COVEYOU FARMS LLC

# Innovative geothermal / solar on-farm refrigeration demonstration system

Conservation Innovation Grant Final Report

**NRCS 69-3A75-9-125**
**12/23/2013**

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## Executive Summary

The purpose of this project as highlighted in the grant agreement is for Coveyou Farms LLC to design, install, demonstrate and evaluate a geothermal based on farm produce refrigeration system that would consume minimal fossil fuel resources when solar collectors are part of the system. The project was successful in demonstrating the on farm geothermal cooling system and solar PV generation component that significantly reduces the operating costs and minimizes the fossil fuel needs of a small farm operation. The net result of applying these new technologies to the small farm is to make vegetable production more viable and sustainable for the many people transitioning their farms to local food production.

The Goals of the project were to:

- Demonstrate that commercially available geothermal heat pumps that are conventionally used to heat and cool structures can be used very efficiently to cool agricultural fruits and vegetables.
- Demonstrate geothermal refrigeration tables can be designed and implemented that can replace electric refrigeration units in small farm display markets.
- Demonstrate that a geothermal heat pump system can be used to cool walk in vegetable and fruit coolers for small farm operations.
- Demonstrate that solar photovoltaic energy can be used to power the highly efficient geothermal heat pumps when net-meter averaged over a one year period.
- Collect data and evaluate the effectiveness, utility, affordability, usability and overall benefits of this geothermal / solar PV system over a two year period in a commercial growing environment.
- Document the design, installation, operation and effectiveness of the project in a manner that it can be transferred and used by others.

The technologies used in this project are commercially proven methodologies that are applied in an innovative fashion to benefit small farm applications with direct transferability and scalability to larger farm operations. Improving on farm energy efficiency through the use of "green" technologies was the focus of this demonstration project.

In this project a produce walk in cooler and vegetable retail chiller display tables were designed and assembled in a typical small farm produce wash room area. A commercially available geothermal heat pump was installed in the existing barn along with a lateral ground geothermal heat sink field in the area outside of the barn. The geothermal heat pump was used to transfer heat out of the walk in cooler and chiller tables to the ground outside of the barn. Additionally, the geothermal heat pump created a chilled potable water source allowing a system that removes field heat from incoming vegetables to be demonstrated. Another byproduct of this system is the ability to take the heat energy from the coolers and use it to preheat the hot water heater minimizing any energy inputs to heat hot water in the produce preparation room. The actual energy consumption was shown to be 20% of a conventional refrigeration system. A solar PV array was also constructed and net-metered to the utility grid that will result in the on farm cooler system consuming no grid power (fossil fuel) when averaged over the year.

The details behind many of these project goals were shared at the Northern Michigan Small Farm Conference attended by over 700 hundred regional farmers as well as through a USDA extension bus tour field trip allowing farmers from around the state and region to hear first-hand details of these systems. We view that the main benefactor of this type of project are the fellow farmers who can observe, learn, and apply features of these systems to their own operation. It is these technologies that will allow farmers to enhance their production systems and improve their bottom line.

This project was completed within the budget planned and ongoing improvements to the systems will be funded from our farm resources. The timeline was stretched out by a year to allow all activities to get completed. There were some hurdles that resulted in a delay but the real challenge was being able to make the progress desired on the project during the very busy growing season.

On the whole we view this project demonstrated a sustainable method of lowering the operating costs as well as decreasing a farms dependence on fossil fuels. This technology is an integral part of our operation and we believe others who embrace this technology will value what it brings to the sustainability of small local produce farms.

## Introduction

This project to demonstrate high efficiency geo-thermal cooling capabilities was carried out by Coveyou Farms LLC of Petoskey, Michigan. Coveyou Farms LLC is a 140 year old family farm in the northern portion of Michigan's Lower Peninsula that focuses on growing produce, flowers and other items for sale to the local and regional community. This project was funded solely through the resources of Coveyou Farms LLC and the USDA CIG grant program. The results and findings of the demonstration project were shared with regional and state farmers through the Northern Michigan Small Farm Conference and through on farm tours with USDA extension coordination.

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## Project Background:

Small and midsized farms across America are transitioning to produce more locally grown crops. Farmers in this new model not only grow vegetable and fruit crops on their land but also sell directly to the customer from their farm. Farmers are challenged to find cost effective and energy efficient technologies to refrigerate their crops for storage and when they are displaying their crops for sale. The cost of running these cooling systems can run from hundreds to thousands of dollars a month based on the farm size significantly impacting the profitability of the operation. Refrigerative cooling is a large expense from a capital investment viewpoint as well as a very significant consumer of fossil fuel based electricity. The purpose of this project was to demonstrate that commercially available geothermal and solar technology can be used for refrigerative vegetable and fruit storage coolers as well as innovative market display coolers resulting in significant reductions in fossil fuel based electricity consumption.

Geo-thermal systems are increasing in use as the commercial technology has improved in efficiency over the years. The use of geothermal heating systems for residential and commercial applications is growing steadily over the years. The core of this technology is the advances in highly efficient heat pumps that can transfer heat energy out of the ground for use in heating the interior space of buildings. The ground temperature at five feet below the earth surface is generally in the 45-50F degree range constantly throughout the year in our part of the world. This constant heat mass allows the heat pump to slowly pull heat energy out of this ground area and use the heat energy to heat water or air inside a structure. Heat pumps these days can now pull from three to five times the heat energy out of the ground compared to the energy used to run the equipment. It is this heat pump technology that we demonstrated in this project not to take heat out of the ground but to run in reverse and take heat out of a walk in cooler or around a produce display table and transfer that heat energy into the ground. Our discussions with experts in this field found little experience in running walk in coolers with this technology. The uncertainty lies in how cold one could cool a space. It was pleasing to confirm that we had no issues keeping a walk in cooler in the 36-38F degree range.

## Review of Methods

This section will review the details of what was implemented in this project.

This project field demonstrated the application of geothermal cooling of farm produce using walk-in coolers and display tables. The walk in cooler was built in the basement of an existing barn that had been converted to be the produce processing and preparation area for vegetables grown on the farm. Metal studding was chosen to frame in the roughly 16’x20’ room. The 6” metal was also used on the ceiling to allow insulation to be added into the ceiling as well. Closed cell foam insulation was blown in and shaved flat. The closed cell material has a high insulation value but more importantly will not absorb moisture from condensation. An inner ½’ insulation board was installed and covered with ½” pressure treated plywood prior to gluing a washable food grade FRP wallboard paneling over the entire inside surface. The floor which was concrete was left in the original condition with ¾" rubber horse stall matting installed to minimize heat transfer through the floor. A conventional walk in cooler door was procured and used for the main entrance doorway. High performance T8 cooler grade lighting was installed as well as a thermostat and condensate drain for the air handler. Produce is kept in this cooler on racking that runs around the perimeter and center section of the cooler. Figure 1.1 show a picture of the interior of the cooler and Figure 1.2 shows a picture of the exterior of the cooler.

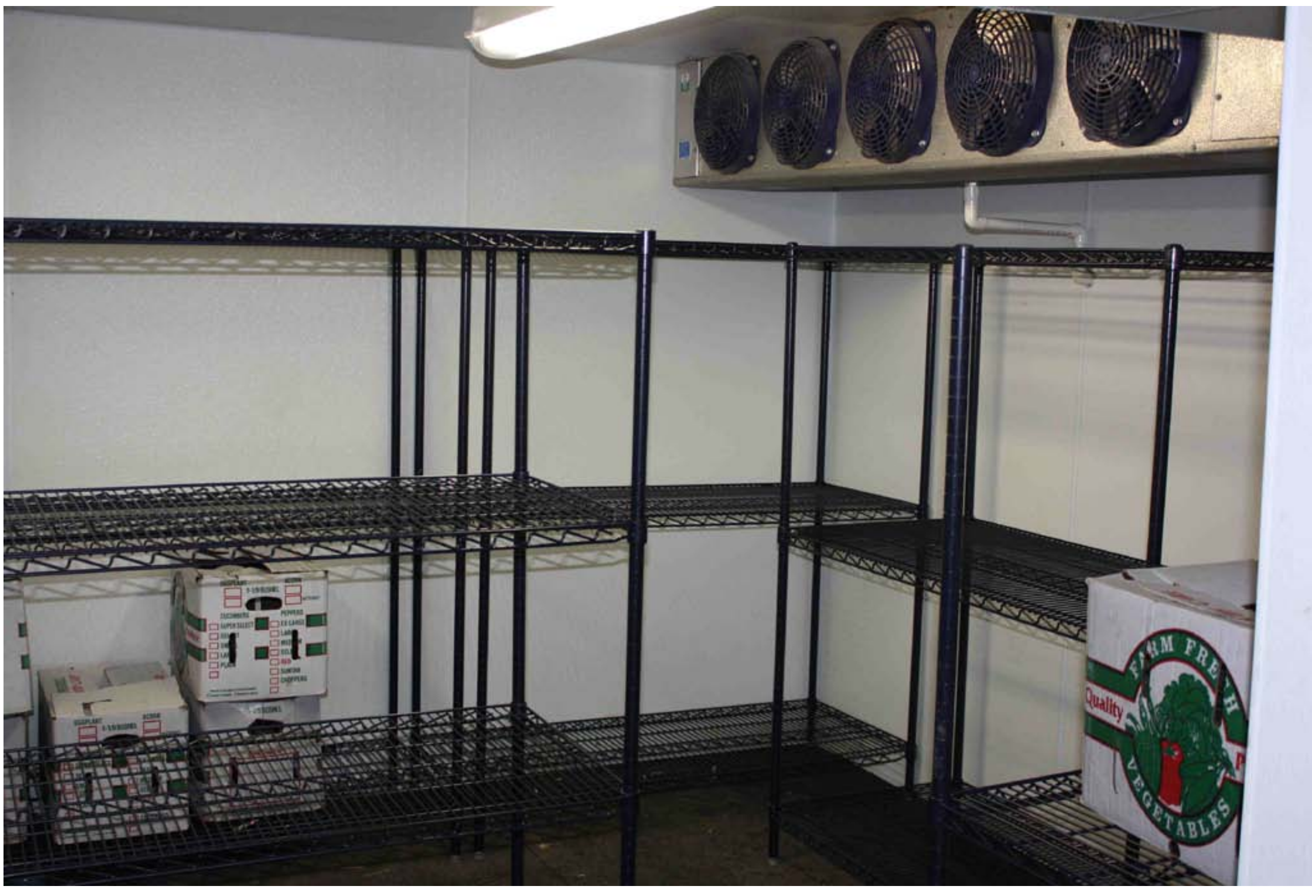


Figure 1.1; Interior of Geothermal Walk in Produce Cooler

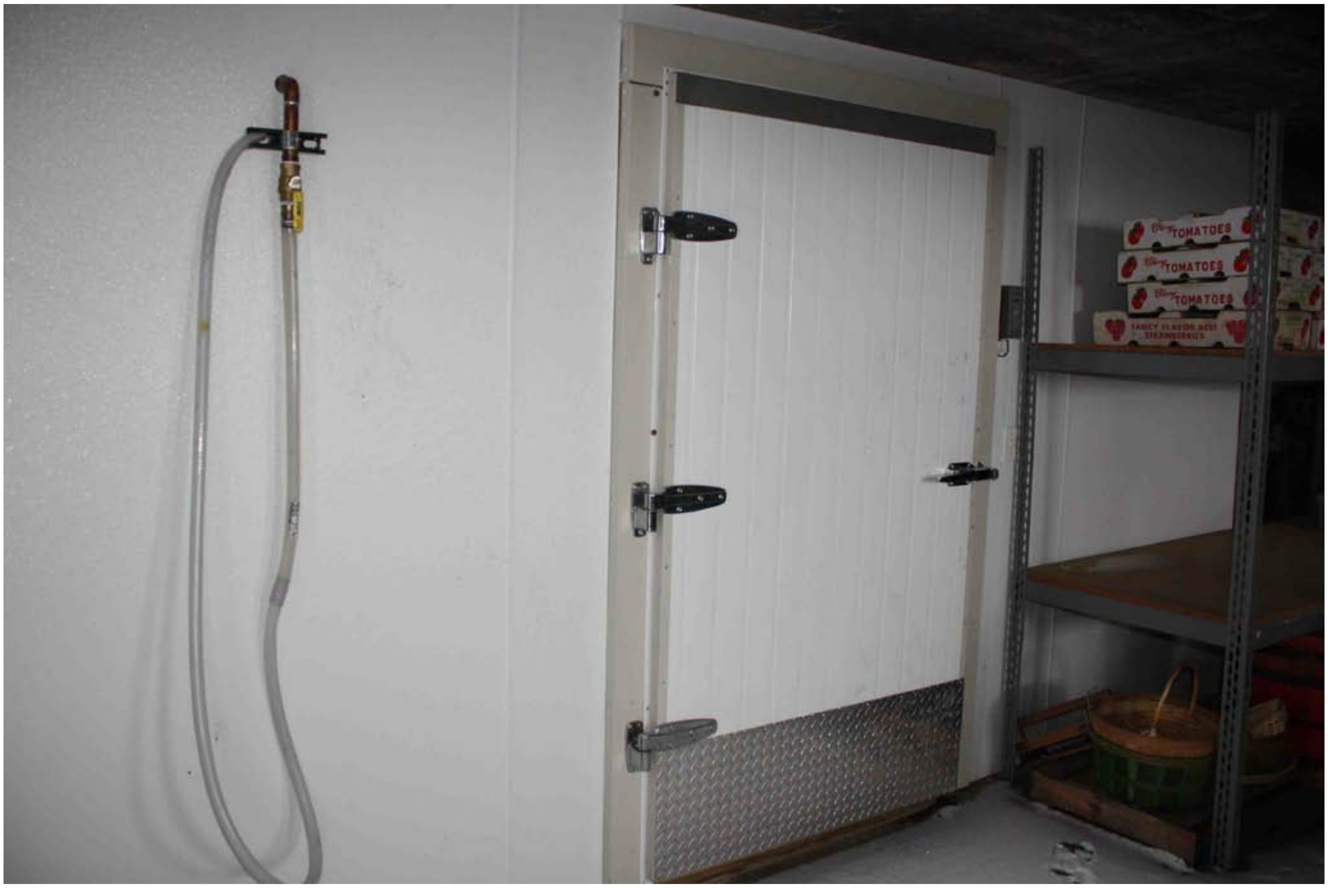


Figure 1.2; Exterior of Geothermal Walk In Produce Cooler

The heat pump system was installed in the basement of the barn adjacent to the walk in cooler space. The system is made up of the main heat pump unit and a reserve insulated chilled fluid tank. The geo heat pump chills this reserve tank which holds an environmentally save antifreeze solution to a temperature of 28F. It is this chilled fluid that is circulated to the cooler when called upon and transferred to the air in the walk in cooler with a chilled water fan coil blower which uses higher efficiency ECM motors. This unit is a water to air chiller unit and is physically larger than a conventional refrigerant based system. The cooler fan coil unit is wired to blow air only when the temperature rises above the desired set point on the interior thermostat. This again is different than conventional systems where the blower unit runs all the time. We have chosen to set our thermostat at 38F for the type of produce we grow. At this cooling level the geo unit runs at a consistent but minimal level to maintain the temperature.    Figure 1.3 shows a picture of the geothermal chilling equipment.

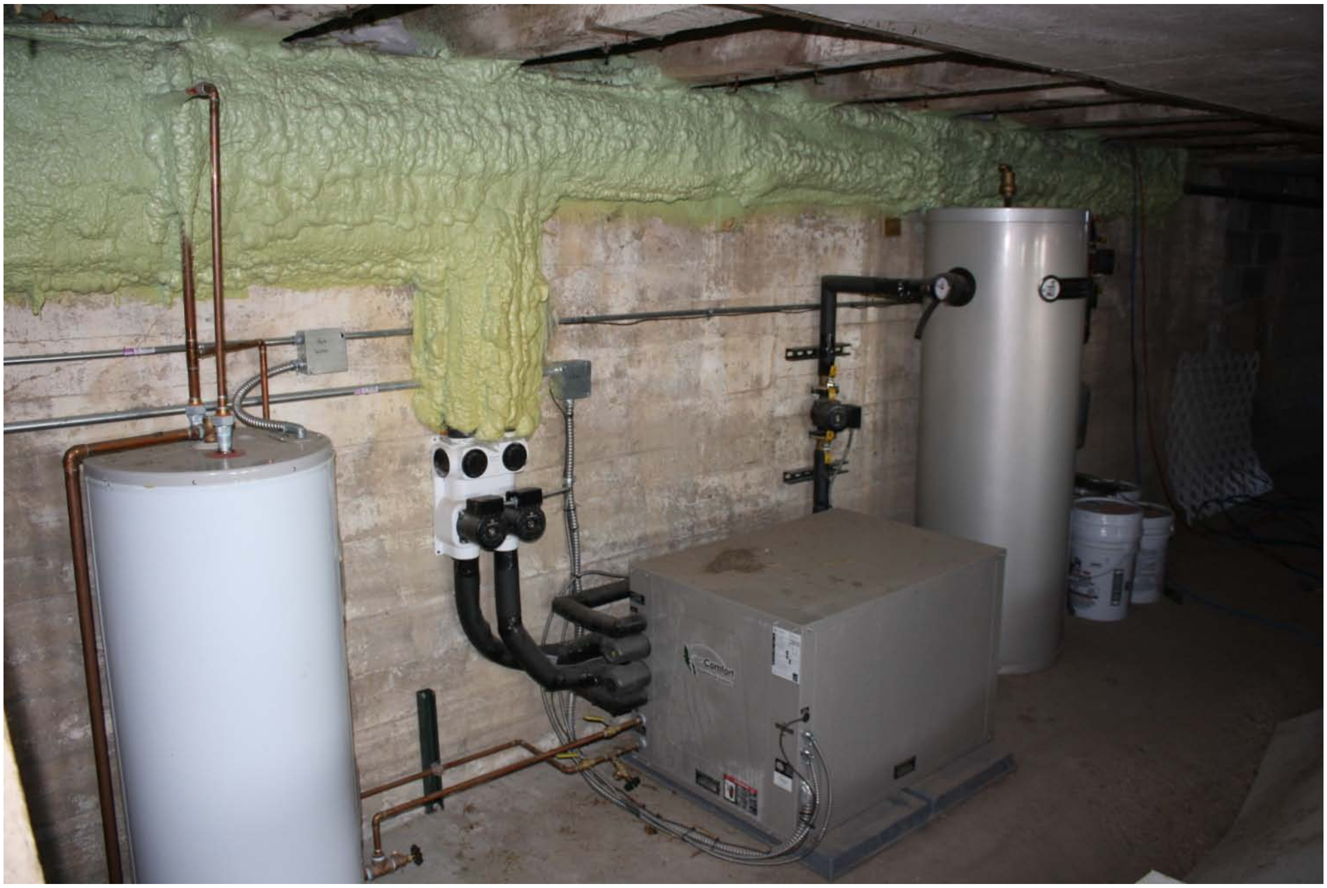

Figure 1.3:  Geothermal chilling Heat Pump and chilled fluid holding tank

The heat is transferred by the geo pump to an exterior geothermal ground loop field.   The field consists of five trenches that are 4’ wide, 6’ deep and approximately 150’ long.  The field is approximately 50’ wide. In the bottom of each trench were laid two ¾” runs of geothermal oxygen barrier grade thermoplastic tubing.  A second loop was put in each trench at approximately 2’ above the bottom (4’ below ground level).  Two headers tie all 5 trenches together and bring the supply and return lines into the geo pump in the barn using 1.5” poly tubing.  All of the tubing is designed for geothermal fields and includes oxygen barriers for system longevity. Heat from the coolers is slowly spread into the ground as the geo fluid is circulated through the field.

This project also was to demonstrate that this heat pump could cool produce in a retail environment. The upper portion of the barn housing the walk in coolers is the farm's retail space for our farm grown produce. Piping was run around the perimeter edge of the upper barn and foamed in with the same closed cell foam to minimize sweating from the air humidity coming in contact with the chilled water tubing. Condensation and wood rotting over time in the structure are key considerations given in this design. This piping also included potable water for fog misting of the produce in the tables and a condensate drain pipe. Figure 1.3 shows the perimeter edge piping during construction.

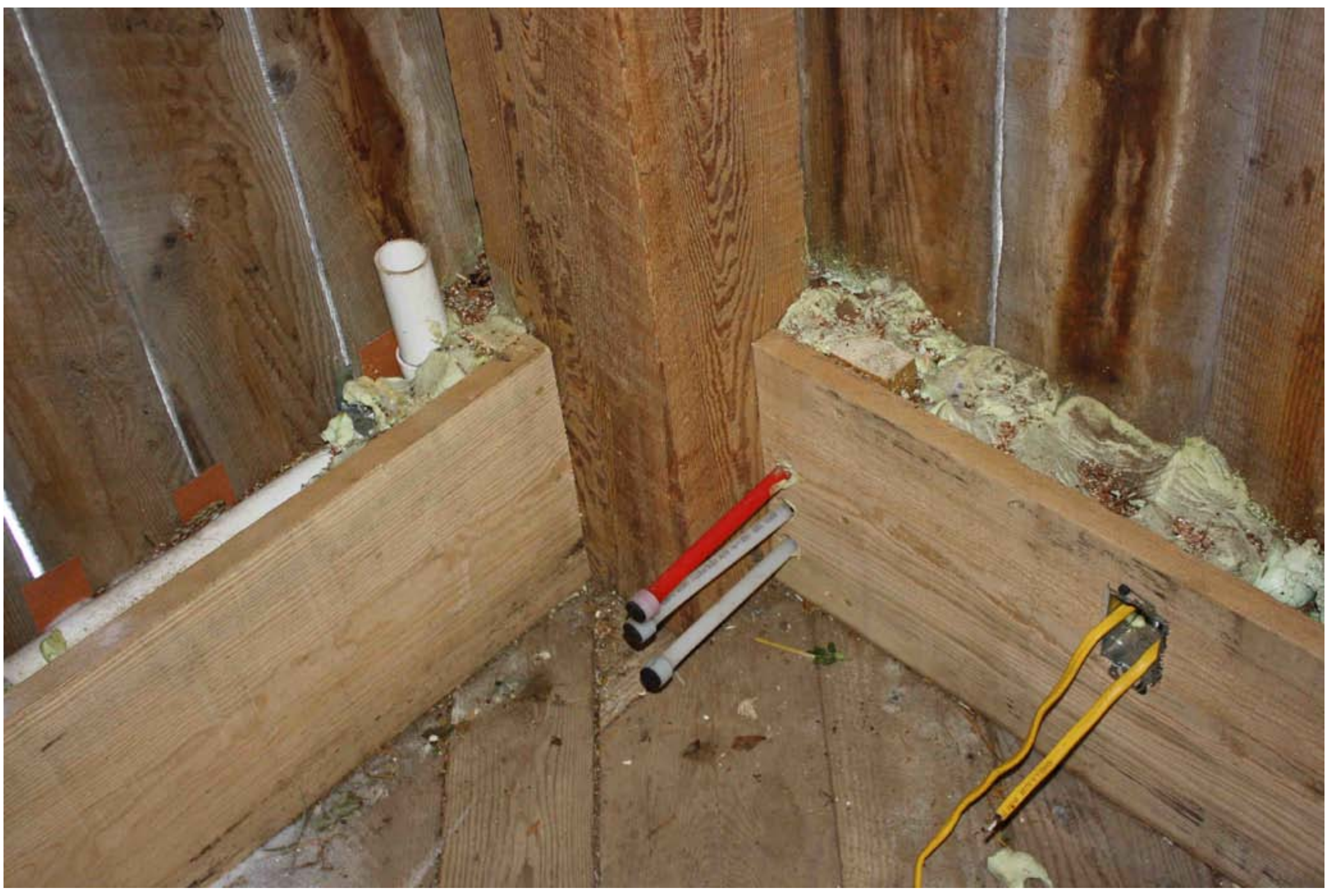

Figure 1.3 Geothermal display tubing installation

The exterior wall piping connects to a custom made display table through a flexible insulated pipe. This flexible connection continues to be one of the largest challenges with the display table system. Even a small air access to the 28F chilled water tubing to the ambient air temperature results in condensation and sweating. We are still working to perfect this portion of the design with even the mounting brackets of the tubing sweating enough to create saturated wood around the fittings. Refinements in this area will continue in the future.

The cooling display tables themselves have a large amount of effort that went into the design. Everything from the laminar air flow over the top of the produce to the customer access and condensation drainage challenges. The tables are made from local white cedar due to their need to handle moisture. A slanted top allows the produce to be on an angle for the customer's eye but also allows a chilled layer of air to have a slow laminar flow over the top of the produce. A low profile fan coil unit is within the triangular cavity beneath the produce and it pulls air from slots across the front of the table and returns chilled air out the top slot above the produce in the table. A stainless steel pan is used on one version with a washable wallboard used on others to keep cost down. A NSF food grade rack is used to set the produce on in this design. We have trialed multiple versions of this table with a focus on reducing the cost of the fan coil unit and pan along with reducing the sound of the fans in operation. Although the display table system functions it is not yet optimized to the point where we could offer it for others to trial. We are continuing this refinement effort after the conclusion of the grant to improve on this component of the system. Figure 1.4 shows a picture of the produce display table.

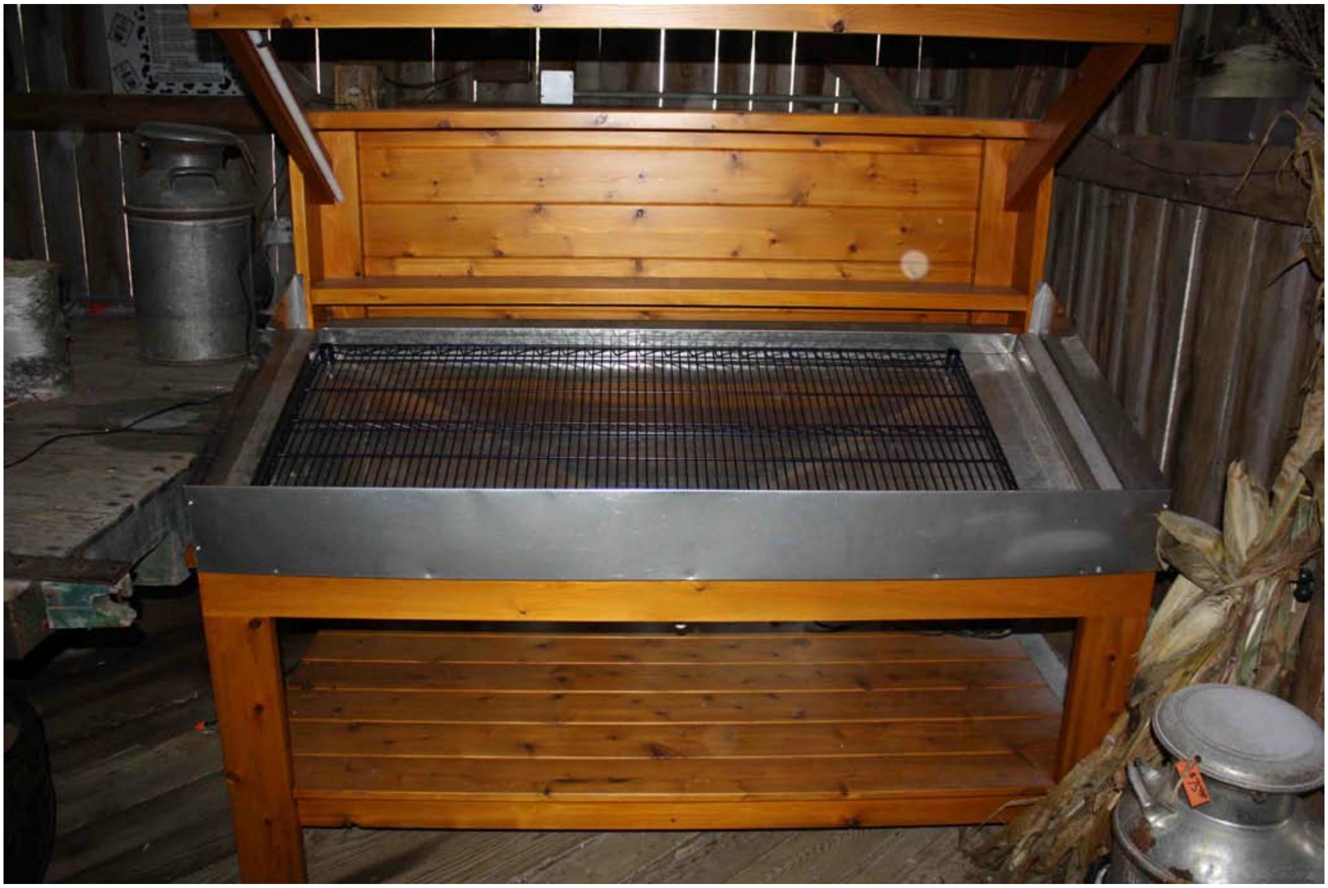

Figure1.4 Produce Display Table

In addition we are working to explore further the use of existing used produce coolers that could be retrofitted out of their standard compressor technology to be used with the existing geothermal systems. We believe this approach may be more cost effective than building stand alone produce display coolers in the future.

The real effort in this project was to see how efficient this geothermal technology would be compared to standard existing technology. We had an independent review of our system done by Franklin Energy Advisors of Lansing, MI where they compared the efficiency of a similarly sized walk in cooler that uses a traditional refrigerative compressor with the data collected on the energy consumption from our geothermal unit. The findings revealed that the geothermal system used about 80% less energy than a conventional unit. This calculation was based on the energy consumption of a conventional new walk in cooler of the same size would consume 58kWh of electricity per day. The actual measured consumption was calculated to be 10.8kWh and included not only the walk in cooler but also the field heat chilled water usage as well. The calculations were based on our electrical consumption numbers for the entire farm over a four month summer period based on year over year historical averages. Later in 2013 we added a separate electrical meter to run the geothermal unit from to allow us to capture the exact consumption of just the geo heat pump. The second meter was motivated by the fact the utility company will charge a reduced rate for energy used to run a geothermal system which may be another factor for other farmers to consider when exploring installing this type of system. It was rewarding to see that the cooling system uses a very small amount of additional electricity and is exactly the type of direction we were looking to explore with this project.

There were a couple unexpected added benefits of this system not originally planned. During the detailed design and implementation of the geo system it became evident that we could easily use this system to add a produce field heat removal system. Instantly chilling produce as it comes in from the field is the best way to improve eating and storage quality. The 28F fluid in the storage tank could additionally chill the potable water used to drench / wash our produce coming in from the field. This addition has been a great improvement on the storability of produce and a key feature to be added to any system design in the future. Figure 1.5 is a picture of the chilled water tank for produce field chilling.

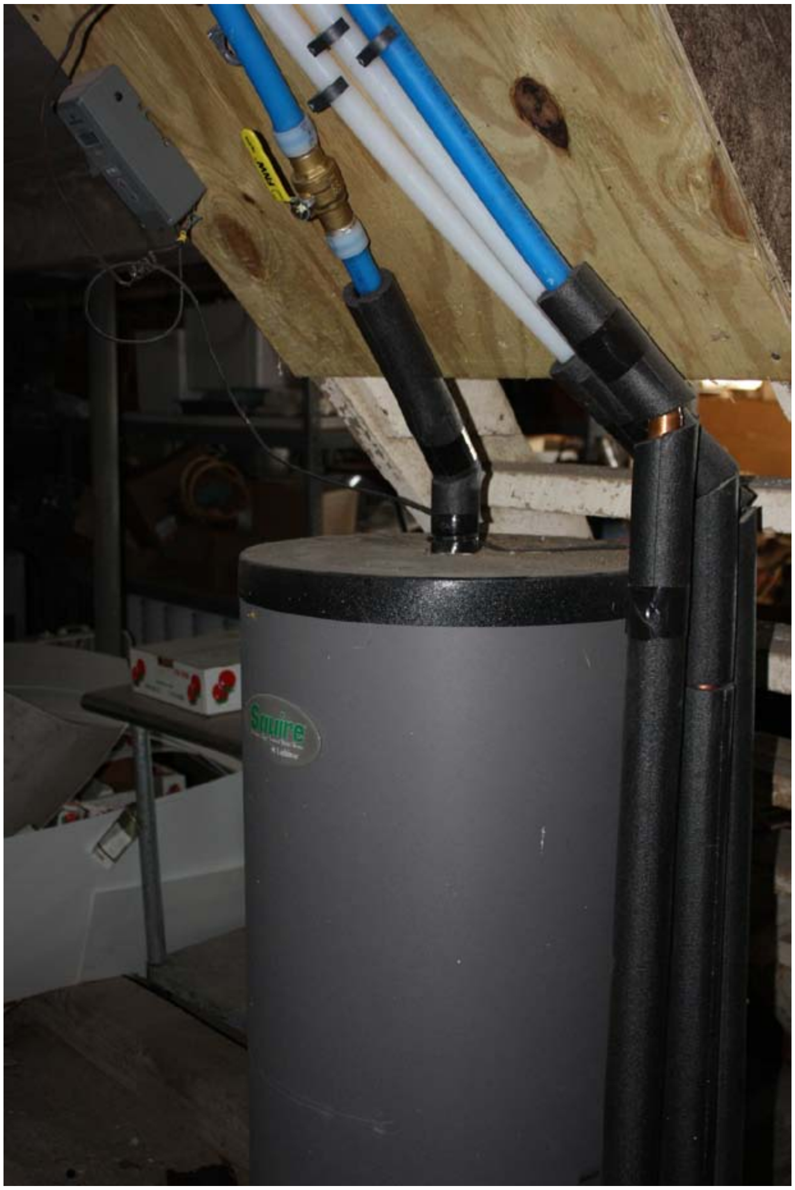

Figure 1.5  Chilled water heat exchanger tank for field heat removal system.

Another bonus of this system has been the ability to use the warmer fluid that is going out to the geo field to preheat a hot water heater in the wash area.  The use of this "free" heat prior to it going out to the geo field is another bonus and adds to further energy savings on the farm.

In our application there is not a need for heat in this building during the winter months.  If other farms have walk in coolers that are in a building that also needs heat in the winter when the coolers may not be used then there is the added potential for using the geo heat pump to pull the stored heat energy out of the ground field and use it to heat the building during the offseason. We are planning to use this geothermal heat pump to generate heat for an in floor heating system to support winter lettuce growing and seed propagation in an adjacent greenhouse. This multipurpose use of the investment will bring additional savings to the farm.

As the years have gone forward we are realizing that electrical systems are bringing some of the greatest advancements in energy conservation. We are moving our irrigation pump to use a higher efficiency variable frequency drive electric pump system replacing our gas water pump. The produce coolers, field harvest removal, hot water heating and greenhouse supplemental heat are all now part of higher efficiency systems that use electricity. It is this move to higher efficiency and electricity use that explains our focus on generating electricity on farm.

This project additionally planned to minimize the fossil fuel impact of the cooling system by adding a solar PV system to the farm complex. This solar PV system was designed, procured and installed and net metered into the same service from which the geothermal system is run and would effectively decrease or eliminate any fossil fuel electrical energy generation when averaged over the year. An 18KW solar PV system was installed with the net metering hook up. The system is comprised of US made SW265 Mono solar panels with US made M250 Enphase Micro inverters on each panel. The system uses an Envoy data tracker to allow the monitoring and tracking of energy consumption on each panel individually. There are no battery storage components of the system. Any excess solar production spins the electrical meter backwards effectively creating a bank account of energy to be used at some other time of the year on the farm. In typical years we believe this solar array will provide all the energy needs of the geothermal system when averaged over a full calendar year. Figure 1.6 shows a picture of the solar array.

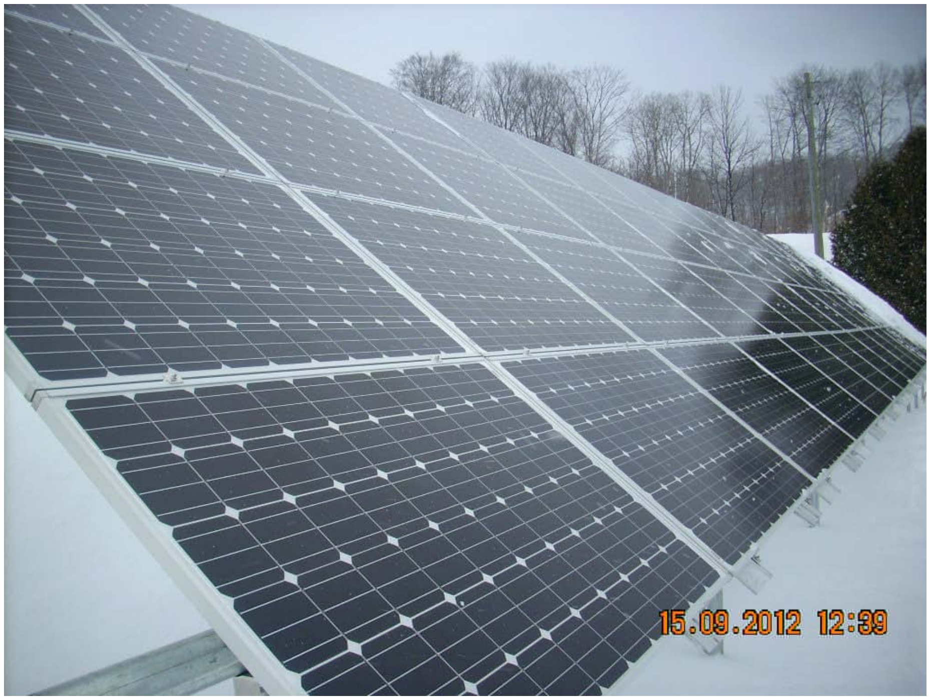


Figure 1.6 Solar PVArray

This move to a more electric based farm not only allows all the cooling to be performed with the geothermal heat pump but will also provide the electricity to be more efficient in other areas as well. The conversion of our cooling system to geothermal, our hot water generation from geothermal, our produce chilled water from geothermal and future produce growing heating systems based on geothermal along with the movement of our gas based irrigation pump to electric with the use of a high efficiency variable frequency drive are all examples of significant reductions in operating costs for the farm through energy conservation. This cost improvement is based on the elimination of a fossil fuel based conventional system and replacing it with a newer technology that brings greater operating efficiency. On small farms where solar or wind can produce enough energy to power their operation this move to electric has potential that is worth exploring further.

## Outreach and Sharing of Results

The results of this demonstration project have been shared in multiple ways. A presentation was given at the yearly Northern Michigan Small Farm Conference in Grayling, MI in January of 2013. This conference brings over 600 small farmers from around the region together. Our presentation on these conservation innovation technologies was standing room only with many rating in the post presentation survey that the material presented was very applicable to their operation and that many replied they would consider using these ideas in their farm practices. The positive responses led the conference committee to ask that we repeat the presentation at the February, 2014 Small Farms Conference where we will update the presentation with the latest improvements and additional work.

The second main outreach activity took place in August of 2012 with a USDA NRCS planned bus tour bringing farmers from around the state and greater Midwest to see innovative farms. This walking tour and first hand being able to answer questions from the many farmers was another good way for people to take away the insight and knowledge developed in this project.

Additionally, an overview of this conservation project was presented at the USDA Value Added National Conference in June of 2012 in Traverse City, MI. This presentation was well received by those in attendance.

In addition to these formal presentations on the technology there have been many individuals who have asked for insight or I have shared what we are doing with conservation innovation technologies on the farm.

## Deliverables

This project has six deliverables.

1. **Demonstrate that commercially available geothermal heat pumps that are conventionally used to heat and cool structures can be used very efficiently to cool agricultural fruits and vegetables.**

   This deliverable has been met by the design, procurement, installation and operation of the geo-thermal cooler system using a commercially available heat pump. The heat pump was able to consistently and reliably keep the walk in cooler at 39 degree F over the full production year with significantly reduced energy inputs.

2. Demonstrate geothermal refrigeration tables can be designed and implemented that can replace electric refrigeration units in small farm display markets.

   This deliverable has been met by the design, assembly and operation of a geo-thermally chilled produce table.

3. Demonstrate that a geothermal heat pump system can be used to cool walk in vegetable and fruit coolers for small farm operations.

   This deliverable has been met by the design, assembly, installation and operation of the geo-thermal walk in cooler which ran superbly through the entire produce production season.

4. Demonstrate that solar photovoltaic energy can be used to power the highly efficient geothermal heat pumps when net-meter averaged over a one year period.

   This deliverable has been met by the design, assembly and installation of a net-metered solar PV array which feeds into the same service as the geo-thermal cooling system.

5. Collect data and evaluate the effectiveness, utility, affordability, usability and overall benefits of this geothermal / solar system over a two year period in a commercial growing environment.

   We are concluding that this deliverable has been met. We have been able to collect sufficient enough data to prove the conclusions even though a full two years of commercial growing were not achieved with all portions of the project.

6. Document the design, installation, operation and effectiveness of the project in a manner that it can be transferred and used by others.

We view that this deliverable has been met. The communication of our demonstration project findings have been described in previous the Outreach section along with this final report.

## Findings, Conclusions and Recommendations

This project demonstrated that geothermal technologies have real potential to decrease the operating costs of farms that use on farm refrigeration. In our demonstration this saving was significant with consumption a mere 20% of conventional systems. These improvements come with the added benefit of removing the reliance on fossil fuels and helping to reduce carbon footprint. It is our conclusion that geothermal technology can play a role in farm systems that deals with moving heat from one location to another or that involve heating or cooling areas. Farms have the added benefit of the land area needed for these systems. Urban areas where land parcels are not as large would have difficulty implementing these systems without significant additional costs. Farms, in general, have the land and can implement a system similar to what was demonstrated here.

Technologies keep evolving and we are growing stronger in our belief that the efficiency improvements now taking place with electrical systems are making their use more practical and economical than a decade ago. The continual rise in fossil fuel prices and the variability of these prices makes it all the more important to find solutions that reduce cost and are more predictable. On small farms where solar or wind can produce enough energy to power their operation this move to electric has potential that is worth exploring further.

Keeping abreast of the evolving commercial technologies and finding ways to apply them to our farm operations will go a long way to improving the environmental and economic character of agriculture.

It is our hope and intention that others in the farming community will be able to benefit from this demonstration project and be able to build upon this work to further the use of this technology and spur the application of others in the future.