Vegetable Production in Isolated Arctic Settlements

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Abstract --This paper presents a design for a greenhouse equipped to produce vegetables in isolated Arctic settlement, in particular, Arviat, Nunavut. The main components in this design are wind turbines as an energy source, passive heating system as a heat source and an irrigation system utilizing groundwater to provide required moisture. The greenhouse is structured to minimize wind stresses and contains a water-wall designed to absorb and store solar energy emitted from sunlight. This facility will operate for nine months of the year. The primary focus is on the production of tomatoes to introduce to the community of Arviat. In order to supply the needed amount of produce, there will be a total of six greenhouses.

Index Terms -- vegetable, Arviat, greenhouse, water-wall

I. INTRODUCTION

In the Arctic regions of Canada it is very difficult and expensive to import produce that is readily available in more Southern communities. This is becoming a concern since it is evident that a healthy diet should consist of a certain number of fruits and vegetables daily; however, as energy and transportation costs are very high in these regions, it is not feasible to import fresh vegetables into these areas. In order to address this problem Frozen Foods Engineering Firm (FFEF) has designed a greenhouse facility, located in Arviat, Nunavut, that is equipped to produce vegetables that can be supplied to the local community. The facility uses the latest renewable energy technologies designed to minimize the cost of production and operation. The major constraints for this design are that there must be no on-going fuel costs, the facility must be entirely energy self-sufficient and the design must be evaluated for economic feasibility. The criteria are as follows: to ensure the design is as fuel/energy efficient as possible as well as maximizing economic feasibility. Arviat has a population of 2000. Since the people of Arviat are not used to vegetables in their diet, FFEF has decided to provide sufficient produce for one to two vegetables per person per day. Although this is the initial target production level for this facility, it is being designed to handle an increase in production should the need arise in the future. This project is unique since there is no existing greenhouse facility in Arviat. The technologies and number of resources in the past made it very difficult for this design to be economically feasible.

Today's renewable energy sources and energy efficient technologies make this design possible to implement. In order to complete this design, each component was thoroughly researched and the most appropriate economically feasible and energy efficient solution was used. This design presented many challenges; one in particular was the clear layout and structure of each greenhouse with every system incorporated into the main design. A very detailed drawing of the entire greenhouse facility, therefore, is presented as the milestone for this design. The drawing is laid out in a manner that allows the viewer to see every component of the greenhouse individually and/or as a complete system.

II. CONCEPTUAL DESIGN/METHODOLOGY

A. Overall Design

Since there is an extreme difference in temperature during the winter and summer months, each greenhouse will be operational from March to the end of November since this is the only time to gather sufficient energy for operation. The overall structure of the facility consists of a 49 m long by 6.3 m wide span with a south facing wall 3.5 m in height and a north facing wall 2.4 m in height. The inner structure is designed to have aisles that allow for workers to easily access the trough for planting, harvesting or any other required maintenance. The trough system is divided into two rows of 16 sections. Each row is approximately 44.8 m in length and covers a total surface area of 215.04 m² in one greenhouse. The plants require a surface area of 0.25 m². These parameters allow for 860 plants to be grown in one greenhouse. It is estimated that 55 tomatoes will be grown on one plant, resulting in approximately 47,000 tomatoes per greenhouse. Since the original need was 540,000 tomatoes over 9 months (2 cycles), there will be 6 greenhouses constructed.

B. Major Components

The major components of this design include the irrigation system, the water supply and heat and energy source. The soil type for the plants will be sandy loam because it is sought to be the most nutritious soil for these types of plants.

III. DETAILED DESIGN

A. Water Supply

The source of the water supply is groundwater from an aquifer located in Arviat. This aquifer provides 0.3 L/s of water in a well. The water supply network consists of pumps, storage reservoirs, underground piping networks, mixing reservoirs for soil nutrients and an irrigation system. The pipe network uses 300 mm ductile iron piping and a total of 8 pumps for the distribution of water throughout the facility. There is trace heating element installed in each pipe to ensure that the network remains above freezing temperatures.
B. Irrigation System

The irrigation to the plants will be provided by a sprinkler system. The Ontario Ministry of Food, Agriculture and Rural Affairs (OMAFRA) [1] has aided FFEF to develop a detailed irrigation schedule. The maximum amount of useful water that the soil can store is called field capacity. The tomatoes use a certain amount of water each day based on crop development until the total available water reaches a depletion point. Once the depletion point is met there is a need for irrigation. The irrigation amount is ultimately calculated by dividing the depletion level by the efficiency of the sprinkler system, which is taken to be 85% efficient. Fig 1 shows a visual plan for the irrigation schedule, where the peaks are the days when irrigation takes place, and the valleys are the days when the total available water in the root zone falls below the depletion level. It can be seen that flowering begins on approximately the 44th day of the cycle. When flowering begins the depletion level (valleys) rises from 15.75 mm H2O to 31.5 mm H2O [1].

C. Heat and Power Supply

Heat to the greenhouse will be provided partially through solar radiation, but predominantly through a wind powered turbine. The turbine heats the system via an electric heater in an 18 m3 tank of water. Tomatoes can grow in a greenhouse with temperatures ranging from approximately 18 to 29 °C. However, for ideal growing temperatures 27.5 °C is maintained. In order for the indoor temperature to be maintained there must be no change in internal energy. In order for there to be no internal energy, the energy in from radiation plus heat transfer from the water tank to the indoor air, via the turbine, must be equal to the energy losses through the exterior walls and the floor. This allowed FFEF to determine appropriate water temperatures in the tank and thus the energy requirements from the turbine on a daily basis. It was found that over the coldest operating month the average daily turbine energy requirement is approximately 38 kW per greenhouse. As the outdoor temperature warms the average daily energy requirements drop to approximately 130 W per greenhouse.

The water supply system in the greenhouse facility is controlled by 8 pumps. The total power required by these pumps is 20 kW. The trace heating element system used to keep the water from freezing within the pipes requires a power input of 18 kW. The lighting system in the greenhouse facility consists of 22 lights in each greenhouse; for a total of 132 lights in the facility. Each light requires 400W; this gives a total power consumption of 53 kW for the lighting system.

The total power required by the greenhouse facility is 119 kW. The turbine chosen for the site must provide this amount of power using a mean wind speed of 8 m/s.

IV. DISCUSSION

The greenhouse facility designed by FFEF is the first in Arviat. It will provide an easier and lesser expensive means for Arviat’s population to consume a nutritious diet. Since this is the first time a project like this is being implemented into this region, there are bound to be some future challenges. FFEF is confident that this design is based on thorough research and the safety factors incorporated into the design will ensure the quality of this facility. It is also evident that the extreme temperature differences pose the most difficult challenge. This is the main reason why the facility is operational for 9 months of the year and is making use of renewable energy resources such as wind energy. FFEF is hopeful that this facility will be very beneficial for the community of Arviat both economical and health reasons.

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REFERENCES