Sustainability Demonstration House Project

Alternative Energy Enterprise -Spring Final Report

April, 2020

Advisors: Jay Meldrum, Dr. David Shonnard

Team Members:

Cassidy Tieman
Luke Haskin
Jenna Kivela-Heinz
Jessie McInnis
Olivia Rockwood

Table of Contents

Introduction

The goal of the Sustainability Demonstration House (SDH) project is to retrofit the former president's residence, built in 1953, titled the Kettle-Gundlach Building, into a sustainability demonstration house. The SDH will serve as a resource for the community to learn from, and experience energy efficient, low carbon living. The house is located on Woodland Drive, next door to the Innovation Center for Entrepreneurship, very close to the East McNair Residence Hall.

Motivation

One of the biggest motivating factors for this project is the electricity rate in the area. The rates in Houghton and the surrounding area are 63% higher than the national average [1]. Reducing electricity use is not only environmentally friendly, but is an easy way to save money. From a broader perspective, it is easy to ignore the environmental impact of modern day conveniences, like waste removal, instant electricity and gas, and clean water. Unfortunately, many of these conveniences depend on the availability of limited resources. Electricity is still largely generated by coal-burning, which has an adverse impact on Earth's atmosphere. Waste taken from your home is ultimately sent to a landfill. Sustainability, in short, is understanding the impact of human actions on the environment to preserve resources and ensure healthy living communities for future generations. The SDH project was created to educate both the Michigan Tech and Keweenaw communities on sustainable living and demonstrate its impact on the local environment. This provides experiences that people can view firsthand and apply to their own lifestyle. Students will be able to put their own ideas into action and directly see the benefits and challenges this lifestyle brings, while also positively impacting the local community.

The mission of the SDH is to provide a real life example of sustainable living in the western UP in order to educate students and the surrounding community about sustainable living practices. This shall be completed through home improvement projects aimed at increasing the energy efficiency of the house as well as implementation of sustainable living practices. All changes to the home will be recorded. The effects will be made public through the use of open houses occurring at least once a semester and an SDH blog. Ultimately, the SDH team looks to raise awareness and promote feasible actions individuals can take to build a healthier, more sustainable future.

It is the team's hope that the public and well-documented nature of the SDH will make implementing sustainable living practices more accessible to the general public and encourage students and the surrounding community to implement them in their own homes.

Background

The SDH is being reworked from what was previously known as the Kettle Gundlach House, a Michigan Tech owned building. The university allowed the Alternative Energy Enterprise to gain control over the house and transform it into a Sustainability Demonstration House. The SDH has a deep history that started with the people who built it in 1953: the Gundlach family. Herman Gundlach Sr. was the founder of the very popular Keweenaw construction company, Herman Gundlach Inc, and was especially well known in the Houghton area. His son, Herman Jr. went to Houghton High School and then went on to play football at Harvard. Herman Jr. then served in World War II. After returning from war and working within the family business for years, he took over as the new president of Herman Gundlach Inc. Years later, after owning the company for some time, Herman Jr. built what is now known as the Kettle Gundlach house. This is the house in which multiple Michigan Tech presidents have lived. At this time, many renovations were done to the house. The renovations were intended to make the house better for entertaining guests. It was designed in a way to allow large crowds to occupy the house all at once. This building then became known as the Kettle Gundlach University Residence in 2004, open to the public and various university groups. It was typically used for university-related social gatherings with large groups of people.

The Kettle Gundlach house is a good choice for the SDH project for several reasons. Much like other older homes in the area, it lacks efficient insulation, appliances, furnace, and other features common in modern homes. This lack of modern efficiency is seen as an opportunity for the team. This will allow the team to create a baseline reference as well as a model procedure for increasing sustainability that is applicable to a majority of the houses in the community. The Kettle Gundlach house is also highly visible due to its history as well as its location. This will help to serve the public outreach aspect of this project. With the location of the building, many students and community members will be able to view it.

Ch 1. Greenhouse Team

I. Motivation

In Houghton, MI, the growing season, defined as a continuous period of temperatures above 32 degrees F, lasts roughly 4- 5 months, beginning in the middle of May and ending in early October (1). Realistically, many fruits and vegetables that are attractive to gardeners are warm-season crops that grow best during the warmer months of summer, such as tomatoes, peppers, cucumbers, and more (2). The susceptibility to cold weather damage gives these crops a much shorter growing season, and therefore makes it quite difficult for gardeners in the Upper Peninsula to grow them in outdoor gardens. A greenhouse could allow for gardeners in the UP to grow warm weather crops for an extended growing season.

The two most energy intensive processes required in a greenhouse are the heating mechanisms and methods of irrigation. In order to minimize the amount of energy used in heating, passive solar design will be utilized. A surprisingly large amount of energy is also used in irrigation. An automatic irrigation system would be useful to gardeners who cannot frequently tend to their crops, or are worried about over and under watering them. Designing the system to water plants the correct amount would conserve water and protect the crops from receiving an incorrect amount of water, while also making a system that is more labor efficient.

The overall goal of this project is to design a functional greenhouse that can heat and irrigate plants from early spring through late fall. Since it will be attached to the Sustainability Demonstration House, another goal of the project is to make a greenhouse that is affordable and relatively simple so that it can serve as an example for the community.

II. Location

In order to determine where to place the greenhouse, a few different considerations were made. The first consideration was that the SDH currently has a small, six by six foot raised bed garden in the yard. Perhaps the greenhouse could be built over top of the garden to give that garden an extended growing season. Another option to be considered was an attached greenhouse, which means to put the greenhouse up against a wall of the house. These are common in cold, harsh climates because they provide additional support and heating to the greenhouse. The final consideration was that the greenhouse needed to primarily face south in order to receive the greatest levels of solar exposure. With these factors in mind, the final decision was made to design an attached greenhouse connected to the north side of the house. Figure 1 circles the area of the house that the greenhouse will be built against.

Figure 1. Location of Greenhouse on SDH

III. Structure

There were many different options to consider when designing the structure. Many warm climate greenhouses have all translucent sides to allow maximum light through, but since Houghton is a colder climate, we were swayed towards a design with one glazed side and the rest insulated, which in this case would face south to receive the most solar exposure as detailed earlier. Because of this, an asymmetric design was chosen, with the sketched model shown below. A single roof wall directly sloped up to the house was chosen so that snow would not be able to build up in the valley between the roof and the house.

Other design challenges included how to slope the roof. The primary factors that went into considering roof angle involved sun exposure, snow load, and space. In order to get maximum solar exposure, it is advantageous to have a roof angle that is perpendicular to the angle of the sun. In order to determine these angles, the winter and summer solstices were used as well as fall and spring equinoxes. The sun angle was found for these days at noon in Houghton, MI and the perpendicular roof angle was then calculated, shown in Table 1.

Table 1. Roof angles for 21st day of the month at noon in Houghton

Month	Sun Angle (º)	Roof Angle (º)
December	18.51	71.49
March	36.25	53.75
June	56.89	33.11
September	38	52

Recommendations for roof angling tend to suggest that the roof should be angled for the winter solstice, as most solar exposure is needed in the middle of winter. Summer tends to get adequate sun and heat regardless, and angling the roof for maximum exposure in summer can lead to overheating and require additional ventilation. Other factors that needed to be considered include snow load. A relatively shallow angle would cause snow build-up and may put unnecessary loading on the roof. Anything as shallow as 30 degrees or more will not allow snow to slide off. The final factor that needed to be balanced with these needs is space and area for growing inside the greenhouse. Steep angles combined with an asymmetric design can make it difficult to create adequate space for plants and grow beds. Looking at these factors altogether, and understanding that this greenhouse's purpose is most intended to function spring through summer, an angle of 50 degrees was chosen. Figure 2. shows a sketch of the greenhouse (dimensions in feet). Beams are standard 2x4 beams with 16 inch spacing.

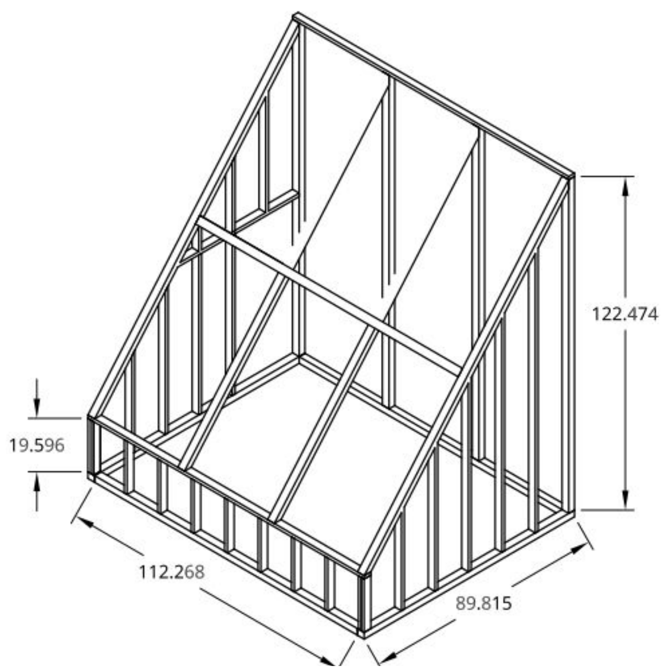

Figure 2. Greenhouse Drawing

IV. Model Greenhouse

To demonstrate the greenhouse structure, a small scale model of the greenhouse was built using balsa wood and wood glue and a 1:14 scale. This model was not only useful when discussing structure and angles, but also for examining different interior grow bed layouts and plant spacings.

Figure 3. Model Greenhouse

V. Materials

Typical materials used to design greenhouses include aluminum, steel, and wood for pillars and films, plastics, and glass for the glazed portion (3). Designing a permanent greenhouse for a climate that has harsh winters like Houghton requires sturdy materials, so aluminum beams and plastic sheeting would not be sufficient. We also wanted to use materials that were easily accessible and cheap, so we decided on wood and single or double polycarbonate. The insulation will likely be fiberglass but this may change based on the available materials.

VI. Interior Layout

In order to maximize growing space in the greenhouse while still allowing room for walking and maintenance, the grow beds inside of the greenhouse were designed to be positioned as shown below (dimensions in feet).

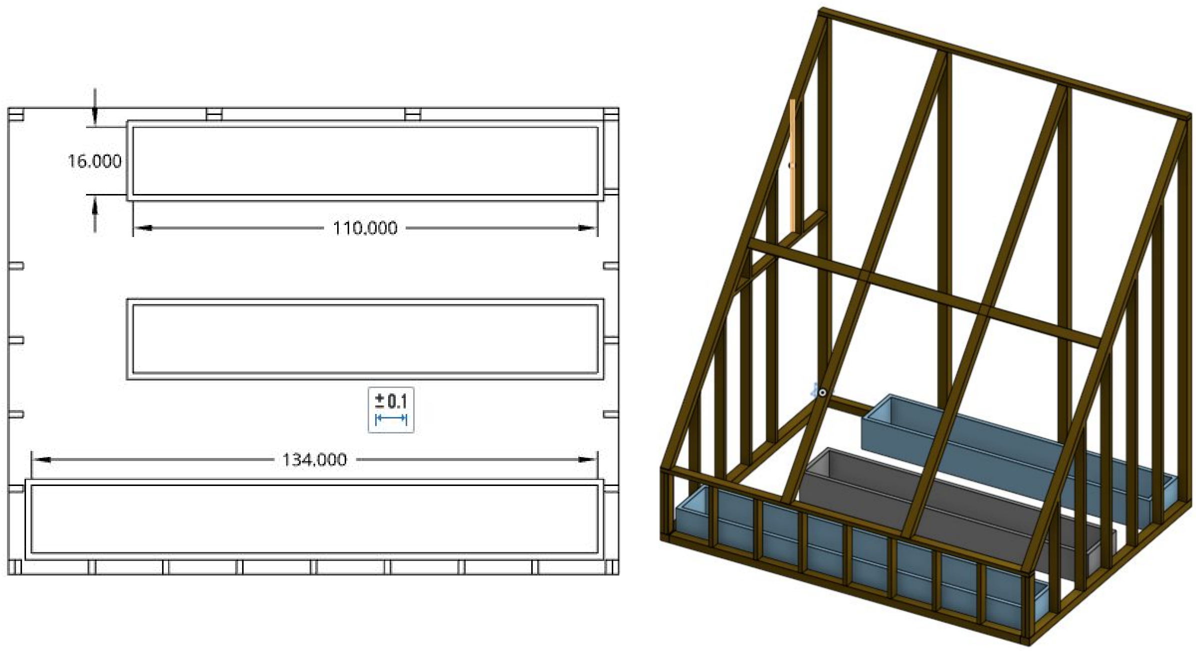

Figure 4. Greenhouse Grow Beds Layout

One intent of this positioning was to group plants of like heights in the same bed. Since the greenhouse is dramatically sloped, this allows for tall plants such as tomatoes to be grown against the back wall, while shorter plants like carrots can be grown near the footwall.

VII.Ventilation

Another key consideration when designing a greenhouse is ventilation. The key purposes of having ventilation in a greenhouse are for controlling temperature and humidity and allowing fresh air in for plants. Ventilation is needed both in winter and summer climates. The recommended air changes per hour regardless of volume are two air changes per hour in the winter and between thirty and sixty air changes per hour in the summer depending on location. As the greenhouse is intended to be in operation from early spring to late fall, more than two air changes per hour will be necessary. A value in between winter's two and summer's thirty to sixty will be our goal. In order to create these air changes per hour; a passive system will be introduced initially. Wind between april and october is mostly from the North West which fits well with the greenhouse's position. The passive system will involve three wooden hatches. One will be three by three inches in the middle of the door. This hatch will be used in early spring and late fall when it is a bit too cold for full ventilation. The second will be two by two feet on the wall opposite the door, near the top. This hatch would be used during the summer along with the door acting as a ventilation in tandem. The third and last hatch will be in the second hatch. It will also be three by three inches in the center of the hatch and be used with the first hatch for a constant airflow. This system would fit the winds direction maximizing air changes per hour without use of an active system. These matches would have to be manually maintained depending on the weather. An automated system for the hatches may be installed eventually if desired. On site testing was not available to determine if only the use of wind would be viable during this part of the year due to the quarantine established during this time.

VIII. Heating and Insulation

The growing season in the UP is cut short by the colder climate of the area every year. This hinders produce production for many gardeners seeking to practice sustainable eating habits by growing some of their own food. A greenhouse is a fantastic way to increase produce production because of the way it traps heat for the plants among other benefits. Gardeners seek extra help to extend the growing season to early spring and late fall by adding additional heating sources to their greenhouses. The solution that the SDH team has come up with involves several heating methods to work together rather than one single method.

Last semester, the SDH team designed and constructed a solar air heater for the greenhouse after deciding that it would be the most effective method of heating. However, solar air heaters rely on clear skies for sun exposure which isn't always readily available in the early spring months. This semester it was decided that more efforts should be taken to explore other possible heating methods to be used in tandem with the solar air heater, as well as developing a plan for better insulating the greenhouse. One method of heating that the team saw potential in was utilizing the already existing in-floor heating system at the house. There are pipes underneath the first floor and part of the sidewalk at the house that transport hot water to heat the floor above. The SDH team is currently exploring the possibility of expanding the piping system past the sidewalks to the location where the greenhouse will be built. This would be extremely beneficial to the greenhouse as the hot water pipes would heat the ground directly, keeping the roots of the plants warm and preventing the soil from freezing in the event of an April frost. The feasibility of this heating method is still not known, as there is very little information about the piping system available in the house blueprints. More information will be needed in order to decide if this heating method will be cost-effective, but it is a promising opportunity to utilize an already existing feature of the house and the SDH team looks forward to exploring it further next semester.

Producing heat for the greenhouse is important for ensuring that plants thrive, but equally important is ensuring that the heat that is generated is not lost to the outside air. Insulation methods are being considered for not only extending the growing season, but also keeping plants warm during the night. When a part of the Earth is experiencing nighttime, radiant heat losses occur as the warmth of the Earth is transferred into space. To mitigate these heat losses in the greenhouse, it was determined that additional insulation methods may be needed. The SDH team had already planned on insulating all of the non-glazed portions of the greenhouse, but the glazing on the top will allow for radiant heat losses at night time. To solve this problem, an energy blanket or screen is being considered. Energy blankets act as thermal barriers within the greenhouse by reducing the amount of surface area where heat loss can occur while also reducing radiant losses during nighttime hours. Energy screens trap a layer of air on either side and have the potential of reducing heating demand by 30 to 50 percent. However, energy blankets can be costly to install and may not be necessary for this small scale greenhouse. It is possible that simply using horticultural fleece to cover the plants on particularly cold nights could be effective enough for the scale of this project. Insulation design will carry over into next semester.

IX. Irrigation

This semester, some further work was done on designing an efficient, automatic irrigation system for the greenhouse. Last semester we determined that we wanted to be able to control the flow to each individual row using some sort of PVC irrigation. This semester a few additional elements were determined.

Water Demand

In order to determine a collection system, we needed to know how much rain we would be getting between the operating months of April through October. For the pretend design scenario, we estimated fitting about 17 tomato plants in the greenhouse, giving each roughly one square foot to grow. Since most vegetable plants need about 1 inch of water per week, we equated this to about 1 gallon a week per plant, or 17 gallons of water per week total.

Water Collection

In order to meet this water demand, we looked into a few different ways of collecting water, including collecting it directly into an open barrel, having a rain cone, or intercepting the water from the roof to instead be funneled to the greenhouse before it goes down the roof drain. The final decision that yielded the most water for the least amount of complexity was to have a rain cone collection on the roof that can then be piped down into a rain barrel next to the greenhouse. Using average precipitation levels for Houghton, MI, the gallons per week of water expected was calculated using different sized rain cones. A rain cone with a radius of 4 feet resulted in values consistently close to or above 17 gallons per week, as shown below in Table 2.

.

Month	Week	Volume (gal)
April	1	13.47
	2	12.53
	3	12.21
	4	19.73
May	1	17.23
	2	17.23
	3	18.48
	4	23.49
June	1	17.23
	2	18.48
	3	19.73
	4	22.24
July	1	19.73
	2	18.48
	3	17.23
	4	22.24
August	1	14.72
	2	17.23
	3	16.29
	4	24.74
September	1	23.49
	2	24.74
	3	25.68
	4	34.45
October	1	23.49
	2	22.24
	3	22.24
	4	25.68

Table 2. Estimated gallons of rainwater collected using a 48 inch radius rain cone.

Water Distribution

After the water is collected into the rain barrel, the water then needs to be piped to each grow bed. Last semester, a decision matrix led us to determine that we wanted a PVC system with drip lines or holes to water the plants. The first consideration when designing this distribution system was whether or not to use a pump. Pumps provide extra flow needed to reach desired pressures, and this would be useful to achieve steady water release in the pipes. Pumps also require energy, and since the intent of the SDH is to minimize energy usage, a gravity fed system was chosen. Gravity fed rain barrel irrigation primarily gets its pressure from a difference in height between the rain barrel spigot and water release point. Since we wanted the water to flow out of holes in the PVC directly to the plant, we used the basic concept of the continuity equation to determine that we would need very small drilled holes in the PVC to achieve an adequate velocity within this system. We would also need to raise the rain barrel a considerable amount off the ground. The PVC pipes would be positioned to one side of the grow bed, with the holes drilled so that the water streams out onto the plants in the middle of the bed. The following preliminary drawing illustrates this goal, with the black lines representing PVC, the green boxes representing the grow beds, and the blue circle representing the rain barrel.

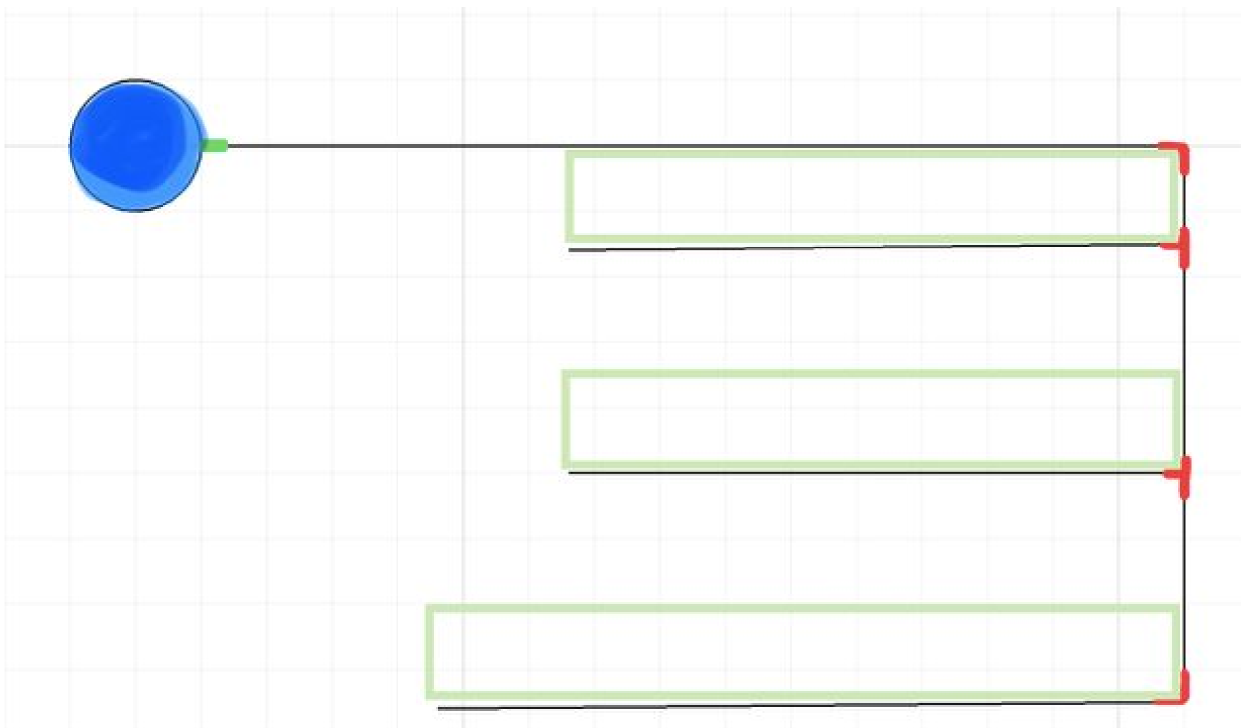

Figure 6. Irrigation System Pipeline Distribution

The fittings were converted into equivalent pipe length and the Hazen Williams equation was then used to estimate potential flow rates from the release points. For this example shown in Table 3, the barrel was raised one meter off the ground and the holes had a 1/32 inch diameter.

Table 3. Pipe Flow Calculations

Knowns		
Variable	Value	Unit
Pipe Radius, r	0.002	m
Length of Pipe, L	30.480	m
Viscosity of water, n @20 C	0.001	Pa/s
Change in Height from spigot to drip, h	1.000	m
Gravity, g	9.810	m/s^2
Density of water, rho	997.000	kg/m^3
Number of Elbows	4.000	
Number of Tees	4.000	
Equivalent Pipe length of Elbow	0.091	m
Equivalent Pipe length of Tee	0.043	m
Calculated		
Equivalent Pipe Length, L	30.615	m
Pressure, P	9780.570	kg/m*s^2
Flow rate, Q	0.000	m^3/s
Velocity, v	0.101	m/s
Flow rate ,Q	0.013	gpm
Flow rate ,Q	0.757	gph

Overall, a system like this one has many benefits. As mentioned before, the small holes and raised barrel provide enough pressure to get adequate flows. A PVC system allows for easy changes if another growbed were to be added or the current ones were to be moved. Also, additional holes can be drilled where needed, and unneeded holes can be easily patched.

Automation and Cost Estimate

The final step to this irrigation system would be automating it. Since the PVC branches off to each growbed, it would be very simple to have a sensor timed valve that could control the water flow before it branches off. These would be placed at each fitting and would talk to a moisture sensor placed within the bed. Other necessary parts are shown below in the irrigation cost estimate.

Table 4. Automated Irrigation Cost Estimates

Part Name	Quantity	Cost per unit	Total Cost
3/4 in. PVC Sch. 40 90-Degree S x S Elbow	2	$0.55	$1.10
3/4 in. PVC Sch. 40 S x S Tee	2	$0.61	$1.22
3/4 in. x 10 ft. 480-PSI Schedule 40 PVC Plain End Pipe	6	$2.44	$14.64
Charlotte Pipe 3/4 in. PVC Sch. 40 Female S x FPT Adapter	1	$0.74	$0.74
Warrior High Speed Steel Micro Drill Bit Set, 30 Piece	1	$3.99	$3.99
Rain barrel	1	$110.00	$110.00
Total Cost for Irrigation System			$131.69
Springfield Precise Temp Soil Monitor	3	$5.00	$15.00
12V ½" Hose Normally Closed Solid Electric Solenoid Valve	3	$25.00	$75.00
Arduino	1	$20.00	$20.00
433 MHz radio receiver	1	$5.00	$5.00
Relay	1	$5.00	$5.00
Total Cost for Automation			$120.00
Total Cost for Automated Irrigation System			$251.69

The largest costs for this irrigation would appear to be the rain barrel and the system automation. The SDH may be able to receive a second donation from the company MIRainBarrel, who donated a rain barrel last year to the garden irrigation, which would reduce costs considerably. Levels of automation and resulting costs can be altered depending on the tenants needs and available funding.

X. Future Work

Next steps for this project will include completing a ventilation design and heating design. Once this is completed, available materials can be sourced and a build of the greenhouse can begin. There are many aspects of this greenhouse that can be altered and fitted for the tenants needs, such as location of doors, placement of grow beds, and levels of automation for irrigation and ventilation.

Ch 2. Mt Ripley Recycling Initiative Team

I. Motivation

The motivation for this new Alternative Energy Enterprise project sprouted from passion for sustainability and awareness of the waste production going on at Mt. Ripley. Jessie, a new member of AEE and the SDH team as of the Spring 2020 semester, works at Mt.Ripley as a cashier and would see the everyday excessive use of paper food boats, paper fountain drink cups and coffee/hot chocolate cups, and plastic water cups. This project was also motivated by the fact that there are more sustainable alternatives including but not limited to: recycling paper and plastic, encouraging Mt.Ripley guests to bring their own water bottles, and the possibility of implementing reusable food containers.

II. Process and Key Findings

The process for the Mt. Ripley Recycling Initiative was in a way cut short. Originally, the plan was to gather information on whether the idea was feasible. Second, the plan was to conduct a waste output study so there was concrete data to present to Mt. Ripley and Michigan Tech staff in order to convince them that recycling was necessary. However, this process was cut short because it was determined that recycling at Mt. Ripley was not entirely feasible. Mt. Ripely is located in Ripley, MI, although it is located only five minutes from Michigan Tech. Being that Ripley and towns north of Ripley are so rural and not dense population wise, it is not economically beneficial for waste management to drive to those areas and pick up trash or recyclables. Additionally, recyclables cannot be grease-contaminated. Given that the majority of the food sold at the Mt.Ripley cafe is fairly greasy, this brings about another issue. Therefore, even if waste management was able to pick up waste from the skill hill, we'd have to find a way to prevent grease from contaminating the paper, like possibly putting paper in the food bowls to prevent grease. After evaluating this idea, it'd be reducing some waste but just adding to it another way. Due to this, focus shifted to encouraging bringing your own water bottle and the possibility of implementing reusable food containers.

III. Future Work

The plan for the Fall 2020 semester, and possibly over the summer, is to look into the OZZI systems. OZZI is a revolutionary system that eliminates disposable food containers and replaces them with reusables on college and university campus dining centers. This system has been implemented at University of Wisconsin Green Bay and many other Wisconsin universities, but not one Michigan college or university has adopted OZZI systems. In or by Fall 2020, the plan is to hopefully gather data that proves success from other colleges and universities across the nation. By doing this, it will help guide the recycling initiative in a clear direction.

Ch 3. Sustainability Demonstration House Team

I. Open Houses

The overall goal of the open houses hosted at and about the Sustainability Demonstration House is to educate the community on sustainable living and to provide an example of how they can adopt sustainable practices within their own home. The SDH team hosted one open house on February 6 at the SDH during this spring semester. It was intentionally held during the week of Winter Carnival when many students' families are visiting the area, and we noticed several students who brought their families to the event. There were about 100 people who attended this spring's open house, and each attendee received sustainable goodies to take home with them. Plantable business cards were given out with information about the SDH, as well as wooden pencils that can be planted once used up. New interactive stations were also incorporated into the open house, including a matching game using newly available CURB data to demonstrate how much power different home appliances use on a daily basis, as well as a game that educated visitors on sustainable and reusable alternatives to everyday single-use items. Although the SDH was only able to hold one open house this semester due to in-person instruction ending after spring break, the one open house that was held was a success and future open houses will be better because of it.

Figure 7. Open House Volunteers

IV. Sustainable Projects Workshop

The goal of the workshops hosted by the SDH is to get the community involved with sustainable projects that are simple and fun to construct. This semester, a workshop was planned that involved doing a series of three different small sustainable projects that families could rotate through. The first project was making beeswax wraps, which can be used to replace plastic baggies when wanting to store and wrap food items. The second project involved making glass jar planters to start herbs and other plants in. Extra aquaponics grow bed material would be used as well as SDH compost, so everyone could have a small piece of the house to take with them. The final project was to make coasters from our in-house plastic waste recycling system. This workshop was scheduled for April, but will now be postponed until fall due to social distancing and stay at home orders. We are confident that when it is eventually held, it will be a great success and an exciting event for families around the community to participate in.

V. Waste Reduction Drive

This semester, the SDH tenants and enterprise team worked to create a waste reduction drive that would collect items that people would usually throw away and recycle or repurpose them. Egg cartons would be donated to farmers, granola bar wrappers would be turned into hard plastics, bottle caps would be turned into kitchenware, and batteries and plastic bags would be properly recycled. Many different forms of advertising were done for this, including hanging posters, making a TV advertisement, reaching out to different departments and the staff, and advertising at open houses. The initial plan was to advertise for the month preceding the event, and then have everyone bring their collected items to campus on a day during "Earth Week" (the week of Earth Day). Due to social distancing protocols, this event is being postponed until next fall.

VI. Tenants

The overall goal of the SDH is to demonstrate sustainable living for the surrounding community. The students selected to live in the house during the school year are encouraged to work collaboratively with one another to progressively limit their environmental impact. Along with this, the students work on general upkeep of the house. Specifics about these responsibilities are discussed below.

There are currently five students living at the SDH, and these students were hand selected by the current SDH tenants, SDH AEE team, and the selection board. Students were selected based on transcripts, letters of recommendation, responses to several essay questions, interview performance, and group-activity performance. To avoid issues amongst students, and between the University and enterprise, a housing policy similar to that of other Michigan Tech housing is being utilized. Michigan Tech Housing manages the SDH with regards to university policies, and the enterprise manages the SDH with regards to sustainability.

a. Sustainable Tasks

The tenants are all responsible for weekly sustainable chores that ensure that the SDH stays on track with its sustainability goals. Below are the weekly tasks.

1. **Compost** - tenants working with compost are responsible for both operating the Zera indoor composting machine and maintaining the outdoor compost bin. The Zera must be filled with food scraps and emptied once those food scraps have been processed. The processed food waste is then mixed with dirt to create a nutrient-rich soil. New this semester, the SDH has an agreement with Cyberia Cafe Express that donates their waste coffee grounds to the house each week. Tenants are responsible for picking up the coffee grounds, dropping off an empty bucket for a new round of coffee grounds, and mixing the coffee grounds into the outdoor compost bin.
2. **Waste Output Tracking** - each time the compost, recycling, or waste bins are full, tenants are responsible for weighing the bins and tracking the output in a spreadsheet.
3. **Aquaponics** - tenants responsible for the aquaponics systems must feed the fish, ensure the pump is working, and check the PVC piping for leaks every day. Tenants also do a weekly chemical test on the system to ensure optimal nitrate, nitrite, ammonia levels, pH, and temperature.
4. **Hydroponics -** the tenant responsible for the hydroponics system must measure and maintain pH levels in the water, and feed the plants on a weekly basis to ensure the plants stay healthy.
5. **Miscellaneous** - this chore varies every week depending on the needs of the house coordinator for additional help. This task includes (but is not limited to): general house cleaning, open house advertising, shoveling snow, preparation of project documents, and data collection.

b. Sustainable Projects

To demonstrate sustainability and improve the sustainability of the house, tenants are responsible for working on their own sustainable projects.

1. **Twist Tie Clothesline-** This semester, one of the tenants had the idea to recycle twist ties into a clothesline with which the tenants could hang their clothes to dry. This saves the house energy from not needing to use the dryer and creates a functional use for something that others may consider garbage.

2. **Plastic Processing** - A cross cut paper shredder is used to shred the houses HDPE milk/water jugs, and a toaster oven is used to melt the plastic into solid, machinable sheets of HDPE. The sheets are then brought to the Maker Space on campus and routed into useful objects such as correct room numbers.
3. **Website-** A website to demonstration sustainability was started this semester. The tenants are working on creating sustainable downloadable designs, sustainable tips, and much more to put on their new website.
4. **Recycled Plastic Bathroom Tile -** In an effort to replace old bathroom carpeting, the tenants are working to print bathroom tiles out of the plastic from their plastic processing.
5. **Tankless Water Heater-** The tenants along with some of the SDH team began sizing a tankless water heater for the house in an effort to eliminate water wasted due to warm water wait times. One problem encountered was that the house could not sustain two tankless water heaters, which was discovered when the house's electrical system was tested. From that point on the project has been at a stand still and may continue into next fall.

VII. Future Work

There are many project ideas that have not been started due to time constraints. These projects include implementing a moss lawn, adding grow lights to the hydroponics system, redesigning the heating system for the house, adding a plant wall to the house, installing extremely low flow showers to all the bathrooms, and adding mirrors to the house to reduce the need for lighting. Other future work for the house will include holding the postponed open houses, workshops, and waste reduction drive that were postponed until next fall.

References

1. https://weatherspark.com/y/13633/Average-Weather-in-Houghton-Michigan-United-States-Year-Round
2. https://www.hunker.com/13427465/when-should-you-plant-a-vegetable-garden-in-michigan
3. https://www.novagric.com/en/greenhouses-apr/greenhouses-supplies/greenhouse-materials
4. https://edis.ifas.ufl.edu/pdffiles/AE/AE03000.pdf