long-term and incremental process. It will also need to be supported by culturally-appropriate training, mentoring and networking.

Communities must also understand the risks and costs of greenhouse development when there are other options available for such as market gardens which can produce storable root crops.

Viable Models for Greenhouse Development in the North
Simple greenhouse designs will satisfy the majority of the communities engaged in this study. Since there are not many remote northern communities across Canada that currently operate functional greenhouses, it will be important for most communities to start with a simple design, which will enable them to learn the needed skills and build capacity in the labour pool before advancing to a more sophisticated system.

However, for communities with limited or no gardening and greenhouse production experience, multiple goals for greenhouses and a limited focus on profitability, it is important to ask whether non-commercial greenhouse models make the most sense. If the ultimate goal is improved diets, health and food security in the north, separate funding mechanisms may be needed to facilitate the development of non-commercial greenhouses to work toward meeting important goals in northern communities related to food security, improved health, self sufficiency and empowerment.

Finding Competitive Advantage: Key Economic Drivers
The economic modeling, which was completed on a wide range of greenhouse systems and sizes, indicates that there is great variability in potential returns for each, ranging from negative to positive. Price and productivity are the two main drivers of positive returns on the revenue side. Inability to achieve high prices and/or productivity will limit the ability of a greenhouse to be successful. For northern greenhouses this means being able to sell as much produce as possible at retail over wholesale prices and ideally in more remote communities with higher prices. Productivity will similarly be key as a factor and relates to both management capacity and the human resource issues identified earlier.

On the cost side, energy costs are a critical element in the development of economically-viable northern greenhouses. Forest biomass does present an opportunity to potentially reduce energy costs in northern greenhouses although it will be highly site-specific. The greatest competitive advantage in reducing energy costs can be undertaken by locating greenhouse operations near industrial facilities that can supply heat, near forestry operations which can supply either free or cheap biomass, or by tying greenhouses in with district heating systems for a community. In each case, however, the needs for sustainable supply of biomass needs to be assessed and measured on a site specific basis as it will vary with technology, greenhouse size and feed stock.

Technology and Greenhouse Development in the North

The technology exists to grow greenhouse vegetables in the north year-round. An information gap, however exists in terms of the economic performance of new technologies in the north. As a result it is important that economics partner with technology rather than let technology (and funding for it) solely drive northern food production. Even more importantly, much more applied (technical and economic) research and testing is required before these new technologies are undertaken in remote northern communities. Remote northern communities are not in a position to do testing with unproven prototypes and technology.

This being said, a number of technologies are very near on the horizon which may transform the viability northern greenhouses in the near future. Energy costs are a key economic constraint to northern greenhouses generally and there are new technologies that may be able to overcome these problems – insulated plant factories, LED lighting, Chinese solar greenhouses etc. However more work is required on these at present to prove their commercial viability in the north.

Recommendations

Based on the aforementioned conclusions, Agriteam provides the following ideas and recommendations as part of possible policy and programming options that could be undertaken by AAFC, Aboriginal Affairs and Northern Development Canada (AANDC) and others.

1. ***Aboriginal Agriculture Initiative (AAI) funding priority should go to greenhouse application that address the "four key factors":*** Achieving high prices and/or productivity will be a crucial factor in the development of successful northern greenhouses. Similarly, greenhouses that can reduce electrical and heating costs through biomass, renewables or any other method can also be successful. Human resources must match skills and/or be accompanied by relevant training plans. Governance factors must also be adequately addressed.
2. ***Focus AAI funding on greenhouses whose main priority is profitability and commercial viability:*** Having multiple objectives for a greenhouse (employment, lower food prices, health and wellness centres) will greatly lower its chance of being sustainable. This is confirmed by the Harvard Project which illustrates the dangers of working to achieve multiple objectives with an enterprise. Northern greenhouses will certainly be fragile, especially in their infancy, and trying to address other objectives which reduce profitability, at least in the beginning, will reduce the chances of long-term sustainability.
3. ***Integrated policy approach:*** If the goal is to increase health and food security in the north, a solely commercial approach to supporting greenhouse development may not make sense given: 1) the level of gardening and greenhouse vegetable production skills that exist in many northern communities at present – which is generally little or none; 2) thus the need to start small and simply and work upwards in complexity with a community greenhouse or garden to build skills over time; 3) the need to introduce greenhouse crops to some community members; and 4) the multiple objectives that communities may have for a northern greenhouse which limit its

profitability and increase its likelihood of failure. Thus an integrated policy approach may be needed to cover these communities that look at the broader macro-economic and social benefits from greenhouse development including health. These policy approaches and/or funding could cover both market gardens and greenhouses. Just as this report has endeavoured to look at northern greenhouse development from a holistic perspective, so must any programming.

4. ***Entrepreneurship**:* Individual entrepreneurship needs to be supported in the development of sustainable (i.e., commercially viable) northern greenhouses. The most sustainable northern greenhouses will exist when individuals are market-oriented, are able to match productive capabilities with market needs and skilled in identifying, assessing and managing risk.
5. ***Applied research and linkages:*** More applied research is required with new technologies before they can be utilized in northern communities. Northern communities are not in a position to test out new technologies using their own funds and given their existing skill levels as this will lead to failure in most cases. In addition, economic assessments are needed of new technologies and we cannot let the technology drive the process – the technology exists to grow food in the north already. There also needs to be greater linkages between northern communities and researchers within academic centres of greenhouse expertise in Canada.
6. ***Develop modeling software to support community decision making for greenhouse development:*** The development of programs to provide economic modelling, such as already exist in other sectors (Alberta Agriculture and Rural Development's Crop Choice$ as an example) would be of great use and benefit to those planning greenhouses. This could also be undertaken as an joint initiative with a provincial department of agriculture.
7. ***Key constraint #1 – energy costs:*** There are many promising new technologies available or on the horizon that can address the key problems that a northern greenhouse faces with energy costs. However, there is nothing yet in a commercially available package that has proven to be economic in the north (although some efforts are being made). Driving down energy costs is to a degree the "holy grail" that will allow for the development of commercially viable northern greenhouses. As efforts need to be directed to finding a model that overcomes these barriers, this can be supported through innovation grants or a challenge prize (i.e., similar to an X prize) for the development of a greenhouse that could achieve key breakthroughs in energy efficiency while being commercially viable (i.e., limited capital costs).
8. ***Key constraint #2 - training and experience:*** A second major constraint to greenhouse development in the north which can be addressed are the skills and experience required for greenhouse production. If the goal is to develop sustainable food production in northern communities, either commercial or non-commercial, it is necessary to develop programming to address the current skills gap. This needs to be undertaken in a socially acceptable way, especially with remote communities as training in southern centres may not necessarily work. As a result, a greenhouse training program that could be delivered in the north and tailored to northern growers may be one solution for some communities in overcoming this barrier. Alternately for other communities, there are many options for greenhouse training programs available at training institutions across Canada. This will need to be supported through long-term mentorship and networking programs, as just training will not be enough, to help build on the job experience for northern growers. This may also require supporting internships for

northern residents to acquire skills in northern greenhouse production in existing greenhouses. This will be a long-term process but short circuiting it may lead to failure.

9. ***Subsidized southern foods:*** A northern greenhouse will face additional competitive pressures from imported vegetables which are subsidized through the northern food subsidy. Although the northern food subsidy does cover “country or traditional foods processed in the north,” the subsidy or at least its definition could be expanded to cover: 1) all agricultural inputs going to the north for either vegetable or greenhouse production; and/or 2) all vegetables produced in northern greenhouse enterprises. This would help to provide a level playing field rather than having a greenhouse compete against subsidized imported products.

1 INTRODUCTION

1.1 Goals and Objectives

The goal and objective of this research study as identified by AAFC are as follows.

*The **goal** of this research study is to provide a better understanding of the interrelationship among the critical success factors (listed in Section 1.2 below) that contribute to a sustainable northern greenhouse that uses biomass as an alternate energy source. With this understanding, informed decision making can be made for a financial investment in a community's business model that best meets their expected outcomes for economic development and possibly matches a financial investor's model.*

*The **objective** is to produce a comprehensive background study on greenhouse production for northern/isolated communities, including greenhouse design components, technologies, management, marketing and mostly importantly cost/benefit analyses. This report will highlight current knowledge and identify information gaps which will provide AAFC and partners a greater capacity to make well-informed decisions when reviewing northern greenhouse project proposals in various locations across Canada. This research study will focus on the technologies most suited for northern latitudes, and remote/isolated regions of the country and should consider the overall social, economic and environmental sustainability factors.*

1.2 Scope of Work

Agriteam will carry out and provide a report on the findings of a comprehensive literature review along with interviews on northern food production and greenhouse technologies in order to develop a thorough understanding of current best practices in northern greenhouse production, including the financial viability of certain enterprise choices along with an economic analyses that supports investments in northern/remote greenhouses. The analyses will specifically provide a comprehensive understanding towards the adoption of biomass (renewable wood products) as an alternate energy source for energy.

The information gathered will support the feasibility of a greenhouse investment in general (not site-specific) for profit in a business proposition that could be funded by government programs and/or the private sector.

The following critical success factors should be considered in the research study design:

- Community Engagement
- Market Demand
- Labour Supply
- Resources
- Technologies
- Economics

COMMUNITY ENGAGEMENT

What is the community's interest and expectations for northern greenhouse production?

a. What is the business proposition that most interests the community?
b. What are the community's short-term / long-term visions, and how does a greenhouse support that vision?
c. How simple or sophisticated does the greenhouse operation need to be to meet the community's interest?
d. Does the community want a not-for-profit business model where fresh food is provided, labour is volunteered and the produce is shared, e.g., community gardens?
e. What's the community's level of commitment i.e., time and money for taking on this venture?
f. Is there community leadership with possible succession planning to ensure the long-term viability of operations?

MARKET DEMAND

What are the drivers around the potential greenhouse services wanted and needed by consumers?

a. What are the current foods consumed in the community?
b. What is the size of the servicing area, where one community serves as a hub to providing services, and can a map be drawn for various opportunities?
c. Are there food catering opportunities to local camps (e.g., mining, forestry) and how big does that service contract need to be for cost-effectiveness?
d. What are the local diets and how does culture affect the introduction of new foods?
e. Is there a historical understanding that might prohibit the introduction of new foods?
f. What are the non-food services that a greenhouse could provide, (e.g., tree transplants for forestry and mining reclamation operations)?
g. Are there transportation back haul opportunities within the northern routes for other commodities?
h. Does the greenhouse serve a seasonal market (May – October) or is it a 9 to 12-month operation, and at what point is it feasible and desirable to switch, if it is technically or economically possible?

LABOUR SUPPLY

What is the demographic make-up of the local labour market?

a. What is the proportion of skilled and non-skilled labour?
b. What are the competencies and minimum education requirements in running a greenhouse operation?
c. Is there community leadership that can champion the project?
d. What are the competing industries for the same labour pool?
e. Is it cost-prohibitive to import labour, seasonally or full-time to meet educational requirements?
f. What are the short-term and long-term training requirements and associated costs to addressing a skilled labour shortage?

RESOURCES

What are the available resources?

a. Are there any competitive advantages to be captured in the community because of its location to resources, e.g., natural resources or man-made infrastructure?

b. How is the community accessed, e.g., by air, road, winter roads, boat?
c. What is the source of water and its quantity and quality?
d. What are the capital resources that could be tapped through building relationships and partnerships, e.g., mining, forestry companies?
e. What are the government financial assistance programs that can be used to initiate and pay for start -up costs? (e.g., AANDC – Eco-Energy Program, federal/provincial government Growing Forward programs, etc.)
f. What level of support can the Aboriginal infrastructure provide, for example, EDCs that may exist for some Bands?
g. What are the known limitations to development because of lack of certain resources (e.g., capital, human, natural, etc.)?
h. What are the short-term and long-term training requirements and associated costs to addressing a skilled labour shortage?
i. What are the energy and power sources?
j. What are the resource management strategies for the energy feed stocks to be ecologically sustainable?

TECHNOLOGIES

What are the proven sustainable northern greenhouse technologies that could be adopted?

(Note: The assumption is that there is "transferability and relevance" or the technologies for wide use among northern/remote communities inclusive of the Territories and provinces.)

a. What are the agronomics for growing food and non-food commodities, including pest management, growth medium, light, temperature, humidity, air exchange, etc.?
b. What are appropriate varieties of warm and cool season vegetables and fruits that can be grown effectively in northern greenhouse operations?
c. What are the operational requirements and technologies/techniques required for the growing of wood and herbaceous plants for landscaping, fibre, reforestation and mitigation needs?
d. What are the most cost-effective building materials to be used, e.g., double-walled poly, insulated shares, etc.?
e. Which technologies are tried and true and can be operated and maintained by local staff? i.e., What are the most appropriate technologies given the existing labour supply to support it?
f. What are the alternative energy/power technologies that can substitute for diesel and propane, e.g., biomass (wood, plant materials), biofuel (biodiesel, ethanol), biogas (bio-digestion from crops, manure, food by-products, landfill gas), solar, wind, thermal sinks, etc.?
g. What can we learn from other countries like China with similar environments on low-tech solutions and what is the certainty of success in Canada?
h. What are the other promising emerging technologies that could be commercialized in the future?
i. What is the energy feed stock regime to supporting the different energy technologies?
j. What are the proven best practice technologies in regards to energy efficient options for heating, cooling and lighting, e.g., Stirling engine, LED lights?

ECONOMICS

What are the micro- and macro-economics surrounding the adoption of northern greenhouse technologies in support of economic development and food security?

a. What is the most likely business proposition(s) that best aligns with the community's vision and aspirations?
b. What are the different commodities that could be feasibly grown and marketed along with their associated revenues and costs given the market potential, available human resources and natural resources, cost of production, revenue projections? (Provide enterprise budgets.)
c. Are there niche market opportunities to pursue?
d. What are the set-up costs in the establishing a greenhouse using biomass – renewable wood products, as a fuel source for generating light and heat relative to **one** other regionally applicable technology? (This other technology should be financially competitive to burning wood for comparative purposes, and could be, for example; anaerobic digesters, gasifiers, solar, wind, thermal, natural gas, etc.)
e. What are the risk management solutions for the different technologies, including back-up energy systems?
f. What are the food safety business costs that need to be included?
g. What are the capital resources that could be tapped through building relationships and partnerships e.g., mining, forestry companies?
h. What are the economies of scale and size to capture, especially other uses of the heat source, e.g., through a district heating system using schools and other buildings?
i. What are the government financial assistance programs that can be used to initiate and pay for start-up costs, including any food/transportation subsidies? (e.g., AANDC – Eco-Energy Program, federal/provincial government Growing Forward programs, Nutrition North, etc.)
j. What level of support can the Aboriginal infrastructure provide, for example, EDCs that may exist for some Bands?
k. When is it economical to go from a seasonal greenhouse to a 9 to 12-month period?
l. What is the full cost accounting that includes carbon emissions and possibly reducing the current carbon foot print of a community?
m. What are the associated economic benefits that could accrue to a community from a greenhouse investment using an input/output model on costs and benefits to determine the macroeconomics for a region?
n. What are the socio-economic benefits accruing to a greenhouse project that could include personal health, etc.?

1.3 Methodology

Based on the Scope of Work outlined in the preceding section, Agriteam designed a multi-faceted methodology in order to assess the range of factors to be considered in the development of sustainable (economically, socially, environmentally, etc.) greenhouses in northern communities and to inform AAFC and AANDC in their funding of northern aboriginal communities in greenhouse development.

As such, the study does not simply examine the question of how can we grow food in the north. Instead it examines what integrated greenhouse systems might be sustainable in the context of remote northern communities given the economics, socio-cultural factors, and existing resources. Thus, while it is possible to look solely at the technical or economic feasibility of greenhouse production in the north, this study attempts to take a more holistic look at the many factors that will impact the viability and sustainability of greenhouse vegetable production in northern and remote/isolated communities.

The study was undertaken over the November 2012 to June 2013 timeframe by a multi-sectoral team that included expertise in greenhouse vegetable production, economics, biomass, engineering and community engagement. The methodology utilized included:

- Extensive review of secondary sources on northern food production, biomass utilization, community governance and market demand, as well as other topics.
- Field consultations and follow-up with five communities in northern Saskatchewan (Pinehouse and Buffalo Narrows) and northwest Ontario (Red Rock, Kitchenuhmaykoosib Inninuwig and Wabigoon) which included both road access and fly-in communities. The community consultations included community meetings and discussions with community leaders and youth.
- Phone interviews with community leaders involved in greenhouse development in the Yukon (Carmacks and Haines Junction).
- Field consultations with smaller-scale greenhouse growers in Saskatchewan.
- Phone interviews with greenhouse enterprises in northern Manitoba and the Yukon.
- Phone interviews with and costed quotations from greenhouse input suppliers and alternative energy (biomass) retailers.
- Phone interviews with recognized experts, including working group members, in the areas of forestry/biomass, northern nutrition, greenhouse production, training and other areas.
- Wholesale and retail market price data from northern mining camps, northern retailers and government data for northern retail prices.

Based on this methodology, this report has been developed to answer the questions identified in the preceding sections and provides the following four key deliverables.

1. A comprehensive literature review on northern food production.
2. A compilation of best practices of current design technologies relative to the main focus of using biomass – renewable wood products, as an energy source for northern greenhouse food and fibre production.
3. Cost/benefit analyses that include financial enterprise budget scenarios and macro-economic analyses of community greenhouse investments that use biomass as an energy source.
4. Recommendations on the application of these report findings to support an Aboriginal community's project proposal under the Strategic Partnerships Initiative (SPI) for the AAI.

2 LITERATURE REVIEW ON NORTHERN FOOD PRODUCTION

2.1 Greenhouse Vegetable Production

2.1.1 Greenhouse Vegetable Production in Canada

The greenhouse industry is an important and growing segment of the Canadian agri-food industry having grown in value from $200 million in 1994 to an estimated $2.5 billion today. Of this, greenhouse vegetables account for approximately half. The rest of the greenhouse industry includes greenhouse crops such as ornamental flowers, bedding plants and tree seedlings in addition to vegetable production.

The main greenhouse vegetable crops in Canada are tomatoes (540 ha), cucumbers (309 ha), sweet peppers (371 ha) and lettuce (32 ha) as detailed in the table below. These crops account for almost all greenhouse vegetable production because of the yield and revenue they generate per square metre. Significant new greenhouse vegetable production technology has been primarily responsible for dramatic yield increases over the last 15 to 20 years, estimated at 200 – 300% for tomatoes and cucumbers (Anon 1988, 1990, 1993; Papadopoulos 1991a, 1991b, 1994a, 1994b).

Table 3: Greenhouse Vegetable Sales (C$ million) – 2011 for Major Producing Provinces

Province	Tomato	Cucumber	Sweet Pepper	Lettuce	Other	Total[2]
Ontario	292	217	189	x[1]	x	711 (63%)
Quebec	69	3	x	x	x	97 (9%)
BC	116	39	103	x	7	265 (24%)
Alberta	11	18	7	x	x	39 (3%)
Nova Scotia	x	1	x	x	x	6 (1%)
Canada Total[3]	**496 (44%)**	**279 (25%)**	**300 (27%)**	**28 (2%)**	**25 (3%)**	**1123 (100%)**

[1] x = Confidential data [2] Includes confidential data [3] Includes all Provinces

Source: Statistics Canada, Catalogue No. 22-202-XIB, 2011

Table 4: Area (ha) of Greenhouse Vegetable Production in Canada, Major Producing Provinces

Province	Tomato	Cucumber	Sweet Pepper	Lettuce	Total[2]
Ontario	347	232	247	x[1]	818
Quebec	58	7	x	x	84
BC	116	39	122	2	272
Alberta	13	28	9	x	50
TOTAL[2]	**540**	**309**	**371**	**32**	**1228**

[1] x = Confidential data *[2] Includes confidential data, in some Provinces*

Source: Statistics Canada, Catalogue No. 22-202-XIB, 2011

Ontario is by far the largest producer of greenhouse vegetables in Canada (818 ha out of total area of 1228 ha in 2011) and is a net exporter of greenhouse tomatoes, cucumbers, and sweet peppers to the United States. Other major centers of greenhouse vegetable production in Canada are located in BC as well as Quebec and Alberta. In general, the greenhouse vegetable industry of Western Canada (primarily in the Fraser River Valley) differs from that of Eastern Canada (primarily the Leamington district in Southwest Ontario) in the following three important ways:

1. The climate in BC and the Fraser River Valley, being a Marine climate, is quite moderate and closely resembles the climate of the Netherlands. In contrast, the climate of southwest Ontario is typically continental with characteristically cold winters, hot and humid summers, and widely fluctuating light, temperature and humidity conditions.
2. The BC greenhouse industry lies at a latitude of about 49^0N, similar to Northern Europe. The industry in Southwest Ontario (42^0N) is about the same latitude as that of the northern border of California or Rome, Italy. It follows that day length and similarly affected weather parameters are different between BC and southwest Ontario.
3. The BC greenhouse industry is modeled closely on European technology, with a large part of it made up of typical Venlo-style glasshouses. The Southwest Ontario greenhouse industry is modeled on a blend of European and North American technology with a large part of it consisting of double-inflated polyethylene covered greenhouses which are a Canadian design.

These differences indicate the different challenges and opportunities faced by the Ontario and BC industries. The conditions and technologies adopted by the Quebec and Alberta industries lie somewhere in between.

2.1.2 Greenhouse Vegetable Production in the Northern Canada and Alaska

The literature search produced no reports in refereed journals on greenhouse vegetable production and associated technologies in northern Canada and Alaska, including the study area defined as *"the geographic area south of the tundra and includes remote/isolated communities with limited access to affordable foods because of climate and/or high transportation costs."* Outside of Canada, studies in other northern countries were limited with the exception of Finland, or results are not searchable as is the case in China.

Despite the lack of scientific literature, a number of Canadian as well as Alaskan research reports have been produced in recent years. A small number of these reports are based on well-structured scientific investigations but for the most part the research results for greenhouse vegetable production are survey-type data and not subjected to statistical analysis. The findings of the studies are instructive as a guide but there are major limitations in the scientific methodology and their findings should be characterized as educated guesses in most cases.

Greenhouse Production

A very comprehensive study report for the Yukon Government Agriculture Branch and AAFC (Serecon, 2012) developed strategies for all key agricultural sub-sectors including greenhouse production. The report identified the following key strategies for the development of greenhouse, as well as non-storable field vegetable crops: 1) further work with processors to market value added products (salsas, pickles, jams, jellies, sauces, etc.); and 2) research to extend greenhouse production into the shoulder seasons. In addition to this, it also identified key market development supports required including a study to assess the potential for value-added production and related infrastructure needs, and marketing support for both First Nations communities and other producers in order to access retail markets.

A significant effort by Yukon College to develop a greenhouse prototype for the climatic conditions of the Yukon was illustrated in a PowerPoint presentation (Drury, 2012). Innovative ideas incorporated in the research greenhouse included: a Stirling engine to provide electrical power; quad pane 25mm polycarbonate glazing; LED grow lights (Hydrogrow and LED Growmaster); mechanization of greenhouse systems (watering, shutters, lighting, ventilation for carbon dioxide (CO_2) and relative humidity (RH), bed temperature, battery charging and Stirling operation); and thermal storage and heat modulation in the form of water under the beds to trap daytime heat and release it during the night. This is a research prototype that focuses on solutions to the challenge of the energy costs (heat and lighting requirements) needed for year-round production in northern latitudes.

"Emerging Trends and Issues in the Horticulture and Greenhouse Industry" (Assiniboine Community College, 2009) provides a preliminary analysis of emerging trends and issues in the horticulture and greenhouse industry, many of which are highly germane to this study as well. The study identifies a great need for the production of fresh food in northern Manitoba but also major constraints including a lack of applied research and training.

The study also provides an important discussion on the development of specific greenhouse technology for the north. It notes that important advances are being made for the development of greenhouse technology for northern conditions but ongoing applied research is necessary in order to further develop and test greenhouses that can be established and sustainably operated under northern conditions. The study correctly notes that northern communities are not in a position to test and develop technology. The study also identifies renewable energy sources as important to greenhouse development, and that while important advances are being made in this area, more research is required to ensure that workable systems are developed.

In the area of training, the study importantly notes that the establishment and operating of greenhouses in both southern and northern communities appears to be an area that requires not only formal training but also hands on training as well as the opportunity to receive ongoing mentoring. The need for greenhouse operators to network with others in the industry is also identified.

At the University of Alaska-Fairbanks, Karlsson (2006) provides a number of United States Department of Agriculture (USDA) research progress reports summarizing the findings of a six-year project that aimed at determining the importance of natural and artificial light energies and spectral distributions for high-latitude crop production and photoperiodic control of flowering. Various combinations of natural light, filters, black-out materials and supplemental light (high-pressure sodium (HPS), LED) were used to determine optimum conditions for the growth, flowering and fruiting of agricultural crops, and for the activity of pollinators.

The study and research reports conclude that “combining and adapting long and short days to specific stages of development can produce highly desirable plants and crops” based on its research with Rudbekia hirta cultivars. Combinations of red LEDs (peak emission at 660 nm) and HPS lamps were used. Environments with 16 hours of HPS lighting were supplemented with 1-hour exclusively of LED at the end of the dark period or 1-hour of LED in combination with the first daily hour of HP. They also reported that different day and night temperatures promoted growth and flowering of Rudbeckia Toto Gold and of the compact sunflower Pacino Gold when compared to steady daily temperature.

The research reports also summarize the findings of experiments with the objective of developing best practices for raising lettuce seedlings. It was concluded perlite is beneficial for producing compact lettuce (cv. Alpha) plants. It also provides evidence that (white) plastic mulch or perlite cover at germination stage support quality lettuce transplant production.

Another solidly scientific report “Growing Fresh Vegetables – Midnight Light & the Earth’s Warmth, Chena Fresh” has been published by the University of Alaska-Fairbanks based on their research with the Chena Hot Springs Resort. The resort uses geothermal water for heating and also converts geothermal energy to electricity at the resort throughout the year which it now uses for year-round greenhouse production.

Chena erected its first greenhouse in 2004. This 1,000ft^2 structure was a test installation to determine if growing conditions could be maintained year-round utilizing the geothermal resources at Chena Hot Springs. During the winter of 2005 the outside temperature went as low as -56°F but at the same time, an interior greenhouse temperature of 78°F was maintained. The hoop house was divided into two areas; an 800ft^2 grow area and a 200ft^2 air-mixing area. A two-inch radiant fin tube was used around the perimeter of the grow area. 165°F water was pumped from one of the geothermal production wells through the fin tube. The same water was also pumped through a radiant air exchanger in the air-mixing area. The water from both heat sources was then returned into the outdoor Rock Lake. The exterior of the hoop house was 6 mm greenhouse polyfilm. A second layer was added on during the winter season. Warm air from inside was then blown in between the layers to inflate the roof and end walls creating an insulation of warm air. Cold air in the winter season was drawn into the air-mixing area and mixed with the warm air from the radiant air exchanger. The warm air was then transferred into the grow area via a ventilation tube. This method prevented any cold air from coming into contact with the plants. A heated arctic entry was also used to prevent large amounts of heat loss or too much cold air from entering at once. The concept of the hoop house was taken one step further once successful results were demonstrated in the original house. Two Poly-Tex XA-300 gutter-connected greenhouses, with a total area of 4,320ft^2, were erected on a radiant heated concrete slab. The same 165°F water was pumped through the concrete slab. Each 30' x 72' greenhouse had its own environment controller and was maintained at different temperatures.

One greenhouse was used for growing hydroponic tomatoes. There were approximately 450 tomato plants consisting of 6 Dutch varieties; 1 cherry tomato variety, one grape tomato variety, 1 beefsteak tomato variety, and 3 intermediate cluster tomato varieties. These tomatoes were grown using a Dutch technique in buckets with perlite and drip irrigation. The other greenhouse was used for growing hydroponic lettuce using a Nutrient Film Technique (NFT) bench system. This bench system was capable of growing approximately 2,000 head of lettuce on a rotating schedule, producing approximately 100 head of lettuce per week. The nutrient solution was monitored and adjusted by its own controller.

The report gives unique information and some guidelines on the production of tomatoes and lettuce in Alaska. Most notably, it is reported that the tomato cultivars Trust (7 – 7.5 oz size) and Conchita and Picolino (cherry type) have been grown successfully in buckets filed with a perlite/peat-based growing medium, and that different kinds of lettuce (Romaine and Butterhead types, including cvs. Nevada, Lollo Rosso, Lollo Bianco) have been grown in NFT with varying degrees of success. The study also alerts to the challenges of growing crops under unusual photoperiods, as observed at very high latitudes.

Chinese-Style "Solar Greenhouse" in Canada

The first in a series of bulletins by Manitoba Hydro (2005), "Solar Greenhouse from China – Testing its Feasibility in Manitoba's Winters" announced the construction in late 2004 of a traditional Chinese-style greenhouse (22x100 feet in size) on a vegetable grower's lot at Elie, just west of Winnipeg. The objective of the project was to assess the feasibility of using solar energy greenhouses for winter greenhouse production in Manitoba. This was done by testing whether the solar energy stored in the north sand-filled wall would be sufficient for maintaining desirable greenhouse temperatures overnight, in combination with a cotton blanket, and if it were not, how much supplementary heat would be required. It was reported that upon a site visit in the afternoon of December 2004 when the outside temperature was -22°C, with winds gusting at 20 km/h, the inside temperature was -1°C. There is no mention on experiences growing vegetable crops.

A second research bulletin (Manitoba Hydro, 2006) reported that the 'Elie greenhouse' had been constructed at several other sites in Southern Manitoba to investigate greenhouse design variations in the search for upgrades that would improve performance. Very limited research data was reported, however, and the research report concentrated on options for improving efficiency and reliability of Chinese solar-type greenhouses. Furthermore, in none of the studies on variations of the Chinese-style solar greenhouse was there a mention of experiences with growing vegetables as a commercial crop (i.e., potential growing season, expected yields and product quality). Options considered for improving the efficiency and reliability of the solar greenhouse based on the 2006 testing results included:

- *Active heating of the rear wall:* Instead of building a sand-filled wall, the grower poured a concrete wall embedded with 120 m of 25 mm diameter polyethylene pipe. The pipe could carry heated water or other heat storage fluid from an electric heating system to supplement solar heating of the wall or compensate for falling temperatures on extremely cold nights.
- *Inside thermal blanket:* A chamber of the modified greenhouse at St. Francis Xavier was equipped with thermal blankets stored inside the structure just underneath the plastic covering, instead of on top as in the Elie design. The inside configuration would avoid problems with

freezing of the blanket, as occurred at the Elie installation. For the greenhouse at Elie, the blanket was to continue to be unrolled across the outside of the plastic. When rolled up it could be stowed in a housing that shielded it from the elements.

- *Supplementary biomass heating:* Researchers determined that geothermal heating of solar greenhouses was not economically feasible because of the high cost of installation and lengthy payback. A pellet/corn-fired heating system with automatic stoker was to be tested in a second solar greenhouse at Elie.
- *Air-bubble plastic:* Air-bubble plastic with a very high R-value and good transmittance for solar radiation would replace the conventional 6 mm poly cover. Heat loss through the plastic would be reduced and keep the plants warm through the coldest hours, replacing the thermal blanket.
- *Black wall:* Researchers also expected to confirm the advantage of painting the sheet metal clad interior wall of the greenhouse at Elie a flat black.
- *Double inflated poly:* The introduction of a double inflated polyethylene cover instead of the usual 6 mm single layer was considered as a remedy to frequent tears observed due to winds.
- *Insulated plastic cover:* A reportedly "first of its kind" greenhouse in Canada was to have a specially designed plastic cover that according to the manufacturer had a insulation value equivalent to R19. Its specialized galvanized steel structure was to be capable of withstanding wind speeds up to 140mph.
- *Locally-available materials:* Room to Grow Nurseries in Boissevain built a solar greenhouse using locally-available materials. Two-by-six spruce rafters supported the plastic covering of the greenhouse which is framed with wood. The rear wall was insulated to R-50 with stacked straw bales sandwiched between protective layers of stucco. Sheets of roofing tin form an inner wall, four inches from the stucco, to hold gravel that stores heat during the day and releases it at night to help keep plants warm. A wood-fired boiler provided supplemental heat, and a small fan circulated air between double sheets of poly covering the front half of the greenhouse.

Brief summaries of findings during the 2006/2007 season from several sites where variations of the Chinese-style solar greenhouse was studied were reported in a third report (Manitoba Hydro, 2007). The summarized findings included:

- A covering of conventional, air-inflated, double-poly-lined with argon-filled plastic kept the greenhouse warmer than bubble insulation or the poly alone. The argon-filled lining also appeared to be an effective substitute for the thermal blanket that normally covers solar greenhouses at night to reduce heat loss.
- Additional research at a 2200ft^2 solar greenhouse equipped with a thermal blanket showed that the greenhouse could be operated with supplementary electric heat for about $10/day during the coldest month. On the negative side, the thermal blanket failed during tests of the first solar greenhouse at Elie in 2005/06. The blanket, which tore and was thought to have soaked up rainwater in the fall, froze in place one night during a cold spell in January. It could not be rolled up in the morning, causing a crop failure. Also, the interior blanket installed in St. Francis Xavier in 2005/06, proved difficult to operate and ineffective at holding heat overnight.
- At St. Francis Xavier where the greenhouse was divided into four sections for the research, the <u>first section</u>, for conventional operation, was equipped with auxiliary electric unit heaters and

electric heat mats (for keeping root zones of plants warm). The other three sections, each with different insulation coverings, were unheated. Argon was selected as one of the insulating media because it is transparent and was expected to have an R-value that would match that of the thermal blanket. Cost of the Argon in the test section was about $80. In the second section, strips of 3mm nylon/poly blend in tubes four-feet wide were fed between the rafters and outer greenhouse air-inflated double-poly. These elongated "pillows" were filled with Argon gas and the ends sealed. Air-bubble plastic, made commercially, was used as insulation in the third section. It comes in two-foot wide rolls, which were cut into strips and installed in two layers between the rafters and the outer poly. Two layers of bubble insulation, with the bubbles facing the sky, were rated at R-2. The fourth section of the greenhouse was covered with conventional double-poly without any insulation lining. The argon-filled plastic lining kept the highest temperature of the test sections on the coldest night of the year.

- The insulating blanket on each section was sandwiched between protective layers of plastic to seal out moisture that could freeze and render the blanket inoperable. Supplementary heat was provided by two 5-kW agricultural GX heaters along the rear wall in the first greenhouse, and by a small wood stove at one end of the second. The 5-kW heaters were set for a minimum temperature of 13˚C. They ran about 18 hours per day during the coldest days. The unit heaters kept the first greenhouse warm for $10/day in the coldest month. On average, energy consumption of the heaters was roughly 20% of what it would have been in a conventional greenhouse.

Updated summaries of findings during the next season from several of the sites where variations of the Chinese-style solar greenhouse were studied were reported in a fourth report by Manitoba Hydro (2008). This season's tests looked at an LED lighting system for extending the plant growing season during the winter months, an 8mm plastic covering for the greenhouse, and an "earth charger" system that, like the solar wall, was designed to store solar energy during the day for release at night. Findings suggested that LED lighting promoted plant growth and health better than conventional HPS lighting, at about one-tenth the cost in electricity. However, the LED lighting cluster cost roughly four times as much as the HPS lighting.

Temperatures for February during the 2006/07 and 2007/08 research seasons were compared to test the effectiveness of the 8mm poly over conventional 6mm double-poly. With nearly identical outdoor average monthly temperatures, the average indoor temperature in the section covered with 8 mm poly was 1˚C warmer than the section covered with conventional 6 mm poly – even though daily average solar radiation in February was 8% lower in 2007/08 than in 2006/07. Average temperatures in the earth charger section were very similar to those in the section without any auxiliary heat, with a night-time average temperature of -1°C in January, and 10°C in March. Commenting on the research findings of the previous year it was stated that: 1) the failure of the exterior cotton blanket on one of the test greenhouses at Elie underscores the importance of a source of a supplementary heat in any solar greenhouse; 2) the interior thermal blanket tested at St. Francis Xavier was also unsuccessful and the concept of an interior blanket required more research; and 3) heat loss calculations for the greenhouse at St. Francis Xavier had shown that an Argon-filled plastic lining installed beneath the conventional air-inflated double-poly should have, theoretically, been able to hold temperatures in the greenhouse above 10˚C overnight – without an external thermal blanket. However, in practice, this insulation was not nearly that effective. Further, the installation of the Argon-filled lining is a time-consuming, annual chore that may not be practical for greenhouse operators.

A fifth report (Manitoba Hydro, 2009) summarized research findings at the Glenlea Research Station where the solar greenhouse was adapted for supplemental heating by hog barn exhaust air through a bio-filter consisting of wood chips and compost, for odour reduction. It was found that air temperature inside this greenhouse ranged from -3.2 to 40°C while the outside temperature ranged from -29.9 to 13.4°C. The average temperature inside the greenhouse ranged from 1.5 to 20.9°C while the outdoor average temperature ranged from -25 to 10.4°C. The mean hydrogen sulphide (H2S) concentration of exhaust air in the plenum of the bio-filter was 0.56 ppm. After it passed through the bio-filter, the mean H2S concentration ranged from 0.15 to 0.39 ppm. Based on these inlet and outlet H2S concentrations, the bio-filter reduced H2S concentrations to between 35 and 55%. The mean concentrations of CO_2 inside the greenhouse varied between 877 and 1,536 ppm over six sampling periods.

A student project at the University of Saskatchewan (Bertelsen et al, 2009) looked at the optimization of the materials and geometry of a solar greenhouse adapted for the Canadian Prairies with the use of modeling programs such as Excel and MATLAB. An experimental greenhouse design modeled after the conventional Chinese-style solar greenhouse was compared with a traditional Canadian greenhouse by way of standard heat transfer and energy balance routines.

The study concluded that a low wall at 63° and 1.62m width, and a high wall at 50° spanning to the shading roof were optimal. The performance of the thermal rammed earth wall did not vary drastically with thickness, and increasing the thickness beyond 300 mm showed no significant increase in performance. It was estimated that this design geometry and materials would require approximately 90% less heating requirements than a conventional greenhouse during the winter months, thus reducing need for fossil fuels and environmental impacts. The authors do recognize that the model they use was simplified and future models needed to also include "thermal storage of the east wall, west wall, north roof, and floor; shading effects; an aquaponic system; an in-floor heating system; and supplemental lighting. Modeling using three-dimensional, multi-physics computer software should be undertaken to validate energy requirements." They also identified the need for economic analysis of this model to determine payback periods compared to conventional greenhouses and that adaptations to the rammed earth model may need to be adapted for specific environmental conditions.

Community Greenhouses

A research project was undertaken to investigate the possibility and feasibility of developing a community greenhouse and cold storage facility in Dawson City and to build public support for and understanding of the need to work towards food security (Clarke, 2010). The study identifies the existing community gardens and greenhouses in many Yukon communities and their different aims and operations:

- Downtown Urban Gardeners began from an Anti-Poverty Coalition effort to combat poverty by providing low-cost garden plots to low-income families.

- The greenhouse, cold-storage and garden community operation in Carmacks is run by the First Nations and provides free vegetable delivery to elders as well as assistance to those in need with their backyard gardens. They also sell some produce and give the remainder for public feasting events. The program has been funded federally and supports youth workers in the summer months. The First Nations pays the salary of a year-round coordinator through the Health and Social Department.
- The Haines Junction Employment Development Society runs a community greenhouse providing support for individuals with social disabilities. The municipality does all the administration and payroll and public works manages the maintenance. The greenhouse is supported through the United Way and sales from bedding plants – which is their primary focus.
- Teslin, Carcross, Pelly and Old Crow all have community gardens that are run by the First Nations to provide healthy, fresh food for their citizens.
- Greenhouses in the Arctic communities of Inuvik, Paulatuk, Resolute and Iqaluit are all run by non-profit societies with various types of community and corporate support. All the arctic greenhouses have a “pay for a plot” arrangement and some aspect of commercial sales to help support the maintenance and operations of the space.
- The report also identifies a number of community greenhouses across Alaska in communities such as Sitka, Galena, Fairbanks, Tanacross and Girdwood. Most of these are operated similarly to the Dawson Community Garden – started up with public funds and maintained through volunteer effort and donations. The University of Alaska-Fairbanks runs tests of northern species (cold tolerant) under different conditions and shares their findings with interested growers.

A study was conducted by the University of Guelph to strengthen community agriculture initiatives, specifically community greenhouses, in Nunavut by examining current community agriculture practices in both the NWT and Nunavut (Holzman, 2011). The Inuvik Community Greenhouse and the Iqaluit Community Greenhouse Society were chosen as case studies because it had previously been determined that they were strong examples of community agricultural projects that have had the longest continued operation. Through site visits to these two locations and key informant interviews with involved members and community stakeholders, six different themes were identified as leading to a successful arctic community greenhouse: organizational structure, operations, outreach, aboriginal involvement, partnerships and economics.

A report by the University of Laval (2011) reviewed the existing Kuujjuaq greenhouse and plans for construction of a new greenhouse. The existing greenhouse in Kuujjuaq is presently home to a community garden that has been operating for approximately 20 years. The study notes a small number of plants have the potential to yield a significant volume of produce at the end of the season including 6 lettuce plants (cultivar: Grand Rapids) that yielded 7.1kg over the course of the summer; 6 spinach (cultivar: Tetragonia tetragonioides) plants yielded 4.25kg; and, a 1 m-long row of densely planted radishes yielded 1.27kg as early as July 21.

2.1.3 Greenhouse Vegetable Production in Other Northern Countries

Greenhouse Vegetable Production in Finland

A series of papers by Jokinen et al. (2007, 2010, 2011, 2012), Kaukoranta et al (2008a, 2008b, 2009) and Sarkka (2006a, 2006b, 2007) review greenhouse production in the north of Finland at northern latitudes of 60 − 65°N. In these latitudes, practically all light is provided by supplemental lighting from November to January. Large greenhouses produce year-round while smaller family greenhouses do not use heavy lighting and have a three-month break in winter when daily global radiation is 1 − 2 MJ/m^2 in the areas where greenhouses exist. In other seasons the lights are used whenever weather is cloudy. Even in summer when the daily light integral in the north is as high as in the middle latitudes, lighting in the morning and evening, and in cloudy periods, substantially increases yield but not always profit as the prices can dip in summer.

In commercial operations, HPS lights (150 − 250 W/m^2 for vegetable crops) are used to supply the necessary heat when outside temperature is above -5°C if energy screens are installed on walls and above a crop. Some heating is needed to adjust for temperature fluctuations and move the transpired water vapor from the bottom of the crop. The low and variable heating load is not well suited for using biofuels, which require high capital investment. With high HPS lighting, energy screens and outside temperatures ranging in winter from -10 to +5°C, the double cover is not much better than the single glazing because the double cover requires much more ventilation to remove humidity.

The research notes that LED lights are just now becoming commercially viable for salads and inter-lighting of cucumber and tomato if a grower has not invested much in HPS. But growers of high crops have invested in inter-lighting (with HPS lighting above crops and LED lighting within) in the past 10 years. Therefore it will take time before a full switch occurs to LEDs. The studies estimate that if one was allowed to start from zero, in the north of Finland, the LED inter-lighting (HPS is still needed above the crop) would now be accompanied with a double-layered cover with an energy screen, humidity extraction by a heat exchanger, and a small heat storage reservoir. These together would make some 20 − 50% less total energy use per unit of produce when compared to single glazing with screens, HPS, and ventilation, plus there is better load for heating with biofuel. Energy costs are crucial in this environment as greenhouse production in these northern latitudes uses twice as much energy as Dutch greenhouse production and 20 times more than outdoor Spanish vegetable production.

From 2005 to 2010, experimentation was undertaken with the a closed greenhouse using the Novarbo droplet screen inside as a heat exchanger and the shower droplet cooler outside to cool the circulating water well below the dew point of the inside temperature (www.novarbo.fi). Since then the commercial version has been tuned with more emphasis on humidity extraction and less on heat removal but the results are mainly still valid. Running a semi-closed greenhouse in cold climate increased the total vegetable yields 20 − 40% over the period May to September (outside daily max temp 20 − 25°C, and 5 − 15 days 25 − 28°C, daily global radiation in a cloudy day 6 − 10 MJ/m^2, on a clear day 25 − 30 MJ/m^2). The benefit came from the response to high CO_2 and better control of development. This type of system may work but it is not used commercially in Finland yet because the installation price asked by the company has been deemed too high and summer prices of vegetables are volatile. The Novarbo system or any similar system would work better in a continental climate at lower latitudes with cheap water – such as the south of Canada – because of higher summer temperatures and a higher radiative load in spring and autumn.

Greenhouse Vegetable Production in China
Greenhouse production in China is widespread but there is limited searchable data available as most research is in Chinese. In addition, the vast majority of Chinese production is done at latitudes south of the study zone as the northern tip of China lies at 53° latitude.

The solar greenhouse has wide application in China. Within the Chinese greenhouse industry, soil planting is still the main growing pattern, even if substrate based cultivation systems are adopted in a few areas by some growers. The average yield for tomato in Chinese solar greenhouses was about 7 kg/m^2 for furrow irrigation, by far the most common method, or 9 – 10 kg/m^2 for drip irrigation (Ya, 2011).

A study (Hu et al 2011) conducted in the northern regions of China to measure heat fluxes of several kinds of greenhouse walls concluded that a sunken greenhouse with a wide span and a thick soil wall was superior for heat preservation. The wall of the greenhouse could absorb about 110 – 150 W/m^2 during the daytime, and could release about 20 – 50 W/m^2 during the night. The temperature of the greenhouse could be improved by up to 10°C by the energy released by the wall.

According to a study report from the Shenyang Agricultural University (Bai et al, 2011) there is a lack of all-purpose design and standards on design, fabrication and construction of solar greenhouses in China. They also reported that incorrect design and construction of solar greenhouses entail hidden safety troubles and influences their stability. Their study put forward a detailed analysis of the cause of solar greenhouse collapses and structural issues, and also put forward appropriate recommendations for improvement (not specified in the English abstract). Zou and Zhang (2011) also reviewed the construction and performance of hillside solar greenhouses in Northwest China. They conclude that the absence of theoretical studies made the construction of hillside solar greenhouse somewhat haphazard. Their results did show however that temperature and light capability of the Wuxing-type greenhouse was better than in other types of Chinese solar greenhouses.

2.2 Greenhouse Economics

2.2.1 Feasibility Studies for Northern Greenhouses

A novel facility (the "Arctic Salad") was designed by Curtis et al (2007) at the University of Guelph to produce by fresh tomatoes, cucumbers, lettuce, peppers, potatoes, onions and carrots in Arviat, Nunavut. The design consisted of three buildings; two greenhouses, one actively heated and one unheated, and a germination chamber that would house the growing plants. Soilless NFT and static hydroponics would be used to raise the crops over a 26-week growing period to be sold to the local community to supplement their nutritional needs. Energy was to be provided by a combination of wind power and solar heating. The design was determined to produce $86,000 annually from crop and excess energy sales with initial costs of $896,000 and annual operating cost of $28,600. The economic feasibility of the "Arctic Salad" was deemed marginal given the high capital costs.

A comprehensive feasibility study was carried out for the establishment of a community greenhouse in the North Slocan Valley, in the West Kootenays of BC (Mahr et al 2010). The investigation addressed how a community greenhouse would serve the community needs while assessing the potential pros and cons, as well as costs and benefits of a greenhouse.

The feasibility study assesses a development plan that includes two 30' X 48' greenhouses (1,440ft^2 each); one 30' X 15' potting and equipment shed; and two 500ft^2 outdoor beds for berry production. The greenhouse would be structured as a producer-consumer cooperative through which they would sell a wide mix of quality produce directly to community members, local stores and restaurants. They also envisioned the North Slocan Community Greenhouse as a facility that would provide growing space for area residents seeking an opportunity to increase their own food production as well as educational opportunities for the community to learn more about extended season growing.

The capital costs total was estimated at approximately $75,000. Large capital expenses included the two greenhouses; potting and equipment shed; market stand; wood furnace; cooling system; lighting; electrical services; and irrigation and equipment costs. Their annual operating cost was expected to be around $45,560 which included such large expenses as salary for a greenhouse manager, utilities, transportation, and possible land lease. Their analysis concluded that a community greenhouse would be a viable investment, especially if the initial infrastructure costs of $75,000 were paid off within the first three years with a substantial source of funding. In terms of financial feasibility, partial funding of 50% at $37,500 would reduce the overall payback time of 16 years to 8 years.

A study "Establishing a Vegetable Greenhouse in Northern Saskatchewan" was conducted for the establishment of a commercial greenhouse at Beauval Forks, considered a gateway to 10 of the 12 communities in Keewatin Yatthe Health Region with approximately 12,000 persons. The study does not provide any overall economic analysis of the feasibility of greenhouse but it does provide some interesting cost, price and production data. Making a series of assumptions, the report arrives at the suggestion that "a freestanding shed-type solar greenhouse" would be ideal for Beauval Forks. The cost of the materials for the construction of such a greenhouse (30' by 144') was estimated at $20,991.15. Production and revenue figures on greenhouse vegetables in Canada, for the years 2005 – 2009, are presented as published by Statistics Canada, along with a comparison of prices for key salad vegetables between the Beauval Northern Store and the Superstore in Saskatoon.

O'Brian (2011) assessed the economic viability of greenhouse ventures in four communities in southwest Alaska. This investigation relied on statistical data to assess the economic feasibility of the different greenhouse ventures. The study concludes that for a greenhouse venture to be viable in certain communities input costs must be reduced. As well the study points out the importance of studying local market conditions in order to properly understand the demand for greenhouse products.

2.2.2 Greenhouse Costs and Returns

The literature does provide assessments of the costs and returns achieved by greenhouse operations in Canada and elsewhere which are very instructive for greenhouse enterprises in northern communities. However there is very little in the way of cost and return information specific to northern regions.

Chaudhary (2011) offers cost and return analyses that reflect current economic conditions for the greenhouse industry in Alberta. The economic analyses include capital investment budgets along with cost and return assessments for specific greenhouse crops for 2010.[1] Summaries of previous year's costs and returns are provided in the appendices.

Although these measures of costs and returns are specific to Alberta they can provide a framework as well as a baseline for estimating or extrapolating costs and revenues of greenhouse enterprises in Northern Canada on a crop-by- crop basis. A summary of the investment as well as production costs and returns for the three greenhouse vegetable crops analysed in the Alberta study is presented in the following table.

Table 5: Alberta Greenhouse Vegetable Production Costs and Returns, 2010

	Tomatoes		Cucumbers		Peppers
	Medicine Hat /Redcliff	North-Central	Medicine Hat /Redcliff	North-Central	Medicine Hat /Redcliff
Average Production Area (m^2)	12670	10717	8540	3824	9907
			$ / m^2		
Average Investment	$116.42	$110.48	$129.68	$168.95	$142.03
Gross Returns	**$108.45**	**$106.48**	**$84.98**	**$124.29**	**$94.13**
Material Inputs	$9.23	$10.39	$10.81	$12.92	$10.75
Natural Gas	$12.07	$8.72	$9.02	$7.50	$10.99
Hired labour	$27.92	$28.86	$19.88	$30.91	$20.94
Marketing Costs	$23.85	$18.29	$16.90	$17.37	$12.85
Other Cash Costs	$10.59	$11.70	$9.58	$32.01	$10.50
Operator labour	$1.18	$0.00	$0.00	$0.76	$0.00
Capital Costs	$11.47	$10.22	$9.66	$13.69	$10.60
Total Production Costs	$96.31	$88.19	$75.84	$115.15	$76.63
Gross Margin	**$21.45**	**$26.03**	**$15.77**	**$19.53**	**$26.42**

Source:Chaudhary, G.N (2011). The Economics of Production and Marketing of Greenhouse Crops in Alberta

Statistics Canada (2009, 2011) has published costs and returns data for greenhouse vegetable production aggregated by province and for Canada. Once again these analyses do not provide any

[1] *Data on the 2008 crop was gathered from 40 producers and updated to reflect 2010 costs and revenues using farm input prices indices and market price data.*

information specific to the northern regions, likely since there are few if any commercial operations providing data to the survey. The measures of greenhouse vegetable operating expenses are aggregated for the different regions of Canada as well as for the whole of Canada. This does not provide the same crop by crop perspective as the Alberta data but it does provide some insight on the key expenses required in growing greenhouse vegetable crops. The following table presents the aggregated data on Canadian greenhouse vegetable operating expenses for the last four years.

This operating expense data can be used to calculate the relative significance of individual costs. The following tables provide calculated estimates of individual operating costs expressed as a percentage of total operating expenses and in terms of production costs per square meter derived from the Statistics Canada data.

Table 6: Greenhouse Vegetable Operating Expenses as % of Total Operating Expenses – Canada

	2008	2009	2010	2011
Plant Material for Growing on	7.61%	8.42%	7.69%	7.57%
Gross Yearly Payroll	24.32%	23.89%	25.64%	27.32%
Electricity	3.62%	3.24%	3.35%	3.02%
Fuel	20.31%	18.06%	16.97%	15.92%
Other Crop Expenses	13.39%	12.96%	12.73%	12.53%
Other Operating Expenses	30.64%	33.39%	33.61%	33.60%
Total Operating Expenses	100.00%	100.00%	100.00%	100.00%

Table 7: Greenhouse Vegetable Operating Expenses ($/m^2) – Canada

	2008	2009	2010	2011
Plant Material for Growing on	$4.55	$6.23	$5.46	$5.14
Gross Yearly Payroll	$14.53	$17.66	$18.20	$18.52
Electricity	$2.16	$2.39	$2.38	$2.05
Fuel	$12.13	$13.35	$12.05	$10.79
Other Crop Expenses	$8.00	$9.58	$9.03	$85.16
Other Operating Expenses	$18.30	$24.68	$23.85	$22.78
Total Operating Expenses	$59.73	$73.91	$70.97	$67.79

There are differences in the measures of total operating cost per square meter given in the Alberta study and the calculated measures using the aggregated Canadian (Statistics Canada) data. This may be due to the inclusion of capital costs and perhaps marketing costs in the Alberta numbers.

The Statistics Canada publications also give provincial and Canadian measures of production and corresponding values of production for greenhouse vegetables crops for the period 2008 to 2011. These measures provide an indication of trends in productivity and can be used to develop imputed prices for the main vegetable crops. In the following tables, the productivity measures are calculated using the production and area data identified within the overall survey data.

Table 8: Greenhouse Vegetable Productivity and Value of Production, Canada, 2008-2011

		2008	2009	2010	2011
Tomatoes	Productivity (kg/m^2)	44.94	46.30	50.87	49.69
	Value of Production/m^2	$79.63	$87.30	$96.57	$91.77
Cucumbers	Productivity (dozens /m^2)	10.43	10.62	13.63	14.20
	Value of Production m^2	$73.51	$77.47	$90.14	$90.20
Peppers	Productivity (kg /m^2)	24.64	25.82	24.43	23.77
	Value of Production/m^2	$69.91	$66.47	$73.43	$78.96
Lettuce	Productivity (heads/m^2)	n/a	109.24	90.64	85.42
	Value of Production/m^2	$129.55	$119.82	$93.59	$85.24

Hickman (2011) in a global overview of greenhouse vegetable production presents similar measures expressed in US$. As well, Hickman offers estimates of construction (US$36.10/m^2), annual heating costs (US$12.10/m^2) and annual operating costs (US$41.42/m^2).

Production revenues and cost information gained through a survey of Saskatchewan producers was published in Greenhouse Vegetable Production in Saskatchewan: Production and Economic Info (Saskatchewan Agriculture, Food and Rural Revitalization, 2003). The survey data provided average values for operating revenues and operating expenses for the 1998 operating period. Although these measures may not accurately reflect the current economic conditions in the industry they can contribute to developing a baseline for estimating costs and revenues in a northern scenario. The following table summarizes the enterprise budget developed for a 0.2 acre Saskatchewan vegetable greenhouse.

Table 9: Summary of Saskatchewan Greenhouse Vegetable Survey for 1998/99

Average Production Area (ft^2)	8,752
Average Total Investment (land, building, equipment)	$128,692
Average Total Investment per ft^2	$1.43
$ / ft^2	
Average Revenue per ft^2	$7.67
Average Total Operating Expenses	$5.06
Average Return Over Operating Expenses	$2.16
Total Fixed Costs (Investment and Depreciation)	$1.43
Return to Operator Labour and Management	$0.73

The revenue and expense numbers available in the literature and presented above will not reflect the revenues and costs a greenhouse venture in a northern community might achieve. They do however indicate critical areas of research necessary in any proposed northern greenhouse venture.

Evans (2008) developed models for small-scale greenhouses in Iqaluit and Goose Bay in order to compare the costs of growing fresh produce locally with the cost of shipping in produce. These models provide detailed estimates of production costs and potential returns for smaller-scale greenhouses operating in northern conditions and are summarized in the following table.

Table 10: Costs to Grow Greenhouse Tomatoes, Iqaluit and Goose Bay

	Iqaluit		**Goose Bay**	
	No Lights	**Lights**	**No Lights**	**Lights**
Sales	$19,414	$29,835	$52,179	$316,533
Thermal Energy	$22,964	$19,461	$37,457	$28,251
Electrical Energy	$3,548	$21,895	$2,158	$18,032
Total Cost to Grow	$32,667	$50,167	$125,228	$156,256
Total Cost to Grow per pound	$3.84	$4.03	$1.43	$1.06
Earnings (loss)	($13,263)	($20,332)	$52,179	$160,277
Earnings (Loss) per Pound	($1.56)	($1.63)	$0.59	$1.09

The Goose Bay facility would have access to extremely low electricity rates giving this facility a competitive advantage in heating and lighting costs and potentially allowing it to be economically viable. The estimates in the Iqaluit model do not allow for a lower-cost energy source. Evans noted that greenhouse vegetable production in northern regions generally faces the economic challenges of high heat and electrical costs as well as economies of scale limited by local consumption. In cases where there is access to lower-cost energy sources there may be potential for a greenhouse venture to be viable.

2.2.3 Opportunities and Constraints Affecting the Economic Viability of Northern Greenhouses

The economic viability of a northern greenhouse will be challenged by a series of economic constraints. Economic viability will ultimately depend on overcoming these challenges. The literature does provide some investigation of these economic obstacles and strategies for overcoming them.

Marketing

The economic viability of a northern vegetable greenhouse venture will be impacted by how well the Four P’s of marketing are addressed. These fundamental market issues of product, price, promotion and place are addressed in the following questions presented in the Alberta Agriculture (2001) publication Commercial Greenhouse Vegetable Production.

- What products do consumers buy?
- Who buys the products?

- Where are the buyers located?
- What is the market size?
- What, when and where do the buyers buy?
- What are the packaging requirements of each market?
- What are the market prices?
- How much do the prices fluctuate?
- Is the market mature or growing?
- Does the market have room for additional production?
- How will the size of the local market and local consumption affect the scale of the greenhouse venture, pricing, promotion and distribution?

Evans (2008) points out that market size will determine the scale of greenhouse operations since all production needs to be consumed in local or nearby markets that can easily be accessed. The implication is that market size should determine the scale of the greenhouse facility. Limited market size will then limit the economies of scale that the greenhouse might achieve. As well, a greenhouse may have to look at a wide range of vegetable crops to meet market needs which could further constrain economies of scale.

The North Slocan Community Greenhouse Feasibility Study (Mahr 2010) includes a market survey that explores how a community greenhouse might meet the needs of individual consumers, retailers and other stakeholders in the community. Although the focus of the North Slocan survey is on organic production, it could serve as a guide for assessing the interaction of consumers in localized northern markets with a community driven or private sector-driven greenhouse venture.

Food pricing in northern communities is a complex multi-dimensional issue. An effective pricing strategy will be necessary for a greenhouse vegetable venture in a northern community. The Alberta Agriculture publications Pricing Horticulture Products (1999) and The Essentials of Pricing (2009) offer advice on the differing strategies of cost-based, competition-based pricing and customer-based pricing.

Evans' (2008) analysis indicates that in months with higher heating and lighting costs locally grown greenhouse tomatoes would have higher costs relative to the freight adjusted wholesale price of shipped in tomatoes. However, retailers often apply a 50% margin to imported produce which could be an opportunity for a greenhouse venture with a strategy of marketing directly to consumers.

Market prices for vegetable products will vary from month-to-month based on supply and demand, availability and transportation costs of imported products. The economic performance of a northern greenhouse venture will be affected by both the flow of various vegetable products to market in different months as well as the different market prices these products realize in different months. Information on monthly supplies of greenhouse vegetables and monthly wholesale prices is available through the AAFC publication – Canada's Tomato Report and Weekly Wholesale to Retail Market Prices. For some markets these weekly wholesale prices adjusted for freight will provide an estimate of a localized wholesale price.

Product quality will also be a factor in the long-term sustainability of a northern greenhouse. Evans (2008) points out that shipped in vegetables are often of fair to poor quality due to the time required for shipping to a remote market. Local production can provide better quality produce but will have to overcome the economic challenges of limited scale and any incremental costs for storage and handling.

Holzman (2011) identifies the challenge that many northerners may be disconnected from their food sources. Effective marketing would include a promotion strategy aimed at awareness and education as well as engaging individuals in development of the local food source.

Energy Cost Volatility

When natural gas is the primary heating fuel, greenhouse operations can be exposed to volatile natural gas prices. Chaudhary (2007) provides data on varying natural gas prices as well as the sensitivity of production costs, gross margins and returns to equity from fluctuating gas prices.

Fluctuations in natural gas prices were assessed for their effects on the economic performance of different greenhouse vegetable crops. The following table illustrates the effects of year to year variations in natural gas prices on the costs and returns of tomato production.

Table 11: Production Costs and Returns for Tomatoes, 1998 – 2006

	1998	1999	2000	2001	2002	2003	2004	2006
Natural Gas Price ($/Gj)	2.91	3.63	4.54	7.35	4.48	7.00	6.95	7.29
	$ / m^2							
Sales (18 kg/plant)	90.17	84.47	88.99	95.76	109.32	109.21	90.44	93.63
Heating Fuel Cost	12.16	15.17	18.94	30.77	18.72	28.19	14.94	16.99
Labour	25.72	26.47	28.08	28.51	30.02	30.24	23.40	23.82
Total Production Costs	95.76	100.93	93.29	115.24	103.08	116.10	94.28	96.58
Gross Margin	9.47	-1.29	10.87	-4.41	21.30	8.18	4.77	5.55
Return to Equity	-5.60	-16.46	-4.30	-19.48	6.24	-6.89	-3.84	-3.06

Source: Chaudhary 2007

Chaudhary also looked at the combined effects of variable crop yields and fluctuating natural gas prices. The following table presents the effects on gross margins of varying cucumber yields and natural gas costs.

Table 12: Gross Margin – Sensitivity to Varying Tomato Yields and Natural Gas Prices

	Tomato Yield per Plant (kg)				
	16	18	20	22	24
Gas Price ($/Gj)	$ / m^2				
5.50	-$0.65	$12.91	$26.58	$40.24	$53.91
6.50	-$4.95	$8.61	$22.27	$35.94	$49.60
7.50	-$9.15	$5.55	$18.08	$31.74	$45.41
8.50	-$13.45	$2.47	$13.77	$27.44	$41.10

	Tomato Yield per Plant (kg)				
	16	**18**	**20**	**22**	**24**
9.50	-$17.65	$0.75	$9.58	$23.24	$36.91

Source Chaudhary 2007

These analyses demonstrate the effect of volatile heating costs on the economic viability of greenhouse operations. It is also noted that varying natural gas prices have contributed to a high-level of uncertainty in the greenhouse industry.

High Energy Costs

Regardless of the heating sources, the viability and sustainability of greenhouse vegetable ventures requires strategies for managing energy/heating costs. Energy and heating costs are often key barriers for northern greenhouse development due to high fuel costs (diesel or propane) and high heating and electrical usage given cold temperatures and limited sunlight in winters.

Increasing productivity to manage volatile energy costs was explored by Mirza (2004). He notes that producer knowledge may be limiting greenhouse productivity increases even though new crop production technologies were available. Producers had not taken advantage of technologies and practices that would increase their productivity. As a result they had limited ability to cope with energy costs. Mirza encourages producers to assess their crop production practices and make changes that increase the productivity of their greenhouse operations. Enhanced production practices combined with greater energy efficiency are framed as necessary strategies for dealing with the effects of volatile energy costs.

The idea that knowledge management may be a limiting factor in dealing with energy costs was also mentioned in a profile of Alberta greenhouse operators in 2004 (Alberta Agriculture Food and Rural Development (AAFRD) (2004). This document points out that the increasing complexity of heating systems and environmental control systems requires technically trained staff with the capability to effectively work with modern environmental control systems.

Chambers (2004) in a study prepared for AAFRD focuses on strategies producer might adopt in order to reduce energy use and energy cost per unit of crop yield.[2] Greenhouse operators are encouraged to implement energy audits to better understand the energy consumption characteristics of their facility and to identify possible strategies for reducing energy use. A number of energy audits were performed and payback periods were estimated for the recommendations made for each facility. The following were identified as practices that could reduce greenhouse energy use:

- Heating system performance and maintenance.
- Flue gas condensers could be installed to recover energy that would normally be exiting the facility.

[2] *It is noted that the average natural gas consumption per area of greenhouse in Alberta is in the range of 1.95 gigajoules (Gj) per square meter*

- Computerized climate control could achieve energy savings of 10 – 15% by maintaining greenhouse temperature at the lowest possible level without harming the crop.
- Greenhouse structure maintenance would reduce heat losses by methods such as fixing leaks and ensuring proper air circulation.
- Alternative fuel sources were explored as a means of reducing energy costs.
- Windbreaks to reduce energy losses from wind.
- Thermal Curtains can achieve energy saving by reducing night time heat losses.
- Recovery of CO_2 from boiler or furnace flue gas.
- Cogeneration units producing both electricity and heat for a greenhouse.
- Waste heat from an adjacent industry. It was noted that the capital costs to utilize this source of energy may be higher than conventional systems and that there may be the need for a back-up system for times when the waste heat is not available.
- Active humidity control was mentioned as an area that is being researched.

Evans (2004a) offers a detailed study of potential energy savings through adopting various technologies in a greenhouse facility. Technologies are identified and assessed in terms of potential savings in energy use, reduced energy costs and estimated payback periods. These assessments were made in the context of a one acre greenhouse located in the Medicine Hat region of Alberta. The energy savings energy calculations are rigorous and consider historical temperature data, solar radiation and day length. The final assessment is that the greatest energy savings might be achieved through thermal screens, infrared thermal poly and reducing air infiltration rates.

Evans (2008), Canadian Agricultural Energy End-Use Data and Analysis Centre (CAEEDAC) (2002) and Mager (2008) assessed the economic potential for greenhouses with access to a low-cost energy resource. The trade-off is between the savings gained by using the waste heat and the cost of implementing an alternate heat system. The heat source and the distance between the greenhouse facility and the heat source will be key factors. The further the distance the greater the capital costs of the heat system are likely to be. Mager developed enterprise budgets for a lettuce production greenhouse established at the Chena Hot Spring Resort in Alaska. The greenhouse utilizes geothermal energy providing lower heating and electrical costs that had been developed for the resort. The heating costs for the greenhouse were estimated by calculating the heating oil equivalent that would be required to heat the greenhouse then costing it at a discounted price of $1.50 per gallon while the average price in the area is $3.73 per gallon. The electricity costs are calculated using a discounted price of $0.10 per kWh while the going rate is $0.14 per kWh. These estimates indicated cost savings of $35,000 for heating and $12,000 for electricity. When combined with the higher prices for lettuce ($3.00/head) these savings contribute to a viable of the northern greenhouse venture. Of note is that in an integrated system, the energy-related costs to the greenhouse can also provide additional revenue to the thermal power plant and the district heating system at the resort.

Andrews and Pearce (2011) consider how a northern greenhouse might utilize waste heat from an industrial source. The focus is on developing methods for assessing the technical and economic feasibility of reusing waste heat from a wide range of industrial operations. The benefits to a greenhouse operation would include gaining a low-cost source of heat as well as the potential of gaining the CO_2 from the exhaust gases. These could provide another revenue stream to the industrial enterprise. Net Present Value (NPV) analysis was used to compare a system using waste heat to a system using natural gas. The economic model was developed for a 3.9 acre greenhouse producing tomatoes and includes a waste heat system with a capital cost of $1,152,162 which includes a back-up burner. The model includes calculations for total heat required and calculations of hourly energy demand. The analyses indicate that over a 20-year life and for a range of range of capital costs and discount rates the waste heat system is significantly less expensive than a natural gas system. As well, the waste heat system could provide the added benefits of CO_2 offsets.

Biomass

Biomass as an alternative fuel source for greenhouses was explored by Evans (2004b) in a report prepared for AAFRD. The trade-off is between lower cost biomass fuel and the higher capital and maintenance costs (relative to gas fired boilers) of installing a biomass combustion system in a greenhouse. The report emphasizes that the energy savings achieved by a biomass combustion system will be due to having access to inexpensive biomass fuel. Furthermore energy savings will depend on the moisture content of the material since combustion energy is used to evaporate the water content in the material. In an example, natural gas prices at $0.33 per cubic meter results in a cost of $10.80 per Gj of output. Biomass with 20% moisture content with a cost of $29.50 per ton delivered would have a cost of $2.75 per Gj including a maintenance cost of $0.25 per Gj. For a 10-acre greenhouse requiring 60,000 Gj per year the fuel cost difference is estimated to be $420,618 per year which includes the carrying costs for both fuel sources. These savings in fuel costs would need to be sufficient to cover the higher capital costs of a biomass combustion system as well as additional costs related to biomass storage, handling ash, back-up systems, a greater need for cleaning flues and possibly for a technically trained operator.

In Greece, Gousgouriotis et al (2007) provide an investment analysis (NPV, Internal Rate of Return (IRR) and payback period) approach for assessing the economic viability of biomass heating systems in the context of greenhouses. Of note is that the methodology "takes under consideration all the parameters involved in the planning and application of biomass heating systems, both from a technical as well as from a financial perspective". In this study two cases are developed, a five-acre tomato greenhouse and two adjacent tomato production greenhouses with a total area of 11 acres. When compared with the conventional alternative of a diesel fuel heating system, significant annual savings can be achieved using the biomass system. The study identifies the availability of a low-cost biomass supply as well as the availability of subsidies and grants as the factors (in Greece) expected to have the greatest influence on the technical feasibility and economic viability of a biomass heating system investment.

The following graphic (Figure 3) in the Gousgouriotis document captures the key issues to be addressed when assessing the technical feasibility and economic viability of a biomass heating system.

Figure 3: An Illustration of the Techno-Economic Considerations in Assessing a Biomass Heating System

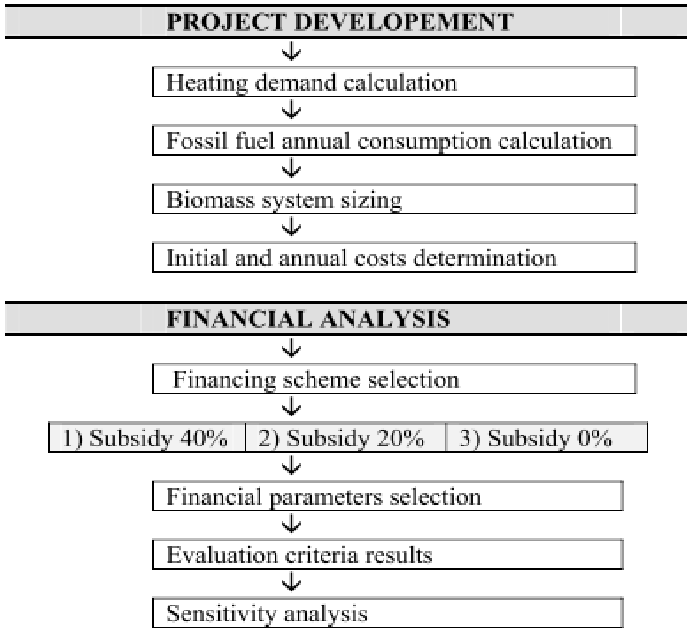


***Figure 2**: Techno-economic study flow chart*

Chau (2009b) identifies techno-economic factors in assessing the feasibility and economic viability of a biomass heating system for a greenhouse. The technical feasibility requires assessing the demand for heat (influenced by greenhouse size, structure and location), boiler system, boiler efficiency, fuel type and CO_2 demand. The economic viability will be a function of the capital investment, the fuel requirement and annual operating costs.

Von Zabeltitz (1994) suggests that the following questions must be answered when considering renewable energy sources for greenhouse heating.

- How much heating energy is required in the different months of the growing season?
- How much energy is available from renewable sources in the different seasons?
- Can this energy be delivered only on certain days, in certain seasons or throughout the year?
- What is the temperature level of the energy?
- What is the expected expenditure for the use of the renewable energies?
- What is the amount of energy, which cannot be recovered by renewable energies?
- What are the consequences for grower, greenhouse construction and crop cultivation?

NPV assessments were also used to assess hardwood residue chips as a heating source for greenhouses in Tennessee (Jensen et al). The investment analysis approach was used to assess the trade-off between reduced annual heating costs and the higher capital costs of developing the wood-based heating system. The methodology followed in this assessment is similar to that of the others and includes the following elements:

- Estimating the heat requirements of the greenhouse.
- Calculating heat conduction loss.
- Determining the energy available from a particular kind of wood product.
- Determining the cost per unit of energy.
- Calculating the NPV of the investment in the wood heating system. That is the NPV of the initial capital investment in the heating system and the future flow of savings due to reduced annual heating costs.

A number of worksheets are provided in this Tennessee publication for use in assessing the economic benefits of biomass heating systems compared to conventional fuel systems. These could be applied in northern regions of Canada.

Effective decision making when using investment analysis to assess the economics of a biomass combustion system requires considering a range of possible values for the key parameters. Chau (2009a) considered variations in the prices of wood pellets and natural gas as well as variations in the contribution of the biomass heating system to the overall heat requirements for a range of greenhouse sizes. They found that price increases of more than 20% per year for wood pellets would result in a negative NPV for a 7.5 acre greenhouse requiring 5MW of heating power from a biomass combustion system providing 40% of total heat requirements. As well, they suggested that to be economic, a wood pellet system should contribute at least 40% of heat requirements while a wood residue heat system to be economic should contribute at least 30% of heat requirements. Furthermore, they noted that a greenhouse fully supported by a biomass heating system could incur the added cost of liquid CO_2 which would reduce the NPV. They concluded that a wood pellet system may not be economical for small-scale greenhouses (3 ha in their work) while wood biomass systems may be economically feasible when providing 40% of the heat requirements for large-scale greenhouses (7.5 ha and 15 ha) over a 25 year investment life.

The costs of harvesting, drying, processing and delivering biomass fuel to a greenhouse will be a key economic factor affecting the economics of the biomass heating system and the viability of the greenhouse venture. Mani (2009) compares the costs of two systems for chipping wood residues as well as a pelleting system. Chipping costs of residues of whole trees and stems cost in the range of US$15 to US$18/ton. Pelleting costs are US$40/ton with drying and US$27/ton without drying. New pelleting technology may be able to reduce these costs to US$30/ton of pellets. Note that these estimates do not include any amount charged for the wood residues.

Ledrew (2004) and Norris (2010) identify transportation costs as a key economic variable in the cost of biomass fuel. In addition to location and travel time, the key challenge in transporting biomass fuel to the end-user such as a greenhouse is optimizing the weight per load and ultimately the energy per load. In Figure 4 Norris presents the key biomass properties that could affect the energy per load transported to a greenhouse.

Figure 4: Biomass Properties and their Effect on Energy Density

Woody Biomass Properties				
	Bulk Density (kg m^{-3})	Moisture Content (%)	Ash Content (%)	Energy Density (MJ kg^{-1})
Mill Residues, sawdust	-	13	0.75	16
Forest Residues, green chips	350	50	1.94	10
Densified Residues, pellets	640	10	-	17
Liquefied Residues, bio oil	1200	25	0.1	18

Source: Norris 2010

Norris describes the general rule of thumb used in determining whether weight or volume determines the quantity that can be transported in a load. When the density of the biomass material is greater than the ratio of the truck weight capacity to the truck volume capacity then weight determines the quantity per load. When the density is less than this ratio then volume determines the load capacity. There is an economic trade-off between transportation costs and the added capital and operating costs of further processing such as densification. In this case the rule of thumb is that the further the travel distance the more beneficial the densification of the biomass material becomes.

Norris also addresses the importance of the logistics of energy flow to an end user. A greenhouse operation would need to invest in suitable storage in order to have an assured supply of biomass material on hand to ensure a reliable source of heating energy. At the same time on-site storage of biomass material needs to address the threats of loss from fire as well as losses due to moisture and biological degradation.

Combined Heat and Power (CHP)

CHP generation may be another technology that could be adopted by greenhouse growers to reduce energy costs. CHP can provide lower cost energy, increased availability of CO_2 and the potential of selling surplus electricity to the electrical grid or the local community. The BC (2011) study of cogeneration for greenhouse operators focused on the regulatory forces that might impact on the economics of CHP. The primary economic factors were the high capital costs such that the best fit would be for large-scale operations able to spread this cost over greater levels of production and being able to profitably sell electricity generated by the system.

2.2.4 Assessing the Macro-Economic Effects of a Northern Greenhouse Venture

Greenhouse ventures in northern regions will stimulate economic activity through input purchases and jobs. The total economic impact that a greenhouse venture might generate would include the direct input purchases required to support a greenhouse venture as well as the ripple effect these expenditures would have in the local economy. As well, a greenhouse venture could contribute to changes in household expenditures resulting from increased employment income earned directly from the greenhouse venture or indirectly from associated businesses. The total economic effects then are all the economic effects of the initial economic activity (greenhouse venture) working its way through the economy.

Although there are no studies specific to the macro-economic effects of a new greenhouse venture in northern Canada there are studies of the economic activity generated by the greenhouse industry in other regions. These studies can provide an understanding of the linkages and potential effects that a northern greenhouse venture may have with other sectors of a local or regional economy.

Investigations of the greenhouse industry in Ontario were undertaken (Ontario Greenhouse Alliance 2006 and 2009) to determine the current and expected future contributions of the greenhouse industry to the economy of Ontario. These studies found that the greenhouse sector was a significant contributor to the provincial economy with strong linkages to other sectors of the economy. The 2006 study developed a regional impact model to assess the direct, indirect and induced effects of the Ontario greenhouse industry. Direct effects were the outputs of the greenhouse sector which were measured by the direct purchases (goods, services and labour) of inputs by that industry. Indirect impacts were the additional rounds of spending due to input suppliers purchasing inputs from their suppliers. Induced impacts were the additional expenditures due to changes in income earned by individuals working either directly or indirectly in the greenhouse industry. Generally, the greater the linkages an economic activity such as a greenhouse has the greater would be the total economic activity.

Output multipliers are the total economic effects divided by the direct economic effects and are a means of quantifying the total effect of an initial economic activity. The 2006 study developed output multipliers to assess the ability of the greenhouse sector to generate economic benefits throughout the Ontario economy. These multipliers measured the expected increase in the total output ($) of the Ontario economy for each dollar of increased production generated by the greenhouse industry. The following table presents the multipliers developed in the 2006 study.

Table 13: Simple and Total Output Multipliers (TOM) for the Ontario Greenhouse Industry

	Simple Output Multiplier (SOM)	TOM
Ontario Greenhouse Industry	2.01	2.81
Vegetable Greenhouse Operations (ON)	2.00	2.84
Flowers, Potted Plants, Bedding Plants and Cuttings	1.99	2.92
Tomato Greenhouse Operations	2.06	2.91
Pepper Greenhouse Operations	2.15	3.06
Cucumber Greenhouse Operations	1.95	2.73
Crop and Livestock Production (less greenhouse activity)	1.85	2.39
Manufacturing	1.84	2.47
Mining, Oil & Gas Extraction	1.61	2.30

Source: Greenhouses Grow Ontario: An Economic Impact Study of Greenhouses in Ontario. (2006)

The output multipliers suggest that for each dollar of output generated by the Ontario greenhouse industry there was $2.81 of activity generated in the economy as a whole due to the direct, indirect and induced effects. Therefore for every dollar of output generated by the greenhouse industry there was an additional $1.81 of economic activity in economy. The economic impact without the induced effects of labour income was $1.01 of additional activity for each dollar of output achieved by the greenhouse sector.

A further assessment of the greenhouse industry indicated that greenhouse peppers and tomatoes generated the greatest levels of economic spin-offs in the Ontario economy. These macro-economic effects of the Ontario greenhouse sector were considered quite strong when compared with other sectors of the economy such as manufacturing and crop and livestock production.

The Ontario study (2006) also assessed the distribution of the economic effects generated by the greenhouse sector. The greatest beneficiary was the household sector which gained nearly 19% of the total economic effects of the greenhouse sector, followed by manufacturing (14%) and the finance, insurance, real estate, rental and leasing (FIRE) sector (10%).

A study of the local economic impact of agricultural production in the City of Hamilton, Ontario (2008) used a similar approach to generate output multipliers for a range of agricultural activities.

Table 14: TOM by Agricultural Activity for the City of Hamilton

Agricultural Activity	(TOM)
Greenhouse Production	2.96
Hog Production	3.30
Poultry and Eggs	3.09
Fruit	2.88
Dairy	2.86
Nursery Products and Sod	2.89

In this assessment, each dollar of additional greenhouse output there was an additional $1.96 of additional economic activity in the local (City of Hamilton) economy.

A similar study (Swenson 2010) was undertaken to explore the economic effects of increased fruit and vegetable production in Southwest Iowa. The focus of the study was to assess whether profitable small-scale local production of fruit and vegetables could enhance local economic activity and add stability to the local economy that is facing population declines and limited economic opportunities.

Input—output models were developed to reflect two likely scenarios. The import substitution scenario considered the effects of local production of fruit and vegetables increasing to a level sufficient to meet local consumption requirements. This scenario generated a TOM of 1.42. An export scenario was also developed to measure the economic effects of local production of fruit and vegetables increasing to meet the demands of nearby cities. This scenario also generated a TOM of 1.42. In both cases the multiplier was interpreted to mean that a $1 increase in fruit and vegetable output would generate an additional $0.42 of economic activity in the rest of the economy.

Of note is that output multipliers need to be used with caution when estimating the total economic activity that might result from an initial action. In particular is the assumption that money spent on greenhouse vegetables will stay in the local economy. In particular, regions with wide geographic dispersion may have limited economic spin-offs from an initial activity such as a greenhouse venture when there are limited interactions with other local industries.

There are cases where public contributions are made to support an economic activity. Generally, these contributions are made to generate public benefits that accrue to the community as a whole. In these cases a more appropriate measure of the macro-economic effects might in using a cost benefit framework to determine the net public benefit or the net public cost.

An Australian study (Council of Rural Research and Development Corporations; 2008) describes public benefits as "benefits that accrue to a wide cross-section of the community and, that many members of the community value highly and which to ensure that they continue to be produced." These benefits include economic benefits such as improved productivity and reduced costs as well as environmental and social benefits. Environmental benefits can include improved biodiversity outcomes, reduced waste, reduced harmful effects and increased efficiencies. Social benefits can include improved food safety and food security, improved human health, strengthening of communities and improved occupational health and safety. For many of these benefits there are no readily accessible market values to quantify as well as accurately reflect the value held by society. As a result, public benefits may be under-valued when considered in a cost-benefit framework.

The Australian study addresses these measurement challenges and applies a two-stage methodology of quantifying benefits where "robust and credible cases " can be made and providing descriptive assessments where such cases cannot be made.

2.3 Integrated Methodology for Assessing the Success Potential of a Northern Greenhouse Venture

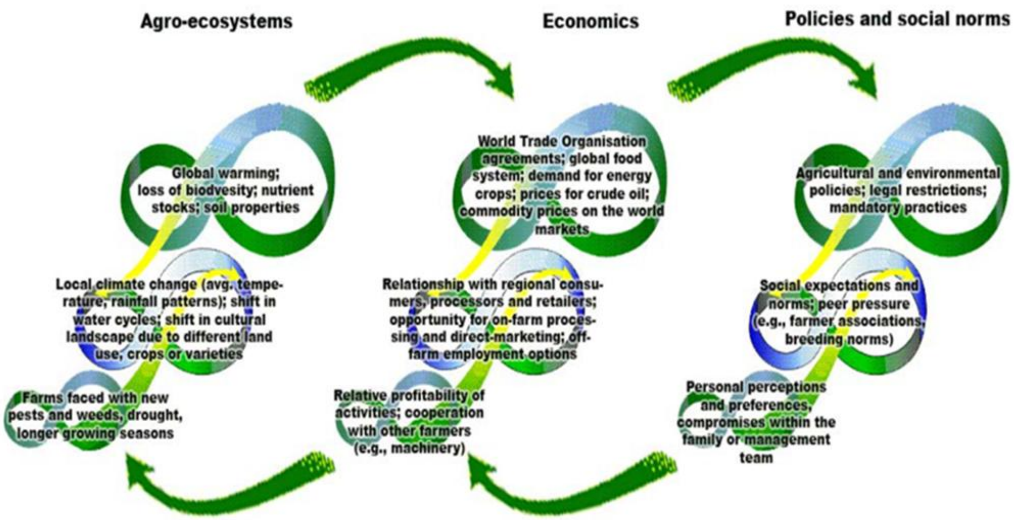
The viability and sustainability of greenhouse ventures in northern aboriginal communities will be shaped by the interaction of multiple factors. The literature on complex systems can offer insights to the dynamics of a food production system such as a greenhouse with linkages to economic, environmental, social and cultural systems.

Darnhofer (2009) describes complex systems as inter-connected and interdependent systems with no clear boundaries where one system ends and another begins. Figure 5 illustrates the interconnectedness a farming system (lower left-hand corner) could have with the agro-ecosystems of which it is part as well as with economic systems and social-political systems. The interconnectedness of food production systems with other systems is also illustrated by Holzman (2011) and the Northern Food Prices Project Steering Committee (2003).

Greenhouses in northern communities will interact with other social, cultural and political systems so that information, knowledge and energy will flow from one system to another. These interactions will change over time such that a greenhouse system will continuously be affected by change coming from other these domains.

The implications for a proposed greenhouse in a northern community are that the viability of the venture will continuously be affected by the change emanating from the interrelationships with other systems. This suggests that a proposed northern greenhouse venture must be able demonstrate the capacity to adapt to the evolving current situation and have the ability to withstand major shocks and disturbances without incurring significant losses or failure.

Figure 5: The Interrelationships Affecting a Farming System



Source: Darnhofer (2009); Navigating the Dynamics: Resilient Farms through Adaptive Management.

A greenhouse venture must be flexible enough to adapt to natural and economic stresses as it strives toward the goals of productivity, profitability, environmental quality and increasing contributing to community wellness. This capacity is often referred to as resiliency. There are different perspectives on resilience however the idea of a threshold seems to be widely held. Resilience is lost when the activities of a production system or business venture cross a certain threshold from which it is difficult to recover without some significant reorganizing of the system. Even though greenhouse systems are designed to control the environment, there are still interdependencies that will affect the sustainability of the venture.

Northern greenhouse ventures may face trade-offs between investing to achieve gains in productivity or investing resources to ensure the greenhouse venture has sufficient resiliency to ensure it has the ability to adapt to change emanating from economic, social and political systems without compromising long-term sustainability. A critical success factor for northern greenhouse ventures could be in understanding of where these critical threshold lie for the particular proposal.

Economic viability in the traditional sense of cash revenues and cash expenses will be a critical element underpinning the success of a northern greenhouse venture. However, there are broader indicators of success (sometime called triple bottom line or TBL) which provide an expanded perspective on measuring the potential of success of an undertaking such as a northern greenhouse venture. These include economic, environmental and social indicators that reflect on the broader social-ecological-economic environment effects of a greenhouse venture. The work of Michael et al. (2009) for Indian and Northern Affairs Canada offers key performance indicators (health and wellbeing; environment; education; economy; governance and infrastructure) that might be used in assessing the broader effects of a northern greenhouse venture.

The success potential of a northern greenhouse venture may be strengthened through effective risk management processes. Greenhouse ventures that take ownership of risk and implement processes of identifying, assessing and developing strategies to manage risk events that might impact on the sustainability of their farming systems would gain the following benefits:

- Reduced surprises and their related costs.
- Identify elements of change that can be overlooked.
- Focus on change most critical to the sustainability of the greenhouse venture.
- Operate more effectively in environments filled with uncertainty.
- Determine a path to managing threats at an acceptable cost.

Risk can be either positive (opportunity) or negative (threat). As well risk has two dimensions the probability of a risk event occurring and the impact the risk event could have if it were to occur. Risk Choices is a tool developed to support the risk management process. It can guide the process of identifying, assessing and developing strategies to manage future events that might impact on the viability and sustainability of a greenhouse venture in a northern community.

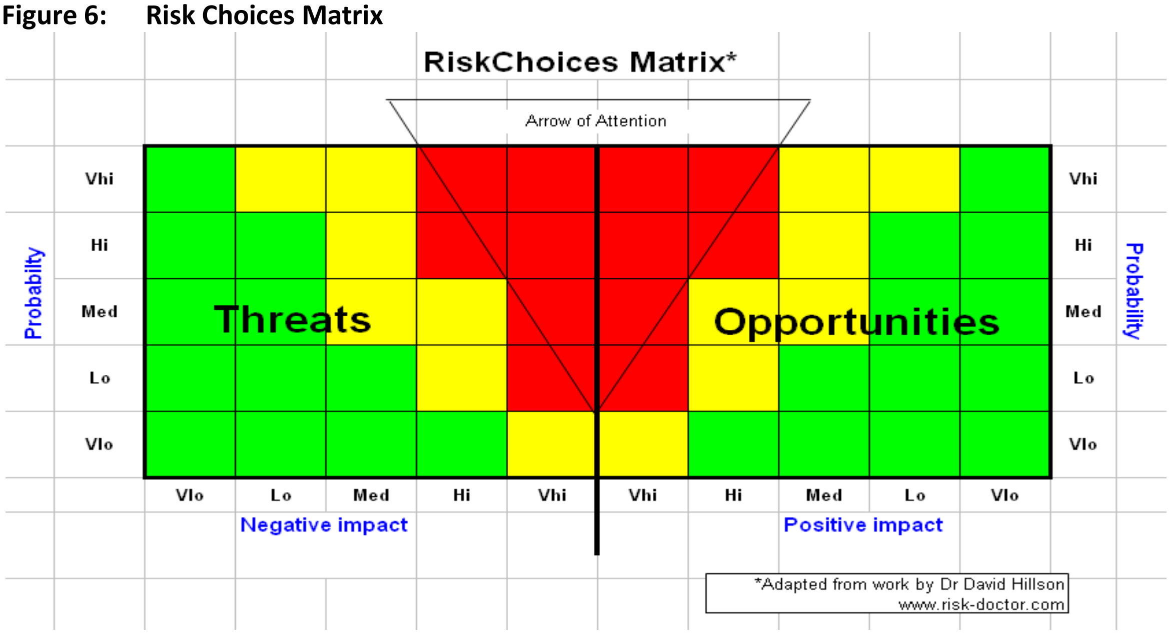
Risk choices offers the following descriptions of probability and impact that could be used in scoring the identified risk events that might impact on the viability and sustainability of a northern greenhouse venture.

Probability	Descriptions
Very High	Almost certain to occur in the context of the sustainability of the farming system
High	Likely to occur in the context of the sustainability of the farming system
Medium	May occur in the context of the sustainability of the farming system
Low	Unlikely to occur in the context of the sustainability of the farming system
Very Low	Extremely unlikely to occur in the context of the sustainability of the farming system

Impact	Descriptions
Very High	Significant consequences on the sustainability of the farming system
High	Considerable consequences on the sustainability of the farming system
Medium	Modest consequences on the sustainability of the farming system
Low	Limited consequences on the sustainability of the farming system
Very Low	Negligible consequences on the sustainability of the farming system

The Risk Choices Matrix (Figure 6) can be used by northern greenhouse operators to rank identified risk events for future action. In the case of scoring the risk impacting on the viability and sustainability of a northern greenhouse venture, those future events in the red area would be identified as requiring the most immediate action.

Figure 6: Risk Choices Matrix



Source: http://www1.agric.gov.ab.ca/$department/deptdocs.nsf/all/bmi12504

3 REVIEW OF TECHNOLOGIES FOR NORTHERN GREENHOUSES

3.1 Greenhouse Design

Greenhouse Structures

Although this study focuses on ***commercial greenhouse production,*** **i**t is important to remember that vegetable production in the north that can range over a continuum from outdoor market gardens at the simplest level, as well as cheap outdoor grow tunnels which may extend the season a few weeks, to actual greenhouses which are the focus of this study and come in an array of designs and levels of complexity.

Greenhouse designs range from low technology, lower cost and lower productivity designs to higher technology, higher cost and higher productivity designs. At the low end, the greenhouses may be nothing more than sealed high-tunnels covered with polyethylene film (poly). At the highest end, agricultural production moves beyond greenhouses to "plant factories" which are enclosed buildings ranging in size from small container type growth rooms to large industrial-type buildings.

It is well recognized that one type or style of greenhouse is not going to serve the needs of all northern communities that might be interested in greenhouse crop production. Some of the key factors that will determine the best option for a particular community are the size of the community (and corresponding market), the location of the community (ease of access), the availability of resources (i.e., skilled labour, fuel, funds, etc.) and the socio-economic conditions. These factors are detailed in subsequent sections of this report. In consideration of these conditions but also in an effort to remain realistic, this section reviews the following four main "greenhouse" designs which are suitable for northern environments.

High-Tunnel Style Greenhouse

A simple high-tunnel style greenhouse is the simplest and cheapest greenhouse option. These low-tech greenhouses are unheated structures made of steel hoops covered with a single poly layer that needs to be removed before the winter and replaced in the spring, which can be done by the grower with a small team. Most high-tunnel style greenhouses are approximately 2,500 ft^2 (25–30 feet by 100 feet) but this can vary. Expansion to meet market or community needs can be done by adding additional greenhouses.

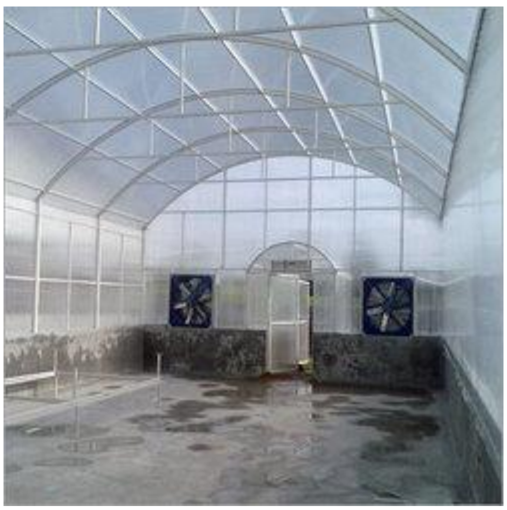
High-Tunnel Greenhouse

High-tunnel style greenhouses will only serve to facilitate production for an extra month or so, allowing for perhaps up to six-months of production although this will depend heavily on climate and latitude. This type of greenhouse can be constructed cheaply and small-scale high-tunnel style greenhouses for non-commercial production often utilize locally available materials and scrap to reduce costs. Operating costs are low as no heating or grow lights are utilized.

Because of the lack of climatic and plant nutrition controls used in low-tech greenhouses, the volume and quality of produced vegetables will be very low compared to other options. Another disadvantage is that these types of greenhouses will not guarantee the availability of fresh vegetables out of season.

Stand-Alone Greenhouse

The stand-alone greenhouse forms much of the small-scale greenhouse industry in Canada. It is typified as an engineered steel structure with two layers of poly with blown air in between the layers to provide insulation, although other coverings such as glass can be used.



Stand-Alone Greenhouse

The level of technology and the production within the stand-alone greenhouse can vary widely along a continuum of complexity. At the low end, it will have soil-based production with little or no environmental controls. Productivity will resemble the high end of the high-tunnel style greenhouses. It will utilize more but less specialized labour than gutter-connected greenhouses (described below) in this case.

At the high end, the stand-alone greenhouse can be a high-tech facility with soilless production, grow lights and full environmental controls suitable for year-round production (if economical). In these cases, production can approximate the gutter-connected greenhouses described below and it will have similar requirements for specialized labour. It is less energy efficient than gutter-connected facilities.

Gutter-Connected Greenhouse Facility

This type of facility is the norm for commercial greenhouse production in Canada. The key advantage is that it can guarantee the availability of high quality produce to remote areas year-round. It is a proven technology, used already in Canada and many other countries. The greenhouse structure can be designed to withstand the harshest winter conditions in Northern Canada.

Gutter-Connected Greenhouse

Modern gutter-connected greenhouses are high technology facilities which is both an advantage and a disadvantage. It is an advantage because it has a computerized environment and plant nutrition controls which allows pre-programming and remote access for service and management, and because it creates high paying employment. On the other hand, it is a disadvantage because it is also a higher cost system with high operating costs, employing specialized labour. This type of facility requires trained growers with sufficient skills to properly utilize and maintain the systems and growth environment. Gutter-connected greenhouse facilities can utilize grow lights to produce vegetables year-round although some facilities may choose to shut down for two to three months per year to minimize energy costs.

Modern gutter-connected facilities are modular and can be expanded to meet market requirements. There are also economies of scale in heating costs as it expands modularly. Modern gutter-connected facilities can range in size from smaller-scale facilities which are quarter or half an acre up to very large-scale facilities encompassing 10, 20 or more acres.

A small gutter-connected greenhouse would be a good match for a small but dynamic community with adequate financial resources and trained labour. However, some of the overhead costs will have to spread over a much smaller production area, and the cost of produce can be expected to be higher than larger-scale facilities. It will also be necessary to find trained growers to utilize such a facility properly. Larger-scale facilities will only make sense in a select few communities with a sizable market, financial resources and the ability to attract and retain skilled labour; or, the availability of locals who are willing to enter this business through training.

Chinese- Style "Solar" Greenhouse

The advantage of the traditional Chinese-style "solar" greenhouse is its energy efficiency which allows it to produce fresh vegetables out of season. The Chinese-style "solar" greenhouse does this by storing energy in the north greenhouse wall built with heat absorbing material (soils, cement blocks, etc.) during the daytime which is then released at night. The original Chinese-style greenhouse (small in size, very low-tech, some organic growing elements, no or primitive heating, exclusive use of soil, hand operated exterior mats for shading and insulation) has undergone several modifications with the latest designs offering much wider spans, heating, motorized vent opening and mat insulation rolling up and down and the use of soilless methods of production.

Chinese-Style Solar Greenhouse

The very extensive use of this type of greenhouse throughout China makes it an obvious subject of interest for Northern Canada. Heat storage in colder months for Canadian models will however be somewhat less than similar models in China given the lesser sunlight and higher latitudes in the Canadian north. It should be remembered that the furthest point north in China is equivalent to Edmonton in latitude and "northern" centres in China such as Beijing lie at a similar latitude to Chicago.

All greenhouses are solar collectors to a degree, but the advantage of the Chinese-style solar greenhouse is its ability to store and retain greater amounts of energy. The key question however at the present time for their applicability to the Canadian north is how much more solar energy is stored with the Chinese-style greenhouse compared to the capital cost of construction. At present, there are serious concerns about the extremely high cost of construction of the Chinese-style greenhouse in Canada which are approximately four times higher than higher-tech systems on a per square foot basis when fully commissioned. The high cost of construction is surprising given that these are generally low-cost and low-tech greenhouses in China. The Chinese-style solar greenhouses do hold potential in Canada but costs need to come down as they leave the experimental phase if they are to be commercially viable.

Productivity in Chinese-style solar greenhouses, if it is possible to use raised gutter system and modern commercial greenhouse production methods, will be much higher than the high-tunnel style greenhouses but lower than gutter-connected greenhouses profiled below. The low profile of the Chinese-style solar model, along with the irregularly shaped greenhouse cover, means that the greenhouse environment inside the greenhouse is very location dependent. This results in a lack of uniformity in plant growth which is translated into reduced yields and product quality. It is unclear at present whether Chinese-style greenhouses have enough strength in their roof and truss system to utilize the raised gutter system used in modern commercial greenhouse vegetable management. However, if they are designed to do this, this will greatly increase their chances of successful commercial production.

Insulated Industrial Building with all Crop Production Facilities

Although this is not technically a greenhouse as it produces vegetables in an insulated industrial building that depends exclusively on artificial light, this type of facility provides another option for greenhouse vegetable production in the north. This type of system trades off the disadvantages of higher capital investment and electrical consumption against the advantages of environmental control and lower heating costs. This type of facility would also address concerns about potential vandalism on glass or plastic covered greenhouses.

Plant Factory

An insulated industrial building, used as a controlled environment agriculture system would enjoy all the advantages of a modern gutter-connected greenhouse. The key additional advantage of this option is the maximum reliability it offers for controlled environment agriculture. First, the structure will certainly be stronger than any greenhouse, able to withstand any snow or wind load, anywhere in northern Canada. Because of the exclusive use of artificial lighting, crop production can be expected to be stable throughout the year, as it will not be affected by seasonal variation in climatic conditions. The opportunity offered for a well insulated cover promises minimal heating energy needs but extremely high electrical costs for lighting. In fact, excess heat generations by the light fixtures will require the design and installation of an effective cooling system compatible with the crop requirement for stable environmental conditions.

Some examples do exist of operating facilities in northern environments such as Finland – although this only occurs where there is a large population of around 100,000 persons which is necessary to support such capital investments. Other "plant factory" type models are becoming more common but they are not yet a proven technology in terms of commercially viable production in the Canadian north. There are other hybrid designs being developed which include a combination of insulation buildings and solar windows but the commercial viability has not yet been proven.

The potential combination of insulated buildings with LED lights does hold promise in the potentially near future as this could reduce energy costs which are a key constraint to the development of northern greenhouses. More research needs to be conducted into identifying commercially viable prototypes for northern Canada as the technology is advancing and could be a solution to northern food production needs in the near future.

Table 15: Comparison of Different Greenhouse Technologies

Technology	Pros	Cons
High-tunnel style greenhouse	• Low-cost • Low energy requirement • Simple technology, low-cost for tooling and training. • Low-cost products • Wide variety of products • Opportunity for greater community involvement • Can be movable, to minimize soil-borne diseases	• Short growing season • No products available when most needed • Very low yields/revenue • Low quality products • Dependency on soil • Low profile • Low strength, to support the weight of tall crops • Must be re-glazed every year to prevent collapse due to snow
Stand-alone greenhouse	• Good starting place for commercial greenhouse production • Can be either low, medium or high-tech depending on needs and skills of grower • Pros depend on the technology employed as it will range from high-tunnel to gutter-connected	• More expensive than high-tunnel • Can do anything but wont be the most efficient necessarily • Less energy efficient than gutter-connected. • Cons depend on the technology employed
Gutter-connected greenhouse	• Maximum capabilities, proven Canadian technologies. • Efficient use of greenhouse space, small or large • Year-round production, with supplemental lighting. • High yields of high quality products; very high revenue. • High-tech; sophisticated (computer controlled) greenhouse environment and crop nutrition control; the same for energy use, CO_2 enrichment and supplementary light application. • Job creation, with high paying positions; community pride.	• High capital and operating cost • High-tech • High energy input • Requires highly trained grower/manager • Requires trained labour • May require larger market to be sustainable • Must be protected against vandalism. • High risk business venture.
Chinese-style solar greenhouse	• Permanent structure • Strong building to withstand snow and wind loads • Can be heated • Can be low-tech or medium tech • Retractable energy curtain saves energy	• Extremely high capital costs at the present time • New to Canada, structure and technology must be initially imported • Potential issues with local building codes • Inefficient land use, when large acreage is needed and greenhouses must be spaced far apart from each other to prevent shading; Logistics. • Uneven crop growth due to the uneven climatic conditions in the greenhouse. • Problematic functionality of the retractable energy curtain in very cold climates
Insulated plant factory	• All items listed for gutter-connected greenhouses • Strong and durable building • No dependence on natural light • Easier to manage than a gutter-connected greenhouse. • Easier to focus its maximum productivity during the winter months. • No need for energy curtain or shade curtain. • Low need for cooling • Low heating costs	• All items listed for gutter-connected greenhouses. • Larger capital investment than for gutter-connected greenhouses because of the need for a much more powerful lighting system. • Very high electric power demand • The technology is not widely used and therefore this is an even higher risk business than a greenhouse.

Greenhouse Glazing

The most common greenhouse glazing materials are glass, various kinds of plastic film (mostly polyethylene), and various kinds of rigid panels (mostly acrylic and polycarbonate). Each one has its advantages and disadvantages. Simple high-tunnel style greenhouses will use poly covering but other types of greenhouses have a variety of options.

Low-cost high-tunnel greenhouses with a single plastic film cover, by far, are the most widely used greenhouse around the globe. These are used for only a few months in each year and for this reason alone cannot support high yields.

In Canada, the double-inflated poly greenhouse was the greenhouse of choice for nearly two decades and laid the foundation for the impressive growth of the greenhouse vegetable industry, especially in Ontario. The reasons for the popularity of the double-poly greenhouse was its lower cost of construction; its resistance to hailstorms; the energy savings realized with the higher insulation value due to the air trapped in between the two layers of plastic; and, the lower air temperatures achieved in the greenhouse during the hot summer months due to lower light transmittance of mostly diffuse light.

Double-poly can be installed on stand-alone greenhouses by a small team but no special training is required. Specialized installation assistance is required however when installing double-poly on gutter-connected facilities which may be an important consideration in remote communities.

Glass is probably the best recognizable and oldest greenhouse glazing material, associated with long life and high cost. However, modern glasshouses, usually of Dutch design and origin, are very competitively priced and are becoming increasingly popular with growers in Canada. Some of the key advantages of glass are its high transparency to photo-synthetically active radiation (PAR) coupled with high retention of infra-red (heat) radiation, its strength, long life, and attractive appearance. There have also been a number of key improvements to glass technology in recent years.

The concern about accidental breakage, or from hailstorms, as well as from vandalism has been alleviated to large extent with the introduction and wide use of high-impact tempered glass. Since glass is commonly used as a single cover, it had the serious disadvantage over many of the plastic films and rigid panels that are routinely used as double-covers that resulted in significantly higher energy costs. However, even these problems have been resolved with the use of a shade and an energy curtain, or both. Finally, the concern that glass allowed for more direct radiation entry into the greenhouse, especially in the hot summer months, with negative effects on crops, is being addressed with the introduction of diffuse glass.

Rigid panels made of acrylic or polycarbonate are not used widely because of their high cost of acrylic and the tendency of poly-carbonate to change color over time. However, because these panels provide added insulation (being double-walled) and because of their high strength and resistance to breakage, they might hold promise for their use in the north, especially where there is a high concern about vandalism and hailstorms.

In reality, the glasshouse and double-poly houses will likely be the top two contenders for Canada for stand-alone and gutter-connected greenhouses in the north. The modern glass house does provide advantages for the north as it is likely to trap less snow on its roof than the double-poly house which is an added safety measure against greenhouse collapse in the case of an unhappy coincidence of heavy snowfall and heating system failure.

Table 16: Comparison of Glazing Technologies

Technology	Pros	Cons
Glass	• High transmittance of PAR (short wave radiation) • Long life • High impact (when tempered) • Low transparency to long wave radiation (heat).	• High cost • Low R value, single layer • Needs to be cleaned • Might break if stressed in the right direction (wind, large hail) • High-levels of direct light • Very hot in the summer.
Double inflated poly	• High R value, two layers with trapped air in between. • Low-cost • Diffuses light • Can be custom designed • Can be updated according to plastics technology development • Cooler greenhouse in the summer than glass. • Easy to use on simple high-tunnel greenhouses	• Needs to be changed every three to five years. • Can be ripped easily by vandals • High transparency to long wave radiation • Low transparency to PAR (short wave radiation), double layer • Transparency to PAR (short wave radiation) declines over time. • Need specialized assistance to put on gutter-connected greenhouses
Polycarbonate panel	• Strong rigid panels • High R value, twin wall • Reasonable price, compared to glass • Diffuses light • Cooler greenhouse in the summer than glass • Can easily be cut to measure.	• Expensive • Low transparency to short wave radiation, twin wall • Might turn light yellow over time. • If not properly installed and maintained, might develop molds inside its channels.
Acrylic panel	• Strong rigid panels • High R value, twin wall • High transparency to short wave radiation despite being twin-walled • Does not turn color over time.	• Very expensive • Not easy to cut, brittle • If not properly installed and maintained, might develop molds inside its channels.

Carbon Dioxide

Photosynthesis depends upon two essential chemicals – CO_2 and water. As one of the feeder chemicals in the primary photosynthesis reaction, the CO_2 concentration affects the speed of the reaction. As expected the effects of ambient carbon concentration on photosynthetic productivity have been extensively studied and it is generally held that for most plants the response is linear with concentrations up to at least 1,000 ppm (the ambient CO_2 atmospheric concentration is in the area of 330 – 350 ppm, depending on air pollution level). In practical terms, the greenhouse atmosphere of commercial greenhouses is enriched with CO_2 to a target level of 1,000 ppm when the greenhouse is closed and to a level of 400 ppm when the greenhouse is ventilated. These recommendations have been developed as a financial threshold rather than as an optimum for plant productivity; when the supply of CO_2 is free much higher concentrations can be implemented provided the health and safety conditions of the greenhouse workers are not at risk. Usually, an upper limit of 5,000 ppm is observed.

A greenhouse in the north is likely to remain closed for a much longer period than a greenhouse in the southern Canada, and in that regards offer an opportunity for proportionally greater yield increase with CO_2 enrichment (estimated at 30% for temperate climates).

A difficulty might arise with biofuel as the source of heating energy because the required technology for the treatment of the flue gases from biofuel furnaces before they can be used for direct CO_2enrichment of commercial greenhouses is still under development. Liquid CO_2, which is expensive, or CO_2 as a by-product in local industries, if available, may be options. Ideally, a commercial greenhouse in the north heated with biofuel would also employee a small gas, propane or oil powered boiler to provide CO_2 to the crops and to assist in snow melting when heavy snowstorms threaten the structural integrity of the greenhouse.

Assimilation Light

In the process of photosynthesis, CO_2 and water are assimilated into simple carbohydrates with light energy in the presence of chlorophyll – there can thus be no plant productivity without light. In fact, when dealing with sun-plants (as are the common greenhouse crops, i.e., tomatoes, cucumbers and peppers) the photosynthesis rate of a single leaf is not light saturated even at record light levels observed on the surface of the earth. A greenhouse crop can use all the natural light we can provide to it; the only condition is that we can effectively control the temperature in the greenhouse within acceptable limits for a particular crop. Natural light however becomes a plant growth limiting factor in the winter as the day-length gets shorter and shorter. The problem becomes more acute as we more north, culminating in continuous darkness in the arctic north during the winter months.

The application of artificial lighting in commercial greenhouses to advance plant growth and productivity was first introduced in Canada and the Scandinavian countries; first on ornamental crops and later on vegetables. The most common method of application is as a supplement to natural radiation, which is known as supplemental lighting. Supplemental lighting can be applied any time of the year to promote more production of higher quality vegetables but the primary reason is to facilitate production during the winter months when low light availability is a limiting factor to production.

This practice is now slowly becoming common in Northern Europe and North America with the objective of achieving year-round production. Because of the anticipated significant economic returns from the application of supplemental lighting on greenhouse vegetable crops, the study of the effects of artificial lighting on crop productivity and the search for new more efficient light sources are top research priorities of greenhouse crop specialist worldwide.

Great hope is placed that the various types of LED and plasma lights will replace the high intensity discharge (HID) lights (HPS and metal halide (MH)) which currently dominate the market. At present though, the HPS light is the standard for providing assimilation light to greenhouse crops, with the use of LED lights in the canopy as a minor secondary light source. HPS lights represent a major electrical load and cost for operations as each light can be 1,000W.

LEDs are gaining popularity due to their high electrical efficiency and long life. One of the reasons for their high efficiency is that each LED only produces a very narrow frequency band of light. This can be a problem in terms of plant response because certain physiological processes are dependent on a specific wavelength of light. If the LEDs do not contain that specific wavelength, the plant will not behave as anticipated. Short of trying all of the combinations and permutations of specific frequency requirements for each crop, the solution is to provide all of the possible wavelengths in order to not miss any. This then cuts into the efficiency and due to the still relatively high capital cost of LEDs, may not be economically viable.

The LED industry is starting to find better lighting solutions, but may be a few years away from truly replacing HPS or MH lighting systems in commercial applications. There is a tremendous opportunity for LEDs and they are being used in many research and commercial operations, but they are at present not a proven commercial solution. It may not be long however until they are and potential growers should investigate opportunities for LED lighting within their greenhouse operations.

The most promising use of LED lights is at present in “plant factory” type operations where low profile vegetables (i.e., lettuce and spinach) are grown in multilevel hydroponic systems in a totally enclosed well insulated container of industrial building.

Table 17: Comparison of Lighting Technologies

Technology	Pros	Cons
HPS lighting	• Proven technology • Efficient in converting electrical power to PAR light (so far) • Reasonable cost	• Gives off a lot of heat • Large units, not allowing for uniform light distribution when lights are placed close to plants • Heavy units, making the installation problematic • Large units, causing significant shading of plants when the sun is out.
LED lighting	• Efficient conversion of electrical power to specific wavelengths (could become customer designed) • Available in different colours • Small, miniature units, allows for placement close to plant, even inside the leaf canopies • Gives off less heat • Promising more advantages in the future	• Still in the research and development stage • Expensive • Small output

Insulated Covers

Gutter-connected greenhouses typically use energy curtains which are extendable covers inside the greenhouse which provide an extra layer of air above the crop to help insulate it. These can also be used to reduce the cooling load on the greenhouse in the summer by simply shading a portion of the greenhouse. The issue that an interior cover presents is that it will trap cold air above it, and when it is retracted in the morning, the cold air can fall on the crop and cause stress. A “defrost” cycle may need to be employed which would involve heating, air circulation, and a slow retraction of the cover.

Chinese solar greenhouses usually have an insulating cover which is rolled up at dawn and down after dusk. This allows for better heat retention during the night or when it is too cloudy to gain any thermal energy. The challenge in Canada of using a removable exterior insulated cover is that in the event of a severe snowstorm or freezing rain, the cover can become stuck or frozen in an undesirable position.

A combination of exterior and interior insulated covers will decrease the heating load during the night. An automated system may be complicated and costly, but the energy savings as well as a smaller heating system may prove appropriate.

3.2 Agronomics

Crop selection and crop scheduling

The most popular greenhouse vegetable crops are tomato, cucumber and peppers because they provide the highest revenue per square metre. Although there are some minor differences in the cost of production of different crops, the main opportunity a greenhouse enterprise has to maximize their revenue is to select crops that promise high yields and high market prices. This is exactly what the tomato, cucumber and pepper crops have delivered for many years both in Canada and around the world.

The key reason why these crops produce far more tonnage of product than other vegetable crops is that within these species, there are cultivars of indeterminate type of growth; this means that these plants keep on producing throughout seasons and years behaving like perennial plants. In addition, because of the endless growth habit of the main stem, it is possible (with proper pruning, and vertical training of the plants) to create a deep leaf canopy so that such a crop to resemble a tree forest. The benefits of such a uniform deep leaf canopy are maximum interception of available light, in the most efficient way possible, which is a precondition for maximizing yield. Lettuce is another profitable crop on a yield per square foot basis, as are herbs, but there may be limited markets for large-scale herb production in northern greenhouses.

Recommendations on the most appropriate varieties or cultivars to grow in greenhouses change according to the rate of development and testing on new cultivars. It is advisable to consult the Provincial Greenhouse Crop Advisor before starting a new greenhouse crop. At the time of writing the following greenhouse vegetable cultivars were recommended:

- Greenhouse Tomatoes:

    - cv. Big Dina (large fruited)
    - cv. Komeet (cluster type)
    - cv. Flavorino (Cherry type)
- Greenhouse Cucumbers:
    - cv. Camaro (full size)
    - cv. Picowel (mini)
- Greenhouse Peppers:
    - cv. Healey (red)
    - cv. Baselga (Yellow)
    - cv. Orangelo (Orange)
- Greenhouse Lettuce:
    - cv. Ideal Cos (Romaine)
    - cv. Simpson Elite (Leaf type)

It should be noted that root crops are not normally grown in greenhouses as these crops can be grown outdoors in market gardens in the north and stored over the winter months. Commercial production of potato and other root crops already exists in the NWT and the Yukon, as well as other locations in the Canadian north. These crops are storable, easily transportable and provide a low value of a per square foot basis.

During the community discussions undertaken there was a lot of interest in root crop production (potatoes, onions, carrots). However, these crops should be grown in market gardens and it is important for communities to see the full spectrum of agricultural opportunities that ranges from market gardening, which is low-cost and lower risk, to higher cost and higher risk greenhouses.

More detailed information on the performance of various vegetable cultivars under Northern Canada conditions can be found in a series of cultivar evaluation reports published by the University of Saskatchewan at: http://www.usask.ca/agriculture/plantsci/vegetable/publication/VCCT2011.htm. Similarly, useful information, is published by the University of Alaska-Fairbanks at: http://www.uaf.edu/files/snras/VT_2010_02.pdf

The scheduling of the crops will depend on the type of the greenhouse (or controlled environment) chosen and the market dynamics. It can be assumed that the market prices will be stronger in late fall, the winter, and early spring seasons. Therefore, when conditions allow (i.e., when within modern gutter-connected or insulated plant factory facilities) crops will be started in late summer time so that products can be available for harvest during the long winter season. However, when only simple greenhouse structures are available, crops will be started in the spring so that planting can take place once the ambient temperature has advanced to higher levels than the crop chilling threshold.

Soil versus Soilless Cultivation

When simple (low-cost, low-tech) greenhouses are used, as is the case in the great majority of greenhouses around the world, production is in soil. The main reasons are that the anticipated revenue is low, due to the short season of cropping and low inputs, and therefore this is the only option the grower has. The development of soil borne diseases is minimized through crop rotations or in some cases by moving the greenhouse to a new location every year.

Soil was also the growing medium in conventional heated greenhouses until about 20 years ago when methyl bromide and steam were still available for soil sterilization (pasteurization). After the signing of the Montreal Protocol about the phasing out of the ozone depleting substances, methyl bromide gradually disappeared from the market and research advances on soilless methods of crop production allowed the quick adoption of soilless methods of production by greenhouse growers in developed countries.

The key reason for the adoption of the soilless methods of production in modern high-tech greenhouses is the relative assurance offered by the soilless methods for continuous monoculture with greatly reduced root disease risk. The elimination of risk factors in modern greenhouse vegetable production is essential to the sustainability of the industry because of the high capital investment and high running costs. Production in low-cost greenhouses in less developed countries continues to rely on soil because of the added cost of a soilless method and the inadequate technology transfer services in those countries.

For the reasons explained, the adoption of soilless methods of production is nearly universal by the commercial greenhouse industries of Canada, United States, Northern Europe and other developed countries. Similarly, for higher-tech greenhouses contemplated for Canada's north, the use of soilless methods of production must be seen as the obvious choice.

On the other hand, for simple (low-cost, low-tech) greenhouses soil should be the first choice because of the low anticipated revenue. However, it is probably quite possible that a soilless method of production will be adopted, perhaps due to lack of soil in some locations, with the understanding that the production cost will be higher.

The most appropriate soilless methods for greenhouse tomato, cucumber and pepper production in the Canadian North will be the ones using rockwool or coco peat slabs as the growing medium. The reason is that these media have a proven record of success around the world and are best supported by a network of crop advisors.

For lettuce and other low profile vegetables, if they happen to be under consideration, the most appropriate soilless method of production would be the "floating raft" method – i.e., plants growing on Styrofoam boards, floating on a shallow pond on nutrient solution. This system is used extensively in the greenhouse industry.

Table 18: Comparison of Different Growing Mediums

Technology	Pros	Cons
Soil	• Natural • Free medium • Releases free nutrients	• Might not be available • Quality is variable and unpredictable • Releases or absorbs nutrients in an uncontrollable way • Might be contaminated • Needs to be sterilized to avoid root diseases • It is too heavy to move
Rockwool	• Widely used in many countries • Inert; does not release or absorb nutrients, allowing the grower to have absolute control over the nutrition of the crop • Light in weight • Sterile on delivery • Good system of technology support by the supplier	• Man-made • Expensive • Difficult to recycle • Requires knowledge of plant nutrition • Requires an elaborate system for the preparation and delivery of complete nutrient solution to the plants • Crop failure can result if water or nutrients are not delivered in time and in the right amounts
Coco peat	• Widely used in several countries • Not completely inert, releasing some nutrients, but allows reasonable control over the nutrition of the crop • Light in weight • Easy to recycle • Natural product	• Expensive • Requires knowledge of plant nutrition • Requires an elaborate system for the preparation and delivery of complete nutrient solution to the plants • Crop failure can result if water or nutrients are not delivered in time and in the right amounts

Fertigation and Recirculation

Crops grown in soil are usually irrigated by low-tech irrigation systems and fed by dry organic and inorganic fertilizers which are incorporated in the soil before planting, or as side-dressings during the cropping season. Because the method has been used for many decades, many countries have published guidelines and recommendations for optimal fertilizer application throughout the cropping season.

The irrigation and fertilizations of crops grown without soil is a more exact science, usually referred to as fertigation. Ideally, in a soilless method of production, the growing medium is totally inert (i.e., it does not release or absorb any nutrients) so that the grower has absolute nutritional control of the crop. This being the case, the grower must know exactly what are the needs of the crop for water and nutrients at any time throughout the cropping season and must be able to deliver efficiently and effectively the right amount of nutrient solution of the right nutrient composition.

This is a routine process in modern commercial greenhouses in Canada and other countries as crops' requirements for water and nutrients throughout their lifespan have been extensively studied. The usual method of applying the nutrient solution to the plants (sometimes 15 – 20 times per day) is through a drip irrigation system. This system delivers the exact same volume of nutrient solution to each plant. Elimination of nutrient solution leaks and waste means less waste of fertilizer but also less heating energy to evaporate water resting on the floor of the greenhouse.

Fertilizer incorporation into the irrigation water is usually done in two stages. First, concentrated solutions of each fertilizer are prepared and then, a fertilizer mixer is used to incorporate the right amount of each stock solution into the irrigation water before it is delivered to the plants. In the most advanced technology, a pre-programmed computer controlled multi-fertilizer injector (i.e., the Harrow Fertigation Manager) is used to automatically apply water and nutrients throughout the entire cropping season of a number of crops.

It must be noted that the present knowledge and technology for water and nutrient delivery to plants grown on soilless media such as rockwool and coco peat is not perfect. Because of this, and to prevent nutrient depletion, nutrient unbalance, or water stress on plants, it is a common practice to apply 30 – 40 % more nutrient solution than is theoretically considered the required amount. As a result some nutrient solution run-off ends up as a pollutant to the environment. The greenhouse industry was originally given warnings by governments to stop this practice and now it is the law in many countries that any excess nutrient solution must be collected and, following the appropriate adjustments, re-used.

This problem was resolved with the introduction of the raised gutter. The raised gutter is a raised platform (usually coated metal, about 30 cm wide and made to the length of the plant row) configured to give it the strength to support plants and to allow for the channelling of the run-off solution to a return pipe for eventual transfer to a large collection tank. The raised gutter not only facilitates the collection of the run-off solution but also allows for raising the plants to a convenient height for planting, pruning, and harvesting. Furthermore, the raised gutter ensures uniform plant growth, better air circulation around the lower part of the plants (therefore, less disease incidence) and easier inspection of the growing media and irrigation system. The raised gutter is now considered an essential tool in any commercial greenhouse in Canada and that should be the case for any higher-tech greenhouse in the Canadian North as well.

Soil versus Soilless - Raised Troughs

Plant Protection
In protected cultivation, pests and diseases find more favourable conditions for their development than in open field cultivation. The mortality of the insects due to abiotic factors (rain, wind, cold temperatures, etc.) is enormously decreased and the climate conditions (high humidity, higher temperatures) favour the development of diseases.

Until recently, the control of pests and diseases had been based in the use of chemicals. Biological control, which is now widely used, is based in the use of natural enemies of the pests and pathogens, to maintain their populations below the “economical damage threshold.”

The development of resistances to pesticides and the general worry for the conservation of the environment and food safety have been the main causes which have displaced chemical control in favour of integrated pest management. Integrated pest management constitutes a different way of understanding pest and disease control. It discards the extermination of populations and instead tolerates the presence of pests and diseases under the “economic damage threshold” and gives preference to other types of control (biological, cultural, genetic) in relation to chemical control, which is only used as a last resort. This allows for a notable decrease in the phytosanitary treatments.

The climatic factors directly influence the development of pests and diseases of the crops. Therefore, a proper greenhouse climate control system can help to decrease their development. The soil and aerial organ’s fungi, together with the virus diseases, are the main greenhouse crops diseases. Bacteria and nematodes are less of a threat. The main greenhouse crop pests are the aleourodids (white flies), noctuids, thrips, leaf miners, mites and aphids. Biological control is widely used for pest control, especially against white fly, noctuids, leaf miners, aphids and spider mites. Prevention is essential in greenhouse phytosanitary control.

Post-Harvest and Storage
The perishable nature of vegetables is a critical factor in the marketing process. Post-harvest management is critical to maximize the duration of product quality. The harvest must be done at the proper time, keeping in mind that the consumption ripening point does not have to coincide with the physiological ripening. Once exceeding a certain ripening point, vegetable quality deteriorates very quickly. In order to extend their post-harvest life some products are harvested before complete ripening, as is the case with green tomatoes.

After being harvested, fresh greenhouse vegetables maintain a metabolic activity which is essential to preserving their quality. The changes during the ripening process of the fruits are very complex and contribute to maintain and even enhance the initial quality of the product. The colour, a result of modifications in the content of chlorophylls, carotenoids and anthocyanins, the firmness, derived from alterations in the cell walls, the taste, consequence of the metabolism of the carbohydrates, and the characteristic aromas, caused by the release of volatile compounds, are determining characteristics of the quality of the greenhouse vegetables. In the initiation of these ripening processes several plant hormones are involved, mainly ethylene, apart from being regulated by specific ripening genes.

The intensity of the physiological processes associated with the ripening process is affected by external factors, mainly temperature, humidity and composition of the atmosphere. The technology used to extend the storage period of plant products is the application of low temperatures, which limits the respiration, the main post-harvest physiological process.

Pre-cooling is the quick cooling operation of just harvested products, to decrease their ripening process and to limit their deterioration before the storage or before sending them to the market. The cold storage of perishable products aims to decrease their respiration to retard the microbial activity and decrease the water losses, by means of temperature, oxygen and CO_2 level regulation. The storage temperature must be constant, which must be surveyed permanently because respiration (although reduced) generates heat that must be removed. An excessively low temperature may interfere with the ripening process. In tomatoes, for instance, maintaining temperatures above 13°C, and even up to 16–18°C is advisable to induce the ripening of the tomatoes harvested green. The use of plastic films has contributed to the development of the controlled or modified atmosphere packaging. These films, which provide selective permeability to oxygen and CO_2, maintain the desired gas composition, within certain limits, and extend the shelf-life of fresh cut products in combination with low temperatures.

Other preserving techniques, at low or high pressure, or those based in the use of microwaves or radiant energy, for instance, are not widespread, and some are in the development stage.

Woody and Herbaceous Plants

In addition to vegetable production, greenhouse enterprises might find it profitable to engage in bedding and woody plant production, for local landscaping needs. These crops will require modifications to the physical lay-out of the greenhouse interior (i.e., rolling beds, hanging baskets, irrigation booms, etc.) but also of the greenhouse environmental conditions and plant nutrition strategies.

The most critical difference in the operational requirements of woody and herbaceous plants for landscaping, in comparison to warm season vegetables, is their lower requirement for greenhouse heating. Depending on the species, this difference in air temperature optima could exceed 15^{0}C which should result in significant energy savings.

In the case only bedding and woody plants were grown, more savings would be realized in fertigation equipment because these crops do not require a sophisticated plant nutrition management program (i.e., varied according to season and stage of growth) like the greenhouse vegetable crops do. Bedding plants are usually grown in plastic flats of pots filled with readily available peat based growing media. Similarly, woody plants are raised in large pots filled with either peat-based media, or soil if available in acceptable volume and quality. Finally, significant savings can be expected due to greatly reduced labour needed to manage the bedding and woody plant crops. An economic analysis will show if the anticipated savings in energy costs, growing media, labour, and fertigation, with bedding and woody plants will compensate for the revenue loss from a more lucrative vegetable crop.

Another option for greenhouse growers has been the raising of fruit crops. Crops such as grapes and oranges were the favourite of European royalty in the past and it was their type of interest that gave rise to the first primitive greenhouses. Today, fruit crops (i.e., peaches, cherries) are rare and limited to indoor botanical gardens for demonstration purposes.

One fruit crop grown commercially in greenhouses (i.e., in Japan, France, Belgium. Iran, United Kingdon) is strawberries. Strawberries have been tried in southern Canada as a commercial crop but failed because of poor economics. The best yields obtained in other countries were about 10 kg/m^2, while greenhouse tomato yields in Canada are averaging 50 – 60 kg/m^2. Therefore, strawberries will have to sell at about five times the price of tomatoes to be a competitive greenhouse crop in Canada.

3.3 Biomass and Other Energy Technologies

Energy is generally the second largest, but most variable, operating cost (after labour) in most greenhouses in Canada. The variability in energy costs is due to variations in both energy sources and pricing. Given both the high heating needs and electrical needs in supplying lighting during the cold and dark winter months in the study area, energy costs have been a traditional barrier to greenhouse development in the north.

Natural gas is the main heating source used in the greenhouse industry in Canada. Natural gas has been widely available, its cost has been relatively low most of the time, it burns cleans, the engineering of the natural gas boiler is simple and a natural gas heating system requires minimal maintenance. An important additional advantage is that the flue gases from a natural gas boiler with little extra treatment can be used for CO_2 enrichment of the greenhouse atmosphere.

Given the lack of availability of natural gas in the study area, combined with the high cost of fossil fuels alternatives (oil and propane) which would render a greenhouse completely uneconomic in the north, the following section reviews different technologies for biomass utilization (forest biomass generally speaking but other alternatives exist) as well as other energy/power technologies that can potentially substitute for oil and propane.

3.3.1 Feed Stock

In assessing the opportunities for utilizing biomass to provide energy to greenhouse operations, it is important to analyze the suitability of the different types of biomass sources. The main sources of biomass include wood pellets, mill residues (hog fuel including barks and damaged pieces of wood, chips, sawdust, shavings), roadside residue and standing trees (Ministry of Forests, Lands and Natural Resource Operations, 2011). The Biomass Feedstock Composition and Property Database as well as the resources of CanMet are valuable in determining the composition of a biomass source such as energy, ash, moisture, etc. (United States Department of Energy, 2012; Natural Resources Canada, 2012).

Wood Pellets

Wood pellets, which are made up of compressed sawdust, are “between 6 mm (¼ inch) and 8mm (5/16 inch) diameter and less than 38mm (1 ½ inch) in length” (Arctic Energy Alliance , 2009). Wood pellets can be produced from any wood species however softwood species pelletize more efficiently (Karwandy, 2007). Wood pellets are clean burning and easy to handle and transport and there is a long history of utilizing wood pellets as a renewable energy source in district heating and greenhouse operations. Wood pellets are an excellent source of energy and Canada is the world leader in the production of wood pellets, the majority which come from BC and are exported. The following table provides a comparison of wood pellets as a source of heating against other energy sources:

Energy content of Heating Fuels

Wood Pellets	19,700 MJ per tonne
Heating Oil	38.4 MJ per litre
Propane	26.6 MJ per litre
Cordwood	19,800 MJ per cord
Natural Gas	1,000 MJ per GJ
Natural Gas	1,062 MJ per Mcf

For comparison, 1 tonne (1000kg) of wood pellets contains the energy equivalent of:

513	litres of Heating Oil
741	litres of Propane
0.99	cords of Wood
19.7	GJ of Natural Gas
18.5	Mcf of Natural Gas

(Arctic Energy Alliance, 2009)

Pellets from white wood residues such as sawdust, planer shavings and chips are desired in that they have very low ash content. Pellets can also be produced from bark and slash material and whereas they have a higher heating value and greater durability they have a higher ash content of up to 3%. Pellet standards are available for North America which grade wood pellets in categories such as diameter, length, density, ash content, fines and chlorides (Karwandy, 2007; Prairie Practitioners Group, 2008).

Wood pellets are an ideal feedstock due to the consistency of the product and a wood boiler industry which has tailored designs to specifically handle wood pellets. While biomass in the form of wood pellets may be a preferred option for a northern greenhouse this will depend on such factors as pellet availability, distance from a source of pellets, price of pellets, and assurance of supply and transportation costs. The economical production of pellets depends on a ready supply of feedstock for the pelleting facility and the proximity of that feedstock. Pellet mills are normally located immediately adjacent to a forest product mill or in close proximity (Karwandy, 2007; Prairie Practitioners Group, 2008).

As an example of costing and the impact of transportation on prices, wood pellets are available as of March 2012 from NorSask Forest Products in Meadow Lake, Saskatchewan at $170/T which equates to approximately $9.40 per Gj. However when transport costs are factored in at a cost of $375 – $500/T per 100km, this increases costs by $3.75 – $5.00 per Gj for every 100 km of transport required. As a result, although wood pellets are an energy dense and useful product, their utilization will be limited by the proximity of the greenhouse to a mill. There are presently 16 wood pellet producers in Canada, including those within the biomass region identified within this study. The Wood Pellet Association of Canada has a list of members who produce wood pellets along with their contact information.

The NWT Studies on the utilization of wood pellets in district heating systems use a pre-feasibility cost analysis of communities in order to determine communities that should be considered for the utilization of pellets. This analysis takes into account such factors as all weather roads, distance from pellet source, storage, packaging and other factors (Arctic Energy Alliance, 2009).

Mill Residue

Another potential source of biomass is mill residue in the form of bark, chips, damaged wood pieces, shavings or sawdust. Sowlati et al. (2008) studied the utilization of mill residue in greenhouses and concluded that biomass from mill residue is a potential option as “the attractiveness of using wood biomass will increase if the price of fossil fuels increases more than 3% per year or carbon taxes and regulations are applied.”

The utilization of biomass from mill residue and other forms is very advanced in Europe. An example is the Nahwarme District Heating Plant system in Austria. In this network of 38 district heating plants linked by computer, the individual community heating plants utilize forest residue chips provided by local industry and residents. Chips and other wood residue are delivered to the plant, separated and then combusted in a boiler to provide hot water for community residential heating (Digby, 2008; Prairie Practitioners Group, 2008). In Canada excess mill residues have been declining due to increased use of these residues to replace fossil fuels in pulp mills and sawmills. As well, increasing demand by cogeneration companies places increased pressure on this resource (Bradley, 2006).

Roadside Residue

Another important potential source of biomass is what is referred to as roadside residue which is generally found at the logging roadside from a forestry operation. The inventory of roadside residue is a very large potential biomass energy source in provinces that have forest product mills in operation and although variable, generally comprises from 15 to 25% of the volume of the merchantable components (FPInnovations, 2011). The costs of recovering roadside residue (forest floor biomass) is high and there is a need to integrate the gathering of these residues in with the harvest operations. Countries such as Sweden and Finland have considerable experience with forest residue supply chains and have been quite successful in reducing costs (Bradley, 2007).

A number of factors must be considered in using roadside residue for an energy source. The following paragraph provides a good overview of these factors: “Collection and transportation of large amounts of forest biomass from harvest sites to energy plants entails additional cost. Depending on jurisdiction, harvesting methods and equipment may need to be revised to allow forest residues to be consolidated alongside roads during harvesting to minimize the cost of collection. Access to many logging roads is seasonal, and in some cases the terrain and road conditions may not be suitable for chip vans.” The study goes on to indicate the necessity of densification (grinding and size reduction) at the logging site

(FPInnovations, 2011). Preto (2007) highlights the low bulk densities of various biomass sources such as hardwood and softwood compared to coal and the need for densification.

The Vaxjo Energy AG CHP Plant in Sweden is an example where the forestry chips come from the final logging or thinning of an area of forest, with the treetops and branches collected into large piles which are covered in order to dry. Material is then chipped before being delivered to the plant (Digby, 2008; (Prairie Practitioners Group, 2008). This is a very large community heating example with large boilers that are capable of handling this type of feedstock. Increasingly in Europe, stumps are becoming an important part of the forest residue that is being harvested for energy (Backlund 2006; Digby, 2008).

Standing Trees
The utilization of standing trees as an energy source is increasingly being considered for northern greenhouses as many northern communities do not have access to sources of biomass feedstock such as wood pellets, mill residue and roadside residue, however they may have access to standing forest (NWT Environment and Natural Resources, 2010). While this is an option that may need to be considered for northern communities it is also a controversial practice. Many question not only the economics of this practice but also challenge it from the standpoint of climate change mitigation and length of time to pay back the carbon debt (Climate Change Foundation, 2010; Prairie Practitioners Group, 2008).

The feasibility of sustainably using standing trees will depend on the size of the greenhouse and if there is sufficient logging infrastructure available, although in most cases they will need to use pelletized wood or be located close to a forestry processing facility. In a large-scale logging operation, standing wood can be accessed for approximately \$43/m^3 roadside but this price will be at least double, if not higher, for small-scale operations due to economies of scale and equipment requirements (Sigurdson, 2013 personal communication). Stumpage and reforestation fees will be extra. Actual costs however will be highly site specific and must be investigated by individual greenhouse enterprises.

Sustainability will however be a key concern given an 80-200 year window for regrowth. As a practical example, the study team visited Kitchenuhmaykoosib Inninuwig, Ontariowhich built their first school with a biomass boiler and they have consequently cleared all of the trees in a 10km range from their community, which means that they have to travel increasingly long distances to collect wood for the boiler.

3.3.2 Wood Heaters

Round wood systems for small-scale greenhouses
For a small-scale or series of small-scale greenhouses, a wood heater system using round wood logs could potentially be utilized as a viable option. Although this could be workable for some small greenhouses, it is expected that automated options described in subsequent sections will be more reliable and effective given the need to regularly stoke the wood heaters.

Wood heaters are more efficient than traditional wood stoves, increasingly simple to operate and simple to maintain as no steam boiler ticket is required to operate them. Wood heaters do not actually boil the water to produce steam as wood boiler would; instead they keep the water temperature just below boiling. A recent advancement in wood heater technology is that they typically gasify wood which gives an opportunity for the unburned gases and particulates normally present in combustion to be burned at higher temperatures, resulting in higher overall efficiency and a reduction in emissions. Gasifying heaters achieve this by limiting and monitoring the amount oxygen present during combustion, resulting in the production of syngas, which is then burned in a secondary chamber. These boilers need electricity to operate a fan and a control system which monitors the airflow, water flow, and temperatures.

Wood heaters produce 100 – 130 kg of CO_2 per million BTU's produced. The new gasification heaters are quite efficient and produce less than 70mg/m^3 of particulate matter. Greenhouse heaters in BC average 30mg/m^3 but can be as low as 6mg/m^3 using a well managed system that involves investment in exhaust technology or scrubbers.

Wood heaters typically use water to transfer and store the heat generated in the heater. They can be fitted with a radiator and fan system which can then heat up air if a forced air system is preferred. For a greenhouse application, the usage of water in the heating system is appropriate due to water's ability to transfer and store heat very efficiently. The flexibility of a hydronic heating system also allows for the integration of other heat sources such as solar thermal, thermal storage, ground source heat pump (GSHP), and electric backup. One strategy being used by existing greenhouses is to store heat in a large insulated water tank which is used as a thermal battery. The exact size of the tank and level of insulation on the water tank will depend on the heating needs of the greenhouse, the heating output of the boiler, and the amount of time desired to heat the tank. If the boiler and hot water tank is relatively small this may mean spending an hour or two per day during colder times in the winter. For small systems a type of alarm can be fitted which alerts the operator to fire up the boiler. Smaller systems will have faster temperature swings due to the lack of overall mass and may require the operator to be able to predict firing times based on environmental conditions.

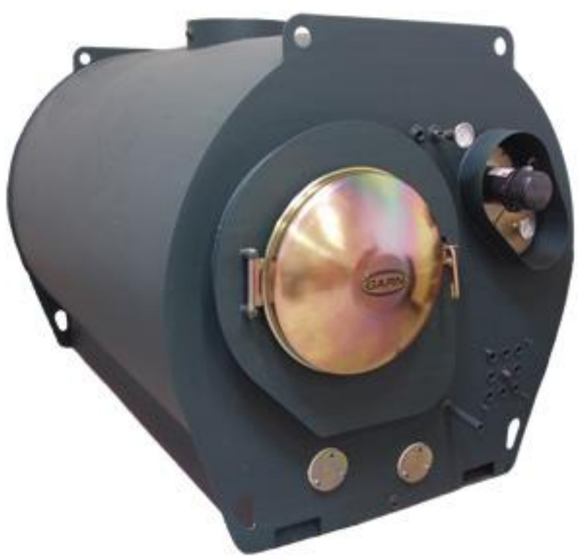
Wood heaters which burn dried wood logs as a feedstock will require an operator to put logs in the unit when there is a heating demand – which is a key issue. A single load of wood may burn for eight hours depending on the specific heater but the stored heat within a hot water storage tank may last up to three days depending on the heating needs and outside weather. During winter and colder months, a boiler could need to be fired twice per day depending on the required heat load and size of the storage tank.

The use of dried logs as feed stock is a key limitation for these types of wood heaters. There is an ongoing labour requirement, as it essentially requires someone to be available to fire up the heater when the temperature drops – which is a key risk and requires backup systems. For small systems a type of alarm can be fitted which alerts the operator to fire up the boiler. Smaller systems will have faster temperature swings due to the lack of overall mass and may require the operator to be able to predict firing times based on environmental conditions. A generator (diesel or propane) and a backup heating coil will be needed with an auto-start feature. Some models such as the Garn system detailed below already have an auto-start backup built in.

The danger with non-automated wood heaters is that operators will use the highly inefficient back-up systems too easily which will cause heating costs to greatly increase when the system switches over to diesel or propane backup. Given the likelihood that this could happen, greenhouse operations need to determine whether such a system is a realistic option of whether a more expensive automated system that utilizes wood chips or wood pellets would be make more sense.

Regular maintenance requirements will include approximately 30 minutes per week to clean out the ash pit and the heat tubes. Longer-term maintenance will be to inspect and replace any of the seals around the doors and compartments as well as the fire bricks inside the burn chambers. Other maintenance which will require general mechanical skill will be replacing moving parts such as the fan or the water pump. A general knowledge of plumbing will be required to operate and maintain a hydronic heating system.

One example of wood heaters are produced by Garn which offers an option for burning logs continuously or in batches. The Garn wood heaters hold a large amount of water which stays warm for an extended period. This can be coupled with an external insulated hot water tank to allow for a larger thermal battery. The Garn units also feature a series of electric heating elements which can be used for emergency or extended leaves. The heaters lifespan is estimated at a minimum of 30 years.



(<http://woodheating.ca/page8.htm>)

The Garn WHS2000 can produce 125kW (425,000 BTU/hr) and can store over 239kWh (1,000,000 BTU) while the Garn WHS1500 uses 120 lbs. of wood to produce 719,279 BTU's of heating load. This can be used to approximate the amount of wood needed for a greenhouse. In order to approximate the amount of wood needed to supply a heating system like this would require a model of the specific greenhouse which estimates the heating load based on local temperature, wind, and solar data.

A second example of wood heaters are those produced by Econoburn. The Econoburn has a 25-year warranty and can be positioned outdoors which reduces costs but also reduces efficiency in the winter. The same life cycle accounting costs as used for the Garn can be also assumed for the Econoburn.

Table 19: Sample Comparison of Different Wood Heater Model Utilizing Round Wood Logs

Manufacturer	Model	Input	Output	Regulations/ Standards	Cost	Comments	Installation
Garn	WHS 2000	Dried wood logs. 120V AC to run fan.	425,000 BTU/hr	UL and CSA standards. Below EPA Phase II limits.	$14,500 base cost plus shipping and system.	Electric heat backup, thermal storage.	Needs to be in a heated building.
Econo-burn	EBW 300	Dried wood logs. 120V AC to run 175W fan.	300,000 BTU/hr	UL and CSA standards. Below EPA Phase I limits.	$11,000 base cost plus shipping and system.	Non-proprietary parts.	Can be installed indoors or outdoors.

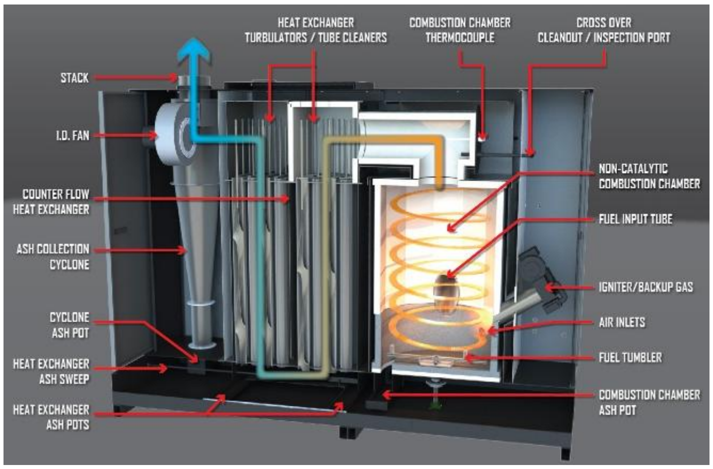
In addition to the capital cost of the wood heater, the following additional costs which will fluctuate from location to location need to be considered including: shipping ($2,000); installation including plumbing, electrical, pumps, pressure relief valve, mixing valve, temperature sensors, etc. ($5,000); monthly maintenance (1 hour), yearly maintenance (4 hours); yearly water sampling and adjusting water quality ($500); after 10 years, replace pump, fan, etc. ($2,000); disposal of unit after lifetime ($2,000). As well, the wood should be cut up to one year before burning to ensure it is dried properly. Logs can be split to make drying quicker and loading easier.

A hot water tank is also required as part of a wood heater system. The Garn already has a built in hot water storage system which avoids the need for another tank. As mentioned earlier, it is possible to put a heat exchanger or integrate a solar thermal or other heating source to the water storage tank. Econoburn recommends oversizing the heater slightly and using a 2,000 – 4,000 litre (500 – 1,000 gallon) insulated water tank in order to run the heater using a full burn in order to maximize efficiency. The hydronic heating system can then pull heat from the water tank instead of straight from the heater. American Tank Company offers a 500 gallon water tank for $4,518 + shipping. This tank has an epoxy liner on the inside to avoid corrosion. This insulated water tank can hold low pressures and has the ability to integrate many different heating systems and heat exchangers with eight-flanged fittings. The cost of water pump(s), fittings, valves, pressure release valve, expansion tank, float valve, piping, and any other plumbing parts can be approximated at $2,000.

Automated wood pellet and wood chip systems for small- to medium-sized greenhouses

Automated wood heaters are a very good option for small to medium sized greenhouses, and are probably a necessity for anything beyond small stand alone greenhouses, as they remove the need to constantly monitor and stoke wood heaters and can utilize a wide range of feed stock. Many wood heaters are designed to handle a range of materials including wood chips, wood pellets, sawdust, or food waste such as corn cobs or nut shells.

Automated systems are designed to use a feedstock of relatively uniform and small particle size which allows the heater to be automatically fed using an auger and/or hopper system. The BioBurner 500 unit shown below is an example of a wood heater which can handle a variety of fuels and is fully automated.



(http://www.leiprod.com/leiproducts/portfolio-view/bb-500/)

For smaller greenhouses, the added infrastructure allows the system to be computer controlled leaving only occasional input from the operator to fill up the feed stock storage bin and ensure the feed system is operating properly. The same weekly maintenance of emptying the ashes will apply to these systems as the non-automated options systems identified above. Maintenance will require general mechanical skills in dealing with bearings, augers, chains, etc. Greater operator training is however required due to increased system complexity. Automated wood heater systems will require regular maintenance of all the moving parts, including lubricating and replacing parts such as bearings, belts, and chains.

Table 20: Sample of Wood Heater System Utilizing Variety of Biomass Sources

Manufacturer	Model	Input	Output	Cost	Regulations/ Standards	Comments
LEI-Products	BB-500	Wood pellets, wood chips, sawdust, animal bedding, grains. 120V AC to run fan.	500,000 BTU/h	$35,900 Hopper $3,500 DIY Bin $500 Shipping $2,850	Below EPA Phase II and CSA B365 emissions ratings.	Needs propane or natural gas for start-up a few minutes of gas. Can be hydronic or forced air.

Many of the biomass heating systems use wood chips and the ability to produce wood chips on-site will be needed for communities not located near pellet manufactures or other sources of biomass residue. Beyond capital costs, the cost of producing wood chips will vary depending on the cost of accessing the supply of wood but it is generally less than the cost of pellets.

Depending on the method of loading the biomass into the boiler, a tractor with a front end loader can be utilized for smaller-scale systems. Tractors typically have a Power Take-Off (PTO) shaft to which various implements can be attached to use the tractor's power. If a tractor is an already necessary tool, a PTO driven wood chipper may be most appropriate. They are only able to handle branches, not large logs, and require an operator to manually load the branches into the machine. The wood chips can then be stockpiled or blown right into the storage bin. A PTO driven wood chipper costs approximately $2,000. The blades will need to be sharpened professionally about once per year depending on amount of usage ($2,000).

Larger gas-powered wood chippers have the added maintenance costs of oil and filter changes which go along with an internal combustion engine. A Duratech wood chipper which can handle up to 12 inch logs costs approximately $40,000 and about $1,500 for shipping. Uniquip sells Salsco wood chippers which can handle up to 18 inch diameter logs for $64,828 plus shipping.

Although the energy density varies, the burn quality is essentially the same when comparing wood logs, wood chips and wood pellets. The choice of one type over another is reached by determining the appropriate fuel handling system for the specific site. Wood logs need to be cut, split, dried, and then fed into the heater by a person. Wood chips need to be cut, chipped, and then stored in a hopper. The machine then feeds the chips into the heater. Wood pellets need to be bought and then stored in a hopper. The machine then feeds the pellets into the burn chamber. Each system has advantages and disadvantages in terms of cost, labour, and machinery/complexity.

Table 21: Comparison of Wood Heater Systems

	Round Wood	Wood Chip	Wood Pellet
Approximate cost for 0.5 acre system	$33,000 for two heater system	$41,500 for chipper $39,900 for boiler	$22,000
Amt of wood/ biomass per Gj	72kg	93kg	50kg
Carbon emissions per Gj	7kg	7kg	7kg
Pros	Simple to operate. Simple to maintain.	Automated, computer controlled. Less manual labour.	Less manual labour. Fuel is delivered to site.
Cons	Most manual labour required as need to stoke heater regularly which may not be practical. Backup systems are very important and potential to overuse expensive backup energy sources. Need to use dried wood. Need a dry storage space for one-year prior to burning.	More complicated machinery to maintain including wood chipper, hopper, and augers.	Price of pellets. Complicated machinery to maintain including hopper and auger system.

3.3.3 Wood Boiler Systems

Larger high-pressure wood boiler systems are also available for large-scale applications such as district heating systems and large multi-acre greenhouses. These boilers produce steam, which is then circulated through a heat exchanger to heat up water, which is then circulated throughout the greenhouse. Because of the higher operating pressures, an operator with a steam boiler certification ticket will need to always be on site to inspect and maintain the system. Due to the large-size and complexity of a high pressure system, it would be suitable to large greenhouse systems (greater than five acres). These high pressure boilers are costly to build and maintain due to their complexity.

Usage of boilers of this type is widespread and Canada Biomass Magazine has contact information for a number of manufacturers. Sample boilers, including small-scale options, are described below.

Manufacturer	Model	Input	Output	Cost	Regulations/ Standards	Comments
ZGH	100	Wood pellets. 230V AC.	340,000 BTU/h	$22,000	Will need to be approved by the local rural municipality and insurance carrier. This has been done in the past in Canada with no problems.	Wide range of boiler sizes.
	1,000		3,400,000 BTU/h	$92,700		

Blue Flame Stoker, which is manufactured in Winnipeg, produces automated wood heater systems custom built for each specific application, which are used by a number of greenhouses. These systems can burn green chips (at 50% moisture content) or seasoned chips (30% moisture content). They recommend 600 to 1,000 kW (60 to 100 boiler horsepower) per acre of greenhouse. A 10-acre system is recommended to have a boiler 5,000 to 6,000 kW (500 to 600 boiler horsepower) in size. A recommended strategy would be to have a large system which can easily handle the heating loads, and a smaller boiler which can be used during maintenance of the large boiler.

Drake Landing Solar Community in Alberta is using solar thermal heat and a ground source heat system to super heat a large mass of ground during the summer, and then recover the heat for heating their homes in the winter. This same strategy could be applied for other heating systems such as biomass boilers. Large biomass systems can range from $3,000 to $10,000 per kW. A 25MW system would be in the range of $75 to $250 million. For a reference, this could power a small community consisting of hundreds of homes and buildings.

3.3.4 Combined Heat and Power (CHP)

CHP systems are used to produce both heat and electricity. They do this by producing either heat or electricity as the main output, depending on the needs and system design, and the secondary element is then generated as by-product. Given this structure of CHP systems, the proportion of heat and electricity produced is relatively fixed and CHP systems focus on one or the other so it is not possible to generate an even split between heat and electricity generation.

There are a few small CHP systems but the sizes and ranges of system outputs are limited. For larger CHP systems the entry size is 100kW for the CPC Biomax 100 system. Other CHP systems (Organic Rankine Cycle (ORC) or sterling engine) will need to be evaluated in terms of the site specific quality and quantity of feedstock available as well as the specific heating and electrical needs of the building(s).

Electricity-focused CHP systems

Gasification technology is typically used in electricity focused CHP systems. In a gasification system the biomass is heated, but not combusted, under low oxygen conditions which produces a syngas. This syngas is then burned in a conventional engine which can be connected to a generator to produce electricity. A heat exchanger can then be used to harness the heat generated in this process to provide heating.

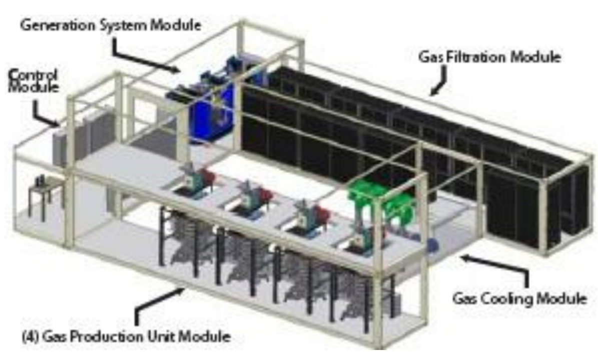
For smaller-scale greenhouses or other operations which do not have an electrical grid connection, APL manufactures a GEK 20kW gasifier shown below which gasifies wood chips. The unit fits on a pallet and is relatively simple to operate. It requires a start-up procedure and the operator will need to be somewhat knowledgeable about the operation of the unit to adjust the settings to achieve optimal operation. The unit costs $27,000 plus $1,000 for shipping, and will output 5-20 kW of electricity. Although the unit is not equipped to utilize the waste heat generated during combustion, it is possible to retrofit the unit to recover some of the heat. The GEK takes 22kg of wood chips per hour.

The GEK has the added benefit of being able to attach PTO machines to the generator and use various PTO implements. PTO machines are generally quite simple with the only maintenance tasks being to lubricate the moving parts. This shifts the maintenance away from the machine, and on to the engine. This may be suitable for an operation which does not want to invest in an independently powered machine and may have many PTO machines to use. The maintenance of this unit will be very minimal with the gasifier requiring weekly cleanout of ash and occasional inspection and replacement of seals. The generator will require regular oil and filter changes which require general mechanical skills and common knowledge of internal combustion engines.

APL is prototyping a larger 100kW system which fits in a standard 20 foot shipping container. This is still in the development stage but is basically a scaled up version of the power pallet. This system looks promising as it is a plug-and-play system which can start generating power immediately after delivery.

Other companies manufacturing gasifiers include Vecoplan who have systems that can chip trees, transport, store, and meter the wood chips into a gasification unit or a biomass boiler unit. The University of British Columbia and Nexterra have implemented a biomass gasification system which takes wood chips and produces a syngas which then fuels a generator and the heat can also be harvested from the generator.

For large greenhouses or district heating/electrical systems, Community Power Corporation produces the Biomax CHP system which gasifies wood chips to produce 2.4MWh of electricity per 24 hours, 103kW (350,000 BTU/h) of heat and up to 70kW (20 ton) of cooling. These systems are modular and can be chained together for even large power needs. The Biomax can handle about 2 dry tons of biomass per day and requires 2 pounds of biomass to produce 1kW of electricity. The biomass has to be small pieces, such as wood chips or wood pellets, in order to be fed automatically. The Biomax can also take cardboard, paper, cartons, spoiled produce, and food scraps which can help reduce the waste stream to the landfill.



http://www.gocpc.com/more-information/biomax-overview.html

With the Biomax system, emissions are low for nitrogen oxides (NOx), carbon monoxide (CO) and volatile organic compounds (VOCs) and it complies with United States Environmental Protection Agency (EPA) emission standards. It operates as a closed system with no exhaust except for the internal combustion engine (engine-generator). The only effluent is a non-toxic char/ash that is collected automatically and can typically be used as a soil amendment. Daily maintenance averages 30 minutes per day. Other routine maintenance includes monthly oil and filter changes on the generator depending on the running time.

The Biomax system can operate in a low (20kW) or high (100kW) energy mode. Multiple systems can also be tied together for multiples of 100kW energy demands. Community Power Corporation provides the required five-days of training required for operation, maintenance, and health and safety issues. Operation does not require a full-time operator, but definitely a part-time operator to ensure everything is operating properly and maintenance is done in a timely manner. It can be tied to the grid to provide power to other facilities or for a net metering program. The power availability is about 80%, so the need for a backup system is essential. A backup generator can be used for the electrical requirements during maintenance of the Biomax.

One example of a large-scale CHP system in operation is the Pineland Forest Nursery in Manitoba which is currently operating a Biomax 100. Pineland uses the system to provide electricity to its 4 acres of greenhouses, although the system could provide electricity for 10 acres. This is supplemented with a Blue Flame Stoker boiler for additional heating as the Biomax is being used mainly for electrical generation. The entire heating and power system cost approximately $1 million after all the installations and hook-ups. This is one of the first systems like this so the cost may drop subsequently. Including the total life cycle cost of plant, the cost of electricity can be as low as $0.10/kWh if biomass is available at $25/tonne, for a 25MW biomass gasification plant. If the cost of biomass is $150/tonne, the cost of electricity is estimated to be $0.25/kWh. It may not be economical to only utilize biomass for electricity, but the process produces heat which can then be used for district heating.

KMW energy uses a different technology where they utilize a boiler to produce steam which in turn produces electricity. KMW recommends that the electrical production using a steam turbine not be below 1MW to gain sufficient economies of scale. A range of heating system sizes can be fitted to this electrical system. The entire system will cost upwards of $1 million. One CHP unit KMW installed which had free biomass fuel was able produce electricity at less than 2 cents/kWh (not including life cycle costs which are include in the Biomax example above). Given the free biomass feedstock, the 2 cents/kWh figure essentially illustrates the operating cost for a large CHP system.

It should be noted that despite the above cost estimates, the pricing for CHP and district heating systems more broadly, will be completely site specific depending on the technology and size of system chosen and biomass costs. Its economic viability is similarly dependent on the costs of existing fuel sources and an in-depth examination is required to assess feasibility for any specific location. Large systems can be quite complicated and a detailed analysis of the feedstock quality and quantity as well as the heating and electrical needs should be done in order to determine the appropriate type of technology, the exact products, and their potential uses.

Heat-Focused CHP Systems

A number of different technologies exist to generate electricity from waste heat which is generated as the primary output. Stirling engines provide an option to do this for small-scale greenhouses and biomass heaters.

Stirling engines are very simple heat engines which take advantage of a hot and a cold source to produce electrical power. Their overall efficiency is quite low, but they are versatile in their ability to use an array of different fuel sources which can include fuel, concentrated solar thermal, or biomass combustion. A number of stirling engines are being developed for solar thermal applications where a large amount of solar energy can be focused on a small area.

Stirling engines are not in widespread use but are starting to make a resurgence in the renewable energy industry. The versatility of the heating source may make a stirling engine appropriate for systems where a single dependable fuel source is not available. Prices for stirling engines are very high at present however. Companies such as Genoa Stirling produce 3kW stirling engine which sells for approximately $20,000.

A second heat-focused CHP option is the ORC which would be suitable for large-scale biomass boilers that serve as district heating systems or for large-scale greenhouse operations. The ORC is a process which utilizes heat from another system and evaporates an organic fluid. The evaporated fluid is then passed through a turbine which spins a generator to produce electricity. The organic fluid is then condensed, cooled, and the process repeats.

ORC systems are starting to become more popular and as more research and development continues, it is expected that their usage will increase while their price will decrease. Manitoba Hydro is experimenting with a ORC unit which will likely be marketed in the future. Deltech has a ORC CHP system currently operating in Vanderhoof, BC which provides 9MW of heat and 1.4MW of electricity. Costs will vary based upon input costs and while these type of systems cannot compete with natural gas and cheap electricity found in Canadian cities, they can compete in many other locations where heat and power is more expensive. In order to find the point where these systems become economical, it requires detailed analysis of the cost and quality of feedstock, as well as capital costs sized to the exact market, compared to existing heating and power prices.

Large-Scale CHP Systems

There are efficiencies to be gained from the utilization of larger-scale systems, whether boilers or CHP. The large-scale CHP systems that are operating today are the ones which have taken advantage of the "low hanging fruit" – either they have a competitive advantage in terms of very cheap wood waste or expensive heat and power.

A large biomass CHP system has an optimum size around 25MW based on the capital cost as well as the logistics of fuel transportation. A very large greenhouse would be needed to utilize this amount of electricity. A system of this size is probably best suited for a series of buildings. This would probably utilize a high pressure steam system, would be very complex, very expensive, and would need to employ several full-time staff who have the necessary training and certification to operate high pressure steam boilers. An industrial process which needs a constant source of heat and electricity would be ideal for a large system like this which will constantly produce electricity and heat.

However, there is no concrete break point in terms of scale and cost due to the nature of biomass to being different from site to site. Each specific site and each scenario needs to be evaluated before a definitive comparison can be made between different sizes of systems. The largest factor for the cost of different scenarios will most likely be the fuel cost, quality, and quantity. When investigating various heating and power options, the starting point should be the fuel source and then the different options can be assessed that can utilize that specific fuel at the amounts available. From there, a number of options will emerge and the best option chosen.

A challenge, however, when sizing a large CHP system is that both the heat and power generation will most likely not exactly match the needs. This may require the integration of another building or another process to fully utilize all the energy generated. Thus for larger greenhouse systems, or a series of buildings with a district heating system, combining the heat and power generation systems may be an appropriate option.

The challenge of sizing a CHP system for district heating is to take into account the daily and seasonal variation in heating and power requirements of the buildings. The CHP system will need to be able to produce heat and power in the appropriate daily and yearly ranges. If heat and power generation is less than demand, a system to supply the difference in production and consumption is necessary, this can be in the form of having other electrical or heat generation systems to make up the difference. When electrical production is greater than demand, a grid tied electrical system is one way of utilizing extra electricity and getting credit for times when electrical demand is higher than production. Haines Junction, Yukon has completed a feasibility study for this kind of system that would sell electricity to the grid as well as provide heat to a greenhouse.

3.3.5 Other Biomass Technologies

Biodigester

Biodigesters are widely utilized in European agricultural areas where there is an abundant supply of farm by-products (animal manure, bedding, feed waste, crop waste). Biodigestion is also used in areas where there is large waste stream of fats, oils, and grease from the commercial food industry or other manufacturing facilities. These waste streams would degrade over time in a landfill and release methane to the atmosphere. Anaerobic digestion utilizes these waste products to produce methane in an efficient controlled environment and then collects the methane to be burned in a generator to produce heat and power. The by-product can be used as a soil amendment or fertilizer.

Biodigestion is a proven and viable alternative heat and power generation system when it is coupled with an appropriate feedstock. However, because of the relatively small agricultural and food manufacturing facilities in Northern Canada, a biodigester system may not be appropriate. However, there may be certain sites which can exploit a locally available biomass feedstock. The sizing and design of the biodigester will depend on the quantity and quality of the feedstock available. In Canada, CH-Four, has a number of operating biodigester systems in Canada and can be contacted for further information on biodigesters.

Waste to Energy Conversion

An emerging technology, which has had some adoption in Europe and is starting to become more commonplace in large cities, is waste to energy conversion. This process takes municipal garbage and produces electricity and heat, and also recovers raw materials which can be recycled or used in various products. The processes used are gasification and/or pyrolysis which essentially separate the waste into its basic compounds without actually burning the material. These compounds are either gases which can be burned in a generator or solids that can be recovered.

Waste to energy conversion systems are not widely adopted yet and are still being demonstrated and prototyped in many areas. These systems are very large currently and only in centers with a lot of municipal solid waste and an expensive disposal system. Plasco Energy Group is planning to develop a facility in Ottawa which can handle up to 100 tonnes per day of municipal solid waste. Each tonne of waste is converted into 1MWh of electricity, 300L of potable water, and 150kg of construction aggregate. This process could also be used to recover heat and provide district heating that could be used for greenhouses and other buildings.

Although waste to energy conversion systems are large at present, there is potential for these technologies to be scaled down for smaller applications. Although some centres in the north may have enough population and waste to support these kinds of systems, it is expected that this option will become more viable in future years as the technology advances.

3.3.6 Other Heating and Power Technologies

Thermal Storage

One important issue with wood heaters is that the heat produced and the heat needed is rarely equal. The excess thermal energy can be stored in an insulated hot water tank. The hot water tank then acts to buffer this difference and allow the heater to operate efficiently and the greenhouse to have proper heating requirements at appropriate times. The hydronic heating system can then pull heat from the water tank instead of straight from the heater.

For small greenhouses, building a hot water storage tank may be suitable if appropriate trades people are available. A wooden or concrete vessel which is lined with an Ethylene Propylene Diene Methylene (EPDM) rubber layer with heat exchangers submerged in the water can be used. EPDM can handle the high temperatures without leeching into the water.

For thermal storage, depending on the site, a large thermal battery of water or earth is a strategy for seasonal heat storage. In summer, when overheating is a problem, temperatures can be controlled through active ventilation. In winter the need for heat requires generating heat through combustion of a fuel.

Both of these seasonal issues can be rethought of as a solution to the other problem. For example, when overheating in the summer, store the excess heat in a large thermal battery using air and/or water to transfer the heat. Then when the need for heat arises in the winter, draw heat previously stored in the summer from the thermal battery. A large insulated water tank can be used.

In situations where the size and cost of a water tank is prohibitive, soil can be used as a thermal battery. A looped coil of pipe can be buried underground in a series of elevations in order to create a large mass of soil which hot water can be circulated through during times when excess hot water is available. In times where heating is needed, water is circulated through the pipes and picks up the heat stored in the soil. The water is then circulated through the greenhouse to heat it. The major cost for a system that uses a soil thermal battery will be the excavation.

The length of pipe and volume of soil needed will have to be estimated using an involved mathematical model which is developed specifically for the location and size of greenhouse. This may not be suitable for many types of subsoil. There are some systems which have essentially excavated a basement, insulated the envelope, then filled it back in while running loops of pipe in layers. Maintenance of the system will be minimal, only filling up fluid in the case of leaks and replacing parts which are degrading. An occasional water sample is a good practice to ensure that the water quality is not changing and causing corrosion or degradation of the pipes or tanks.

Solar Thermal

Solar hot water heaters are also a viable heating option for greenhouses in conjunction with radiators, radiant floors, or radiant coils. Evacuated tube units are ideal for winter, low sun angle, and slight overcast conditions. Both evacuated tube and flat plate solar hot water collectors may be used to super heat a large thermal battery (water tanks or soil/earth) during the summer months.

Solar thermal can be complicated, involving pumps, pressure tanks, pressure relief valves, regular heat transfer fluid replacement (in the case of glycol based systems) and demand directed controls. Depending on installation, flat plate collectors require less maintenance and are easier to clean, especially with respect to snow removal. In the event of breakage or vandalism, some evacuated tube collectors will continue to operate with fewer tubes (the heat transfer fluid does not enter the tubes themselves and flows through a manifold instead) whereas a flat plate collector will require replacement of the glass sheet at a minimum. Required maintenance will include brushing snow off in the winter, fixing leaks, topping up fluid as well as replacing any tubing which is degrading over time.

Passive solar orientation and design makes efficient use of free solar energy to offset the heating cost of the greenhouse. Using passive solar strategies in the fundamental design and then building on this with renewable heat and power technologies is recommended. This will allow for reduced loads and therefore reduced capital costs for heating and power generation technology.

Solar Electric (Photovoltaic) (PV)

For sites which have no grid connection, PV systems require a large load to dissipate energy when the batteries are full and the panels are still producing power. To do this, PV systems can be integrated with a solar thermal system in which there is a large mass which is continually heated when there is excess energy.

The variable nature of available sunshine produces intermittent power requiring possible schedule adjustments, programming flexibility, and/or the incorporation of battery storage. PVs should not be sized or depended upon as the sole electricity source as the system is subject to changing environments and weather conditions (i.e., when the sun is shining).

There are many local providers of solar electric with scalable systems. The size and type of system is strongly site dependent both in terms of physical location, microclimate, and greenhouse demand. A 4kW system which includes PV panels, charger, controller (with auto switch to backup generator), and batteries costs approximately $17,000. The panels are expected to last 30 years, and the batteries should last 15 years. The price of PV keeps steadily dropping and if the trend continues, it will be a very economical source of electricity in the future

Wind

Small-scale wind power may be an alternative electrical power generation option for some remote or isolated communities, or for projects aiming to reduce their environmental footprint through renewable energy production. However, wind is not a viable solution in all locations. Site specific geometry, climate, microclimate, layout, turbulence, time of day, season, etc. will influence wind patterns and determine the viability of this source as well as the appropriate type and size of turbine. In addition, the variable nature of wind produces intermittent power in small-scale applications requiring possible schedule adjustments, programming flexibility, and/or the incorporation of battery storage.

Wind power generation should not be sized or depended upon as the sole electricity source as the system is subject to changing environmental conditions (i.e., the sun is shining and the wind is blowing). However, a provider should be able to assess the site and predict the average output of a small-scale system. It is expected that a battery or thermal storage system will be required in combination with any wind power system.

There are many local providers with scalable systems. The maintenance of most wind turbines requires a yearly inspection and lubrication of the bearings.

Ground Source Heat Pump

GSHP systems, commonly referred to as geothermal, consist of a long length of pipe which uses a fluid to extract energy from the system by exploiting the temperature difference between the top six metres of the earth and the earth below six metres. A geothermal system can be integrated with a solar thermal system which will then allow heat to be put into the ground during the summer which will increase the efficiency of the system in the winter.

The advantage of a GSHP is that it can provide heating in the winter as well as cooling in the summer. The difference between a GSHP and the thermal storage as explained above is the scale. The vertical GSHP is able to tap into the Earth’s enormous thermal battery and transfer and store heat seasonally.

For the shallow or horizontal system, excavation costs will depend on the services available as well as the type of subsoil present. For bedrock areas, this may not be an option. For a deep or vertical system, drilling costs will depend on the location as well as the subsurface properties. Not all locations are appropriate for GSHPs but the analysis by an expert of the specific site should yield results as to its viability. Geothermal systems do need electricity for operations and needs to be budgeted for as the main operating cost. The pump should last about 25 years and the ground loop should last at least 50 years but could last much longer assuming it is not punctured or located in an area of seismic activity.

Biofuels

Biodiesel made from waste vegetable oil is an option for powering liquid fuel boilers and diesel generators for heat and power if a large quantity of free oil is available. The process to make biodiesel from vegetable oil is relatively simple, needing only a heated space and a few tanks and ingredients. The key issue is the supply of the vegetable oil. Business ventures exist in many larger cities which collect waste vegetable oil from restaurants due to the large volume of free oil available.

Many of the gasification systems can produce a liquid fuel by-product which can be refined into a useable liquid fuel for heating and/or electricity generation. This is a relatively complex problem and the type of fuel depends on the specific feedstock and the type of process is used.

Cellulosic ethanol is becoming more popular and may be an important fuel source in the future. Cellulosic ethanol is typically produced from wheat straw. This is probably not a good feedstock for locations in Northern Canada. Lignol Energy is developing processes to produce ethanol from wood biomass. This technology may be a few years away from commercial uptake but it may be worth investigating in coming years.

Table 22: Pros and Cons of Alternative Heating Technologies

Technology	Pros	Cons
Thermal Storage	Can be integrated with multiple sources of heat Can address heating and cooling issues	May be very large and expensive
Solar Thermal	Relatively inexpensive Can be integrated into a hydronic heating system	Only produces power in sunlight
PV	Can sometimes be cheaper than connecting to the grid	Only produces electricity in sunlight
Wind	Large systems can be economical for a community	Only produces electricity in wind
GSHP	Can be integrated with multiple sources of heat Can address heating and cooling issues	High capital cost
Biofuels	Can store fuel for later and use in many types of existing engines	Complicated process to produce high quality fuels.

4 KEY RESOURCES AFFECTING NORTHERN GREENHOUSE DEVELOPMENT

The human, financial and natural resources available to a community will greatly impact on their ability to develop and operate a greenhouse enterprise. The availability of different resources – human, financial or natural – and the advantages and disadvantages these create, needs to be considered closely in the development of any greenhouse operation.

4.1 Human Resources

Human resources will be a critical determining factor in the development of a northern greenhouse enterprise. Key competencies and skills must either exist or be acquired and skill levels must be matched to the complexity of the greenhouse operation.

Key competencies for greenhouse operations

A number of different roles and functions are necessary in operating a greenhouse enterprise, including production, business and facilities management. The table below details the different roles and key functions required in any greenhouse enterprise.

Table 23: Roles and Functions required in Greenhouse Enterprises

Role	Key Function/Skills	Key Function/Skills	Key Function/Skills
Business Management	Developing and implementing business plan	Managing costs of production	Developing business relationships
Facilities Management	Upgrading facilities	Managing the repair and maintenance of facilities.	Managing greenhouse environment
Head Grower/Production Management	Scheduling of operations. Management of production systems	Hiring and training workers	Food safety management
Assistant Grower/Foreman	Supervision of cultural and harvest activities	Manage plant nutrition and greenhouse environment	Harvest and post – harvest handling
Production Workers	Skilled and non-skilled labour in growing practices	Skilled and non-skilled labour in harvest practices	Skilled and non-skilled labour in post-harvest handling and clean-up

The human resources required to operate an individual greenhouse enterprise will depend on the scale and complexity of the greenhouse itself. In smaller less complex operations one individual can be responsible for more than one of the key functions and roles. Larger-scale more sophisticated greenhouse systems may require a number of individuals to perform the key functions in certain roles. Lower-tech greenhouses can have less skilled labour while higher-tech greenhouses will alternatively require more skilled and specialized labour.

Looking specifically at the area of greenhouse vegetable production, previous needs assessments have identified the following basic competencies required to run a greenhouse enterprise:

- Knowledge of the greenhouse industry as well as the market and management requirements of developing and operating a greenhouse enterprise.
- Knowledge of fundamental concepts of botany and soil science.
- Technical knowledge and skills to manage different growing media.
- Technical skills in soil testing and the interpretation of soil test results.
- Technical knowledge and skills to select the best fertilizer and application rates for different crops.
- Computer skills needed to manage fertilizer applications control systems.
- Technical and computer skills to manage irrigation systems.
- Technical knowledge to diagnose and deal with nutritional problems.
- Technical skills in using pesticides to control insect and disease pests.
  Technical skills in using biological pest control methods.
- Technical skills in integrated pest management.
- Technical and computer skills needed to manage the greenhouse environment (temperature, relative humidity and CO_2 of the growing area).
- Knowledge of the cultivars, traits, cultural practices and disease issues of the different vegetable crops.

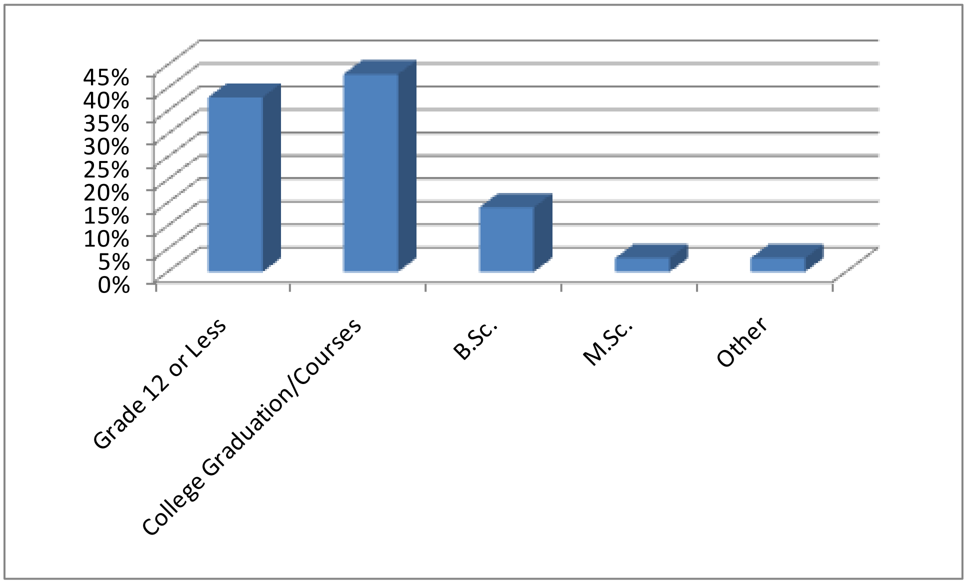
A more recent profile of greenhouse growers in Alberta identified the need for the following capabilities as greenhouse systems become more sophisticated and complex (Albert Greenhouse Industry Profile 2004 and Profile of Greenhouse Operators).

- Monitor light levels and manage irrigations systems.
- Monitor and adjust CO_2 levels.
- Monitor and adjust temperature.
- Monitor and adjust relative humidity and moisture conditions.
- Monitor pH and electrical conductivity of nutrient solutions.
- Monitor water loss from slabs.

Educational and skills requirements for greenhouse operation

The same Alberta study collected the following survey information on the education levels of greenhouse operators in Alberta. This shows an array of education levels and that formal education is not necessarily required within the industry. Obviously though, less-educated growers will still need to have the requisite and skills in greenhouse vegetable production to survive.

Figure 7: Level of Education for Greenhouse Operators in Alberta, 2004



Depending on the size and the sophistication of the operation, educational and skills requirements will vary greatly. For lower-tech greenhouses, the head grower can simply be an experienced greenhouse labourer, or an experienced gardener, who will run the operation and supervise a number of labourers. Larger-scale enterprises with intensive production systems and leading edge technologies may require a combination of appropriate university training plus relevant industry experience. The study team also visited a number of half-acre or smaller modern gutter-connected facilities who were run by persons with expertise that ranged from no formal training in greenhouse production but a strong farm background and knowledge of plant requirements, to others with diplomas and master degrees in horticulture and greenhouse production.

This leads to the key question – ***How can northern aboriginal communities acquire the skills and knowledge to run a greenhouse operation?*** The answer to this question depends on both the complexity of the greenhouse operation and each community's (and specific individuals) expertise and experience with greenhouse production.

There are a number of northern aboriginal communities that have sufficient experience to develop greenhouse enterprises as they have: 1) vegetable production experience within community greenhouses or also potentially if they have extensive market gardening experience; and 2) if they have experience working in other types of greenhouse operations such as tree seedling production. It is important for northern communities to see that it may not make sense to leap directly to commercial greenhouse production. A first, simpler and easier step will be to gain expertise through commercial market gardening or through the development of a small-scale community greenhouse. This latter option could be undertaken with locally available materials to reduce costs as well.

Once communities gain experience in vegetable production, whether outdoor market gardens or non-commercial greenhouses, they can then begin to move further up the ladder to actual commercial greenhouse production. Acquiring this experience will be a long-term progression for communities and individuals that will take a number of years as many communities have little or no agricultural skills for greenhouse production. For others who are doing small-scale backyard gardens or community gardens, moving to commercial greenhouse production will still take time.

One example of this progression is the Flying Dust First Nation in Saskatchewan. After developing a market garden they then received funding through the AAFC/AANDC SPI program for simple grow tunnels to extend their season and bring their peppers and tomatoes to market sooner. This is a low-risk approach and moves them up the ladder of complexity in vegetable production without taking on the capital risk of a greenhouse. The study team also held discussions with leaders of the community greenhouse in Carmacks, Yukon who were selling small amounts of production and felt after over 15 years of community greenhouse production that they were now ready to move into full commercial production. This is not to say that it will take 15 years in all communities but it does show that for communities with no or limited agricultural skills, the skills required to a run commercially sustainable greenhouse will take time to acquire.

Alternatively, training and greenhouse experience can be acquired for community members who are interested in greenhouse production. This can be used to speed up the progression of a community down the path to commercial greenhouse production, including more complex forms of production and technology. It must be remembered that training alone will be sufficient for greenhouse vegetable production as hands-on experience within a greenhouse environment will be crucial.

Communities must be careful in the training process however. The study team visited one location where ten young adults were given training in gardening (outdoor) through a series of three two week training sessions at a southern centre. The first trip (in winter) to learn about preparing the soil and seeding, the second trip (in late spring) to learn about weeding and maintenance, and the third trip (in late summer) was to learn harvesting and storage. The following year not a single participant from the program was interested in working on a community garden project. It is possible that the participant selection process was flawed, or that participants merely signed up for the opportunity to travel. Regardless, the program design was not sustainable and the result is that 10 participants were trained that had no interest in pursuing a community garden.

Given the evolution of technology there are also opportunities to support learning through distance education programs via the internet. Online vegetable production courses do exist and Olds College has delivered a videoconference based training program on market garden and high-tunnel production to a number of First Nations in Alberta. This type of programming could be tailored and/or expanded to support both training and long-term mentorship/consulting for northern greenhouse producers.

A wide variety of horticulture and greenhouse training programs exist across Canada. There are a number of university programs (four year and masters-level) but short-term technical training programs at the college level may make more sense depending on the skill levels required. Six different colleges in BC provide greenhouse training programs, ranging from 18 weeks to two years. Two-year diploma programs tailored specifically for the greenhouse industry do exist in at institutions such as Niagara

College and Olds College. These are practical hands-on training programs with extensive time spent working in greenhouse environments. It may also be possible for a first nations affiliated organization to work with colleges or universities to design a training program focused on either horticulture or specifically on greenhouse vegetable production.

The question remains whether a young person sent to these programs would have sufficient experience afterward to immediately begin running a commercial greenhouse operation, however simple, given the responsibility that it would entail. It is most likely that additional years of experience working in the industry or in a non-commercial community greenhouse operation would be necessary.

Importing skilled labour

Higher-technology greenhouses may have to consider importing seasonal labour and/or full-time professionals to ensure the key functions and task are being performed effectively. However, there can be additional costs above and beyond wages and salaries attached to imported labour. These include the costs of providing housing or housing allowances as well as relocation costs and any incentives that may be needed to attract individuals to northern regions. Salaries for head growers for large multi-acre greenhouse operations in the south are generally well in excess of $120,000 not including benefits and a northern operation may have to pay much more. Most commercial greenhouses below 10 acres are normally run by an owner/operator rather than a contracted head grower.

The challenge will be in balancing labour costs with productivity for a higher technology operation. Generally greenhouse enterprises with business objectives of achieving acceptable return on investment and ensuring the long run survival of the business will require labour costs and productivity levels that are competitive with other operations serving the same market. The following tables provide labour costs and productivity estimates derived from Alberta survey data. Northern greenhouses with labour costs and labour productivity levels that are offside with these benchmarks may be disadvantaged in a competitive market environment.

Table 24: Labour Costs and Productivity Estimates for Alberta Tomato Production

Tomatoes	2008	2010	2011
Sales ($/m^2)	$108.41	$108.45	$108.56
Productivity (kg/ m^2)	53.16	53.16	60.31
Labour Cost ($/m^2)	$26.91	$29.10	$30.12
Total Production Costs ($/m^2)	$106.91	$96.13	$99.21
Labour Costs as % of Total Costs	25.43%	30.27%	30.36%
Labour (kg/$ of Labour/ m^2	1.98	1.83	2.00
$ Sales Revenue/$ Labour/ m^2	$4.03	$3.73	$3.60

Source: Original Data Laate (2013). Industry Update & Economics of Greenhouse Crops Production; Alberta Agriculture and Rural Development

Another key challenge to consider is whether an external greenhouse manager will be accepted by the community. Interviews with key informants during the field visit indicated caution that bringing in external managers rather than training from within the community will result in a failed project. Some from outside the community would need to be accepted by the community, who would then train community members to run the enterprise. At the same time, a manager would not be brought in for anything less that a multi-acre greenhouse due to costs so as this will be a major enterprise and the mindset behind this type of development would be much different than a small-scale greenhouse serving an individual community. This is an area that would have to be assessed closely in the development of a northern greenhouse enterprise as conditions may vary by location.

Technology does however present increasing opportunities for northern greenhouses, even those in remote communities. One option would be to set up a consulting system where trained or experienced growers in northern aboriginal communities could take photos or videos of greenhouse issues and discuss via skype or other medium. This would allow a transfer of knowledge at a distance while support capacity development and problem solving at the same time.

Skilled versus non-skilled labour

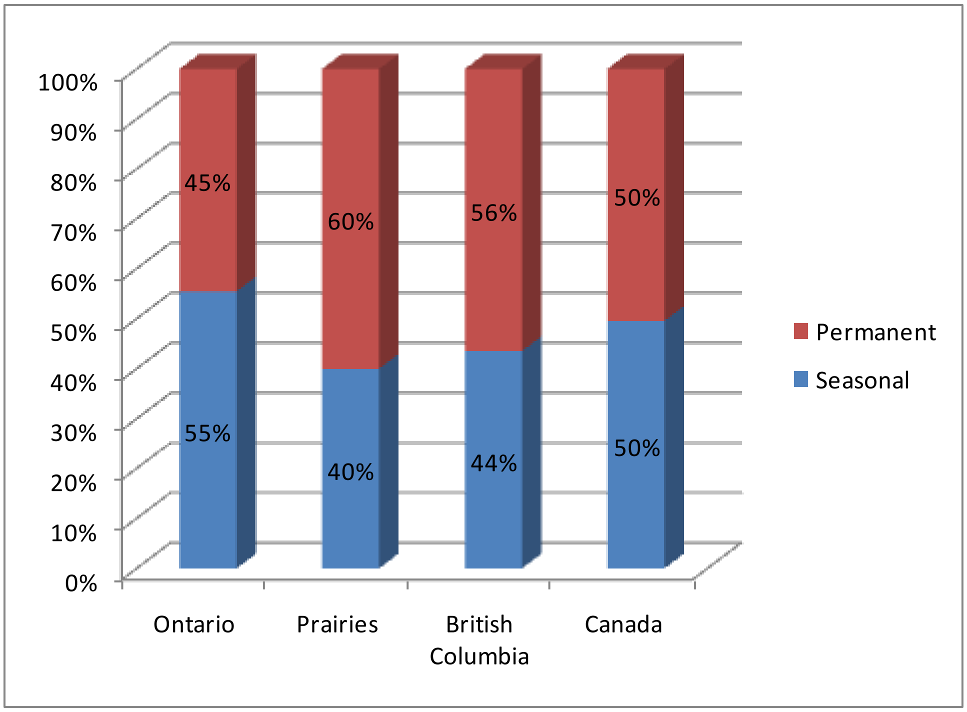
The labour pool, ideally, would be staffed with individuals with some experience in greenhouse crops. However, it is more likely that workers will have no greenhouse experience. The difficulty will be at the start-up of the greenhouse operation when workers will very likely be inexperienced. At this time, the head grower and assistant grower should be prepared to spend extra time with the new staff showing them how to perform the different greenhouse production techniques. Once the greenhouse operation is up and running, any new worker will be assigned simple tasks and gradually be trained to assume more responsible tasks (i.e., weighing and mixing fertilizers).

There is a role for both skilled and non-skilled workers within non-skilled workers in providing the labour component in cultural, harvest and cleaning processes. The key factor in determining the proportion of skilled and non-skilled labour will be the level of technology within the greenhouse. Low-tech greenhouses will require more but less skilled labour and higher technology facilities will alternately require less but more skilled labour. Smaller size gutter-connected facilities will fit in between on this continuum. However, each northern greenhouse venture will be unique in terms of how it combines skilled and non-skilled labour with other production resources and technology.

Seasonality

Jobs for greenhouse workers in northern regions may be seasonal rather than year-round. The following chart illustrates the proportions of seasonal and permanent greenhouse vegetable employees in different regions of Canada. Approximately half of employment is seasonal within the greenhouse industry while half is permanent.

Figure 8: Seasonal and Permanent Greenhouse Vegetable Employees – 2011



Source: Statistics Canada (2011) Greenhouse Sod & Nursery Industries

Competing Industries

There do not seem to be many competing industries for the labour pool in most northern communities. Each of the communities engaged had high unemployment and a need for more employment opportunities in the community.

The current labour pool for most remote First Nations communities is primarily employment for government services. The employment surrounding the communities is primarily in mining, forestry, oil and gas, pulp and paper, and other resource based industries. Often in remote communities the demand for labour is seasonal with the Band council or the community hiring workers for local civic and community driven projects. Other seasonal work could include scientific research projects, tourism related work and construction projects.

There are many barriers to full-time employment for citizens in remote communities. Much of the employment opportunities available, both in and outside of the communities, offer seasonal or part-time employment, which do not generate a sustainable income. Also, employment outside the community for extended periods may not be a viable option if family commitments or children require the individual to stay accessible. Employment insurance becomes a viable and preferred option since family, health and socio-economic factors play a role and create further barriers to full-time employment.

When considering a greenhouse, year-round employment is preferred, however some communities are so desperate for employment that nine months employment for a three season greenhouse would still be in high demand, because of high unemployment in the community.

4.2 Financial Resources

Having sufficient financial resources for greenhouse development will be crucial as it may allow for increased resilience of the enterprise when dealing with issues such as lower productivity during start-up, a crop failure or weather damage. Similarly, there are definite economies of scale in greenhouse production so constraints to capital will limit the ability of a greenhouse to achieve optimal profitability. Some greenhouse designs, such as the Chinese solar model, are highly capital intensive so the ability to access required capital is very important.

Partnerships
Northern greenhouse ventures may be able to develop relationships with partners that allow them to gain access to resources without incurring the full costs of acquiring or developing the resource. This can be used to drive down capital or operating costs. These opportunities could include the following:

1. Production contracts in which an end user provides the key inputs while the greenhouse venture provides the facilities and labour to produce a needed product. An example of this is the Wabigoon Lake Ojibway Nation which has a production contract to produce Black Spruce seedlings required in the reforestation work of a nearby mill. In this arrangement the mill provides the seed and agrees to purchase a set number of seedlings at an agreed upon price. This business relationship reduces the seed costs and working capital required by the greenhouse enterprise. As well these types of arrangements can provide assured markets and possibly a price commitment that may be bankable by the greenhouse enterprise.
2. Arrangements with retailers can provide a greenhouse enterprise with reliable retail markets for its vegetable production. These business arrangements can provide a greenhouse enterprise with a market presence without incurring the costs of developing their own retail facility. This type of relationship can also reduce operating (cash) requirements when the retailer pays in a set period of time (net 20 days).
4. Access to a developed power system. A greenhouse venture may be able to develop a business relationship with an industrial firm that has developed its own power generating system. The relationship would enable the greenhouse to gain access to a needed power supply without incurring the full cost of developing the system.
5. Access to biomass. A greenhouse venture may be able to develop a relationship with a lumber mill to gain ongoing access to dried wood residue that can be used in a biomass system. A greenhouse may also be able to locate itself close to another type of industrial operation that can provide its waste materials (biomass) for free to reduce haulage and dump fees. This type of arrangement can give the greenhouse venture access to biomass without incurring the capital and operating costs of harvesting the wood residue themselves. A further benefit is the greater efficiency of dried wood residue versus undried residues.

6. Connection to a larger (district) heating system. A greenhouse venture may be able to form a relationship with an industry or local government to integrate the greenhouse system with a local heating system. This would provide the greenhouse with access to a lower cost heat source without incurring the full capital costs.

Government Funding Programs

There are several federal and provincial government funding assistance options available depending on the focus of the program. The availability of funding options will change with time, but some examples include:

Agriculture	• AAI, AAFC, http://www.absn.ca/TermsandConditionsoftheAAISPI.pdf • Agri-Innovation: The program supports industry-led pre-commercialization research, development and knowledge transfer, as well as support to enable commercialization and adoption. It may provide non-repayable support up to a maximum of $10 million per year. http://www4.agr.gc.ca/AAFC-AAC/display-afficher.do?id=1354301302625&lang=eng • Agricultural Greenhouse Gasses Program (AGGP) http://climatechange.gc.ca/default.asp?lang=En&n=4FE85A4C-1
Technology	• Sustainable Development Tech Fund, – Sustainable Development Technology Canada (SDTC): This program is aimed at supporting the late-stage development and pre-commercial demonstration of clean technology solutions: products and processes that contribute to clean air, clean water and clean land, that address climate change and improve the productivity and the global competitiveness of the Canadian industry. SDTC does not require any repayments of the financial contributions it provides to funded projects through the SD Tech Fund http://www.sdtc.ca/index.php?page=soi-information&hl=en_CA • Community Infrastructure Improvement Fund (CIIF), CanNor: This program is a two-year national program that is investing $150 million to rehabilitate and improve existing community infrastructure across Canada. It is helping to modernize infrastructure and provide broad-based economic benefits to communities. • Strategic Investments in Northern Economic Development (SINED), CanNor: This program SINED focuses on strengthening the driver sectors of the territorial economies, economic diversification and encouraging Northerners' participation in the economy. Projects are prioritized based on five-year territorial investment plans developed with input from territorial stakeholders, and are approved by the Minister of CanNor. Potential federal contributions of $25,261,667 over 5 years for the Targeted Investment Program, the Innovation and Knowledge Fund and the Partnership and Advisory Forums in each territory. In addition, a new $5 million dollar Pan-Territorial Fund has been established for projects impacting more than one territory.
Energy	• Green Infrastructure Fund, Infrastructure Canada: This program supports projects that promote cleaner air, reduced GHG emissions and cleaner water. This includes new or rehabilitation infrastructure projects that fall into the following categories: wastewater infrastructure, green energy generation and transmission, solid waste, carbon transmission and storage

	http://www.infrastructure.gc.ca/prog/gif-fiv-eng.html http://actionplan.gc.ca/en/initiative/green-infrastructure-fund • *ecoENERGY for Aboriginal and Northern Communities Program 2011-2016* (EANCP): The ecoENERGY for Aboriginal and Northern Communities Program 2011-2016 (EANCP) is focused exclusively on providing funding support to Aboriginal and northern communities for renewable energy projects. It is delivered by AANDC and is part of a suite of clean energy programs funded by the Government of Canada that address action on climate change. The main objective of EANCP is to reduce greenhouse gas (GHG) emissions arising from electricity and heat generation in Aboriginal and northern communities by supporting the development and implementation of renewable energy projects. EANCP provides funding support for the development stages of renewable energy projects and for the engineering and implementation of renewable energy projects integrated with community buildings. Proponents may request a maximum of up to $ 250,000 per project
Training	• Industry Canada Small Business Financing Program www.ic.gc.ca

Health	• Aboriginal Health Transition Fund, Health Canada: This program is a $200 million initiative aimed at addressing the gap in health status between Aboriginal and non-Aboriginal Canadians by improving access to existing health services. The Aboriginal Health Transition Fund supports:
	  ◦ First Nations and Inuit communities in identifying and implementing projects that promote the integration of federally-funded health services within First Nation and Inuit communities, with those funded by provincial and territorial governments;
	  ◦ Provinces and territories in adapting their health services to better meet the needs of Aboriginal Canadians, including First Nations living on and off reserve, Inuit and Métis; and
	  ◦ Aboriginal people's participation in the design, delivery and evaluation of health programs and services.
	www.hc-sc.gc.ca

Aboriginal entrepreneurs	• AANDC funding opportunities www.aandc-aadnc.gc.ca • Government Services for Entrepreneurs, Canada Business Network: A database of government grants, loans and financing are available for entrepreneurs
Community gardens	• Coaction Community Fund Program (Environment Canada) • Ontario Trillium Foundation

Aboriginal Infrastructure

Aboriginal infrastructure including EDCs and Marketing Cooperatives can provide support to a northern greenhouse venture in a number of ways:

1. EDCs may have access to start-up financing for a greenhouse venture.
2. EDCs may be able to fund pre-feasibility assessments and feasibility assessments that contribute to stronger business cases going forward.

3. EDCs may be able to assist a greenhouse venture in obtaining a line of operating credit that would be necessary to sustain operations throughout the growing season.
4. EDCs may be able to organize and fund training opportunities for gardeners and greenhouse workers.
5. Local marketing cooperatives supported by Aboriginal institutions can provide access to retail outlets that are supported by the community.
6. Aboriginal institutions may be able to support the development of community gardens which support gaining the skills and knowledge to develop a greenhouse venture. This could be the first step in the development ladder leading to viable and sustainable greenhouse enterprises.

Most Canadian First Nations Bands have economic development personnel, departments or corporations that operate from within or outside of their Band Office. The Canadian Council for Aboriginal Business recently completed a survey (CCAB, 2011) of aboriginal EDCs which identified 260 active aboriginal EDCs in Canada. Half of EDCs reported sales of $5 million or more for the previous fiscal year and 38% of EDCs reported that they are the major employer in their community. Accessing capital however was reported as a significant concern by aboriginal EDCs and 84% said their relationship with financial institutions was their key priority, ahead of aboriginal owned businesses and training and education facilities.

The capacity within each EDC will vary drastically in terms of the resources and staff as well as the responsibilities required of them. There can be as little as one individual with varying levels of experience or knowledge around economic development opportunities and strategies for the community. The advantages and disadvantages of the various economic development structures vary depending on the community’s needs and capacity.

An internal economic development body run from within the Band will require significant resources and administration and may not have the capacity to run large or even several small projects at the same time. In this structure, economic development is tied to the everyday politics of the Band. Whereas when economic development is run from a corporation outside of the Band, it has much more independence and resources to allocate to their project. However the EDC can conflict with the views of the Band.

Another level of Aboriginal infrastructure that can provide support to communities is Tribal Councils. In 2002, there were 78 Tribal Councils providing services to 475 First Nations. Tribal Councils can provide advisory services regarding economic development, financial management, community planning, technical services and Band governance.

Under the Canada Business Network and Government Services for Entrepreneurs, Aboriginal Business Canada is a resource for grants, loans and financing. Aboriginal Business Canada and the Aboriginal business community have partnered to provide credit options to finance Aboriginal small business development. There is now a network of Aboriginal-owned loan corporations, structured as non-governmental financial institutions. The Aboriginal Capital Corporations (ACCs) provide support and customize for regional market conditions, and focus on providing developmental loans that may not receive loans from conventional banks. There are 32 active ACCs throughout Canada. The National Aboriginal Capital Corporation Association (NACCA) has been set up to provide support in the form of training, access to capital initiatives, advocacy and other institutional capacity-building services to its 45 member Aboriginal Financial Institutions (AFIs) (www.aadnc-aandc.gc.ca). Access to capital will be crucial in the development and operation of a resilient and sustainable greenhouse that can survive potential shocks (crop loss, damage etc.) and achieve economies of scale in its operation.

For further financial support, there is a First Nations Bank of Canada that prides itself in being a leader in the provision of financial services to Aboriginal people and an advocate for the growth of the Aboriginal economy.

There are also non-profit models of Aboriginal infrastructure in place to support development projects. Nishnawbe Aski Nation (NAN) in Ontario is providing funds for community level projects that support individual citizen garden projects that contribute to food security and food sovereignty. The funding does not place an emphasis on economic development and creation of jobs.

4.3 Natural Resources

Location and Access

A community's location has key implications for greenhouse development both positive and negative. In the case of the communities covered within this study, there are key differences between easily road accessed communities and communities with fly-in/winter road access. These patterns will have implications on the likely success of a greenhouse project.

Table 25: Year-Round Versus Fly-In Communities, Advantages and Disadvantages for Greenhouse Enterprises

	Advantages and Implications	Limitations and Implications
Easily accessed communities (year-round road)	• Increased access to training resources increases ease and quality of training opportunities. • Lower capital and operating costs. • Easier to access specialized technical assistance. • If a heating source for a greenhouse suddenly becomes restricted, it is likely that there will be other options available in the vicinity.	• The products grown in a greenhouse will need to be competitively priced to compete with locally available produce from other growers and suppliers. • Since it is easier for citizens to travel to other communities for work, the labour force will not be as reliant on local employment in the community, which means it may be more challenging to find interested labourers.
Communities with reduced access (fly-in/winter road)	• The main competitive advantage of remote communities is the high cost of vegetables/food and potential revenue for a greenhouse. Price data gathered by the study indicated that retail vegetable prices are generally 2 –	• High costs of materials due to transportation costs will increase start-up, maintenance and operations costs. • There will be difficulty bringing in skilled labour from outside the community, as well as trying to keep skilled labour in the community when

	Advantages and Implications	Limitations and Implications
	2.5 times higher in fly-in communities within the study zone (non-arctic) than Canadian cities, even with the northern transportation subsidy, compared to approximately 50% higher in road access communities on average. • Citizens will likely be more reliant on local employment, preferring to choose unemployment near family and the community over leaving for mining or forestry work. This is one factor that ensures that there will be interest in employment with a community greenhouse. • More isolated communities often have a stronger sense of community and self-sufficiency and are therefore more likely to act collaboratively to ensure that projects lead to success.	opportunities for better employment arise outside of the community. It will also be difficult and expensive to bring in training. • Problem solving and repairs to a greenhouse become more costly due to the shipping costs, time lag and potentially the lack of skilled labour. Lack of experience, as well as vandalism become much larger concerns for budgeting of operational and maintenance costs. If frequent repairs are necessary or if vandalism is a concern in the community, this can lead to downtime in greenhouse operations, which can result in sick or damaged crops and further lost income. • Fuel and energy sources for greenhouse heating and operations will be limited; therefore it is critical that secondary and possibly tertiary energy sources be identified prior to committing to a large greenhouse project requiring high sources of energy, as well as spare parts. • Winter roads cannot be relied on for regular transportation, because of inconsistent lengths of season and safety, especially in recent years with changing climates. • Communities with reduced access often have a different mentality around innovation. Social acceptance of a new idea such as a greenhouse may take time to achieve widespread community buy-in.

Water Quality

Water quality is of paramount importance when crops are grown hydroponically or in soilless media such as rockwool. Therefore water quality and supply for a greenhouse operation are very important. A site must be selected that can provide ample quantity of high quality water.

Maximum acceptable limits of the various water quality criteria have been suggested as follows below although there are many functioning greenhouses in excess of these limits. In any case, potential greenhouse growers should consult with greenhouse specialists in their provincial department of agriculture to ensure that they have adequate water quality:

- Conductivity of 0.5 mS/cm
- Sodium content of 30 ppm
- Chloride content of 50 ppm
- Sulphate content of 100 ppm

If available, lake water or treated municipal water is ideal, and so is rain water. Rivers and streams should be avoided because of the possibility for their contamination and subsequent crop damage due to the contaminants. Water sample analysis before starting a commercial greenhouse is a must regardless of where the greenhouse is to be located.

Energy and Power Sources

A northern greenhouse venture will require energy and power sources suitable for the heating and lighting requirements of the proposed greenhouse system as well as the general operations of the business. The available energy and power sources need to be assessed in terms of the following criteria:

1. Have the energy requirements of the proposed greenhouse system been assessed in terms of intensity, timing and duration?
2. What are the proven technologies that fit with the local expertise required for maintenance?
3. How well do the energy and power sources meet the operating requirements of the proposed greenhouse throughout the production period?
4. Is there sufficient capacity to allow the greenhouse venture to expand operations over time?
5. Are there times of peak use when there may not be sufficient energy or power for the safe operation of the greenhouse system?
6. Are there other ways to mitigate costs through use of district heating systems?
7. Do the costs of the available energy and power sources create a cost advantage or a cost disadvantage for greenhouse production?
8. Are the energy sources subject to volatile price movements?
9. Are there opportunities to mitigate the effects of volatile energy prices?

Energy costs (expressed as dollars per Gj) will range widely according to the fuel, location and transport costs, and local pricing factors. Natural gas is the fuel of choice in greenhouses in major production centres in southern Canada but the study team did meet with one grower in Saskatchewan who utilized coal that was much cheaper than natural gas. Data from the All Canadian Coal-Fired Heaters website is used to provide some initial benchmarks.[3]

[3] *www.allcanadianheaters.com/coal.html.*

Table 26: Relative Energy Prices (April 2008)

Fuel	$CDN/Gj
Electricity (2 to 20 cents per kWh)	$8.50to $60
Diesel ($1.32/litre, 0.039Gj/litre)	$33.85
Propane ($0.65/litre, 0.025GK/litre)	$26.00
Wood Pellets ($250/tonne, 18 Gj/tonne)	$13.89
Natural Gas (0.037 Gj/m^3)*	$8.50
Coal ($350-445/tonne, 18Gj/tonne)	$1.95-$2.50

**Since this date the prices for natural gas have come down to a range of $3 to $6 per Gj depending on location.*

Diesel and propane are often the main energy and/or heating source in many northern communities. Cold, northern locations have a high demand for diesel and heating fuel which contributes to high energy expenditures which will be especially true for greenhouse development, especially with the use of artificial lighting during winter months. Diesel fuel must be flown in, shipped in, or driven in on winter roads, which leads to high transportation costs, contributing to high energy expenditures. Costs of heat and propane in providing energy to a greenhouse in the north will be multiples of the cost of natural gas available in southern Canada and will render the greenhouse uneconomic in most cases.

Heating systems utilizing biomass will have heating costs that are determined by the energy content or heat value of the biomass along with the market determined costs of the biomass. The following tables have been developed to illustrate how energy content and biomass costs affect the energy costs of various biomass sources. The data has been gathered from a variety of sources but indicates the competitiveness of biomass heating compared to natural gas used in most southern greenhouses, as well as the important cost reductions compared to diesel and propane. propane (Penn State College of Agricultural Sciences, Characteristics of Biomas as a Heating Fuel and North American Wood Fiber Review ; April-June 2012). Depending on location, coal may also be another viable and low-cost heating option if it can be accessed.

		Energy Costs ($/GJ)				
Wood Pellets		Heat Value (GJ/Tonne)				
		16	17	18	19	20
Cost per Tonne ($/MT)	$170	$10.63	$10.00	$9.44	$8.95	$8.50
	$200	$12.50	$11.76	$11.11	$10.53	$10.00
	$225	$14.06	$13.24	$12.50	$11.84	$11.25
	$250	$15.63	$14.71	$13.89	$13.16	$12.50
	$270	$16.88	$15.88	$15.00	$14.21	$13.50

Wood Chips						
		Energy Costs ($/GJ)				
		Heat Value (GJ/Tonne)				
		12.00	14.00	16.00	18.00	20.00
Cost per Tonne	$100	$8.33	$7.14	$6.25	$5.56	$5.00
	$110	$9.17	$7.86	$6.88	$6.11	$5.50
	$120	$10.00	$8.57	$7.50	$6.67	$6.00
	$130	$10.83	$9.29	$8.13	$7.22	$6.50
	$150	$12.50	$10.71	$9.38	$8.33	$7.50

Capital costs must also be considered when selecting fuel sources. A 500,000 BTU natural gas unit can be purchased for approximately $14,000 retail which should be doubled when installation is included. The cost of installing the gas line may be expensive depending on location. A similarly sized wood pellet burner (LEI BB-500) will cost approximately $40,000 plus 20% installation. Installation does not however require a license natural gas technician as a natural gas boiler would. Higher-tech facilities will still require a CO_2 source to maximize productivity which must also be considered.

The key question for northern communities is whether they can gain competitive advantage by using biomass given specific locations, such as being close to mills, pellet facilities and or other enterprises that can provide biomass at a competitive price. Another option is to use biomass-based district heating systems to reduce energy costs.

For small-scale greenhouses, biomass requirements will be minimal and standing wood, can potentially be used as could wood chips or pellets. For larger-scale facilities, although it is possible that standing wood can be used if there is sufficient logging infrastructure nearby, it is most likely that they will need to be located close to operations (mills, industrial facilities etc.) that have the infrastructure to provide large amounts of forest biomass.

In assessing the availability and the potential for utilizing forest biomass as a source of heat for northern greenhouses, it will be extremely location specific as there are large differences in climates, forest biomass and growth rates across the study area which stretches from the Yukon through to Northwestern Ontario and Quebec . Each situation will vary from one community to another and need to be assessed on a case-by-case basis based on site and transport logistics (FPInnovations, 2011). FPInnovations in their 2011 Report recognize the efficiencies of integration with existing pulp and paper mills or sawmills.

In evaluating forest residues available to any one potential greenhouse operation, various resources are available to assist in determining the volume and the recovery costs. One such computer module is the BiOS (Biomass Opportunity and Supply) module available in FPInterface which is recommended for any specific community or group looking at this option.

All the provinces and territories have forestry agreements with First Nations and have policies in place for consultation with aboriginal communities as well as the handling of requests coming forward for the utilization of forest resources (Saskatchewan Ministry of Environment, 2009). As of 2009 Saskatchewan Government had 5 active area-based tenures under licence to Aboriginal owned and/or partnered forest industry businesses which included 25.1% of the commercial Provincial Forest (Saskatchewan Ministry of Environment, 2009). In BC in 2008 there were 145 First Nations with Forestry Agreements (The State of British Columbia's Forests Third Edition, 2010). The importance of aboriginal consultation is highlighted in criterion 6 of the Sustainable Forest Management in Canada document (Canadian Council of Forest Ministers, 2005).

4.4 Competitive Advantages and Limitations

Advantages

A northern greenhouse enterprise can gain a competitive advantage through having access to resources − either human, natural or financial − that competitors do not have. This would include natural resources or man-made infrastructure that provide a northern greenhouse venture with the capability to produce the same products (as competitors) at a lower cost or to produce products that are differentiated by having specific attributes. Access to specific resources (human, natural or financial) also contribute to the long run sustainability of a northern greenhouse venture when it is able to leverage the initial location advantage into developing and growing a core group of loyal customers.

In general the basis for assessing a competitive advantage will be how well access to specific resources contributes to the fundamental business objectives of: gaining an acceptable return on the investment; ensuring the long run survival of the business; and ensuring the business has the capacity to take advantage of opportunities that arise from time to time.

Access to natural resources or man-made infrastructure can provide a northern greenhouse venture with the following capabilities that competitors do not have:

1. A greenhouse venture may have a location advantage through <u>proximity to a market</u> such as a larger population centre or population area, or a camp housing workers involved in resource development. This location advantage can give the greenhouse a cost advantage due to having lower overhead costs or lower shipping costs. As well, proximity to a market can give a greenhouse the capability to better meet the quality expectations of customers compared with competitors who ship products long distances to the market. Proximity to a local market can also give a greenhouse venture the capability to provide services that add value to customers.
2. Access <u>to low-priced inputs</u> such as energy for heating or lighting through biomass or other sources. A northern greenhouse venture that can secure the benefits of reduced energy costs can gain a cost advantage relative to competitors. This cost advantage could in turn provide the greenhouse with the capability to be price competitive. As well, access to a source of low-cost energy may allow a greenhouse venture to adopt production processes to produce products with attributes that provide greater value to end users.

3. Access to lower cost labour or skilled labour relative to competitors can provide a competitive advantage in terms of either price or productivity.
4. Ability to integrate the greenhouse facility with existing infrastructure such as a district heating systems or a community centres. This could allow the enterprise to overcome economies of scale limitations that can constrain the development of a greenhouse business.
5. Being geographically connected to a cluster of input suppliers, transportation services and knowledge-based services can enhance a ventures' capability to capture opportunities while overcoming constraints. For example proximity to a college or a research centre can provide a greenhouse venture with access to new ideas and technologies.
6. Access to a supply chain that has a developed infrastructure can reduce the costs of serving a particular market and enhance a greenhouses' capability to be price competitive.
7. Being located in a region in which government is prepared to take an active role in supporting greenhouse development by providing an enabling environment for start-up enterprise. This could be through financial support as well as research and development activities can provide costs advantages as well as enhanced ability to adapt to changing conditions.

Access to specific resources will not necessarily ensure a competitive advantage without the greenhouse enterprise being able to demonstrate how the resources will provide enhanced capabilities as follows:

1. Does access to certain resources enhance the capabilities of the greenhouse venture to meet the needs of the market relative to competitors?
2. Does access to certain resources provide capital cost advantages that enhances the capability of the greenhouse venture to be price competitive?
3. Does access to certain resources provide operating costs advantages that enhance the ability of the greenhouse venture to be price competitive?
4. Does access to certain resources enhance the capabilities of the greenhouse to produce greenhouse products with specific attributes or services that set it apart from the competition?
5. Does access to certain resources enhance the resilience of the greenhouse and increase its ability to be sustainable over the long-term?

Limitations

The development of a northern greenhouse venture can be constrained by limitations in critical resources. Accordingly, proposals to develop northern greenhouses should be able to demonstrate that limitations have been identified and strategies developed to manage their impact on the viability and sustainability of the enterprise.

Examples of resources limitations with the potential to impact on the development of a northern greenhouse venture could include the following:

1. Lack of understanding on what is involved in starting a greenhouse or growing plants – community members lack the basic understanding of growing requirements, harvesting soil composition and the basic requirements for optimal growing conditions. One community

member the study team met had recently participated in a three week training program on gardening and still had many question about very basic photosynthetic concepts.

2. Lack of skills, knowledge and experience to work in a garden or greenhouse – remote communities do not have access to the same resources and opportunities for skill development. Larger urban centres are able to provide many opportunities for education and training though that does not mean that having northern residents travel to those educational institutions will necessarily be an effective approach. Many of the communities engaged have stories of gardening being popular 30 years ago but very few, if any, are practicing the skills currently. Thus any programming will need to literally build gardening skills from scratch in some communities. Other communities with function market gardens or community greenhouses will be further along and need less support to build their skills to run a commercial greenhouse enterprise.
3. A lack of community support, a lack of leadership and/or weak governance within northern aboriginal communities.
4. Lack of capacity to complete an in-depth feasibility study. The study team has seen a number of "back of the envelope" feasibility studies which can be a good step on the road to assessing the assessing the feasibility of greenhouse production. However a detailed feasibility study is required to support any greenhouse enterprise. The study team, however, visited one community that had recently hired a consultant to research potential greenhouse designs for the community. The consultant's proposal was deemed by the community to be inappropriate (based on proposed location, cost, design, objectives, etc.) and therefore no greenhouse was developed. The funding for the project consequently had to be returned and the project was stopped. This experience increased the scepticism of outside experts being unable to relate to the needs of the community. This will likely increase resistance in the mentality of citizens to be open to guidance and advice from outside experts, which will be a significant barrier to development.
5. Lack of access to sufficient capital to ensure resilience when troubles arise and/or maximize economies of scale in production.
6. Small market size and distance to markets are key barriers to achieving economies of scale which are important for achieving profitability.
7. A viable greenhouse enterprise will require a reliable supply of good quality water. Limitations in the water resource can add costs or have adverse effects on production performance.
8. Soil may be a limiting factor to the development of a greenhouse venture. Ideally a greenhouse will have suitable soil for effective production performance. However if this resource is not available the business will incur added costs for growing medium or for building up the soil quality. An assessment of soil quality will also be critical, as importing quality soil or soil amendment may be necessary for many communities and that cost could drastically increase the cost to operate in remote fly-in communities. Fortunately, many communities have maintained traditional knowledge of soil amendment practices involving fish entrails, which can be used to add nutrients back into the soil, rather than flying in amendments.

5 NORTHERN ABORIGINAL COMMUNITIES AND GREENHOUSE DEVELOPMENT

In examining the question of greenhouse development in northern aboriginal communities, it is necessary to go beyond the questions of technical and financial feasibility and examine:

1. What goals do northern aboriginal communities seek to achieve through greenhouse development?
2. What are the governance and leadership factors in northern aboriginal communities that will lead to successful greenhouse development, and what risks need to be mitigated against?

5.1 Community Visions for Greenhouse Development

Community Vision

Each community will have their own unique visions for greenhouse development over both the short- and long-term. The study team engaged with five communities in northern Saskatchewan and Ontario where they met with both community members and community leaders. Within the five communities' visited by the study team, three main themes were articulated in the community members and leaders visions for greenhouses development in their community:

- Improved health, wellbeing and diet
- Increased affordability of foods and food security
- Increased independence and self sufficiency

The short-term vision for the majority of the communities engaged included a community garden. Their longer-term visions often included youth and elder engagement and mentorship programs, with the end goal of a full scale greenhouse. "Full scale" sometimes referred to a commercial greenhouse, and other times it referred to a full service community greenhouse open to at least part of the public in some form. The long-term visions were usually multifaceted and included increased health in the community, increased self-reliance, and higher employment.

Health and wellbeing was discussed throughout the communities as there was a strong recognition of community health problems related to diet, focusing on diabetes, and the need to change this. In Pinehouse, Saskatchewan, the focus is to create holistic healing initiatives. Tying the greenhouse in with a family healing centre and recovery program is an eventual goal of the community. The perceived challenges are cost and community buy-in. In Buffalo Narrows Saskatchewan, there was interest in a community garden and/or greenhouse so that they can provide healthy fresh food to the daycare and the friendship center. It was also hoped they would also likely purchase from a community greenhouse or community garden.

Affordability of foods was a key topic. In each community, high food prices, as well as quality, were important issues. Many communities wanted to see either reduced vegetable prices (10-20%) to improve affordability or subsidization of vegetables to poorer or food insecure residents. Two communities, Wabigoon and Red Rock in Ontario, referred to their long-term vision of helping other remote First Nations communities with their food health and income challenges. This concept of supporting other Aboriginal communities was frequently mentioned, perhaps due to the timeliness of the Idle No More campaign.

Reclaiming independence and self-sufficiency were key themes within the communities visited. In the communities visited in Saskatchewan there was much discussion of traditions of vegetable production, stemming back to the local missions, which were lost within recent generations. There was also much discussion of reclaiming traditional ways of accessing traditional foods (hunting, trapping, foraging) that had largely been lost in recent generations.

5.2 Business Models

The communities were primarily interested in either non-profit or limited profit models in almost all cases as they all recognized the multiple uses of a greenhouse – reduced food prices, health and wellness, food security, etc. This was true both in meetings with community members as well as meetings with community leadership. There was a large emphasis placed on health and wellbeing by the community and tying this to greenhouse development with recognition of the serious health issues in many First Nations communities.

Profit generation was seen as important but was never the dominant objective of any of the communities the study team spoke with. In the five visits to communities in Saskatchewan and Ontario as part of the study, each of the communities mentioned jobs and occasionally profit in their desired outcomes of the greenhouse, however most of the emphasis was placed on improved health, reduced prices for food and better quality food availability in the community, as well as community involvement and engagement, and youth and elder programs. A break-even or “profitable enough” model that also met other community objectives was the norm. As an example, in Pinehouse, Saskatchewan, there was interest in a greenhouse that was financially self-sustaining, generating at least some profit, but which also served as a wellness centre.

Even when the community and leadership was very focused on operating a successful business, the focus was placed on increased local employment for community members while breaking even at a minimum or making a small profit, although discussing profit ahead of community issues may have not be culturally sensitive or appropriate. This is not to say however profit generation will not or should not be the predominant objective of other communities, EDCs or individual entrepreneurs. It will certainly be much easier for a northern greenhouse, which is not guaranteed of survival let alone profitability, to be viable economically if it is focused solely on profit generation rather than serving multiple goals which will reduce revenue or increase costs and ultimately reduce the resilience of the enterprise.

The majority of communities visited were interested in supplying fresh produce to the locally-owned stores to improve quality, reduce costs and increase self-sufficiency of the community. Most communities are interested in operating a community garden with various programs that can be linked to a greenhouse that breaks even or makes a small profit. The study team's assessment of food quality in the northern communities visited showed much variability. Band-owned stores in road accessible communities had better quality and better priced produce than other retailers.

In the communities visited, there was a high level of interest from various community groups to support a greenhouse and contribute volunteer labour in exchange for fresh food being provided. This is definitely a model that interests many remote First Nations communities. This model would build food security with labour being exchanged for food vouchers which would support poorer members of the community who have the greatest food needs.

The study team also found existing food non-profit models in at least one community it visited. In Kitchenuhmaykoosib Inninuwig, Ontario, there is an existing market garden run by the Band. Potatoes grown by the Band have been shared and distributed freely for so long that the Band councillors fear that people may resist paying for the potatoes. The councillors stated this as a reason that a greenhouse should maybe not focus on potatoes or onions or carrots because the community is used to receiving those for free. This belief was not universal as the study team did meet community members in KI who believed that people will easily pay for potatoes and the community will continue to support those that cannot afford to purchase them. One community member was already selling his garden potatoes for five dollars a bag (half the store price) and did not find any resistance in the community to purchasing vegetables.

5.3 Governance and Leadership

In order to develop sustainable commercial greenhouse enterprises in northern aboriginal communities, both leadership and governance factors supporting economic development must be in place. There are many factors which can cause enterprises in aboriginal communities to fail so it is necessary to assess both what factors will lead to success as well as what factors may inhibit greenhouse development.

Governance

Before assessing the champions and leaders within the communities, it is important to consider First Nations governance systems as context. The Harvard Project on American Indian Economic Development (http://hpaied.org) is a research project that aims to explain why American Indian tribes differ in their economic development strategies and in the outcomes of those strategies, and to discover what it takes for self-determined economic development to be successful. Research from the Harvard Project essentially finds that the problem of poverty in American Indian communities stems from political problems, rather than economic problems.

The research lists the following as potential obstacles to development for American first nations groups:

- Tribes and individuals lack access to financial capital.
- Tribes and individuals lack human capital (education, skills, technical expertise) and the means to develop it.
- Reservations lack effective planning.

- Reservations are subject to too much planning and not enough action.
- Reservations are poor in natural resources.
- Reservations have natural resources, but lack sufficient control over them.
- Reservations are disadvantaged by their distance from markets and the high costs of transportation.
- Tribes cannot persuade investors to locate on reservations because of intense competition from non-Indian communities.
- Federal and state policies are counterproductive and/or discriminatory.
- The Bureau of Indian Affairs is inept, corrupt, and/or uninterested in reservation development.
- Non-Indian outsiders control or confound tribal decision making.
- Tribes have unworkable and/or externally imposed systems of government.
- Tribal politicians and bureaucrats are inept or corrupt.
- On-reservation factionalism destroys stability in tribal decisions.
- The instability of tribal government keeps outsiders from investing.
- Reservation savings rates are low.
- Entrepreneurial skills and experience are scarce.
- Non-Indian management techniques won't work on the reservation.
- Non-Indian management techniques will work, but are absent.
- Tribal cultures get in the way.
- The long-term effects of racism have undermined tribal self-confidence.
- Alcoholism and other social problems are destroying tribes' human capital.

There are challenges with the current system of governance for Canadian First Nations. Because there is limited employment in most remote First Nations communities, municipal employment is highly valued. Also, individual Bands work to provide municipal and provincial-level services, and therefore require more staff than non-First Nations communities.

When elections take place, often every two years, and a new council is elected, there is often high turnover in administrative services as well since the new council wants to support their networks and provide employment to friends and family. In many communities this has become common practice. This turnover in administrative staff further politicizes the Band Office. Any projects that are being managed by the Band Office will be delayed due to the turnover, but projects may also change direction if the new leadership has different objectives.

Researchers on the Harvard Project consistently find that there are three factors to successful economic development in American Indian communities:

1. Communities with culturally appropriate institutions that can provide the community with:
    - Fair dispute resolution - for example, tribes that keep their dispute resolution mechanisms distinct from politics and safe from political influence experience an employment rate five percent higher than tribes that do not (Jorgensen & Jonathan, 2005).

- Distinct business and government institutions - enterprises whose management is distinct from elected officials have a seven-to-one chance of profitability, whereas enterprises where elected leaders participate in management face odds of just above one-to-one (Jorgensen & Jonathan, 2005).
- Effective administration to provide legitimacy.

2. Communities who make their own decisions about economic development strategies consistently out-perform those communities with external decision-makers.
3. Culturally appropriate governance of a community contributes to its success in economic development.

As part of this separation of business and politics, it is important that the leadership for the project not be influenced by political budgets, constraints or issues (Cornell, 1998). A clear division of responsibilities is important for effective business operations. Operating a council-controlled business makes the division of responsibilities less clear by imposing political agendas onto the priorities of the business. Once a Band starts to operate their businesses independently of the Band, often forming an EDC, the business can operate with the business's best interests in mind. The chances of being profitable rise by 400% when the business is separated and protected from political interference with day-to-day operations (Cornell and Kalt, 1998).

Communities with EDCs or economic development departments operating independently from the politics of Band Councils will be better equipped to deal with succession planning as they make independent decisions based on the needs of the business, whereas communities with internal economic development bodies will be very heavily influenced by the political election cycle.

To ensure long-term commitment, it is also recommended to look for champions and leaders that are not part of the municipal staff. Developing a greenhouse enterprise may require long hours beyond what can be expected from an employee. With their own "skin in the game," entrepreneurs are more likely to have the determination to ensure that the business both survives and succeeds. Thus local entrepreneurs will provide the best long-term commitment and succession options, as they are motivated to see the project through to completion. Committed citizens will also place a longer-term perspective on planning than one driven by shorter-term political processes and election cycles. Once a champion or a set of champions have been determined, a succession plan and long-term success of that plan can be considered. Until then it will be difficult to ensure commitment from community members. Long-term planning with municipal representatives can be particularly challenging as there is often high turnover with elections.

The Harvard Project research has also shown that initiatives started based on a need for employment creation have a high rate of failure and are not sustainable, whereas enterprises based on an interest to operate profitably have a much higher rate of success, profitability and sustainability (Jorgensen & Jonathan, 2005). If an enterprise is cautious of their profitability the employment will be created and sustained naturally.

For communities interested in a greenhouse enterprise, profitability should be the dominant objective, with job creation as a desired outcome, rather than the other way around. However, placing a high importance on the members of the community is a norm for many First Nations cultures, therefore job creation is likely to be listed as a top priority for many communities interested in a greenhouse project. Consequently, communities placing a large focus on job creation must demonstrate a strong plan for profitability and a realistic expectation for employment creation to ensure that there is understanding of the importance of profitability and an ability to sustain the enterprise profitably.

Leadership

Leadership within a community can take on several forms. It can exist in civic or political leadership but it may also exist at the citizen level. It may be found within groups or single individuals. There are single Chiefs and political leaders that want to make sure their community succeeds and there are also teams of civic leaders that want to make sure their community succeeds. What is important are the characteristics of the leadership, a commitment to see the project through to the end, willingness to personally invest, and to incur risk. Having commitment to a project is a factor that is much more likely to contribute to project success than particular skills and prior experience. Also, a champion for one type of project may not necessarily be able to successfully champion a different type of project. It is important that the group or individual have high levels of personal motivation to complete that specific project successfully.

There are always individuals in a community who are high achievers and are able to accomplish much in a short time. These individuals are excellent for initiating projects (start-up champions), however they often have so many tasks running concurrently (as they are known in the community to be high achievers) that they seldom have the capacity or even motivation to complete large or long-term projects.

No matter where the project leadership comes from within the community, it is important that civic leadership, the Band council and the Chief be approached and consulted first. It is equally important that the rest of the community be engaged throughout the entire process as well to ensure buy-in from the community.

If the majority of the engagement and commitment for a community project comes from external sources, or is only from civic leadership, then the project is less likely to succeed. Civic and political leadership is usually able to accomplish much for short-term projects, whereas motivated citizens are likely to endure the turnover during elections and therefore maintain more continuity in the project development.

To ensure that there is strong long-term community leadership to champion a greenhouse project:

- Start the project with a committed group or individual within the community and ensure that they are dedicated to the project to see it through to completion and to commit and incur risk.
- Gain support and backing from respected civic and political leadership in the community, which will enable governance decisions to be supported and passed.

- Support the champion with the knowledge of resources, skills training, and partnerships they will need.

A model that has had great success with empowering local people to take on long-term sustainable initiatives is the enterprise facilitation model for economic development, used by the Ernesto Sirolli Institute (www.sirolli.com). Enterprise facilitation uses a grassroots approach where the facilitator finds local individuals with ideas they are committed to and supports them by connecting the individuals to additional resources. The advantages of this approach are that the champion will be self-motivated and have reason to complete the project for themselves. It will be much more likely to succeed and sustain a long-term. The disadvantage of this approach is that it is a slow process to find the leadership for the project and to then customize a tailored set of resources.

6 MARKETING

6.1 Market Demand

Greenhouse enterprises must naturally be market-driven and produce the vegetables demanded by their market, with the same time understanding the profitability of different crops. This market demand will be dependent upon location and populations. The appropriate size for a local greenhouse will in turn be shaped by expected productivity levels in the greenhouse system and the expected per capita consumption of the vegetables produced.

The current consumption patterns of individual communities and markets along with estimates of per capita consumption are likely to be unique and can only be understood through some assessment of consumption patterns and the factors that might lead to adjustments in the demand estimates for individual products. Key areas of inquiry for individual greenhouse enterprises will include:

1. Average weekly expenditures on different food groups.
2. What vegetables are consumed and in what quantity.
3. Identifying factors influencing food choices.
4. Factors that might prevent consumers from purchasing more local food.
5. Whether lower priced vegetables (10 – 20% was frequently mentioned in communities) will stimulate demand and to what degree.
6. Whether there is a willingness to pay a premium for locally-produced food over imported food products.
7. Whether there is a foundation of personal involvement in food production on which to build a local food system involving a greenhouse.
8. The social and cultural importance of traditional foods in the target market as well as the nutritional role of these foods in the diets of consumers.

The following table details estimated demand in the Yukon compared to USDA estimates for consumption of fresh vegetables. It is interesting to note the differences are not large indicating high demand for vegetables in certain areas in the study's zone, such as the Yukon, which may have a higher non-aboriginal population and existing patterns and traditions of agricultural production.

Table 24: Per Capita Consumption of Selected Vegetables, Yukon (2008 – 2012) and USDA (2011)

Greenhouse Vegetable Consumption (kg per capita)	Yukon Estimates of Per Capita Consumption	USDA Estimates of Per Capita Consumption
Peppers	3.23	4.5
Tomatoes	8.3	9.5
Cucumbers	4.24	3.1
Lettuce	11.05	7.3

Source: Multi Year Development Plan for Yukon Agriculture and Agri-Food, 2008-2012; USDA website

Per capita consumption of fresh vegetables in more urban areas may be similar to the above estimates. In larger centres, or in areas with a larger percentage of southerners living in the north, a wider range and higher volume of vegetables can be sold per person. This also includes mining or oil sands camps for which market demand will more closely mirror Canadian or provincial/territorial averages for vegetables. This level of market demand will create at least some minimal economies of scale that can enable the development of somewhat larger-sized greenhouses, as compared to small-scale greenhouses.

Despite this the very small populations in cities in the north (as well as the regions surrounding them), which are very dispersed, will put major limits on market demand for individual greenhouses. This will inhibit greenhouses from achieving economies of scale in many cases. Even for the largest population centres and areas in the north, populations are small overall compared to similar areas in Europe at northern latitudes with greenhouse vegetable industries. For instance in Finland and Sweden, greenhouse industries exist at high latitudes but they crucially serve much larger, much less dispersed population bases. This allows larger greenhouses to achieve crucial economies of scale in production. The greenhouse industries in these locations also exist within at least partially marine climates which reduce heating needs compared to northern Canada.

Per capita consumption in more remote First Nations communities will likely be shaped by local economic, social and cultural factors. Within the field visits completed, the foods consumed in the engaged communities were relatively high in meats and starches, based on the food served in restaurants, sold in stores and witnessing what locals were purchasing and eating. Since the quality of the produce is usually lower than average and the cost is high, it is not expected that there would be high demand for produce in remote northern communities. The most popular vegetables were primarily root crops (potatoes, onions, carrots) as well vegetables suited for greenhouse production such as peppers and tomatoes. Many residents stated meat, pasta, rice and potato as staples. Other foods are considered side dishes and are less essential. The stores are more heavily stocked than average with potatoes, rice, pastas, breads, as well as crackers and chips. Interestingly, it was commented in many locations that previous traditions of vegetable production that often accompanied local missions had been lost during the past 40 years.

Research undertaken in northern communities also sheds some light on potential demand for vegetables in some northern communities, although it should be cautioned that there may be differences between more remote communities in the arctic/sub-arctic and more southerly ones with more amenable climates and traditions of vegetable production and consumption.

Lawn and Harvey (2002) ran a month-long food survey on 95 households in the Inuit community of Kangiqsujuaq in Nunavik, Quebec. The fresh and frozen vegetables that were most purchased were French fries (by 85% of households), carrots (82%), onions (79%) and then fresh potatoes (75%). The majority of fruits and vegetables were rated as poor quality which was listed as by 30% as a barrier to consumption. Cost (71%), availability (51%) and lack of variety (33%) were also listed as major barriers to purchasing more of these foods. The average consumption of fruits and vegetables was 2-3 servings per day against the 7-10 servings recommended in the Canadian nutritional recommendations.

The diets of three Inuit communities in Nunavut were studied in 2010 and the results uncovered that the diets had transitioned to a higher consumption of non-nutrient-dense foods and lower consumption of traditional foods and fruits and vegetables (Sharma, 2010). In the three communities studied, low income and unemployed populations consumed a large percentage of their diet from non-nutrient dense foods.

An increase in employment and income was associated with a tendency towards more traditional foods. However, increased education was associated with a reduced consumption of traditional foods but an increased consumption of fruits and vegetables (Sharma, 2010), therefore a community with a highly educated population may have a higher chance of success with community engagement and buy-in around a community greenhouse.

Also, food insecurity has been linked to lower consumption of fruits and vegetables, meaning that when there is anxiety about whether or not there will be food to eat, the consumer will be more likely to stock up on non-nutritionally dense foods rather than fruits and vegetables (Lawn and Harvey, 2004). This means that a community struggling with high levels of food insecurity will not be a great target market for a greenhouse and will therefore need to increase food security and the perception of food security within the community before they can fully reap the health and diet benefits of a greenhouse throughout the entire community.

There is also a key question that if vegetables were subsidized to certain community members, or sold at 10-20% less than retail prices as was mentioned in a number of communities that the study team visited, would demand for vegetables increase? This topic will need to be addressed but it is important to note that any plans for subsidization will decrease the sustainability of the greenhouse enterprise and will need to be accounted for in any feasibility or economic assessment. A northern greenhouse enterprise is certainly not guaranteed to make money and reducing revenue will have impacts on its sustainability and ability to survive any shocks such as crop failure.

If food insecurity is due to limited variety, availability or low quality of produce this may be reduced or solved through a greenhouse. However, if the food insecurity is due to the unaffordability of foods or due to a large percentage of the population having low-income or being unemployed, these barriers will be more challenging to conquer.

Dietary Change and Culture

Regarding the introduction of new foods, aboriginal cultures tend to place a strong emphasis on the community as a whole and as a collective. Therefore healthy foods grown in the community will be seen as benefiting the whole community and the produce will likely be shared amongst the community. If healthy foods from a greenhouse are accepted by those that are well respected in the community, acceptance and buy-in will spread much faster. If foods are brought in to the community from an outsider, it will be very challenging to introduce the new foods and to achieve acceptance.

It is very important the new foods are selected from within the culture and introduced from within the culture. Any introduction of new foods coming from outside the community members is likely to encounter more resistance and reduced likelihood of long-term success. This resistance stems from historical patterns and beliefs around imposed changes to Aboriginal diets by non-Aboriginal groups, and the associated health implications. One example that is frequently referred to is the introduction of sugar to the Aboriginal diet.

Once new foods are introduced, programming will be needed to support the uptake and acceptance of the foods. New foods will be unknown which means even if citizens have the desire and motivation to eat healthier, these foods will not yet be part of routines and individuals won't know how to use them, cook them, or eat them. They will have a lack of recipes, a lack of nutritional knowledge and a lack of awareness around why they should eat them.

Perceived beliefs about nutrition will also need programming to discourage. For example, the belief that meat and potatoes are healthier since they can be harvested and hunted locally from the land regardless of the methods used to cook them. Also, there has been a pattern of poor quality produce being available in local stores for an extended period of time. This pattern will likely have reinforced that the fruits and vegetables lack flavour and appeal and will take significant efforts to undo those reinforced beliefs. To reengage citizens it will be important for them to have opportunities to try the new more flavourful varieties in an attempt to break the current pattern of avoidance.

6.2 Market Opportunities

Local or Regional Markets

There are a number of different market opportunities available for northern greenhouses. The most obvious one is to sell within the local community or the region depending on the size of greenhouse. This will include retail and/or wholesale sales depending on the size of the greenhouse. Larger-scale greenhouses will have to sell most of their vegetables at the wholesale level while smaller-scale greenhouses can sell predominantly to the retail market in their community. For mid-sized greenhouses, a split of wholesale and retail sales will most likely be viable.

Opportunities will also be location specific. In certain areas such as the Yukon and the NWT around larger centres, there are opportunities to capture higher-revenues through sales at farmer's markets or at the greenhouse itself to high income consumers, or at least consumers willing to pay higher prices for locally produced or organic products. In more remote communities it is highly doubtful that this would be possible.

For many communities, there is interest in selling vegetables through band owned stores which is a logical market outlet. There are also opportunities in selling produce to the Northern Stores operated by the Northwest Company which is the largest retailer in the north although an investigation would need to be taken of wholesale pricing with the company. Northwest Company representatives indicated they are very open to selling locally produced vegetables and have done this in the past, albeit on a limited basis, where it has been possible.

A key strategy adopted by small-scale greenhouses currently operating in northern regions is producing a variety of crops often in conjunction with an outside garden. This allows the enterprise to offer a wider range of products to consumers directly as well as supply local retailers with specific crops. This strategy may be necessary for the owner operator of a small-scale greenhouse venture to attain economies that provide a reasonable return to their investment of capital and labour.

A further opportunity for a northern greenhouse venture may be contributing to an integrated food system. Rather than operating as a standalone business dependent on markets, the greenhouse is supported by the personal involvement of community members. In return the community gains social and health benefits through greater access to food choices.

Other market opportunities

The viability and sustainability of a northern greenhouse venture can also be determined by identifying and realizing unique market opportunities. These market opportunities, some niche and some less so, for a northern greenhouse venture could include:

- Bedding plants for community gardens and home gardeners.
- Outdoor market gardens
- Contract production of tree seedlings for reforestation or land reclamation activities.
- Native species for environmental remediation.
- Medicinal herbs and other native plants for local consumption.
- Contract production of vegetables for industrial camps associated with resource development.
- Vegetable production to be marketed through a roadside stand located on a major highway with significant tourist traffic (Trans Canada in NW Ontario etc.).
- Partnerships with schools where the greenhouse provides a training facility.

These market opportunities can fall into one of three categories:

1. They be a greenhouse enterprise on their own.
2. They can be a stepping stone to greenhouse production as community members gain the skills in greenhouse production (bedding plants, trees seedling etc.).
3. They can provide a northern greenhouse enterprise the opportunity to attain economies of scale that can help it profit and survive. This provides an opportunity to reduce costs and includes the potential to subsidize food production for the community although this would have to depend on profitability.

Although Canada-wide data is not available, Chaudhury's (2011) assessment of the Alberta greenhouse industry shows much higher returns to bedding plant and ornamentals than to greenhouse vegetables. Bedding plants are a very large market on their own as greenhouse vegetables only account for approximately half of greenhouse production in Canada.

Figure 9: Gross Margin ($) per m² for Alberta Greenhouse Producers

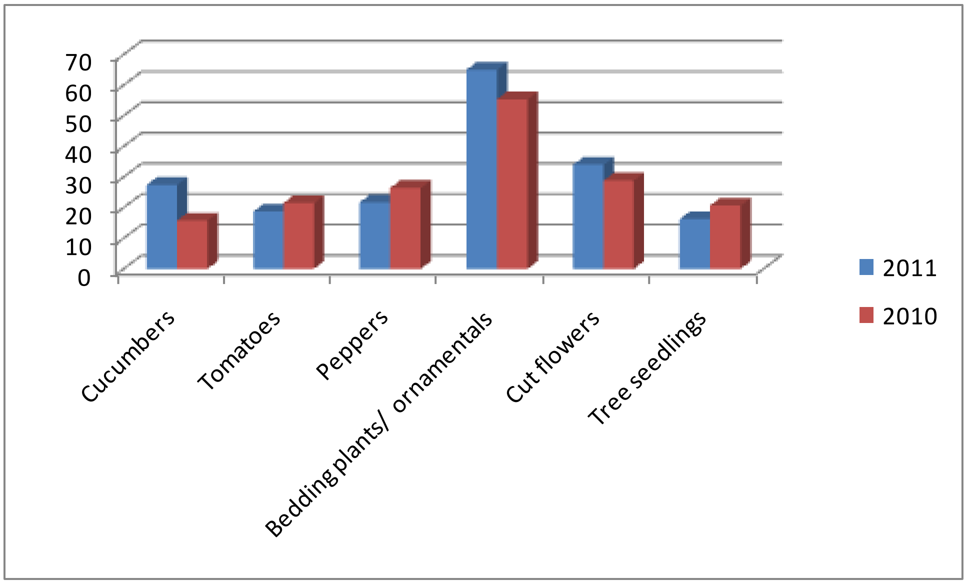
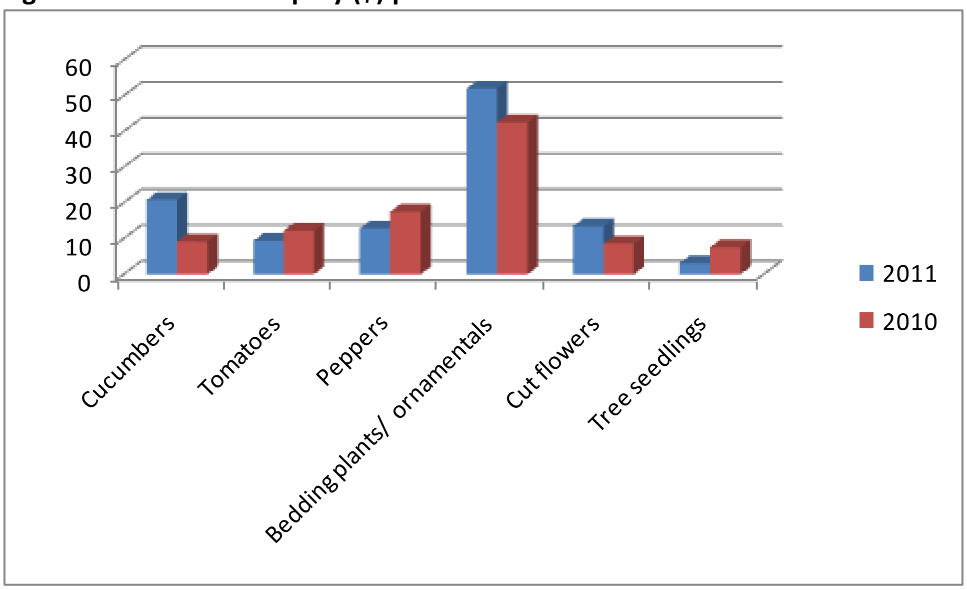


Figure 10: Return to Equity ($) per m² for Alberta Greenhouse Producers



This data fits with what was observed by the study team in interviews and discussions with existing commercial greenhouses in the north (Yukon, northern Saskatchewan, northern Manitoba, northern Ontario). The vast majority of existing commercial greenhouses in the north utilize bedding plants as their primary business at present. Some have now begun to branch out into vegetable production as their skills have increased with greenhouse production. This is an option that should be reviewed by all potential greenhouse enterprises.

Although not a market for a greenhouse itself, combining a greenhouse with an outdoor market garden makes tremendous sense for a greenhouse enterprise. This would allow production of a variety of products, including roots crops which are most popular in the north. This is another strategy utilized by most greenhouse growers in the north.

Although it is very location specific, there is interest from both mining and oil sands companies with large camps to purchase products, such as greenhouse vegetables, from First Nations Communities or even partner with them in a greenhouse enterprise. Some communities even have agreements with nearby industry, which provides them with the first right of refusal to partnerships. For example, Pinehouse, Saskatchewan recently signed an agreement with Cameco that contains a "same cost" clause, guaranteeing Pinehouse any contracts for products and services they can provide at the same price as existing contractors.

In the area of tree seedlings, the Wabigoon Lake Ojibway Nation has a production contract to produce Black Spruce seedlings required in the reforestation work of a near by mill. In this arrangement the mill provides the seed and agrees to purchase a set number of seedlings at an agreed upon price. This reduces operating capital requirements and guarantees a market for production.

There are also a number of examples in BC of First Nations Communities working on contract with mining companies to provide native species for environmental remediation. The study team is also aware of an EDC from a Saskatchewan First Nations community that was potentially buying an environmental remediation company-based in Saskatoon. This could allow the community to have some members build their skills with greenhouse production outside of the community, which they could then utilize within the community at another time almost as an apprenticeship type arrangement.

6.3 Marketing

Food Safety

Food safety is a key marketing component that is increasingly important for the consumer and an important element of greenhouse operations. The prevention of the product's contamination is the only way to minimize the risks and to achieve healthiness and food safety, so the systems that provide food safety are based in prevention programs of good practices during the production and processing of the food.

The Canadagap Food Safety Manual for Greenhouse Products documents food safety practices for greenhouse enterprises.[4] Greenhouse activities can have biological, chemical and physical hazards that adversely affect human health. The documented practices are to ensure that the production, harvesting and handling activities of greenhouses minimize any hazards or contamination that could threaten food safety and human health.

Implementing practices that ensure food safety will have economic costs. Capital costs could include the following:

4 *www.canadagap.ca/uploads/file/English/Manuals/Version%206.1%20Updates/Greenhouse/Greenhouse%20Manual%206.1%202013.pdf*

- Capital investment to ensure that food handling areas are designed to be kept safe, clean and sanitary.
- Capital investment to ensure that greenhouse equipment does not present a hazard to workers or the potential for contamination of greenhouse products.
- Investment in proper storage for chemicals, fertilizers and soil amendments.
- Investment to ensure the systems for handling fertilizer and chemicals can be easily cleaned and maintained. As well, investments to ensure these systems are designed to prevent contamination of food products by chemicals and fertilizers.
- Facilities to ensure the personal hygiene of greenhouse workers.
- Infrastructure to support the disposal of compostable materials, garbage and recyclables.
- Equipment and systems to control pests.
- Investment in proper storage for greenhouse products.
- Investment in proper containers and vehicles for transporting products to markets.
- Capital investment that may be required to develop the greenhouse site including protective barriers to prevent contamination from runoff.
- Capital investment may be required to prevent contamination of the water supply.
- Investment to ensure hand held tools are kept clean.
- Investment in proper storage facilities to ensure there is no contamination of packaging materials.

Potential operating costs required to support food safety include the following:

- Costs associated with training greenhouse workers in biosecurity measures and food safety practices.
- Costs associated with training and managing the packaging of greenhouse products to ensure proper packaging is used and contamination is minimized.
- Costs required to regularly clean greenhouse equipment and facilities.
- Costs associated with developing and managing visitor protocols.
- Costs associated with developing and implementing an effective traceability system.
- Costs associated with regular food safety audits by a qualified third party.
- Costs associated with testing for potential hazards in the soil and water to be used in the greenhouse production systems as well as in the greenhouse cleaning activities.
- Costs of regularly calibrating equipment used in the growing system.
- Costs of regularly cleaning the personal hygiene facilities used by greenhouse workers.

Packaging

For a greenhouse enterprise, the key functions of packaging include containing and protecting greenhouse vegetables during handling and transportation as well as labelling and presenting the freshness of the locally grown product. A further function of packaging could be providing the greenhouse vegetables in a form that provides convenience or added value to the end user. For example recyclable packaging could allow a greenhouse enterprise to meet the expectations of consumers seeking to be environmentally responsible in their food purchases. Packaging is also a means of supporting a marketing strategy such as differentiating greenhouse vegetables from conventionally grown vegetables or differentiating the locally grown product from others.

Northern greenhouses will need to choose a packaging strategy that combines these functions to best meet the specific requirements of the end users in the different target markets, and to connect the greenhouse to the end user. Different target markets and their packaging requirements may include:

- Industrial lodges (camps) which operate institutional kitchens, will have requirements for large packaging, containers that are stackable (to save space) and features that align with their handling and cooking processes. As well, the size of the packaging should be consistent with the size and weights used in this wholesale market so buyers are able to make price comparisons of equivalent amounts.
- Packaging for wholesalers and retailers will have requirements for elements such as size, appearance and labelling that supports name recognition. Packaging may be a key element in an overall marketing strategy focused on locally grown fresh produce and putting a face to the grower who is prepared to stand behind the product. In this market channel the end user will be the consumer who will have needs related to convenient sizes (three packs of tomatoes or peppers for example), freshness, being able to see the production they are purchasing and some indication of freshness.
- Retailers may have more than one packaging requirement. This would include specialty packages of mixed vegetable such as vegetable trays or some partially prepared products such as a salad. In these cases the packaging may need to align with some additional handling by the retailer. A trend among retailers is to have their own private label on packaged greenhouse vegetables. In this case northern greenhouses may have to concede their own branding initiatives in order to gain shelf space for their product.

Distribution

The opportunity for northern greenhouses is to market locally-produced greenhouse vegetables to a growing market in the nearby region. Distribution channels will be the primary means of ensuring physical delivery to consumers and making sure end users gain maximum value from the greenhouse vegetables. Distributions channels will also affect the pricing, transportation and storage of the greenhouse vegetables as well as cash flow performance and risk exposure of the greenhouse business.

The primary objective in choosing a distribution channel is ensuring that end users have the right product at the right time in the right place in the right form. Other functions to be considered include gathering intelligence on market forces and changing consumer behaviour, connecting with new buyers, negotiating prices and terms, as well as meeting the specific needs of individual buyers. Accordingly, the decisions related to the choice of distribution channel should consider not only how the vegetables are going to reach the target market but also how the choice of distribution channel will affect economic performance, control over the marketing of the greenhouse vegetables and the ability to adapt to changing market conditions.

6 MARKETING

The distribution system for a northern greenhouse venture would need to be able to meet the requirements of a range of buyers including end users such as consumers and the lodges housing industrial workers in the region as well as wholesalers, retailers, and institutions. This may include direct selling by the enterprise which will entail significant efforts, developing a system of intermediaries to meet the buyer's needs, or a combination of the two depending on the market the greenhouse is selling into.

7 ECONOMICS

This study has developed a series of financial models for a range of greenhouse systems that could be developed within the identified study zone. These greenhouse systems and the different variations modeled are identified in the following table.

Table 28: Type of Greenhouse Systems Modeled

<table>
<tr><th>Type of Greenhouse</th><th>Size</th><th>Details</th></tr>
<tr><td>High-tunnel style greenhouse</td><td>278m^2 (3,000ft^2– approximately 30ft by 100ft) as base case with expansion up to 1,394m^2</td><td>Small-scale low-cost, low-tech greenhouse producing crops 4 – 6 months per year.</td></tr>
<tr><td>Stand-alone greenhouse</td><td>278m^2 (3,000ft^2– approximately 30ft by 100ft) as base case with expansion up to 1,394m^2</td><td>Small-scale, higher-level of technology in design and structure producing crops 8 – 10 months per year.</td></tr>
<tr><td rowspan="4">Gutter-connected greenhouse</td><td rowspan="2">12,140 m^2 (3 acres)</td><td>Larger-scale high-tech greenhouse operating year-round with grow lights</td></tr>
<tr><td>Larger-scale high-tech greenhouse operating 9 – 10 months per year with no grow lights.</td></tr>
<tr><td rowspan="2">2,023m^2 (half-acre)</td><td>Smaller-scale high-tech greenhouse operating year-round with grow lights</td></tr>
<tr><td>Smaller-scale high-tech greenhouse operating 9 – 10 months per year with no grow lights.</td></tr>
<tr><td>Chinese-style solar greenhouse</td><td>150m^2 (1,600ft^2 – approximately 30ft by 50ft)</td><td>Small-scale passive solar design producing crops 7 – 8 months per year.</td></tr>
</table>

The greenhouse models investigate:

1. The net returns for different technologies ranging from low-cost, low-tech, small-scale greenhouses to higher cost, higher-tech greenhouses.
2. The net returns for both small and large market opportunities (i.e., returns to scale).
3. The net returns for systems able to produce year-round versus seasonal production.

The different greenhouse systems and scale of operations can reflect either an end game for a greenhouse enterprise or an intermediate step in a long-term development process. The following chart illustrates a development ladder that might apply to vegetable production in northern communities.

	Development Ladder of Incremental Scale and Complexity of Northern Vegetable Production Systems			
	Market Garden	**High-Tunnel Greenhouse**	**Stand-Alone Greenhouse**	**Gutter-Connected Greenhouse**
Physical Characteristics	Outdoors with no protection from the environment. Generally used to produce root crops.	Single layer of poly on widely spaced light weight steel frame. Cheap and easy to build. Soil based growing system.	Engineered structure with double-poly covering. Much variability as can be lower-tech and grow in soil or utilize similar technologies as gutter-connected greenhouse.	Engineered straight wall structure with controlled environment and mechanized growing and handling systems.
Business Focus	Direct sales at garden site or through farmer's markets.	Market focus remains direct sales to consumers. Grower can capture price premiums by having market ready vegetables earlier in spring and later in fall.	Can market directly to consumers as well as to wholesale markets. Market size will be a key factor in determining appropriate size of operation.	Focus on being a reliable and consistent supplier to retailers and wholesalers. Market size will be the key determinant of greenhouse scale.
Production	Production of root crops and hardy vegetables suitable for outdoor growing season.	Structure used to complement a market garden through a wider range of crops including bedding plants and ornamentals.	Can have ability to produce year-round by starting seedlings in January. As well the structure allows for supporting vining crops such as English cucumbers.	Specialized production focused on tomatoes, cucumbers, lettuce and possibly peppers.
Labour	Generally an owner operator along with family labour	Owner operator along with spouse and family labour. Does require a wider range of skills including production, marketing and business capabilities.	Hired labour may become necessary depending on scale of operations. Recruiting, training and retaining productive workers can be a key challenge.	Mechanized systems can reduce labour requirements. However, qualified growers and greenhouse workers are needed to consistently achieve acceptable levels of production. Housing for a qualified grower may be a critical limitation in northern communities.

7.1 Key Variables within the Enterprise Budgets

The financial models are based on estimated ranges (low/mid/high) for critical economic variables affecting the costs and revenues of each greenhouse system. These estimates are derived from existing research, quotes and data from input suppliers, price data from wholesale and retail sources, and discussions with greenhouse experts including those on the study team and the AAFC working group. Ranges of capital costs have been extrapolated from quotations from suppliers for full systems as well as a recently costed and commissioned model in the case of the Chinese solar greenhouse model. Since costs and revenues will vary by location, in-depth studies of these economic variables will be needed to properly assess the feasibility of a specific greenhouse venture proposal in any given location.

There are six key variables that have been determined to have the greatest effect on the economic/financial performance of a northern greenhouse venture. These six factors are:

1. Matching greenhouse size to market size
2. The crops grown
3. Crop productivity and marketable production
4. Market prices achieved for the marketable production
5. Energy use and costs
6. Labour use and costs

Matching greenhouse size to market size

Market size will determine the appropriate scale of operations and shape economic performance. Generally the products of greenhouse enterprises in northern regions will have to be consumed in local or in near-by markets that can be accessed without incurring high costs. Small populations and small-scale markets will limit the ability of the enterprise to spread capital costs over higher levels of production. As well, small-scale markets and the corresponding small-scale of operations can limit the withdrawals owner/operators might make in return for their contribution of management and labour. Population statistics for the three northern territories can provide some context for the issue of matching greenhouse size to market size.

Table 29: Population of Northern Territories and Centres

Territory/Major Center	2006	2011
Yukon	30,372	33,897
• Dawson	1,319	1,327
• Whitehorse	20,562	18,141
Northwest Territories	41,464	41,462
• Yellowknife	17,863	18,352
• Hay River	2,874	2,866
• Inuvik	3,479	3,403
Nunavut	29,474	31,906
• Iqaluit	4,796	6,254
• Rankin Inlet	2,358	2,266

Source: Statistics Canada Census Profile

The economic viability of a northern greenhouse venture will hinge on having an effective balance between greenhouse production and local consumption. Although consumption levels in individual markets cannot be known with certainty, the following estimates of per capita consumption of greenhouse vegetables can be used as rough guidelines for assessing whether there is sufficient market size to support a new greenhouse venture. These estimates are derived from earlier investigations and USDA data (USDA/Economic Research Service, February 2012; Serecon Management Consulting, December 2007). It should be recognized that the low end of these estimates may be unrealistically high for more remote communities particularly in the initial years of greenhouse operation. It may be necessary for small greenhouses in more remote communities to develop strategies for increasing the market size or for having patient capital to allow for local consumption to increase over time as fresh vegetables become more consistently available.

Table 30: Range of Estimated Per Capita Vegetable Consumption

Per Capita Consumption Estimates	Low	Mid-Point	High
Tomatoes (kg/person/year)	7.5	8.5	9.5
Cucumbers (Units/person/year)	14	15	16
Peppers (kg/person/year)	3	4	5
Lettuce (kg/person/year)	10	11.5	13

Crops grown

The controlled environment conditions of greenhouse facilities make it technically feasible to grow a wide range of vegetable crops year-round in northern regions. However, four crops - tomatoes, cucumbers, peppers and lettuce - dominate the greenhouse vegetable sector worldwide as they provide the highest revenue per square foot and are generally very popular. These crops have been chosen for modeling purposes within the financial models. Related niche products such as mini-cucumbers and different varieties of hot peppers also command high prices and strong revenue in most instances. It should also be noted that greenhouses which grow a wide variety of crops without segmentation will likely receive lower productivity and revenues.

Crop productivity and marketable production

Productivity performance will be a critical factor in the economic/financial performance of a northern greenhouse enterprise. Productivity levels (output per square meter) will vary according to the type of structure and growing system as well as local conditions, technical knowledge and growing experience.

Generally, productivity levels for a simple high-tunnel greenhouse will be lower than for the other systems due to: 1) a lack of environmental controls; 2) the short growing season; and 3) growing crops or varieties suited for high-tunnel conditions that have lower productivity levels than those suited for higher-tech greenhouses. The production levels used in the models are based on practical knowledge gained from individuals with considerable experience in operating high-tunnel greenhouse systems in the northern prairies.

There is very little available information or data on productivity levels for Chinese-style solar greenhouse in northern conditions. The projections in the financial models are based on achieving 65% of the production performance achieved by gutter-connected greenhouses. These estimates could be qualified as optimistic due to uncertainty surrounding the design of this system and how it might perform in extreme conditions. Of note is that the design of the greenhouse will create a lack of uniformity in growing conditions with more light at the front and less light in back. This can in turn create temperature stratification in the growing area. The productivity estimates do assume that a modern raised gutter soilless system is used to maximize productive capabilities. However, another area of uncertainty is whether Chinese solar greenhouses can hold the weight of these systems within their roof trusses. These issues would need to be thoroughly assessed along with expected productivity performance in individual feasibility studies. Individuals considering an investment in this type of system would be wise to explore the consequences of productivity levels that are much lower than those used in the financial models.

There is considerable variability in the design of stand-alone greenhouses as well as in the types of environmental control systems and growing systems used in them. Accordingly, this type of system is likely to have the greatest range in capital costs, production performance, growing costs, energy costs, labour costs and overall economic performance. The financial models have incorporated productivity levels that generally range from well below gutter-connected systems to close to gutter-connected systems at the high end. The stand-alone greenhouse is assumed in the analysis to operate for 8-10 months per year rather than 9-10 months in the case of the gutter-connected greenhouse as it is expected that lower-tech stand-alone greenhouses which will operate for less slightly less months during the year.

The productivity estimates for the gutter-connected greenhouse models are based on production estimates from within the commercial greenhouse industry adjusted for northern conditions. The models assume that grow lights will only be used in the gutter-connected model that operates year-round. The study team did visit a gutter-connected greenhouse outside Prince Albert, Saskatchewan which used no grow lights and operated 9-10 months per year. The need for grow lights will again vary by location as more northerly locations would need to shut down earlier in the year while more southerly locations would have a longer ability to operate with sufficient sun.

In the year-round models where grow lights are used, the productivity estimates (and the associated energy costs) assume that lights will be used five to six months per year which accounts for the high cucumber productivity which is a result of their light response compared to other vegetables. All modern commercial greenhouses in Canada who grow cucumbers use lights while there are no greenhouses that use lights on peppers.

Table 31: Range of Projected Productivity Levels for Different Greenhouse Systems

Greenhouse System	Crop	Low	Mid-Point	High
High-tunnel greenhouse operating 4-6 months per year	Tomatoes (kg/m^2/Year)	9	13	17
	Cucumbers (Units/ m^2/Year)	13	19	25
	Peppers (kg/m^2/Year)	2	4	5
	Lettuce (kg/m^2/Year)	10	13	15
Stand-alone greenhouse operating 8-10 months per year	Tomatoes (kg/m^2/Year)	31	42	52
	Cucumbers (Units/ m^2/Year)	68	91	113
	Peppers (kg/m^2/Year)	15	20	25
	Lettuce (kg/m^2/Year)	41	54	67
Gutter-connected greenhouse operating 9-10 months per year	Tomatoes (kg/m^2/Year)	40	48	55
	Cucumbers (Units/m^2/Year)	90	105	120
	Peppers (kg/m^2/Year)	20	23	26
	Lettuce (kg/m^2/Year)	55	63	70
Gutter-connected greenhouse operating 12-months per year	Tomatoes (kg/m^2/Year)	56	63	70
	Cucumbers (Units/m^2/Year)	190	213	235
	Peppers (kg/m^2/Year)	20	23	26
	Lettuce (kg/m^2/Year)	65	75	85
Chinese-style solar greenhouse operating 7-8 months per year	Tomatoes (kg/m^2/Year)	26	31	36
	Cucumbers (Units/m^2/Year)	59	68	78
	Peppers (kg/m^2/Year)	13	15	17
	Lettuce (kg/m^2/Year)	36	41	46

Marketable production as a percentage of total production is a related factor linking production with economic performance. Professionals in the greenhouse industry have indicated that there is likely to be differences in the percentage of marketable production achieved in different systems. The following table summarizes the marketable production factors used in the different models.

Table 32: Percentage of Growing Area and Marketable Production within Greenhouse systems

Greenhouse System	Growing Area as % of Greenhouse Area	Marketable Production as % of Total Production
High-Tunnel Greenhouse	85%	80%
Stand-Alone Greenhouse	85%	85%
Gutter-Connected Greenhouse	95%	85%
Chinese-Style Solar Greenhouse	70%	85%

Market prices
The ranges of potential wholesale and retail prices used in developing the enterprise budgets are presented in the table below. These prices ranges are extrapolated from price data gathered from the following sources: wholesale prices freight on board (FOB) Fort MacMurray; retail prices in 12 communities in northern Alberta, Saskatchewan, Manitoba and Ontario including both road, winter road and air pricing; a survey of prices in band-owned and commercial stores in three communities in Saskatchewan; Nutrition North Canada food price data; and, AAFC wholesale to retail market price data.

The "high" estimates, especially at the retail level, reflect the extremely high costs of produce in fly-in and difficult to access communities. The "low" estimates generally reflect the prices in easier to access northern communities. However given the large size of the study zone, individual communities will need to identify the most relevant price levels for an individual greenhouse enterprise.

Also of note is that the price ranges given in the table below may not cover all prices that could be achieved in a particular market. The price ranges are intended to reflect prices at which a significant portion of the marketable production could be sold.

Table 33: Range of Wholesale and Retail Price Estimates for Northern Greenhouses

	Crop	Units	Low ($/Unit)	Mid-Point ($/Unit)	High ($/Unit)
Wholesale	Tomatoes	kg	$2.25	$3.25	$4.25
	English Cucumbers	Each	$1.00	$1.75	$2.50
	Field Cucumbers	Each	$0.70	$1.10	$1.50
	Colored Peppers	kg	$2.75	$4.13	$5.50
	Green peppers	kg	$2.00	$3.00	$4.00
	Lettuce	kg	$2.00	$4.00	$6.00
Retail	Tomatoes	kg	$3.50	$6.50	$9.50
	English Cucumbers	Each	$2.00	$3.00	$4.00
	Field Cucumbers	Each	$1.17	$1.83	$2.50
	Colored Peppers	kg	$4.50	$7.25	$10.00
	Green Peppers	kg	$3.00	$4.50	$6.00
	Lettuce	kg	$3.33	$7.17	$11.00

Market size and market prices can be interconnected. Higher prices and potential revenues are available through accessing retail markets. The ability of a green house enterprise to access retail markets will be shaped by the size of the operation which is also determined by the market size. As suggested larger-scale operations are more likely to sell the majority of their marketable production to wholesale markets in order to match production with consumption. Smaller sized greenhouses may have greater opportunity to sell directly to local customers or potentially within co-operative or Band-owned stores.

Somewhat larger operations (half-acre) will most likely sell into a mix of both wholesale and retail markets based on operations of similar sized greenhouses in Canada.

Table 34: Estimate Wholesale to Retail Sales Ratio for Different Greenhouse Systems

Wholesale to Retail Sales Ratio		
	Wholesale (%)	**Retail (%)**
278m^2 high-tunnel greenhouse	0	100
278m^2 stand-alone greenhouse	0	100
3-acre (12,140m^2) gutter-connected greenhouse	90	10
Half-acre (2,023m^2) gutter-connected greenhouse	60	40
150m^2 Chinese-style solar greenhouse	0	100

Energy Use and Costs

Larger-scale greenhouses with mechanized systems can have high energy requirements for heat and lighting. Intensive energy use combined with high energy costs in northern regions can be a significant constraint to achieving economic viability.

Table 35: Range of Estimated Energy Use (Gj) per m^2 for Different Greenhouse Systems

Greenhouse Model	Duration of Operation	Gigajoules per m^2		
		Low	**Mid-Point**	**High**
278m^2 high-tunnel greenhouse	4-6 months	0.00	0.00	0.00
278m^2 stand-alone greenhouse	8-10 months	1.536	1.795	2.054
3-acre gutter-connected model	9-10 months	1.215	1.897	2.579
3-acre gutter-connected model	12 months	1.688	2.365	3.042
Half-acre gutter-connected greenhouse	9-10 months	1.330	2.080	2.829
Half-acre gutter-connected greenhouse	12 months	1.728	2.425	3.122
150m^2 Chinese-style solar greenhouse	7-8 months	0.450	0.529	0.608

The above estimates of energy consumption reflect the total energy requirements (per square meter) for both heating and electricity. The small-scale greenhouse estimates are based upon discussions with greenhouse suppliers and designers. For the gutter-connected greenhouses, the estimates of energy consumption are extrapolated from estimates given in a range of published documents. In particular are actual data on total energy use by Ontario greenhouses provided by Ag Energy Cooperative and Agviro in the presentation "Demand Side management program for Greenhouses".[5] These measures are used to provide a baseline for a three-acre greenhouse system operating 9 to 10 months per year. Adjustments are made from this database to reflect northern conditions as well as differences in systems and in scale of operations.

[5] *http://www.gtmconference.ca/site/downloads/presentations/2B1234%20-%20Ron%20MacDonald.pdf*

Energy consumption for heating is expected to increase by roughly 10% for smaller-scale (half-acre) operations due to the efficiencies of a large-scale (three acre) operation. A greenhouse system operating 12 months will have additional energy requirements for heating and lighting. However, supplemental lighting is expected to provide heat such that the energy requirements for heating in the 12 month system are reduced by 10%. The expected energy requirements for the supplemental lighting and 12 month production are derived from Quebec data (*Dorais, M.; The Use of Supplemental Lighting for Vegetable Crop Production)*. Additional cost for the repair and replacement of lights where supplemental lighting is used are projected to range from $4 per square meter to $6 per square meter.

The energy costs used in the economic models is extrapolated from a range of sources, including the biomass pricing costs contained in Section 4.3, in order to best reflect likely costs in northern regions. These are summarized in the following table.

Table 36: Range of Estimated Energy Costs ($/Gj) Applied in Models

	Low	Mid-Point	High
Heating ($/Gj)	$5.00	$8.50	$12.00
Electrical ($/kWh)	$0.05	$0.10	$0.15

Labour Use and Costs

Greenhouse systems will have varying labour requirements and labour costs. Smaller-scale systems (less than 1,500 m^2) could possibly be operated by an owner/operator with no hired labour and no labour cost. In these cases the owner/operator would draw from the bottom line (net return) achieved by the greenhouse enterprise for their return on labour and management which generally is used to cover some portion of living costs. Owner operators who provide all the labour to a greenhouse enterprise will require a diverse skill set that includes production as well as marketing and sales capabilities.

As greenhouses increase in their scale of operations, hired labour becomes necessary. However larger-scale systems (over 2,000 square meters) could also employ mechanized systems that would reduce labour requirements. A further factor of relevance to potential northern greenhouses is the need for trained and experienced workers. In cases where qualified workers are not available the labour requirements (number of workers) can be higher. The result is a range of potential combinations of labour requirements and labour costs. These are illustrated in the following table.

Table 37: Range of Estimated Labour Requirements (hired workers per acre) for Different Greenhouse Systems

Greenhouse Model	Hired Workers per Acre		
	Low	Mid-Point	High
278m^2 high-tunnel greenhouse	0	0	0
278m^2 stand-alone greenhouse	0	0	0
3-acre gutter-connected model	2	3	4

Greenhouse Model	Hired Workers per Acre		
Half-acre gutter-connected greenhouse	2	3	4
150m^2 Chinese-style solar greenhouse	0	0	0

For those greenhouse systems requiring hired labour, the combination of labour requirements and labour wage rates can have significant effects on the total labour costs per square meter and ultimately on overall economic performance.

Table 38: Range of Estimated Labour Costs Requirements (hired workers per acre) for Different Greenhouse Systems

Greenhouse Model	Duration of Operation	Labour Cost per Square Meter ($/M^2)		
		Low	Mid-Point	High
3-acre gutter-connected model	9-10 months	$13.64	$23.87	$36.37
3-acre gutter-connected model	12 months	$17.05	$29.84	$45.47
Half-acre gutter-connected greenhouse	9-10 months	$20.46	$27.85	$36.37
Half-acre gutter-connected greenhouse	12 months	$25.58	$34.81	$45.47

7.2 Enterprise Budgets

Section 7.2 provides overall enterprise budgets based on full life cycle accounting (including depreciation costs on capital investments) for the different greenhouse systems that might fit northern conditions. The budgets identify ranges of critical variables for each system and can be used to explore how differences in market size, technological complexity and related skills, capital costs, and seasonality of production (i.e., winter production) affect costs, revenues and overall economic performance.

The following key terms are used in the budgets:

- Structure costs are the costs of the structure and key components that are internal elements within the structure.
- Capital costs reflect the full costs of a fully commissioned and operating greenhouse enterprise including the structure, header house, site and land preparation, equipment, vehicles etc. The total capital costs will thus be larger than the structure costs per square metres multiplied by the number of square metres.
- Sales revenues are determined by applying market prices (wholesale and retail) to total marketable production
- Variable operating costs are for those inputs that vary with levels of production. A key assumption is that all of these costs are paid in the production period.
- Fixed operating costs are those costs that would be incurred whether the greenhouse produces or not. These costs include depreciation, permanent salaries as well as taxes and insurance. Furthermore, fixed costs (in the models) include a calculated interest on capital cost (6%) on all invested capital. This is an opportunity cost to reflect what the capital could have earned in the

next best alternative. This allows the greenhouse enterprises (in the models) to be assessed in terms of their ability to generate returns (net returns) on capital above what could be earned in an alternative investment.

  - Within the fixed operating costs, depreciation is calculated by spreading the capital costs of each item over the expected life of the asset assuming zero salvage value at the end of life. More specifically this calculation is made by dividing the capital cost by the expected years of life for each capital item.

- Net returns projected in the enterprise budget are the dollar returns generated by the greenhouse enterprise after all operating costs as well as depreciation and interests on capital have been deducted from total revenues.
- Net cash income adds back the non-cash expenses of interest on capital and depreciation to provide a measure of the net cash generated by the enterprise.
- %ROA is a measure of profitability that reflects the rate of return being earned by all the assets invested in the greenhouse enterprise. It is the return that is earned by both debt capital and equity capital. For this reason any interest deducted as a cost is added back to net returns since this is a return generated by the capital. The %ROA presented in the enterprise budgets is calculated as follows:

ROA Calculation

1. Sales Revenues - Total Variable Operating Costs - Total Fixed Operating Costs (which include an opportunity interest cost and depreciation) = Net Returns

2. Net Returns + Interest on capital = Total Returns Earned by Capital
(Since interest payments that have been deducted as a cost are returns generated by capital they are added back to reflect the total returns earned by all capital irrespective of whether it is equity or debt).

3. Average Total Capital Investment = (Initial Total Capital Investment + (Initial Total Capital Investment – Depreciation))/2
(Average total capital investment is used in order to provide a realistic assessment of the total value of capital assets used in the greenhouse enterprise over the operating period.)

4. Total Returns Earned by Capital/Average Total Capital Investment = %ROA

The calculation undertakes to establish the total dollar returns earned by all capital assets. Once the contribution of labour and management have been covered either as a cost or by an estimate (where it is assumed there is an owner/operator drawing from profits), the remaining returns are attributed to the total capital employed in the business. Net returns plus the interest costs on capital equals the total returns earned by all (both debt and equity) capital. In other words, all the other costs and contributions have been covered so what ever is left over (net returns plus interest cost) is a return to total capital.

The thinking behind the %ROA measure is that capital, management and labour are organized by management to generate returns. This includes the decision to invest in a greenhouse enterprise as well as how the assets are employed in the greenhouse enterprise. %ROA provides an assessment of how effectively the capital assets have been employed in the business so it is often an assessment of management. If a particular greenhouse enterprise was reliably achieving a return of 10% on total assets invested in the business this could be compared with other investment alternatives. Similarly the business could make the case to expand the operations as long as the cost of new (borrowed) capital were less than 10%.

Special attention should be given to how this calculation is made in the cases of smaller-scale greenhouses in which there are no labour or management salaries included as operating costs. Since the owner operator draws from net returns some allowance has to be made to cover the labour and management contribution of the owner operator. In these cases the calculations of %ROA include an allowance for an arbitrary amount from net returns to cover the owners contribution of labour and management. The mechanics of this calculation are illustrated as follows:

For small-scale high-tunnel greenhouses of less than 1,000 square meters. $5,000 is deducted from net returns to account for the owner operator`s contribution of labour and management.

Net returns -$5,000 + Interest on capital = Total Returns Earned by Capital
Total Returns Earned by Capital/Average Total Capital Investment = %ROA

For small-scale high-tunnel greenhouses of greater than 1,000 square meters. $10,000 is deducted from net returns to account for the owner operator`s contribution of labour and management.

Net returns -$10,000 + Interest on capital = Total Returns Earned by Capital
Total Returns Earned by Capital/Average Total Capital Investment =%ROA

Achieving acceptable returns on the capital invested in a northern greenhouse venture can be framed by the following general guidelines for return on assets that have been adapted from an earlier AAFRD publication.

Table 39: Guidelines for Return on Assets

Financial Objective	Return on Assets	Effect on Business Performance
Minimum	4-7%	Minimum long-term return necessary to ensure survival.
Target	8-10%	May meet owners minimum needs but does not provide for growth or provide capacity for recovering from adverse shocks.
Top Performance	15-20%	Most profitable and efficiently run businesses.

The financial models are also used to explore the effects of subsidizing the capital investment required to establish a greenhouse venture. In this case the total operating costs will be reduced as a portion (50%) of depreciation costs and opportunity cost of capital are not incurred by the greenhouse business. Accordingly net returns and %ROA will be higher.

It is crucial to note that the financial models/enterprise budgets are modeled on a series of basic parameters. As such they allow for a preliminary look at the potential economic returns of various greenhouse systems operating in northern conditions. The following limitations should be recognized when assessing individual business cases in the light of the models presented in this study:

- In order to provide an assessment of an individual business case these models would have to be coupled with specific data reflecting the uniqueness, complexity and uncertainty surrounding the proposal for any given location.
- The models may omit entire processes or resources that could give a specific business case a competitive advantage. Different communities and locations with unique competitive advantages could potentially do better than the models suggest so the basic parameters in the models should not necessarily preclude a community or investors from investigating a certain greenhouse system for a given location.
- The models do not recognize differences in management capabilities that would affect the sequence and timing of key management choices that will have an effect on economic performance.

There will be uncertainty surrounding the likely productivity levels, vegetable prices and operating costs that a northern greenhouse venture might achieve. The potential economic performance of a northern greenhouse system should be investigated with a wider rather than narrower perspective. Rather than rely on a few possible outcomes for sales revenues and total operating costs, decision makers can benefit from exploring multiple combinations of sales revenues and operating costs. Included in the analyses of the models are the following:

- The effects on net returns by combining the low, mid-point and high of sales revenues and total operating costs in different combinations.
- Attaching subjective probabilities to each of the possible outcomes for sales revenues and total operating costs. These are personal judgements that reflect individual beliefs and the evidence that has been gathered about uncertain events including productivity levels, market prices and operating costs.

- Attaching probabilities to each of the possible outcomes for sales revenues and total operating costs allows for calculating expected values for each possible combination. Expected values are the net return for each combination multiplied by the probability of it happening.
- Expected values of net returns for a particular greenhouse system can be calculated by summing expected value for each possible combination of sales revenues and total operating costs.

Considering multiple possible outcomes for sales revenues and total operating costs combined with thinking in terms of probabilities can provide useful information to decision makers.

7.2.1 High-Tunnel Greenhouse

The potential economic performance of a low-cost and low-tech, 278m^2 high-tunnel greenhouse system operating in a northern region is presented in the table below. This is the most basic system with a single layer of polyethylene covering a structure, soil based production, no heating and a limited operating period.

High-tunnel greenhouses can be very inexpensive with structure costs ranging from \$13/m^2 to \$51/m^2 depending on structure and transport costs. Of note is that the poly covering is expected to have a limited life and is depreciated over four years. Additional capital costs reflected in the budgets include estimates for equipment, land development, commissioning, a vehicle etc. Also note that the capital cost estimates for the pick-up truck are for the share that is allocated to the greenhouse enterprise. Accordingly it is possible for an enterprise to build a high-tunnel facility more cheaply using locally available materials and sharing of other capital items with another activity.

Within this model, the there are no costs for either hired labour wages or management salaries. In most cases, such a small-scale greenhouse would not pay a management salary but the owner would instead take a draw from net returns as their return on labour and management.

Other key assumptions applied in the models for this system are:

1. The growing area is allocated equally among the four crops (tomatoes, cucumbers, peppers and lettuce).
2. Production estimates for cucumbers are based on lower yielding field varieties rather than English cucumbers.
3. All marketable production is projected to be sold at retail prices.
4. 25% of the marketable production of peppers is projected to be sold as coloured peppers (higher price) and 75% are projected to be sold as green peppers.
5. Growing costs reflect soil based production.
6. There are no expectations of energy use and energy costs.

Table 40: Estimated Economic Performance for High-Tunnel Greenhouse (278 m²) Operating 4-6 Months per Year

	Range of Possible Parameters, Prices and Costs		
	Low	**Average**	**High**
Structure Costs ($/m2)	$13	$32	$51
Total Capital Costs ($)	$6,765	$15,820	$27,075
(A) Sales Revenues			
Tomato Sales Revenues ($)	$1,580	$4,177	$7,922
Cucumber Sales Revenues ($)	$710	$1,631	$2,926
Pepper Sales Revenues ($)	$351	$906	$1,704
Lettuce Sales Revenues ($)	$1,559	$4,194	$7,726
(A) Total Sales Revenues	*$4,200*	*$10,907*	*$20,279*
(B) Variable Costs			
Growing Costs	$1,099	$1,300	$1,501
Energy Costs	$0	$0	$0
Labour costs	$0	$0	$0
Marketing and Distribution Costs	$598	$946	$1,360
Repair Costs (Building & Equipment)	$372	$824	$1,648
Other Costs	$1,394	$2,439	$3,484
(B) Total Variable Costs	*$3,463*	*$5,509*	*$7,993*
Gross Margin (A-B)	**$737**	**$5,399**	**$12,286**
(C) Fixed Costs			
1. Depreciation	$833	$1,635	$2,709
2. Interest on Capital	$203	$475	$887
3. Taxes & Insurance	$246	$632	$1,378
4. Salaries	$0	$0	$0
(C) Total Fixed Costs	*$1,283*	*$2,741*	*$4,974*
(D) Total Costs	**$4,746**	**$8,250**	**$12,967**
(E) Net Cash Income (A-D+C1+C2)	**$491**	**$4,767**	**$10,908**
(F) Net Returns (A-D)	**-$546**	**$2,657**	**$7,311**
Net Returns /m²	-$1.96	$9.56	$26.30
%ROA	**-84.16%**	**-12.45%**	**12.44%**
50% Capital Subsidy - Net Returns	**-$28**	**$3,712**	**$9,110**
50% Capital Subsidy - Net Returns /m²	-$0.10	$13.35	$32.77
50% Capital Subsidy - %ROA	**-77.60%**	**-7.00%**	**17.70%**

The results for the single high-tunnel greenhouse producing greenhouse vegetables suggest profitability (net returns) in some cases which the study team feels fit closely to what they have observed through discussions with small-scale greenhouse operators in the north and other parts of Canada. More specific observations include:

- Small-scale greenhouses tend to generate modest returns which highlights the importance of having modest expectations for profitability and returns on the labour and management contribution.
- Most small-scale greenhouses in the north are either: 1) integrated with an outdoor market garden; and/or 2) focus on bedding plants as they are a higher margin commodity. Some are now moving into greenhouse vegetables on the side as they gain expertise with greenhouse production with bedding plants. Those that do focus on vegetables in places such as the Yukon sell into higher margin farmers markets or other higher-priced markets.
- Small-scale greenhouses can be built more cheaply that the above estimates using local materials, family labour, free land, used equipment and not accounting for vehicles etc.
- Multiple small-scale greenhouses are normally combined to gain economies of scale in production.

The following table provides estimates of population market size required to support a system of this scale although the estimates used could be high for some communities.

Table 41: Market Size Estimates for 278m^2 High-Tunnel Greenhouse Operating 4 – 6 Months per Year Assuming Mid-Point Productivity

	Tomatoes	Cucumbers	Peppers	Lettuce
Total Marketable Production (kg)	643	890	169	585
Per Capita Consumption Estimates (kg)	8.5	15	4	11.5
Population When Market Share at 75%	101	79	56	68
Population When Market Share at 50%	151	119	84	102

The advantage of the small-scale system may be in having a better fit with the smaller populations of northern communities. At the same time, the single high-tunnel of 278 square meters could be expanded, as is a common strategy amongst high-tunnel operators, providing there is market support for the increased production. The following table summarizes the potential economic performance for incremental sizes of the basic high-tunnel greenhouse as additional greenhouses are added.

Table 42: Key Operating Metrics for Development of Multiple (2 and 5) High-Tunnel Greenhouses

	Range of Possible Parameters, Prices and Costs		
557 Square Meters	**Low**	**Mid - Point**	**High**
Net Cash Income	$1,227	$10,025	$23,286
Net Returns	-$266	$6,905	$18,124
Net Returns /m^2	-$0.48	$12.40	$32.54
%ROA	-50.33%	11.26%	36.80%
50% Capital Subsidy - Net Returns	$481	$8,465	$20,705
50% Capital Subsidy - Net Returns /m^2	$0.86	$15.20	$37.17
50% Capital Subsidy - %ROA	-44.34%	16.32%	41.71%
Population When Market Share at 75% *	160	202	234
Population When Market Share at 50% *	241	302	351
1,394 Square Meters	**Low**	**Mid - Point**	**High**
Net Cash Income	$3,437	$25,801	$60,420
Net Returns	$574	$19,649	$50,563
Net Returns /m^2	$0.41	$14.10	$36.27
%ROA	-43.23%	22.84%	54.10%
50% Capital Subsidy - Net Returns	$2,005	$22,725	$55,492
50% Capital Subsidy - Net Returns /m^2	$1.44	$16.30	$36.27
50% Capital Subsidy - %ROA	-37.77%	27.54%	58.67%
Population When Market Share at 75% *	401	504	585
Population When Market Share at 50% *	602	756	878

**Based on estimates for Tomato production and consumption*

These budgets and the figures below suggest that a high-tunnel system could grow incrementally to achieve more acceptable economic performance providing there is sufficient market size and population to support it. A key assumption in these estimates is that the owner/operator is willing to accept the modest salary levels. Note that the %ROA calculation allows $10,000 as a return to labour and management in the 1,394m^2 system and $5,000 as a return for the smaller-scale systems. The 1,394m^2 system is likely the largest size system that could be handled by an owner operator or a husband and wife team.

Figure 11: Comparison of Unsubsidized Net Returns per m² for 278, 557 and 1,394m² High-Tunnel Greenhouses

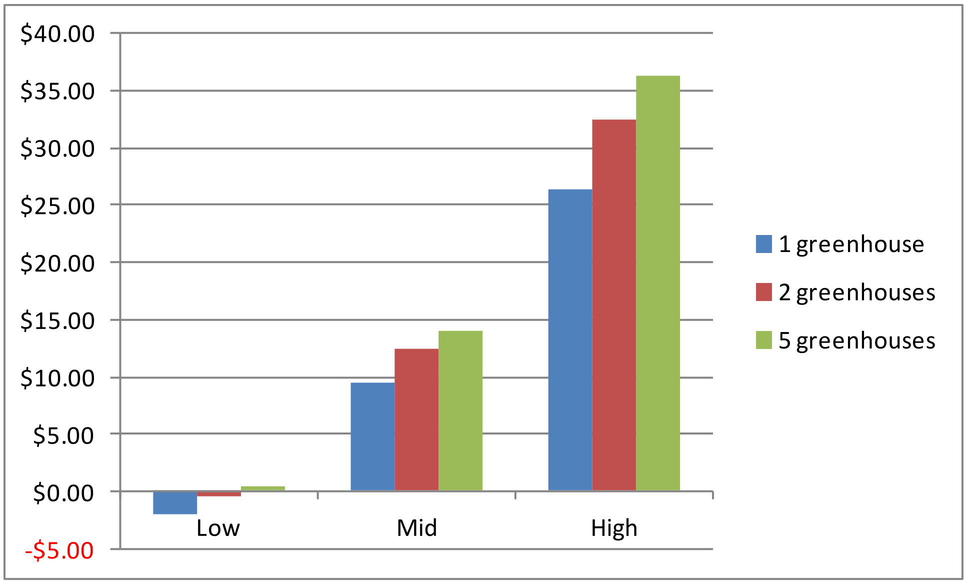
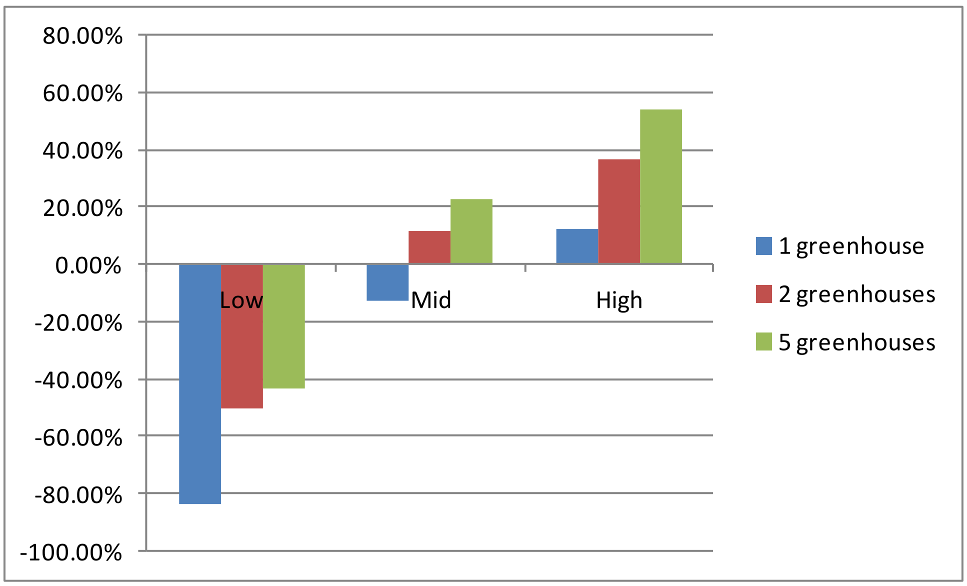


Figure 12: Comparison of Unsubsidized %ROA for 278, 557 and 1,394m² High-Tunnel Greenhouses



The projections in the model also indicate considerable variability surrounding the potential economic performance that might be achieved. As suggested there is value to decision makers in considering the effect on net returns by combining sales revenues and total operating costs in different combinations as follows.

Table 43: Potential Net Returns for 1,394m^2 High-Tunnel Greenhouse (Operating 4 – 6 Months per Year)

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	$574	$34,112	$80,968
Mid-Point	-$13,888	$19,649	$66,505
High	-$29,830	$3,708	$50,563

As suggested, probabilities can also be applied to the different levels of sales revenues and total operating costs generated in the models to give a wider view of the possible outcomes. In the following table probabilities are applied to each of the possible outcomes for sales revenues and total operating costs for the 1,394m^2 high-tunnel enterprise. Each of the cells in the coloured area is the probability of the particular combination of sales revenues and operating costs.

Table 44: Estimated Cost and Revenue Probabilities for 1,394m^2 High-Tunnel Greenhouse

		Sales Revenues		
		Low	**Mid-Point**	**High**
Total Operating Costs		**35.00%**	**45.00%**	**20.00%**
Low	**20.00%**	7.00%	9.00%	4.00%
Mid-Point	**45.00%**	15.75%	20.25%	9.00%
High	**35.00%**	12.25%	15.75%	7.00%

The expected values for each combination can be added together to calculate an expected value for the 1,394m^2 high-tunnel system. The sum of all the possible outcomes in the above table is $14,595 which suggests a %ROA of 12.52%. As well, the probability of achieving a positive net return can be determined by summing the individual probabilities for outcome with a positive net return which is 72%. Similarly the probability of achieving net returns greater than $20,000 is determined to be 29%. It is important to remember that these estimates are determined by the subjective probabilities given to the different sales revenues and operating cost outcomes.

7.2.2 Stand-Alone Greenhouse System (278 m^2)

Stand-alone greenhouse systems are more technically advanced (higher cost) structures and can incorporate environmental and growing systems that allow them to operate over longer periods and achieve higher levels of productivity. Although they can function as lower-tech greenhouses, at the high end, additional capital costs can include heating systems, electrical and environmental control systems matching that of high-tech gutter-connected models.

Productivity levels and sales revenues are expected to be higher than for the high-tunnel system due to the longer operating period and greater environmental controls. Of particular note is that this type of structure allows for growing higher yielding English cucumbers (that require vining) while the high-tunnel system is generally limited to field variety cucumbers. Operating costs are expected to generally be higher owing to higher capital costs, greater energy costs, greater growing costs and higher marketing and distribution costs. Estimates of operating costs are derived from greenhouse professionals as well as survey data gathered by Alberta Agriculture and Rural Development (Chaudhary, 2011).

Other key assumptions applied in the stand-alone greenhouse system models are:

1. The growing area is allocated equally among the four crops (tomatoes, cucumbers, peppers and lettuce).
2. Production estimates for cucumbers are based on English cucumbers.
3. All marketable production is projected to be sold at retail prices.
4. 50% of the marketable production of peppers is projected to be sold as coloured peppers (higher price) and 50% are projected to be sold as green peppers.
5. Growing costs reflect soilless based production systems.
6. The stand-alone greenhouse system is expected to have an extended growing system of 8-10 months. The higher productivity of the stand-alone greenhouse systems compared to the high-tunnel system is likely to require hired labour. Accordingly the stand-alone models do have labour costs.
7. The small-scale stand-alone greenhouse systems are not likely to pay a fixed salary to the owner operator. The owner operator would instead draw from net returns to cover their return on labour and management. However to calculate %ROA some allowance for the owners contribution of labour and management must be made so that the returns generated by total assets are not overstated. The following allowances for the contribution of labour and management have been made in the models representing the economic performance of stand-alone greenhouse systems:
    - 278m^2: $20,000
    - 557m^2: $35,000
    - 1,394m^2: $35,000.

The projected economic performance for the stand-alone greenhouse structure and systems are summarized in the following table.

Table 45: Estimated Economic Performance for Stand-Alone Greenhouse (278 m^2) Operating 8-10 Months per Year

	Range of Possible Parameters, Prices and Costs		
	Low	**Average**	**High**
Structure Costs ($/m2)	$79	$110	$140
Total Capital Costs ($)	$31,618	$51,219	$68,519
(A) Sales Revenues			
Tomato Sales Revenues ($)	$5,655	$14,059	$25,747
Cucumber Sales Revenues ($)	$6,766	$13,507	$22,487
Pepper Sales Revenues ($)	$2,798	$5,846	$9,950
Lettuce Sales Revenues ($)	$6,799	$19,253	$36,665
(A) Total Sales Revenues	$22,018	$52,665	$94,849
(B) Variable Costs			
Growing Costs	$3,507	$4,750	$5,993
Energy Costs	$2,230	$4,494	$7,316
Labour costs	$9,504	$13,305	$17,740
Marketing and Distribution Costs	$2,708	$4,115	$5,778
Repair Costs (Building & Equipment)	$1,580	$2,256	$3,424
Other Costs	$4,181	$6,968	$9,755
(B) Total Variable Costs	$23,710	$35,888	$50,005
Gross Margin (A-B)	**-$1,691**	**$16,777**	**$44,844**
(C) Fixed Costs			
1. Depreciation	$2,899	$4,505	$6,019
2. Interest on Capital	$949	$1,537	$2,101
3. Taxes & Insurance	$1,454	$2,064	$3,154
4. Salaries	$0	$0	$0
(C) Total Fixed Costs	$5,301	$8,106	$11,273
(D) Total Costs	**$29,011**	**$43,994**	**$61,278**
(E) Net Cash Income (A-D+C1+C2)	**-$3,145**	**$14,713**	**$41,690**
(F) Net Returns (A-D)	**-$6,992**	**$8,671**	**$33,571**
Net Returns /m^2	-$25.15	$31.19	$120.76
%ROA	**-86.33%**	**-20.00%**	**23.92%**
50% Capital Subsidy - Net Returns	**-$5,069**	**$11,692**	**$37,630**
50% Capital Subsidy - Net Returns /m^2	-$18.23	$42.06	$135.06
50% Capital Subsidy - %ROA	**-81.52%**	**-15.40%**	**28.52%**

The results for the small-scale stand-alone greenhouse system suggest a wide range of potential economic performance. The population and market size required to support this type of system are suggested as follows:

Table 46: Market Size Estimates for 278m² Stand-Alone Greenhouse Operating 8 – 10 Months per Year Assuming Mid-Point Productivity

	Tomatoes	Cucumbers	Peppers	Lettuce
Total Marketable Production (kg)	2,163	4,502	995	2,686
Per Capita Consumption Estimates (kg)	8.5	15	4	11.5
Population When Market Share at75%	339	400	332	311
Population When Market Share at 50%	509	600	497	467

The stand-alone system of 278m² could be expanded to gain economies of scale providing there is market support for the increased production. The following table summarizes the potential economic performance for incremental sizes of stand-alone greenhouse systems.

Table 47: Key Operating Metrics for Development of Multiple Stand-Alone Greenhouses

	Range of Possible Parameters, Prices and Costs		
557 Square Meters	**Low**	**Mid-Point**	**High**
Net Cash Income	-$2,237	$31,998	$84,220
Net Returns	-$9,632	$20,421	$67,959
Net Returns /m²	-$17.29	$36.66	$122.01
%ROA	-76.23%	-13.58%	31.38%
50% Capital Subsidy - Net Returns	-$5,934	$26,209	$76,090
50% Capital Subsidy - Net Returns /m²	-$10.65	$47.05	$136.61
50% Capital Subsidy - %ROA	-71.23%	-8.51%	36.66%
Population When Market Share at 75% *	574	679	761
Population When Market Share at 50% *	862	1,018	1,141
1,394 m²	**Low**	**Mid-Point**	**High**
Net Cash Income	-$15,395	$74,526	$211,600
Net Returns	-$36,034	$45,504	$171,564
Net Returns /m²	-$25.85	$32.64	$123.07
%ROA	-45.97%	8.25%	53.83%
50% Capital Subsidy - Net Returns	-$25,715	$60,015	$191,582
50% Capital Subsidy - Net Returns /m²	-$18.45	$43.05	$137.43
50% Capital Subsidy - %ROA	-40.42%	13.70%	59.54%
Population When Market Share at75% *	1,436	1,696	1,902
Population When Market Share at 50% *	2,154	2,545	2,853

**Based on estimates for Tomato production and consumption*

The above projections include both additional labour costs as the greenhouse enterprise expands above a single greenhouse and an increase in contribution to management and labour to $35,000 for both models. As a result, net returns per square metre are similar amongst all three sizes of stand-alone greenhouse operation. The %ROA does however increase indicating economies of scale.

The projections for the stand-alone model clearly illustrate the variability in capital costs, productivity, sales revenues and operating costs due to the wide range of structures and components that make up this type of system. Given the variability surrounding the potential economic performance that might be achieved there will be value for decision makers in taking a more inclusive view of the possible outcomes and applying subjective probabilities to the different possible combinations of sales revenues and total operating costs. A wider range of potential net returns for the 1,394m^2 stand-alone greenhouse system can be generated by considering all possible combinations of the estimated levels of sales revenues and total operating costs.

Table 48: Potential Net Returns for 1,394m^2 Stand-Alone Greenhouse Operating 8 – 10 Months per Year

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$36,034	$117,198	$328,118
Mid-Point	-$107,728	$45,504	$256,424
High	-$192,588	-$39,356	$171,564

The probabilities in the following table are for each of the possible outcome of sales revenues and total operating costs for the 1,394m^2 stand-alone system. Each of the cells in the coloured area is the joint probability of the particular combination of sales revenues and operating costs.

Table 49: Estimated Cost and Revenue Probabilities for 1,394m^2 High-Tunnel Greenhouse

		Sales Revenues		
		Low	**Mid-Point**	**High**
Total Operating Costs		**35.00%**	**45.00%**	**20.00%**
Low	**20.00%**	7.00%	9.00%	4.00%
Mid-Point	**45.00%**	15.75%	20.25%	9.00%
High	**35.00%**	12.25%	15.75%	7.00%

The expected values for each combination can be added together to calculate an expected value for the 1,394m^2 stand-alone system. The sum of all the possible outcomes in the above table is $18,695 which suggests a %ROA of 9.18%. The probability of achieving a net return greater than zero is 49.25% while the probability of achieving net returns greater than $50,000 is also determined to be 29%. Once again these results are affected by the probabilities applied to the different outcomes for sales revenues ands total operating costs. Decision makers who have completed feasibility studies will have evidence that can allow them to apply more informed probabilities that will in turn provide more-meaningful assessments of the likelihood of achieving acceptable levels of net returns at acceptable levels of risk.

7.2.3 Three-Acre Gutter-Connected Greenhouse

The 3 acre (12,140m^2) gutter-connected greenhouse model is intended to examine the financial performance of modern greenhouse serving a larger centre or population base in a number of locations in the north. Even at three acres, this is a smaller sized greenhouse in terms of the commercial greenhouse industry in Canada where greenhouse sizes range from 10 acres upward. The 3-acre size has been chosen due to the smaller population base in the north which is a key factor in greenhouse development.

The smaller size of facility can limit the economies of scale that are being achieved by larger greenhouses. Agriteam has recently completed a feasibility study for a private greenhouse operator at a location within the north that shows a much higher return on assets and internal profitability for a 11 acre operation compared to the 3 acre operation modeled below. It should be stated again, as has been noted in other sections, that this type of greenhouse will require a range of specialized technical and management skills as it is a more complex operation than the earlier systems that have been presented in this document.

9-10 Month per Year Three-Acre Gutter-Connected Greenhouse

The first financial model assumes that production is seasonal with no production occurring during December-January.

Table 50: Estimated Economic Performance of 3-Acre Gutter-Connected Model Operating 9-10 Months per Year

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid- Point**	**High**
Structure Costs ($/m^2)	$128	$171	$213
Total Capital Costs ($)	$1,661,993	$2,232,467	$2,832,941
(A) Sales Revenues			
Tomato Sales Revenues ($)	$343,123	$581,051	$862,322
Cucumber Sales Revenues ($)	$153,244	$312,003	$512,749
Pepper Sales Revenues ($)	$176,463	$237,413	$307,005
Lettuce Sales Revenues ($)	$302,705	$696,028	$1,173,841
(A) Total Sales Revenues	$975,535	$1,826,495	$2,855,917
(B) Variable Costs			
Growing Costs	$169,300	$206,943	$233,659
Energy Costs	$80,735	$212,612	$404,281
Labour costs	$165,600	$289,800	$441,600

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid- Point**	**High**
Marketing and Distribution Costs	$76,758	$117,841	$166,724
Repair Costs (Building & Equipment)	$98,670	$131,998	$166,106
Other Costs	$97,125	$171,486	$245,847
(B) Total Variable Costs	$688,187	$1,130,680	$1,658,218
Gross Margin (A-B)	**$287,348**	**$695,815**	**$1,197,700**
(C) Fixed Costs			
1. Depreciation	$118,200	$158,498	$200,863
2. Interest on Capital	$49,860	$66,974	$84,388
3. Taxes & Insurance	$94,740	$127,498	$159,356
4. Salaries	$212,750	$232,875	$253,000
(C) Total Fixed Costs	$475,549	$585,845	$697,607
(D) Total Costs	**$1,163,736**	**$1,716,524**	**$2,355,825**
(E) Net Cash Income (A-D+C1+C2)	**-$20,142**	**$335,442**	**$785,343**
(F) Net Returns (A-D)	**-$188,201**	**$109,970**	**$500,092**
Net Returns /m^2	-$15.50	$9.06	$41.19
%ROA	-8.63%	8.22%	21.39%
50% Capital Subsidy - Net Returns	**-$104,171**	**$222,706**	**$642,718**
50% Capital Subsidy - Net Returns /m^2	-$8.58	-$18.34	$52.94
50% Capital Subsidy - %ROA	**-4.94%**	**11.90%**	**25.07%**

The enterprise budgets in the above table suggest a wide range of potential economic performances. From being unacceptable (unsubsidized/subsidized %ROA of -8.63% / -4.94%) to modest (%ROA of 8.22% / 11.90%) to quite strong (%ROA of 21.39% / 25.07%). The key driver of economic performance is productivity and prices. High productivity levels combined with the higher prices contribute to substantial sales revenues with modest increases in total operating costs.

Decision makers should recognize that the possible outcomes for net returns of this type of northern greenhouse venture could vary much more than what is presented. A wider range of possible outcomes for net returns can be established by combining the estimates for sales revenues and total operating costs differently. The following table presents each possible outcome for net returns when all combinations of sales revenues and total operating costs are considered.

Table 51: Potential Net Returns for 3-Acre Gutter-Connected Greenhouse Operating 9 – 10 Months per Year

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$188,201	$662,759	$1,692,181
Mid-Point	-$740,989	$109,970	$1,139,393
High	-$1,380,290	-$529,330	$500,092

This wider range of possible net returns reflects the uncertainty surrounding the productivity levels, market prices and operating costs that a northern greenhouse venture might achieve. Given the inherent difficulty in forecasting future outcomes for sales revenues and total operating costs, decision makers can have difficulty in choosing one combination of sales revenues and total operating costs when deciding whether a particular venture is worthwhile. Rather than rely on one specific combination of outcomes decision makers can incorporate their beliefs about the uncertainty of possible outcomes by applying subjective probabilities to each of the identified outcomes for sales revenues and total operating costs. In the following table probabilities are applied to each possible outcome for sales revenues and total operating costs. Accordingly, each of the cells in the coloured area is the joint probability of that particular outcome for net returns.

Table 52: Joint Probabilities for Possible Net Returns for Three-Acre Gutter-Connected Greenhouse

		Sales Revenues		
		Low	**Mid-Point**	**High**
Total Operating Costs		**25.00%**	**50.00%**	**25.00%**
Low	25.00%	6.25%	12.50%	6.25%
Mid-Point	50.00%	12.50%	25.00%	12.50%
High	25.00%	6.25%	12.50%	6.25%

The sum of each of each expected value in the above table is the expected value of the net returns for the particular greenhouse system which in this case is $132,958. This estimate of net returns suggests a %ROA of 9.29%. By incorporating personal beliefs about possible outcomes for sales revenues and total operating costs, expected values can be a means by which decision makers assess and compare alternative greenhouse investments. As well, the probabilities attached to each possible outcome for net returns can also be used to determine the likelihood of achieving a net return greater than some targeted level. From the above tables the likelihood of achieving net returns greater than $100,000 is 62.5%. This is done by adding the joint probabilities for each possible net return.

Although these estimates of economic performance suggest this greenhouse system can achieve modest economic returns, it would require the support of a fairly large market. The following table calculates the market size (population) that would be required to consume the production from the three-acre greenhouse enterprise.

Table 53: Estimated Market Size Requirements for Three-acre Gutter-Connected Greenhouse Operating 9-10 Months per Year Assuming Mid-Point Productivity

	Tomatoes	Cucumbers	Peppers	Lettuce
Total Marketable Production (kg)	162,532	166,402	46,438	161,242
Per Capita Consumption Estimates (kg)	8.5	15	4	11.5
Population When Market Share at75%	25,495	14,791	15,479	18,695
Population When Market Share at 50%	38,243	22,187	23,219	28,042

The high-level of productivity that can be achieved by this greenhouse system will need to be supported by having access to markets with populations ranging from 20,000 to 40,000 people. This clearly demonstrates the importance of matching the scale and productivity of a greenhouse system with market size. There may be cases where a greenhouse enterprise could serve distant communities however transportation costs and the effect of shipping on product quality would have to be considered.

12 Month per Year 3-Acre Gutter-Connected Greenhouse

Year-round production can be achieved through investing in lighting systems. The increased capital costs associated with the year-round system are related to the grow lights and energy curtains. These are summarized as follows.

Table 54: Increased Capital Costs for Year-Round Production in Three-Acre Gutter-Connected Greenhouse

	Low	Mid- Point	High
Grow Light System (\$ per m^2)	\$30	\$38	\$45
Energy curtain (\$ per m^2)	\$6	\$9	\$12

The increased energy use and energy costs of the year-round system compared with the 9-10 month system are as follows.

Table 55: Energy Use and Costs for 3-Acre Greenhouses, 12 Month versus 9-10 Months per Year

	Energy (Heat and Electricity) requirements	Low	Mid-Point	High
12 months per year	Total Gj	20,493	28,712	36,932
	Gj per m^2	1.688	2.365	3.042
	Light Repair/Replacement Costs	\$48,562	\$60,703	\$72,843
	Total Energy Costs (\$)	\$220,958	\$473,270	\$801,278
9–10 months per year	Total Gj	14,748	23,031	31,313
	Gj per m^2	1.2148	1.897	2.5792
	Total Energy Costs (\$)	\$80,735	\$212,612	\$404,281

The following charts illustrate the possible outcomes for the 3-acre facility with increased capital costs associated with operating 12-months per year along with projections for increased production.

Figure 13: Net Cash Income for 3-Acre Gutter-Connected Greenhouse, 9-10 Months versus 12 Months per Year

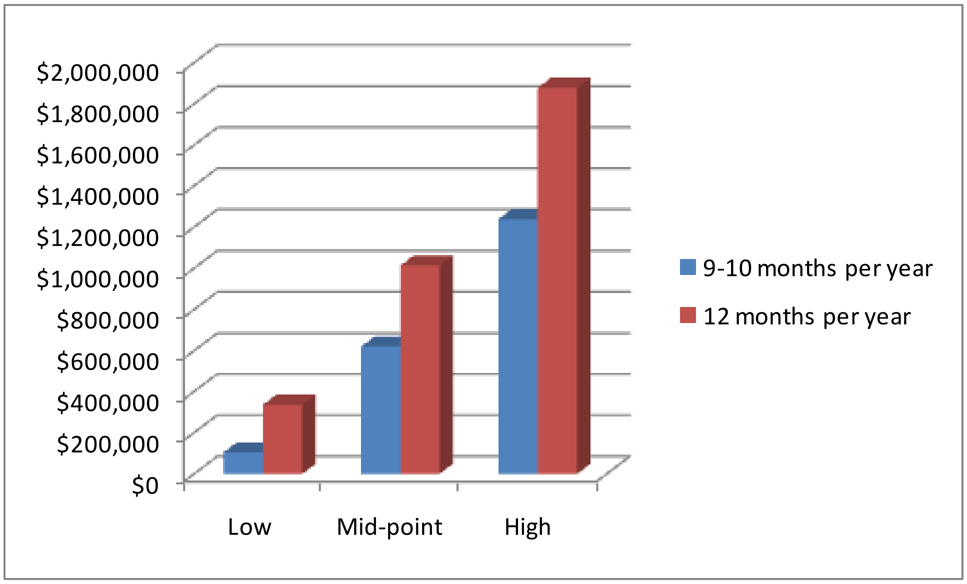
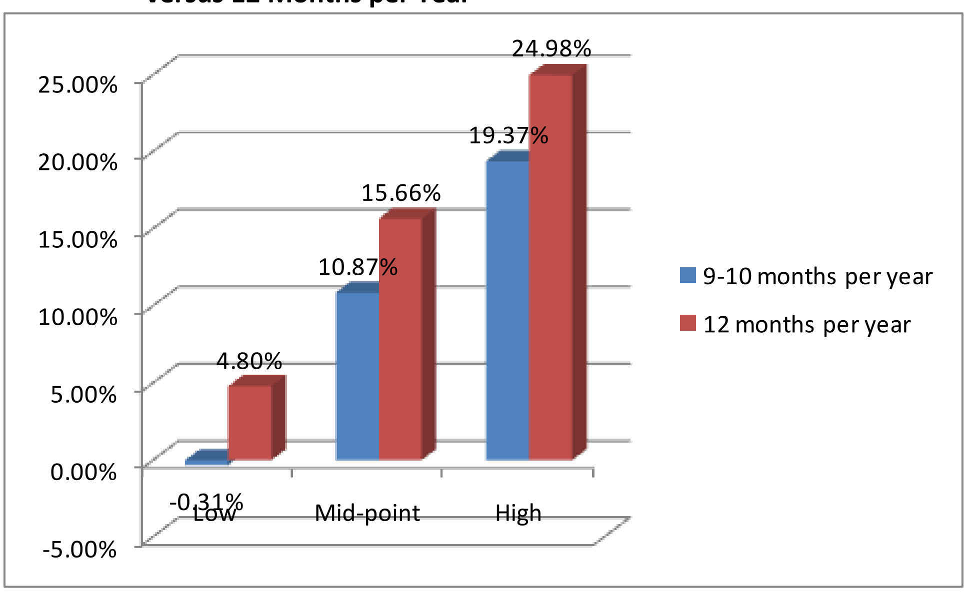


Figure 14: Return on Assets for 3-Acre Gutter-Connected Greenhouse, 9-10 Months versus 12 Months per Year



With the increased production (and sales) from operating year-round the 3 acre system could achieve higher levels of net cash income, returns and %ROA. Of note is that the increases in gross margin (sales revenues minus variable operating costs) are greater than the increased annual fixed costs of depreciation and interest on the increased capital related to the grow lights.

Once again the potential economic performance for this greenhouse system in a northern environment could vary much more than has been presented in the above charts. The table below presents the range of possible outcomes for net returns by considering the different combinations of sales revenues and total operating costs are as follows.

Table 56: Range of Net Returns for 3-Acre Gutter-Connected Greenhouse Operating 12-Months per Year

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$218,886	$1,004,401	$2,476,856
Mid-Point	-$970,604	$252,683	$1,725,137
High	-$1,845,785	-$622,499	$849,956

Applying the same subjective probabilities as were applied to the 9-10 month system produces an expected value of $284,109. This estimate of net returns suggests a %ROA of 13.64%. Once again this approach to assessing the expected economic performance of the year-round greenhouse enterprise considers the uncertainty of the different outcomes for sales revenues and total operating costs.

Individual greenhouse systems will have unique energy requirements and resulting energy costs. The following table illustrates the effect on the projected net returns for the three-acre greenhouse system operating 12 months per year (mid-point values) with varying energy costs and energy use levels. For this table total energy use reflects total annual energy use from all sources including biomass and electricity

Table 57: Effect of Net Returns due to Variations in Energy Use and Costs

	Total Energy Use (Gj per m^2 per Year)				
Energy Costs ($/Gj)	**1**	**2**	**3**	**4**	**5**
$4	$677,390	$628,828	$580,265	$531,703	$483,141
$6	$653,109	$580,265	$507,422	$434,579	$361,735
$8	$628,828	$531,703	$434,579	$337,454	$240,330
$10	$604,547	$483,141	$361,735	$240,330	$118,924
$12	$580,265	$434,579	$288,892	$143,205	-$2,482
$14	$555,984	$386,016	$216,048	$46,080	-$123,888
$16	$531,703	$337,454	$143,205	-$51,044	-$245,293
$18	$507,422	$288,892	$70,362	-$148,169	-$366,699

The above table illustrates the extreme variability in net returns that could result from variations in total energy use and energy costs. Since energy consumption and energy costs for a northern greenhouse enterprise will be context specific it is essential that projections of energy use and costs are based on detailed assessments of temperatures, light conditions, crops to be produced, heating and lighting systems as well as energy source and energy costs.

The sensitivity of net returns to energy use and energy costs also points out the benefits that might be gained from connecting a greenhouse to a district heating system. This approach could provide a greenhouse enterprise with both reduced capital costs and reduce energy costs.

7.2.4 Half-Acre Gutter-Connected Greenhouse (2,023m^2)

Nine – Ten Months per Year Gutter-Connected Greenhouse
Smaller-scale greenhouse systems can be a better fit for northern regions with smaller populations that are often widely dispersed with limited access. A half-acre greenhouse will provide for a smaller greenhouse model that may be appropriate for northern centres of clusters of population within the north with populations ranging from 3,000-10,000 persons.

Table 58: Estimated Market-Size Requirements for Half-Acre Gutter-Connected Greenhouse Operating 9 – 10 Months per Year Assuming Mid-Point Productivity

	Tomatoes	Cucumbers	Peppers	Lettuce
Total Marketable Production (kg)	28,594	27,089	7,912	26,874
Per Capita Consumption Estimates (kg)	8.5	15	4	11.5
Population When Market Share at 75%	4,485	2,408	2,637	3,116
Population When Market Share at 50%	6,728	3,612	3,956	4,674

A number of changes to the three-acre gutter-connected model have been made to adjust for the facility size within this half-acre model:

- Total capital costs for the smaller-scale greenhouse structure are expected to be 20% higher (per square meter) to reflect the higher per unit costs that generally go with smaller-scale structures
- Sales revenues will be higher than the large-sized facility as the portion of retail to wholesale sales is higher (40/60 versus 10/90).
- The growing costs of the half-acre facility are expected to be 10% higher than for the three-acre facility due to economies of scale.
- Energy costs are expected to higher than the larger-scale facility. This is due to 10% higher expected energy consumption for heating.
- Labour costs for wage earning greenhouse workers are expected to be similar or higher as there is likely to be fewer mechanized (labour reducing) systems in the smaller-scale facility.
- Salaries are expected to be lower as owner/operators provide are likely to accept less than the going market rate for their labour and management.
- Marketing and distribution Costs are expected to be the same on a per unit sold basis as for the three-acre enterprise.

- Repair Costs will be estimated using a factor of 6% of the new cost of the item.
- Other costs are expected to be 10% higher than the three-acre facility due to economies of scale.

The financial model for the half-acre gutter-connected greenhouse operating 9-10 months per year is summarized in the following tables.

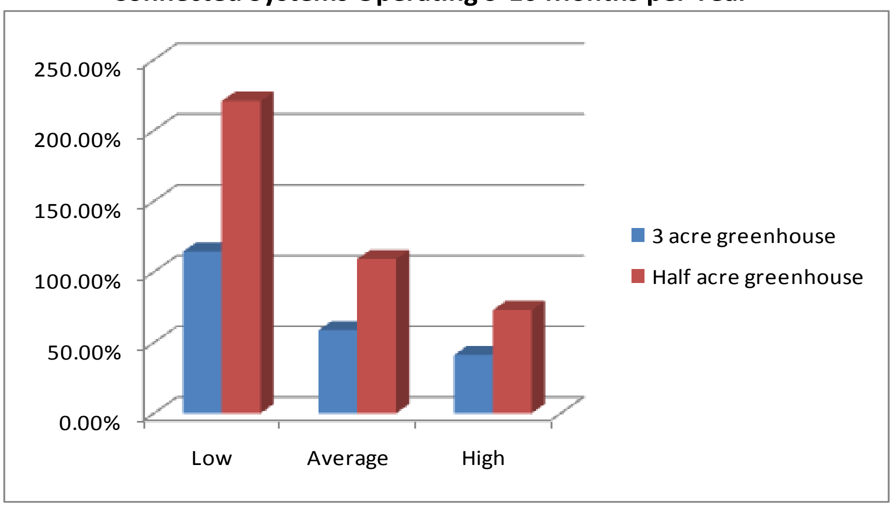
Table 59: Estimated Economic Performance of Half-Acre Gutter-Connected Model Operating 9 – 10 Months per Year

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid-Point**	**High**
Structure Costs ($/m2)	$152	$202	$251
Total Capital Costs ($)	$356,061	$490,221	$634,880
(A) Sales Revenues			
Tomato Sales Revenues ($)	$66,217	$130,101	$210,238
Cucumber Sales Revenues ($)	$32,506	$60,949	$95,971
Pepper Sales Revenues ($)	$23,735	$42,525	$65,288
Lettuce Sales Revenues ($)	$59,910	$141,535	$240,788
(A) Total Sales Revenues	$182,368	$375,110	$612,285
(B) Variable Costs			
Growing Costs	$33,681	$38,054	$42,427
Energy Costs	$14,619	$38,574	$73,450
Labour costs	$27,600	$48,300	$73,600
Marketing and Distribution Costs	$21,383	$30,147	$40,397
Repair Costs (Building & Equipment)	$20,614	$27,763	$35,573
Other Costs	$18,009	$31,545	$45,082
(B) Total Variable Costs	$135,906	$214,384	$310,529
Gross Margin (A-B)	**$46,462**	**$160,726**	**$301,756**
(C) Fixed Costs			
1. Depreciation	$26,871	$37,948	$49,492
2. Interest on Capital	$10,682	$14,557	$19,046
3. Taxes & Insurance	$19,054	$25,363	$31,673
4. Salaries	$103,500	$126,500	$149,500
(C) Total Fixed Costs	$160,106	$204,368	$249,711
(D) Total Costs	**$296,012**	**$418,752**	**$560,240**
(E) Net Cash Income (A-D+C1+C2)	**-$76,091**	**$8,862**	**$120,583**
(F) Net Returns (A-D)	**-$113,644**	**-$43,642**	**$52,045**

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid-Point**	**High**
Net Returns /m^2	-$56.18	-$21.57	$25.73
%ROA	**-33.17%**	**-9.26%**	**8.53%**
50% Capital Subsidy - Net Returns	**-$94,867**	**-$17,390**	**$86,314**
50% Capital Subsidy - Net Returns /m^2	-$46.89	-$8.60	42.67
50% Capital Subsidy - %ROA	**-26.13%**	**-2.15%**	**15.71%**

The economic performance for the smaller-scale enterprise (half- acre) as presented above reflects the economic challenge of not being able to capture economies of scale. Capital and other fixed costs such as salaries become a more significant factor. Fixed operating costs relative to gross margin for the three-acre and the half-acre enterprises are presented in Figure 15.

Figure 15 Fixed Operating Costs as % of Gross Margin for 3-Acre and Half-Acre Gutter Connected Systems Operating 9-10 Months per Year



Once again, the issue of paying salaries can be a key problem as greenhouse operations of this scale will need qualified and experienced technical/growing capabilities as well as the business and marketing skills required to develop both wholesale and retail markets. Owner operators with these capacities may be prepared to receive less than the going market rate for their contribution of labour and management. This would increase the return on total capital investment.

The study team visited two smaller-scale greenhouse operators with gutter-connected facilities similar but even slightly smaller than the one modeled. The following key points can be seen from their operations and shows the strategies they use which may indicate how a smaller sized greenhouse can survive:

- These were generally family-run enterprises who, although they paid employees, did not pay an outside owner/operator.

- In both cases, the greenhouses split their retail to wholesale sales roughly in the range of 60/40 to 50/50.
- For wholesale sales, one greenhouse sold to local grocery stores where they were able to receive higher wholesale prices than competing stock from Mexico/United States because their product was well known locally and in demand. The grocery store sold their vegetables at a premium although at less profit than imported vegetables, because the locally produced supply was a key calling card to get customers to come in to the grocery store. For the other greenhouse, they wholesaled to higher end restaurants in a urban centre who were willing, and had customers willing, to pay for high quality locally produced food. These strategies may work in some urban centres in the north but will clearly not work in remote communities which are food insecure.
- On the retail side, the greenhouses both sold as much product as possible at farmers markets to capture higher prices.
- One greenhouse also took waste product and did value-added processing and sold it at farmer's markets as well.
- Finally, one greenhouse used a coal boiler which enabled them to drive their energy costs below natural gas heating costs. This was a crucial cost reduction enabling profitability for the greenhouse.

Once again the range of potential economic performance for this greenhouse system in a northern environment could vary much more than what is presented in the table above. The potential net returns based on the different combinations of sales revenues and total operating costs are as follows:

Table 60: Range of Net Returns for Half-Acre Gutter-Connected Greenhouse Operating 9-10 Months per Year

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$113,644	$79,098	$316,273
Mid-Point	-$236,384	-$43,642	$193,533
High	-$377,872	-$185,131	$52,045

Different subjective probabilities (compared to those applied to three-acre systems) are applied to each of the different levels of sales revenues and total operating costs. These are to reflect the belief that a smaller greenhouse system aligned with a smaller market size may have a greater likelihood of achieving higher levels of sales revenues as well as a greater likelihood of achieving higher total operating costs. The probability for each possible outcome multiplied by the net return for each possible outcome produces the following.

Table 61: Range of Expected Values for Net Returns for Half-Acre Gutter-Connected Greenhouse Operating 9 -10 Months per Year

		Sales Revenues		
Total Operating Costs		20.00%	45.00%	35.00%
Low	**20.00%**	-$4,546	$7,119	$22,139
Mid-Point	**45.00%**	-$21,275	-$8,838	$30,481
High	**35.00%**	-$26,451	-$29,158	$6,375

The sum of the expected values for each of the possible outcomes produces an expected value (for net returns) of -$24,152.This estimate of net returns suggests a %ROA of -2.04%. It is important to note that salary costs have been reduced to reflect situations where owner/operators are willing to take less than market rate for their contribution of labour and management. This increases the net returns to capital. As before the subjective probabilities are intended to be descriptors of the uncertainty surrounding the different outcomes for sales revenues and total operating costs.

Twelve-Month per Year Half-Acre Gutter-Connected Model

Increasing the productivity of the half-acre system by investing to achieve year-round production is presented in the following tables and chart. The increased capital costs associated with the year-round system are related to the grow lights and energy curtains. Using the same assumptions as within the three-acre model but adjusting for increased energy consumption in the half-acre model, there are large improvements to both net cash income and %ROA as illustrated in the following two figures.

Figure 16: Net Cash Income for Half-Gutter-Connected Greenhouse, 9 – 10 Months versus 12 Months per Year

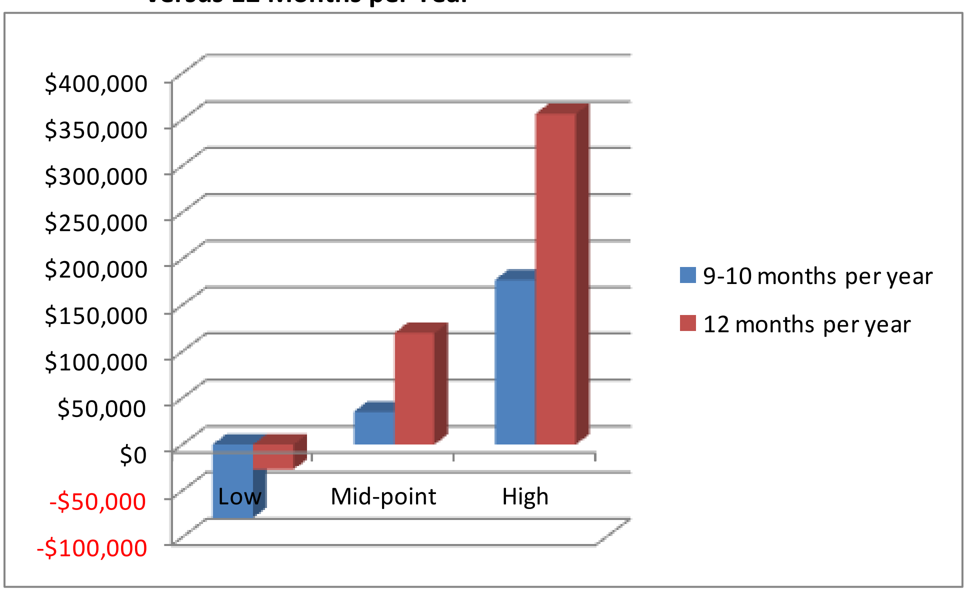
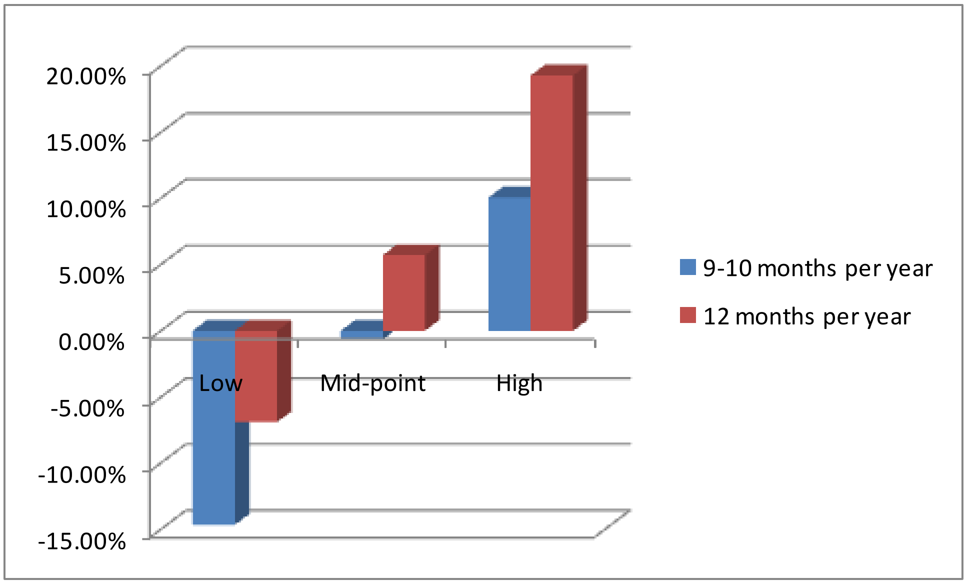


Figure 17: Return on Assets for Half-Gutter-Connected Greenhouse, 9 – 10 Months versus 12 Months per Year



As before the potential economic performance for the half-acre greenhouse system in a northern environment will likely vary much more than what is presented below. The possible outcomes for net returns based on the different combinations of sales revenues and total operating costs are as follows.

Table 62: Range of Net Returns for Half-Acre Gutter-Connected Greenhouse Operating 12-Months Per Year

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$99,271	$159,356	$471,161
Mid-Point	-$272,800	-$14,173	$297,632
High	-$426,229	-$167,602	$144,203

The sum of the expected values using the same possible outcomes as within the 9 – 10 month half-acre model produces an expected value (for net returns) of $24,239.This estimate of net returns suggests a %ROA of 7.31%. Once again these measures may be over stated when salary costs have been reduced to reflect situations where owner/operators are willing to take less than market rate for their contribution of labour and management.

7.2.5 Chinese-Solar Greenhouse (150 m^2)

The Chinese-style solar greenhouse is designed to utilize passive solar energy in combination with a biomass heating system to reduce energy costs. The feasibility of the Chinese solar model can be limited by capital costs. Capital costs for the Chinese solar model in Canada are very high at present and the figures presented here based on actual design work completed by Integrated Designs Inc in Saskatoon for a fully commissioned model expected to be built in La Ronge, Saskatchewan.

A challenge for this style of greenhouse system can be overcoming the capital costs issues. The potential lays in energy efficiency being able to overcome the higher capital costs as well as lower capital costs in the future. The quandary is that low-cost low-tech models are available in China, yet low-cost low-tech models do not appear to be available in Canada at this time. Possible reasons for this include more expensive labour, higher input prices and the costs of constructing the back wall and overall building to Canadian construction code and to account for snow mass.

As previously suggested there is little information on how this type of system might perform in northern conditions. The productivity levels at estimated 65% of a gutter-connected (9-10 month) system are higher than for the high-tunnel system and lower than stand-alone systems. Fixed operating costs are expected to generally be higher owing to higher capital costs. Other key assumptions applied in the model for the Chinese Solar greenhouse system are:

1. Only 70% of the total greenhouse area may be available as growing area. Chinese solar greenhouses are designed to run east-west to take advantage of the north wall as a heat sink. The walkway design is the same for most greenhouses; the main wider walkway runs east-west and the narrow walkways run north-south. In general the Chinese greenhouse is longer east-west walkway will cause a higher walkway ratio to growing space than a north-south greenhouse.
2. 50% of the growing area is allocated to tomatoes and 20% to English cucumbers.
3. All marketable production is projected to be sold at retail prices.

The projected economic performance for this type of structure and system is summarized in the following table.

Table 63: Estimated Economic Performance of Chinese Solar Greenhouse (150m^2) Operating 6-8 Months per Year

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid - Point**	**High**
Structure Costs ($/m^2)	$758	$892	$1,025
Total Capital Costs ($)	$136,533	$170,287	$204,242
(A) Sales Revenues			
Tomato Sales Revenues ($)	$5,839	$12,928	$21,943
Cucumber Sales Revenues ($)	$3,028	$6,153	$8,007
Pepper Sales Revenues ($)	$0	$0	$0
Lettuce Sales Revenues ($)	$0	$0	$0
(A) Total Sales Revenues	$8,867	$19,082	$29,950
(B) Variable Costs			
Growing Costs	$481	$645	$832
Energy Costs	$408	$910	$1,585

	Range of Possible Parameters, Prices and Costs		
	Low	**Mid - Point**	**High**
Labour costs	$0	$0	$0
Marketing and Distribution Costs	$1,061	$1,446	$1,886
Repair Costs (Building & Equipment)	$7,592	$9,167	$11,954
Other Costs	$755	$1,321	$1,887
(B) Total Variable Costs	$10,297	$13,489	$18,145
Gross Margin (A-B)	**-$1,430**	**$5,593**	**$11,806**
(C) Fixed Costs			
1. Depreciation	$9,382	$11,779	$14,383
2. Interest on Capital	$4,096	$5,109	$6,577
3. Taxes & Insurance	$7,466	$8,975	$11,684
4. Salaries	$0	$0	$0
(C) Total Fixed Costs	$20,944	$25,863	$32,645
(D) Total Costs	**$31,241**	**$39,352**	**$50,789**
(E) Net Cash Income (A-D+C1+C2)	**-$8,896**	**-$3,382**	**$121**
(F) Net Returns (A-D)	**-$22,374**	**-$20,270**	**-$20,839**
Net Returns /m^2	-$80.48	-$12.26	-$9.78
%ROA	**-17.66%**	**-12.26%**	**-9.78%**
50% Capital Subsidy - Net Returns	**-$15,635**	**-$11,826**	**-$10,359**
50% Capital Subsidy - Net Returns /m^2	-$56.24	-$42.54	-$37.26
50% Capital Subsidy - %ROA	**-14.10%**	**-8.68%**	**-6.13%**

Different combinations of sales revenues and total operating costs for this system indicated operating losses in all possible outcomes. For this reason probability analyses were not considered for this system.

Table 64: Potential Net Returns for 150m^2 Chinese Solar Greenhouse (Operating 6-8 Months per Year)

	Sales Revenues		
Total Operating Costs	**Low**	**Mid-Point**	**High**
Low	-$22,374	-$12,160	-$1,291
Mid-Point	-$30,485	-$20,270	-$9,401
High	-$41,922	-$31,708	-$20,839

At this time the economics of the Chinese solar greenhouse are challenged by high capital costs and moderate levels of production. Furthermore, the high capital costs make attaining economies of scale essentially unattainable as it would cost around $1 m to build approximately 1,000m^2 (one-quarter of an acre) of Chinese-style solar greenhouses. For the same amount of funds, six-times the amount of gutter-connected greenhouses can be built and this cannot be compensated for through energy costs savings.

Despite the fundamental economic challenge, the Chinese-style greenhouse model does make intuitive sense for northern Canada as its overall goal is to reduce energy costs. Reducing energy costs is crucial for greenhouses in the north, but with the existing Chinese solar greenhouse models it does not appear to reduce energy costs nearly enough given its capital costs. If and when these greenhouses can move out of the prototype stage and into practical cost-efficient construction packages, Chinese-style solar greenhouses may be very useful for northern communities in the future. Looking forward, reduced capital costs in combination with strategies of producing higher value niche crops that fit with this growing system may offer an economic opportunity in specific cases.

7.3 Enterprise Budget Summary and Discussion

The enterprise budgets highlight both the opportunities and constraints facing northern greenhouse venture. The following points provide a summary of key issues and conclusions from the analysis within the above sections.

1. The economic performance of Chinese solar models in their current form appear to be constrained by limited productivity and high capital costs. These systems may hold promise in the future providing they can consistently achieve acceptable levels of production in northern conditions, and capital costs begin to come down so that energy savings begin to offset high capital costs.
2. Each of the other greenhouse systems shows a range of returns ranging from unacceptable to quite positive. This indicates that each could be viable under the right circumstances but that survival and sustainability is not guaranteed.
3. The key drivers for positive returns are prices and productivity. A key benefit for smaller-scale operations is being able to sell produce at retail prices – a key assumption within the models. Small-scale greenhouses are less efficient than larger-scale greenhouses but can make up at least some of this difference by selling at retails rather than wholesale prices. It may be difficult for greenhouses who receive lower prices and productivity to survive.
4. On the cost side, electrical and heating costs (based upon requirements and per unit costs) will be critical elements in the economic viability of a northern greenhouse venture. The challenge for an individual greenhouse enterprise can be in finding the appropriate balance between the capital costs and reduced operating costs of heating systems with greater efficiencies and reduced energy use. Achieving an advantage in energy costs, especially heating costs, will be crucial for a northern greenhouse enterprise. The use of district heating systems or locating near forestry operations can be key elements of this strategy but any method that will reduce heating costs (biomass or non-biomass based) should be reviewed.
5. Subsidizing capital costs does improve the profitability and returns of different greenhouse enterprises, providing greater resiliency to withstand potential shocks.
6. There needs to be modest expectations for low-cost and low-tech high-tunnel greenhouses but they have an opportunity to be successful. In areas with high food prices, these systems may be

feasible, especially if there is an opportunity to expand over time to achieve economies of scale. Opportunities may also exist to improve profitability through the use of local materials and the use of an owner/operators labour.

7. Stand-alone greenhouses may be profitable depending on the level of productivity and pricing achieved.
8. The opportunities for larger-scale commercial gutter-connected greenhouse systems will be dependent on finding effective balances between year-round production, large market size and accessing higher wholesale prices.
9. The opportunity for smaller-scale gutter-connected systems may be in achieving higher prices in the wholesale and retail markets along with minimal salary costs.
10. More remote communities may have opportunities for greenhouse development providing all production is consumed locally, consumers are willing to pay for higher cost produce (close or similar to present prices) and the production systems are able to overcome the obstacles of limited skills and the high costs of inputs.
11. There are clear economies of scale to greenhouse production, as illustrated in the differences between the half-acre and three-acre gutter-connected systems, as well as the smaller-scale high-tunnel greenhouses.
12. Paying salary costs within the financial models is a barrier to profitability. In most small-scale greenhouses owner/operators draw from the available net return rather than a fixed salary. Paying salary costs in the larger-scale models is a barrier to their profitability and returns.
13. Within commercial greenhouse operations, it does appear that there are positive returns from year-round production. This will obviously vary however within the study zone given the large variation in latitudes and climates so this will need to be assessed on a case by case basis, but it is possible.
14. The size of local markets will determine the appropriate scale and scope of a greenhouse enterprise. Smaller-scale greenhouses may be constrained by not being able to capture economies of scale but they will have the benefit of higher prices if they are able to sell their produce at retail prices. The critical success factors for smaller greenhouse enterprises aligned with smaller sized markets can include producing a wider range of items, developing the greenhouse enterprise to complement an outside garden, selling bedding plants and ensuring they sell directly to consumers in markets that place a higher value on the attributes of locally produced and freshness.
15. The challenge of serving as a hub to serve an expanded market area. A northern greenhouse venture could pursue a market beyond its local area. This strategy would enable a greenhouse enterprise to increase its scale of operations and capture economies of scale. However for this to be an effective strategy the distances which the greenhouse production is transported must not add excessive costs. As well, transporting produce to expanded markets can affect the product quality. At greater distances, transportation costs can give imported products a price advantage for produce of comparable quality. The critical success factor for a northern greenhouse pursuing expanded markets will be determining which markets that can be accessed without incurring excessive transportation costs or diminishing the attributes of freshness and high quality.

16. Achieving acceptable and reliable levels of greenhouse productivity will be necessary if a northern greenhouse venture is to be viable and sustainable. Generally productivity is measured in terms of production (kg or units) per square meter. Accordingly the critical success factors will be having the economic resources and human resources (expertise) in place to ensure acceptable levels of production can be achieved early in the life of the greenhouse enterprise and sustained over the life of the greenhouse venture.
17. Greenhouse ventures in remote communities can face the economic challenge of markets taking long periods to develop. Social and cultural factors can determine the rate at which consumers change their purchase choices to consume more locally produced greenhouse vegetables. The rate of adoption by consumers will affect the viability of a northern greenhouse venture. A slow or modest rate of adoption by consumers can mean that not all greenhouse production is being consumed in the local market. As a result the greenhouse enterprise may not be able to generate sufficient revenues to cover all operating costs as well as provide for a reasonable return to owner/operators. A critical success factor in these situations will be for the greenhouse enterprise to have sufficient financial ability to withstand limited cash flows while the market for the locally produced greenhouse vegetables develops.
18. Northern greenhouse ventures will have the challenge of being reliable suppliers to retail and wholesale markets. Retailers in particular will have limited patience for intermittent or unpredictable supplies of greenhouse vegetables. The worse-case scenario could be losing market share due to the inability to be a reliable supplier. Accordingly the critical success factors required to be a reliable supplier could include not only reliable production performance but also strategies for communicating the timing and quantity of expected production to markets.
19. Northern greenhouse enterprises can have the advantage of supplying locally produced greenhouse vegetables to a particular market. However, imported products will always have a presence in some of the larger markets. As a result a northern greenhouse enterprise may be challenged to compete with imported products on price. In these situations a critical success factors would be developing a value proposition for consumers that reflects both quality and price.
20. Management capabilities including decision making processes, risk management and human resources management will be a key factor in the economic viability and long-term sustainability of a northern greenhouse enterprise.
21. The long run survival of the greenhouse enterprise will require the capacity of the operators to withstand unplanned events with adverse effects on the facilities, the productivity performance and the economic performance. Critical success factors then are the ability to recover from these events which include having access to sufficient capital to replace damaged facilities, be able to make investments to replace technologies and systems that have either worn out or have become obsolete and to be able to adapt to changing market requirements in order to retain market share.
22. A critical success factor for a larger-scale greenhouse enterprise will be for the construction and development of the greenhouse facility to be completed on time and on budget. If critical completion dates are not met, the timing of the first planting of crops could be adversely affected to the extent that productivity will be significantly reduced. This risk could be managed through an assortment of incentives and penalties built into the contract. As well, cost over-

runs can be another issue that can have adverse effect on economic performance. A critical success factor will be having the financial capacity to properly finance cost overruns.

23. Community engagement will be a critical success factor needed to support the production performance, market performance and overall economic performance of a northern greenhouse venture. Without community support there may not be the commitment of workers or consumers that are essential to achieving a viable and sustainable enterprise.

7.4 Macro-Economic Effects

Economic Multiplier

A viable greenhouse enterprise can generate economic benefits in a local area as well as contribute to community wellness. The economic benefits of a northern greenhouse venture will include:

1. The direct effects of the new greenhouse venture which can be measured by the sales of greenhouse vegetables as well as any related services.
2. The indirect effects of the new greenhouse enterprise buying inputs and hiring labour in the local economy as well as additional rounds of spending due to input suppliers purchasing inputs from their suppliers.
3. The induced effects are the additional expenditures due to changes in income earned by individuals working either directly or indirectly in the greenhouse industry.

The total economic benefits of a new greenhouse enterprise in a local economy will be determined by the changes in local spending by the greenhouse enterprise, the local suppliers of inputs and the employees of the greenhouse enterprise. The longer money continues to be spent in the local economy the greater are the economic spin-offs. Generally, the greater the linkages an economic activity such as a greenhouse has, the greater would be the benefits to the local economy. However, as more money leaks out of the local economy the economic benefits are reduced.

The total economic benefits of a greenhouse enterprise can be measured using output multipliers which are the total economic effects divided by the direct economic effects. Although there are no studies that specifically undertake to quantify the total economic effects of a new greenhouse venture in northern Canada there are studies of the economic activity generated by the greenhouse industry in other regions. These studies can provide an understanding of the linkages and potential effects that a northern greenhouse venture may have with other sectors of a local or regional economy.

A 2006 study developed output multipliers to assess the ability of the greenhouse sector to generate economic benefits throughout the Ontario economy.[6] These multipliers measured the expected increase in the total output ($) of the Ontario economy for each dollar of increased production generated by the greenhouse industry. The output multipliers suggest that for each dollar of output generated by the Ontario greenhouse industry there was $2.81 of activity generated in the economy as

[6] *Ontario Greenhouse Alliance (2006). Greenhouses Grow Ontario: An Economic Impact Study of Greenhouses in Ontario. [http://www.planscape.ca/planscapePDFs/50-plan1.pdf]*

a whole due to the direct, indirect and induced effects. Therefore for every dollar of output generated by the greenhouse industry there was an additional $1.81 of economic activity in economy. The economic impact without the induced effects of labour income was $1.01 of additional activity for each dollar of output achieved by the greenhouse sector.

The additional rounds of spending that are generated by a greenhouse venture will determine the total economic benefits of a new greenhouse venture in a local economy. In particular will be proportion of greenhouse expenditures that are made locally such as for utilities, transportation and labour. As well, will be the proportion of household earnings that are spent locally for food, general merchandise and consumer goods. Since there will be proportions of these expenditures that are made outside of the local economy for both greenhouse inputs and household purchases the output multiplier is expected to be much less than what is being achieved in the much larger Ontario economy. The potential economic benefits of a greenhouse venture working its way through a local economy in a northern community are considered in the following table.

Table 65: The Potential Economic Benefits of a Northern Greenhouse Venture in a Local Economy

Direct Effects ($ Sales) of New Greenhouse Enterprise	Range of Output Multipliers				
	1.1	1.3	1.5	1.7	1.9
$100,000	$110,000	$130,000	$150,000	$170,000	$190,000
$500,000	$550,000	$650,000	$750,000	$850,000	$950,000
$750,000	$825,000	$975,000	$1,125,000	$1,275,000	$1,425,000
$1,000,000	$1,100,000	$1,300,000	$1,500,000	$1,700,000	$1,900,000

Health Benefits

By providing a reliable supply of vegetables with the attributes of freshness and nutrition, a northern greenhouse can contribute to healthy food choices by consumers. Reduced costs for healthy food choices can in turn lead to improved public health and reduced incidents of reduced obesity, diabetes and high blood pressure. As noted in the table below, the prevalence and costs of diabetes is highest in northern Canada.

Table 1. Predicted healthcare costs of patients with diabetes in Canadian provinces and territories between 2000 and 2016							
	Healthcare costs (millions of $)*				*% change (2000–2016)*		
	2000	**2005**	**2010**	**2016**	**Healthcare cost**	**Total population**	**Diabetes prevalence**
Newfoundland	79.4	94.0	111.3	135.4	70.5	-4.3	64.8
Prince Edward Island	21.9	25.3	29.4	35.7	63.0	5.9	62.3
Nova Scotia	149.8	175.5	206.0	249.3	66.4	2.9	63.5
New Brunswick	119.0	139.8	164.1	198.0	66.4	-0.6	62.7
Quebec	1295.4	1508.8	1747.0	2069.0	59.7	2.0	53.2
Ontario	1763.0	2131.0	2551.4	3143.6	78.3	18.2	76.5
Manitoba	189.6	214.9	247.9	295.3	55.8	2.8	52.1
Saskatchewan	165.8	188.7	214.5	250.3	51.0	0.1	50.1
Alberta	386.1	477.6	584.2	733.3	89.9	14.0	85.8
British Columbia	635.1	775.9	941.2	1177.9	85.5	22.6	84.3
Yukon	3.0	3.7	4.6	6.0	103.9	2.9	87.1
Northwest Territories	3.1	4.0	5.3	7.1	128.3	11.5	107.8
Nunavut	1.4	2.0	2.8	3.7	170.1	27.1	146.3
Canada (totals)[†]	4657.8	5592.5	6658.1	8142.7	74.8	11.9	71.9

*Monetary values are expressed in 1996 Canadian dollars

Source: http://www.diabetes.ca/files/johnsonCJDjune2004.pdf,

Benefits to society from reduce obesity will accrue to the government via reduced health care costs and to the community through a more productive labour force. The direct and indirect costs of diabetes in Canada are estimated to be 3.5% of public spending on healthcare costs and expected to increase substantially in the future[7].

The financial burden of diabetes and its complications is enormous. People with diabetes incur medical costs that are two to three times higher than those without diabetes. A person with diabetes can face direct costs for medication and supplies ranging from $1,000 to $15,000 per year[8]. US data suggest that the individuals diagnosed with diabetes incur health care cost of an additional $6,649 per year attributed to diabetes[9]. Thus using a range of $5,000 to $12,000 per person per year of increased health care costs attributed to diabetes, the potential health care savings that might be achieved for a community of 5,000 persons via greenhouse vegetable production and greater access to healthy food choices might be as follows.

[7] *The Costs of Diabetes in Canada: The Economic Tsunami, http://www.diabetes.ca/documents/for-professionals/CJD--March_2010--Beatty.pdf*

[8] *http://www.diabetes.ca/diabetes-and-you/what/prevalence/*

[9] *American Diabetes Association, Economic Costs of Diabetes in the US in 2007.*

Table 66: Potential Savings in Health Care Costs ($/Year) for a Population of 5,000 Gaining Access to Healthy Food Choices

% of Total Population that achieves reduced health care costs due to access to healthy food choices		Range of Health care costs per person attributed to Diabetes			
		$5,000	**$7,500**	**$10,000**	**$12,500**
	1%	$250,000	$375,000	$500,000	$625,000
	3%	$750,000	$1,125,000	$1,500,000	$1,875,000
	5%	$1,250,000	$1,875,000	$2,500,000	$3,125,000
	7%	$1,750,000	$2,625,000	$3,500,000	$4,375,000

The above are estimates framed by a range of potential savings per person per year and the percentage of the population that via healthy food choices achieves improved health (or does not succumb to diabetes as much of the literature is suggesting).

Socio-Economic Benefits
A northern greenhouse enterprise can also provide socio-economic benefits that accrue to the local community and to the wider economy. These include the following:

1. A northern greenhouse venture can generate increased economic activity and economic benefits that are beyond what is considered in the output multiplier. A successful greenhouse business can lead the local community to pursue other business ventures that will further contribute to the economic growth of the community. These benefits would be measured via the direct, indirect and induced economic effects of the new economic activities.
2. Opportunities for employment in a greenhouse enterprise can develop technical knowledge and skills that along with experience can be used to replicate similar greenhouse ventures in other communities. Employment opportunities can also contribute to improved labour productivity and a skilled workforce that could attract further new economic activities to the community.
3. Increased use of biomass as an energy source can contribute to increased opportunities for renewable energy production and use in the local community. Greater use of biomass as an energy source throughout the community can contribute to reduced heating costs for households as well as to further opportunities for new economic activities using renewable energy. Reduced emissions from renewable energy will benefit all of society.
4. A viable biomass based business can contribute to greater values of woodlots and wood fuel sources. As well a viable biomass based business will can also contribute to greater attention to conservation and land management that will contribute to improved air quality and improved water quality.
5. Participation in the workforce. Greenhouse enterprises can provide local employment opportunities in northern communities that in turn can lead to increased disposable incomes, improved housing and improved health.
6. Greenhouse enterprise can contribute to educational benefits for schools and community members. Greenhouse enterprise can be partners with education institutions and governments in needs assessments, providing learning environments and developing learning paths for

interacting with productive technologies. Individuals who complete high school can have greater opportunities for employment and well-being. A summary of the potential economic benefits of completing a high school education in Saskatchewan are presented as follows.

Table 67: Estimates of Increased Lifetime Earnings for Completing a High School Education

	Males	Females
Non-aboriginal resident of Saskatchewan	$291,500	$247,951
Metis Resident of Saskatchewan	$428,554	$349,505
North American Indian resident of Saskatchewan	$434,739	$277,509

Original Source: Howe, E. (2011), Bridging the Aboriginal Education Gap in Saskatchewan, The Gabriel Dumont Institute, www.gdins.org

7. Greenhouses can provide community green spaces that in turn can provide social and therapeutic benefit to community members. Community green spaces can contribute to greater cohesion as well as reductions in antisocial behaviours that spill over to the community. Furthermore community green spaces (indoor) can contribute to reduced stress and reduced health costs.

8 FRAMEWORK FOR ASSESSING NORTHERN GREENHOUSE PROPOSALS

8.1 Introduction

The following framework has a number of objectives. First is to ensure that the full range of factors that need to be considered in developing a northern greenhouse enterprise have in fact been considered in developing the proposal. Second is to be able to assess the fit of the proposed greenhouse enterprise with the local context of the community and its resources. Third is to draw attention of funders to areas of strength that can enhance the likelihood of success as well as draw attention to areas that are weak and might limit the potential for success unless some action is taken. A fourth objective can be to enable reviewers to gain insights on the sequence of decisions and the decision making processes that led to the specific proposal.

The framework is based on the key issues identified in the study along with identified practices and strategies. Ten areas of inquiry have been identified which are combined into the framework on the following pages that reflect the critical success factors of a northern greenhouse venture that are explored in the study. A suggested decision matrix has then been provided illustrating a potential method of assessing the quality of proposals. The ten areas identified within the framework are:

1. Governance and Goals
2. Market Size and Market Potential
3. Energy Use, Energy Sources and Energy Costs
4. Economic Assessments/Risk Assessments
5. Human Resources
6. Greenhouse Structure/Technology
7. Community Engagement
8. Resiliency
9. Competitive Advantages/Disadvantages
10. Other

Within the framework the first five factors are seen as primary and of greatest importance to success and sustainability. Within each, a number of mandatory factors are included which provide a greater chance of success for a greenhouse. These are followed by a series of strengths/weaknesses that need to be assessed by funders in the context of applications. Also, a series of contextual information must be included in any application that will show that applicants have considered all key questions in developing a greenhouse enterprise which funders need to see in order assess the quality of this information and proposal.

Within the decision matrix, the first five factors are seen as having double the importance (and potential scoring value) of the last five. It must be noted that however that there will be many differences by location, technology, size, human resources and experience that must be assessed and no one matrix will provide a cut and dried solution to this. The matrix and framework questions can be used to guide decision making but a broader perspective and assessment of individual applications, with an understanding that there is no one size fits all solution, should be undertaken. Greenhouse expertise should also be sought by funders in the decision making process.

The questions within the decision framework, as well as the overall decision matrix, will need to be refined and developed over time in order to provide value to users.

8.2 Decision Framework

1. Governance and Goals

Mandatory Requirement

- None

Strength/Limitation

- Who will run the enterprise – the Band or an EDC or other authority removed from political interference?
- Is the enterprise focused on making a profit as a key goal or are other goals primary?
- Do the goals chosen detract from the profitability and eventual sustainability of the enterprise?
- Will the project be run by an individual entrepreneur with their own funds invested?

Contextual Information to be Included

- What are the key objectives to be achieved in developing the greenhouse enterprise?
    - To develop a viable business enterprise achieving an acceptable rate of return at acceptable risk______
    - To reduce the dependence on imported food products and gain greater food self-sufficiency as well as reduce food insecurity________
    - To increase the availability, quality and quantity of local foods sold by retailers or used by local restaurants and institutions_________
    - To develop a community-led sustainable food production system that provides greater access to healthy food choices__________
    - To elevate the importance of local food production in the community and increase the community's capacity to produce vegetable crops_______
    - To address climate change and resource conservation_______
    - To creating food-related partnerships with other communities as well as with government agencies and private businesses________
    - To contribute to economic development as well as local employment and training opportunities_________
    - To develop a model for viable local food production that can be replicated in other remote communities_____

(Identify and prioritize the top three objectives)

- What is the organizational/ownership structure of the proposed greenhouse enterprise?
  - A community-owned and operated business enterprise ______
  - A partnership between the community or Band and a private sector investor/greenhouse operator_____
  - A non-profit or limited profit business organization providing reduced food prices, food security, health and improved wellness________
  - A community-owned and operated business with the main focus of increasing local employment for community members while breaking even or making a small profit_____
  - An independent business owned but not operated by the local community or band_________
  - A cooperative in which the community (or Band)has membership _________
  - An investment in which the community or local Band invests capital with the objectives of achieving an acceptable rate of return for the investors at an acceptable risk._______
  - A business owned by the local community or Band operating with the benefit of production contracts to supply near-by businesses operating in the resource economy including mines and lumber mills______
  - An investment in land and greenhouse facilities in which the community or Band becomes the landlord of facilities that are leased to a commercial greenhouse venture_____

(Indicate which of the above apply)

2. Market Size and Market Potential

Mandatory Requirement

- Market assessment completed
- Market size must be larger than or match proposed greenhouse size

Key Factor (Increase/Decrease Likelihood of Success)

- Can the greenhouse attain higher prices as a result of location or is there a well thought out strategy to market produce to higher niches?
- Market size is realistic
- Market size matches proposed greenhouse size
- What strategies have been developed to facilitate the development of markets where cultural and social factors might affect the consumption of locally produced greenhouse vegetables?

Contextual Information to be Included

- What are the main crops that will be offered to the market place?
  a. ____________________
  b. _____________________
  c. _____________________
  d. _____________________
- What type of market assessment has been completed?

  - An informal survey of target markets______
- A formal market survey that assesses:
  - What greenhouse products consumers buy_____
  - Where are the buyers located _______
  - The market size______
  - Whether the market mature or growing_____
  - Whether the market has room for additional production_____
  - The packaging requirements of the market____
  - Whether consumers will pay a premium for greenhouse vegetables with specific attributes such as locally grown and fresh_____
- Describe the target market(s) including location and size, where the greenhouse production will be sold.
- What is the size of target market required to support the scale of the proposed greenhouse enterprise?
- How will the size of the local market and local consumption affect the scale of the greenhouse venture?
- The market size will limit the size of the greenhouse enterprise______
- The market size will not limit the scale of the greenhouse enterprise________
- Which of the following best describes the target market
  - A remote market with generally higher prices for vegetables_____
  - A market in an area with larger populations, greater competition from imported products and greater price competition_____
  - A niche market with consumers prepared to pay a price premium for greenhouse production with specific attributes_______
- Are there social and cultural factors that will determine the rate at which a market for greenhouse vegetables might develop and at which consumers change their purchase choices to consume more locally produced greenhouse.
- Do most consumers in the target market eat the main greenhouse vegetables (tomatoes, cucumbers, peppers, lettuce) regularly? If not…
  - What strategies have been developed to facilitate the development of markets where cultural and social factors might affect the consumption of locally produced greenhouse vegetables?
- Which best describes the market?
  - A market in an area with larger populations, greater competition from imported products and greater price competition_____ - less chance of success
  - A remote market with generally higher prices for vegetables_____
  - A market in an area with larger populations, greater competition from imported products and greater price competition_____
  - A niche market with consumers prepared to pay a price premium for greenhouse production with specific attributes_______

3. Energy Use, Energy Sources and Energy Costs

Note: Skip this section if application is for unheated high-tunnel greenhouse.

Mandatory Requirement

- Have the energy requirements of the proposed greenhouse system been assessed in terms of intensity, timing and duration?
- Does the capacity exist to repair the proposed power source?
- Have backup power systems be identified (if necessary).

Key Factor (Increase/Decrease Likelihood of Success)

- How well do the energy and power sources meet the operating requirements of the proposed greenhouse throughout the production period?
- Do the energy related technologies require specialized training and certification and if so do these skills exist or is there a training plan in place to acquire them?
- Is there an innovative component that enables the proposed greenhouse enterprise to mitigate energy costs?
- Do the costs of the available energy and power sources create a cost advantage or a cost disadvantage for greenhouse production?
    - o Cost advantage___________
    - o Cost disadvantage________
- Will the greenhouse facility be exposed to volatile energy price movements?

Contextual Information To Be Included

- What will be the primary energy source for the proposed greenhouse enterprise?
    - o Natural gas_______
    - o Biomass (Wood Residue) _________
    - o Biomass (Wood Pellets) __________
    - o Biomass (Logs)__________
    - o Residual Energy from an Industrial Source______
    - o Hydro Electricity__________
    - o Coal-Generated Electricity_________
    - o Other _____________________
- Are there sufficient sources of energy to allow the greenhouse venture to expand operations over time?
- Are there times of peak use when there may not be sufficient energy or power for the safe operation of the greenhouse system?
- What are the capital costs for the energy source, including backup systems?
- What are the maintenance requirements and how will these be provided?
- What will the operating costs be and how competitive are they?
- Discussion of different energy options and why this system has been chosen, including both human and natural resource issues, as well as cost comparisons among systems.

4. Economic Assessments/Risk Assessments

Mandatory Requirement

- Have the economic projections considered ranges of
  - Projected capital costs_______
  - Expected Productivity levels (kg/m^2)__________
  - Market Prices ($/kg)____________
  - Energy costs ($/Gj of energy)______________
  - Growing Costs ($/Square meter)__________
- Risk analysis and identification of mitigation strategies completed

Key Factor (Increase/Decrease Likelihood of Success)

- Based on the feasibility study, does the greenhouse achieve a satisfactory %ROA or IRR?
- Based on the feasibility study, does the greenhouse achieve a satisfactory net returns and net cash income?
- Is the greenhouse integrated with a market garden?
- Will the greenhouse also sell other products such as bedding plants?
- Assess quality of and whether assumptions are realistic behind projected returns.
- Assess quality of risk identification and mitigation strategies.

Contextual Information to be Included

- Detailed financial assessment with detailed assumptions provided for both costs and revenues.
- What risks have been identified and assessed that could lead to failure or under performance in development of the greenhouse structure and operating system?

Risk events that could impact on the construction and development of the greenhouse structure and system	**Risk Mitigation Strategies**

- What risk events have been identified and assessed that could lead to failure or poor economic performance?

Risk events that could impact on the construction and development of the greenhouse structure and system	Risk Mitigation Strategies

5. Human Resources

Mandatory Requirement

- Human resources plan with clear delineation of roles and responsibilities
- Training plan if skills do not already exist in the community
- Human resources and training plan must be realistic

Key Factor (Increase/Decrease Likelihood of Success)

- Is there relevant skills and expertise in the community to run the greenhouse given the level of technology, size, complexity, etc.?
- What is the plan to acquire both skills and experience to support greenhouse operation assuming this is needed?
- Does the existing human resources and training plan fit with the level of complexity and size of the greenhouse?
- What is the plan for long-term support (training, mentorship, etc.) assuming this is needed.
- Will the human resources and plans enable the greenhouse to achieve either average or high levels of productivity?
- Is the human resources and training plan realistic including any plans for sourcing outside expertise?
- Competitive advantage through low labour costs.
- Are human resources management and developing an effective team of employees a strength or a limitation in this proposal?
- Are there clear goals and responsibilities for each individual involved in the greenhouse operations
- Has succession/transition planning taken place to ensure there are properly trained individuals to step in to key roles in the event that the individuals in those roles choose to leave their jobs?

Contextual Information To Be Included

- Full human resources plan and associated training and skills acquisition plan.
- What are the key roles in the proposed greenhouse enterprise and the training and experience levels required for the role

Key Roles in the Greenhouse Enterprise	Training/Certification requirements required in the role	Level of relevant Greenhouse experience required by the role
Greenhouse workers ___		
Head Grower_____		
Assistant Grower_____		
Facilities Manager____		

- What training will be needed by new staff?
  - ________________________
  - ________________________
  - ________________________
- What are the expected labour costs ($/Square Meter)_______________
- What is the competition for labour? _____________________________

6. Greenhouse Structure/Technology

Mandatory Requirement

- Have the type of structure and the growing system been tested under commercial conditions in a similar northern environment? If no, there must be strong justification and feasibility analysis for using this on a commercial basis.

Key Factor (Increase/Decrease Likelihood of Success)

- How well does the type of structure, technology and scale of the proposed greenhouse enterprise fit with the growing experience of the community?
- How well does the type of structure, technology and scale of the proposed greenhouse enterprise fit with the location of the community?
- How well can parts be found and repairs completed and is there a plan for this in remote communities?
- How well does the greenhouse structure match the human resources of the community?
- How well does the greenhouse structure match the market size and market requirements?

Contextual Information To Be Included

- What is type of greenhouse structure is being considered and what is the scale of the proposed greenhouse facility?
  - Greenhouse Structure(high-tunnel, passive solar, gutter-connected) _______________

    - Size (Square meters of Growing area) of the Greenhouse structure______________
- What are the key issues to be resolved in the design of the greenhouse structure?
- What are the key issue to be resolved in the design and implementation of the greenhouse growing system?

7. Community Engagement

Mandatory Requirement

- None

Key Factor (Increase/Decrease Likelihood of Success)

- Is the understanding of what is involved in starting a greenhouse or growing plants a strength or a limitation in this proposal?
- Is the level of community support a strength or a limitation in this proposal?
- Are the leadership capabilities and governance in the community a strength or a limitation in this proposal?
- Is the ability of the community to work with and gain value from outside advisors a strength or a limitation in this proposal?
- Does the local community have a financial stake in the proposed greenhouse enterprise?

Contextual Information To Be Included

- How will community be engaged in the process?
- What is the role of the community in planning and implementation?
- What shows that the community support this project?

8. Resiliency

Mandatory Requirement

- None

Key Factor (Increase/Decrease Likelihood of Success)

- Does the greenhouse enterprise have the capacity to adapt to changes in markets and the ability to withstand major shocks and disturbances without incurring significant losses or failure?

Contextual Information To Be Included

- What are their strategies to build resilience in order to ensure the long run sustainability of the greenhouse enterprise?
    - Maintaining flexibility by limiting debt, avoiding long-term commitments that reduce flexibility (such as contracts) and recombining existing resources to gain new capabilities?
    - Continually seeking new opportunities by diversifying sources of information?
    - Continuous experimentation to develop new production or market opportunities?

- Connecting with networks that support combining scientific knowledge with practical knowledge as well as how to be prepared for unexpected changes that can have both harmful and beneficial consequences.
- Others.

9. Competitive Advantages/Disadvantages

Mandatory Requirement

- None

Key Factor (Increase/Decrease Likelihood of Success)

- Competitive advantages and plans to capitalize on them.
- Competitive disadvantages and plans to overcome them.

Contextual Information To Be Included

- Does the proposed greenhouse facility have a competitive advantage through:
  - Access to low priced inputs_________
  - Access to a large-scale market_____
  - Access to a low-cost energy source_________
  - Access to a unique/niche market opportunity________
  - Potential to be a hub serving a larger regional market_______
  - Access to lower cost labour that can offer an advantage in terms of lower costs______
  - Access to skilled labour that can provide a competitive advantage in terms of productivity_____
  - Other factors
- Identification of disadvantages and strategies to overcome them.

10. Other

Mandatory Requirement

- Is there a sufficient supply of water to meet the needs of the greenhouse system without affecting the supply of others in the community?
- Is the quality of the available supply of water acceptable for the greenhouse system?

Strength/Limitation

- Overall quality of feasibility study or other (if before pre-feasibility study phase)
- Other strengths/weakness within the application
- Availability and sustainability of natural resources if appropriate (fuel source)

Contextual Information To Be Included

- What is the stage of development of the greenhouse project/proposal?
  - Requires a feasibility assessment________
  - Requires funding to support the development of the greenhouse facility_____
  - Requires funding to support an expansion or technology upgrade for an existing greenhouse enterprise_____

- Has a pre-feasibility assessment taken place to provide an initial assessment of the following?
    - An economic assessment that provides initial measures of expected capital costs, expected production, expected revenues, expected costs of operations and whether the project has the potential to achieve acceptable returns on investment_____
    - A technology assessment that assesses whether the proposed technology is right for the local conditions________________
    - A technology assessment that identifies the key issues to be resolved for successful design and implementation______________
    - An environmental assessment that identifies the available resources to support the greenhouse enterprise.
    - An initial assessment of market location, market need and potential market size______
- What is the fit of the proposed greenhouse project with the local food system?
    - Pilot testing new a new technology to determine feasibility in remote northern community_____
    - A simple greenhouse structure to complement an existing outdoor market garden______
    - An expansion to an existing greenhouse enterprise that is an established part of the local food system____
    - An investment in technology to increase productivity of an existing greenhouse facility that is part of the local food system ____
    - An investment in an existing greenhouse facility to expand the range of vegetables being produced______
    - A small-scale facility that is integrated into existing infrastructure (heating system) or facilities (community centre) _____
    - A large-scale commercial venture with modern design and systems________

      (Indicate which of the above apply)

- Does the location of the proposed greenhouse facility provide easy access to markets?
- Is the location of the proposed greenhouse in accordance with local land use plans?
- Is there sufficient local infrastructure to support the needs of the greenhouse enterprise?
- Are the strategies to ensure the long run sustainability of the natural resources a strength or limitation in this proposal?

8.3 Decision Matrix

Critical Success Factor	Mandatories Met (Yes/No)	Score	Comments
PRIMARY SCORING FACTORS (SCORE 1-10)			
1. Governance and Goals			
2. Market Size and Market Potential			
3. Energy Use, Energy Sources and Energy Costs			
4. Economic Assessments/Risk			
5. Human Resources			
SECONDARY SCORING FACTORS (SCORE 1-5)			
6. Greenhouse Structure/Technology			
7. Community Engagement			
8. Resiliency			
9. Competitive Advantages/ Disadvantages			
10. Other			
TOTAL SCORE:			

9 CONCLUSIONS AND RECOMMENDATIONS

9.1 Conclusions

Key Conclusions

This study has undertaken an integrated investigation of both the success factors for, and the constraints to, developing greenhouses in northern communities that are both viable and sustainable (economically, socially, environmental, etc.).

In undertaking this integrated investigation, it is important to go beyond:

- The technological questions of "how can we produce food in the north?"; and,
- The economic questions of "which of the technologies are commercially viable and on what scale?"

To do this we must also look more broadly at:

- The social questions of "what do communities want and what are the success factors/barriers for economic development in northern communities"; as well as,
- The resource questions of "what resources or factors might provide competitive advantages and or disadvantages to a northern greenhouse venture?"

Based on the analysis undertaken, the following four factors will be key to address in developing successful northern greenhouses:

1. The skills and experience required to successfully run a viable and sustainable commercial greenhouse in the north.
2. Governance issues in First Nations communities.
3. Achieving high price and/or productivity levels.
4. Energy costs and usage which are magnified in northern greenhouses given heating and lighting requirements in the cold and dark winter in northern latitudes.

Successful greenhouses will have strategies for addressing each of these issues. There is no one single approach or model that will ensure success for all situations. Individual greenhouse enterprises will need to identify strategies that correspond to their own situation, optimize competitive advantages and overcome disadvantages.

Matching Complexity to Skills and Experience

When looking at greenhouse vegetable production in the north, greenhouses need to be seen as one element of a ladder or spectrum that ranges from simple to more complex forms of vegetable production. At its simplest level, this includes outdoor market gardens on one side and modern high-technology greenhouses on the other end. In between are a range of greenhouses with differing levels of technological complexity.

Table 68: Types of Vegetable Production Systems Available for Northern Community, Based on Complexity, Cost and Risk

Complexity	Type of Production	Comments
Least complex and lowest cost/risk	Outdoor market garden	• Commercial market gardens exist for summer production throughout the north including NWT and Yukon • Highly suitable for roots crops (potatoes, carrots, onions) which are storable and which form the bulk of vegetables consumed in more remote northern communities • Low-cost and low risk
↕	High-tunnel style greenhouse	• Unheated single layer poly covered structure that extends the growing season an extra few weeks on either side • Allows production of some additional crops/varieties and enables some crops to come market sooner • Low-cost and low-tech greenhouse • Fewer skills are required but much less productivity also.
	Stand-alone greenhouse	• Engineered steel structure with double-poly covering • Range of technology levels from simple soil-based cultivation to soilless cultivation with full environmental controls • Range of cost and risk as well as productivity
Most complex and highest cost	Gutter-connected greenhouse or other high-tech options	• Capable of year-round production with full environmental controls • Costlier and high-tech • Highly productive • High-level of skills required

In assessing the viability of different greenhouse models for the north, the human resources available to an individual greenhouse enterprise will be a critical success factor. Higher technology greenhouses will require skilled and experienced growers who then can build the skills of local labourers. Communities who already have experience with either market garden or smaller-scale greenhouse vegetable production can move forward to more complex greenhouse models and production technologies. This will be a long-term and incremental process. It will also need to be supported by culturally appropriate training, mentoring and networking.

For many northern communities the determining factor of how simple or sophisticated a greenhouse venture will be is the existing community knowledge base on agricultural and vegetable production. In many communities there may be significant gaps in the basic skills and knowledge required for growing garden vegetables or for growing greenhouse vegetables. This knowledge gap will be a constraint on the level of sophistication that is appropriate for a greenhouse venture. Community gardens growing root and other crops can be an indicator of the abilities and attitudes towards developing skills that would be a resource to a greenhouse venture.

Simple greenhouse designs will satisfy the majority of the communities engaged in this study. Since there are not many remote northern communities across Canada that currently operate functional greenhouses, it will be important that most communities start with a simple design, which will enable them to learn the needed skills and build capacity in the labour pool before advancing to a more sophisticated system.

Communities and Greenhouse Development in the North

In discussion with communities, there were clearly numerous goals desired from greenhouse development, and limited profit or non-profit models tended to generate the most interest. Other goals included reduced food prices, subsidized food for food insecure community members, integration with health and wellness centres etc.

Small-scale greenhouse vegetable production will generally be a modest proposition, let alone having other objectives that will reduce a greenhouse to non-profit or limited profitability status. The research from the Harvard Project clearly shows that having businesses in First Nations communities with other goals than simply profit generation usually leads to failure. Thus for communities who do focus on profit generation as a top priority, this creates a higher chance of success.

However, for communities who are less interested in profit and more interested in health, self-sufficiency and community development, simpler greenhouse facilities, or simply market gardens, which entail less capital risk may be more appropriate.

This also brings up an extremely important question – just what is the goal that is seeking to be accomplished?

- Is it commercial greenhouse production? If yes, then communities should investigate how this could work in their location.
- Is the goal to improve food security, community health and self sufficiency? If so, then a non-commercial model that focuses on the macro-economic and social benefits of a greenhouse, or perhaps more broadly, vegetable production, may make most sense.

In many remote communities, residents may also have limited knowledge of how to cook and prepare certain greenhouse crops and poorer residents may have limited funds to buy them. Thus if food security is the real goal, these factors point to the need for holistic programming to address the problem more broadly. Just as this study has endeavoured to take a holistic view of the issue of developing northern greenhouses, so must any programming take the same perspective. Separate funding mechanisms may thus be needed to facilitate the development of non-commercial greenhouses and work toward meeting important goals in northern communities related to food security, health and self sufficiency.

Finding Competitive Advantage: Key Economic Drivers

The economic modeling completed by the study on a wide range of greenhouse systems and sizes indicates that there is tremendous variability in potential returns for each, ranging from negative to positive. Price and productivity are the two main drivers of positive returns on the revenue side. Inability to achieve high prices and/or productivity will limit the ability of a greenhouse to be successful. For northern greenhouses this means being able to sell as much produce as possible at retail rather than wholesale prices and ideally in communities with higher prices. Productivity is a similarly key factor and relates to both management capacity and the human resource issues identified earlier.

On the cost side, energy costs (composed of electrical and heating requirements and costs) are also a critical element in the development of economically viable northern greenhouses. Forest biomass does present an opportunity to potentially reduce energy costs in northern greenhouses although it will be highly site specific. The greatest competitive advantage in reducing energy costs through biomass can be undertaken by locating greenhouse operations near industrial facilities that can supply heat, near forestry operations which can supply either free or cheap biomass, or by tying greenhouses in with district heating systems for a community. In each case, however, the needs for sustainable supply of biomass needs to be assessed and measured on a site specific basis as it will vary with technology, greenhouse size and feed stock.

Technology and Greenhouse Development in the North

The technology exists to grow greenhouse vegetables in the north year-round. An information gap, however, exists in terms of the economic performance of new technologies in the north. As a result it is important that economics partner with technology rather than let technology (and funding for it) solely drive northern food production. Even more importantly, much more applied (technical and economic) research and testing (and the funding for it) is required before these new technologies are undertaken in remote northern communities. Remote northern communities are not in a position to do testing with unproven prototypes and technology.

This being said, a number of technologies are very near on the horizon which may transform the viability northern greenhouses in the near future. Energy costs are a key economic constraint to northern greenhouses generally and there are new technologies that may be able to overcome these problems – insulated plant factories, LED lighting, Chinese solar greenhouses etc. However, more work is required on these at present to prove their commercial viability in the north. There have been few if any economic assessments of these new technologies in the north and this must be undertaken before any of these can seriously be considered as a practical option and sold to northern communities as a viable alternative.

Other Key Findings

Literature Review

- Little if any scientific data exists on greenhouse production in northern Canada or the United States. There are some research reports that review various prototypes and small-scale experiments but little in the way of scientific evidence on northern greenhouse production.

- Examples from Scandinavia do show a viable greenhouse industry at northern latitudes but the applicability of these findings to the Canadian north is limited by two crucial factors: 1) higher population densities and sizes; and 2) a milder more marine climate.
- The literature does show the sensitivity to, and impact of, high energy costs on greenhouse production and on northern greenhouses in particular. Biomass is a potentially viable alternative to lower energy prices for larger greenhouse facilities if they can locate close to forestry operations or other forestry infrastructure where they can access low-cost inputs.

Review of Northern Greenhouse Technologies

- Almost all greenhouse vegetables grown commercially are tomatoes, peppers, cucumbers and lettuce due to their economic advantages (yield multiplied by price) which greatly exceed other vegetables.
- There are key technological advances such as LED lights which are starting to become commercially viable, at least for some crops, at present.
- Biomass does present a viable alternative to provide energy to support greenhouse production. However, it is necessary to assess on a project specific and site specific basis. Important advances are being made in other renewable technologies (solar, solar thermal, etc.) which could be integrated into different greenhouse technologies. Other technologies such as geothermal also need to be assessed on a site specific basis. Although there is promise with these emerging renewable technologies, more applied research is generally needed before these are ready for utilization by northern communities.

Resources

- Location will have a key impact on northern greenhouse production. More accessible (i.e., easily road accessible) communities who are further south will find it more difficult to compete with imported produce although it will be easier to develop and run a greenhouse enterprise. Alternately, more remote and less accessible communities will be greatly advantaged through the high-priced and generally poor-quality vegetables which exist in their marketplace. Developing and operating a greenhouse in these communities will however be much more difficult due to supply of inputs, energy, training and other access issues.

Communities

- Governance is a key factor in determining the success of economic development in First Nations communities. A key factor in this is the independence of EDCs and investment arms from Band leadership.
- To ensure long-term commitment, it is recommended to look for champions and leaders that are not part of the municipal staff. Committed local entrepreneurs will be motivated to see the project through to completion and ensure long-term sustainability.
- No matter where the project leadership comes from within the community, it is important that civic leadership, the Band Council and Chief be approached and consulted first. It is equally important that the rest of the community be engaged throughout the entire process to ensure buy-in from the community.

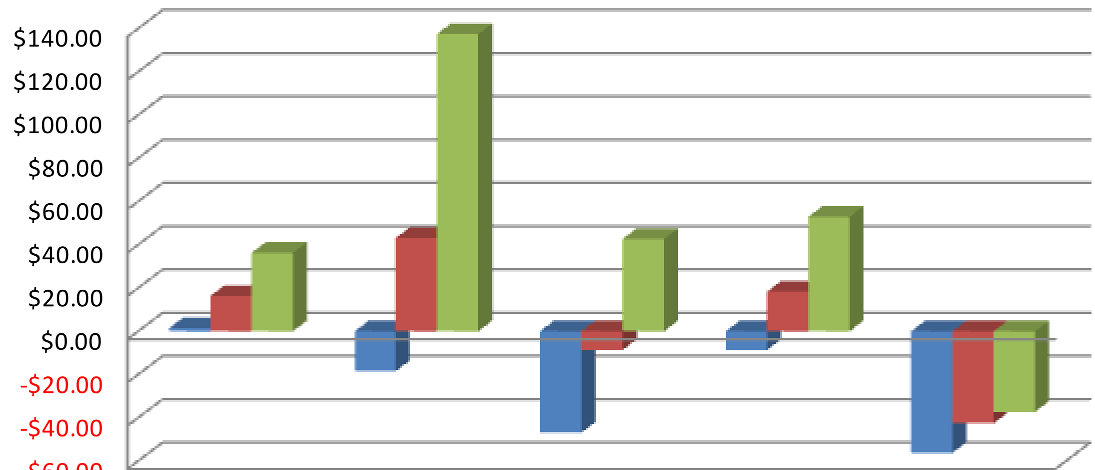
Marketing

- Market demand will vary between urban and more remote communities.
- Within larger urban centres or population areas in the north, there are some limited economies of scale. Market demand will generally mirror southern averages for per capita food consumption in these locations.
- Within more remote communities, it is likely that vegetable demand will be much lower. At present the most popular vegetables are root crops which can be grown in outdoor market gardens and then stored – these crops do not make sense for greenhouse production.
- For other vegetables, there is a need to change diets as introducing new vegetables will be difficult for populations who are not used to eating them. This may need to be supported by programming to help residents with ways of preserving and cooking as well as dietary knowledge.
- There are a number of other viable market opportunities for northern greenhouse enterprises. The two primary strategies realized by existing commercial greenhouses in the north are bedding plant production and/or integration with market gardens. Bedding plants appear to have higher returns than greenhouse vegetables and most greenhouses in the north presently focus on bedding plants which can also then be integrated into market gardens. Alternately where there are integrated greenhouse and market garden enterprises, this is often near higher education/income urban centres where they can sell locally produced vegetables at a premium.
- Other market options for northern greenhouses which are actively being exploited by First Nations communities at present include tree seedling production (on contract) which is less energy and labour intensive than greenhouse production, and native plant species for environmental remediation.

Economics

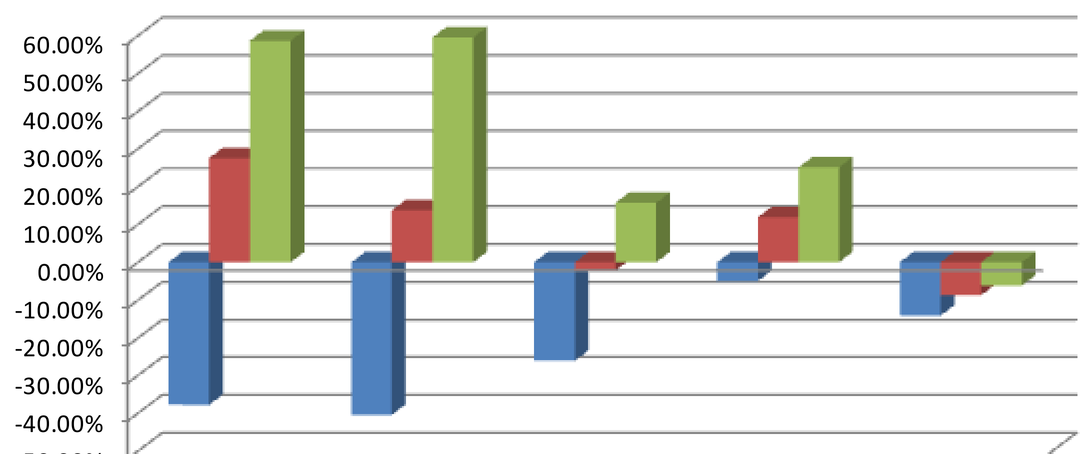
- The economic modeling has covered a wide range of greenhouse systems and scenarios (size and economies of scale, year-round production etc.). Apart from the Chinese solar greenhouse model which does not appear to be viable at present given its high capital costs, all the other models showed great variability of returns based upon low, mid and high estimates for individual costs and revenues. This variability is illustrated in the following figures which provide best case estimates for both net returns per square metre and %ROA as it assumes 50% subsidization of capital.

Figure 18: Net Returns per m² (Assuming 50% Capital Subsidy) for Low, Mid and High Estimates for Different Greenhouse Systems



	High tunnel (1394 sq.m.)	Stand alone (1394 sq. m.)	Gutter connected (2023 sq.m)	Gutter connected (12140 sq. m)	Chinese solar (150 sq. m.)
Low	$1.44	-$18.45	-$46.89	-$8.58	-$56.24
Mid	$16.30	$43.05	-$8.60	$18.34	-$42.54
High	$36.27	$137.43	42.67	$52.94	-$37.26

Figure 19: %ROA (Assuming 50% Capital Subsidy) for Low, Mid and High Estimates for Different Greenhouse Systems



	High tunnel (1394 sq.m.)	Stand alone (1394 sq. m.)	Gutter connected (2023 sq.m)	Gutter connected (12140 sq. m)	Chinese solar (150 sq. m.)
Low	-37.77%	-40.42%	-26.13%	-4.94%	-14.10%
Mid	27.54%	13.70%	-2.15%	11.90%	-8.68%
High	58.67%	59.54%	15.71%	25.07%	-6.13%

- There are opportunities for smaller-scale greenhouses to be profitable if they can maximize price and/or productivity.
- The opportunities for larger-scale commercial gutter-connected greenhouse systems will be dependent on finding effective balances between year-round production, large market size and accessing higher wholesale prices. Overall however, the smaller population sizes in the north are a limitation on the overall profitability of this model, as are the human resource requirements.
- Subsidizing capital costs obviously improves the profitability and returns of different greenhouse enterprises, providing greater resiliency to withstand potential shocks.
- There generally are economies of scale within the each model. However, as price is a key driver of positive returns in the models, a key benefit for smaller-scale operations is being able to sell produce at retail prices. Smaller-scale greenhouses may be able to compete with larger-scale greenhouses if they can achieve higher prices (retail versus wholesale) and pay an operator out of profit. This may allow them to compete with lesser efficiency and/or productivity than larger-scale systems.
- Within commercial greenhouse operations, it does appear that there are positive returns from year-round production where this is technologically possible (higher-tech systems).

9.2 Recommendations

Based on the above conclusions, Agriteam provides the following ideas and recommendations as part of possible policy and programming options that could be undertaken by AAFC, AANDC and others.

1. ***AAI funding priority should go to greenhouse application that address the "four key factors":*** Achieving high prices and/or productivity will be a crucial factor in the development of successful northern greenhouses. Similarly, greenhouses that can reduce energy costs (heating and electrical requirements and costs) also can be successful. Funding applications that show an ability to capitalize on these issues show the best chance of success. Greenhouses that similarly are connected to other greenhouse enterprises (bedding plants, trees, etc.) will also see a higher chance of success. Human resources must match skills and/or be accompanied by relevant training and skills development plans. Governance factors must also be adequately addressed.
2. ***Focus AAI funding on greenhouses whose main priority is profitability and commercial viability:*** Having multiple objectives for a greenhouse (employment, lower food prices, health and wellness centres) will greatly lower its chance of being sustainable. This is confirmed by the Harvard Project which illustrates the dangers of working to achieve multiple objectives with an enterprise. Northern greenhouses will certainly be fragile, especially in their infancy, and trying to address other objectives which reduce profitability, at least in the beginning, will reduce the chances of success.
3. ***Integrated policy approach:*** If the goal is to increase food security in the north, a purely commercial approach to supporting greenhouse development may not make sense given: 1) the level of gardening and greenhouse vegetable production skills that exist in many northern communities at present – which is limited or none; 2) thus the need to start small and simply and work upwards in complexity with a community greenhouse or garden to build skills over time; 3) the need to introduce greenhouse crops to some community members; and 4) the

multiple objectives that communities may have for a northern greenhouse which limit its profitability and increase its likelihood of failure. Thus an integrated policy approach may be needed to cover these communities, which may be the majority of remote northern communities, that looks at the broader macro-economic and social benefits from greenhouse development including health. These policy approaches and/or funding could cover both market gardens and greenhouses. Just as this report has endeavoured to look at northern greenhouse development from a holistic perspective, so must any programming.

4. ***Entrepreneurship****:* Individual entrepreneurship needs to be supported in the development of sustainable (i.e., commercially viable) northern greenhouses. The most sustainable northern greenhouses will exist when individuals are market oriented, are able to match productive capabilities with market needs and are skilled in identifying, assessing and managing risk.
5. ***More applied research:*** More applied research is required with new technologies before they can be utilized in northern communities. Northern communities are in no position to test out new technologies using their own funds and given their existing skill levels as this will lead to failure in most cases.
6. ***Linkages with centres of greenhouse expertise:*** There is a very high-level of interest in northern food production, both academically and among northern communities at present. However there appears to be limited linkages with the actual centres of greenhouse knowledge in universities in Canada. There is a great amount to be gained by linking northern researchers or communities with the academic centres which are most specialized in greenhouse production.
7. ***Finding commercially viable and sustainable models:*** Economic assessments are needed of new technology before they can be seen as an option for northern communities. There appears to be a "build it and they will come" mentality, especially when funding is available, given the availability of technology that will produce food in the north. Prototyping, supported by funding, needs to occur but there needs to be integrated assessments of technology with economics.
8. ***Develop modeling software to support community decision making for greenhouse development:*** The development of programs to provide economic modelling, such as already exist in other sectors (AAFRD's Crop Choice$ as an example) would be of tremendous use and benefit to those planning greenhouses. This could be undertaken as an initiative with a provincial department of agriculture as well.
9. ***Key constraint #1 – energy costs:*** There are many promising new technologies available or on the horizon that can potentially address the key problems that a northern greenhouse faces with energy costs. However, there is nothing yet in a commercially available package that has proven to be economic in the north (although some efforts are being made). Driving down energy costs is to a degree the "holy grail" that will allow for the development of commercially viable northern greenhouses. As efforts need to be directed to finding a model that overcomes these barriers, this can be supported through innovation grants or a challenge prize (i.e., similar to an X prize) for the development of a greenhouse that could achieve key breakthroughs in energy efficiency while being commercially viable (i.e., limited capital costs).
10. ***Key constraint #2 - training and experience:*** A second major constraint to greenhouse development in the north which can be addressed are the skills and experience required for greenhouse production. If the goal is to develop sustainable food production in northern communities, either commercial or non-commercial, it is necessary to develop programming to

address the current skills gap. This needs to be undertaken in a socially acceptable way, especially with remote communities, as training in southern centres may not necessarily work. As a result, a greenhouse training program that could be delivered in the north and tailored to northern growers may be one solution for some communities in overcoming this barrier. At least one videoconference training program exists which is a start. Alternately for other communities, there are many options for greenhouse training programs available at training institutions across Canada. This will also need to be supported through long-term mentorship and networking programs, as just training will not be enough, to help build on the job experience for northern growers. This may also require supporting internships for northern residents to acquire skills in northern greenhouse production in existing greenhouses. This will be a long-term process but short circuiting it may lead to failure.

11. ***Subsidized southern foods:*** A northern greenhouse will face additional competitive pressures from imported vegetables which are subsidized through the northern food subsidy. Although the northern food subsidy does cover, “country or traditional foods processed in the north”, the subsidy or at least its definition could be expanded to cover: 1) all agricultural inputs going to the north for either vegetable or greenhouse production; and/or 2) all vegetables produced in northern greenhouse enterprises. This would help to provide a level playing field rather than having a greenhouse compete against subsidized imported products.

APPENDIX A: HIGH-TUNNEL GREENHOUSE – 278m³ (4 – 6 MONTHS PER YEAR)

GH STRUCTURE COST

		Length	Width	No.	Ft.^{2}	M^2
	Dimensions (Ft.)	30	100	1	3000	278.71
	1 square foot = 0.092 903 04 square meter					
			1 acre = 4 046.856 422 4 square meter			
Capital Costs of GH System		**Area (Square Meters)**	**Acres**	**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
Structures	Greenhouse Structure	278.71	0.069	$8	$22	$36
	Plastic Covering			$2	$3	$4
	Total Structure Costs			$10	$25	$40
Heating System				**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
	Biomass Heating System			$0	$0	$0
	Total Heating Costs			$0	$0	$0
Electrical	Electrical/Lights/Environmental Controls			$0	$0	$0
	Total Electrical Costs			$0	$0	$0
Water systems	Complete Water System			$0.15	$0.33	$0.50
	Total Water System Costs			$0	$0	$1
Construction Costs	Freight			$3.00	$6.50	$10.00
	Total Construction Costs			$3.00	$6.50	$10.00
				Low ($/M^2)	**Mid Point**	**High ($/M^2)**
	Total ($/M2) Cost of GH Structure/System			$13	$32	$51
	Total ($) Cost of GH Structure/System			$3,665	$8,870	$14,075

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**		**Mid Point of The Range**			
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse System						
			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$0			$0		
Site Preparation includes engineering & soil studies	$0	15	$0	$0		
Greenhouse Structure	$8,034	15	$536	$241	$482	$482
Greenhouse Plastic	$836	4	$209	$25		
Work/Retail Area	$2,500	15	$167	$75	$150	$150
Water Connection	$1,250	15	$83	$38		
Electrical Installation/Connection	$0	15	$0	$0		
Total Construction Costs	$12,620		$995	$379	$632	$632
			Annual Charges			
Greenhouse Durables	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$750	5	$150	$23	$45	
Other Equipment	$750	5	$150	$23	$45	
Total Greenhouse Durables	$1,500		$300	$45	$90	
			Annual Charges			
Other Capital Costs	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles (Share Allocated to Greenhouse Enterprise)	$1,500	5	$300	$45	$90	
Bobcats/Forklifts/Other Equiment	$200	5	$40	$6	$12	
Office Equipment		5	$0	$0		
Total Other Capital Costs	$1,700		$340	$51	$102	
			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	$15,820		$1,635	$475	$824	$632

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	278.71		
	Low	**Mid Point**	**High**
Tomatoes	22.0%	22.0%	22.0%
Growing Area (Tomatoes)	61	61	61
Production (Kg/Sq. meter)	9.2	13	17
Total Production (Kg.)	564	803	1,042
Cucumbers	21.0%	21.0%	21.0%
Growing Area (Cucumbers)	59	59	59
Production (Cucumbers/Sq. meter)	13	19	25
Total Production (Cucumbers)	761	1,112	1,463
Peppers	21%	21%	21%
Growing Area (Peppers)	59	59	59
Production (Kg/Sq. meter)	2.00	3.60	5.20
Total Production (Kg.)	117	211	304
Lettuce	21%	21%	21%
Growing Area (Other)	59	59	59
Production (Kg/Sq. meter)	10	12.5	15
Total Production (Kg.)	585	732	878
Total Growing Area (Sq.Meters)	237	237	237
Tomatoes			
Marketable Yield (%)	80%	80%	80%
Total Marketable Production (Kg.)	451	643	834
Cucumbers			
Marketable Yield (%)	80%	80%	80%
Total Marketable Production (Units)	609	890	1,171
Peppers			
Marketable Yield (%)	80%	80%	80%
Total Marketable Production	94	169	243
Lettuce			
Marketable Yield (%)	80%	80%	80%
Total Marketable Production	468	585	702

SALES REVENUES

Greenhouse Area (Sq. Meters)	278.71		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	451	643	834
% Retail sales	100%	100%	100%
Retail Kg.	451	643	834
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$1,580	$4,177	$7,922
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$0	$0	$0
Total Tomato Sales Revenues	$1,580	$4,177	$7,922
Cucumbers			
Total Marketable Production (Units)	609	890	1,171
% Retail sales	100%	100%	100%
Retail Units	609	890	1,171
Retail Price ($/Unit)	$1.17	$1.83	$2.50
Total Retail sales	$710	$1,631	$2,926
% Wholesale Sales	0%	0%	0%
Wholesale Units	0	0	0
Wholesale Price ($/Unit)	$0.70	$1.10	$1.50
Total Wholesale Sales Revenues	$0	$0	$0
Total Cucumber Sales Revenues	$710	$1,631	$2,926
Peppers			
Total Marketable Production	94	169	243
% Retail sales	100%	100%	100%
Retail Kg.	94	169	243
% Coloured Peppers	25%	25%	25%
Retail Price Coloured Peppers ($/Unit)	$4.50	$7.25	$10.00
Total Retail Sales Coloured Peppers	$105	$306	$609
% Green Peppers	75%	75%	75%
Retail Price Green Peppers ($/Unit)	$3.50	$4.75	$6.00
Total Retail Sales Green Peppers	$246	$601	$1,096
Total Pepper Sales Revenues	$351	$906	$1,704
Lettuce			
Total Marketable Production	468	585	702
% Retail sales	100%	100%	100%
Retail Kg.	468	585	702
Retail Price ($/Kg.)	$3.33	$7.17	$11.00
Total Retail sales	$1,559	$4,194	$7,726
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Kg.)	$2.30	$4.28	$6.25
Total Wholesale Sales Revenues	$0	$0	$0
Total Lettuce Sales Revenues	$1,559	$4,194	$7,726
Total Sales Revenues	$4,200	$10,907	$20,279

GROWING COSTS

	Square Meters		278.71						
	Growing Area	22.00%	61						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**\$ per M^2/Crop**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**
Seed	$0.33	1	$20	$0.37	1	$22	$0.40	1	$25
Fertilizers –All	$0.90	1	$55	$1.08	1	$66	$1.25	1	$77
Water Usage Costs	$0.00	1	$0	$0.38	1	$23	$0.75	1	$46
Pest Management	$1.10	1	$67	$1.18	1	$72	$1.25	1	$77
Greenhouse Supplies	$1.35	1	$83	$1.45	1	$89	$1.55	1	$95
Total Tomato Growing Costs	$3.68		$226	$4.44		$272	$5.20		$319
	Growing Area	21.00%	59						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**\$ per M^2/Crop**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**
Seed	$0.02	1	$1	$0.04	1	$2	$0.05	1	$3
Fertilizers –All	$0.90	1	$53	$1.08	1	$63	$1.25	1	$73
Water Usage Costs	$0.00	1	$0	$0.38	1	$22	$0.75	1	$44
Pest Management	$1.10	1	$64	$1.18	1	$69	$1.25	1	$73
Greenhouse Supplies	$1.35	1	$79	$1.45	1	$85	$1.55	1	$91
Total Cucumber Growing Costs	$3.37		$197	$4.11		$241	$4.85		$284
	Growing Area	21.00%	59						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**\$ per M^2/Crop**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**
Seed	$0.33	1	$19	$0.37	1	$21	$0.40	1	$23
Fertilizers –All	$0.90	1	$53	$1.08	1	$63	$1.25	1	$73
Water Usage Costs	$0.00	1	$0	$0.38	1	$22	$0.75	1	$44
Pest Management	$1.10	1	$64	$1.18	1	$69	$1.25	1	$73
Greenhouse Supplies	$1.35	1	$79	$1.45	1	$85	$1.55	1	$91
Total Tomato Growing Costs	$3.68		$215	$4.44		$260	$5.20		$304
	Growing Area	21%	59						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**\$ per M^2/Crop**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**	**\$ per M^2**	**# of Crops**	**Total Cost**
Plugs	$0.33	5	$97	$0.37	5	$107	$0.40	5	$117
Seeds	$0.55	5	$161	$0.66	5	$193	$0.77	5	$225
Fertilizers –All	$0.20	5	$59	$0.23	5	$67	$0.26	5	$76
Pest management	$0.22	5	$64	$0.24	5	$69	$0.25	5	$73
Greenhouse Supplies	$0.28	5	$80	$0.31	5	$91	$0.35	5	$102
Total Lettuce Growing Costs	$1.58		$461	$1.80		$527	$2.03		$594
Total Growing Costs			$1,099			$1,300			$1,501

ENERGY COSTS

Square Meters		278.71	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	0	0.00	0.00
Annual GJoule required	0	0	0
Heating Cost $/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$0	$0	$0
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	0.00	0.00	0.00
Annual kWh. required	0	0	0
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electrical Costs ($/ Year)	$0	$0	$0
Total Energy Costs ($/Year)	$0	$0	$0
Total Gj	0.00	0.00	0.00
Gj per M^2	0	0	0

LABOUR COSTS

Acres		0.069	
Square Meters		278.71	
Contributions as % of Annual Cost =		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	0	**0**	**0**
Total Labour Required (Hours/Week)	0.00	0.00	0.00
Weeks per Year	40	40	40
Total Hours per Year	0	0	0
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$0	$0	$0
Contributions	$0	$0	$0
Total Annual GH Worker Cost	$0	$0	$0
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Owner Operator			
Annual Salary	$0	$0	$0
Contributions	$0	$0	$0
Total Annual Cost	$0	$0	$0
Total Salaried Fixed Costs ($/Year)	$0	$0	$0

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	451	643	834
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$225.64	$353.43	$500.34
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL TOMATO Marketing Costs ($)	$226	$353	$500
Cucumbers			
Total Retail Kg	609	890	1,171
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$91.31	$177.93	$292.64
Total Wholesale Kg.	0	0	0
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL CUCUMBER Marketing Costs ($)	$91	$178	$293
Peppers			
Total Retail Kg	94	169	243
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$46.82	$92.71	$146.09
TOTAL Pepper Marketing Costs ($)	$47	$93	$146
Lettuce			
Total Retail Kg	468	585	702
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$234.12	$321.91	$421.41
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL LETTUCE Marketing Costs ($)	$234	$322	$421
Total Marketing & Distributions Costs	$598	$946	$1,360

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	278.71					
Enterprise Budgets for Northern Greenhouse	**Low**		**Mid Point**		**High**	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$1,580	$5.67	$4,177	$14.99	$7,922	$28.42
Cucumbers	$710	$2.55	$1,631	$5.85	$2,926	$10.50
Peppers	$351	$1.26	$906	$3.25	$1,704	$6.12
Other Crops	$1,559	$5.59	$4,194	$15.05	$7,726	$27.72
Total Sales Revenues	**$4,200**	**$15.07**	**$10,907**	**$39.14**	**$20,279**	**$72.76**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M2**	**Total $**	**$/M2**
Growing Costs	$1,099	$3.94	$1,300	$4.66	$1,501	$5.39
Energy Costs	$0	$0.00	$0	$0.00	$0	$0.00
Labour costs	$0	$0.00	$0	$0.00	$0	$0.00
Marketing and Distribution Costs	$598	$2.15	$946	$3.39	$1,360	$4.88
Repair Costs (Building & Equipment)	$372	$1.34	$824	$2.96	$1,648	$5.91
Vehicle Expenses (*Not included in Marketing costs*)	$139	$0.50	$348	$1.25	$557	$2.00
Small Tools/Hardware/Supplies	$279	$1.00	$418	$1.50	$557	$2.00
Freight Costs (*Not included in marketing or growing costs*)	$139	$0.50	$209	$0.75	$279	$1.00
Custom Work	$139	$0.50	$279	$1.00	$418	$1.50
Operating Interest, Bank Charges	$279	$1.00	$557	$2.00	$836	$3.00
Dues, Fees, Promotion, Donation	$139	$0.50	$209	$0.75	$279	$1.00
Misc. Expenses	$279	$1.00	$418	$1.50	$557	$2.00
Total Variable Operating costs	$3,463	$12.43	$5,509	$19.77	$7,993	$28.68
Gross Margin (A-B)	$737		$5,399		$12,286	
Fixed Operating Costs (C)						
1. Depreciation	$833	$2.99	$1,635	$5.86	$2,709	$9.72
2. Interest on Capital	$203	$0.73	$475	$1.70	$887	$3.18
3. Taxes & Insurance	$246	$0.88	$632	$6.00	$1,378	$4.94
5. Salaries	$0	$0.00	$0	$0.00	$0	$0.00
Total Fixed Operating Costs	$1,283	$4.60	$2,741	$13.57	$4,974	$17.85
(D) Total Operating Costs	$4,746	$17.03	$8,250	$29.60	$12,967	$46.53
(E) Net Returns (A-E)	**-$546**		**$2,657**		**$7,311**	
(F) Net Cash Income (E+C1+C2)	**$491**		**$4,767**		**$10,908**	
% ROA (Allow $5,000 for labour & management)	-84.16%		-12.45%		12.44%	
Total Operating Costs with 50% Subsidization of Total Capital	$4,228		$7,195		$11,169	
Net Returns when 50% of Total Capital are Subsidized	-$28		$3,712		$9,110	
% ROA When 50% of Total Capital Costs Subsidized	-77.60%		-7.00%		17.70%	

APPENDIX B: STAND-ALONE GREENHOUSE – 278m^2 (8 – 10 MONTHS PER YEAR)

GH STRUCTURE COST

		Length	Width	No.	Ft.^{2}	M^2
	Dimensions (Ft.)	100	30	1	3000	278.71
	1 square foot = 0.092 903 04 square meter					
Capital Costs of GH System		**Area (Square Meters)**	**Acres**	**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
Structures	Greenhouse Structure	278.71	0.069	$44	$57	$70
	Plastic Covering double poly			$10	$13	$16
	Includes air system, vents and end walls					
	Total Structure Costs			$54	$70	$86
Heating System				**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
	Biomass Heating System			$10	$15	$20
	Total Heating Costs			$10	$15	$20
Electrical	Electrical/Lights/Environmental Controls			$4.00	$5.00	$6.00
	Total Electrical Costs			$4.00	$5.00	$6.00
Growing Systems	Water/Irrigation/Fertilization Systems			$2.00	$3.50	$5.00
	Internal Transportation System			$4.00	$6.00	$8.00
	Total Growing System Costs			$6.00	$9.50	$13.00
Construction Costs	Freight			$3.00	$6.50	$10.00
	Construction & Insurance Costs			$2.00	$3.50	$5.00
	Total Construction Costs			$5.00	$10.00	$15.00
				Low ($/M^2)	**Mid Point**	**High ($/M^2)**
	Total ($/M2) Cost of GH Structure/System			$79	$110	$140
	Total ($) Cost of GH Structure/System			$22,018	$30,519	$39,019

CAPITAL COSTS AVERAGE

			Mid Point of The Range			
Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse Syster Option						
			Annual Charges			
Greenhouse Construction	Capital Investment Cost	Life-Years	Depreciation	Interest	Repair Costs	Taxes & Insurance
Land	$0			$0		
Site Preparation includes engineering & soil studies	$0	15	$0	$0		
Greenhouse Structure	$26,895	15	$1,793	$807	$1,614	$1,614
Greenhouse Plastic	$3,623	4	$906	$109		
Header House/Work/Retail Area	$7,500	15	$500	$225	$450	$450
Water Connection	$5,000	15	$333	$150		
Electrical Installation/Connection	$5,000	15	$333	$150		
Total Construction Costs	$48,019		$3,865	$1,441	$2,064	$2,064
			Annual Charges			
Greenhouse Durables	Cost	Life-Years	Depreciation	Interest	Repair Costs	Taxes & Insurance
Spraying Equipment	$750	5	$150	$23	$45	
Other Equipment	$750	5	$150	$23	$45	
Total Greenhouse Durables	$1,500		$300	$45	$90	
			Annual Charges			
Other Capital Costs	Cost	Life-Years	Depreciation	Interest	Repair Costs	Taxes & Insurance
Trucks/Vehicles (Share Allocated to Greenhouse	$1,500	5	$300	$45	$90	
Bobcats/Forklifts/Other Equiment	$200	5	$40	$6	$12	
Office Equipment		5	$0	$0		
Total Other Capital Costs	$1,700		$340	$51	$102	
			Annual Charges			
			Depreciation	Interest	Repair Costs	Taxes & Insurance
Total All Capital Costs	$51,219		$4,505	$1,537	$2,256	$2,064

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	278.71		
	Low	**Mid Point**	**High**
Tomatoes	22.0%	22.0%	22.0%
Growing Area (Tomatoes)	61	61	61
Production (Kg/Sq. meter)	31	42	52
Total Production (Kg.)	1,901	2,545	3,188
Cucumbers	21.0%	21.0%	21.0%
Growing Area (Cucumbers)	59	59	59
Production (Cucumbers/Sq. meter)	68	91	113
Total Production (Cucumbers)	3,980	5,297	6,614
Peppers	21%	21%	21%
Growing Area (Peppers)	59	59	59
Production (Kg/Sq. meter)	15	20	25
Total Production (Kg.)	878	1171	1463
Lettuce	21%	21%	21%
Growing Area (Other)	59	59	59
Production (Kg/Sq. meter)	41	54	67
Total Production (Kg.)	2400	3161	3921
Total Growing Area (Sq.Meters)	237	237	237
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	1,616	2,163	2,710
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	3,383	4,502	5,622
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	746	995	1,244
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	2,040	2,686	3,333

SALES REVENUES

Greenhouse Area (Sq. Meters)	278.71		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	1,616	2,163	2,710
% Retail sales	100%	100%	100%
Retail Kg.	1,616	2,163	2,710
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$5,655	$14,059	$25,747
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$0	$0	$0
Total Tomato Sales Revenues	$5,655	$14,059	$25,747
Cucumbers			
Total Marketable Production (Units)	3,383	4,502	5,622
% Retail sales	100%	100%	100%
Retail Units	3,383	4,502	5,622
Retail Price ($/Unit)	$2.00	$3.00	$4.00
Total Retail sales	$6,766	$13,507	$22,487
% Wholesale Sales	0%	0%	0%
Wholesale Units	0	0	0
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$0	$0	$0
Total Cucumber Sales Revenues	$6,766	$13,507	$22,487
Peppers			
Total Marketable Production	746	995	1,244
% Retail sales	100%	100%	100%
Retail Kg.	746	995	1,244
% Coloured Peppers	50%	50%	50%
Retail Price Coloured Peppers ($/Unit)	$4.50	$7.25	$10.00
Total Retail Sales Coloured Peppers	$1,679	$3,607	$6,219
% Green Peppers	50%	50%	50%
Retail Price Green Peppers ($/Unit)	$3.00	$4.50	$6.00
Total Retail Sales Green Peppers	$1,119	$2,239	$3,731
Total Pepper Sales Revenues	$2,798	$5,846	$9,950
Lettuce			
Total Marketable Production	2,040	2,686	3,333
% Retail sales	100%	100%	100%
Retail Kg.	2,040	2,686	3,333
Retail Price ($/Kg.)	$3.33	$7.17	$11.00
Total Retail sales	$6,799	$19,253	$36,665
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Kg.)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$0	$0	$0
Total Lettuce Sales Revenues	$6,799	$19,253	$36,665
Total Sales Revenues	$22,018	$52,665	$94,849

GROWING COSTS

	Square Meters		278.71						
	Growing Area	22.00%	61						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Growing Media	$2.75	1	$169	$3.63	1	$222	$4.50	1	$276
Plugs, Seeds	$2.00	1	$123	$3.00	1	$184	$4.00	1	$245
Fertilizers –All	$2.00	1	$123	$3.00	1	$184	$4.00	1	$245
Water Usage Costs	$0.50	1	$31	$0.75	1	$46	$1.00	1	$61
Pest Management	$1.50	1	$92	$2.25	1	$138	$3.00	1	$184
Greenhouse Supplies	$1.00	1	$61	$1.50	1	$92	$2.00	1	$123
Total Tomato Growing Costs	$9.75		$598	$14.13		$866	$18.50		$1,134
	Growing Area	**21.00%**	59						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Growing Media	$2.75	2	$322	$3.63	2	$424.33	$4.50	2	$527
Plugs, Seeds	$2.00	2	$234	$3.00	2	$351.17	$4.00	2	$468
Fertilizers –All	$2.00	2	$234	$3.00	2	$351.17	$4.00	2	$468
Water Usage Costs	$0.50	2	$59	$0.75	2	$87.79	$1.00	2	$117
Pest Management	$1.50	2	$176	$2.25	2	$263.38	$3.00	2	$351
Greenhouse Supplies	$1.00	2	$117	$1.50	2	$175.59	$2.00	2	$234
Total Cucumber Growing Costs	$9.75		$1,141	$14.13		$1,653	$18.50		$2,166
	Growing Area	**21.00%**	59						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Growing Media	$2.75	1	$161	$3.13	1	$182.90	$3.50	1	$205
Plugs, Seeds	$2.00	1	$117	$2.50	1	$146.32	$3.00	1	$176
Fertilizers –All	$2.00	1	$117	$2.75	1	$160.95	$3.50	1	$205
Water Usage Costs	$0.50	1	$29	$0.75	1	$43.90	$1.00	1	$59
Pest Management	$1.50	1	$88	$2.25	1	$131.69	$3.00	1	$176
Greenhouse Supplies	$1.00	1	$59	$1.50	1	$87.79	$2.00	1	$117
Total Tomato Growing Costs	$9.75		$571	$12.88		$754	$16.00		$936
	Growing Area	**21%**	59						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Styroform boards	$0.83	6	$290	$1.04	6	$364.34	$1.25	6	$439
Plugs,	$0.33	6	$116	$0.35	6	$121.68	$0.36	6	$127
Seeds	$0.55	6	$193	$0.66	6	$231.77	$0.77	6	$270
Fertilizers –All	$1.10	6	$386	$1.21	6	$424.92	$1.32	6	$464
Water Usage Costs	$0.22	6	$77	$0.25	6	$88.85	$0.29	6	$100
Pest Management	$0.11	6	$39	$0.12	6	$42.49	$0.13	6	$46
Greenhouse Supplies	$0.28	6	$97	$0.58	6	$202.80	$0.88	6	$309
Total Lettuce Growing Costs	$3.41		$1,198	$4.21		$1,477	$5.00		$1,756
Total Growing Costs	$19.50		$3,507			$4,750			$5,993

ENERGY COSTS

Square Meters		278.71	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	1.5	1.75	2.00
Annual GJoule required	418	488	557
Heating Cost $/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$2,090	$4,146	$6,689
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	10.00	12.50	15.00
Annual kWh. required	2,787	3,484	4,181
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electrical Costs ($/ Year)	$139	$348	$627
Total Energy Costs ($/Year)	$2,230	$4,494	$7,316
Total Gj	428.10	500.28	572.47
Gj per M^2	1.536	1.795	2.054

LABOUR COSTS

Acres		0.069	
Square Meters		278.71	
Contributions as % of Annual Cost=		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	5	**6**	**7**
Total Labour Required (Hours/Week)	13.77	16.53	19.28
Weeks per Year	40	40	40
Total Hours per Year	551	661	771
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$8,264	$11,570	$15,426
Contributions	$1,240	$1,735	$2,314
Total Annual GH Worker Cost	$9,504	$13,305	$17,740
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Owner Operator			
Annual Salary	$0	$0	$0
Contributions	$0	$0	$0
Total Annual Cost	$0	$0	$0
Total Salaried Fixed Costs ($/Year)	$0	$0	$0

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	1,616	2,163	2,710
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$807.84	$1,189.61	$1,626.10
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL TOMATO Marketing Costs ($)	$808	$1,190	$1,626
Cucumbers			
Total Retail Kg	3,383	4,502	5,622
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$507.45	$900.47	$1,405.43
Total Wholesale Kg.	0	0	0
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL CUCUMBER Marketing Costs ($)	$507	$900	$1,405
Peppers			
Total Retail Kg	746	995	1,244
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$373.12	$547.25	$746.24
TOTAL Pepper Marketing Costs ($)	$373	$547	$746
Lettuce			
Total Retail Kg	2,040	2,686	3,333
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$1,019.87	$1,477.56	$1,999.93
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL LETTUCE Marketing Costs ($)	$1,020	$1,478	$2,000
Total Marketing & Distributions Costs	$2,708	$4,115	$5,778

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	278.71					
Enterprise Budgets for Northern Greenhouse	**Low**		**Mid Point**		**High**	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$5,655	$20.29	$14,059	$50.44	$25,747	$92.38
Cucumbers	$6,766	$24.28	$13,507	$48.46	$22,487	$80.68
Peppers	$2,798	$10.04	$5,846	$20.97	$9,950	$35.70
Other Crops	$6,799	$24.40	$19,253	$69.08	$36,665	$131.55
Total Sales Revenues	**$22,018**	**$79.00**	**$52,665**	**$188.96**	**$94,849**	**$340.31**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Growing Costs	$3,507	$12.58	$4,750	$17.04	$5,993	$21.50
Energy Costs	$2,230	$8.00	$4,494	$16.13	$7,316	$26.25
Labour costs	$9,504	$34.10	$13,305	$47.74	$17,740	$63.65
Marketing and Distribution Costs	$2,708	$9.72	$4,115	$14.76	$5,778	$20.73
Repair Costs (Building & Equipment)	$1,580	$5.67	$2,256	$8.09	$3,424	$12.28
Vehicle Expenses (*Not included in Marketing costs*)	$557	$2.00	$975	$3.50	$1,394	$5.00
Small Tools/Hardware/Supplies	$557	$2.00	$836	$3.00	$1,115	$4.00
Freight Costs (*Not included in marketing or growing costs*)	$557	$2.00	$975	$3.50	$1,394	$5.00
Custom Work	$557	$2.00	$975	$3.50	$1,394	$5.00
Operating Interest, Bank Charges	$279	$1.00	$557	$2.00	$836	$3.00
Dues, Fees, Promotion, Donation	$279	$1.00	$557	$2.00	$836	$3.00
Misc. Expenses	$1,394	$5.00	$2,090	$7.50	$2,787	$10.00
Total Variable Operating costs	$23,710	$85.07	$35,888	$128.76	$50,005	$179.42
Gross Margin (A-B)	-$1,691	$157.55	$16,777	$240.49	$44,844	$337.33
Fixed Operating Costs (C)						
1. Depreciation	$2,899	$10.40	$4,505	$16.17	$6,019	$21.60
2. Interest on Capital	$949	$3.40	$1,537	$5.51	$2,101	$7.54
3. Taxes & Insurance	$1,454	$5.22	$2,064	$6.00	$3,154	$11.32
5. Salaries	$0	$0.00	$0	$0.00	$0	$0.00
Total Fixed Operating Costs	$5,301	$19.02	$8,106	$27.68	$11,273	$40.45
(D) Total Operating Costs	$29,011	$104.09	$43,994	$157.85	$61,278	$219.86
(E) Net Returns (A-E)	**-$6,992**		**$8,671**		**$33,571**	
(F) Net Cash Income (E+C1+C2)	**-$3,145**		**$14,713**		**$41,690**	
% ROA*	-86.33%		-20.00%		23.92%	
Total Operating Costs with 50% Subsidization of Total Capital	$27,087		$40,973		$57,219	
Net Returns when 50% of Total Capital are Subsidized	-$5,069		$11,692		$37,630	
% ROA* When 50% of Total Capital Costs Subsidized	-81.52%		-15.40%		28.52%	

*** Allowance for owner contribution of management and labour is $20,000**

APPENDIX C: GUTTER-CONNECTED GREENHOUSE – 3-ACRES (9 – 10 MONTHS PER YEAR)

GH STRUCTURE COST

Details of GH Structure	Modern Gutter Connected facility		1 acre = 4 046.856 422 4 square meter			
Description of System	Artifical lighting for year round production					
Main Energy Source	Natural gas/biomass					
Planned Growing Season	Optimized for individual crops					
Capital Costs of GH System		**Area (Acres)**	**Area (M^2)**	**Low ($/$M^2$)**	**Mid Point**	**High ($/$M^2$)**
Structures	Greenhouse	3	12,141	$75	$85	$95
	Total Structure Costs			$75	$85	$95
Biomass Heating System				**Low ($/$M^2$)**	**Median ($/Unit)**	**High ($/$M^2$)**
	Complete Heating System with piping etc			$20	$35	$50
	Total Heating Costs			$20	$35	$50
Electrical	Electrical/Control System			$5	$8	$10
	Environmental Control Systems			$5	$8	$10
	Total Electrical Costs			$10	$15	$20
Water systems	Water/Irrigation/Fertigation System			$10	$13	$15
	Total Water System Costs			$10	$13	$15
Growing System	Growing system			$5	$8	$10
	Internal Transportation System			$4	$6	$8
	Total Growing System Costs			$9	$14	$18
Construction Costs	Freight			$2.00	$6.00	$10.00
	Construction Insurance			$2.00	$3.50	$5.00
	Total Construction Costs			$4.00	$9.50	$15.00
				Low ($/$M^2$)	**Median ($/Unit)**	**High ($/$M^2$)**
	Total ($/M2) Cost of GH Structure/System			$128	$171	$213
	Total ($) Cost of GH Structure/System			$1,553,993	$2,069,967	$2,585,941

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse System		Average				

			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$5,000			$150		
Site Preparation includes engineering & soil studies	$15,000	15	$1,000	$450		
Greenhouse Structure	$2,069,967	15	$137,998	$62,099	$124,198	$124,198
Header House/Warehouse/Retail Area	$40,000	15	$2,667	$1,200	$2,400	$2,400
Biomass Housing/Biomass Storage Areas	$15,000	15	$1,000	$450	$900	$900
Electrical Installation/Connection	$7,500	15	$500	$225		
Water Connection	$5,000	15	$333	$150		
Gas Installation/Connection	$0	15	$0	$0		
Total Construction Costs	$2,157,467		$143,498	$64,724	$127,498	$127,498

			Annual Charges			
Greenhouse Durables	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$10,000	5	$2,000	$300	$600	
Other Equipment	$10,000	5	$2,000	$300	$600	
Total Greenhouse Durables	$20,000		$4,000	$600	$1,200	

			Annual Charges			
Other Capital Costs	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles	$40,000	5	$8,000	$1,200	$2,400	
Bobcats/Forklifts/Other Machinery	$10,000	5	$2,000	$300	$600	
Office Equipment	$5,000	5	$1,000	$150	$300	
Total Other Capital Costs	$55,000		$11,000	$1,650	$3,300	

			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	$2,232,467		$158,498	$66,974	$131,998	$127,498

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	12,141		
	Low	**Mid Point**	**High**
Tomatoes	35.0%	35.0%	35.0%
Growing Area (Tomatoes)	4,249	4,249	4,249
Production (Kg/Sq. meter)	40	45	50
Total Production (Kg.)	169,968	191,214	212,460
Cucumbers	15.0%	15.0%	15.0%
Growing Area (Cucumbers)	1821	1821	1821
Production (Cucumbers/Sq. meter)	90	108	125
Total Production (Cucumbers)	163,898	195,767	227,636
Peppers	20%	20%	20%
Growing Area (Peppers)	2,428	2,428	2,428
Production (Kg/Sq. meter)	20	22.5	25
Total Production (Kg.)	48562.27707	54632.5617	60702.84634
Lettuce	25%	25%	25%
Growing Area (Other)	3035	3035	3035
Production (Kg/Sq. meter)	55	62.5	70
Total Production (Kg.)	166933	189696	212460
Total Growing Area (Sq.Meters)	11534	11534	11534
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	144,473	162,532	180,591
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	139,313	166,402	193,490
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	41,278	46,438	51,597
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	141,893	161,242	180,591

SALES REVENUES

Greenhouse Area (Sq. Meters)	12,141		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	144,473	162,532	180,591
% Retail sales	10%	10%	10%
Retail Kg.	14,447	16,253	18,059
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$50,565	$105,646	$171,561
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	130,025	146,279	162,532
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$292,557	$475,406	$690,760
Total Tomato Sales Revenues	$343,123	$581,051	$862,322
Cucumbers			
Total Marketable Production (Units)	139,313	166,402	193,490
% Retail sales	10%	10%	10%
Retail Units	13,931	16,640	19,349
Retail Price ($/Unit)	$2.00	$3.00	$4.00
Total Retail sales	$27,863	$49,921	$77,396
% Wholesale Sales	90%	90%	90%
Wholesale Units	125,382	149,762	174,141
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$125,382	$262,083	$435,353
Total Cucumber Sales Revenues	$153,244	$312,003	$512,749
Peppers			
Total Marketable Production	41,278	46,438	51,597
% Retail sales	10%	10%	10%
Retail Kg.	4,128	4,644	5,160
Retail Price ($/Unit)	$4.50	$7.25	$10.00
Total Retail sales	$18,575	$33,667	$51,597
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	37,150	41,794	46,438
Wholesale Price ($/Unit)	$4.25	$4.88	$5.50
Total Wholesale Sales Revenues	$157,888	$203,745	$255,407
Total Pepper Sales Revenues	$176,463	$237,413	$307,005
Lettuce			
Total Marketable Production	141,893	161,242	180,591
% Retail sales	10%	10%	10%
Retail Kg.	14,189	16,124	18,059
Retail Price ($/Unit)	$3.33	$7.17	$11.00
Total Retail sales	$47,298	$115,557	$198,650
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	127,704	145,118	162,532
Wholesale Price ($/Unit)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$255,407	$580,471	$975,191
Total Lettuce Sales Revenues	$302,705	$696,028	$1,173,841
Total Sales Revenues	$975,535	$1,826,495	$2,855,917

GROWING COSTS

	Square Meters		12,141						
	Growing Area	15.00%	1,821						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Plugs, Seeds	$0.30	1	$546	$0.33	1	$601	$0.36	1	$656
Seeds	$1.50	1	$2,732	$1.65	1	$3,005	$1.80	1	$3,278
Fertilizers –All	$3.00	1	$5,463	$3.30	1	$6,010	$3.60	1	$6,556
Water Usage Costs	$1.50	1	$2,732	$1.65	1	$3,005	$1.80	1	$3,278
Biological Control	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Chemical Control	$1.00	1	$1,821	$1.10	1	$2,003	$1.20	1	$2,185
Greenhouse Supplies	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Total Tomato Growing Costs	$14.80		$26,952	$16.28		$29,647	$17.76		$32,342
	Growing Area	**15.00%**	1,821						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	2	$9,105	$2.75	2	$10,015.97	$3.00	2	$10,927
Plugs, Seeds	$0.30	2	$1,093	$0.33	2	$1,201.92	$0.36	2	$1,311
Seeds	$1.50	2	$5,463	$1.65	2	$6,009.58	$1.80	2	$6,556
Fertilizers –All	$3.00	2	$10,927	$3.30	2	$12,019.16	$3.60	2	$13,112
Water Usage Costs	$1.50	2	$5,463	$1.65	2	$6,009.58	$1.80	2	$6,556
Biological Control		2	$0	$3.00	2	$10,926.51	$3.00	2	$10,927
Chemical Control	$1.00	2	$3,642	$1.10	2	$4,006.39	$1.20	2	$4,371
Greenhouse Supplies	$2.50	2	$9,105	$2.75	2	$10,015.97	$3.00	2	$10,927
Total Cucumber Growing Costs	$12.30		$44,799	$16.53		$60,205	$17.76		$64,685
	Growing Area	**20.00%**	2,428						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Plugs, Seeds	$0.30	1	$728	$0.33	1	$801.28	$0.36	1	$874
Seeds	$1.50	1	$3,642	$1.65	1	$4,006.39	$1.80	1	$4,371
Fertilizers –All	$3.00	1	$7,284	$3.30	1	$8,012.78	$3.60	1	$8,741
Water Usage Costs	$1.50	1	$3,642	$1.65	1	$4,006.39	$1.80	1	$4,371
Biological Control	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Chemical Control	$1.00	1	$2,428	$1.10	1	$2,670.93	$1.20	1	$2,914
Greenhouse Supplies	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Total Tomato Growing Costs	$14.80		$35,936	$16.28		$39,530	$17.76		$43,123
	Growing Area	**25%**	3035						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Styroform boards	$0.75	7	$15,934	$1.00	7	$21,246.00	$1.25	7	$26,557
Plugs,	$0.30	7	$6,374	$0.32	7	$6,705.49	$0.33	7	$7,037
Seeds	$0.50	7	$10,623	$0.60	7	$12,747.60	$0.70	7	$14,872
Fertilizers –All	$1.00	7	$21,246	$1.10	7	$23,370.60	$1.20	7	$25,495
Biological Control	$0.10	7	$2,125	$0.11	7	$2,337.06	$0.12	7	$2,550
Greenhouse Supplies	$0.25	7	$5,311	$0.53	7	$11,154.15	$0.80	7	$16,997
Total Tomato Growing Costs	$2.90		$61,613	$3.65		$77,561	$4.40		$93,508
Total Growing Costs	$27.10		$169,300			$206,943			$233,659

ENERGY COSTS

Square Meters		12,141	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	1.15	1.83	2.50
Annual GJoule required	13,962	22,157	30,351
Heating Costs $/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$69,808	$188,331	$364,217
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	18.00	20.00	22.00
Annual kWh. required	218,530	242,811	267,093
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electricity Costs ($/ Year)	$10,927	$24,281	$40,064
Total Energy Costs ($/Year)	$80,735	$212,612	$404,281
1 kilowatt hour = 0.003 6 gigajoule			
Total Gj	14,748	23,031	31,313
Total Gj per M2	1.215	1.897	2.579

LABOUR COSTS

Acres		3	
Square Meters		12,141	
Contributions as % of Annual Cost=		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	2	**3**	**4**
Total Labour Required (Hours/Week)	240	360	480
Weeks per Year	40	40	40
Total Hours per Year	9600	14400	19200
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$144,000	$252,000	$384,000
Contributions	$21,600	$37,800	$57,600
Total Annual GH Worker Cost	$165,600	$289,800	$441,600
Labour Cost per Square Meter ($/M^2)	$13.64	$23.87	$36.37
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Head Grower			
Annual Salary	$85,000.00	$92,500.00	$100,000
Contributions	$12,750	$13,875	$15,000
Total Annual Cost	$97,750	$106,375	$115,000
Assistant Grower/Facilities Mgr.			
Annual Salary	$55,000	$60,000	$65,000
Contributions	$8,250	$9,000	$9,750
Total Annual Cost	$63,250	$69,000	$74,750
Marketing/ Administration			
Number	1	1	1
Annual Salary	$45,000	$50,000	$55,000
Contributions	$6,750	$7,500	$8,250
Total Annual Cost	$51,750	$57,500	$63,250
Total Salaried Fixed Costs ($/Year)	$212,750	$232,875	$253,000

MARKETING AND DISTRIBUTION

These are the costs required to ensue the products are at the right place, at the right time and in the right form to meet end-user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	14,447	16,253	18,059
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$7,224	$8,939	$10,835
Total Wholesale Kg.	130,025	146,279	162,532
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$19,504	$30,792	$44,046
TOTAL TOMATO Marketing Costs ($)	$26,727	$39,731	$54,882
Cucumbers			
Total Retail Units	13,931	16,640	19,349
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$2,089.70	$3,328.03	$4,837.26
Total Wholesale Units	125,382	149,762	174,141
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$18,807	$31,525	$47,192
TOTAL CUCUMBER Marketing Costs ($)	$20,897	$34,853	$52,030
Peppers			
Total Retail Kg	4,128	4,644	5,160
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$2,064	$2,554	$3,096
Total Wholesale Kg.	5,463	6,119	6,774
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$819	$1,288	$1,836
TOTAL Pepper Marketing Costs ($)	$2,883	$3,842	$4,932
Lettuce			
Total Retail Kg	14,189	16,124	18,059
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$7,094.65	$8,868.31	$10,835.46
Total Wholesale Kg.	127,704	145,118	162,532
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$19,156	$30,547	$44,046
TOTAL LETTUCE Marketing Costs ($)	$26,250	$39,416	$54,882
Total Marketing & Distributions Costs	$76,757.99	$117,841.43	$166,724.46

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	12,141					
Enterprise Budgets for Northern Greenhouse	**Low**		**Mid Point of Ranges**		**High**	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$343,123	$28.26	$581,051	$47.86	$862,322	$71.03
Cucumbers	$153,244	$12.62	$312,003	$25.70	$512,749	$42.23
Peppers	$176,463	$14.54	$237,413	$19.56	$307,005	$25.29
Lettuce	$302,705	$24.93	$696,028	$57.33	$1,173,841	$96.69
Total Sales Revenues	**$975,535**	**$80.35**	**$1,826,495**	**$150.45**	**$2,855,917**	**$235.24**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M2**	**Total $**	**$/M²**
Growing Costs	$169,300	$13.95	$206,943	$17.05	$233,659	$19.25
Energy Costs	$80,735	$6.65	$212,612	$17.51	$404,281	$33.30
Labour costs	$165,600	$13.64	$289,800	$23.87	$441,600	$36.37
Marketing and Distribution Costs	$76,758	$6.32	$117,841	$9.71	$166,724	$13.73
Repair Costs (Building & Equipment)	$98,670	$8.13	$131,998	$10.87	$166,106	$13.68
Vehicle Expenses (*Not included in Marketing costs*)	$12,141	$1.00	$24,281	$2.00	$36,422	$3.00
Small Tools/Hardware/Supplies	$18,211	$1.50	$27,316	$2.25	$36,422	$3.00
Freight Costs (*Not included in marketing or growing costs*)	$12,141	$1.00	$24,281	$2.00	$36,422	$3.00
Custom Work	$6,070	$0.50	$12,141	$1.00	$18,211	$1.50
Operating Interest, Bank Charges	$24,281	$2.00	$36,422	$3.00	$48,562	$4.00
Dues, Fees, Promotion, Donation	$12,141	$1.00	$16,693	$1.38	$21,246	$1.75
Misc. Expenses	$12,141	$1.00	$30,351	$2.50	$48,562	$4.00
Total Variable Operating costs	$688,187	$56.68	$1,130,680	$93.13	$1,658,218	$136.58
Gross Margin (A-B)	$287,348		$695,815		$1,197,700	
Fixed Operating Costs (C)						
1. Depreciation	$118,200	$9.74	$158,498	$13.06	$200,863	$16.54
2. Interest on Capital	$49,860	$4.11	$66,974	$5.52	$84,388	$6.95
3. Taxes & Insurance	$94,740	$7.80	$127,498	$6.00	$159,356	$13.13
5. Salaries	$212,750	$17.52	$232,875	$19.18	$253,000	$20.84
Total Fixed Operating Costs	$475,549	$39.17	$585,845	$43.75	$697,607	$57.46
(D) Total Operating Costs	$1,163,736	$95.86	$1,716,524	$141.39	$2,355,825	$194.05
(E) Net Returns (A-E)	**-$188,201**		**$109,970**		**$500,092**	
(F) Net Cash Income (E+C1+C2)	**-$20,142**		**$335,442**		**$785,343**	
% ROA	-8.63%		8.22%		21.39%	
Total Operating Costs with 50% Subsidization of Total Capital	$1,079,706		$1,603,789		$2,213,200	
Net Returns when 50% of Total Capital are Subsidized	-$104,171		$222,706		$642,718	
% ROA When 50% of Total Capital Costs Subsidized	-4.94%		11.90%		25.07%	

APPENDIX D: GUTTER-CONNECTED GREENHOUSE – 3-ACRES (12-MONTHS PER YEAR)

GH STRUCTURE COST

Details of GH Structure	Modern Gutter Connected facility		1 acre = 4 046.856 422 4 square meter			
Description of System	Artifical lighting for year round production					
Main Energy Source	Natural gas/biomass					
Planned Growing Season	Optimized for individual crops					
Capital Costs of GH System		**Area (Acres)**	**Area (M^2)**	**Low ($/$M^2$)**	**Mid Point**	**High ($/$M^2$)**
Structures	Greenhouse Structure	3	12,141	$75	$85	$95
	Total Structure Costs			$75	$85	$95
Biomass Heating System				**Low ($/M2)**	**Mid Point**	**High ($/M2)**
	Biomass Heating System			$20	$35	$50
	Energy curtain			$6	$9	$12
	Total Heating Costs			$26	$44	$62
Electrical	Electrical/Control System			$5	$8	$10
	Environmental Control Systems			$5	$8	$10
	Grow Light system			$30	$38	$45
	Total Electrical Costs			$40	$53	$65
Water systems	Water/Irrigation/Fertigation System			$10	$13	$15
	Total Water System Costs			$10	$13	$15
Growing System	Growing system			$5	$8	$10
	Internal Transportation System			$4	$6	$8
	Total Growing System Costs			$9	$14	$18
Construction Costs	Freight			$2.00	$6.00	$10.00
	Construction & Insurance			$2.00	$3.50	$5.00
	Total Construction Costs			$4.00	$9.50	$15.00
				Low ($/$M^2$)	**Mid Point**	**High ($/$M^2$)**
	Total ($/M2) Cost of GH Structure/System			$164	$217	$270
	Total ($) Cost of GH Structure/System			$1,991,053	$2,634,504	$3,277,954

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse System		Average				

			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$5,000			$150		
Site Preparation includes engineering & soil studies	$15,000	15	$1,000	$450		
Greenhouse Structure	$2,634,504	15	$175,634	$79,035	$158,070	$158,070
Header House/Warehouse/Retail Area	$40,000	15	$2,667	$1,200	$2,400	$2,400
Biomass Housing/Biomass Storage Areas	$15,000	15	$1,000	$450	$900	$900
Electrical Installation/Connection	$7,500	15	$500	$225		
Water Connection	$5,000	15	$333	$150		
Gas Installation/Connection	$0	15	$0	$0	$0	$0
Total Construction Costs	$2,722,004		$181,134	$81,660	$161,370	$161,370

			Annual Charges			
Greenhouse Durables	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$10,000	5	$2,000	$300	$600	
Other Equipment	$10,000	5	$2,000	$300	$600	
Total Greenhouse Durables	$20,000		$4,000	$600	$1,200	

			Annual Charges			
Other Capital Costs	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles	$40,000	5	$8,000	$1,200	$2,400	
Bobcats/Forklifts/Other Machinery	$10,000	5	$2,000	$300	$600	
Office Equipment	$5,000	5	$1,000	$150		
Total Other Capital Costs	$55,000		$11,000	$1,650	$3,000	

			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	$2,797,004		$196,134	$83,910	$165,570	$161,370

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	12,141		
	Low	**Average**	**High**
Tomatoes	35.0%	35.0%	35.0%
Growing Area (Tomatoes)	4,249	4,249	4,249
Production (Kg/Sq. meter)	56	63	70
Total Production (Kg.)	237,955	267,700	297,444
Cucumbers	15.0%	15.0%	15.0%
Growing Area (Cucumbers)	1821	1821	1821
Production (Cucumbers/Sq. meter)	190	213	235
Total Production (Cucumbers)	346,006	386,981	427,955
Peppers	20%	20%	20%
Growing Area (Peppers)	2,428	2,428	2,428
Production (Kg/Sq. meter)	28	32	35
Total Production (Kg.)	67987.1879	76485.58638	84983.98487
Lettuce	25%	25%	25%
Growing Area (Other)	3035	3035	3035
Production (Kg/Sq. meter)	65	75	85
Total Production (Kg.)	197284	227636	257987
Total Growing Area (Sq.Meters)	11534	11534	11534
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	202,262	227,545	252,827
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	294,105	328,934	363,762
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	57,789	65,013	72,236
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	167,692	193,490	219,289

SALES REVENUES

Greenhouse Area (Sq. Meters)	12,141		
Tomatoes	**Low**	**Average**	**High**
Total Marketable Production (Kg.)	202,262	227,545	252,827
% Retail sales	10%	10%	10%
Retail Kg.	20,226	22,754	25,283
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$70,792	$147,904	$240,186
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	182,036	204,790	227,545
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$409,580	$665,568	$967,065
Total Tomato Sales Revenues	$480,372	$813,472	$1,207,251
Cucumbers			
Total Marketable Production (Units)	294,105	328,934	363,762
% Retail sales	10%	10%	10%
Retail Units	29,411	32,893	36,376
Retail Price ($/Unit)	$2.00	$3.00	$4.00
Total Retail sales	$58,821	$98,680	$145,505
% Wholesale Sales	90%	90%	90%
Wholesale Units	264,695	296,040	327,386
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$264,695	$518,070	$818,464
Total Cucumber Sales Revenues	$323,516	$616,750	$963,969
Peppers			
Total Marketable Production	57,789	65,013	72,236
% Retail sales	10%	10%	10%
Retail Kg.	5,779	6,501	7,224
Retail Price ($/Unit)	$4.50	$7.25	$10.00
Total Retail sales	$26,005	$47,134	$72,236
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	52,010	58,511	65,013
Wholesale Price ($/Unit)	$2.75	$4.13	$5.50
Total Wholesale Sales Revenues	$143,028	$241,360	$357,570
Total Pepper Sales Revenues	$169,033	$288,494	$429,807
Lettuce			
Total Marketable Production	167,692	193,490	219,289
% Retail sales	10%	10%	10%
Retail Kg.	16,769	19,349	21,929
Retail Price ($/Unit)	$3.33	$7.17	$11.00
Total Retail sales	$55,897	$138,668	$241,218
% Wholesale Sales	90%	90%	90%
Wholesales Kg.	150,922	174,141	197,360
Wholesale Price ($/Unit)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$301,845	$696,565	$1,184,161
Total Lettuce Sales Revenues	$357,742	$835,233	$1,425,379
Total Sales Revenues	$1,330,663	$2,553,950	$4,026,405

GROWING COSTS

	Square Meters		12,141						
	Growing Area	15.00%	1,821						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Plugs,	$0.30	1	$546	$0.33	1	$601	$0.36	1	$656
Seeds	$1.50	1	$2,732	$1.65	1	$3,005	$1.80	1	$3,278
Fertilizers –All	$3.00	1	$5,463	$3.30	1	$6,010	$3.60	1	$6,556
Water Usage Costs	$1.50	1	$2,732	$1.65	1	$3,005	$1.80	1	$3,278
Biological Control	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Chemical Control	$1.00	1	$1,821	$1.10	1	$2,003	$1.20	1	$2,185
Greenhouse Supplies	$2.50	1	$4,553	$2.75	1	$5,008	$3.00	1	$5,463
Total Tomato Growing Costs	$14.80		$26,952	$16.28		$29,647	$17.76		$32,342
	Growing Area	**15.00%**	1,821						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	3	$13,658	$2.75	3	$15,023.95	$3.00	3	$16,390
Plugs, Seeds	$0.30	3	$1,639	$0.33	3	$1,802.87	$0.36	3	$1,967
Seeds	$1.50	3	$8,195	$1.65	3	$9,014.37	$1.80	3	$9,834
Fertilizers –All	$3.00	3	$16,390	$3.30	3	$18,028.75	$3.60	3	$19,668
Water Usage Costs	$1.50	3	$8,195	$1.65	3	$9,014.37	$1.80	3	$9,834
Biological Control	$2.50	3	$13,658	$2.75	3	$15,023.95	$3.00	3	$16,390
Chemical Control	$1.00	3	$5,463	$1.10	3	$6,009.58	$1.20	3	$6,556
Greenhouse Supplies	$2.50	3	$13,658	$2.75	3	$15,023.95	$3.00	3	$16,390
Total Cucumber Growing Costs	$14.80		$80,856	$16.28		$88,942	$17.76		$97,027
	Growing Area	**20.00%**	2,428						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Plugs, Seeds	$0.30	1	$728	$0.33	1	$801.28	$0.36	1	$874
Seeds	$1.50	1	$3,642	$1.65	1	$4,006.39	$1.80	1	$4,371
Fertilizers –All	$3.00	1	$7,284	$3.30	1	$8,012.78	$3.60	1	$8,741
Water Usage Costs	$1.50	1	$3,642	$1.65	1	$4,006.39	$1.80	1	$4,371
Biological Control	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Chemical Control	$1.00	1	$2,428	$1.10	1	$2,670.93	$1.20	1	$2,914
Greenhouse Supplies	$2.50	1	$6,070	$2.75	1	$6,677.31	$3.00	1	$7,284
Total Pepper Growing Costs	$14.80		$35,936	$16.28		$39,530	$17.76		$43,123
	Growing Area	**25%**	3035						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Styroform boards	$0.75	10	$22,764	$1.00	10	$30,351.42	$1.25	10	$37,939
Plugs,	$0.30	10	$9,105	$0.32	10	$9,579.28	$0.33	10	$10,053
Seeds	$0.50	10	$15,176	$0.60	10	$18,210.85	$0.70	10	$21,246
Fertilizers –All	$1.00	10	$30,351	$1.10	10	$33,386.57	$1.20	10	$36,422
Water Usage Costs	$0.20	10	$6,070	$0.23	10	$6,980.83	$0.26	10	$7,891
Biological Control	$0.10	10	$3,035	$0.11	10	$3,338.66	$0.12	10	$3,642
Chemical Control	$0.05	10	$1,518	$0.06	10	$1,821.09	$0.07	10	$2,125
Greenhouse Supplies	$0.25	10	$7,588	$0.53	10	$15,934.50	$0.80	10	$24,281
Total Lettuce Growing Costs	$3.15		$95,607	$3.94		$119,603	$4.73		$143,599
Total Growing Costs			$239,351			$277,722			$316,093

ENERGY COSTS

Square Meters		12,141	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	1.04	1.65	2.25
Annual GJoule required	12,626	19,971	27,316
Heating Costs $/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$63,131	$169,756	$327,795
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	180.00	200.00	220.00
Annual kWh. required	2,185,302	2,428,114	2,670,925
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electricity Costs ($/ Year)	$109,265	$242,811	$400,639
Light Repair/Replacement Costs ($/M2)	$4.00	$5.00	$6.00
Total Light Repair/Replacement Costs ($)	$48,562	$60,703	$72,843
Total Energy Costs ($/Year)	$220,958	$473,270	$801,278
1 kilowatt hour = 0.003 6 gigajoule			
Total Gjoule	20,493	28,712	36,932
Total Gjoule/M2	1.688	2.365	3.042

LABOUR COSTS

Acres		3	
Square Meters		12,141	
Contributions as % of Annual Cost=		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Average**	**High**
Labour per Acre	2	**3**	**4**
Total Labour Required (Hours/Week)	240	360	480
Weeks per Year	50	50	50
Total Hours per Year	12000	18000	24000
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$180,000	$315,000	$480,000
Contributions	$27,000	$47,250	$72,000
Total Annual GH Worker Cost	$207,000	$362,250	$552,000
Labour Cost per Square Meter ($/M^2)	$17.05	$29.84	$45.47
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Average**	**High**
Head Grower			
Annual Salary	$85,000.00	$92,500.00	$100,000
Contributions	$12,750	$13,875	$15,000
Total Annual Cost	$97,750.00	$106,375.00	$115,000.00
Assistant Grower/Facilities Mgr.			
Facility Manager Annual Salary	$55,000	$60,000	$65,000
Contributions	$8,250	$9,000	$9,750
Total Annual Cost	$63,250	$69,000	$74,750
Marketing/ Administration			
Number	1	1	1
Annual Salary	$45,000	$50,000	$55,000
Contributions	$6,750	$7,500	$8,250
Total Annual Cost	$51,750	$57,500	$63,250
Total Salaried Fixed Costs ($/Year)	$212,750.00	$232,875.00	$253,000.00

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	20,226	22,754	25,283
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$10,113	$12,515	$15,170
Total Wholesale Kg.	182,036	204,790	227,545
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$27,305	$43,108	$61,665
TOTAL TOMATO Marketing Costs ($)	$37,418	$55,623	$76,834
Cucumbers			
Total Retail Units	29,411	32,893	36,376
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$4,411.58	$6,578.67	$9,094.05
Total Wholesale Units	264,695	296,040	327,386
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$39,704	$62,316	$88,722
TOTAL CUCUMBER Marketing Costs ($)	$44,116	$68,895	$97,816
Peppers			
Total Retail Kg	5,779	6,501	7,224
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$2,889	$3,576	$4,334
Total Wholesale Kg.	5,463	6,119	6,774
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$819	$1,288	$1,836
TOTAL Pepper Marketing Costs ($)	$3,709	$4,864	$6,170
Lettuce			
Total Retail Kg	16,769	19,349	21,929
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$8,384.58	$10,641.97	$13,157.34
Total Wholesale Kg.	150,922	174,141	197,360
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$22,638	$36,657	$53,485
TOTAL LETTUCE Marketing Costs ($)	$31,023	$47,299	$66,642
Total Marketing & Distributions Costs	$116,266.13	$176,680.84	$247,461.78

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	12,141					
Enterprise Budgets for Northern Greenhouse	**Low**		**Mid Point of Ranges**		**High**	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$480,372	$39.57	$813,472	$67.00	$1,207,251	$99.44
Cucumbers	$323,516	$26.65	$616,750	$50.80	$963,969	$79.40
Peppers	$169,033	$13.92	$288,494	$23.76	$429,807	$35.40
Lettuce	$357,742	$29.47	$835,233	$68.80	$1,425,379	$117.41
Total Sales Revenues	**$1,330,663**	**$109.60**	**$2,553,950**	**$210.36**	**$4,026,405**	**$331.65**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M2**	**Total $**	**$/M2**
Growing Costs	$239,351	$19.72	$277,722	$22.88	$316,093	$26.04
Energy Costs	$220,958	$18.20	$473,270	$38.98	$801,278	$66.00
Labour costs	$207,000	$17.05	$362,250	$29.84	$552,000	$45.47
Marketing and Distribution Costs	$116,266	$9.58	$176,681	$14.55	$247,462	$20.38
Repair Costs (Building & Equipment)	$124,893	$10.29	$165,570	$13.64	$208,347	$17.16
Vehicle Expenses (*Not included in Marketing costs*)	$12,141	$1.00	$24,281	$2.00	$36,422	$3.00
Small Tools/Hardware/Supplies	$18,211	$1.50	$27,316	$2.25	$36,422	$3.00
Freight Costs (*Not included in marketing or growing costs*)	$12,141	$1.00	$24,281	$2.00	$36,422	$3.00
Custom Work	$6,070	$0.50	$12,141	$1.00	$18,211	$1.50
Operating Interest, Bank Charges	$24,281	$2.00	$36,422	$3.00	$48,562	$4.00
Dues, Fees, Promotion, Donation	$12,141	$1.00	$16,693	$1.38	$21,246	$1.75
Misc. Expenses	$12,141	$1.00	$30,351	$2.50	$48,562	$4.00
Total Variable Operating costs	$1,005,594	$82.83	$1,626,978	$134.01	$2,371,026	$195.30
Gross Margin	$325,069		$926,971		$1,655,379	
Fixed Operating Costs (C)						
1. Depreciation	$146,670	$12.08	$196,134	$16.16	$246,997	$20.34
2. Interest on Capital	$62,972	$5.19	$83,910	$6.91	$105,749	$8.71
3. Taxes & Insurance	$121,563	$10.01	$161,370	$6.00	$199,677	$16.45
5. Salaries	$212,750	$17.52	$232,875	$19.18	$253,000	$20.84
Total Fixed Operating Costs	$543,955	$44.80	$674,289	$48.25	$805,423	$66.34
(D) Total Operating Costs	$1,549,549	$127.63	$2,301,267	$189.55	$3,176,448	$261.64
(E) Net Returns (A-E)	**-$218,886**		**$252,683**		**$849,956**	
(F) Net Cash Income (E+C1+C2)	**-$9,244**		**$532,726**		**$1,202,702**	
% ROA	-7.70%		12.47%		28.10%	
Total Operating Costs with 50% Subsidization of Total Capital	$1,444,728		$2,161,245		$3,000,076	
Net Returns when 50% of Total Capital are Subsidized	-$114,065		$392,704		$1,026,329	
% ROA When 50% of Total Capital Costs Subsidized	-4.08%		16.10%		31.73%	

APPENDIX E: GUTTER-CONNECTED GREENHOUSE – HALF-ACRE (9 – 10 MONTHS PER YEAR)

GH STRUCTURE COSTS

Details of GH Structure	Modern Gutter Connected facility		1 acre = 4 046.856 422 4 square meter			
Description of System	10 Month production period					
Planned Growing Season	Optimized for individual crops					
Capital Costs of GH System		**Area (Acres)**	**Area (M2)**	**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
Structures	Greenhouse	0.5	2,023	$90	$102	$114
	Total Structure Costs			$90	$102	$114
Heating System				**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
	Biomass Heating System			$24	$42	$60
	Total Heating Costs			$24	$42	$60
Electrical	Electrical Control System			$6	$9	$12
May not be needed if incorporated into heating system or CHP system	Environmental Control Systems			$6	$9	$12
	Total Electrical Costs			$12	$18	$24
CO_2 system						
Water systems	Water/Irrigation/Fertigation System			$12	$15	$18
	Total Water System Costs			$12	$15	$18
Growing System	Growing System			$6	$9	$12
	Internal Transportation System			$4	$6	$8
	Total Growing System Costs			$10	$15	$20
Construction Costs	Freight			$2.00	$6.00	$10.00
	Construction Insurance			$2.00	$3.50	$5.00
	Total Construction Costs			$4.00	$9.50	$15.00
				Low ($/M^2)	**Mid Point**	**High ($/M^2)**
	Total ($/M2) Cost of GH Structure/System			$152	$202	$251
	Total ($) Cost of GH Structure/System			$307,561	$407,721	$507,880

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.00%**					
Capital Costs of Developing Greenhouse System						
			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$5,000			$150		
Site Preparation includes engineering & soil studies	$7,500	15	$500	$225		
Greenhouse Structure	$407,721	15	$27,181	$12,232	$24,463	$24,463
Header House/Warehouse/Retail Area	$7,500	15	$500	$225	$450	$450
Biomass Housing/Biomass Storage Areas	$7,500	15	$500	$225	$450	$450
Electrical Installation/Connection	$8,000	15	$533	$240		
Water Connection	$5,000	15	$333	$150		
Gas Installation/Connection	$0	15	$0	$0		
Total Construction Costs	$448,221		$29,548	$13,297	$25,363	$25,363

			Annual Charges			
Greenhouse Durables	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$5,000	5	$1,000	$150	$300	
Other Equipment	$5,000	5	$1,000	$150	$300	
Total Greenhouse Durables	$10,000		$2,000	$300	$600	

			Annual Charges			
Other Capital Costs	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles	$20,000	5	$4,000	$600	$1,200	
Bobcats/Forklifts/Other Machinery	$10,000	5	$2,000	$300	$600	
Office Equipment	$2,000	5	$400	$60		
Total Other Capital Costs	$32,000		$6,400	$960	$1,800	

			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	#		$37,948	$14,557	$27,763	$25,363

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	2,023		
	Low	**Average**	**High**
Tomatoes	35.0%	35.0%	35.0%
Growing Area (Tomatoes)	708	708	708
Production (Kg/Sq. meter)	40	48	55
Total Production (Kg.)	28,328	33,639	38,951
Cucumbers	15.0%	15.0%	15.0%
Growing Area (Cucumbers)	304	304	304
Production (Cucumbers/Sq. meter)	90	105	120
Total Production (Cucumbers)	27,316	31,869	36,422
Peppers	20%	20%	20%
Growing Area (Peppers)	405	405	405
Production (Kg/Sq. meter)	20	23	26
Total Production (Kg.)	8093.712845	9307.769772	10521.8267
Lettuce	25%	25%	25%
Growing Area (Other)	506	506	506
Production (Kg/Sq. meter)	55	63	70
Total Production (Kg.)	27822	31616	35410
Total Growing Area (Sq.Meters)	1922	1922	1922
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	24,079	28,594	33,108
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	23,219	27,089	30,958
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	6,880	7,912	8,944
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	23,649	26,874	30,098

SALES REVENUSE

Greenhouse Area (Sq. Meters)	2,023		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	24,079	28,594	33,108
% Retail sales	40%	40%	40%
Retail Kg.	9,632	11,437	13,243
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$33,710	$74,343	$125,812
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	14,447	17,156	19,865
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$32,506	$55,757	$84,426
Total Tomato Sales Revenues	$66,217	$130,101	$210,238
Cucumbers			
Total Marketable Production (Units)	23,219	27,089	30,958
% Retail sales	40%	40%	40%
Retail Units	9,288	10,835	12,383
Retail Price ($/Unit)	$2.00	$3.00	$4.00
Total Retail sales	$18,575	$32,506	$49,534
% Wholesale Sales	60%	60%	60%
Wholesale Units	13,931	16,253	18,575
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$13,931	$28,443	$46,438
Total Cucumber Sales Revenues	$32,506	$60,949	$95,971
Peppers			
Total Marketable Production	6,880	7,912	8,944
% Retail sales	40%	40%	40%
Retail Kg.	2,752	3,165	3,577
Retail Price ($/Unit)	$4.50	$7.25	$10.00
Total Retail sales	$12,383	$22,944	$35,774
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	4,128	4,747	5,366
Wholesale Price ($/Unit)	$2.75	$4.13	$5.50
Total Wholesale Sales Revenues	$11,351	$19,581	$29,514
Total Pepper Sales Revenues	$23,735	$42,525	$65,288
Lettuce			
Total Marketable Production	23,649	26,874	30,098
% Retail sales	40%	40%	40%
Retail Kg.	9,460	10,749	12,039
Retail Price ($/Unit)	$3.33	$7.17	$11.00
Total Retail sales	$31,532	$77,038	$132,433
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	14,189	16,124	18,059
Wholesale Price ($/Unit)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$28,379	$64,497	$108,355
Total Lettuce Sales Revenues	$59,910	$141,535	$240,788
Total Sales Revenues	$182,368	$375,110	$612,285

GROWING COSTS

	Square Meters		2,023						
	Growing Area	15.00%	304						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.75	1	$835	$3.03	1	$918	$3.30	1	$1,002
Plugs, Seeds	$0.33	1	$100	$0.35	1	$105	$0.36	1	$109
Seeds	$1.65	1	$501	$1.74	1	$528	$1.83	1	$555
Fertilizers –All	$3.30	1	$1,002	$3.47	1	$1,053	$3.64	1	$1,105
Water Usage Costs	$1.65	1	$501	$1.74	1	$528	$1.83	1	$555
Biological Control	$2.75	1	$835	$2.90	1	$879	$3.04	1	$923
Chemical Control	$1.10	1	$334	$1.16	1	$351	$1.21	1	$367
Greenhouse Supplies	$2.75	1	$835	$2.90	1	$879	$3.04	1	$923
Total Tomato Growing Costs	$16.28		$4,941	$17.27		$5,240	$18.25		$5,539
	Growing Area	**15.00%**	304						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.75	2	$1,669	$3.03	2	$1,836.26	$3.30	2	$2,003
Plugs, Seeds	$0.33	2	$200	$0.35	2	$209.42	$0.36	2	$219
Seeds	$1.65	2	$1,002	$1.74	2	$1,056.23	$1.83	2	$1,111
Fertilizers –All	$3.30	2	$2,003	$3.47	2	$2,106.39	$3.64	2	$2,210
Water Usage Costs	$1.65	2	$1,002	$1.74	2	$1,056.23	$1.83	2	$1,111
Biological Control	$2.75	2	$1,669	$2.90	2	$1,757.35	$3.04	2	$1,845
Chemical Control	$1.10	2	$668	$1.16	2	$701.12	$1.21	2	$735
Greenhouse Supplies	$2.75	2	$1,669	$2.90	2	$1,757.35	$3.04	2	$1,845
Total Cucumber Growing Costs	$16.28		$9,882	$17.27		$10,480	$18.25		$11,078
	Growing Area	**20.00%**	405						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M^2/Crop**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**	**$ per M^2**	**# of Crops**	**Total Cost**
Growing Media	$2.75	1	$1,113	$3.03	1	$1,224.17	$3.30	1	$1,335
Plugs, Seeds	$0.33	1	$134	$0.35	1	$139.62	$0.36	1	$146
Seeds	$1.65	1	$668	$1.74	1	$704.15	$1.83	1	$741
Fertilizers –All	$3.30	1	$1,335	$3.47	1	$1,404.26	$3.64	1	$1,473
Water Usage Costs	$1.65	1	$668	$1.74	1	$704.15	$1.83	1	$741
Biological Control	$2.75	1	$1,113	$2.90	1	$1,171.56	$3.04	1	$1,230
Chemical Control	$1.10	1	$445	$1.16	1	$467.41	$1.21	1	$490
Greenhouse Supplies	$2.75	1	$1,113	$2.90	1	$1,171.56	$3.04	1	$1,230
Total Pepper Growing Costs	$16.28		$6,588	$17.27		$6,987	$18.25		$7,386
	Growing Area	**25%**	506						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M2/Crop**	**# of Crops**	**Total Cost**	**$ per M2**	**# of Crops**	**Total Cost**	**$ per M2**	**# of Crops**	**Total Cost**
Styroform boards	$0.83	7	$2,921	$1.10	7	$3,895.10	$1.38	7	$4,869
Plugs,	$0.33	7	$1,169	$0.35	7	$1,226.96	$0.36	7	$1,285
Seeds	$0.55	7	$1,948	$0.66	7	$2,337.06	$0.77	7	$2,727
Fertilizers –All	$1.10	7	$3,895	$1.21	7	$4,284.61	$1.32	7	$4,674
Water Usage Costs	$0.22	7	$779	$0.25	7	$895.87	$0.29	7	$1,013
Biological Control	$0.11	7	$390	$0.12	7	$428.46	$0.13	7	$467
Chemical Control	$0.06	7	$195	$0.07	7	$233.71	$0.08	7	$273
Greenhouse Supplies	$0.28	7	$974	$0.58	7	$2,044.93	$0.88	7	$3,116
Total Lettuce Growing Costs	$3.47		$12,270	$4.33		$15,347	$5.20		$18,424
Total Growing Costs			$33,681			$38,054			$42,427

ENERGY COSTS

Square Meters		2,023	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	1.27	2.01	2.75
Annual GJoule required	2,560	4,062	5,564
$/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$12,798	$34,527	$66,773
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	18.00	20.00	22.00
Annual kWh. required	36,422	40,469	44,515
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electrical Costs ($/ Year)	$1,821	$4,047	$6,677
Total Energy Costs ($/Year)	$14,619	$38,574	$73,450
Total Gj	2,691	4,208	5,725
Gj per M2	1.330	2.080	2.829

LABOUR COSTS

Acres		0.5	
Square Meters		2,023	
Contributions as % of Annual Cost=		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	2	**3**	**4**
Total Labour Required (Hours/Week)	40	60	80
Weeks per Year	40	40	40
Total Hours per Year	1600	2400	3200
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$24,000	$42,000	$64,000
Contributions	$3,600	$6,300	$9,600
Total Annual GH Worker Cost	$27,600	$48,300	$73,600
Labour Cost per Square Meter ($/M^2)	$13.64	$23.87	$36.37
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Head Grower			
Annual Salary	$55,000	$65,000	$75,000
Contributions	$8,250	$9,750	$11,250
Total Annual Cost	$63,250	$74,750	$86,250
Facilities/Business Mgr./Marketing			
Facility Manager Annual Salary	$35,000	$45,000	$55,000
Contributions	$5,250	$6,750	$8,250
Total Annual Cost	$40,250	$51,750	$63,250
Total Salaried Fixed Costs ($/Year)	$103,500	$126,500	$149,500

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	9,632	11,437	13,243
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$4,815.76	$6,290.59	$7,946.00
Total Wholesale Kg.	14,447	17,156	19,865
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$2,167	$3,611	$5,383
TOTAL TOMATO Marketing Costs ($)	$6,983	$9,902	$13,329
Cucumbers			
Total Retail Kg	9,288	10,835	12,383
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$1,393.13	$2,167.09	$3,095.85
Total Wholesale Kg.	13,931	16,253	18,575
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$2,090	$3,421	$5,034
TOTAL CUCUMBER Marketing Costs ($)	$3,483	$5,588	$8,130
Peppers			
Total Retail Kg	6,880	7,912	8,944
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$3,439.83	$4,351.38	$5,366.13
Total Wholesale Kg.	4,128	4,747	5,366
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$619	$999	$1,454
TOTAL Pepper Marketing Costs ($)	$4,059	$5,351	$6,820
Lettuce			
Total Retail Kg	9,460	10,749	12,039
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$4,729.76	$5,912.20	$7,223.64
Total Wholesale Kg.	14,189	16,124	18,059
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$2,128	$3,394	$4,894
TOTAL LETTUCE Marketing Costs ($)	$6,858	$9,306	$12,118
Total Marketing & Distributions Costs	$21,382.83	$30,147.31	$40,397.12

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	2,023					
Enterprise Budgets for Northern Greenhouse	**Low**		**Mid Point**		**High**	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$66,217	$32.73	$130,101	$64.30	$210,238	$103.90
Cucumbers	$32,506	$16.07	$60,949	$30.12	$95,971	$47.43
Peppers	$23,735	$11.73	$42,525	$21.02	$65,288	$32.27
Other Crops	$59,910	$29.61	$141,535	$69.95	$240,788	$119.00
Total Sales Revenues	**$182,368**	**$90.13**	**$375,110**	**$185.38**	**$612,285**	**$302.60**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Growing Costs	$33,681	$16.65	$38,054	$18.81	$42,427	$20.97
Energy Costs	$14,619	$7.23	$38,574	$19.06	$73,450	$36.30
Labour costs	$27,600	$13.64	$48,300	$23.87	$73,600	$36.37
Marketing and Distribution Costs	$21,383	$10.57	$30,147	$14.90	$40,397	$19.96
Repair Costs (Building & Equipment)	$20,614	$10.19	$27,763	$13.72	$35,573	$17.58
Vehicle Expenses (*Not included in Marketing costs*)	$2,226	$1.10	$4,452	$2.20	$6,677	$3.30
Small Tools/Hardware/Supplies	$3,339	$1.65	$5,008	$2.48	$6,677	$3.30
Freight Costs (*Not included in marketing or growing costs*)	$2,226	$1.10	$4,452	$2.20	$6,677	$3.30
Custom Work	$1,315	$0.65	$2,327	$1.15	$3,339	$1.65
Operating Interest, Bank Charges	$4,452	$2.20	$6,677	$3.30	$8,903	$4.40
Dues, Fees, Promotion, Donation	$2,226	$1.10	$3,065	$1.52	$3,905	$1.93
Misc. Expenses	$2,226	$1.10	$5,564	$2.75	$8,903	$4.40
Total Variable Operating costs	$135,906	$67.17	$214,384	$105.95	$310,529	$153.47
Gross Margin (A-B	$46,462		$160,726		$301,756	
Fixed Operating Costs (C)						
1. Depreciation	$26,871	$13.28	$37,948	$18.75	$49,492	$24.46
2. Interest on Capital	$10,682	$5.28	$14,557	$7.19	$19,046	$9.41
3. Taxes & Insurance	$19,054	$9.42	$25,363	$6.00	$31,673	$15.65
5. Salaries	$103,500	$51.15	$126,500	$62.52	$149,500	$73.88
Total Fixed Operating Costs	$160,106	$79.13	$204,368	$94.47	$249,711	$123.41
(D) Total Operating Costs	$296,012	$146.29	$418,752	$206.95	$560,240	$276.88
(E) Net Returns (A-E)	**-$113,644**		**-$43,642**		**$52,045**	
(F) Net Cash Income (E+C1+C2)	**-$76,091**		**$8,862**		**$120,583**	
% ROA	-33.17%		-1.62%		8.53%	
Total Operating Costs with 50% Subsidization of Total Capital	$277,236		$392,500		$525,971	
Net Returns when 50% of Total Capital are Subsidized	-$94,867		-$17,390		$86,314	
% ROA When 50% of Total Capital Costs Subsidized	-26.13%		-0.37%		15.71%	

APPENDIX F: GUTTER-CONNECTED GREENHOUSE – HALF-ACRE (12 MONTHS PER YEAR)

GH STRUCTURE COSTS

Details of GH Structure	Modern Gutter Connected facility		1 acre = 4 046.856 422 4 square meter			
Description of System	Artifical lighting for year round production					
Main Energy Source	Natural gas/biomass					
Planned Growing Season	Optimized for individual crops					
Capital Costs of GH System		**Area (Acres)**	**Area (M2)**	**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
Structures	Greenhouse	0.5	2,023	$90	$102	$114
	Total Structure Costs			$90	$102	$114
Heating System				**Low ($/M^2)**	**Mid Point**	**High ($/M^2)**
	Biomass Heating System			$24	$42	$60
	Energy curtain			$7.20	$10.80	$14.40
	Total Heating Costs			$31	$53	$74
Electrical	Electrical Control System			$6	$9	$12
	Environmental Control Systems			$6	$9	$12
	Grow Light system			$36	$45	$54
	Total Electrical Costs			$48	$63	$78
Water systems	Water/Irrigation/Fertigation System			$12	$15	$18
	Total Water System Costs			$12	$15	$18
Growing System	Growing system			$6	$9	$12
	Internal Transportation System			$4	$6	$8
	Total Growing System Costs			$10	$15	$20
Construction Costs	Freight			$2.00	$6.00	$10.00
	Construction & Insurance			$2.00	$3.50	$5.00
	Total Construction Costs			$4.00	$9.50	$15.00
				Low ($/M^2)	**Mid Point**	**High ($/M^2)**
	Total ($/M2) Cost of GH Structure/System			$195	$257	$319
	Total ($) Cost of GH Structure/System			$394,973	$520,628	$646,283

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**					
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse System		Average				

			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$5,000			$150		
Site Preparation includes engineering & soil studies	$5,000	15	$333	$150		
Greenhouse Structure	$520,628	15	$34,709	$15,619	$31,238	$31,238
Header House/Warehouse/Retail Area	$7,500	15	$500	$225	$450	$450
Biomass Housing/Biomass Storage Areas	$7,500	15	$500	$225	$450	$450
Electrical Installation/Connection	$8,000	15	$533	$240		
Water Connection	$5,000	15	$333	$150		
Gas Installation/Connection	$0	15	$0	$0		
Total Construction Costs	$558,628		$36,909	$16,759	$32,138	$32,138

			Annual Charges			
Greenhouse Durables	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$5,000	5	$1,000	$150	$300	
Other Equipment	$7,500	5	$1,500	$225	$450	
Total Greenhouse Durables	$12,500		$2,500	$375	$750	

			Annual Charges			
Other Capital Costs	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles	$20,000	5	$4,000	$600	$1,200	
Bobcats/Forklifts/Other Machinery	$7,500	5	$1,500	$225	$450	
Office Equipment	$2,000	5	$400	$60		
Total Other Capital Costs	$29,500		$5,900	$885	$1,650	

			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	$600,628		$45,309	$18,019	$34,538	$32,138

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	2,023		
	Low	**Mid Point**	**High**
Tomatoes	35.0%	35.0%	35.0%
Growing Area (Tomatoes)	708	708	708
Production (Kg/Sq. meter)	56	63	70
Total Production (Kg.)	39,659	44,617	49,574
Cucumbers	15.0%	15.0%	15.0%
Growing Area (Cucumbers)	304	304	304
Production (Cucumbers/Sq. meter)	190	213	235
Total Production (Cucumbers)	57,668	64,497	71,326
Peppers	20%	20%	20%
Growing Area (Peppers)	405	405	405
Production (Kg/Sq. meter)	28	32	35
Total Production (Kg.)	11331	12748	14164
Lettuce	25%	25%	25%
Growing Area (Other)	506	506	506
Production (Kg/Sq. meter)	65	75	85
Total Production (Kg.)	32881	37939	42998
Total Growing Area (Sq.Meters)	1922	1922	1922
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	33,710	37,924	42,138
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	49,018	54,822	60,627
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	9,632	10,835	12,039
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	27,949	32,248	36,548

SALES REVENUES

Greenhouse Area (Sq. Meters)	2,023		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	33,710	37,924	42,138
% Retail sales	40%	40%	40%
Retail Kg.	13,484	15,170	16,855
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$47,194	$98,603	$160,124
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	20,226	22,754	25,283
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$45,509	$73,952	$107,452
Total Tomato Sales Revenues	$92,703	$172,555	$267,576
Cucumbers			
Total Marketable Production (Units)	49,018	54,822	60,627
% Retail sales	40%	40%	40%
Retail Units	19,607	21,929	24,251
Retail Price ($/Unit)	$2.00	$3.00	$4.00
Total Retail sales	$39,214	$65,787	$97,003
% Wholesale Sales	60%	60%	60%
Wholesale Units	29,411	32,893	36,376
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$29,411	$57,563	$90,940
Total Cucumber Sales Revenues	$68,625	$123,350	$187,944
Peppers			
Total Marketable Production	9,632	10,835	12,039
% Retail sales	40%	40%	40%
Retail Kg.	3,853	4,334	4,816
Retail Price ($/Unit)	$4.50	$7.25	$10.00
Total Retail sales	$17,337	$31,423	$48,158
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	5,779	6,501	7,224
Wholesale Price ($/Unit)	$2.75	$4.13	$5.50
Total Wholesale Sales Revenues	$15,892	$26,818	$39,730
Total Pepper Sales Revenues	$33,229	$58,241	$87,888
Lettuce			
Total Marketable Production	27,949	32,248	36,548
% Retail sales	40%	40%	40%
Retail Kg.	11,179	12,899	14,619
Retail Price ($/Unit)	$3.33	$7.17	$11.00
Total Retail sales	$37,265	$92,445	$160,812
% Wholesale Sales	60%	60%	60%
Wholesales Kg.	16,769	19,349	21,929
Wholesale Price ($/Unit)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$33,538	$77,396	$131,573
Total Lettuce Sales Revenues	$70,803	$169,842	$292,385
Total Sales Revenues	$265,360	$523,987	$835,792

GROWING COSTS

	Square Meters		2,023						
	Growing Area	15.00%	304						
Tomatoes Projected Growing Costs	Low			Mid Point			High		
Growing Input	$ per M²/Crop	# of Crops	Total Cost	$ per M²	# of Crops	Total Cost	$ per M²	# of Crops	Total Cost
Growing Media	$2.75	1	$835	$3.03	1	$918	$3.30	1	$1,002
Plugs, Seeds	$0.33	1	$100	$0.35	1	$105	$0.36	1	$109
Seeds	$1.65	1	$501	$1.74	1	$528	$1.83	1	$555
Fertilizers –All	$3.30	1	$1,002	$3.47	1	$1,053	$3.64	1	$1,105
Water Usage Costs	$1.65	1	$501	$1.74	1	$528	$1.83	1	$555
Biological Control	$2.75	1	$835	$2.90	1	$879	$3.04	1	$923
Chemical Control	$1.10	1	$334	$1.16	1	$351	$1.21	1	$367
Greenhouse Supplies	$2.75	1	$835	$2.90	1	$879	$3.04	1	$923
Total Tomato Growing Costs	$16.28		$4,941	$17.27		$5,240	$18.25		$5,539
	Growing Area	**15.00%**	304						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Growing Media	$2.75	3	$2,504	$3.03	3	$2,754.39	$3.30	3	$3,005
Plugs, Seeds	$0.33	3	$300	$0.35	3	$314.14	$0.36	3	$328
Seeds	$1.65	3	$1,502	$1.74	3	$1,584.34	$1.83	3	$1,666
Fertilizers –All	$3.30	3	$3,005	$3.47	3	$3,159.58	$3.64	3	$3,314
Water Usage Costs	$1.65	3	$1,502	$1.74	3	$1,584.34	$1.83	3	$1,666
Biological Control	$2.75	3	$2,504	$2.90	3	$2,636.02	$3.04	3	$2,768
Chemical Control	$1.10	3	$1,002	$1.16	3	$1,051.68	$1.21	3	$1,102
Greenhouse Supplies	$2.75	3	$2,504	$2.90	3	$2,636.02	$3.04	3	$2,768
Total Cucumber Growing Costs	$16.28		$14,824	$17.27		$15,721	$18.25		$16,617
	Growing Area	**20.00%**	405						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Growing Media	$2.75	1	$1,113	$3.03	1	$1,224.17	$3.30	1	$1,335
Plugs, Seeds	$0.33	1	$134	$0.35	1	$139.62	$0.36	1	$146
Seeds	$1.65	1	$668	$1.74	1	$704.15	$1.83	1	$741
Fertilizers –All	$3.30	1	$1,335	$3.47	1	$1,404.26	$3.64	1	$1,473
Water Usage Costs	$1.65	1	$668	$1.74	1	$704.15	$1.83	1	$741
Biological Control	$2.75	1	$1,113	$2.90	1	$1,171.56	$3.04	1	$1,230
Chemical Control	$1.10	1	$445	$1.16	1	$467.41	$1.21	1	$490
Greenhouse Supplies	$2.75	1	$1,113	$2.90	1	$1,171.56	$3.04	1	$1,230
Total Tomato Growing Costs	$16.28		$6,588	$17.27		$6,987	$18.25		$7,386
	Growing Area	**25%**	506						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Styroform boards	$0.83	10	$4,173	$1.10	10	$5,564.43	$1.38	10	$6,956
Plugs,	$0.33	10	$1,669	$0.35	10	$1,752.79	$0.36	10	$1,836
Seeds	$0.55	10	$2,782	$0.66	10	$3,338.66	$0.77	10	$3,895
Fertilizers –All	$1.10	10	$5,564	$1.21	10	$6,120.87	$1.32	10	$6,677
Water Usage Costs	$0.22	10	$1,113	$0.25	10	$1,279.82	$0.29	10	$1,447
Biological Control	$0.11	10	$556	$0.12	10	$612.09	$0.13	10	$668
Chemical Control	$0.06	10	$278	$0.07	10	$333.87	$0.08	10	$390
Greenhouse Supplies	$0.28	10	$1,391	$0.58	10	$2,921.32	$0.88	10	$4,452
Total Tomato Growing Costs	$3.47		$17,528	$4.33		$21,924	$5.20		$26,320

ENERGY COSTS

Square Meters		2,023	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	1.08	1.71	2.33
Annual GJoule required	2,185	3,450	4,715
Heating Costs $/G joule	$5.00	$10.50	$12.00
Total Heating Costs ($/ Year)	$10,927	$36,224	$56,575
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	180.00	200.00	220.00
Annual kWh. required	364,217	404,686	445,154
Electricity $/kWh	$0.05	$0.15	$0.15
Total Electricity Costs ($/Year)	$18,211	$60,703	$66,773
Light Repair/Replacement Costs ($/M2)	$4.00	$5.00	$6.00
Total Light Repair/Replacement Costs ($)	$8,094	$10,117	$12,141
Total Energy Costs ($/Year)	$37,231	$96,927	$123,348
Total Gj	3,496	4,907	6,317
Gj per M2	1.728	2.425	3.122

LABOUR COSTS

Acres		0.5	
Square Meters		2,023	
Contributions as % of Annual Cost=		15.00%	

Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	2	**3**	**4**
Total Labour Required (Hours/Week)	40	60	80
Weeks per Year	50	50	50
Total Hours per Year	2000	3000	4000
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$30,000	$52,500	$80,000
Contributions	$4,500	$7,875	$12,000
Total Annual GH Worker Cost	$34,500	$60,375	$92,000

Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Head Grower			
Annual Salary	$55,000.00	$65,000.00	$75,000
Contributions	$8,250	$9,750	$11,250
Total Annual Cost	$63,250.00	$74,750.00	$86,250.00
Facilities/Business Mgr./Marketing			
Facility Manager Annual Salary	$35,000	$45,000	$55,000
Contributions	$5,250	$6,750	$8,250
Total Annual Cost	$40,250	$51,750	$63,250
Total Salaried Fixed Costs ($/Year)	$103,500.00	$126,500.00	$149,500.00

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	13,484	15,170	16,855
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$6,742.06	$8,343.30	$10,113.09
Total Wholesale Kg.	20,226	22,754	25,283
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$3,034	$4,790	$6,852
TOTAL TOMATO Marketing Costs ($)	$9,776	$13,133	$16,965
Cucumbers			
Total Retail Kg	19,607	21,929	24,251
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$2,941.05	$4,385.78	$6,062.70
Total Wholesale Kg.	29,411	32,893	36,376
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$4,412	$6,924	$9,858
TOTAL CUCUMBER Marketing Costs ($)	$7,353	$11,310	$15,921
Peppers			
Total Retail Kg	9,632	10,835	12,039
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$4,815.76	$5,959.50	$7,223.64
Total Wholesale Kg.	5,779	6,501	7,224
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$867	$1,369	$1,958
TOTAL Pepper Marketing Costs ($)	$5,683	$7,328	$9,181
Lettuce			
Total Retail Kg	11,179	12,899	14,619
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$5,589.72	$7,094.65	$8,771.56
Total Wholesale Kg.	16,769	19,349	21,929
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$2,515	$4,073	$5,943
TOTAL LETTUCE Marketing Costs ($)	$8,105	$11,168	$14,714
Total Marketing & Distributions Costs	$30,916.31	$42,938.59	$56,780.90

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	2,023					
Enterprise Budgets for Northern Greenhouse	Low		Mid Point		High	
Sales Revenues (A)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Tomatoes	$92,703	$45.82	$172,555	$85.28	$267,576	$132.24
Cucumbers	$68,625	$33.92	$123,350	$60.96	$187,944	$92.88
Peppers	$33,229	$16.42	$58,241	$28.78	$87,888	$43.44
Other Crops	$70,803	$34.99	$169,842	$83.94	$292,385	$144.50
Total Sales Revenues	**$265,360**	**$131.14**	**$523,987**	**$258.96**	**$835,792**	**$413.06**
Variable Operating Costs (B)	**Total $**	**$/M²**	**Total $**	**$/M²**	**Total $**	**$/M²**
Growing Costs	$43,881	$21.69	$49,871	$24.65	$55,862	$27.61
Energy Costs	$37,231	$18.40	$96,927	$47.90	$123,348	$60.96
Labour costs	$34,500	$17.05	$60,375	$29.84	$92,000	$45.47
Marketing and Distribution Costs	$30,916	$15.28	$42,939	$21.22	$56,781	$28.06
Repair Costs (Building & Equipment)	$25,948	$12.82	$34,538	$17.07	$44,507	$22.00
Vehicle Expenses (*Not included in Marketing costs*)	$2,226	$1.10	$4,452	$2.20	$6,677	$3.30
Small Tools/Hardware/Supplies	$3,339	$1.65	$5,008	$2.48	$6,677	$3.30
Freight Costs (*Not included in marketing or growing costs*)	$2,226	$1.10	$4,452	$2.20	$6,677	$3.30
Custom Work	$1,315	$0.65	$2,327	$1.15	$3,339	$1.65
Operating Interest, Bank Charges	$4,452	$2.20	$6,677	$3.30	$8,903	$4.40
Dues, Fees, Promotion, Donation	$2,226	$1.10	$3,065	$1.52	$3,905	$1.93
Misc. Expenses	$2,226	$1.10	$5,564	$2.75	$8,903	$4.40
Total Variable Operating costs	$190,485	$94.14	$316,195	$156.27	$417,580	$206.37
Grosss Margin	$74,874		$207,792		$418,212	
Fixed Operating Costs (C)						
1. Depreciation	$32,998	$16.31	$45,309	$22.39	$61,319	$30.30
2. Interest on Capital	$13,349	$6.60	$18,019	$8.91	$23,213	$11.47
3. Taxes & Insurance	$24,298	$12.01	$32,138	$6.00	$39,977	$19.76
5. Salaries	$103,500	$51.15	$126,500	$62.52	$149,500	$73.88
Total Fixed Operating Costs	$174,146	$86.06	$221,965	$99.81	$274,009	$135.42
(D) Total Operating Costs	$364,631	$180.20	$538,160	$265.96	$691,589	$341.79
(E) Net Returns (A-E)	**-$99,271**		**-$14,173**		**$144,203**	
(F) Net Cash Income (E+C1+C2)	**-$52,924**		**$49,154**		**$228,735**	
% ROA	-23.17%		-2.45%		19.15%	
Total Operating Costs with 50% Subsidization of Total Capital	$341,457		$506,497		$649,323	
Net Returns when 50% of Total Capital are Subsidized	-$76,098		$17,490		$186,469	
% ROA When 50% of Total Capital Costs Subsidized	-16.20%		4.58%		26.30%	

APPENDIX G: CHINESE SOLAR GREENHOUSE – 150m^2 (7 – 8 MONTHS PER YEAR)

GH STRUCTURE COST

		Length	Width	No.	Ft.^{2}	M^2
	Dimensions (Ft.)	50	32.5	1	1625	150.97
	1 square foot = 0.092 903 04 square meter					
Capital Costs of GH System		**Area (Square Meters)**	**Acres**	**Low (\$/M^2)**	**Mid Point**	**High (\$/M^2)**
Structures	Greenhouse Structure	150.97	0.037	\$400	\$450	\$500
	Includes doors, windows and walls					
	Total Structure Costs			\$400	\$450	\$500
Heating System				**Low (\$/M^2)**	**Mid Point**	**High (\$/M^2)**
	Biomass Heating System			\$225	\$263	\$300
	Includes boilers, controls, distributin system					
	Total Heating Costs			\$225	\$263	\$300
Electrical	Electrical/Lights/Environmental Controls			\$75.00	\$82.50	\$90.00
	Total Electrical Costs			\$75.00	\$82.50	\$90.00
Water Systems	Water/Irrigation/Fertilization Systems			\$25.00	\$50.00	\$75.00
	Total Water System Costs			\$25.00	\$50.00	\$75.00
Construction Costs	Freight			\$3.00	\$6.50	\$10.00
	Construction & Insurance Costs			\$30.00	\$40.00	\$50.00
	Total Construction Costs			\$33.00	\$46.50	\$60.00
				Low (\$/M^2)	**Mid Point**	**High (\$/M^2)**
	Total (\$/M2) Cost of GH Structure/System			\$758	\$892	\$1,025
	Total (\$) Cost of GH Structure/System			\$114,433	\$134,587	\$154,742

CAPITAL COSTS AVERAGE

Annual Repair Costs Calculated as % of New Price	**6.00%**					
Annual rate for Calculating Taxes & Insurance	**6.00%**		**Mid Point of The Range**			
Opportunity Costs (%)	**6.000%**					
Capital Costs of Developing Greenhouse System	**Option**					

			Annual Charges			
Greenhouse Construction	**Capital Investment Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Land	$0			$0		
Site Preparation includes engineering & soil studies	$10,000	15	$667	$300		
Greenhouse Structure	$134,587	15	$8,972	$4,038	$8,075	$8,075
Header House/Work/Retail Area	$15,000	15	$1,000	$450	$900	$900
Water Connection	$2,500	15	$167	$75		
Electrical Installation/Connection	$5,000	15	$333	$150		
Total Construction Costs	$167,087		$11,139	$5,013	$8,975	$8,975

			Annual Charges			
Greenhouse Durables	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Spraying Equipment	$750	5	$150	$23	$45	
Other Equipment	$750	5	$150	$23	$45	
Total Greenhouse Durables	$1,500		$300	$45	$90	

			Annual Charges			
Other Capital Costs	**Cost**	**Life-Years**	**Depreciation**	**Interest**	**Repair Costs**	**Taxes & Insurance**
Trucks/Vehicles (Share Allocated to Greenhouse	$1,500	5	$300	$45	$90	
Bobcats/Forklifts/Other Equiment	$200	5	$40	$6	$12	
Office Equipment		5	$0	$0		
Total Other Capital Costs	$1,700		$340	$51	$102	

			Annual Charges			
			Depreciation	**Interest**	**Repair Costs**	**Taxes & Insurance**
Total All Capital Costs	$170,287		$11,779	$5,109	$9,167	$8,975

PRODUCTION PARAMATERS

Greenhouse Area (Sq. Meters)	150.97		
	Low	**Mid Point**	**High**
Tomatoes	50.0%	50.0%	50.0%
Growing Area (Tomatoes)	75	75	75
Production (Kg/Sq. meter)	26	31	36
Total Production (Kg.)	1,963	2,340	2,717
Cucumbers	20.0%	20.0%	20.0%
Growing Area (Cucumbers)	30	30	30
Production (Cucumbers/Sq. meter)	59	69	78
Total Production (Cucumbers)	1,781	2,068	2,355
Peppers	0%	0%	0%
Growing Area (Peppers)	0	0	0
Production (Kg/Sq. meter)	13.00	15.00	17.00
Total Production (Kg.)	0	0	0
Lettuce	0%	0%	0%
Growing Area (Other)	0	0	0
Production (Kg/Sq. meter)	36	41	46
Total Production (Kg.)	0	0	0
Total Growing Area (Sq.Meters)	106	106	106
Tomatoes			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Kg.)	1,668	1,989	2,310
Cucumbers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production (Units)	1,514	1,758	2,002
Peppers			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	0	0	0
Lettuce			
Marketable Yield (%)	85%	85%	85%
Total Marketable Production	0	0	0

SALES REVENUES

Greenhouse Area (Sq. Meters)	151		
Tomatoes	**Low**	**Mid Point**	**High**
Total Marketable Production (Kg.)	1,668	1,989	2,310
% Retail sales	100%	100%	100%
Retail Kg.	1,668	1,989	2,310
Retail Price ($/Kg.)	$3.50	$6.50	$9.50
Total Retail sales	$5,839	$12,928	$21,943
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Kg.)	$2.25	$3.25	$4.25
Total Wholesale Sales Revenues	$0	$0	$0
Total Tomato Sales Revenues	$5,839	$12,928	$21,943
Cucumbers			
Total Marketable Production (Units)	1,514	1,758	2,002
% Retail sales	100%	100%	100%
Retail Units	1,514	1,758	2,002
Retail Price ($/Unit)	$2.00	$3.50	$4.00
Total Retail sales	$3,028	$6,153	$8,007
% Wholesale Sales	0%	0%	0%
Wholesale Units	0	0	0
Wholesale Price ($/Unit)	$1.00	$1.75	$2.50
Total Wholesale Sales Revenues	$0	$0	$0
Total Cucumber Sales Revenues	$3,028	$6,153	$8,007
Peppers			
Total Marketable Production	0	0	0
% Retail sales	100%	100%	100%
Retail Kg.	0	0	0
% Coloured Peppers	75%	75%	75%
Retail Price Coloured Peppers ($/Unit)	$4.50	$7.25	$10.00
Total Retail Sales Coloured Peppers	$0.00	$0.00	$0.00
% Green Peppers	25%	25%	25%
Retail Price Green Peppers ($/Unit)	$3.00	$4.50	$6.00
Total Retail Sales Green Peppers	$0	$0	$0
Total Pepper Sales Revenues	$0	$0	$0
Lettuce			
Total Marketable Production	0	0	0
% Retail sales	100%	100%	100%
Retail Kg.	0	0	0
Retail Price ($/Unit)	$3.33	$7.17	$11.00
Total Retail sales	$0	$0	$0
% Wholesale Sales	0%	0%	0%
Wholesales Kg.	0	0	0
Wholesale Price ($/Unit)	$2.00	$4.00	$6.00
Total Wholesale Sales Revenues	$0	$0	$0
Total Lettuce Sales Revenues	$0	$0	$0
Total Sales Revenues	$8,867	$19,082	$29,950

GROWING COSTS

	Square Meters		151						
	Growing Area	50.00%	75						
Tomatoes Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Seed	$0.33	1	$25	$0.37	1	$28	$0.40	1	$30
Fertilizers –All	$0.90	1	$68	$1.08	1	$81	$1.25	1	$94
Water Usage Costs	$0.00	1	$0	$0.38	1	$28	$0.75	1	$57
Pest Management	$1.10	1	$83	$1.18	1	$89	$1.25	1	$94
Greenhouse Supplies	$1.35	1	$102	$1.45	1	$109	$1.55	1	$117
Total Tomato Growing Costs	$3.68		$278	$4.44		$335	$5.20		$393
	Growing Area	**20.00%**	30						
Cucumbers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Seed	$0.02	2	$1	$0.04	2.5	$3	$0.05	3	$5
Fertilizers –All	$0.90	2	$54	$1.08	2.5	$81	$1.25	3	$113
Water Usage Costs	$0.00	2	$0	$0.38	2.5	$28	$0.75	3	$68
Pest Management	$1.10	2	$66	$1.18	2.5	$89	$1.25	3	$113
Greenhouse Supplies	$1.35	2	$82	$1.45	2.5	$109	$1.55	3	$140
Total Cucumber Growing Costs	$3.37		$204	$4.11		$310	$4.85		$439
	Growing Area	**0.00%**	0						
Peppers Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Seed	$0.33	1	$0	$0.37	1	$0	$0.40	1	$0
Fertilizers –All	$0.90	1	$0	$1.08	1	$0	$1.25	1	$0
Water Usage Costs	$0.00	1	$0	$0.38	1	$0	$0.75	1	$0
Pest Management	$1.10	1	$0	$1.18	1	$0	$1.25	1	$0
Greenhouse Supplies	$1.35	1	$0	$1.45	1	$0	$1.55	1	$0
Total Tomato Growing Costs	$3.68		$0	$4.44		$0	$5.20		$0
	Growing Area	**0%**	0						
Lettuce Projected Growing Costs	**Low**			**Mid Point**			**High**		
Growing Input	**$ per M²/Crop**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**	**$ per M²**	**# of Crops**	**Total Cost**
Plugs	$0.33	5	$0	$0.37	5	$0	$0.40	5	$0
Seeds	$0.55	5	$0	$0.66	5	$0	$0.77	5	$0
Fertilizers –All	$0.20	5	$0	$0.23	5	$0	$0.26	5	$0
Pest management	$0.22	5	$0	$0.24	5	$0	$0.25	5	$0
Greenhouse Supplies	$0.28	5	$0	$0.31	5	$0	$0.35	5	$0
Total Lettuce Growing Costs	$1.58		$0	$1.80		$0	$2.03		$0
Total Growing Costs			$481			$645			$832

ENERGY COSTS

Square Meters		151	
Heating Costs			
Total Energy (G Joule) for Greenhouse System	**Low**	**Mid Point**	**High**
G joule/Square Meter/Year	0.4	0.45	0.50
Annual GJoule required	60	68	75
Heating Cost $/G joule	$5.00	$8.50	$12.00
Total Heating Costs ($/ Year)	$302	$577	$906
Lighting Costs			
Total Energy (Kilowatt Hours) for Greenhouse System	**Low**	**Mid Point**	**High**
kWh. /Square Meter/Year	14.00	22.00	30.00
Annual kWh. required	2,114	3,321	4,529
Electricity $/kWh	$0.05	$0.10	$0.15
Total Electrical Costs ($/ Year)	$106	$332	$679
Total Energy Costs ($/Year)	$408	$910	$1,585
Total Gj	68.00	79.89	91.79
Gj per M2	0.4504	0.5292	0.608

LABOUR COSTS

Acres		0.037	
Square Meters		151	
Contributions as % of Annual Cost=		15.00%	
Estimated VARIABLE Labour Costs (Assuming an 8 hour day)			
Greenhouse Workers	**Low**	**Mid Point**	**High**
Labour per Acre	0	**0**	**0**
Total Labour Required (Hours/Week)	0.00	0.00	0.00
Weeks per Year	40	40	40
Total Hours per Year	0	0	0
Labour Wage Cost ($/Hr.)	$15.00	$17.50	$20.00
Total Annual Wage Cost	$0	$0	$0
Contributions	$0	$0	$0
Total Annual GH Worker Cost	$0	$0	$0
Estimating Salaried Labour Fixed Costs			
Salaried Position	**Low**	**Mid Point**	**High**
Owner Operator			
Annual Salary	$0	$0	$0
Contributions	$0	$0	$0
Total Annual Cost	$0	$0	$0
Total Salaried Fixed Costs ($/Year)	$0	$0	$0

MARKETING AND DISTRIBUTION COSTS

These are the costs required to ensure the products are at the right place, at the right time and in the right form to meet end user needs.

Crop	Low	Mid Point	High
Tomatoes			
Total Retail Kg	1,668	1,989	2,310
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$834.10	$1,093.95	$1,385.88
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL TOMATO Marketing Costs ($)	$834	$1,094	$1,386
Cucumbers			
Total Retail Kg	1,514	1,758	2,002
Retail Marketing Costs ($/Unit)	$0.15	$0.20	$0.25
Total Retail Marketing Costs ($)	$227.13	$351.60	$500.46
Total Wholesale Kg.	0	0	0
Packaging ($/Unit)	$0.100	$0.150	$0.200
Distribution ($/Unit)	$0.010	$0.020	$0.030
Transportation ($/Unit)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Unit)	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL CUCUMBER Marketing Costs ($)	$227	$352	$500
Peppers			
Total Retail Kg	0	0	0
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$0.00	$0.00	$0.00
TOTAL Pepper Marketing Costs ($)	$0	$0	$0
Lettuce			
Total Retail Kg	0	0	0
Retail Marketing Costs ($/Kg.)	$0.50	$0.55	$0.60
Total Retail Marketing Costs ($)	$0.00	$0.00	$0.00
Total Wholesale Kg.	0	0	0
Packaging ($/Kg.)	$0.100	$0.150	$0.200
Distribution ($/Kg.)	$0.010	$0.020	$0.030
Transportation ($/Kg.)	$0.040	$0.041	$0.041
Total Wholesale Costs ($/Kg.))	$0.150	$0.211	$0.271
TOTAL Wholesale Marketing Costs ($)	$0	$0	$0
TOTAL LETTUCE Marketing Costs ($)	$0	$0	$0
Total Marketing & Distributions Costs	$1,061	$1,446	$1,886

ENTERPRISE BUDGET

Total Greenhouse Area (Square Meters)	151					
Enterprise Budgets for Northern Greenhouse	Low		Mid Point		High	
Sales Revenues (A)	**Total $**	**$/M^2**	**Total $**	**$/M^2**	**Total $**	**$/M^2**
Tomatoes	$5,839	$38.68	$12,928	$85.64	$21,943	$145.35
Cucumbers	$3,028	$20.06	$6,153	$40.76	$8,007	$53.04
Peppers	$0	$0.00	$0	$0.00	$0	$0.00
Other Crops	$0	$0.00	$0	$0.00	$0	$0.00
Total Sales Revenues	**$8,867**	**$58.74**	**$19,082**	**$126.40**	**$29,950**	**$198.39**
Variable Operating Costs (B)	**Total $**	**$/M^2**	**Total $**	**$/M^2**	**Total $**	**$/M^2**
Growing Costs	$481	$3.19	$645	$4.28	$832	$5.51
Energy Costs	$408	$2.70	$910	$6.03	$1,585	$10.50
Labour costs	$0	$0.00	$0	$0.00	$0	$0.00
Marketing and Distribution Costs	$1,061	$7.03	$1,446	$9.58	$1,886	$12.50
Repair Costs (Building & Equipment)	$7,592	$50.29	$9,167	$60.72	$11,954	$79.19
Vehicle Expenses (*Not included in Marketing costs*)	$75	$0.50	$189	$1.25	$302	$2.00
Small Tools/Hardware/Supplies	$151	$1.00	$226	$1.50	$302	$2.00
Freight Costs (*Not included in marketing or growing costs*)	$75	$0.50	$113	$0.75	$151	$1.00
Custom Work	$75	$0.50	$151	$1.00	$226	$1.50
Operating Interest, Bank Charges	$151	$1.00	$302	$2.00	$453	$3.00
Dues, Fees, Promotion, Donation	$75	$0.50	$113	$0.75	$151	$1.00
Misc. Expenses	$151	$1.00	$226	$1.50	$302	$2.00
Total Variable Operating costs	$10,297	$68.21	$13,489	$89.35	$18,145	$120.19
Gross Margin (A-B)	-$1,430		$5,593		$11,806	
Fixed Operating Costs (C)						
1. Depreciation	$9,382	$62.15	$11,779	$78.02	$14,383	$95.27
2. Interest on Capital	$4,096	$27.13	$5,109	$33.84	$6,577	$43.57
3. Taxes & Insurance	$7,466	$49.45	$8,975	$6.00	$11,684	$77.40
5. Salaries	$0	$0.00	$0	$0.00	$0	$0.00
Total Fixed Operating Costs	$20,944	$138.73	$25,863	$117.86	$32,645	$216.24
(D) Total Operating Costs	$31,241	$206.94	$39,352	$260.66	$50,789	$336.43
(E) Net Returns (A-E)	**-$22,374**		**-$20,270**		**-$20,839**	
(F) Net Cash Income (E+C1+C2)	**-$8,896**		**-$3,382**		**$121**	
% ROA (Allow $5,000 for labour & management)	-17.66%		-12.26%		-9.78%	
Total Operating Costs with 50% Subsidization of Total Capital	$24,502		$30,908		$40,309	
Net Returns when 50% of Total Capital are Subsidized	-$15,635		-$11,826		-$10,359	
% ROA When 50% of Total Capital Costs Subsidized	-14.10%		-8.68%		-6.13%	

APPENDIX H: REFERENCES

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APPENDIX I: LIST OF PERSONS CONSULTED

Northern Communities
Terry Favell, Economic Development Officer, Chief and Council Members, Wabigoon Lake Ojibway Nation
Chief and Council Members, Wabigoon Lake Ojibway Nation
Enus Mckay, Jack Mckay, Councillors, Big Trout Lake First Nation
Billy Albany, Market Gardener and Owner Operator of Rubina's Store, Big Trout Lake Ontario
Arlene Wawia, Chief, Red Rock Indian Band
Bonnie Aubichon, Manager, Ecconomic Development Corporation, Buffalo Narrows, Saskatchewan
Dawn Charlie, Carmacks Community Greenhouse, Carmacks, Saskatchewan
Leo Gardiner, CEO, EDC
Mary Bea Kenny, Environment Advisor, IFNA(Independent First Nations Alliance) Technical Services, Thunder Bay, Ontario
Evelyn McKay, First Nations Food Nutrition Environment Study, Kitchenuh-maykoosib Inninuwug, Ontario
Vince Natomagan,Town Councillor, Pinehouse, Saskatchewan
Mandy Perkles, Economic Development Officer, Red Rock First Nation, Ontario
Michael Riseborough, Town Reeve, Haines Junction, Yukon
Ray Wells, Biomass Consultant, Haines Junction, Yukon
Al Felix, Birch Narrows EDC, Birch Narrows Saskatchewan

Academic and Technical Experts
Tom Allen, Department of Bio-resource Policy, Business & Economics, University of Saskatchewan.
Dr. Connie Nelson, Director, Food Security Research Network Lakehead University
Stephen Mooney, Instructor, Yukon College
Emmanuel Laate, Senior Crop Economist, Economics Branch Alberta Agriculture and Rural Development
Robert Spencer, Commercial Horticulture Specialist Alberta Agriculture and Rural Development
Leo Hunnakko, Greenhouse 365
Dr. Shalin Khosla, Greenhouse Vegetable Crop Advisor, Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA), Harrow, Ontario
Dr. Xiuming Hao, Research Scientist, GPCRC, AAFC, Harrow, Ontario
Gene Hachey, Agriculture, Agri-foods and Commercial Wildlife Development Consultant, Northwest Territories Department of Industry Tourism and Investment
Matthew Ball, Agronomist, Ykon Department of Agriculture
Mike Dixon, Professor, University of Guelph
Dr. Timo Kaukoranta, Senior research scientist, MTT Agrifood Research FinlandJokioinen, Finland
Connie Nelson, Director, Lakehead Food Security Research Network, Lakehead University, Ontario
Dr. Hans Gislerod, Greenhouse Crop Specialist, Agricultural University of Norway
Dr. Andre Gosselin, Professor, Greenhouse Crop Specialist, Universite Laval, Quebec City, QC
Quebec City, Quebec
Gillian Ferguson, Greenhouse Vegetable Pest Control Specialist, OMAFRA, Harrow ON
Dr. Les Shipp, Entomologist, GPCRC/AAFC, Harrow, ON
Dr. John Zhang, Greenhouse Vegetable Specialist, AARD
Prof. Meriam Karlsson, Greenhouse Crop Specialist, University of Alaska-Fairbanks
Prof. Doug Waterer, Vegetable Crop Specialist, University of Saskatchewan

Sangita Sharma, Professor, Faculty of Medicine, Endocrinology, Centenial Professor in Aboriginal and Global Health, University of Alberta
Glen Sweetman, Provincial Specialist, Greenhouse & Nursery Crops, Ministry of Agriculture
Regina, Saskatcheean
Peter Sigurdson, Provincial Leader, Saskatchewan and Manitoba, FPInnovations, Prince Albert, Saskatchewan
John Doornbos, Canada Forestry Service, Edmonton, AB
Prof.Qiang Zhang, Ph.D., P.Eng. Department of Biosystems Engineering, U of Manitoba, Winnipeg, MB
Fernando Preto, National Research Council, Ottawa, ON

Input Suppliers
Bruno Faucher, Greenhouse Engineer, Capital Greenhouse, Thetford Mines QC
Mark Glawdecki, NewLux Modern Horticultural Lighting, Vancouver BC
Peter Berkhout, Managing Director, Kavita Canada Inc
Edwin de Gier, Prins Greenhouses
Dalsem Horticultural Projects BV
Dan De Cloet, DeCloet Greenhouse Manufacturing Ltd., Simcoe, ON
Alain Gendron, Sales Representative, Les Industries Harnois Inc.
Eric Labbate, President, Climate Control Systems Inc.
Garn Wood Heating
American Tank Company
Clarence Waldner, General Manager Fabworks Inc.,
Decker Brand Boilers. Decker, MB.
Gord Bullen, Advanced Wood Heat. Blind Bay, BC.
Dennis St. George, M.Sc., P.Eng., Senior Biosystems Engineer, Manitoba Hydro
All Power Labs Inc.
Chinook Energy Inc.
Plasco Energy Group / Zero Waste Ottawa
Waste to Energy Canada.
Vitale Energi Company
WTEC Waste to Energy Canada
Enerworks Inc.
Apricus Inc.
American Tank Company

Growers
Brad Friesen, VP of Operations, Dunvegan Gardens, Fort McMurray Alberta
Grant Dowdell and Karen Digby, Greenhouse Owner Operators, Dawson City, Yukon.
Rivendell Farm, Whitehorse, Yuko
Bluebell Garden, Whitehorse, Yukon
Brewster's Greenhouse, Prince Albert, Saskatchewan
Floating Garden Greenhouse, Osler Saskatchewan
Peter Quiring, President, South Essex Fabricating Inc., Leamington, Ontario
Mr. Nick Ingratta, greenhouse vegetable producer, Leamington, Ontario
Mr. Bradley Friesen, Greenhouse grower, Fort McMurray, Alberta

Market Data
Tim Ross, General Manager, Arctic Region, The Northwest Company
Leo B. Doyle, Director, Nutrition North Canada, AANDC
Dominic Demers, Manager, Nutrition North Canada, AANDC
Vitaly Galulin, Director, Camp Services, ATCO Structures and Logistics, Calgary, AB

Other
Arik Theijsmeijer, Economic Development Officer, FedNor
gck Consulting Ltd, Thunder Bay Ontario,
Alia Lamaadar, Northern Cleantech Gateway, Vancouver BC
Al Scott, Project Manager, Comdev
Wendy Trylinski, Manager, Public Heath Education, Nishnawbe Aski Nation , Thunderbay, Ontario