Vegetable Production in Arviat, NU, Canada

Roberta Ford, Colin Goodwin, Daniel McCreery, Michael Trudell

Abstract —In this paper a new design is presented for an energy self-sufficient greenhouse located in Arviat, Nunavut, Canada. The goal is to produce vegetables that can be sold at competitive prices to those that are transported in. The design consists of a detailed layout of the facility, including building materials, growing beds, an irrigation system, a heating and ventilation system, and a detailed description of how power will be supplied to the facility using renewable resources. The design meets all specifications outlined by the client. The design was simulated with 2006 climatic data with an Excel model. The results indicate the design can be implemented.

I. INTRODUCTION

Northern Grow-op LTD has developed a comprehensive design for an energy self-sufficient greenhouse that is to be located in Arviat, Nunavut, Canada. The facility will produce vegetables to be sold at a price that is competitive with produce imported from other parts of Canada. The extreme arctic climate (i.e. high winds, extreme cold and permafrost) poses numerous challenges for the design of such a facility. Previous designs utilized propane burners for heat, but this is unfavorable. This facility will be decommissioned over the winter months, and it is assumed no extra materials or labour will be required. Wind turbines are used to meet the need for a self-sustainable energy source as required by the isolated location. Energy generated by the wind turbines will power an air-source heat pump to meet heating needs not met by solar radiation. Cold-weather crops were chosen to maintain manageable heating loads in the greenhouse. Transportation costs to the arctic are restrictive, so maximizing local resources used, such as sand and gravel for concrete is integral.

A thorough model of the daily solar heat flux, additional heating requirements and wind turbine power production has been developed for submission as a milestone. The model allowed optimization of climate control components. Results from the model have proved the design can be successfully implemented.

II. CONCEPTUAL DESIGN/METHODOLOGY

A. Structural design

The issues presented by the continual permafrost at the location require extensive measures to ensure stable structural foundation. To remove the risk of conductive heat from the building melting the permafrost, the entire structure will be elevated. Steel piles will be driven into the ground to the stable subsoil, with 1m left protruding from the ground. Water will then be pumped in the space around the piles and allowed to freeze to improve their lateral stability.

The tops of the piles are pre-fitted with brackets to hold the floor of the structure. The floor is comprised of a ribbed steel composite slab. A 200mm layer of polystyrene R-12 is then laid over the slab, followed by another 50mm layer of concrete.

The walls of the structure will be made from pre-fabricated Zero-Loc insulated panels. These panels consist of an injected polyurethane foam core injected between two steel face sheets. They are manufactured to size to save excess transport weight and hassle on site. A layer of vapor barrier is then installed to seal the wall and joints air-tight. The panel and vapor barrier wall are enough to provide the strength and insulation required of this design.

Steel beams will run inside the upper ridgelines of the four gabled roofs, and along the inside of the 3 valleys. Each 62.5m span will be supported by 7 steel posts spaced at equal intervals. The north-facing roof sections will be comprised of Zero-Loc roof panels for their ease of installation. The south-facing sections will be constructed with polycarbonate windows tilted to 48 degrees.

B. Vegetable Selection

Vegetables cultivated in this greenhouse were chosen considering several criteria. They must deliver high nutritional quality, thrive in relatively low temperatures, have short maturity times and have high yields. An optimal temperature of 15°C is maintained to balance heat loss from the facility with ability for plants to grow. Carrots, Beets, lettuce and broccoli were chosen as the best candidates for this project.

III. DETAILED DESIGN

A. Climate Control Systems

The temperature within the growing facility is maintained at 15°C throughout the operating season. The growing facility requires auxiliary heating to supplement solar heating during the operating season. In order to provide heating or cooling, an air source heat pump designed specifically for cold climate operation has been selected. The air source heat pump is capable of supplying 17.9 kW of heat at an outside temperature of -17°C. The power required to operate the heat pump at maximum capacity is 8.9 kW. The heat pump also acts as the primary air handling unit for the ventilation system in the growing facility and provides 37,000 m³/day or 1.1 room exchanges per hour [1]. The heat pump is controlled by a programmable thermostat to maintain the desired indoor temperature of 15°C.
The above figure displays the heat balance for the facility during the first week of May 2006.

### B. Power Supply

Geographically, Arviat, being on the coastline of Hudson Bay, is rich in wind resources [2]. Preliminary calculations and cost estimates strongly supported the use of wind power generation. The power supply system proposed in this design is based on a proven design used in the region of Arkhangelsk, Siberia [3]. Capable of working at temperatures below minus 40°C, the system consists of two Bergey Wind Company (BWC) 7.5 kWh Excel wind turbines, two 30 meter tilt up guyed lattice towers, a 48 VDC (volts of direct current) battery bank, one 5.5 kW Trace inverter and DC power centre [3]. Loads on the system include a heat pump, water pumps, lighting and monitoring. Based on WindCad and RETScreen modeling results the system will provide a daily average power supply of 106 kWh therefore supplying 100% of the facilities daily average power requirements.

### C. Growing Facility

The interior of the facility is 64.5m long by 12.3m wide. Twelve 20m long growing beds have growing area of surfaces 24m² each. Beds are arranged in three rows, four beds wide. A growth media was chosen to grow the crops as two of the vegetables are root crops (beets and carrots). This media is comprised of 2:1 parts peat to perlite. This mixture will provide adequate void space for oxygen exchange with the roots, drainage and water holding capacity.

The crops will need a total of 2.14m³ of water a day which will be supplied by a drip irrigation system. The system consists of a 0.2 hp pump and 1% sloped pipes to move water from the tank located in the storage room to each growing bed. Water will be pumped up 2m (height of the building) as the irrigation lines have been designed to be suspended from the ceiling. Water will be supplied to the facility from the Wakahchuk River by a 10 hp pump.

### IV. DISCUSSION

The design presented by Northern Grow-Op attempted to consider all significant components for a successful growing operation. However, some components require failsafe systems in order to be completely reliable. Such as backup batteries and diesel generation for low wind periods. The air source heat pump only provides adequate heating to a temperature of -17°C a backup booster heat pump could be installed to ensure full reliability. Further investigation into the extent of the permafrost and depth to bedrock are needed to design adequate piles for the facility. If adequate funding was available, a third wind turbine would allow construction of a larger growing facility and thus increased vegetable production.

### V. CONCLUSION

The detailed design provided by Northern Grow-Op provides an exceptional growing environment for vegetable production in Arviat. The growing facility does not provide the total vegetable requirement of Arviat but offers an alternative and fresher supply of vegetables for the community.

### VI. ACKNOWLEDGMENT

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### VII. REFERENCES

