Wentworth Institute of Technology

Electronics and Mechanical Department

MECH620-03-04 Thermal Design

A Proposal to Design and Implement Green Technology into Greenhouse Operations

Submitted to
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Introduction

Greenhouses can be used for many purposes. Some businesses focus their attention solely on decorative plants which can be used to increase the aesthetics of a landscape. Others grow for the purpose of providing produce such as tomatoes, lettuce and corn. Although the intents are different, one factor proves true in both cases. In the greenhouse industry, it is extremely important to be able to control the environment in which the vegetation is housed. This control is essential in the success of the plant life, whether it is below freezing outside or grueling hot.

In this day and age with fossil fuel prices rising and the threat of global warming constantly being reminded to us, is has become a increasing trend to utilize all of the new “green technologies”. The idea of wind energy, hydro power, thermal energy and even photovoltaic solar cells are not particularly new to the world. In this age of invention, these designs are just being re-invented to become more useful, practical and efficient.

With these “green technologies” and greenhouses in mind, it seemed only practical to combine the two to help these agricultural establishments lower their carbon footprints, and make them self sufficient structures.

Problem Definition

In the greenhouse industry, climate control is vital. Many of these establishments grow and sell non-native produce to their area, and in order to successfully grow vegetation in this way one must simulate its natural habitat. This can range from heat adjustment, to humidity adjustment, to even the amount of light which the plants receive per day. Fluctuation in any of these variables can provide many problems which can lessen the success rate, in turn lowering profits for the business.

Currently, many greenhouses use electricity from a grid to run the electrical and thermal systems. Also, greenhouses rely on water from the water system to supply their irrigation needs. By designing greenhouses in a way that maximizes the use of its environment to produce its own electricity as well as its own heat, the negative effects that fossil fuels leave to the planet will be reduced as well as the local wellbeing of the land. It is possible to combine many different green energy ideas to produce a self sustaining system that has little or no effect on its surroundings.

It is our proposal to combine solar thermal, solar voltaic and geothermal energy sources to completely manage the needs of a greenhouse system. The solar voltaic system will be used solely to run the electronics used in greenhouses. The most energy hungry devices in a greenhouse would be the internal air handler / fans, the control system and the water pumps in irrigation. We hope that the energy from a solar array could charge batteries and adequately provide these electrical devices with enough energy, even on days where sunlight is not readily available.

Geothermal energy will be the resource for heating and cooling the greenhouse. In the summer and winter months where temperatures are at their highest range, it is extremely important to keep the greenhouse at a temperature that is not to severe to kill the vegetation. By designing a system that will distribute the constant temperature of the water deep below the earth's surface, it is possible to keep these extreme temperatures under control.

The concept of solar thermal energy will be used to power purification system, as well as further winter heating. As the temperature drops during the winter months, more heating resources will need to be available to keep the area at a reasonable temperature. Purification is important to regulate the amounts of solvents that are available in the water solution. By purifying this water, any toxins present in the water can be eliminated which allows greater success in vegetation.

Background Research

When looking into the design of a greenhouse, it is important to first go through and sort out the types of technologies which could be used successfully. The simplest example of solar water heating is the warm water inside of a garden hose that has been sitting in the sun. Solar thermal water heating is essentially water moving slowly through a system that is designed to heat and store water. Solar thermal systems use the best technique to capture the sun's heat using plumbing systems. This creates a cost effective way to produce hot water, minimizing the use of gas or electricity to heat water.

Passive solar thermal systems are mostly used in regions which do not have periods of below freezing temperatures. The water circulates in the passive system without the use of pumps or controls. In an active solar water heater pumps are used to circulate the water or antifreeze solution through heat-absorbing solar thermal collectors.

In an indirect system, an antifreeze solution is pumped through the solar heat collector and is then used to heat the water used. In a direct system the water used is heated directly by the sun. A thermometer and controller are used to sense when the solar collector is warm enough to heat the water. The controller then starts a pump which moves the water into the solar collector to be heated. The heated water is then stored in a hot water tank. For the direct system gas or electricity may be used to maintain the hot water tank, also, it is more susceptible to freezing unless insulated properly.

Figure 1: Solar Thermal Collector

The most common and most simple type of solar collector is the flat plate collector. Copper pipes wind back and forth through the collector. The collector is painted black in order to absorb heat and is covered with glass or a glazing to prevent heat from escaping. To maximize heat absorption, the pipes may be painted black and bonded to the material of the collector. Another type of solar collector is the solar pool heating system which uses a similar design, however, the glazing is sometimes removed in order to save money and prevent the water from super-heating. For non-glazed systems that look like flat black mats, inside the mats is a network of headers which the water slowly passes through. For more industrial uses there are more advanced systems such as evacuated tube collectors and parabolic trough collectors which can heat water to much higher temperatures.

Another very effective method of green energy is geothermal. During the colder months of the year, the greenhouse needs some sort of heat to prevent the frost from the outside affect the plants being raised. We proposed a possible geothermal system to be installed. There are several benefits from the geothermal system to that of a greenhouse.

First off, most greenhouses have wells as an alternative to local water treatment plants to cut cost of water for their plants. The alternative water sources include a well and/or reservoir in which they pump from. The existing well for water could be used for an open loop geothermal system to heat the greenhouse during colder months. Also, for the watering of the plants within the greenhouse, not all the water pumped would go back into the ground but dropped in storage tanks that water the plants. Even though the water skimmed from the waste water is very little from the geothermal system, being an average flow rate of 6-15 gallons per minute, it still saves energy from being pumped from somewhere if it is gravity fed. The flow rate is dependent on the size of space required for heating and the exact number of BTU’s to heat that space.

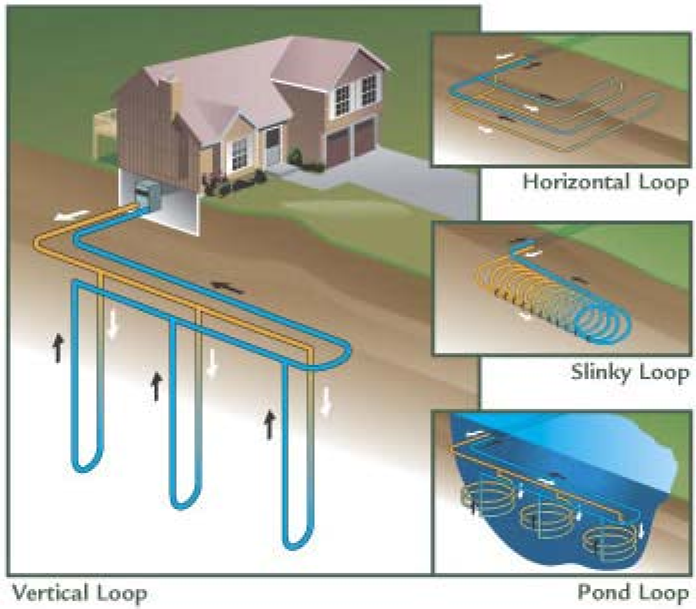


Figure 2: Geothermal Energy System

Secondly, geothermal heat pumps are more efficient than heat pumps that are made for extracting heat from the outside air to heat inside air. Also water is more abundant and cheaper than that of oil as a source of energy for heat. Basically there is 3472 time more heat stored in a cubic foot of water (62.5 BTU per degree F) as in a cubic foot of air. There are only a few substances known to have a higher specific heat than water but water is more abundant and can be very accessible. The average temperature of water for the United States ranges from 37 to 77 degrees Fahrenheit, from Figure 1 below, which is still has plenty of heat that could be extracted and would not freeze water lines. The principles are very simple about how a geothermal system works. The water is pumped through a special type of heat exchanger and is either “chilled” by the evaporating refrigerant (in the heating mode) or heated by the condensing refrigerant (in the cooling mode).

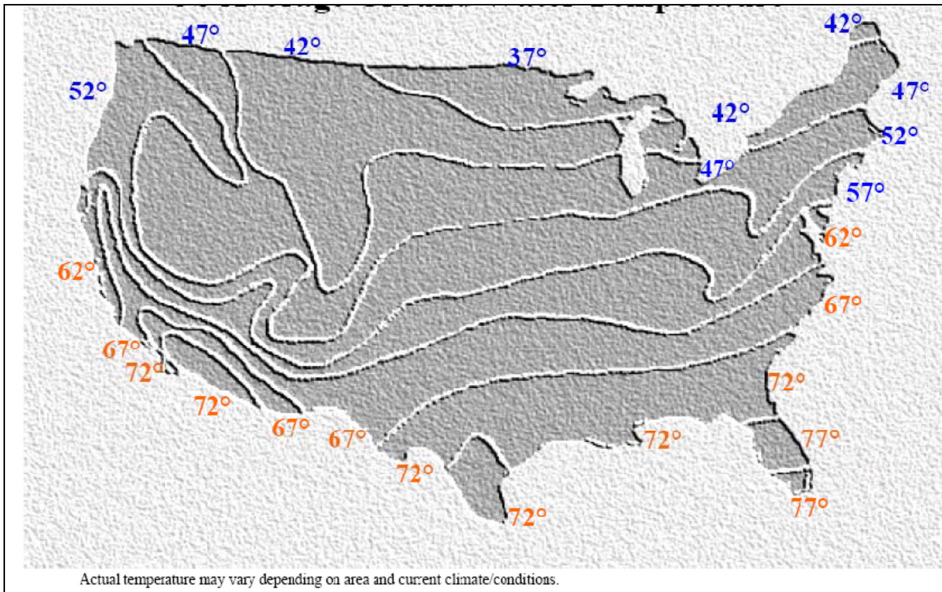


Figure 3: US Average Ground Water Temperature

Another important technology in the green category is the use of solar voltaic cells to produce electricity directly from sunlight. In the past photovoltaic production was much lower than it is now, increasing 50% every year since 2002. This makes this sector the world's fastest growing energy technologies. The term photovoltaic indicates the operation of a photodiode in which current through the device is entirely due to the transduced light energy.

Solar cells can be classified into three main categories; first, second and third generation cells. First generation cells usually take up a large area and are made up of single junction devices. One of the downfalls to this type of solar cell, is its limiting efficiency of approximately 33% and have an average payback period of 5-7 years. The second generation cells are made up of materials that have been developed to take less energy and cost less to make. In the development process, it might cost less to make but in this case the efficiency goes down. The third generation solar cells aim to enhance operation of the second generation cells while still maintaining low manufacturing costs.

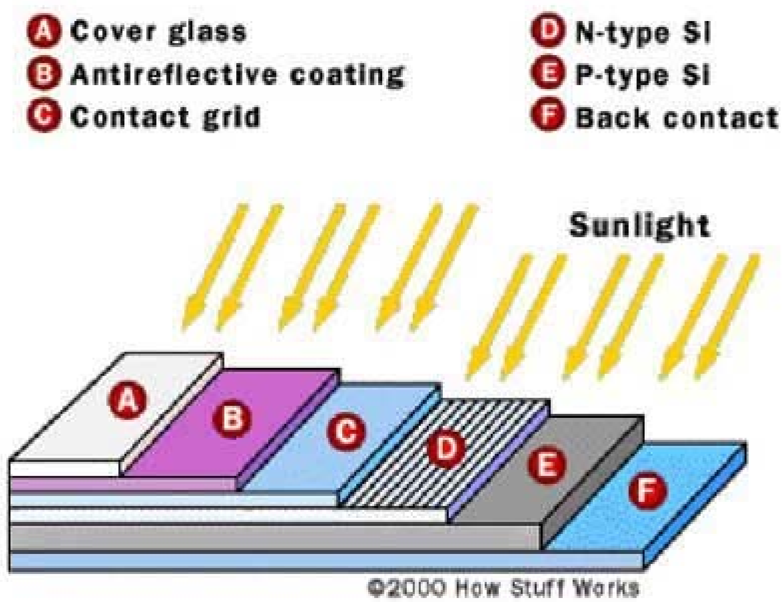


Figure 4: Typical Solar Cell Construction

The theory behind these devices is not that hard to understand. Sunlight is made up of photons, and when they collide with the solar panel they are absorbed by the semiconductor material. Electrons are knocked loose from their atoms, allowing them to flow through the material to produce an electrical current. Because the silicone is made in a way to restrict the electron movement to one direction, a current will flow in only one direction. This current can then be transported through wires to another device or a battery.

The Need

One of the major needs for this project is to find an environmentally friendly way to heat greenhouses. This means using renewable resources and converting the energy into thermal energy that will heat the greenhouse. These resources are also much more environmentally friendly, which is becoming a more sought after feature in products as people start to realize the effects of typical energy waste on the environment. By finding a way to incorporate solar and geothermal energy into greenhouses, the energy waste effecting the environment is minimized if not eliminated completely. This would directly affect people in the greenhouse industry by minimizing their runoff and waste, becoming more environmentally friendly. Also, they would directly benefit through a total cut in cost by using natural resources. This would allow more greenhouses to operate during the winter season because they would be able to more readily afford to heat the greenhouse, increasing their income overall. There is a great need for a design that allows greenhouses to operate on natural resources so that those in the industry have a way to operate during winter or off seasons as well as summer seasons and cut costs overall as well as help the environment.

Objectives

The objective of this design project is to improve on the working conditions of greenhouses and help maximize their efficiency of productivity. In order to achieve this we are going to research, tailor, and, as time permits, to build a scaled model to test out proposed systems. Our proposed systems would involve using a geothermal system, solar panels, solar thermal panels and/or better use of insulation.

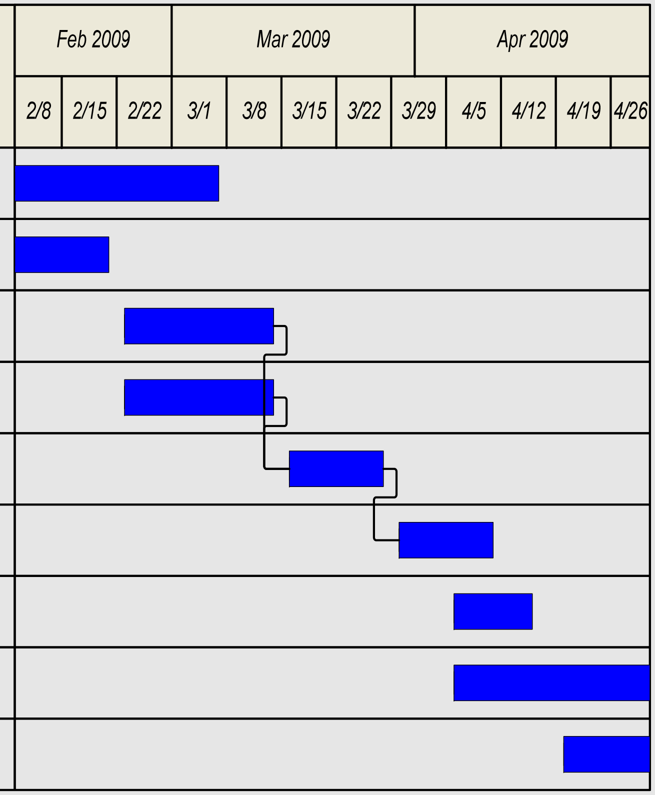
Functional Requirements

The specific requirements for this project are as follows:

- The use of geothermal energy as the main supplier for heating in the winter and cooling in the summer.
- The use of solar cells to produce enough energy to run the electrical requirements
- The implementation of solar thermal purification for water quality.
- The overall use in green supplies throughout the entire project to decrease the net carbon footprint of the greenhouse.

Workplan

ID	Task Name	Start	Finish	Duration
1	Build / Test Solar Thermal Theory	2/9/2009	3/6/2009	4w
2	Build / Test Solar Photovoltaic Theory	2/9/2009	2/20/2009	2w
3	Design Basic Greenhouse Structure	2/23/2009	3/13/2009	3w
4	Design Heating System	2/23/2009	3/13/2009	3w
5	Material Selection	3/16/2009	3/27/2009	2w
6	Build and Modify Scale Greenhouse	3/30/2009	4/10/2009	2w
7	Greenhouse Testing	4/6/2009	4/15/2009	1.6w
8	Greenhouse Modifications	4/6/2009	6/15/2009	10.2w
9	Further Testing	4/20/2009	7/9/2009	11.8w



Qualifications

Please see Appendix I.

Budget

From our background research, we have not definitively came up with a mach up of what our scaled model will be to test our theories of how to make greenhouses better. Below in Table 1 will show some of the basic materials that will be needed to build a small 1ft wide by 2ft long scaled down model of a greenhouse. The framing material at the moment is unknown because we do not know if we are going with aluminum (being a little bit more expensive) or with wood to cut costs. The same thing goes for the tubing, we do not know if we are just going to use some small, flexible plastic tubing to imitate copper because we do not know if such small copper lines are available for our scaled down model. For the solar panel and solar thermal panel, we are going order one and see what the results are through some testing to fully implement an idea how to make it useful in a greenhouse.

Budget		
Items	Quantity	Estimated Cost
Cement Flooring	2 cu ft	$4.00
Water Pumps (type unknown)	1	?
Solar Panels	1	?
Solar Thermal Panels	1	?
Insulation	2 sq ft	$12.00
Framing (material unknown)	?	?
Glass	9 sq ft	$15.00
Tubing (material unknown)	5 ft	?

Table 1: Budget

The Project's Future

This project could be either a standalone project or it could be expanded into a larger project. As it stands it will be a standalone project with the intent to have a scaled down model that works based on our theory and we are able to simulate our design and ideas. On a larger scale we would be able to make this into a much larger project that could be completed in the future. This is a possibility given a realistic time frame and budget. If somebody were to continue with this project it would need to go through "life-size" models and testing in order to test and prove that the design and theory work as intended on a full scale. If the theory and design prove to work properly, with the proper business knowledge it could very well become incorporated in greenhouses around the country.

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Appendix I