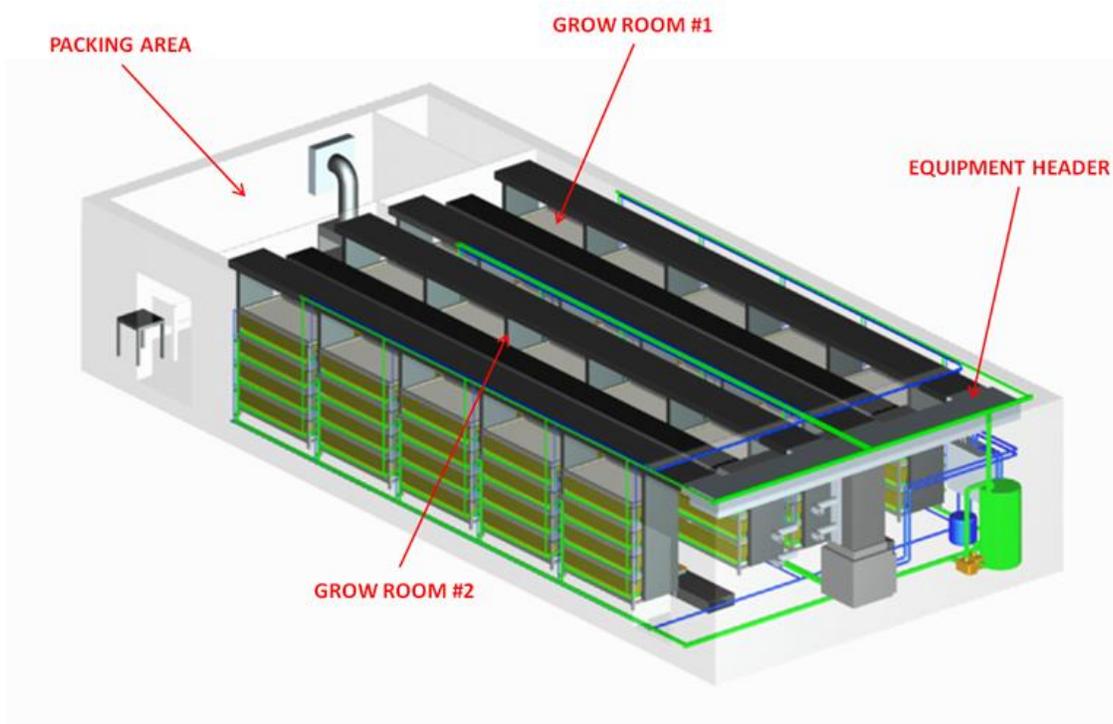


AgNorth Modular Farm Concept

Market Study and Technical Design



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EXECUTIVE SUMMARY

Food security in Canada's north has been identified by all levels of government, and the public at large, as a challenge that needs to be addressed. Fresh produce consumed in the Northwest Territories (NWT) comes from farms as far south as Columbia in the winter months, taking an average of 10 days to make it from the field to Yellowknife, where it is then further distributed around the territory. These distances and travel times significantly inflate costs and reduce quality of produce in NWT communities.

Compounded with the lack of access to quality produce is the fact that aboriginal populations in the NWT have decreased their consumption of traditional food and increased reliance on store-bought foods that tend to be nutrient-poor and energy-rich. Access to quality produce could help improve diet and reduce the prevalence of diet-related chronic diseases such as type II diabetes, heart and circulatory disorders and cancers.

AgNorth is a scalable, modular farm system, that uses highly efficient light emitting diode (LED) lighting and hydroponics technologies to grow high-value, nutritious fruit and vegetable crops. The concept of a modular food production system is based on technology transfer from an ongoing research program in advanced life support systems led by COM DEV Canada and the University of Guelph in collaboration with the Canadian Space Agency and NSERC.

The purpose of this report is to evaluate whether AgNorth is a feasible option for growing nutritious fruits and vegetables to address the NWT's food security needs.

A review of available academic and market information suggests that, per-capita, NWT residents purchase between 130 and 190 kg of fresh fruits and vegetables annually, depending on their location, availability of produce, income level and retail price levels. This is somewhat lower than the Canadian per-capita average consumption of about 213 kg. For the entire NWT, it is estimated that about 8.0 million kg of fresh produce is sold each year, with an estimated retail market value of about \$17.0 million (in current dollars). Most of the produce consumed in the NWT is shipped in from Canadian, American and Mexican farms.

Most of the technologies used in the AgNorth modular farm are identical to those commonly used in Canada's conventional greenhouse industry. The exception is the use of high efficiency computer-controlled LED arrays that allow the operator to grow food year round in a high density multi-layer facility.

Key inputs associated with an AgNorth modular farm facility include:

- a source of uncontaminated irrigation/cleaning water that must be free of pathogens;
- a source of soluble mineral nutrients, acid, and base;
- a source of CO₂ for enhanced growth efficiency (liquid CO₂ preferred);
- a source of reliable electrical power;
- a source of seeds;
- a source of packaging materials; and,
- a source of organic growth media or rockwool (as determined by crop requirements)

Key outputs from an AgNorth modular farm facility would include:

- packaged produce (fruits and vegetables);
- plant inedible biomass (could be used for high quality organic compost);

- 'grey' waste water from cleaning and irrigation; and,
- recovered heat energy from the lights available for redistribution.

The first step in assessing the productivity and economic viability of the AgNorth concept, was to identify nutritious, high-value crops that could be grown efficiently in a multi-tiered growing facility, were commonly consumed throughout the NWT and are being imported to the NWT from foreign markets. Commodities that satisfied these conditions included romaine and other leaf lettuces, red and green peppers, cherry tomatoes, spinach, green onions, strawberries and leafy herbs (e.g., cilantro, basil).

A productivity model was produced to estimate the operating costs required to produce various commodities. A number of different options were considered as well as forecasted improvements in high efficiency LED technology. Key findings from the modeling work indicated that the size of the facility, the specific crops grown, and the cost of power were all significant drivers in determining the total cost of operating an AgNorth facility.

While the cost of production is obviously a critical factor in determining where an AgNorth facility might be located, an equally important consideration is the location and needs of the customers that would potentially purchase fresh produce from an AgNorth facility. Potential wholesale customers for AgNorth produce include Northern Stores (with 18 retail stores in the NWT), the Yellowknife Co-op (the other 7 Arctic Co-op stores in the NWT are served directly by air from Edmonton), Northern Food Services (which supplies hotels, restaurants, caterers, schools, health care facilities, stores etc.) and Bouwa Whee Catering (which serves mine sites) – all of which operate from Yellowknife.

Several different scenarios were examined to develop a better understanding of how factors such as the scale of operation, the location of the facility (i.e. community) and the ability to access / serve key customers might impact on the economic viability of the AgNorth concept.

The first scenario (Yellowknife A) examined the possibility of setting up an AgNorth facility in Yellowknife. The advantages included easy access to many wholesale produce customers and access to key inputs. The facility was sized to 40% of the wholesale market for 5 crops: cherry tomatoes, romaine lettuce, red peppers, herbs and strawberries. This would generate annual produce sales of approximately \$1.0 million. The specific building requirements needed (envelope, airtightness, power etc.) and the systems needed were used to derive an estimated capital budget of about \$9.3 million to construct the facility. An annual operating budget was estimated to be \$956,000. Of this, power costs (65%) and labour costs (17%) were the two largest expense items.

Given the high cost of power, a second Yellowknife scenario (Yellowknife B) was examined in which a conventional greenhouse is added to the AgNorth facility to allow for sunshine to replace the use of LED lights for at least 6 months of the year. This hybrid option would add at least \$1.0 million to the capital budget but would reduce the estimated annual operating costs by about \$200,000 / year due to reduced power consumption. Several potential options were noted that could help improve the economic viability of the AgNorth concept, however, further discussions with other stakeholders and further investigations will be needed to assess these options.

The next scenario that was investigated involved the establishment of a smaller AgNorth facility, located in either Fort Smith or Hay River, to serve the South Slave region. The idea was to determine whether the economic viability might improve with access to cheaper power rates (compared to Yellowknife), even though the scale of operation would be reduced. For analytical purposes, it was assumed that a regional facility would serve about 8,000 people which would result in annual produce sales revenue of \$500,000. At this scale of operation, the annual operating costs for a facility located in Hay River were

estimated to be about \$615,000, which would result in an operating loss. Locating the regional facility in Fort Smith, where power is cheaper would result in breakeven scenario. While this has not yet been discussed with the power utilities, negotiation for an agricultural power rate in this region could result in profits of \$100,000 per year.

From a technical perspective, the AgNorth system is modular in design and can be scaled up or down to fit a particular market. While a very small growing facility could technically be established to serve a single community, the project team found that the operational and economic realities made it an unlikely option at this time. The technical complexity of the facility requires access to skilled tradespeople and an experienced horticulturalist, which are not typically available, on demand, in the smaller communities. In addition, the high power demand would cause problems on an isolated diesel-electric grid and be prohibitively expensive at diesel power rates.

Overall, the Yellowknife and regional scenarios were considered worthy of further investigation and refinement. For either scenario, it is clear that additional revenues, either from retail produce sales and/or sales of by-products (excess heat, organic waste materials), and access to cheaper power are the two main avenues to pursue to potentially improve the economic viability of the AgNorth concept.

The last section of the report outlines the technical tasks necessary to move this technology forward in an economically feasible way. A key activity in this regard is the development of a prototype AgNorth facility at the University of Guelph, currently underway, which will improve performance and reduce technical risks. Lessons learned will be incorporated in the design of a NWT pilot project.

In terms of next steps, the AgNorth team have, through its work on this phase of the project, identified a number of potential northern stakeholders and partners that may be interested in participating in the development of a pilot AgNorth facility and eventually a commercial enterprise. While the technical work proceeds at the University of Guelph, the AgNorth team is proposing to hold engagement meetings with stakeholders (i.e. local growers, wholesalers, aboriginal governments and businesses, utilities, alternative energy suppliers, government agencies etc.) to present the findings in this report and explore possibilities. Once a critical mass of potential partners has been realized, a stakeholder workshop, to be held in Yellowknife, is proposed to build a vision for the AgNorth pilot project.

The AgNorth team has developed a set of objectives for an AgNorth pilot project that would grow a single crop to satisfy the consumption needs of about 3500 people. The facility would have a footprint of 24 x 57 foot, requiring 60 kW and could be completed within a \$2.0 million capital budget.

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1 INTRODUCTION

Food security in Canada's north has been identified by all levels of government, and the public at large, as a challenge that needs to be addressed. Fresh produce consumed in the Northwest Territories (NWT) comes from farms as far south as Columbia in the winter months, taking an average of 10 days to make it from the field to Yellowknife, where it is then further distributed around the territory. These distances and travel times significantly inflate costs and reduce quality of produce in NWT communities.

Compounded with the lack of access to quality produce is the fact that aboriginal populations in the NWT are experiencing a nutrition transition characterized by decreased consumption of traditional food and increased reliance on store-bought foods that tend to be nutrient-poor and energy-rich. Access to quality produce could help improve diet and reduce the prevalence of diet-related chronic diseases such as type II diabetes, heart and circulatory disorders and cancers.

AgNorth is a scalable, modular farm system based on controlled environment food production systems developed for human space exploration. It is being developed through technology transfer from an ongoing research program led by COM DEV Canada and the University of Guelph in collaboration with the Canadian Space Agency (CSA) and NSERC. It uses highly efficient spectrally tuned light emitting diode (LED) lighting, hydroponics and emerging sensor technologies to grow high-value, nutritious fruit and vegetable crops. It will be one of the most volume- and energy-efficient food production systems in the world.

The purpose of this report is to evaluate whether AgNorth is a feasible option for addressing the NWT's food security needs and if it could be deployed in a northern location to grow high-value, nutritious fruit and vegetable crops, either on a year-round basis or when local gardens and greenhouses are not in production (i.e. September to April).

From an economic perspective, the NWT market for fresh produce (fruits and vegetables) is estimated to be about \$17 million per year. Given the fact that most of the NWT's annual produce requirements are shipped in from the south, most of this money leaves the NWT economy. If the NWT could grow more of its annual produce requirements locally, some of the annual expenditures on produce would be retained in the NWT economy, thereby providing economic opportunities for NWT businesses and employment opportunities for NWT residents.

If this approach proves to be both technically and economically viable in a northern location, it has the potential to provide fresh produce to northern communities throughout the winter months, thereby improving the quality and shelf life of perishable produce in northern stores. In turn, the availability of higher quality produce should enable customers in remote communities to increase their consumption of fresh produce which will help improve overall nutrition and address associated health concerns.

1.1 Objectives & Principles

The purpose of this study was to identify a sustainable business model for operation of modular food production systems in northern communities.

The specific objectives of this report are to:

- Provide an accurate estimate of the demand for fresh vegetables in the NWT that could be addressed with this project, and associated pricing information, both wholesale and retail;
- Provide a list of target crops that can be grown based on available information on the dietary needs of northern residents;

- Design a pilot demonstration facility for a NWT community, compatible with Canadian and NWT food safety regulations, along with estimates of power consumption and other resource requirements (water, nutrients, hardware, etc.);
- Provide an accurate cost estimate to build and operate the pilot facility;
- Provide projections of productivity from the resulting facility;
- Perform a site assessment of target communities including available infrastructure (i.e., energy, labour, etc.);
- Perform a trade study for alternative energy supply, focusing on feasibility of bio-gas from plant waste and other local sources; and,
- Develop a business model including an assessment of production scale, crop selection and marketing model (wholesale vs. community cooperative retail).

In undertaking this study, the project team was also cognizant that any consideration of the “public good” generally includes economic, environmental and social factors, all of which are important to the overall well-being of NWT residents.

As such, the project team relied on the following principles to help guide its efforts while conducting this study:

- Focus on identifying nutritious, highly perishable fruits and vegetables that are routinely imported from foreign suppliers (i.e. not produced in Canada or the NWT) and are difficult for NWT consumers to acquire (i.e. either very expensive or hard to get);
- Maximize potential northern economic benefits by not competing with, or impacting on, any existing NWT agricultural initiatives, such as farms, greenhouses, community gardens etc.;
- Minimize any potential environmental impacts by carefully considering all relevant options such as power supply alternatives and management of grey water and organic waste outputs; and,
- Help NWT residents improve their general health and well-being by providing better access to fresh, high-quality produce at reasonable prices.

1.2 Project Team

The Aurora Research Institute led the project team. A brief description of the team members is provided below:

Aurora Research Institute (ARI) is the research division of Aurora College, charged with administering the NWT Scientists Act. ARI licences research taking place in the NWT and facilitates research undertaken by northern, national and international researchers.

ARI’s mandate is to improve the quality of life for NWT residents by applying scientific, technological and indigenous knowledge to solve northern problems and advance social and economic goals.

COM DEV International Ltd. (COM DEV) is a Canadian-based publicly traded (TSX:CDV) global designer and manufacturer of space hardware. COM DEV is a world leader in the production of space-qualified passive microwave equipment, specialized electronics and optical subsystems and has over 1,100 employees at facilities in Canada, the United Kingdom and the United States.

COM DEV's core capability is engineering of complex systems for harsh environments. They understand the unique challenges inherent in producing equipment for use in space and regularly apply the expertise acquired through more than three decades in the aerospace industry to the development of new and innovative space technologies. Their disciplined manufacturing and quality control processes ensure that they can meet the high standards of quality, reliability, timeliness and cost efficiency that their customers demand.

University of Guelph Controlled Environment Systems Research Facility (CESRF) is the world leader in controlled environment agriculture, providing horticultural growth chambers and consulting on advanced life support programs to international space agencies (NASA, ESA, Roscosmos). Led by Professor Mike Dixon, CESRF provides a strong heritage in greenhouse systems, advanced life support, and horticulture, along with 10 years of experience in operating an autonomous greenhouse in the high Arctic on Devon Island. CESRF's ongoing collaborative research program, Innovative Technologies In Challenging Environments (InTICE) is co-sponsored by COM DEV, the Canadian Space Agency and NSERC.



Medina Quality Assurance works with food producers, airlines and large-scale food buyers (i.e., supermarkets, hospitality industry and retail stores) to develop, manage and certify effective and cost efficient food safety and quality assurance programmes and management systems. Medina Quality's team of dedicated and professional scientists and food service experts are committed to providing up to date scientific and regulatory knowledge to help food companies determine the goals of a food safety or quality assurance programme (i.e., HACCP, regulatory or international compliances, GMPs).

Arctic Energy Alliance (AEA) is a not-for-profit organization headquartered in Yellowknife NT, with satellite offices in Norman Wells, Inuvik, Fort Simpson and Whati. The AEA has been involved in northern energy issues and technologies for fifteen years and has a staff of 18, four of which are accomplished engineers with significant northern experience in the alternative and renewable energy sectors.

Dr. Sangita Sharma of the University of Alberta is an expert on northern community nutrition. She is the endowed chair of Aboriginal Health and Professor of Aboriginal and Global Health Research. Dr. Sharma provides a wealth of experience on northern nutrition from her well-known Healthy Foods North program.

R. Marshall & Associates is a consulting firm located in Yellowknife. Rob Marshall is a long-term Yellowknife resident who has been involved in numerous energy, environmental and management projects in the NWT for a range of government, private sector and community-based clients.

2 BACKGROUND

This section provides background information on northern nutrition, NWT food security issues and initiatives and a snapshot of the NWT agriculture sector.

2.1 Northern Diet and Health

Traditional aboriginal foods can vary by geography, seasonality and cultural group but typically a diet comprised of traditional foods is high in animal protein, nutrient-rich and low in fat (or high in marine sources of fat). Given the physical demands of hunting, fishing, trapping and gathering, a significant amount of energy is spent in obtaining traditional foods which also contributes to overall health and well-being.

With the early settlement of communities in the NWT, local food production of vegetables, poultry, meat and milk occurred, often involving European settlers, the Hudson's Bay or Catholic or Anglican missionaries. As transportation systems evolved and became more reliable and cash economies emerged, local food production and traditional harvesting practices declined in favour of imported foods. As a result of an increased reliance on imported, store-bought products, aboriginal diets now tend to be much higher in fat and sugar and lower in nutrition due to consumption of processed and "junk" food.

Information on annual consumption of fresh fruits and vegetables by NWT residents is discussed in Section 3.1 below.

2.2 NWT Agriculture Sector

With a total land mass of approximately 1.17 million square kilometers and a population of only 43,500 people, the NWT has vast tracts of undeveloped land. Some land surveys assessing the agricultural value of land have been completed and indicate that the NWT has a substantial amount of arable land (at least 2 million hectares) suitable for agricultural production (ITI, 2005).

At present, there is very limited grain or livestock production. There are some small farms producing fruits and vegetable crops but the scale of operations is quite limited as shown in Table 2-1 below:

Table 2-1: Overview on NWT Farming

Census of Agriculture, NWT	2001	2011
Number of Farms Reporting	30	29
Total Area	612	n/a
Farms Reporting Land in Crops	18	14
Farms Producing Fruits	6	7
Farms Producing Vegetables	10	5

Source: Statistics Canada

Due to confidentiality concerns, Statistics Canada only reports limited information on agricultural production in the territories.

In 2006, the Territorial Farmers Association commissioned a study of the economic potential of NWT agricultural production (see Serecon, 2006). As part of the study methodology, Serecon conducted interviews with as many NWT farm producers as possible to augment the data available from Statistics Canada. While the Serecon report is now somewhat dated, it provides a good foundation for understanding the economic potential and challenges associated with an expansion of agricultural production in the NWT.

Key findings from the Serecon report are as follows:

1. Estimated NWT Fresh Produce Production

- In 2001, 10 farms reported (based on the 2001 Census of Agriculture) having a total of 30 acres in vegetable production. 17 acres were for potatoes and 13 acres were for other vegetables:
- In 2006, interviews of farm producers indicated that 3.6 acres were in potatoes and another 2.6 acres were producing peas, beans, carrots and turnips. The estimated volumes were 13,000 lbs for potatoes, 290 lbs for peas, 210 lbs for beans and 1,000 lbs for carrots;
- In 2001, farms reported having about 11 acres of fruit and berries in production, with 1 acre in apples, 2 acres in strawberries, 3 acres in raspberries, 4 acres in saskatoons and 1 acre in other fruits and berries. No information on production volumes was provided;
- In 2001, a total area of 21,928 square feet was reported for greenhouse production, including 7,128 sq. ft. for vegetables. In 2006, Serecon interview results indicated there was about 25,612 sq. ft. under glass or plastic, with an estimated 4,910 sq. ft. producing tomatoes and 3,125 sq. ft. producing cucumbers

2. Market Conditions

- Factors cited in favour of development of agriculture in the NWT included:
 - There is lots of land that is adequate for agriculture;
 - There is a strong demand for fresh produce;
 - Fresh produce is expensive; and,
 - Long hours of daylight in the summer facilitate agricultural production.
- Challenges identified that constrain the development of agriculture in the NWT included:
 - Difficulty in accessing land for agriculture, particularly outside of municipal boundaries;
 - No government policy supporting agriculture;
 - A lack of suppliers in the NWT of inputs and equipment;
 - High prices for electricity, water and natural gas (depending on location);
 - The vertical integration of northern stores with suppliers in the south; and,
 - The need to provide a steady and reliable supply (preferably year round) in order to sell to stores in the north.

2.3 NWT Food Security Programs and Initiatives

Following are brief summaries of current government programs and initiatives aimed at addressing nutrition and food security in northern and NWT communities:

Nutrition North Canada

Introduced in 2010 as a replacement for the previous Food Mail Program, Nutrition North Canada is a Government of Canada program that provides a subsidy to retailers and suppliers to help lower the cost of perishable healthy food in isolated northern communities.

To be eligible for the program, a community must lack year-round surface transportation (i.e. no permanent road, rail or marine access) and have used the previous Food Mail Program. The program subsidizes a variety of perishable healthy foods including fresh, frozen or refrigerated items or products with a shelf life of less than one year. To obtain the subsidy, a retailer or supplier must apply to register with the program. Registered businesses are accountable for passing on the subsidy to consumers.

The NWT communities that receive a full subsidy from the program are shown in Table 2-2 below. The Level 1 subsidy rates apply to the most nutritious perishable foods. The Level 2 subsidy rates apply to other perishable foods, non-perishable foods and other non-food items.

Table 2-2: NWT Communities in the Nutrition North Canada Program (in 2011-2012)

NWT Communities Receiving a Full Subsidy	Subsidy Rates (\$/kg)	
	Level 1 (High)	Level 2 (Low)
Aklavik	\$1.60	\$0.05
Paulatuk	\$3.80	\$2.00
Sachs Harbour	\$6.10	\$4.30
Tuktoyaktuk	\$2.50	\$0.70
Ulukhaktok	\$4.50	\$2.70
Trout Lake	\$3.20	\$1.40
Colville Lake	\$5.20	\$3.40
Deline	\$2.70	\$0.90
Fort Good Hope	\$2.90	\$1.10
Norman Wells	\$2.20	\$0.40
Tulita	\$2.70	\$0.90

Note: Gameti, Lutsel K'e and Whati receive a partial subsidy of \$0.05/kg.

Sustainable Northern Greenhouse Technologies (SNGT) Study

In 2012, the federal Department of Agriculture and AgriFood Canada (AAFC) and partners initiated a study to better understand the feasibility of greenhouse technologies, and the related economics, for supporting investments in the development of sustainable northern greenhouses.

A Working Group, comprising AAFC, other federal partners, Canadian universities and other stakeholders was created to help oversee this work. University of Guelph's CESRF was a member of this group.

The SNGT Study has not yet been finished. The results from this work may provide valuable information which could help shape the future direction and focus for the AgNorth project.

Community Garden Initiative

Introduced in 2006 and funded through the Canada/NWT Growing Forward Initiative, the Community Garden Initiative is a local community-based food production program managed by the Department of Industry, Tourism and Investment (ITI).

The program provides support, training and basic infrastructure and works with community residents to design, establish and expand local food production systems for their benefit. As of summer 2011, all but the three most northerly communities had begun some form of local food production system such as a community garden or private gardens. The produce that is commonly grown includes beets, broccoli, brussel sprouts, cabbage, carrots, cauliflower, peas, potatoes, tomatoes, lettuce and turnips.

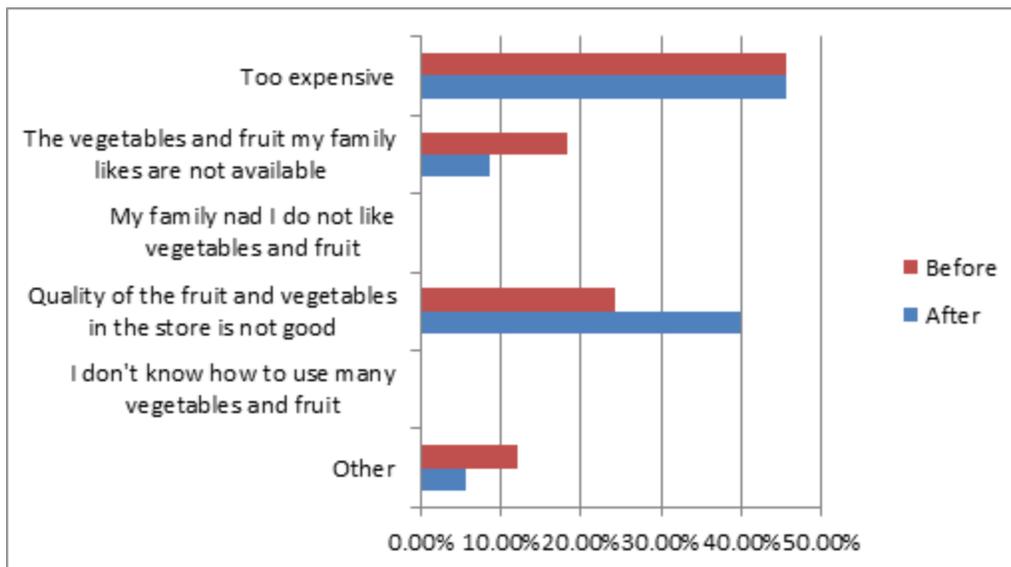
Over time, some communities have moved up to larger, established sites or incorporated greenhouses. For example, the Inuvik community greenhouse (which was independently created in 1999) now consists of 74 individual plots and a 4,000 sq. ft. commercial greenhouse.

Healthy Family Collective Kitchen Cooking Classes program

The Healthy Family Collective Kitchen Cooking Classes program is run through the GNWT Department of Health and Social Services. The Healthy Family Program in the NWT is a voluntary home-visiting program for parents and currently runs in a few communities. The goal of the Healthy Family Collective Kitchen Cooking Classes project (which was piloted in 2012/2013) is:

Families who participate in the Healthy Family program will eat more fruits and vegetables daily, will eat a larger variety of fruit and vegetables, will understand the importance of including fruit and vegetables in their diets and will feel more comfortable preparing and cooking vegetables.

Figure 2-1: Results from survey of participants before and after program



NWT Food Network

In March 2013, Ecology North (with funding from the GNWT Department of Health and Social Services) brought together 42 people with an interest in establishing an NWT Food Network. The meeting was intended to accomplish five objectives:

- Create a vision for a NWT Food Network;
- Share information on food networking in Manitoba;
- Receive information from the UN Special Rapporteur on the right to food;
- Develop Terms of Reference for the NWT Food Network; and,
- Identify priorities for the NWT Food Network.

The participants made progress on all the stated objectives, including the development of draft Terms of Reference for the NWT Food Network and the identification of priority action items to follow up on.

2.4 Context for AgNorth Project

Collectively, the information presented in this section provides the following context for the consideration of the AgNorth concept:

- There is a definite need for access to fresh produce in the NWT on a year round basis;
- The existing production activities (farms, greenhouses, gardens) in the NWT face significant obstacles (climate, access to land, costs) in achieving the scale of operations needed to supply the NWT's fresh produce requirements; and,
- Technology advancements in LED lighting may support the deployment of in-situ, modular farm systems for the local production of fresh produce in the north.

3 NWT PRODUCE MARKET

This section includes a review of information regarding the NWT produce market including academic research, a market study by Serecon (2006), Statistics Canada, and direct contact with wholesalers and retailers. These sources of data are reviewed in Section 3.1

In reviewing the information available, the project team focused on trying to answer the following questions in order to understand which produce items a modular farm should grow (i.e. that would be economically viable, would help improve northern nutrition and reduce food insecurity).

- What are the total quantities of fruits and vegetables products consumed in the NWT per year?
- How much does a typical individual or family in the NWT consume and spend on fresh produce per year?
- What are the most commonly consumed fruits and vegetables? And how much are these worth?

An analysis of the information available regarding NWT demand for fresh produce is provided in Section 3.2 and market value is assessed in Section 3.3. Information on how the NWT market for produce is supplied is summarized in Section 3.4 and the potential market for AgNorth is discussed in Section 3.5.

3.1 Data Sources

Data from several sources were used to evaluate market demand and value of fresh produce consumed in the NWT. A review of these sources is provided below. It should be noted that it was difficult to reconcile some of this information as it was produced for various purposes using different methodologies and/or time periods.

NWT Stores

An estimate of the amount of produce purchased for NWT stores was calculated based on 2012 data from Northern stores, and estimates from Extra Foods and Co-op stores based on a subset of ten commodities over a one month period. The non-store trucking data is based on annual volume estimates supplied by major non-store trucking companies (SYSCO, Gordon, Northern Food Services - NFS), and scaled to each commodity by an average of complete data sources for NWT (Northern, NFS). The trucking data also overstates consumption by including produce spoiled in transit. Estimates from wholesalers indicate that 5-25% of food spoils or is wasted before reaching the consumer. Due to confidentiality requirements, the annual volumes of produce handled by individual wholesalers cannot be released. Interestingly, produce volumes for Yellowknife stores appear to be roughly equal to the total volume of non-Yellowknife stores.

Statistics Canada

Two Statistics Canada publications were used to evaluate market demand. Publication 82-229 examines the frequency (not the quantity) of fruit and vegetables consumption by Canadians aged 12 years or older. Specifically, eating at least five servings of fruits and vegetables per day is considered to be a reasonable proxy for good eating habits. For 2008, 44% of the age-standardized population in Canada reported eating fruits and vegetables 5 or more times per day. By contrast, in the NWT and Nunavut only 21% and 22% respectively of the population (over 12 years old) reported meeting this criterion. Publication 21-020 provides proxy measures of Canadian per-capita produce consumption before and

after adjusting for losses, such as waste and/or spoilage in stores, households, institutions, restaurants etc. This information is available in Appendix B.

Serecon Study

In 2006, the Territorial Farmers Association commissioned a study of the economic potential of NWT agricultural production (see Serecon, 2006). As part of this study, estimates of NWT market volumes were provided. These numbers were derived from Statistics Canada countrywide average data in 2006.

Aboriginal and Global Health Research Group

An academic study undertaken in 2008 (see Aboriginal and Global Health Research Group, 2013) surveyed 230 aboriginal adults from three Beaufort-Delta communities about their consumption and spending on fresh, frozen and processed fruit and vegetable products. This study provides some confirmation that aboriginal people in the NWT (at least in Beaufort-Delta communities which are at the end of the produce distribution channels) may not be spending as much, or consuming as much, fresh produce per year as other consumer groups in the NWT. It shows that some fresh fruit and vegetables are available locally but consumption of canned and frozen vegetables appears to be more prevalent. It also shows that the average (mean) consumption and spending on produce is significantly higher than the “middle point” (median), suggesting that a minority of the sample group has high intake (which skews the average) while the majority of the group has low intake. Data from this study is available in Appendix B.

Remote Camps and Mine Sites

At present, there are about 15-20 active exploration camps and 4 active mining operations. Data on wholesale food supply cost and volumes was provided by Bouwa Whee Catering, a mine site logistics provider owned by Det'on Cho Development Corporation and from an independent supplier who asked not to be identified in this report. To estimate the annual consumption of fresh produce at the mine sites and camps, the wholesale volume data provided to us (which represents more than 50% of the current market) was scaled to the total population at the active mine sites and camps which is estimated to be about 4,000 people (Snap Lake = 635, Ekati = 1,528, Diavik = 1,137, CanTung = 204¹, camps ~500). Of these, only CanTung is expected to run out of projected ore reserves in the next five years. Looking forward, there are currently seven significant mineral projects in various stages of development in the NWT. These include projects proposing to rare earth metals, cobalt, silver, bismuth, nickel, zinc, gold and mine diamonds. Six of these are expected to start operations in 2015-16, and one in 2016-17 for a total of 1,777 additional mine site workers, or roughly a 50% increase over the current market.

¹ NWT Mineral Discussion Strategy Discussion Paper, 2013 (ITI 4346)

3.2 Market Demand

Unfortunately, there is not a lot of detailed or publically available information on how much fresh produce is consumed in the NWT or how this consumption breaks down by community or between aboriginal / non-aboriginal people. In addition, it is even more difficult to gauge how much more produce NWT residents might consume per year if they had access to fresh fruits and vegetables (i.e. not imported from the south) at affordable prices.

- According to Statistics Canada, typical per-capita consumption of fresh fruits and vegetables in Canada is estimated at 213 kg per year (not accounting for losses). Using this value, Serecon estimated fresh produce consumption in the NWT at 9.2 million kg. However, it should be noted that this may be slightly overstated, given that Statistics Canada also indicates that NWT residents typically consume less fruits and vegetables per person per year compared to other Canadians.
- Given the very high costs in the Beaufort-Delta communities and the fact that meals are provided free at mine / campsites, it is reasonable to assume that these two values represent the extremes for typical per-capita consumption of fresh fruits and vegetables in the NWT. Aboriginal adults in Beaufort-Delta communities is estimated to consume 131 kg per year of fresh, frozen and processed fruit and vegetable products; including 58kg fresh produce (Aboriginal and Global Health Research Group), whereas consumption of fresh fruit and vegetables is estimated at 188 kg/person at the mine sites. Based on a population of 43,400 and using an average consumption of 150 kg fresh fruits and vegetables per person, a total market demand is estimated to be 6.5 million kg.
- Compilation of the NWT stores data suggests an annual consumption of 8 million kg of fresh produce. Numbers, by commodity, are compared to the Serecon estimates in Table 3-1 below.

Table 3-1: Estimate of annual fresh produce commonly consumed in the NWT (before losses)

Commodity	NWT Stores (‘000 kg/year) (A)	Non-Store Trucking ² (‘000 kg/year) (B)	Total NWT Market (‘000 kg) (= A + B)	Serecon Market Estimate (2006) (‘000 kg)
Vegetables				
Potatoes, fresh white	489	575	1,064	1,388
Onions, shallots	120	210	330	314
Carrots	79	170	249	274
Broccoli	44	110	153	135
Cauliflower	29	40	70	n/a
Peppers	96	144	240	n/a
Tomatoes	120	168	287	316
Cucumbers	40	51	91	146
Lettuce	142	108	250	471
Fruits				
Strawberries ¹	75	71	146	n/a
TOTAL for above commodities	1,233	1,647	2,880	3,042
TOTAL Fresh Fruit/Veg in NWT	2,681	5,277	7,956	9,252

Note 1: includes data from all major sources

Note 2: includes spoiled produce

Using information from the data sources above, a reasonable estimate of annual fresh produce consumption in the NWT is 8 million kg or 185 kg/person.

3.3 Market Value

Data on produce prices was only provided for certain commodities from NWT stores, and therefore a market value estimate was difficult to achieve from those sources. However, an estimate of the market value can be derived from the Serecon (2006) and Aboriginal and Global Health Research Group (2013) reports and mine site data.

- The Serecon study indicated that for 2003, the NWT retail market for fresh fruits and vegetables was about \$5.26 million and \$6.29 million respectively, for a total of about \$11.55 million per year. Applying a NWT Consumer Price Index² value of 49%, the total retail market for fruits and vegetables (in current dollars) is estimated to be about \$17.2 million (i.e. \$7.8 million for fruits and \$9.4 million for vegetables). This translates to approximately \$400/person.
- People in communities in the Beaufort Delta are estimated to spend less than \$500 per person per year on fresh produce. Adjusting for inflation from 2008 to present, this figure is likely closer to \$540 (in 2012 \$)(Aboriginal and Global Health Research Group).
- The total value of fresh produce purchased by remote camps and mine sites is estimated to be approximately \$5 million, using the wholesale commodity prices in Yellowknife (i.e. what the wholesaler pays a supplier), or approximately \$900-1300 per person per year. The current remote mine / camp market of approximately \$5 million per year is likely to stay stable or increase over the next 10 years as new mines are expected to come on stream well in advance of the eventual closure of the first three diamond mines.

3.3.1 Price Survey

Another area of interest for the AgNorth project is to understand the retail prices for various fruits and vegetables in different regions and communities within the NWT.

An examination of a retail pricing report from the NWT Bureau of Statistics (see Community Price Survey, January 2012) shows there is an enormous range in the retail prices paid by NWT residents for fruits and vegetables, depending on the product and region. The price range for a few produce items is shown below (data is available in Appendix B):

- Iceberg lettuce(per head) = \$1.98 (Yellowknife) to \$5.64 (Deline)
- Yellow onions (per kg) = \$1.20 (Fort Simpson) to \$6.32 (Fort Good Hope)
- Green peppers (per kg) = \$1.99 (Fort Simpson) to \$14.59 (Deline)
- Strawberries (per kg) = \$8.23 (Yellowknife) to \$24.98 (Deline)

Roughly speaking, residents in northern NWT communities (i.e. Sahtu and Beaufort-Delta regions) typically pay prices that are two to five times higher than in southern NWT communities.

² Statistics Canada website January 2013

3.4 Market Supply Assessment

From the analysis above, we have a good understanding of the annual demand for fresh produce in the NWT, including what is consumed within communities and at active mine sites.

The intent of this section is to provide a qualitative description of how the NWT fresh produce market is currently being supplied and to identify potential AgNorth customers.

3.4.1 NWT Produce Supply

The wholesale supply of fresh produce into the NWT is an extension of the commodity-based North American produce supply system. Fresh produce originates as far south as Colombia during the peak winter months, with Canadian produce supply being added to the supply system beginning with spring greenhouse production, transitioning to field crops and trailing off with arrival of fall frosts.

The principal sources of supply to Canada are large corporate farms, located in California, Mexico and Texas. Supply-chains begin at farm source with production contracts that are entered into by large volume buyers including wholesalers, food processors, and produce logistics companies, all seeking committed supply at what is referred to as “farm gate wholesale” pricing. The participant buyers at farm source are large corporate wholesale and transportation logistics companies including CH Robinson Inc., Dole Fresh Produce Inc., and Delmonte Fresh Produce Inc.

On the farm, produce crops are harvested, placed into field coolers and transported to a regional packing house operation where produce is trimmed, tank washed, sorted for grade, cellophane wrapped and packed in 10 to 14 kg corrugated produce boxes. The boxes are placed on pallets consolidated with produce from other farms, and loaded into transport truck trailers (the primary mode of transportation), equipped with moisture and temperature control. Trailers for long-haul are most often loaded with single crop type as each crop has a unique moisture and temperature requirement.

Trucks in the USA carry a regulated maximum load of 43,500 lbs. that equates to approximately 30 pallets. Produce originating in Mexico is transported by trucking companies that handle produce from source, through the border crossings into the USA, and deliver to distribution warehouses in close proximity to the USA-Mexico border in California, Arizona and Texas. The imported produce is off-loaded, consolidated with other shipments, and reloaded into trailers ready for pick-up by truck operators (typically contracted as opposed to company-owned fleets) to move the load to the buyer's destination. The cost for transportation is variable, fluctuating on a daily basis, reflecting level of competition for available loads between contractors.

In western Canada, Edmonton is the regional warehouse and processing centre for produce, from which fresh produce enters the NWT and Western Arctic regions.

Table 3-2 below provides some examples of the typical distances and number of trucking days involved to move fresh produce from southern farm regions to Edmonton (without consideration of weather or mechanical delay):

Table 3-2: Examples of Source Farms and Transportation Links for Fresh Produce Arriving in Edmonton

Source Farm Region	Distance by Road to Edmonton (Km)	Estimated Transportation Days, Single Driver Truck
Cochella California	2800	3.5
Nogales, Arizona	3100	4
Hermosillo, Mexico	3400	5
Winter Garden/Laredo, Texas	3700	4.5
Abbotsford, British Columbia	1100	1.5
Taber, Alberta	560	0.75

For produce originating in Mexico or the southern USA, there is about a 7 day lapse from when produce is harvested on the farm and its arrival in Edmonton. Typically, an additional 3 days is then needed for handling and packaging produce in Edmonton and transport by truck to Yellowknife, Hay River, Fort Smith etc. This means that “fresh” produce is at least 10 days old on arrival in NWT regional centres.

Table 3-3 below provides summary information on the main participants in the Edmonton wholesale fresh produce marketplace that serve the NWT:

Table 3-3: Summary of Wholesale Fresh Produce Suppliers to the NWT

Organization	Description	NWT Customer Base	Transportation Routes to NWT
SYSCO Edmonton	Food services. 400,000 sq.ft. warehouse and processing centre	Commercial kitchens, restaurants and caterers	Road to Yellowknife
Northern Food Services	Wholesaler / distributor. 80,000 sq. ft. consolidation warehouse (Edm). 30,000 sq. ft. warehouse (YK)	Mineral camps, commercial kitchens Consumer Direct FOB Yellowknife	Road to Yellowknife
Gordon Food Services Inc.	Food services. 200,000 sq.ft. warehouse and processing centre	Commercial kitchens, restaurants and caterers	Road to Yellowknife

3.4.2 Potential AgNorth Customers – Wholesale and Retail

The NWT fresh produce market participants that appear to be most relevant to the future direction of the AgNorth business case are described below:

Northern Stores

Northern Stores' parent company, the North West Company, is one of the longest continuing retail enterprises in the world – with roots back to 1668. Today, the North West Company serves retail markets in Northern and western Canada as well as rural Alaska, the South Pacific islands and the Caribbean.

Under the Northern Stores banner, there are 123 stores offering a combination of food, financial services and general merchandise to remote northern Canadian communities. In the NWT, there are a total of 18 Northern stores, located in the following communities:

Aklavik	Behchoko	Deline	Fort Good Hope
Fort Liard	Fort McPherson	Fort Providence	Fort Resolution
Fort Simpson,	Fort Smith	Hay River	Inuvik
Norman Wells	Paulatuk	Tsiigehtchic	Tuktoyaktuk
Tulita	Ulukhaktok		

In terms of population, approximately 48% of NWT residents (including the Hay River Reserve) have local access to a Northern store.

Several of these Northern stores could be serviced out of Yellowknife either for partial or full year. South Slave Stores would typically be serviced directly from Edmonton. Inuvik, Tuktoyuktuk, Aklavik, Paulatuk & Ft. McPherson could be serviced twice a year, break up and freeze up (about 3 to four months in total). In addition to these NWT stores, several Nunavut stores could also be served out of a Yellowknife food hub. These include:

Baker Lake	Cambridge Bay	Chesterfield Inlet	Kugluktuk
Coral Harbour	Arviat	Gjoa Haven	Rankin Inlet
Repulse Bay	Tayloak		

Arctic Co-operatives Limited

Arctic Co-operatives Limited is a service federation that is owned and controlled by 31 community-based Co-operative business enterprises located in the NWT and Nunavut. The organization provides resources, consolidated purchasing power and operational and technical support to the community-based Co-operatives to enable them to provide a range of services to local residents.

Services provided through local Co-ops include retail stores, hotel and tourism operations, fuel distribution, arts and crafts marketing, construction and heavy equipment services, property rental and other agency type services.

In the NWT, there is a Co-op store in the following communities:

Colville Lake	Deline	Fort Good Hope	Fort McPherson
Lutsel K'e	Sachs Harbour	Ulukhaktok	Yellowknife

For the AgNorth project, only the Yellowknife Co-op store appears to be a potential customer. The other 7 Co-op stores in the NWT are supplied directly from Edmonton via air.

Nonetheless, the Yellowknife Co-op is the largest retail food outlet in Yellowknife. Specifically, it is a 55,000 sq. ft. store with 130 staff that serves over 4,500 members plus local businesses and remote mining and exploration camps.

Northern Food Services

Established in 1999, Northern Food Services is a full-service operator with annual sales of about \$30 million. It ships many different types of products (produce, dairy, meat, seafood, frozen foods, bread, dry goods, cleaning products, paper products, pop, chips, candy, tobacco etc.) to locations throughout the NWT, Nunavut, Alberta and BC.

Types of customers served include hotels, inns, restaurants, caterers, remote camps and lodges, schools, government facilities, health care facilities and retail and convenience stores. The company has a 30,000 sq. ft. warehouse in Yellowknife and is increasing its Edmonton warehouse capacity from 20,000 to 56,000 sq. ft. Deliveries from Edmonton to the Yellowknife warehouse occur three times a week using dedicated, dual-temperature transport trailers to ensure food is handled correctly and safely.

Preliminary discussions with representatives from Northern Food Services were positive. In particular, their Yellowknife warehouse and packing facility may be a possible site in which to conduct a pilot project to verify the performance of the AgNorth modular farm.

Bouwa Whee Catering

Bouwa Whee Catering, a subsidiary of the Det'on Cho Corporation, is a Yellowknife-based company that provides catering and other camp services for large-scale events and operations in remote locations including the Diavik and Snap Lake diamond mines. In addition to its catering and camp services, Bouwa Whee also operates the Smokehouse Café in N'Dilo and uses the kitchen there to provide training for new staff hired to work in the camp kitchens and dining rooms of its remote clients.

Currently Bouwa Whee purchases produce from wholesalers such as Gordon and SYSCO who truck the produce to Yellowknife.

The AgNorth project team made preliminary contact with Bouwa Whee representatives and agreed to keep them informed as the AgNorth project proceeds to the next stage.

Given the fact that the companies described above are all sourcing fresh produce from southern markets, it is difficult for them to maintain freshness and quality for the estimated 10 days it takes to ship produce from a farm source to the wholesale buyer and/or northern retail outlets.

For northern residents, the implications of being at the end of long produce supply chains include:

- Short shelf life – fresh lettuce and salad greens are generally considered to have, on average, 10 days or less shelf life from harvest time before the grade of produce falls below suitability for retail sale. Thus, fresh produce coming in to the NWT is typically arriving at the lower limit of freshness and produce is often left on store shelves past the grade expiry point. For the consumer, this means only one or two days of fridge life before the produce is considered food waste;
- Vulnerability to supply disruption – various weather conditions, such as frost, drought or storms, can disrupt or delay the supply of fresh produce. As a result, prices for produce can increase

dramatically with no notice or stores may simply run out of supply, leaving store shelves empty until the supply can be replenished.

From a market supply perspective, the information gathered in this section suggests that the AgNorth modular farm should be focused on growing high-value, highly perishable produce items that are difficult (or impossible) to consistently supply to NWT communities in fresh condition using southern suppliers.

3.5 Potential NWT Market for AgNorth Project

As noted in Section 1.1, the AgNorth project is focusing on producing fruits and vegetables that are commonly consumed by NWT residents, nutritious, and are not produced locally. Crops that satisfy these considerations include cherry tomatoes, strawberries, red peppers and romaine lettuce.

With the exception of communities in the South Slave (which receive produce supplies directly from Edmonton by truck) and the Co-op stores outside Yellowknife (which are supplied by air from Edmonton, much of the NWT's supply of fresh produce is trucked from Edmonton to Yellowknife, then transported by air to communities farther north and to remote camps and mine sites.

Using the annual data provided by specific produce wholesalers, the project team developed a rough estimate of the annual wholesale volumes and market size for specific commodities that are transported via Yellowknife and could be grown in an AgNorth facility, as shown in Table 3-4 below:

Table 3-4: Estimated Annual Market

Commodity	Wholesale Yellowknife	
	Volume (kg)	Market (\$/yr)
Cherry Tomatoes	27,000	\$188,000
Strawberries	123,000	\$769,000
Red Peppers	89,000	\$599,000
Romaine Lettuce	100,000	\$643,000
Total	414,000	\$2,694,000

Using just four crops as an example, Table 3-4 confirms that there is a significant market in the NWT that an AgNorth facility could supply produce to that is consistent with the project principles outlined in Section 1.1. The retail volume is included in the wholesale volume.

4 AGNORTH MODULAR FARM SYSTEM

Due to the remote nature of many communities in NWT, insufficient access to quality fresh produce at a reasonable price is having an impact on the health of residents, the majority of whom are aboriginal. Because of the harsh climate and limited sunlight for extended periods of time, growing food in-situ, even with conventional greenhouse technologies, is not economically or technically feasible for much of the year.

A modular farm station is a hydroponic food production system that uses new high brightness light emitting diode (LED) lighting systems, which are specially designed with specific components of the solar spectrum to enhance plant growth and much more efficient than conventional broadband illumination. The system can be placed within a building or insulated shipping containers, and can be sized to demand. It is capable of producing several vegetable and fruit crops year round, and simultaneously.

4.1 AgNorth Overview

4.1.1 Concept

The proposed AgNorth modular farm station will be a custom plant production system based on artificial lighting (LEDs), soil-less hydroponics, and automated environment control. The modular systems can be deployed in a wide range of settings from retrofitted shipping containers to warehouses or specifically designed insulated enclosures fitted with the appropriate utilities (i.e., electrical, water storage, air handling, etc). This is a **completely customized concept** designed to be adaptable to the challenges of the climate of northern Canada and provide scalable production capacity for a range of commodities, starting with high value, highly nutritious food crops (e.g., tomatoes, peppers, strawberries, etc.).

AgNorth farm stations will optimize productivity with precisely controlled and homogeneous environment conditions. However, most of the technologies used in the AgNorth modular farm are identical to those commonly used in Canada's conventional greenhouse industry. The exception is the use of high efficiency computer-controlled LED arrays. Ongoing progress in the development of ever more efficient LED platforms makes this the most desirable candidate technology for plant growth applications in challenging environments when sufficient sunlight is not available (Massa et al. 2006). High-pressure sodium (HPS) lamps are the current industry standard for greenhouse lighting. HPS are relatively inefficient at converting electrical energy into light (30%) and generate a significant amount of heat.

With LED lighting in a controlled environment, clouds are not a limiting factor. Because it uses artificial lighting, multiple growth trays can be stacked 3-4 layers high (depending on crop), providing a direct multiplier on the productivity compared with conventional two-dimensional greenhouse production systems. The ability to double the effective growing season through the dark northern winter months provides a further enhancement. By providing local markets with a continuous year-round and fresh supply, the AgNorth producer should have a commercial advantage over conventional suppliers of imported produce.

Although the specialized systems in the AgNorth modular farm will cost significantly more per square meter of footprint than a conventional greenhouse, the ability to tailor the lighting spectrum to separately optimize the productivity for each stage of growth from germination, through vegetative

growth, to production, means that the AgNorth modular farm station has the potential to outperform a greenhouse in full sunlight by a significant factor.

4.1.2 LED Technological Advancements

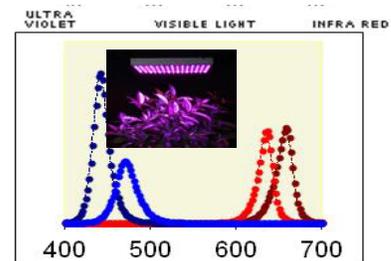
Various groups, mainly in Japan and the Netherlands, have already implemented LED-based growing systems and these are operating successfully in commercial settings. Conversion efficiency of electrical power to photosynthetically active radiation (PAR), lifetime, durability and light output tunability/versatility are key factors favouring LED technology over more conventional alternatives.



The University of Guelph Controlled Environment Systems Research Facility (CESRF)'s is continuing to advance the field by developing programmable banks LEDs. These combine a variety of monochromatic lights to create a light source specifically tailored to plant photosynthetic requirements, rather than what is available through more conventional technologies.

The unique growth chamber technology at the University of Guelph's CESRF allows an understanding of plant responses to specific lighting and nutrient management protocols. This direct linkage with the research and technology development program at Guelph will be sustained and integrated into the ongoing commercial activities of AgNorth. New developments and technologies tested at the University of Guelph will become a valuable contribution to AgNorth's capabilities to increase production and reduce costs.

Photosynthetic Active Radiation



4.1.3 System Components

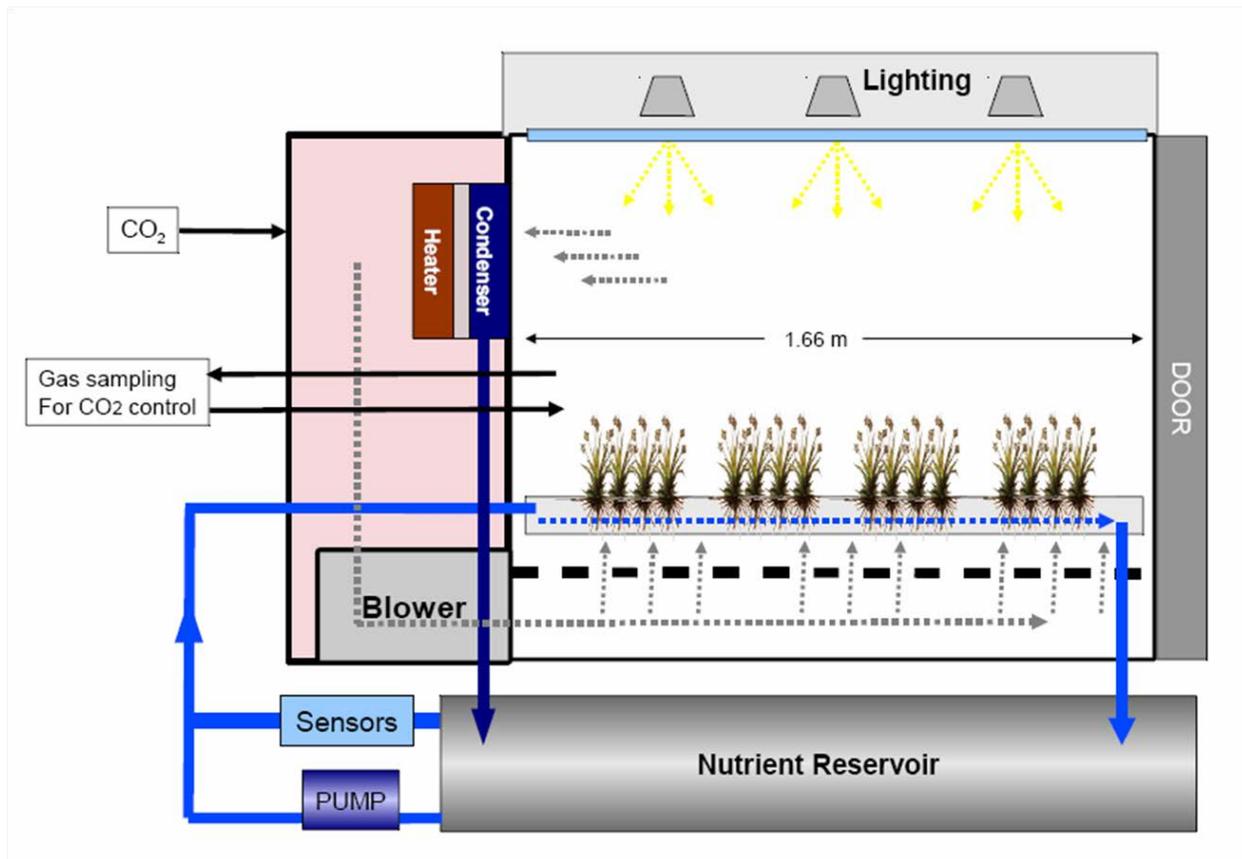
Figure 4-1 shows a schematic diagram of an AgNorth modular farm station. It is comprised of the following major systems:

- Environment control system controlling hydroponic nutrients, temperature, humidity, light, CO₂ levels and providing a uniform distribution throughout the growing region. This includes heat exchange units, radiators, fans, condensers, and propane burners or pressurized storage tanks for

CO₂ enhancement. This equipment is common to many greenhouses and is proven technology. Non-toxic food-grade glycol will be used in cooling loops to minimize the risk of contamination in the event of a leak.

- Hydroponic nutrient circulation system and reservoir controlling nutrient concentrations delivered to the plants. The nutrients are pumped into troughs to form a thin nutrient film where the plant roots are supported in a fibrous substrate such as organic growth media or rockwool. This system includes an electrical conductivity sensor and a pH sensor, as well as nutrient concentrate and pH adjustment tanks, valves and pumps. The hydroponic nutrients can be purchased in pre-mixed powder form. This is proven equipment in the greenhouse industry. Care will be taken in the design to ensure that the system will drain into the reservoir in the event of an extended power outage to prevent inadvertent damage to the plumbing.
- Multi-colour LED lighting system controlling colour balance and intensity of each independent growing region.

Figure 4-1: Functional Block Diagram of AgNorth Modular Farm System



These systems are co-ordinated by a central computer that is programmed with a specific environmental recipe for each crop that will be grown.

Most of the mechanical support equipment will be located in a common 'header house' with the following standard items:

- A planting, processing and packing area certified to industry standard food safety protocols;

- A seedling transplanting and tray-cleaning area;
- An ozonator or similar non-toxic-residue disinfectant for sterile cleaning and wash-down between crops;
- Consumables storage space;
- Temporary temperature-controlled storage with access to distribution;
- Sufficient backup power to survive typical power outages without loss of crops, and to survive an extended power outage without damage to the system.

The systems to be implemented will have the following initial differences to currently existing systems that set them apart:

- Higher intensity 4 to 6-colour LED systems will be implemented to permit efficient growth of higher plants. This will require cooling of the LEDs to maintain die temperatures below the critical temperature for longest lifetime. This will also increase the difficulty of maintaining thermal uniformity throughout the chamber. Detailed computer modeling of the thermodynamics will be used in the design of the environment control system to mitigate this.
- The uniquely cold external environment experienced in a northern Canadian winter will mean that the system will require careful attention to insulation and heat exchange systems to prevent condensation which can cause maintenance issues and foster disease.

4.1.4 Building Requirements and Upgrades

Building Envelope

The building envelope, the components of the building that separate the inside from the outside, will play a critical role in the success of the project. To facilitate optimal growth of the crops and prevent growth of molds and fungi, the indoor environment must be kept consistent throughout the growing chamber. Specialized lighting and HVAC equipment will be used to create the desired interior environment and the building envelope must isolate the warm, moist interior from the cold, dry exterior environment. The building envelope must effectively address temperature and air movement, and in order to do so, it requires attention to detail in the planning, construction and operational phases of the project. The insulation levels and air tightness will be key to keeping the indoor climate consistent.

Insulation

Table 4-1: Recommended levels of insulation (Guide to Energy Efficiency in RFPs for New Buildings, 2012)

Building Envelope Component	Minimum for an energy efficient building	Required for a very energy efficient building
Ceiling Insulation	R60 (RSI 10)	R80 (RSI 14)
Wall Insulation	R40 (RSI 7)	R60 (RSI 10)
Floor Insulation	R60 (RSI 7)	R80 (RSI 10)

The level of insulation recommended for this building will depend on the thermal balance of the building once all the heat sources have been factored in. Early model results suggest that excess heat will be produced and would need to be dumped or sold to a user in another facility for most of the year. Because heat is being dumped throughout the year, a lower level of insulation, as low as R30 in the walls, will be satisfactory. Very low insulation levels are not recommended due to the proximity of the plants to the walls and the damage that can be done by having wet walls and water pooling on the floor.

Air tightness

Air tightness is more important than insulation. A building is air tight if no air leaks into or out of it through holes where services come in, cracks between the wall and doors or windows, flue, or anywhere else. It is impossible to achieve a 100% airtight building, but this facility needs to be very airtight to maintain the consistent and well-controlled indoor environment that is critical for the success of the project. If the building is not airtight, air can leak in (infiltration) or out (exfiltration), depending on the indoor/outdoor pressure differential, and both types of leakage come with their own problems. If indoor air is leaking out, it must be replaced by new, conditioned air and heating and humidifying all that air is expensive. In addition to this, as the indoor air passes through the building wall, it cools down and reaches the dew point. When it reaches this point, the vapour in it condenses where it is, resulting in wet walls and a number of problems:

- Wet insulation is not generally as effective as dry insulation so the R-value of the walls decreases;
- Wet or damp walls provide a good place for mould to grow;
- Pockets of frost build up in the walls and start to destroy the wall by forcing their way through building components.

The last of these problems is a frequent occurrence in northern climates and the deterioration to the building envelope allows more air leakage, which accelerates the process.

If outdoor air is leaking in (infiltration), the effects on the structure are not as serious since the air coming in is dry. Infiltration will however cause problems with maintaining a consistent indoor environment since it could cause cold, dry air pockets near the leakage points or in corners, which would be harmful to the plants growing nearby. A very well designed air distribution system will help mitigate this. The prototype design air flow has been modeled using computational fluid dynamics to ensure that sufficient airflow is maintained along the walls and through the plant growth areas to maintain a reasonable minimum flow rate. The pilot facility design insulation and air supply ducting is shown in the overhead view of Figure 4-2. Figure 4-3 shows the cross sectional view.

Figure 4-2 AgNorth pilot-scale facility layout overhead view

14 " THICK
INSULATED
WALLS

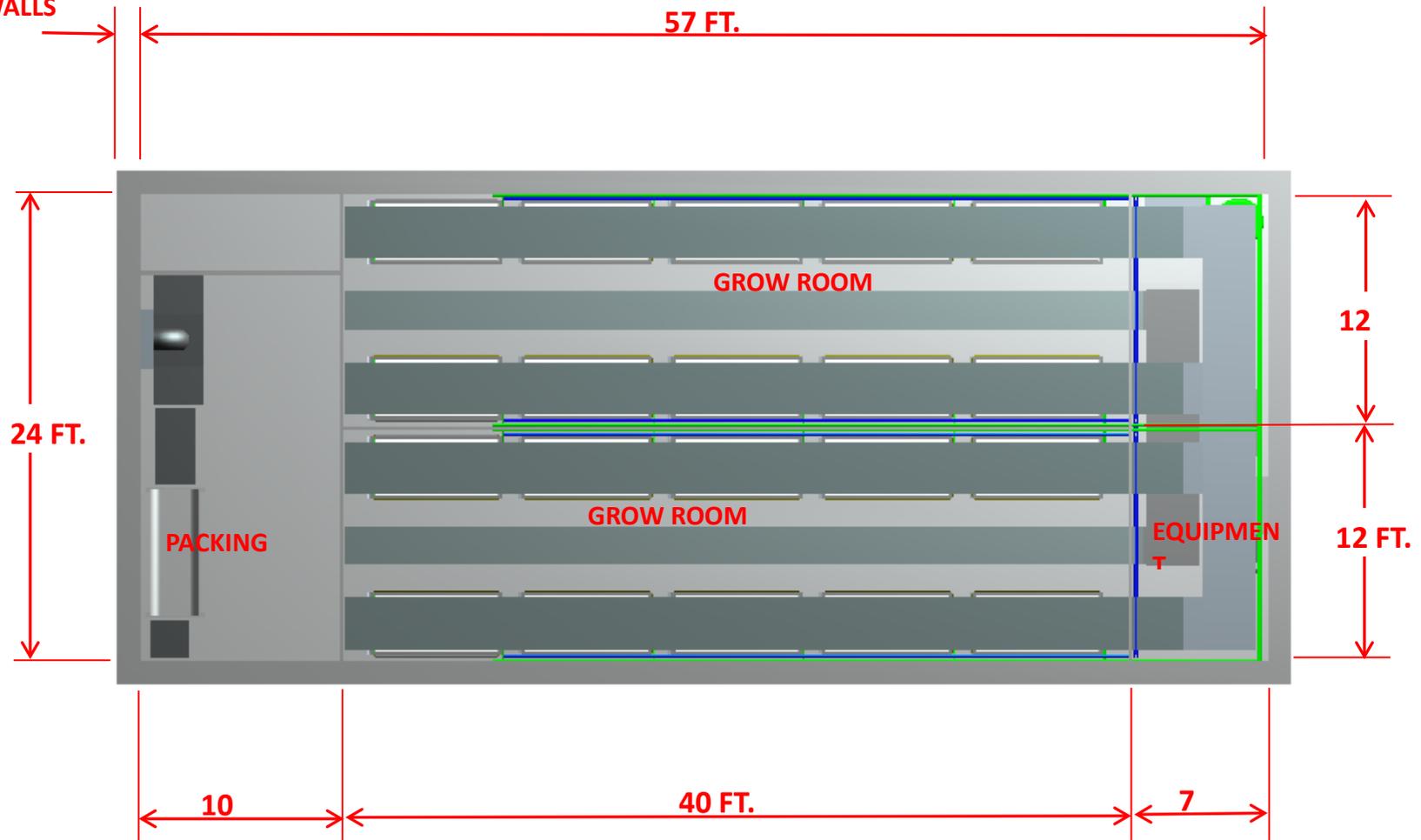
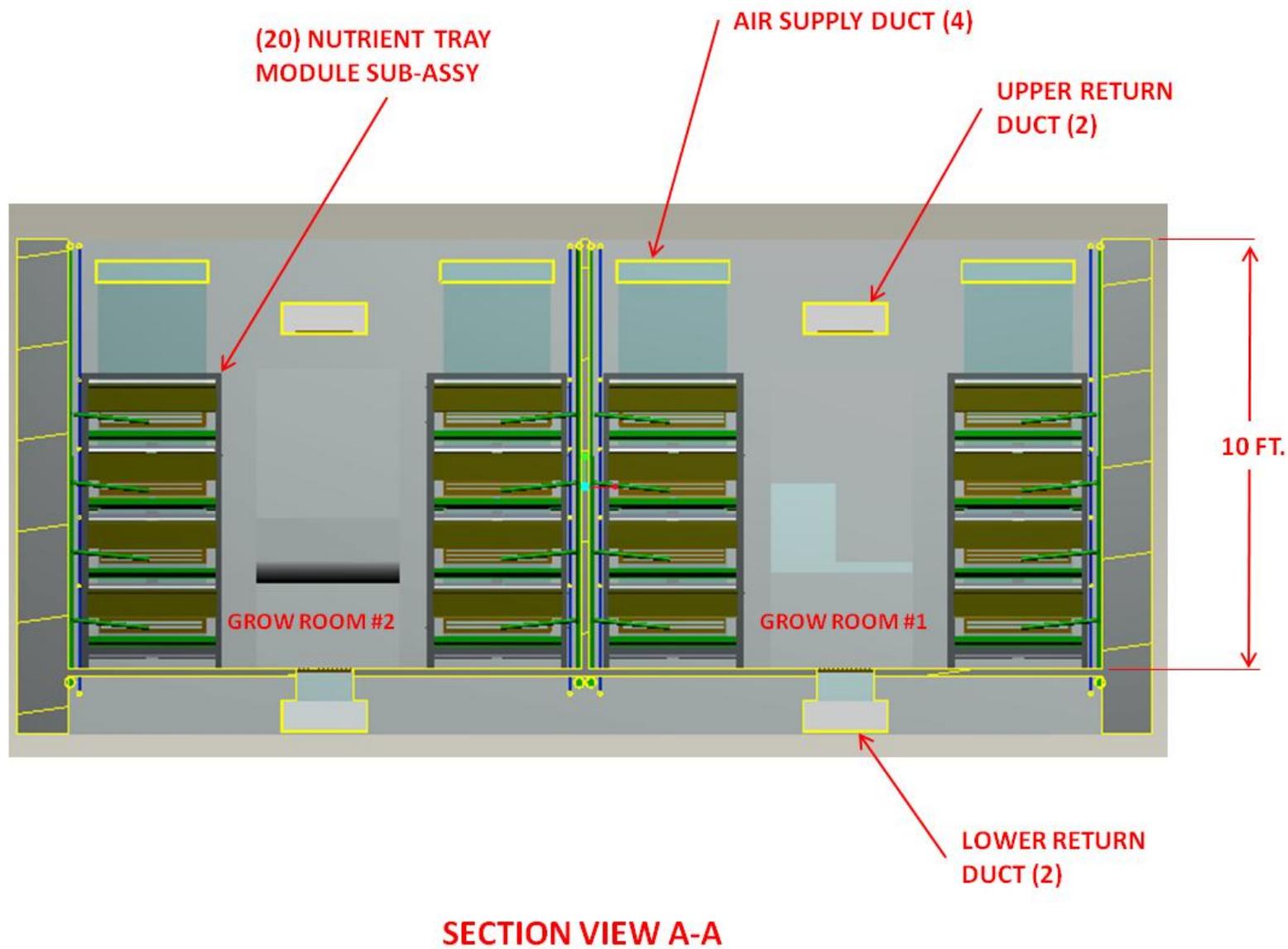


Figure 4-3 AgNorth pilot-scale facility cross-sectional view



Balancing the HVAC system properly and ensuring it remains balanced will be very important. The amount of air that the HVAC system is putting into the facility will be balanced with the air it is pumping out and the natural leakage. If the HVAC system puts too much air into the facility, it will be over-pressure and that will drive air leakage through the walls to the outside whereas if the HVAC system is not supplying enough air, air will leak into the facility from outside.

Air lock

Because the indoor environment is so different from the outdoor one, an airlock between the outdoor environment and the growing chamber should be installed in a stand-alone facility. This will prevent cold, dry exterior air from rushing in every time the door is opened. A simple way to do this is to separate the working space from the growing space and have the outside doors open into the working space. For a facility built within an existing warehouse building this is not as important.

Ventilation

The growth facility will be ventilated to allow for a few air exchanges between the indoor and outdoor environments every day. This will prevent the buildup of harmful contaminants such as oxygen and ethylene gas that are generated by the plant growth process. The ventilation system is designed to distribute the air uniformly throughout the facility. The air being brought into the facility is treated due to the temperature and humidity difference between indoor and outdoor air for most of the year; bringing cold, dry air directly into the growing chamber would otherwise cause damage to the plants. The most efficient equipment possible, including heat reclamation from cooling the LEDs, will be used to heat the incoming air and water. In addition, as much heat and water will be recovered from the exhaust air as possible by using a Heat Recovery Ventilator (HRV) or Energy Recovery Ventilator (ERV). A mature plant canopy will deposit a significant amount of water vapour into the environment, especially when it is under LED illumination. The latent heat associated with this water vapour can easily correspond to 25% of the total lighting energy deposited into the plant canopy. The optimum ventilation rate is kept low to minimize the power required to de-humidify the air, while being high enough to prevent build-up of ethylene gas.

A heat pump will be added to the facility to concentrate the waste heat energy if it can be efficiently transferred to a neighbouring building. This is the preferred option, as the electrical efficiency of a heat pump means that the cost would be roughly half the cost of generating heat from electricity directly. Otherwise, an outdoor radiator & fan system will be used to dissipate waste heat into the cold outdoor environment.

Enthalpy Recovery Ventilators (ERVs), sometimes known as Energy Recovery Ventilators, are similar to commonly used HRVs, however in addition to transferring (sensible) heat, ERVs also transfer moisture (and latent heat). In most ERVs the heat and moisture exchange occurs in a rotary air-to-air enthalpy wheel where desiccants such as silica gel and molecular sieves are used to transfer water between airstreams through adsorption. Molecular sieves are more common where there is concern about the possibility of cross-contamination between incoming and outgoing airstreams.

As with HRVs, there is a high risk of problems due to freeze-up of the heat exchange core and other system components. The problems and solutions are similar, however more damage can be done to an ERV that freezes up because the components that transfer moisture can be damaged. As long as this problem is overcome, an ERV would be ideal for this application. The large temperature gradient that exists in the North for most of the year will result in the overall heat exchange being very efficient. There is also much more water in the inside air than outside so the partial pressure of vapour in the two

airstreams as the outdoor one heats up and the indoor one cools will drive moisture transfer from the outgoing airstream, to the incoming airstream. Using an ERV will decrease the amount of energy required to heat incoming air and will also decrease the amount of water needed to keep up the humidity levels in the growing chamber. There are several manufacturers of ERVs that operate in cold climate, including Broan, Bryant, Carrier Corporation, VanEE, Venmar Ventilation. VanEE ERVs are amongst those that have been used successfully in the North; they can remove 50 to 60% of the moisture in the outgoing air in the temperature range in which this facility will be operating much of the year. Whichever model is chosen, it will be certified by the Home Ventilating Institute (HVI) and tested for operation at low temperatures. In the large operational facility discussed in Section 5.1 'ERVs' would be built into the heating, ventilating and air conditioning system (HVAC) of the building. For the smaller pilot facility, and the estimated airflow of 125 cfm, a factory-built ERV will be adequate.

4.1.5 Research and Technology Development

The following developments will be added to the system at the appropriate time as technology progresses in the ongoing research program at Guelph (being funded by others):

- Ion-specific hydroponic nutrient sensing and recirculation system. Although modern recirculating hydroponic systems are much better than conventional agriculture in terms of water usage and environment pollution, there is still a need to intermittently flush the nutrient system between crops. When a full suite of ion-specific nutrient sensors is available this development has the possibility to entirely eliminate water and nutrient leachate to the environment. This will require further development of ion exchange and sterilization systems to remove both organic and inorganic contaminant build-up.
- Automated planting and harvesting systems (e.g., pictured left to right seeding, planting, packing robots) can be added when the technology becomes economically feasible (i.e., sufficient scale of AgNorth activities). It is unlikely that the size of the Canadian northern market will support such capital-intensive components initially.
- Bio-gas co-generation will be useful if a suitably robust system can be found to economically turn plant waste into electricity in the northern winter. In addition to plant waste, recycling of human waste could also be implemented to provide a 'richer' nutrient stream and reduce environmental pollution.



4.1.6 Inputs and Outputs

From a technical perspective, the AgNorth system is modular in design and can be scaled up or down to fit a particular market. Theoretically, the growing area of a facility can be scaled down to the minimum of a single growth module placed inside a pre-existing building with its own interior climate controls (assuming a suitably sized dehumidifier was available). In this case, a simple nutrient reservoir could be refilled manually for each crop.

While a very small growing facility could be established to serve a single community, there are some operational and economic realities that suggest that a larger facility serving a region or the entire NWT market may make more sense.

For information purposes, following is a summary of the inputs and outputs associated with an AgNorth modular farm facility:

The system requires the following inputs:

- a source of uncontaminated irrigation/cleaning water that must be sterilized of pathogens. This could be done on-site using the ozonation system.
- a source of soluble mineral nutrients, acid, and base.
- a source of CO₂ for enhanced growth efficiency (liquid CO₂ preferred, or liquid propane).
- a source of electrical power
- a source of seeds
- a source of packaging materials
- a source of organic growth media or rockwool as determined by crop requirements

The system will produce the following outputs:

- packaged food products
- plant waste for generation of high quality organic compost
- growing substrate waste (depending on crop) 'grey' waste water from cleaning and irrigation
- recovered heat from the lights available for redistribution.

4.1.7 Operations

The main activities in operating the modular farm include horticultural management of the various crops, maintenance of the production infrastructure and management of waste (water, growth media and inedible biomass) recycling systems.

An overview of specific operational activities is provided below:

Business Management, Procurement & Sales

- Establish a regular source of the necessary inputs discussed in the previous section and maintain sufficient inventories to sustain continuous productivity.
- Establish supply and distribution contracts with consumers and retailers.
- Human resources management.
- Ensure that incomes exceed outlays.

Production Practices

- A central computer will be programmed with nutrition, photoperiod and spectral quality, temperature and humidity conditions desired for various crops. This computer will also balance facility heat and electrical load by offsetting growth modules on different lighting schedules. It will also monitor temperature, CO₂, and humidity levels, and control the condenser and HVAC systems

to stabilize the environment within the desired operating range. It will be accessible to the operator over a web browser interface for continuous remote monitoring and control.

Horticultural Management

- Establish small-scale nursery for sowing of seeds and rearing of seedlings in plug trays or suitable seedling medium. Maintain a schedule of sowing and transplanting production targets and schedules. The University of Guelph will provide germination and seedling nursery protocols for selected crops.
- Transplant seedlings in production scale growing system.
- Inspect crop daily, prune excess or dying foliage, maintain plant support systems (if required as with tomatoes or other vine crops).
- Manual pollination of flowering crops
- Monitor quality of nutrient solution and refill nutrient concentrate, acid and base containers.
- Harvest and package market-ready produce.
- Implement cleaning and disinfection protocols between crops and maintain clean conditions in all production facilities, nurseries and header house areas.

Maintenance

- Monitor environment conditions as reported by various sensors and computer automated feedback controls.
- Monitor status of all electrical components and moving parts.
- Respond to alarms related to environment control settings.
- Calibrate all environment sensors regularly (6 mo.) including: temperature, humidity, pH, electrical conductivity.
- Stock spares of critical sensors (T, RH, pH, EC) and equipment (fan motors, nutrient pumps) and effect repairs/replacement as required.

Waste Management

- Establish composting infrastructure and recycle all organic waste (inedible biomass, spoiled produce, organic growth media such as coco-coir or peat).
- Dispose of inorganic waste (plastic, rockwool substrate)
- Dispose of nutrient solutions contaminated with pathogens or beyond salvage due to unbalanced ion concentrations.

4.1.8 Personnel Requirements

Based on the operating procedures described above, the follow human resources are required:

- A skilled facility manager (operator/owner) is required to run the facility, manage labour, manage supply and distribution contracts, arrange for resupply of consumables, manage finances, and equipment maintenance (i.e., A farmer). For a small facility (up to 2,000 sq. m. of growing area), this person would also be responsible for horticultural management. An additional skilled support

employee or horticultural student is expected to be necessary for each additional 2,000 sq. m. beyond this.

- Systems oversight can be performed remotely through a contract to the University of Guelph, offloading the need for another skilled labourer. This contract could include remote support of horticultural management tasks and production planning of each crop.
- The system is engineered to be low-maintenance. Equipment maintenance (pumps, plumbing, motors, sensors, electrical components) can be performed by local skilled trades-people as required. The cost of equipment maintenance labour will be included in the estimated maintenance cost of the hardware.
- Provision of 2-4 part-time staff during peak harvest and packaging periods. Large production greenhouses typically require one unskilled labourer per acre (~4,000 m²) of growing area. Because the AgNorth controlled environment modular farm will have 2-3x higher productivity, we estimate that an average of 1 full time equivalent unskilled labourer is required for every 2,000 m² of growing area.

4.1.9 Regulatory Requirements

It is important to note that the set-up and operation of an AgNorth facility (i.e. growing and handling food) will involve mandatory compliance with the NWT Food Establishment Safety Regulations and could also involve water licensing and waste disposal regulations.

Based on the research completed to date, the following regulatory considerations would apply:

- Maximum daily water consumption cannot exceed 100 m³ (without obtaining a water license);
- Food Establishment Safety Regulations – a business license cannot be obtained without a valid food establishment permit. The Chief Public Health Officer's approval is required with respect to the following:
 - Areas of interest will include the water supply system, the sewage disposal system, lighting system, ventilation system and toilet and washing facilities; and,
 - To obtain a food establishment permit, operational areas of interest will include procedures for harvesting, washing, packaging and storage of produce, cleaning and sanitizing all surfaces and equipment, use and storage of chemicals, requirements for disposal of waste etc. At least one employee with valid food safety training must be present in the facility during hours of operation.

4.2 Productivity and Unit Cost Estimates

Productivity is the amount of edible/saleable product that can be produced by a facility, and is a factor in choice of produce mix. The cost to produce a product, is influenced by drivers such as productivity, facility size, labour costs, building costs and utility rates (power, water) can vary significantly depending on where (i.e. in which community) the facility is located.

4.2.1 Productivity and Product Mix

The AgNorth modular farm can supply a vast range of fruit and vegetable products. This section provides a rationale for products that have been chosen for this study.

The output from a northern modular farm will compete with crops grown in the south using “free sunlight” but requiring significant time and expense to transport to northern communities. This gives the AgNorth concept an advantage in the production of highly perishable crops with limited shelf life. Robust crops like carrots, potatoes and dry onions, which can be stored for longer periods of time, are therefore inappropriate.

The amount of biomass produced is more or less directly proportional to the light intensity provided by the LEDs, and thus the energy requirements. This means that crops with the largest ratio of edible to inedible biomass, such as tomatoes, peppers and strawberries, will be produced most cost effectively by this system. This essentially rules out crops such as sweet peas and grains as a cost-effective commodity.

Finally, due to high-density vertical stacking of the plant growing areas, commodities which are generally smaller in physical stature would help optimize the production capacity of one of these farms.

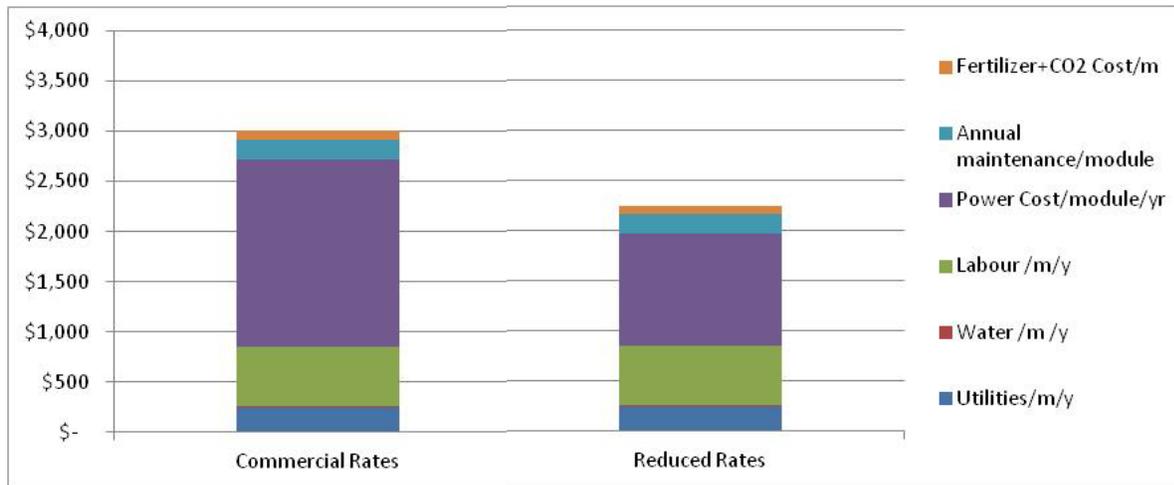
Based on this analysis, the market ‘sweet-spot’ for the AgNorth modular farm includes crops such as cherry tomatoes, certain types of lettuce, sweet peppers, spinach, strawberry, green onion, broccoli, and herbs.

4.2.2 Estimated Unit Costs

As a first step in determining the economic viability of the AgNorth concept, COM DEV developed a model for the AgNorth system that predicts the cost to produce various commodities based on a set of input assumptions. Details of the model are described in Appendix C.

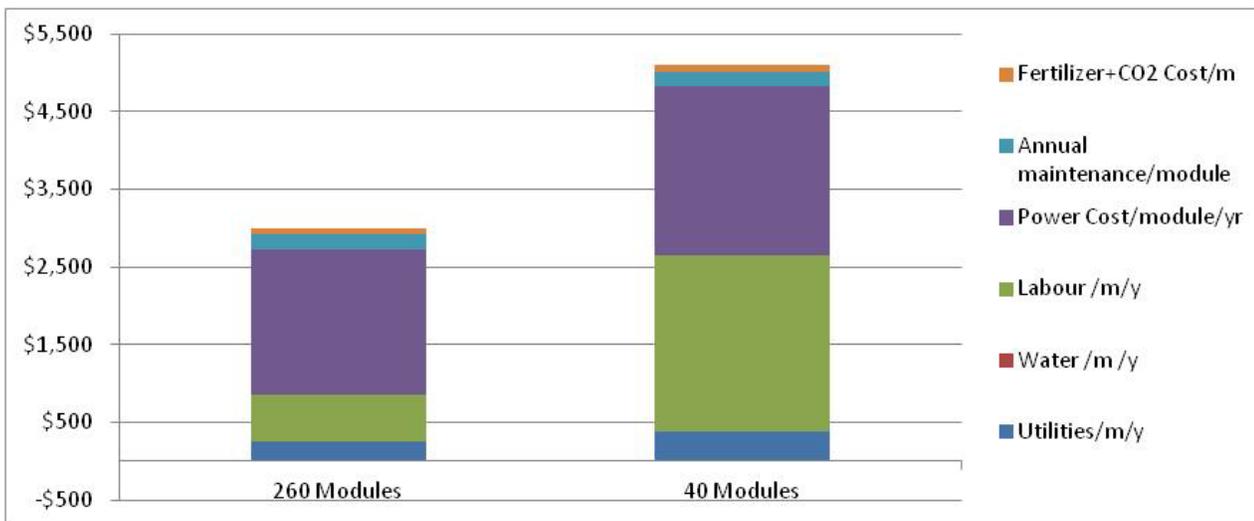
Figure 4-4 shows the cost breakdown calculated for a farm facility with a 1200 m² growing area (which would be sufficient to serve a significant proportion of the NWT market). This is based on a modular growing unit consisting of 3 or 4 plant tray levels (depending on the height of the crop), each 1 x 2 m in area, each with an overhead LED array of specific spectral quality. The figure on the left shows the operating costs for a facility using the current commercial power rate in Yellowknife of \$0.1599/kWh compared to a reduced rate of \$0.095/kWh (on the right). Cheaper power rates may be achieved through locating the facility outside of the city limits of Yellowknife, partnering with an alternative energy program, or negotiating with the utility for a special rate.

Figure 4-4: Breakdown of operating costs per module for a 260-module (1200 m² growing area) facility growing tomatoes in Yellowknife at a commercial electrical rate (left) compared with a potentially reduced rate of \$0.095/kWh (right)



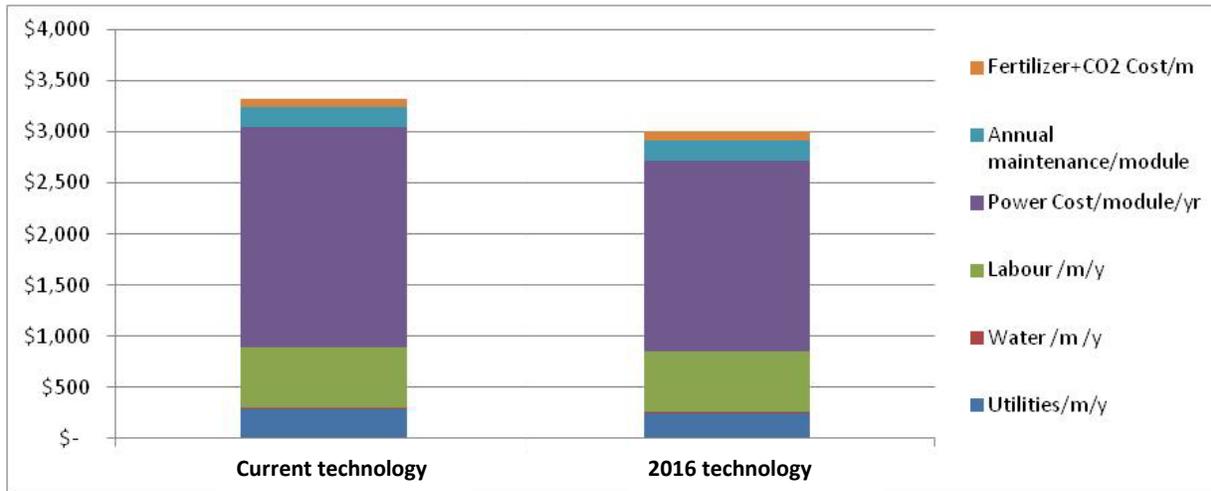
The operating costs are also very dependent on scale. The 1200 m² facility assumes an experienced facility manager with a modest salary (\$80 K), with a qualified student assistant (\$55 K), plus the necessary crew of part time labourers as discussed above and in Appendix C. In a smaller facility, the labour cost fraction would increase substantially, see Figure 4-5.

Figure 4-5: Cost breakdown for smaller (40-Module) farm in Yellowknife (right), compared to proposed 260 module facility (left)



Finally, the efficiency of LED lighting is continually improving. Figure 4-6 compares the costs for a present-day model for a 1200 m² facility (left) to a facility built in 2016 (on the right), based on the expected improvements in commercial high efficiency LED technology.

Figure 4-6: Breakdown of Operating Costs per Module for a 260-module (1200 m² growing area) Facility growing tomatoes with current commercial LED Technology (left) and with predicted LED improvements by 2016 (right)



Clearly, the location of the farm, the scale of the operation and the local power rate are all key factors that will directly impact on the unit cost of produce from an AgNorth modular farm. Other production scenarios, as well as options for managing costs, are presented in more detail in Section 5.

5 AGNORTH BUSINESS CASE

The intent of this section is to determine whether there is a reasonable business case for establishing a modular farm facility in a NWT location to provide fresh produce into the NWT market.

The information presented in the preceding sections suggests that the economic viability of an AgNorth modular farm facility will be largely driven by the following factors:

- The scale of the operation – the higher annual output from a larger facility helps to mitigate the impact of fixed costs;
- The location of the facility – the availability and cost of electricity, access to key inputs, including human resource capacity, and access to end customers are all factors that change depending on which community the facility is located in; and,
- The type and quantity of the produce – actual market prices that can be attained will determine the total annual revenue available.

To better understand the impact of these factors on the economic viability of the AgNorth concept, the project team examined three different scenarios: a Yellowknife location, a location in a regional centre and a location within small communities.

5.1 Yellowknife Scenario A – 40% of the NWT wholesale market for 5 crops

From an operations perspective, Yellowknife probably presents the best option for the location of the facility, as there are no potential limitations in terms of the availability of skilled labour or key inputs. In addition, many of the potential corporate customers that may be interested in purchasing produce at a wholesale level are located in Yellowknife including Northern Stores, Arctic Co-operatives, Northern Food Services, Bouwa Whee, other catering companies and numerous restaurants and other commercial kitchens.

Given these factors, this analysis assumes that a Yellowknife facility should be large enough to produce several different crops (at the same time) and serve a significant portion of the NWT market for those crops. To achieve this level of sales, the facility will need to have the capacity to supply 150,000 to 200,000 kg of high-value produce per year (depending on the actual mix of crops).

5.1.1 Crop Production and Revenue Forecast

The specific high-value crops selected for this scenario include cherry tomatoes, romaine lettuce, red peppers, herbs and strawberries.

Table 5-1 shows that the annual production of approximately 40% of the wholesale market for these 5 crops (\$2.7million) would result in approximately \$1 million in annual sales (at current wholesale prices).

Table 5-1: Product Quantities, Pricing and Sales Forecast for Scenario 1

Selected Crops	AgNorth Volumes (kg / year)	Ave. Price / kg (YK wholesale)	AgNorth Annual Sales	% of NWT Market Served (by volume)
Cherry Tomatoes	20,000	\$6.50	\$130,000	64%
Romaine Lettuce	50,000	\$5.80	\$290,000	36%
Red Peppers	30,000	\$6.00	\$180,000	29%
Herbs	4,000	\$10.00	\$40,000	65%
Strawberries	60,000	\$6.00	\$360,000	41%
Total	164,000	n/a	\$1,000,000	40%

5.1.2 Facility Requirements and Capital Cost

The next step in the analysis was to determine the physical requirements (i.e. building, systems and equipment) of such an AgNorth facility of this size.

Building

The AgNorth facility could be set up in an existing building (through a purchase or a lease) or built new on an available lot. Regardless of which option is selected, the key parameters and specifications for such a facility would include:

- Total available interior space of approximately 1,200 m²:
 - 800 sq. meter growing area (i.e. 520 m² x 3-4 growing levels = 2,000 m² growing capacity, plus aisles)
 - 400 sq. meter common area (office, airlock, washing/packaging, storage, systems “header’ area etc.)
- A very efficient heating, ventilation and air condition (HVAC) system (with an energy recovery ventilation component tested for low temperatures) that is properly balanced to avoid over-pressurising or under-pressurizing the building and can maintain the necessary growing conditions (CO₂, temperature, humidity) for the plants;
- For the growing area or entire building (see AEA 2013):
 - A very tight building envelope to isolate the warm, moist interior from the cold, dry exterior environment (mandatory to avoid condensation, growth of molds and fungi and prevent damage to the building walls):
 - Approximately 14 inches of insulation are estimated to be needed to prevent condensation for a stand-alone facility. Inside an existing warehouse, a plastic vapour barrier would be used to define the environmental control area;

- Air tightness of 0.25 ACH at 50 Pa (i.e. one full air change every 4 hours);
- The use of LED lights will create a very significant electrical load (see Section 5.1.3 below) within the building. The size of this load will likely require the following modifications be made:
 - Upgrading the transformer and other components associated with the connection between the building and the local grid;
 - Installing power factor correction equipment to avoid creating problems on the local grid;
 - Installing a back-up power system (likely batteries) to ensure that power outages do not negatively impact the controlled growing environment for the plants.

Purchasing a 1,200 m² building in Yellowknife would cost in the neighbourhood of \$2 million, whereas it would be less than half that cost in Fort Smith or Hay River. Currently, there are empty buildings in Yellowknife that could be used for this project, however, availability of such buildings changes constantly.

In Yellowknife, the cheapest location for this project would be in the Kam Lake industrial district. The smallest lots available for purchase there are approximately 20,000 square feet and cost about \$2.75 per square foot, for an empty, ungraded site. There are numerous property owners in Kam Lake who would be willing to rent space on their land for about \$1.00 per square foot per year (Weller, 2013). Rental space in a building in Kam Lake would be in the region of \$10.00 to \$17.50 per square foot, depending on the type and quality of the building.

Systems / Equipment

The main systems and/or equipment required within the building to support the growing and harvesting of crops will include:

- Environmental control system (in addition to standard HVAC system) to control temperature, humidity, CO₂ levels and a uniform distribution throughout the growing area. Specific components will include fans, condensers, chillers, heat exchange units and propane burners for CO₂ enhancement;
- Hydroponic nutrient reservoir and circulating system to deliver nutrient concentrations to the plants. Specific components will include sensors, nutrient concentrate and pH adjustment tanks and plumbing (piping, valves, pumps);
- Multi-colour LED lighting system that can control the colour balance and intensity of each independent growing region. For a total growing area of 2,000 m², approximately 1000 high-intensity LED lighting fixtures and 300 controllers will be required;
- A central computer to monitor and control the systems. The computer will be programmed with a specific environmental recipe for each crop;
- Modular growing beds and associated components;
- Key functions to be performed in the produce handling area include wash down of the area with ozonated water for sterilization, harvesting, trimming, disposal of waste plant material, packaging, chilling, storage and shipping. For the harvesting to packaging stages, the room interior will need to be maintained at 3 C and 95% relative humidity to maintain produce crispness during processing. Equipment requirements will include a trim table, a packaging table, a forced air chiller and cooler for storage.

Capital Cost Estimate

Using the specifications outlined above, Table 5-2 below provides an initial estimate of the capital costs that would be incurred to set up an AgNorth facility in Yellowknife:

Table 5-2: Estimated Capital Cost for a Yellowknife AgNorth Facility

Category / Component	Estimated Capital Cost	Notes
Building Capital and Improvements		
Building cost	\$2,000,000	Kam Lake industrial park
Building envelope upgrade	\$26,000	Assume temperature-controlled warehouse, need to add vapour barrier enclosure. Rough Estimate
HVAC modifications / upgrades	\$65,000 +[Environmental control system]	Add outdoor radiator for circulating glycol loop cooling LEDs and dehumidification of indoor air; Add ERV for air exchanges. Add duct work.
Other Renovations (airlock, offices)	\$25,000	Rough Estimate
Electrical Power		
Connection to grid	\$100,000	\$50K for transformer alone. Would be covered by utility with 25 year guarantee.
3-phase AC wiring to growth units	\$26,000	Rough Estimate
Power factor correction equipment		Assumes a 400 kW average electrical load. [Included in custom LED drive system]
Back-up power system	\$5,000	Small uninterruptable supply for control computers, 10 kW diesel generators for air circulation fan and condensing coil glycol loop to prevent condensation. Propane burner can be used for backup heating in the event of extended outage.
Growing Area		
LED lighting system	\$2,570,000	LEDs lifetime expected to be ~8-10 years if operated year round, at which time the replacement cost will be <50%.
Tray support structures and plumbing	\$282,000	Rough Estimate based on classical greenhouses
Local controllers	\$2,136,000	
Sensors/actuators/harnessing	\$428,000	
Produce Handling Area		
Ozonator, trimming and packaging line	\$2,700	
Forced air pre-cooling area with outdoor exchange fan	\$5,000	Rough Estimate
Cooled Storage area	\$5,000	Rough Estimate
Washroom facilities	\$20,000	Rough Estimate
Header Area		
Environmental Control System	\$7,500	
Hydroponic Nutrient System	\$6,500	
Redundant computers and bus wiring	\$147,000	
CO2 injector system	\$7,000	
Ancillary electronics and H/W	\$1,500	
System assembly and commissioning	\$1,500,000	Rough Estimate (need pilot facility to refine)
TOTAL Budgetary Estimate	\$9,365,200	

The projected cost is a budgetary estimate with no explicit margins applied, and contains significant uncertainty surrounding details of the implementation that will not be worked out until a smaller scale pilot facility is built (see Section 6).

This assessment shows that the high tech growing area lighting and control system will drive the cost. Note that this is an estimate of the capital cost at today's LED cost. The price for electronic components includes projected bulk purchase savings. The cost per watt of LED illumination is decreasing rapidly and this line item will probably halve in the next 5-10 years.

5.1.3 Annual Inputs, Outputs and Operating Costs

As noted earlier, the sales for this scenario are projected to be \$1.0 million per year which implies average annual production of 150,000 to 200,000 kg of produce, depending on the actual crop mix grown.

Table 5-3 below provides a breakdown of the estimated quantities of the key inputs required to grow 150,000 to 200,000 kg of produce per year, the waste outputs that would be generated at this level of production and the estimated annual costs:

Table 5-3: Estimated Annual Operating Costs for Yellowknife Facility with \$1.0 Million Annual Sales

Category / Component	Estimated Operating Cost	Notes
Produce Production		
Seeds	\$12,500	Based on \$1.50 m ⁻² per crop cycle
Nutrients	\$6,910	\$0.68/kg based on cost of raw nutrients
Growing Media	\$25,000	Based on \$3 m ⁻² per crop cycle
Utilities		
Power	\$630,000	~400 kW average load and 3.5 GWh/yr at YK commercial demand and energy rates
Water	\$2,500	~750 K litres (YK rate \$14.57 per 4,550 l / month)
Propane	\$29,280	Yellowknife commercial rate of \$0.60 / liter + \$190/month tank rental (1,000 L)
Heat	\$0	The facility will need to shed excess heat created by the LED lights
Labour		
Horticulturalist / Manager	\$80,000	Assumed annual salary of \$80,000
Other staff	\$80,000	1 person at \$55,000, 1 staff at \$25,000
General Overhead		
Maintenance	\$25,000	Rough Estimate
Packaging Supplies	\$25,000	\$0.15/kg rough estimate.
Administration	\$0	Assume run by Manager
Waste disposal	\$12,000	Plant waste = ~10,000 kg / month @ \$99/tonne ³ . Likely less, due to municipal composting facility in YK
Insurance	\$10,000	Rough Estimate
Monitoring (UofG)	\$18,000	20% Research associate time
Estimated Operating Cost	\$956,190	

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http://www.yellowknife.ca/City_Hall/Departments/Public_Works_Engineering/Solid_Waste_Management/TippingFees.html

5.1.4 Yellowknife Scenario B – Conventional Greenhouse Add-on

Scenario B looks at reducing power costs by making use of the abundant sunlight available in NWT during summer months. To do this effectively, one would need to build a large conventional hoop-house growing operation that would be daisy-chained from the hydroponic supply hardware. In this scenario, production would be switched between the two parallel facilities on a seasonal basis. By turning off the lights for 6-9 months of the year, the entire facility power budget will be cut in half.

In order to maintain the same rate of production for institutional customers, a much larger growing footprint would be needed. It is expected that a conventional greenhouse using available solar radiation would need a factor of 2 to 2.5 times more growing area for the same productivity rates. This corresponds to a rather large parallel hoop-house with 5000 m² of single-level growing area, and a footprint of up to 2 acres. One would expect that part-time labour and maintenance costs would double in order to handle the larger growing area. This scenario has the added advantage of doubling the LED system lifetime to 16-20 years at which time replacement costs are expected to be much smaller.

In terms of the capital costs, the estimated additional costs are estimated to be in the order of \$1 million, including ~\$600,000 for the greenhouse, ~\$250,000 for land and up to \$200,000 if leveling is required.

The projection shown in Table 5-4 assumes that all land and buildings are owned. This corresponds to an initial capital investment estimated at \$10.3 Million.

Table 5-4: Estimated Annual Operating Costs for Hybrid Yellowknife Facility Conventional Greenhouse

Category / Component	Estimated Operating Cost	Notes
Produce Production		
Seeds	\$15,000	Based on \$1.50 m ² per crop cycle
Nutrients	\$6,910	\$0.68/kg based on cost of raw nutrients
Growing Media	\$37,000	Based on \$3 m ² per crop cycle
Utilities		
Power	\$315,000	~400 kW average load and 1.8 GWh/yr at YK <u>commercial</u> demand and energy rates
Water	\$3,000	~750 K litres (YK rate \$14.57 per 4,550 l / month)
Propane	\$59,280	Yellowknife commercial rate of \$0.60 / liter + \$190/month tank rental (1,000 L)
Heat	\$0	The facility will need to shed excess heat created by the LED lights
Labour		
Horticulturalist / Manager	\$80,000	Assumed annual salary of \$80,000
Other staff	\$105,000	1 person at \$55,000, 2 staff at \$25,000
General Overhead		
Maintenance	\$50,000	Rough Estimate
Packaging Supplies	\$25,000	\$0.15/kg rough estimate.
Administration	\$0	Assume run by Manager
Waste disposal	\$12,000	Plant waste = ~10,000 kg / month @ \$99/tonne ³
Insurance	\$15,000	Rough Estimate
Monitoring (UofG)	\$18,000	20% Research associate time
	\$741,190	

5.1.5 Potential Up-side Opportunities

Wholesale prices currently being paid for 10-day-old perishable food may not reflect the quality premium that a local grower might expect to receive. Loblaw's, for example, has a "Canada First" commitment to source local and regional products "when the safety, quality, availability and value are right for our customers." Private discussions suggest that 85-90% of retail could be realized in such a case. Similarly, a co-operative or subscription agriculture-marketing model has been successfully demonstrated in many areas to allow entrepreneurial farmers access to the retail market. Either of these approaches could provide a significant mark-up from wholesale prices that typically range from 50-75% of retail. Wholesale trucked-in food prices may rise faster than other operating costs if fuel prices continue to advance.

- Potential revenue increase of up to ~\$400,000/yr.

The facility will produce significant amounts of waste heat from the electricity used to power the LED lights. The baseline assessment assumes that this waste heat is all radiated to the outdoor environment. If a neighbouring customer can be found for this waste heat, the power costs can be significantly defrayed. It is estimated that approximately 300 kW of waste heat would be available from this facility all winter. This heat could be concentrated using an industrial heat pump, with a value of up to \$0.136/kWh, at an additional cost of only \$0.08/kWh of delivered heat.

- Potential operating savings up to \$100,000/yr if a large enough customer can be found.

The City of Yellowknife is studying the possibility of starting an anaerobic bio-gas digester at the local dump. Proponents are looking for a guaranteed customer for 250 kW of year-round power to alleviate risks. They project the cost of this power will be 9.3 cents/kWh vs. the commercial rate of 15.99 cents/kWh. This is not an approved project, and a negotiation would be needed to purchase discounted power. Another option is to locate outside of the city limits where commercial power rates are lower.

- Potential operating savings of \$100,000/yr for every 2.5 cents reduction in electrical tariff.

The facility will produce a significant amount of plant waste material. Currently, disposal of this is included as an expense; however, this is a potential resource that can produce high quality compost. High quality topsoil is a useful commodity in much of the NWT.

- Potential additional revenue source \$50,000/yr for high quality topsoil

Best-guess productivity estimates put forward for this facility could be underestimates of what is actually achievable with combined control of lighting quality and future ion-specific nutrient management techniques emerging from the ongoing research program at U Guelph CESRF. This element is the largest single uncertainty in the economic modeling and will be verified at the pilot scale on a crop-by-crop basis (see Section 6).

5.1.6 Down-side Risks

Potential down-side risks include the long-term reliability of the facility hardware in the northern climate. If any portion of the growth module has an intrinsic or systematic failure mode, it could cost a significant fraction of the capital budget to fix. For this reason, a smaller scale pilot facility is strongly recommended in a northern climate as a precursor risk reduction activity (see Section 6).

The amount of labour projected to operate the system assumes that a high quality motivated entrepreneur with a solid horticultural background is available to lead the work. There are numerous

ways that a sub-par effort could disrupt the projected revenue stream. These include non-sanitary handling procedures, and careless food handling leading to a low quality product. If the operator is not making use of the full production potential of the system due to planning of crops and varying customer demands, revenues can also be affected. Pests and disease can be introduced through carelessness, leading to drastic losses.

Significant productivity improvements have been assumed over state-of-the-art solar greenhouses based on the stated expectations of the world leaders in this field. It is not inconceivable that projected productivity improvements are not borne out under real-world conditions. This element is the largest single uncertainty in the economic modeling and will be verified at the pilot scale on a crop-by-crop basis (see Section 6).

5.1.7 Discussion

The analysis above suggests that an AgNorth facility built in Yellowknife to serve 40% of the NWT wholesale market for cherry tomatoes, red peppers, romaine lettuce, fresh herbs and strawberries will produce \$1 million in sales. It would require a capital investment in the range of \$9-10 million and is expected to yield a modest \$50K/year profit. Again, these projections could be vastly improved with negotiated power rates, alternative energy options, or the sale of waste heat discussed in Section 5.1.5. As well, the addition of a 2 acre summer greenhouse would decrease costs by over \$200 K/yr (at a capital cost of \$1 million).

Without realization of these up-side opportunities, there is currently not sufficient profit potential for a private entrepreneur to expect their capital investments to pay off in a reasonable time scale. A substantial government role, either in terms of capital investment or reduced power rates, is therefore likely necessary for further advancement of the concept.

There are good reasons to believe that government investment is commensurate with the returns to the community. The macro-economic benefits to the local economy are significant. Ontario's greenhouse industry, for example, has an economic multiplier of 2.81. That means that for every dollar of greenhouse activity, the economy as a whole experiences output impacts of \$2.81⁴. This operation should be expected to add on the order of \$2-3 million to the local Yellowknife economy through jobs and other indirect benefits.

In summary, the project team recognizes that the economic viability of the AgNorth concept remains to be confirmed. However, if some arrangement for reduced power rates can be found, there may be a significant opportunity to operate an AgNorth facility in Yellowknife on for-profit basis with significant indirect benefits to NWT residents health and the local economy.

5.2 South Slave Regional Scenario

Another approach to provide communities with fresh produce is to set up AgNorth facilities in several regional centres to supply local needs, including surrounding communities. The intent of the analysis is to gauge whether the regional approach appears to be practical and therefore worthy of additional consideration in the next phase of the project. The analysis assessed two key parameters, namely the

⁴ <http://www.greenhousecanada.com/content/view/1017/38/>

impact of a change in the scale of operations and the impact of different power rates (by changing the community location).

For this scenario, two regions, the South Slave and Beaufort-Delta, were considered. While the Beaufort-Delta region is most in need given the high costs of food, and the fact that it is the farthest from current supply chains, it was eliminated from consideration in this study due to the energy supply crisis currently being experienced in Inuvik which is necessitating the use of diesel generators to supply power. The South Slave region was selected for analysis as most of the communities are connected to the all-weather highway system and the region receives its produce supply directly from Edmonton (not via Yellowknife).

In order to assess the economic viability of a regional approach, the scale of operation was reduced to one-half, i.e. a facility capable of producing 75,000 to 100,000 kg of produce, serving approximately 8,000 people with annual sales revenue of \$500,000. Given the smaller population base in the region, it is likely that the mix of crops would include more variety (with smaller annual quantities) than compared to the Yellowknife scenario.

To see how this size of operation may fare under different power rates, consideration was given to locating the facility in either Hay River or Fort Smith.

Hay River Location

The fact that much of the NWT's current agricultural capacity is located in the Hay River area suggests that there may be local interest in having an AgNorth facility set up in that location. As well, Hay River is centrally located to distribute produce to numerous communities within a few hours' drive. To be clear, this concept has not yet been discussed with the Territorial Farmer's Association and is not intended to impact in any way on the crops and local markets served by existing farms.

Table 5-5 (next page) provides an overview of the annual operating costs for a facility producing \$500K in sales in Hay River. Based on this analysis, a facility in Hay River would operate with an annual deficit of \$115K. However, the possibility of obtaining a special "agricultural" power rate has not been discussed with Northland, the local power distributor. There may be some opportunity to seek a special power rate as Hay River is served from the Taltson power grid, which has significant excess hydropower available. Again, this does not take into account a return on investment for capital costs.

Fort Smith Location

Two advantages that a Fort Smith location may provide include support from the Aurora Research Institute (which has an office in Fort Smith) and access to the lowest power rates in the NWT.

Commercial rates for energy are \$0.13/kWh in Fort Smith, compared to \$0.22/kWh in Hay River. This represents a savings of \$124K/year, which would result in a break-even proposition. If a special agriculture power rate could be obtained (\$0.0844/kWh is the Taltson Zone rate from NWT Power Corporation), this would reduce the annual power costs to about \$170,000, resulting in approximately \$100K/year profit.

Table 5-5: Estimated Annual Operating Costs for Hay River Facility with \$0.5 Million Annual Sales

Category / Component	Estimated Operating Cost	Notes
Produce Production		
Seeds	\$6,250	Based on \$1.50 m ² per crop cycle
Nutrients	\$3,455	\$0.68/kg based on cost of raw nutrients
Growing Media	\$12,500	Based on \$3 m ² per crop cycle
Utilities		
Power	\$386,040	~200 kW average load and 1.75 GWh/yr at Hay River <u>commercial</u> demand and energy rates (\$0.22/kWh)
Water	\$1,500	A rough guess for ~375 K litres per year. Need water meter sizing to calculate exact costs.
Propane	\$14,640	Hay River commercial rate of \$0.60 / liter + \$190/month tank rental (1,000 L)
Heat	\$0	The facility will need to shed excess heat created by the LED lights
Labour		
Horticulturalist / Manager	\$80,000	Assumed annual salary of \$80,000
Other staff	\$40,000	Assuming part-time employees
General Overhead		
Maintenance	\$20,000	Rough guess.
Packaging Supplies	\$15,000	\$0.15/kg rough estimate.
Administration	\$0	Assume run by Manager
Waste disposal	\$6,000	Plant waste = ~5,000 kg / month
Insurance	\$10,000	Estimate
Monitoring (UofG)	\$18,000	20% Research associate time
TOTAL	\$615,405	

5.3 Community Scenario

At the outset of this project, there were some expectations that the AgNorth modular farm concept could be deployed at a community level. If practical, this approach could provide remote communities with a continuous supply of fresh produce, which would greatly reduce food insecurity, help improve nutrition and provide local economic opportunities and jobs.

With the cost of fresh produce much higher in remote communities (sometimes as much 5 times higher), it would seem that the economic potential would be greater. However, there are some compelling factors that suggest that community-scale AgNorth modular farm operations are not practical in the near-term (i.e. next 5-10 years) and may never be practical. These factors include:

- Technical Complexity – the installation, operation and maintenance of computer-controlled LED lighting and hydroponics systems, as well as the specialized building modifications (electrical, HVAC, plumbing etc.) required to support the operation of an indoor modular farm, all requires immediate and continuous access to certified tradespeople and the involvement of an experienced horticulturalist. These skill sets are not typically available, on demand, in the smaller communities;
- Electricity Supply / Cost – location in communities served with diesel-electric power is simply not feasible, both from a power supply perspective and from a cost perspective; and
- Capital costs – it is more expensive to build and maintain the operations in a remote location.

5.4 Evaluation of Scenarios

The following criteria were selected to provide an objective basis for evaluating the different scenarios for a modular farm facility:

Mandatory Factors

Mandatory criteria represent “showstopper” considerations that must be satisfied for a scenario to be considered operationally viable. These include:

- Suitable building available;
- All required inputs available (i.e. skilled labour, power supply, propane supply, etc.); and,
- Able to satisfy regulatory (health, safety etc.) requirements.

Market & Economic Factors

Market and economic criteria include the degree of access to customers and whether the scenario is likely to require a subsidy or operate at breakeven or for a profit. Specific criteria include:

- Capital costs to establish the facility;
- Cost of required inputs such as water, electricity and labour;
- Availability of potential wholesale or retail customers to buy the produce (including costs and complexities of shipping to those customers);
- Overall economic viability; and,
- Degree of risk or market uncertainty involved.

Public Interest Factors

Public interest criteria represent desirable outcomes that are in the general public interest such as health benefits, improved food security, economic opportunities or “spin-off” benefits. Specific criteria include:

- Opportunity to provide NWT residents with improved access to higher quality produce;
- Opportunity for increased local / regional economic development and/or employment; and,
- Opportunity to contribute to other NWT objectives such as development of local energy supply options, reduced greenhouse emissions, etc.

5.4.1 Evaluation Results

In applying these criteria to the findings presented in this report, the project team reached the following conclusions:

1. The AgNorth modular farm concept has the potential of satisfying most, or all, of the criteria listed above if such a project is located in either Yellowknife (to serve as much of the NWT as possible) or in one (or more) regional locations such as Fort Smith or Hay River (for access to lower-cost power); and,
2. There are too many technical and economic difficulties involved to consider setting up numerous AgNorth farms in small communities serving only local produce requirements at this time;

3. The key issues that need to be examined more closely (for either a Yellowknife or regional facility) to improve the potential economic and public interest benefits include:
- Customer Input – the \$1.0 million annual sales figure, selection of crops and wholesale pricing used in this analysis was based on research but did not reflect negotiations with potential customers. The actual scale of operation and crop selection should be derived based on what customers indicate they are willing to purchase and at what prices;
 - Specific Location – once a particular scale of operation is determined, efforts will be required to determine if a suitable building can be secured for the facility or if new construction is required;
 - Capital Cost Estimate – the planned scale of the operation and the existing state of the building (or need to construct a new building) will be the key determinants of the capital investment required;
 - Electricity Supply / Cost – the planned scale of operation and actual crops to be produced will determine the actual electrical load and annual energy requirements. With electricity representing about 50% of the annual operating costs, some arrangement for cheaper power (or means of using less power) needs to be found;
 - Labour Costs – ideally, the personnel required to run the facility should be closely matched to the size of the operation. However, the skills of an experienced horticulturalist are required regardless of the size of the operation. To that extent, the smaller the operation, the larger the labour cost component will become as a percentage of the total annual costs; and,
 - Secondary Opportunities – there may be opportunities to use the waste organic material for composting or as feedstock for power generation. Depending on the site location, there may also be an opportunity to provide waste heat to another building close by.

6 NEXT STEPS

The full development of a NWT modular farm station industry will likely take some years to achieve. The intent of this section is to provide an overview of the suggested steps moving forward.

6.1 Science and Technology Roadmap

This section outlines the technical tasks necessary to bring this technology from the laboratory to operation in an economically feasible way. Successful implementation of the modular farm station vision is based on the following scientific and technical milestones.

6.1.1 Technical Prototype Farm

Currently, the University of Guelph and COM DEV are securing independent funding through NSERC, Ontario Centres of Excellence and the Kuwait Institute for Scientific Research to build a prototype AgNorth module farm at the University of Guelph. This in-kind investment and research is critical to mitigating some technical risks and moving forward with a NWT facility. The University of Guelph's Controlled Environment Systems Research Facility (CESRF) is the world leader in controlled environment agriculture, providing horticultural growth chambers and consulting on advanced life support programs to space agencies around the world. They are currently working on several variations of controlled environment growth chambers and LED arrays, which are providing the research and development venue for continued technology transfer to the AgNorth modular farm application as it develops and beyond.

Specifically, the prototype will be used to address the following engineering risks:

- Demonstrate the expandability and modularity of the design concept;
- Demonstrate environment control and uniformity under varying weather conditions;
- Ensure electrical and mechanical systems are properly sized to handle real-world conditions;
- Test and refine operational procedures over a full crop cycle in a representative facility;
- Demonstrate survival of hardware freeze-up and system recovery from power loss;
- Verify estimates of resource requirements in operation (power, nutrients, CO₂, water);
- Verify productivity estimates on target crops under real conditions;
- Identify any hidden assembly and construction costs;
- Identify unnecessary elements and costs that can be eliminated; and,
- Identify any reliability, human factors, or interface issues where they can be easily addressed.

The first part of the prototype research is expected to be concluded by early 2014 and lessons learned will be incorporated into a pilot plant at a location to be determined. This facility will also be used to accelerate the crop production research discussed in the next section, and thereby verify the economic models developed under the feasibility study. This facility will demonstrate a working model of the system to private investors and entrepreneurs and serve as an early training facility for prospective modular farm operators. The facility will also be used for development and testing of incremental improvements such as improved recycling of nutrients, remote horticultural monitoring and automation.

6.1.2 Crop Production Research and Development

To obtain the optimum growth rate and productivity in a crop, a farmer would prefer to control several environmental factors including temperature, atmospheric composition, nutrient composition, and lighting spectrum and intensity. Many researchers have shown that optimizing a few of these variables in isolation can lead to an increase in food production efficiency in a controlled environment system. Experiments show that adjusting only the light spectrum using modern LEDs can, in some cases, double or triple standard greenhouse productivity. By carefully controlling all of these environmental parameters we expect to provide similar enhancements in productivity in all of our target crops.

The CESRF at the University of Guelph is unique in the world having, over the past two decades, developed the necessary research infrastructure to efficiently address these issues. CESRF is currently the home of a NSERC Collaborative Research and Development (CRD) project entitled Innovative Technologies In Challenging Environments (InTICE). This project includes the support and collaborative contributions of COM DEV Ltd. and the Canadian Space Agency and represents the leading edge of technology developments in controlled environment systems for food production. They are developing detailed lighting and nutrient management strategies for target crop species, specifically tailored to each physiological stage of plant development (i.e. germination, viniferous growth, flowering, and biomass production).

This is an ongoing activity (2012-14), which will continue to engage AgNorth proponents (Dixon – CESRF, Scott – COM DEV) in development initiatives specifically relevant to the modular farm concept. This project and follow-on research projects at the CESRF will continue to provide training and technology transfer opportunities for AgNorth in areas such as LED lighting, horticultural management for specific commodities, nutrient management strategies and sensors and other environment control requirements for the modular farm. This ongoing technology transfer and support role of the CESRF in relation to AgNorth is specifically proposed in their current and future R&D activities.

6.2 Partnership and Pilot Planning

As a result of the discussions and research that were carried out during the development of this report, a number of potential stakeholders and partners have been identified. These include local growers, distributors, investors, aboriginal governments and businesses, utilities, alternative energy suppliers, and government agencies. Many of these have already expressed interest in the potential for commercializing AgNorth, albeit informally. The next step is to secure partners to participate in development of a pilot AgNorth facility, and eventually a commercial enterprise.

The AgNorth team plans to carry out bilateral meetings with as wide a range of potential stakeholders as possible to discuss report findings and their potential for involvement in the pilot facility and/or a commercial facility. Potential partners will be invited to Guelph to visit the prototype facility (see above) and discuss design considerations with the technical team (COMDEV and University of Guelph).

Once the partners are realized, they will collaborate to develop a plan for a NWT AgNorth Pilot Facility. A stakeholder workshop will be held in Yellowknife to bring potential partners together to build a vision for the AgNorth pilot project. The technical design team (University of Guelph and COMDEV) will create technical specifications for the pilot.

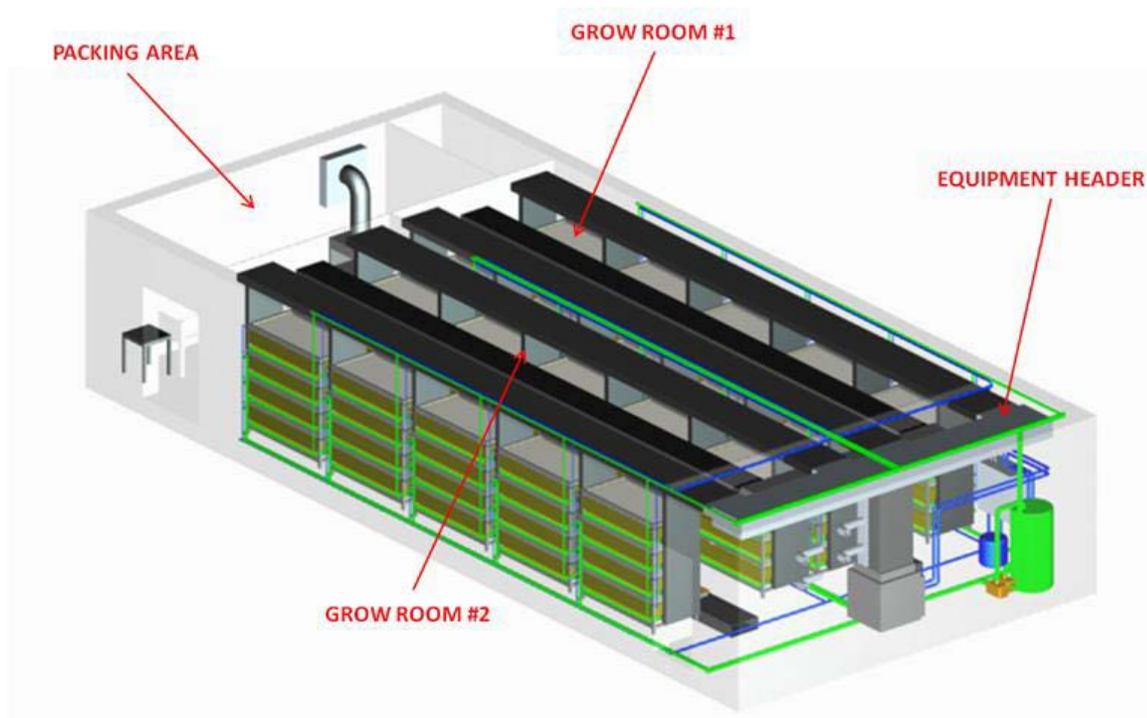
6.3 Technology Transfer: NWT Pilot Facility

The general purpose of the pilot facility would be to verify the expected technical and economic performance of the AgNorth concept and provide customers with an opportunity to gauge the quality of the produce grown. Specifically, it is suggested that the pilot project focus on the following objectives:

- Confirming the building requirements, layout and specifications needed to support a viable AgNorth operation;
- Gathering operational data to enable additional refinements to be made in critical systems such as the CO², humidity, LED lighting, nutrients etc. to ensure optimal growing conditions can be established and maintained;
- Confirming the expected horticultural performance (i.e. output, quality, taste);
- Obtain operational experience to help determine an optimal scale of operations (or range of options); and,
- Confirm customer interest in longer-term produce supply arrangements and determine the specific crops and wholesale pricing that would be involved if a permanent facility is built; and,
- Verify the capital investment needed and overall financial viability of a permanent AgNorth facility.

Figure 6-1 shows a perspective view of a 20-module pilot facility that is envisioned as a precursor to the full operational facilities discussed in Section 5. This 24 x 57 foot ~60 kW modular growth facility would be designed to grow a single crop, and would have the capability to supply the current consumption needs of about 3,500 people. The hardware and building upgrades, software development and integration could be done for <\$2 million, as a rough order of magnitude. If located inside an existing facility, most of the waste heat could be used to offset heating costs during the winter.

Figure 6-1 AgNorth Pilot Facility, perspective view



APPENDIX A: REFERENCES

Publications

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Web Sites

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Canadian Diabetes Association (www.diabetes.ca)

Northern Foodservices (www.nwtfood.com)

Nutrition North Canada (www.nutritionnorthcanada.ca)

Northern Stores (www.northernstores.ca)

NWT Bureau of Statistics (www.statsnwt.ca)

Statistics Canada, CanSim (www5.statcan.gc.ca/cansim)

NWT Water Regulations (laws-lois.justice.gc.ca)

Reference Listing of Accepted Construction Materials, Packaging Materials and Non-Food Chemical Products (active.inspection.gc.ca/scripts/fssa/reference/reference.asp?lang=e)

Territorial Farmers Association (www.farmnwt.com)

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Bouwa Whee Catering, Aug. 22 2012 Snap Lake Mine 12 months produce wholesale by commodity with cost (FOB Yellowknife)

Northern Food Services, Feb. 16, 2013, 12 months produce wholesale, by commodity with cost (FOB Edmonton), and sell price (FOB Yellowknife)

Extra Foods Yellowknife, Mar. 8, 2013, re: pricing of locally grown produce;
Apr. 2, 2013, 1 month selected produce volume and total sales

Northern Stores, Feb. 20, 2013, 12 months produce volume, by commodity and community

Yellowknife Co-op Store, Feb. 13, 2013, monthly volume and average retail, selected produce

Arctic Co-op Stores, Feb 19, 2013, annual aggregate volume, selected produce categories

CH Robinson, Canada, Feb. 19, 2013.

SYSCO Edmonton, Feb. 15, 2013, annual volume estimate, fresh produce, to NWT

GNWT Bureau of Statistics, Jan. 21, 2013.

Gordon Food Services Inc., (April, 2013) annual volume estimate, fresh produce, to NWT

APPENDIX B: MARKET DEMAND DATA

Table B-1 shows the mean and median spending per day and consumption per day in the Beaufort Delta by commodity (Aboriginal and Global Health Research Group, 2013).

Table B-1 Aggregate Beaufort-Delta Aboriginal Fruit/Vegetable Consumption Per Adult by Commodity

Food name	Mean (\$/day)	Median (\$/day)	Mean (g/day)	Median (g/day)
Any vegetable soup- tomato, mushroom, celery	0.25	0.09	69.24	27.21
Orange, fresh	0.17	0.08	26.05	10.92
Apple, fresh	0.11	0.03	16.82	4.61
Banana, fresh	0.14	0.08	24.11	11.33
Pear, fresh	0.05	0	7.11	0
Strawberries or other berries, fresh	0.18	0	6.92	0
Grape	0.18	0.07	17.94	6.27
Any canned fruit e.g. pineapple, mandarin, fruit cocktail in syrup	0.21	0.1	32.7	17.92
Any canned fruit e.g. pineapple, mandarin, fruit cocktail in natural juice	0.07	0	10.08	0
Fruit, frozen (incl. blueberries or mixed fruits)	0.1	0	7.72	0
Fruit salad fresh	0.12	0	8.35	0
Fruit, dried, any kind	0.07	0	4.64	0
Potato, mashed incl. instant	0.13	0.07	30.55	17.17
Potato baked, boiled or roasted	0.05	0.02	10.12	5.15
Hash browns or fried potato French fries	0.14	0.06	22.21	10.39
Carrot, raw or cooked incl. baby carrot	0.08	0.04	12.14	5.75
Frozen vegetables, any kind, incl. mixed vegetables	0.12	0.04	16.4	5.17
Cauliflower or Broccoli	0.07	0.01	7.45	1.97
Vegetables, canned, incl. corn or peas	0.08	0.02	10.24	2.95
Coleslaw or potato salad	0.08	0.03	8.75	2.99
Vegetable salad, any kind	0.07	0.02	3.15	1.17
Pie, fruit any kind	0.08	0	6.31	0

Table B-2 provides an estimate of the price per kilogram that the sample group was paying and the annual expenditure and consumption levels by commodity (Aboriginal and Global Health Research Group, 2013).

Table B-2 Aggregate Beaufort-Delta Retail Pricing and Aboriginal Per Capita Spending and Consumption Per Commodity

Food name	\$/kg	\$/yr	kg/yr
Any vegetable soup- tomato, mushroom, celery	\$ 3.61	\$ 91.25	25.3
Orange, fresh	\$ 6.53	\$ 62.05	9.5
Apple, fresh	\$ 6.54	\$ 40.15	6.1
Banana, fresh	\$ 5.81	\$ 51.10	8.8
Pear, fresh	\$ 7.03	\$ 18.25	2.6
Strawberries or other berries, fresh	\$ 26.01	\$ 65.70	2.5
Grape	\$ 10.03	\$ 65.70	6.5
Any canned fruit e.g. pineapple, mandarin, fruit cocktail in syrup	\$ 6.42	\$ 76.65	11.9
Any canned fruit e.g. pineapple, mandarin, fruit cocktail in natural juice	\$ 6.94	\$ 25.55	3.7
Fruit, frozen (incl. blueberries or mixed fruits)	\$ 12.95	\$ 36.50	2.8
Fruit salad fresh	\$ 14.37	\$ 43.80	3.0
Fruit, dried, any kind	\$ 15.09	\$ 25.55	1.7
Potato, mashed incl. instant	\$ 4.26	\$ 47.45	11.2
Potato baked, boiled or roasted	\$ 4.94	\$ 18.25	3.7
Hash browns or fried potato French fries	\$ 6.30	\$ 51.10	8.1
Carrot, raw or cooked incl. baby carrot	\$ 6.59	\$ 29.20	4.4
Frozen vegetables, any kind, incl. mixed vegetables	\$ 7.32	\$ 43.80	6.0
Cauliflower or Broccoli	\$ 9.40	\$ 25.55	2.7
Vegetables, canned, incl. corn or peas	\$ 7.81	\$ 29.20	3.7
Coleslaw or potato salad	\$ 9.14	\$ 29.20	3.2
Vegetable salad, any kind	\$ 22.22	\$ 25.55	1.1
Pie, fruit any kind	\$ 12.68	\$ 29.20	2.3
Total Fruit/Veg per adult per year		\$ 930.75	131

Table B-3 provides a summary of the data related to fruit and vegetable consumption available from Statistics Canada (2009):

Table B-3: Per-Capita Fruit and Vegetable Consumption in Canada

Consumption Category	Fresh Fruits (kg)	Processed Fruits (kg)	Fresh Vegetables (kg)	Processed Vegetables (kg)	Total Fresh and Processed (kg)
Unadjusted for losses	73.8	9.9	139.6	19.2	242.5
Adjusted for losses	39.3	8.4	68.6	14.0	130.3

Table B-4 provides a comparison of produce costs in different communities based on information from NWT Bureau of Statistics (2012) and Nutrition North (2012).

Table B-4 Retail Price Comparison of Selected Produce Items by Community and Region NWT, Jan 2012⁵

	Iceberg Lettuce (Per Head)	Yellow Onions (Per kg)	Green Peppers (Per kg)	Strawberries (Per kg)	Nutrition North Subsidy (per kg) ⁶
Beaufort-Delta					
Aklavik	\$3.74	\$4.89	\$9.99	\$14.25	\$1.60
Fort McPherson	\$2.99	\$3.54	\$7.60	\$18.04	
Ulukhaktok	\$3.99	\$5.39	\$6.29	\$17.60	\$4.50
Inuvik	\$3.42	\$3.39	\$6.99	\$10.99	
Tuktoyaktuk	\$3.07	\$4.09	\$5.99	\$18.70	\$2.50
Sahtu					
Délj̄ne	\$5.64	\$5.02	\$14.59	\$24.98	\$2.70
Fort Good Hope	\$3.49	\$6.32	\$9.92	..	\$2.90
Norman Wells	\$3.35	\$5.17	\$10.29	..	\$2.20
Deh Cho					
Fort Liard	\$2.02	\$3.75	\$5.71	\$14.91	
Fort Providence	\$2.50	..	\$8.36	\$10.35	
Fort Simpson	\$3.37	\$1.20	\$1.99	\$16.06	
South Slave					
Fort Smith	\$1.84	\$2.39	\$5.82	\$9.85	
Hay River	\$1.32	\$2.21	\$7.73	\$9.45	
Tłjchq					
Whati	\$3.60	\$3.14	\$4.66	\$9.90	
Yellowknife					
	\$1.98	\$3.20	\$4.60	\$8.23	

Notes:

- NWT Communities with only one store are not shown due to confidentiality restrictions
- '..' means data is not available

⁵ NWT Bureau of Statistics January 2012 Community Price Survey

⁶ Nutrition North website January 2013, for 2011-2012 (Level 1 perishable food)

APPENDIX C: AgNorth Productivity Model Detailed Description

The productivity model starts with published values of biomass productivity and the ratio between edible and inedible biomass under known lighting conditions as provided by the NASA Advanced Life Support Baseline Values and Assumptions Document (NASA/CR—2004–208941) and references therein. From this starting point, the model provides a reasonable extrapolation to the lighting intensity, and growth efficiency that is thought to be achievable for each commodity based on similar developments.

A leading example is in the production of dwarf tomatoes. Based on Wheeler (2003), the NASA BVAD shows that a biomass productivity of 65 kg/m²/yr can be achieved for this crop when grown from seed in a 50 cm high tray under fluorescent lighting without replanting. AgNorth can increase this areal productivity substantially by:

- Having workers transplant seedlings to maintain efficient packing of plants throughout the growth cycle in a dense canopy.
- Using LED growth wavelengths scientifically shown to increase photosynthesis rates over classical broadband sources.
- Choosing LED light spectra and nutrient management regimes to selectively increase the edible to inedible biomass ratio of specific crops and increase overall productivity.
- Adjusting the environmental conditions and lighting to allow longer day growth cycles while mitigating leaf damage and providing more uniform light distribution to the canopy.

Based on experiments using simple supplementary high-pressure sodium and enhanced CO₂ pressures, Verheul et al., 2012, suggest that tomato productivity of up to 140 kg/m²/yr is realistic⁷. Our model estimates that 119 kg/m²/yr tomato productivity will be achieved in our facility.

Baseline Model Inputs

All estimates are based on a standard growth module with 2 m² of growing area per level, and either 3 or 4 levels (depending on crop).

Inputs which vary by region

Government Subsidy (\$/kg):	\$0	Possible negotiation to compete with Nutrition North subsidy
Price of electricity \$/kWhr	\$0.1599	Based on Yellowknife commercial rate to \$0.0844 negotiated special agriculture rate
Utility Cost per year	\$14.68*12*Power (kW) + \$190 *12	YK demand charge + 1,000 gallon propane tank rental ⁸
Per litre cost of water	\$0.00299	Published YK rate
Fixed FTE wage	\$55,000+\$80,000	Section 4.1.7
Labourer wage	\$25,000	Section 4.1.7

Fixed inputs

⁷ M.J. Verheul, H.F.R. Maessen, and S.O. Grimstad, "Optimizing a Year-round Cultivation System of Tomato Under Artificial Light", 7th International Symposium on Light in Horticultural Systems, ISHS Lightsym2012.)

Number of Modules	260	size of facility
Crop area/unskilled labourers	2000 m ²	this is for unskilled support and scales the labourer wage with size of facility. See Section 4.1.6
Food Wastage	10%	This is reasonably achievable with careful produce management and timely harvesting practices
Fertilizer Costs (\$/kg):	\$6.84	Retail estimate with volume markdown
Propane Costs (\$/L)	\$0.6001	current price of liquefied propane ⁸)
CO₂ Level	600 ppmV	enhanced control point of atmospheric system
Annual Maintenance (\$/module)	\$200	estimated based on engineering expertise and U Guelph experience
Operating Temperature	295 K	control point of atmospheric system
Relative Humidity	70%	control point of atmospheric system
Humidity Recapture	50%	based on use of an ERV for forced air exchange
Air Exchange Rate	40/dy	estimated based on engineering expertise to minimize buildup of ethylene and oxygen
Cleaning Water Usage	10,000 L/yr/module	rough estimate based U Guelph experience
R-Value	5 m ² K/W	based on engineering design and recommendation of Arctic Energy Alliance
Heat Recapture	25%	based on design of air-exchange system and leak rate vs. forced exchange rate
LED Drive Efficiency	96%	based on design analysis
LED distribution efficiency	90%	based on expected losses
Starting Year	2016	based on commercial roadmap
Red/Blue photon flux ratio	3	based on typical growth application
Peak Intensity	800 μmol/s/m ²	based on predicted intensity for maximum productivity
LED annual cost decrease	13%	based on commercial trend over the past 5 years
LED annual efficiency increase	6.5%	based on decadal trend and laboratory demonstration of continuing improvements

The following inputs are taken directly from minimum specifications on selected LED datasheets and quotations from manufacturers:

Red LED efficiency (μmol/s/W)

Blue LED efficiency (μmol/s/W)

Baseline productivity estimates

The following inputs are taken from the NASA BVAD 2004 and references therein.

Edible biomass (kg/m²/dy)

Light fluence (mol/m²/dy)

Photoperiod (h/dy)

Light Flux (μmol/m²/s)

Inedible biomass (kg/m²/dy)

CO₂ fixation (kg/m² /dy)

Crops assessed:

Dwarf Tomato; Lettuce; Strawberry; Onion; Pepper; Snap Bean; Spinach; White Potato; Pea; Wheat

⁸ Telephone quotation, Feb. 3 2013, Superior Propane, Yellowknife @~1,000 L/mo.

Productivity Model

The Productivity Model calculates the mass of edible biomass that can be produced per module per year for each crop. NASA BVAD productivity data is scaled linearly with daily-applied fluence based on U Guelph expert assessment of the safe limits for each crop for Photoperiod and Light Flux up to a maximum of $800 \mu\text{mol/s/m}^2$ of photosynthetically active radiation. A 25% across-the-board areal productivity increase is assumed based on expected improvements in average crop density achieved by appropriate replanting of seedlings, and improvements in quantum efficiency achieved through spectral optimization and inter-canopy lighting distribution. These estimates will be verified through testing in the prototype facility and through ongoing R&D at the University of Guelph.

Water and Fertilizer Usage Model

Humidity loss is estimated based on the **Air Exchange Rate**, the **Relative Humidity**, and the **Humidity Recapture** percentage.

Water use for plant growth is simply estimated based on the total biomass produced.

Fertilizer use is estimated based on the concentration of solid fertilizer in the nutrient stream, multiplied by the estimated volume of water used for plant growth.

Propane Usage Model

Based on the Productivity Model and scaled NASA BVAD numbers, the mass of CO_2 contained in the plants is calculated and a corresponding uptake rate is established for each module. Based on the **Air Exchange Rate** and the difference between the enhanced **CO_2 level** input and the naturally occurring atmospheric level of 390 ppmV, a CO_2 loss rate is calculated. The sum of these two rates is the necessary CO_2 injection rate.

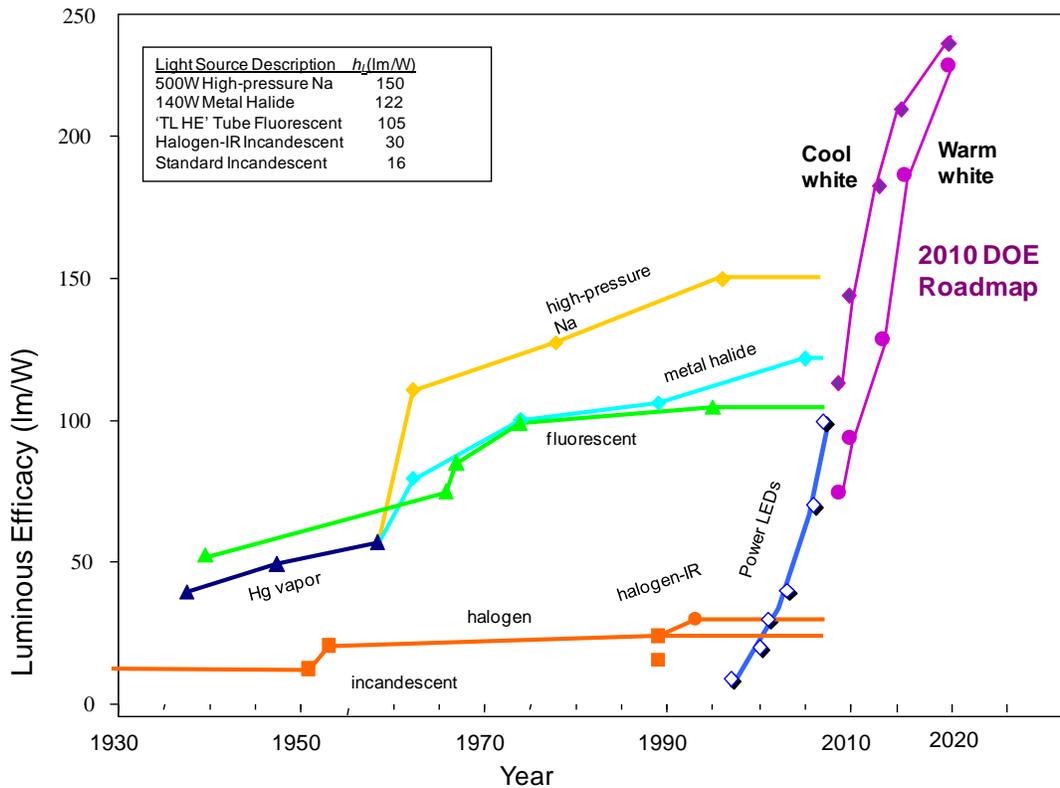
Knowing that each litre of liquid propane will create 1.54 kg of CO_2 when burned⁹, we calculate an annual volume of liquid propane needed to maintain the specified level under full scale production.

Power Usage Model

The Power Usage Model calculates the amount of input power required to provide the illumination level needed for each crop (this is an input into the Productivity Model). This calculation is based on the luminous efficiency of commercially available state-of-the-art high brightness LEDs. It takes into account the electrical efficiency of commercially available drivers, and the expected losses in light distribution. Figure C-1 shows the 2010 US DOE roadmap prediction for advances in luminous efficiency of commercial LED lighting based on current R&D. This indicates that LED power use of future facilities is likely to halve within the decade from the current level. The results will include a discussion of the expected impact of this change.

⁹ US Environmental Protection Agency brochure "UNIT CONVERSIONS, EMISSIONS FACTORS, AND OTHER REFERENCE DATA" NOVEMBER 2004

Figure C-1 LED luminous efficiency roadmap



Cost Model

Based on the **Number of Modules** specified for the facility, the **Fixed FTE wage**, the **crop area/labourer**, and the **Labourer wage**, a cost of labour for each module is calculated.

Based on the Power Usage Model and the **Price of electricity** input, a cost of power for each kilogram of edible produce is calculated.

Based on the Water Usage Model and the **Per litre cost of water** input, a cost of water per unit produce is calculated.

Based on the Propane Usage Model and the **Propane Cost** input, a cost of propane per unit produce is added.

Based on the **Utility Cost** input, and the **Number of Modules** input, a cost per module is calculated.

The **Annual Maintenance** input cost per module is added.

Fertilizer cost is calculated based on the Fertilizer Usage model multiplied by the **Fertilizer Costs** of the pre-mixed dry ingredients.

Based on the Productivity Model for each crop an edible biomass productivity in kilograms per module is achieved for each candidate crop and modified by the **Food Wastage** fraction. The costs are then divided by the module productivity to arrive at a food cost per kilogram.

Thermal Balance Model

Based on the power inputs from the Power Usage Model, weighted by the **Photoperiod** of the crop, and modified for the fraction of energy that gets stored through photosynthesis, this model estimates the electrical heating of the building.

Based on the Propane Usage Model and the heat content from burned propane⁹, this model estimates the propane heating of the building.

Based on the **Air Exchange Rate** and the difference between **Operating Temperature** and external temperature maxima, and the **Heat Recapture** fraction, this model calculates the energy necessary to heat exchanged air.

Based on the input **R-Value**, and the surface area of the building, this model calculates static thermodynamic heat balance in extremes of northern outdoor temperature corresponding to -50°C and +20°C.

APPENDIX D: ELECTRICAL SUPPLY CHARACTERISTICS BY COMMUNITY

Electrical capacity

A reasonably sized modular farm could consume 500 kW, which would overwhelm a small community system. It is important to determine which communities could support this load. It is also important to note the typical duration and frequency of power outages for sizing of the emergency backup system to prevent crop loss. For such a large load, the local utility are likely to require that the Power Factor be maintained at a high level to prevent disruption of the local grid. This is important in the design of the LED drive system.

Installed capacity

Table D-1 Capacity by Community

2007/08 fiscal year data	Total Generation (MWh)	Installed capacity - diesel (MWh)	Installed capacity - hydro (MWh)	Total installed capacity (MWh)
Aklavik	2,996	1.28	0	1.28
Colville Lake	395	0.24	0	0.24
Deline	2,724	1.19	0	1.19
Fort Good Hope	2,944	1.23	0	1.23
Fort Liard	2,786	1.32	0	1.32
Fort McPherson	3,583	1.83	0	1.83
Fort Providence	3,277	?	0	?
Fort Simpson	8,419	3.2	0	3.2
Fort Smith	Part of Hay River system			
Gameti	1,011	0.612	0	0.612
Hay River	68,246	0.3	18	18.3
Inuvik	31,689	3.52	0	3.52
Jean Marie River	322	0.23	0	0.23
Kakisa	422	?	0	?
Lutsel K'e	1,647	0.82	0	0.82
Nahanni Butte	432	0.245	0	0.245
Norman Wells	9,683	2.12	0	2.12
Paulatuk	1,492	0.84	0	0.84
Sachs Harbour	1,063	0.795	0	0.795
Trout Lake	457	?	0	?
Tsiigehtchic	765	0.5	0	0.5
Tuktoyaktuk	4,450	2.21	0	2.21
Tulita	2,700	1.1	0	1.1
Ulukhaktok	2,070	1.16	0	1.16
Wekweeti	635	?	0	?
Wha Ti	1,624	0.975	0	0.975
Wrigley	727	0.781	0	0.781
Yellowknife	204,616	27.66	37.9	65.51

Updated April 2012 Note: Prices do not include GST	Commercial energy prices							
	Electricity				Oil	Propane	Nat Gas	Pellets
	\$/kVa or kW	\$/kWh	\$/kWh (>200 kWh/kW)	minimum charge	\$/Litre	\$/L	\$/GJ	\$/Tonne
Aklavik	\$8.00	\$0.40	N/A	\$40.00	\$1.47			
Behchoko	\$8.00	\$0.30	N/A	\$40.00	\$1.17			
Colville Lake	\$8.00	\$0.40	N/A	\$40.00	\$1.48			
Deline	\$8.00	\$0.40	N/A	\$40.00	\$1.43			
Dettah	\$8.00	\$0.30	N/A	\$40.00	\$1.17	\$0.73		\$265.00
Enterprise	\$5.67	\$0.22	\$0.17	\$28.37	\$1.18	\$0.60		
Fort Good Hope	\$8.00	\$0.40	N/A	\$40.00	\$1.41			
Fort Liard	\$8.00	\$0.40	N/A	\$40.00	\$1.32	\$0.73		
Fort McPherson	\$8.00	\$0.40	N/A	\$40.00	\$1.57			
Fort Providence	\$6.20	\$0.40	\$0.40	\$31.02	\$1.30	\$0.63		
Fort Resolution	\$8.00	\$0.13	N/A	\$40.00	\$1.26	\$0.73		
Fort Simpson	\$8.00	\$0.40	N/A	\$40.00	\$1.20	\$0.67		
Fort Smith	\$8.00	\$0.13	N/A	\$40.00	\$1.18	\$0.73		
Gameti	\$8.00	\$0.40	N/A	\$40.00	\$1.51			
Hay River	\$5.67	\$0.22	\$0.17	\$28.37	\$1.15	\$0.60		
Hay River Reserve	\$5.67	\$0.22	\$0.17	\$28.37	\$1.15	\$0.60		
Inuvik	\$8.00	\$0.40	N/A	\$40.00	\$1.46	\$0.73	\$19.30	
Jean Marie River	\$8.00	\$0.40	N/A	\$40.00	\$1.48			
Kakisa	\$8.00	\$0.40	\$0.40	\$40.02	\$1.26			
Lutsel Ke	\$8.00	\$0.40	N/A	\$40.00	\$1.34			
Nahanni Butte	\$8.00	\$0.40	N/A	\$40.00	\$1.38			
Norman Wells	\$8.00	\$0.34	N/A	\$40.00	\$1.39		\$17.23	
Paulatuk	\$8.00	\$0.40	N/A	\$40.00	\$1.55			
Sachs Harbour	\$8.00	\$0.40	N/A	\$40.00	\$1.49			
Trout Lake	\$6.66	\$0.40	\$0.40	\$33.29	\$1.49			
Tsiigehtchic	\$8.00	\$0.40	N/A	\$40.00	\$1.58			
Tuktoyaktuk	\$8.00	\$0.40	N/A	\$40.00	\$1.52			
Tulita	\$8.00	\$0.40	N/A	\$40.00	\$1.35			
Ulukhaktok	\$8.00	\$0.40	N/A	\$40.00	\$1.41			
Wekweeti	\$8.00	\$0.40	\$0.40	\$40.00	\$1.66			
Wha Ti	\$8.00	\$0.40	N/A	\$40.00	\$1.41			
Wrigley	\$8.00	\$0.40	N/A	\$40.00	\$1.42	\$0.73		
Yellowknife	\$14.96	\$0.16	N/A	\$74.80	\$1.17	\$0.73		\$265.00

Table D-2 Energy cost in NWT communities, Spring 2011

Fort Smith*Capacity*

Fort Smith has excess capacity available from the Taltson hydro system. Since no mines have signed on to use it yet, it is still available. COM DEV could look into obtaining an agricultural power rate as has been accomplished in other jurisdictions to spur agricultural development.

Outages

Fort Smith has their electricity supplied by NTPC. The average NTPC customer had a total of 4.2 hours of power outages in the 2011/12 financial year and 7.7 hours in the 2010/11 financial year. On average the outages in 2011/12 were 25 minutes and those in 2010/11 were 32 minutes.

Power factor

Awaiting reply

Inuvik**Capacity**

Inuvik is currently in an energy crisis. A large portion of their heating and electrical energy needs have been supplied by natural gas in recent years and the natural gas supply is being shut off many years earlier than expected. Their power generation has been switched to diesel, but plant modifications are still underway. Currently there is not enough excess capacity to support a system like this. However, as work is in the planning stages, it might be possible for a load like this to be accommodated. Early negotiations are essential if this route is chosen.

Outages

Inuvik has their electricity supplied by NTPC. The average NTPC customer had a total of 4.2 hours of power outages in the 2011/12 financial year and 7.7 hours in the 2010/11 financial year. On average the outages in 2011/12 were 25 minutes and those in 2010/11 were 32 minutes.

Power factor

Awaiting reply

Yellowknife**Capacity**

Yellowknife has the capacity to accommodate a 500 kW load. NUL believes that since their business is to supply electricity, they will endeavour to supply whatever load is required.

Outages

Yellowknife power is supplied by NUL(YK). From January 2012 to the end of August 2012 there were 53 power outages and the average customer experienced 16 of those. NTPC is partially responsible for power in Yellowknife (but is not the direct supplier for customers) and has vowed to decrease outages in Yellowknife by 7% over the next 3 years.

Power factor

According to NUL Terms and Conditions, the power factor must be above 0.8. However, a power factor of 0.8 on a load of 500 kW and this size grid will cause problems on the grid. NUL will likely require that the power factor be corrected to higher than 0.95.

Hookup Costs

The utility (NUL) charges a \$50 connection fee and a portion of the cost of equipment installation/modification that includes the cost of installing a new transformer for the building (likely in the region of \$50,000). If the lot is not already serviced, it will also include the cost of extending the service; a ballpark estimate for this is \$10,000 per 100 m. The portion of the cost charged to the customer will be pro-rated on a cost recovery basis. At current rates there is no charge for costs below \$340 per kW of anticipated demand provided the installation is permanent. In this case, that works out to no additional charge if the cost is below \$170,000 if the installation is permanent. Since this project facility is expected to be temporary (not 25 years), the cost would be pro-rated. Negotiations with NUL will be necessary, but if the pilot runs for 3 years, the anticipated investment NUL might make would be \$20,400. In addition to the charges passed on from the utility, there will also be charges on the customer's side. The customer is responsible for the lines from the transformer to the building. It needs to be installed by an electrician and according to the electrical code, and because of the load it will need to be buried. The cost is difficult to estimate without knowing the distance to the building and the ground conditions. It will likely be tens of thousands of dollars.

APPENDIX E: COST OF WATER, SELECTED COMMUNITIES

Potable water is available in all NWT communities, however the type of treatment it receives and the method of delivery depends on the community. In many NWT communities there are no water or sewage pipes. Clean water is delivered to buildings by a water delivery truck and is pumped into a water storage tank while sewage is collected in a separate (sewage) tank in each building and pumped out by a truck that takes it to the sewage treatment facility, which may be a lagoon system. Both the clean water and sewage tanks must be kept from freezing. If the growing facility is going to be in a location without access to piped water, the building must be sized to allow for water and sewage tanks inside. Table 3 lists the method of treatment and delivery of water and the cost in NWT communities.

Table E-1 Water treatment method and cost

	Class	Coagulation	Flocculation	Sedimentation	UV Disinfection	Filtration	Softening	Chlorination	Fluoridation	Piped Access Fee (per Month)	Residential Piped (per m3)	Trucked Access Fee (per Month)	Residential Trucked (per m3)	Sewage Pumpout (per m3)
Fort Smith	III	Y	Y	Y	-	Y	-	Y	-	\$ 38.00	\$ 2.09		\$ 6.32	
Inuvik	II	-	-	-	-	Y	-	Y	Y		\$ 10.19			
Yellowknife	I	-	-	-	-	-	-	Y	Y	\$ 6.59	\$ 2.99	\$ 47.63	\$ 12.92	\$ 0.30