Empowering Composting at Midori Farm

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Empowering Composting at Midori Farm

An Interactive Qualifying Project

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Abstract

The goal of the Midori Farm project this year was to aid our sponsor, Chuck Kayser, in expanding organic farming and educating the public about the benefits of organic farming and local produce, by developing a cost-effective solar compost system and electric fence. To accomplish this, we studied the small farm movement in Japan. Next we looked at the current assets on the farm including the amount of sun, wind, and water flow to determine the best renewable energy source. We used this information combined with additional research to determine the most cost-effective power generation method. Lastly, we researched products that could be run on the power generated, including a fan for a forced air compost system, an air pump for a compost tea system, and a fence energizer to deter monkeys.

Acknowledgements

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Chuck Kayser, for the opportunity to work with Midori Farm and his unwavering support for our team and the research we conducted into the development of the compost system.

Executive Summary

Midori Farm is a small volunteer-based farm in Shiga prefecture, which is north of Kyoto. Workers find Midori Farm through Service Volunteer International (SVI) or other work-away programs. The operator of the farm is Chuck Kayser, a man from Chicago who fell in love with traditional and organic farming methods. He also serves as a university lecturer in Japan and teaches English to Japanese students. Midori Farm operates using the *Teikei* system, similar to the Community Supported Agriculture program in the United States. This system allows the customer and farmer to have a more direct relationship, exchanging money for assorted produce with no middlemen.

Midori Farm requested help in designing a composting system that would aid in their mission of organic farming and reducing their dependence on purchasing fertilizer. Research was conducted in order to develop a composting system that would meet the requirements and account for the constraints of the farm's situation. This research led us to a renewable energy source that could provide the power for our chosen composting method: forced air composting.

The goal of this project was to aid Midori Farm in expanding organic farming and educate the public about the benefits of organic farming and local produce, by developing and implementing a cost-effective solar compost system, with potential for other farm systems. To complete this goal, our team divided the project into five main objectives. The objectives of the project are:

1. Understand the small farm movement in Japan
2. Investigate composting and renewable energy methods
3. Determine Midori Farm's assets and resources
4. Determine the best renewable power source for Midori Farm
5. Design and build a compact and expandable composting, compost tea, and electric fence system

While one of our initial objectives was to construct the system at the farm, the time that various components took to arrive, and timing surrounding departure from IQP meant that we could not arrange a time to build the complete system on the site. However, we were able to assist our sponsor in wiring the various electrical components.

Recommendations for future projects at Midori Farm would be to attempt more visits to the farm to allow for more hands-on activities and engagement with our sponsor. Earlier attempts at having a tour at the Ikatachi Composting Center would also be beneficial for the group to better understand the composting process. The composting center also serves as a good example of a successful implementation of a composting system in Japan.

As our project came to a close, our group walked away with a sense of appreciation for what our sponsor does at Midori Farm. Organic farmers face many unique challenges, on top of the already challenging career that is farming. Being on the farm and ankle deep in the mud of the fields gave our group a real sense of how a tsunami can wash away irrigation systems and monkeys can ravage crops. Our group thoroughly enjoyed our time at the farm and working with our sponsor, and we hope to have provided our sponsor with a satisfactory solution to his request.

Authorship

Gabriella Davis, Timothy Giddings, Camden Kulczyk, and Daniel Miller Minkel all contributed to the research and writing of the full report. The following is a more detailed breakdown of what each member worked on in the report.

Gabriella Davis wrote part of the first draft of the executive summary, sections of the literature review, methodology, results and conclusion. Gabriella also completed the formatting of the final paper.

Timothy Giddings wrote the abstract, sections of the literature review, methodology, and results. Timothy also designed the power storage system schematics.

Camden Kulczyk wrote the first draft of the executive summary, the first draft of the introduction, sections of the literature review, methodology, results, and the first draft of the recommendations.

Daniel Miller Minkel wrote appendices A, B, C, D, E, and F. Daniel also contributed to sections of the methodology and literature review.

Gabriella Davis, Timothy Giddings, Camden Kulczyk, and Daniel Miller Minkel all contributed to the editing of the paper. All members contributed to designing the final presentation slides for the project.

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Chapter 1: Introduction

Midori Farm is a small organic farm located about 50km north of Kyoto in Shiga Prefecture. The owner, Chuck Kayser, created the farm 11 years ago and has been running it in his free time, with the goal of creating a self-sustainable farm available to educate others on small-scale organic farming. Midori Farm has been making an attempt to compost on a small scale using the waste on the farm and waste from Kyoto businesses, like coffee chaff from a local roaster. Although this is a step in the right direction, it is not enough to have a measurable impact (Bhatia et al., 2018). Production of compost at a significant rate would mean more financial independence for Midori Farm and would ensure that all crop production is organic. Additionally, the introduction of self-produced compost gives the farm more control over its production methods and components, making sure all steps of the process are done in ways aligning with Midori Farm's organic mission. Midori Farm seeks to share its mission with other small farms in the area, and the composting system would benefit this focus area of the farm as well.

To support their needs, Midori Farm needed a sizable compost system, but has a limited budget and resources. Combatting bugs and diseases is challenging for organic farmers, and recently monkeys have been entering the fields and have done significant damage to the crops. After consulting with our sponsor, our team was asked to consider whether the composting system power supply would be adequate to support an electric fence system to help protect the crops from the monkeys. Although outside the scope of our main project, our team was able to initiate some work on this. Although this additional scope raised the cost of the system, the sponsor will consider a crowdfunding campaign to raise money to help fund the system. This would fund the initial purchase of the power generation method, and the required accompanying pieces like a battery for power storage. The monkey fence system will likely save our sponsor money in the long term and increase the potential to produce a better crop as well as teach more people, while spreading the idea of small-scale, sustainable farming.

Our overall goal is to aid Midori Farm in becoming more sustainable and, in turn, help other people learn about organic and small-scale farming. Our team completed our project by conducting background research on the small and organic farm movements, used our time on the farm to design a composting system, coupled with determining the most suitable renewable power source, and developed the required system needed to meet our sponsor's needs. The compost and renewable energy systems will be used as teaching platforms by our sponsor to demonstrate the potential and versatility of compost, creating a new interest in farms and what they have to offer.

Chapter 2: Literature Review

In order to fully support Midori Farm as well as other farms in the area, our sponsor intended to create a simple, expandable composting system, coupled with the compost tea and electric fence systems. However, since he is not the legal owner of the farmland, he cannot build major permanent structures, limiting the size and complexity of any construction on the farm. Our sponsor had also expressed interest in creating the composting system in order to use it for educational purposes, showing the Japanese people that it is possible to put their food waste to good use. Through his tours, various social media, and organizations he is a part of, Chuck has been able to slowly introduce people to his farm and the ideas of organic farming and sustainability. He has already begun taking steps towards creating a larger composting operation that suits his farm's needs.

A project was completed in 2018 at Midori Farm concerning the beginnings of our sponsor's composting system. The previous team considered various methods of producing compost, both on and off the farm. They first investigated the potential of tapping into existing composting programs or entering into a partnership with other organizations to produce compost somewhere offsite, but quickly determined that neither of these solutions were practical, both due to the quantity of compost required by the farm, as well as the distance from the farm to any potential partner organizations. Having decided that onsite composting was the best solution for the requirements at the farm, the group investigated several methods of producing compost. They eventually settled on windrow composting, due to its simplicity and the ease with which it is possible to scale to suit increased production requirements. While we did consider windrow farming at the beginning of our project, we quickly decided against it, as it requires heavy machinery and anywhere from 9 months to a full year to complete the compost. Our sponsor then suggested we look into forced air composting as an alternative to windrow composting.

Forced air composting uses perforated tubes and fans to push air into the compost pile as a means to control the oxygen levels throughout without the need to mix the piles regularly. Fans are used for volume of air, as the perforated pipe allows a clear path of travel without resistance. The fans run on a timer and push air through the compost for 1 to 2 minutes, every hour. By increasing the airflow, you can lower the moisture content and temperature of the compost pile, and by lessening the airflow you can maintain higher moisture content and allow the compost pile to build up more heat. Because the fans are controlled by timers, it is very easy to make subtle adjustments to the fan cycles to get precise control over the system (i.e. moisture levels relate to how long fans run). One challenge our team came across with this system is that it requires electricity to run, and Midori Farm does not have access to electricity at the composting site. One way to overcome this challenge was to use renewable energy sources like solar power.

Weather and construction limitations led us to search for a method of composting that could rapidly produce large quantities of compost when the weather was favorable and be either resistant to the adverse weather conditions or be stored in an already existing protective structure. These two requirements led our team to consider forced air composting as a workable solution to the farm’s composting problem. Even a rudimentary system is capable of producing usable compost in eight to twelve weeks, as opposed to a full calendar year often required by windrow composting (Hashemi, Kadi, & Kraemer, 2018). This not only allows a forced air system to produce usable compost within the favorable weather period each year, while being able to be stored away in the harsher winter months, but also allows for multiple smaller batches of compost to be produced over time, as opposed to producing all of the required compost in a single large batch. This allows the size, and therefore the cost of the system, to be reduced drastically.

Forced air systems, such as the one in Figure 1, improve upon traditional composting methods by artificially speeding up the natural process of composting. The process of composting is performed mostly by microorganisms, which break down organic material into smaller parts, known as humus, a material rich in nitrogen and phosphorus, which is usable by plants as a nutrient source (Ross, 2018). The most effective composting microbes are aerobic, meaning they require oxygen to survive and function. Forced air composting increases the amount of oxygen present in a compost pile, allowing more aerobic microbes to exist without running out of oxygen, increasing the speed at which a compost breaks down into usable fertilizer.

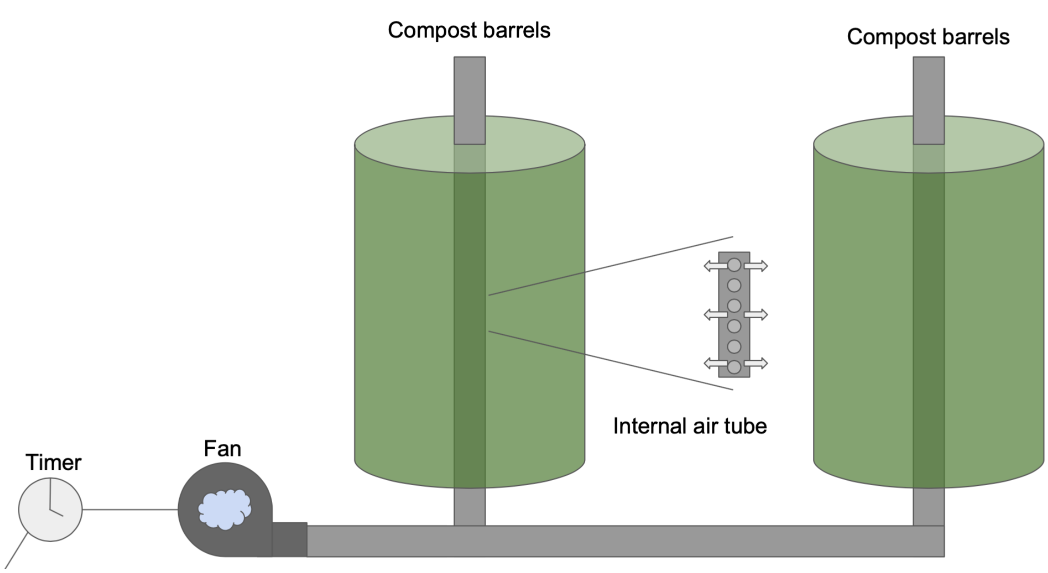

Figure 1 - A simple forced air composting system.

A solar powered system is the most attractive option financially and with regards to power produced, as the Shiga Prefecture gets plenty of sun throughout the year. As seen in Figure 2, the average amount of sun is consistently over 125 hours per month. This roughly translates to sun exposure for one third of all daytime hours. Another reason solar energy is a good option is there are no moving parts in the system, meaning the solar panels can last longer and require far less maintenance. Solar energy is more abundant in the summer due to longer days which makes the solar panels a better option as we will be able to get the most out of the system during the growing season, when compost is being produced.

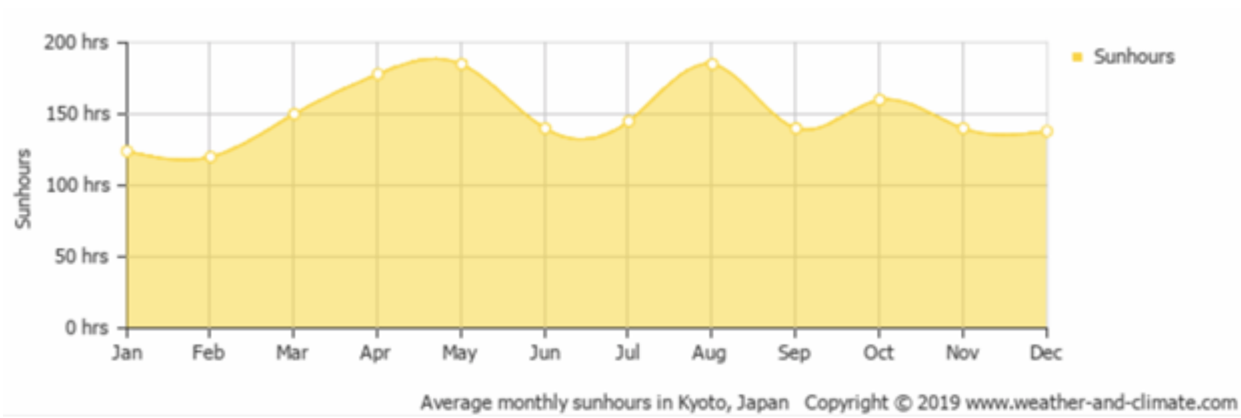

Figure 2 – Sun hours in Kyoto, Japan

With the solar power system, it is necessary to harvest as much power as possible and store it in a power bank (e.g., a marine deep cycle battery). The goal is to store enough energy during the day to provide power to the system overnight. Most forced air compost systems have the fan on a timer, so it blows for 1 to 2 minutes every hour. This means that we can use the remaining time between the fan cycles to recharge the battery before the next cycle.

One additional system that draws from the same power generation system as the forced air composting is a compost tea system. Compost tea is a liquid fertilizer made from mixing water and compost and circulating air through the mixture. To make compost tea, the compost used must be "mature compost", meaning there are no roots or seeds still alive in the compost (Ingham, n.d.). Bacteria-dominated compost tea, which is sprayed directly onto the plants, requires that the mixture be primarily composed of green material and a small amount of woody material (Ingham, n.d.). This creates a rich solution filled with nutrients and helpful bacteria that when sprayed directly onto plants, can prevent harmful bacteria from taking hold onto the plants' leaves.

Although unrelated to composting, when talking to our sponsor on the farm, he mentioned that he was experiencing issues with monkeys entering into his field and eating or destroying his produce. In a follow up meeting he mentioned that monkeys had entered his farm again and destroyed close to $100 USD in crops in a single day. He suggested we investigate the potential of using a non-harming electric fence to ward off monkeys.

While monkeys have been a problem in Japanese agriculture for centuries, they have more recently been expanding into areas considered too snowy for monkeys to survive in (Nicol, n.d.). Monkeys by their nature as tree dwellers are able to climb many types of fences, including the ones our sponsor has installed to attempt to prevent their incursion into farm fields. The National Bank for Agriculture and Rural Development (NABARD) in India did a study to determine effective means of preventing monkeys from entering onto farmland. Their testing revealed that simple electric fencing was enough to stop the monkeys from intruding onto fields. (NABARD, n.d.)

Chapter 3: Methodology

Objective 1	***Background Research***	• Literature review
Objective 2	***Determine on-farm assets***	• Site survey • Interview with sponsor
Objective 3	***Determine best renewable power source***	• Literature review • Site survey
Objective 4	***Develop an expandable power generation and storage system***	• Provide detailed design for power system
Objective 5	***Develop powered systems at Midori Farm***	• Provide detailed design for compost and fence systems

Figure 3 - List of objectives and corresponding methods

Within this chapter, most of the physical research and work is covered. A site visit to our sponsor's farm over a week allowed us to truly understand the lay of the land, the physical constraints for our project, and our sponsor's perspective. Our team was able to determine the on-farm assets and take those assets into account when choosing what method of renewable energy would be the best suited for our sponsor's farm and future composting system.

Objective 1: Background Research

During our preparatory term at WPI, through conversation with our sponsor and independent research we concluded that a forced-air composting system powered by a renewable energy source would be the most ideal solution to the problem. Before arriving at the farm, we conducted general research into forced-air composting systems to familiarize ourselves with the options that we could explore based on variables of size, power, and location of the composting site at the farm.

Objective 2: Determine on-farm assets

After arriving at the farm, our first objective was to determine and record the assets of the farm that would be useful to our project. This inventory included local attributes such as space available for our usage, sources of water, amount of sun, and sources of compost materials. We first started by taking a tour of the farm to get a better understanding of the physical attributes of the land and see where our sponsor hoped to place the system. On the farm there are three fields, the farthest being field three. Above this field there is an overgrown rice field that is not in use; this is where the system is to be built (Figures 4 & 5).

Figure 4 - Overhead view of field Locations

Figure 5 - Proposed site of composting system, behind the crops and against the back fence

Our next task was to investigate the various aspects of the farm that would impact the ability of various types of renewable power generation to function. While on the farm we investigated the prevailing winds, the water flow of a nearby stream, and the number of hours of sunlight the farm receives. Wind was quickly discounted, as the high mountains and winding nature of the valley meant that wind speeds were low and inconsistent.

Next we looked at the water source for field three's previously established irrigation system, as this was a possible source of hydroelectric power. We looked at the elevation change between the beginning and the end of the system to calculate the pressure in the system.

Our sponsor was confident in the water flow and pressure from his system, and desired to make use of his excess water after crop irrigation. We then treated hydro-electric as the priority, but based on our on-site research, testing and assessment into designing the system for hydroelectric power, we determined that it would produce a smaller amount of power than expected at a high cost per kilowatt.

Our team next looked into solar panels as the main source of power as there was a better price to power ratio. We talked with our sponsor about the possibility of solar power, since unlike hydro power there is no guarantee that there is always going to be enough power produced due to cloud cover. Our sponsor shared with us that usually there is much more sun than what we experienced on the farm, and that it was not critical that the system run perfectly because the compost would continue to break down even if the system lost power due to extensive cloud cover.

From conversation and the tour, we received from our sponsor, we learned about our sponsor's current compost system which uses food scraps from the farm and coffee chaff from a Kyoto-based roaster. Once the new composting system is put in place, the raw material currently arriving may not be enough to satisfy our sponsor's composting needs. The material coming from Kyoto is categorized as "brown material", which is comparable to brown dead leaves. For a good compost, there is a ratio of "brown" and "green" (fresher, or alive) material The Kyoto Composting Project states a 3-1 ratio of brown to green material is optimal. (Bhatia, S., et al (2018)) More green material is needed to compensate for the volume of additional brown material our sponsor receives. To help alleviate this problem, we looked into other plants we could use for green material, such as pampas grass, ferns, and cedar branches. We quickly learned that using pampas grass or any part of the cedar trees was not possible. The pampas grass is very invasive and if any seeds get into the compost they may sprout and ruin the compost, and the cedar trees produce a chemical that would kill the crops if used in the compost. This left us with ferns as the most viable option for green material.

Objective 3: Determine best renewable power source

At the beginning of our research into renewable power, we considered wind, hydro, and solar power. Wind was decided against before arriving at the farm, as wind turbines are extremely costly to build, the wind speed is very unreliable as the farm resides in a valley, and our sponsor cannot build permanent structures on his farm.

After removing wind power as an option, we moved on to hydro power. In order to calculate how much power, the water could produce, we first measured the outflow rate by timing how long the water pipe took to fill a 30-liter bucket. The bucket filled in 58 seconds, giving the water pipe an approximate flow rate of .5 liters per second. Next we measured the elevation change between the beginning and the end of the system (Figure 6). After finding a number of different turbines and calculating the energy they would produce from the .5L/second flow rate (Appendix A), we determined that although a large turbine could produce enough energy to power the system, the cost of the turbine, along with the extra piping needed to provide suitable water flow was too high to justify hydro power. While the smaller turbines cost much less and could be placed directly into the piping (Figure 7, bottom), they would not produce enough energy to power the system (Appendix A).

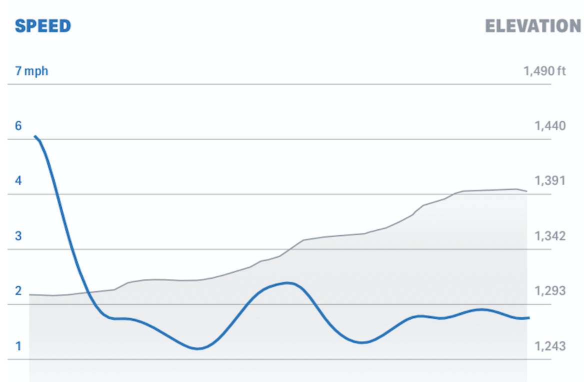

Figure 6 - The head of the stream down to the point at which the turbine would be placed (in feet)

Figure 7 - Beginning of the water piping (top) and the constriction of water flow further down the stream (bottom)

After ruling out wind and hydro power, we then examined solar power. We found that a small 100-watt solar panel can be purchased for approximately $90.00 USD from Amazon.com and shipped to Japan (Table 1). With this solar panel, we would be able to generate approximately 4 times more power compared to the hydropower system while also being far cheaper than the wind or hydro options (Appendix A). Solar power will also be more reliable that hydro, as typhoons regularly hit Midori Farm and wash away or damage the water piping system. Finally, deciding against hydroelectric power gave our sponsor more freedom in deciding where the various systems should be installed to best achieve his goals, as he no longer needed to construct the system near his water supply. This would result in the system being constructed on Field 2 instead of on Field 3.

Objective 4 - Develop an expandable power generation and storage system

Having settled on solar as the best option for supplying the various systems in need of power at the farm, we started the process of determining the overall design and construction process of the power generation systems. Due to various time constraints, including our sponsor's need to source funding for the components, our group would not be able to be present for the construction of the system. This meant that our design would have to be simple enough and include instructions in enough detail to allow our sponsor to construct and maintain the system without our presence on the farm. The design documents would also serve educationally, allowing other farmers to easily establish a composting system of their own. This would in turn contribute to their sustainability. Our sponsor also stressed the importance of keeping both cost and complexity down, in order to both minimize setup costs, as well as allow for maintenance and expansion to be performed with relative ease.

With these requirements in mind, we focused our design around simple, inexpensive, off the shelf components that would be easy for our sponsor to assemble and maintain with limited technical knowledge or access to advanced equipment. In order to meet these requirements, components were selected based on their durability, cost and ease of assembly and operation. The various components (Table 1) were sourced from online retailers such as Amazon to simplify the acquisition process.

In order to aid our sponsor in the construction and maintenance of the system, as well as to allow for the easy duplication of the system in other locations by other individuals, a detailed set of designs and assembly instructions were provided to our sponsor, as well as detailed lists of troubleshooting steps and information on how to expand both the electrical and forced air systems (Appendix B).

Table 1 - Materials required for the forced air, electric fence, and compost tea systems.

Materials	Price	Where to Buy	Price Option 2	Second option
(2) 100W Solar Panels	¥10,516 x2	U-buy	$89.99 usd x2	Amazon
Battery	¥11,980	Amazon JP		
Fan (Leaf Blower)	¥4,432	U-buy	$32.55 usd	Amazon
Air Pump	¥2,597	Amazon JP	$51.98 usd	Amazon
Inverter	¥11,676	U-buy	$76.50 usd	Amazon
Fence Energizer	¥7,017	U-buy	$53.05 usd	Amazon
Timer	¥2,343	U-buy	$15.99 usd	Amazon
Grounding Stakes	¥2,319 x3	U-buy	$29.80 usd	Amazon
Grounding Wire (14 AWG) (~2 mm)	¥2,090	U-buy	$13.98 usd	Amazon
Solar Panel Wire (8 AWG)	¥3,347	U-buy	$23.95 usd	Amazon
Crimp Terminals (8 AWG)	¥2,009	U-buy	$13.34 usd	Amazon
Electric wire	¥5125	U-buy.jp	¥8,801	Amazon JP
Fence Insulators	¥1017 Per bag / 25	U-buy	¥4,500 Per bag / 50	Amazon JP
Fan (Bounce House Blower)	¥9,323	U-buy	¥27,897	Amazon JP
Fence Gate Handles	¥4,138	U-Buy	¥888	Amazon JP
Electric Fence Warning Signs	¥401 Per sign	Amazon JP		
Total Cost	¥95,484 ~ $893.92 usd		$885.12 usd ~ ¥94,543	

Objective 5: Develop powered systems at Midori Farm

With a renewable and easily expandable power generation system, it is now possible to develop systems centered around helping our sponsor and the farm. These systems will also assist our sponsor in teaching and spreading his message.

During our time at the farm our sponsor suggested the addition of a compost tea system and an electric fence to our renewable energy system design. The compost tea system would require a small bubbler to circulate oxygen through a mixture of water and compost. Compost tea is a solution that contains all the beneficial microorganisms and nutrients extracted from compost. This solution can then be sprayed directly onto the plants, occupying the leaf surface and preventing potential diseases from affecting the crops (Jacques, 2019). The electric fence would be used to combat against monkeys that regularly get into the fields and damage and steal the crops. With adequate excess power, the energizer required to power the electric fence and the bubbler for the compost tea could be powered by the same system that provides power for the forced air composting system.

After choosing forced air composting, research was conducted into the size possibilities and inspiration was taken from a University of Massachusetts Amherst paper. Their specific application was for composting horse manure, but much inspiration was taken from their design and ideas. The compostable material can be arranged either vertically (Figure 8) or horizontally (Figure 9).

Figure 8 - Vertical compost system with air blowing in seen in the top left image (The Center for Agriculture, Food and the Environment, 2017).

Figure 9 - Horizontal compost system with perforated PVC pipe running through the pile (The Center for Agriculture, Food and the Environment, 2017).

Table 1 (above) shows the necessary components required to power a forced air system and have excess power for a larger composting operation and/or more farm utilities that the sponsor can add. With a list of materials, we can continue to establish intuitive instructions and a guide for our sponsor and volunteers to use in our absence.

Chapter 4: Results

Due to constraints owing to the delay between proposing a design for the composting system and the purchase and arrival of the required parts for the system, the major component of the project became creating detailed design documents instead of building the system. Although we were not able to assemble the system on site, our group worked with our sponsor to help assemble and wire the solar panels to the inverter. The majority of the final product that we are presenting to our sponsor is the detailed design of the renewable energy system and composting, compost tea, and electric fence systems attached to this report. Along with visual diagrams, detailed written instructions will also be provided for our sponsor, including an explanation on how to build the system (Appendix B), a safety guide (Appendix C), a troubleshooting guide (Appendix D), a maintenance guide (Appendix E), and an expansion guide (Appendix F). Shipping delays also affected our sponsor's final system design. At the time of the report, our sponsor had started construction of the various systems, but the system had yet to begin operating.

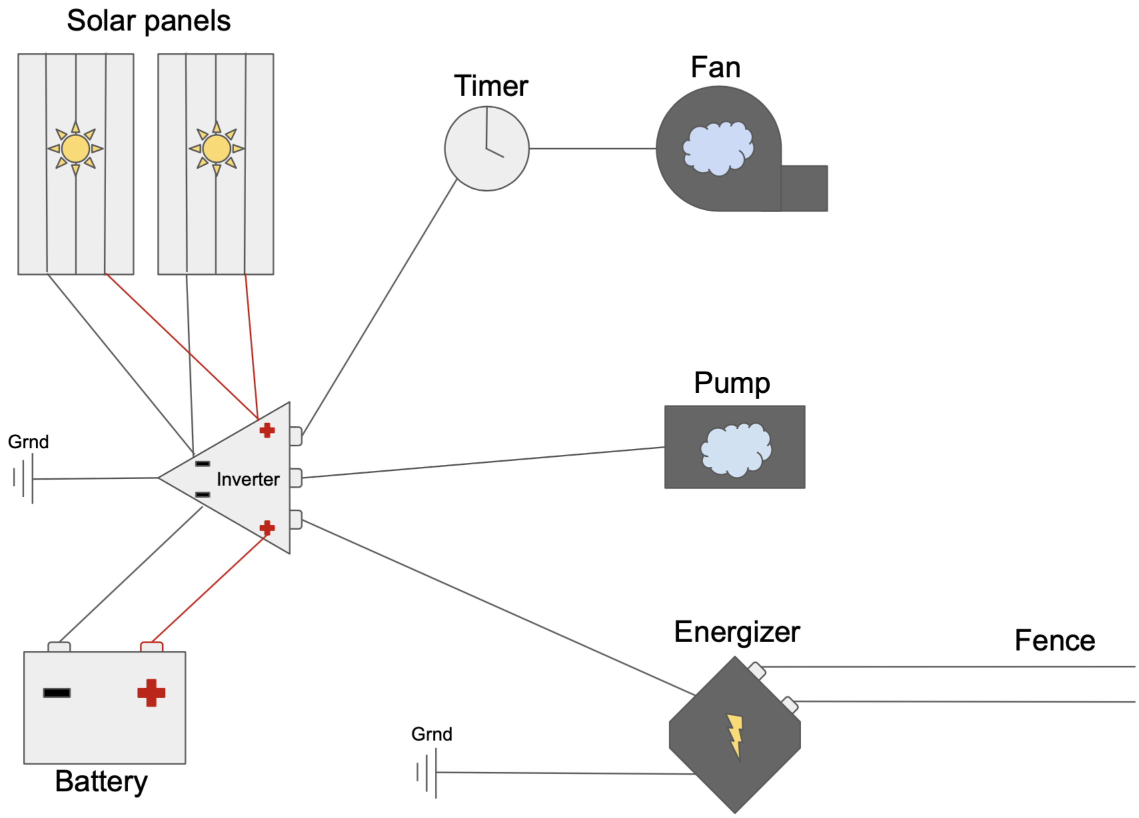

Figure 10 - Design of the solar panels to the battery and other components

The above Figure 10 shows a design of the renewable power system that will be implemented at field 2 on Midori Farm. This diagram along with step by step instructions on how to build it (Appendix B) will be given to our sponsor so that he will be able to construct the system. These resources can also be used by other farmers our sponsor comes in contact with, spreading the idea of renewable energy and the benefits of composting.

The design of the proposed system has been made in direct cooperation with our sponsor. This was to ensure that the end product would be cost efficient and feasible for our sponsor's unique situation. Our initial project goal was to design a sustainable composting system. This was expanded and our project scope slightly changed, mainly in magnitude. Solar panels will charge a battery that feeds into an inverter, converting DC power to AC power. The attached timer, fan, pump, and fence energizer all operate on AC power.

Figure 10 provides a general layout of the various electrical components of the system designed for Midori Farm. The system was designed with a focus on being as simple as possible, to minimize the costs and skills required for construction and maintenance. To achieve that goal, the design of the system was based around off the shelf components.

After our initial meetings with our sponsor, and a survey of the available area at Midori farm, we determined that a power generation system at the cost that our sponsor was initially considering would be able to provide substantially more power than would be required for just the composting system. To that end, our sponsor asked if we could modify the design to supply enough power to feed an electric fence as well as a compost tea system. We determined that this addition could be made with few major changes to the design of the system and with low additional financial cost to our sponsor.

This change shifted the focus of our project somewhat. Previously, we had been developing a power system solely to enable the composting system to function, but the addition of an electric fence and compost tea aerator brought more of a focus onto the power generation aspect. The fact that we were providing a system with generation capabilities able to provide power for a wide range of applications that might benefit a farmer became a major appeal of the system.

Chapter 5: Recommendations

With the majority of our project being the design of a renewable energy and composting system, our recommendations for the construction process are contained in the results section and the related appendices. These recommendations include advice on how the system should be constructed, as well as maintenance, safety, and troubleshooting tips.

Solar power became the agreed upon method to power the composting system and other systems requiring power, beating out hydropower as the most viable option. However, hydropower can still exist as a failsafe, or if the existing water catch at the head of the mountain stream is expanded it can exist as a standalone power source for future expansion of Field 1 and Field 2. A small inline turbine (10W for less than 20 USD) residing in the existing water piping that leads to the farm with the proper hardware can provide small amounts of consistent power to the battery. If the water catch is expanded, this would enable the system to create and store more power, enabling the already existing system on Field 2 to be expanded upon even further.

Our project team is hopeful that our sponsor will share the composting systems design and overall goal with other farmers in similar situations. Our sponsor has stated that he wants to share the concepts of the system with other farmers to use. This sharing can be enhanced by offering working demonstrations of the various systems in action, as well as a simple cost benefit analysis. For instance, our sponsor has mentioned that a single raid by monkeys on one of his fields results in an approximate loss of $100 USD in product. Even at a conservative price of $2,000 USD for the whole system (electric fence, composting system, compost tea, and electrical generation system), a multifunction system like the one developed for Midori Farm will likely pay for itself within a single year of monkey deterrence. This doesn't factor in the value of the more rapidly produced compost or compost tea, other major products of the system that improve the farm's productivity. For small farms such as Midori Farm, the relatively low cost and great potential fiscal reward could provide a major leg up to get started or continue farming. With this, Midori Farm's system can be used as a teaching platform for other farmers in the area.

Future teams working with Midori Farm could look in the direction of initially assessing the success of the system, and then using that information to develop and distribute an improved version of the system designs. Our sponsor has mentioned that he is interested in sharing the idea of a forced air composting system with both farmers and other groups interested in composting such as schools or community gardens. Developing an outreach campaign and related materials would be extremely beneficial to our sponsor and his broader goal of spreading the message and methods of small-scale sustainable agriculture. While we are confident in the design of the system, it remains crucial that our sponsor maintains and frequently checks the health of the system. Routine checks and maintenance should be conducted to not only ensure the uninterrupted performance of the system, but to also ensure the longevity of the items included in the system and the safety of those working with and around the various equipment. Instructions to help with this can be found in Appendices D and E.

In the future, it is certainly possible for the composting system to be expanded, and perhaps be made more efficient. As proposed, the system could be improved upon, especially after setting up the system and witnessing it in operation over time. A regular and systematic evaluation (Appendix E) of the system, coupled with regular attention to maintenance and infrastructure may result in improvements over time. This remains true for composting systems that may be built in different fields in operation at Midori Farm.

In conversation with our sponsor, it became clear that there existed no Japanese customers buying his produce. It also was evident that this was no fault of his own, as cultural norms surrounding buying produce in Japan seemed to go against our sponsors' ideals and best interest. This includes, but not limited to the practice of individually wrapping vegetables with plastic. This is very wasteful in the eyes of many, including our sponsor. Perhaps in the future, a project team could work to tackle this problem. As admirable as the efforts of organic farming may be, if the majority of the people do not buy into the system, the growth of his farm and message will ultimately stagnate. We may not know the exact reason why Japanese consumers are hesitant to buy into his system of distribution, but there must exist a solution to this problem that will help Midori Farm exponentially in the future.

For next year's IQP project, we would recommend to plan multiple visits to the farm throughout the term. We only had five days on the farm during the beginning of the term and were not able to make it back at the end of the term to assemble the system. Planning multiple trips to the farm throughout the term would highly benefit the success of next year's project with Midori Farm.

Chapter 6: Conclusion

Working at Midori Farm was a new and informative experience. Farmers like our sponsor make their best attempt at maintaining sustainable practices to protect the Earth's health. However, there are additional challenges to adhering to organic practices, on top of the already intensive task that is successfully operating a farm. A lack of access to synthetic fertilizers and pest control measures means that organic farmers must go to significantly more effort to raise productive crops, as well as suffer greater losses due to pests and weeds. Both organic and non-organic farms deal with monkey raids that destroy fields and leave customers empty handed. While monkey raids are not unique to organic farms, the resulting damage is felt much harder by a farm like our sponsor, as his crop yields are already much lower than non-organic farms. This is among a multitude of problems that people may never understand at the face level of organic farming.

The work of our project will certainly have a lasting impact and assist in the spread of our sponsor's message. A bridge can be crossed by our sponsor and the Japanese people who do not understand the reasoning behind his DIY (Do It Yourself) projects. Showing farmers the benefits of nurturing their crops with compost and compost tea, and establishing electric fences to protect against the looming monkey threats that affect *all kinds* of farmers will give our sponsor more ground to stand on. The more people that understand and respect his message, the healthier our planet will ultimately be.

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Appendices

Appendix A - Power Calculations

The two options we initially considered for powering the various systems on the site were either solar power, collected using traditional Photovoltaic (PV) panels, or hydropower, using a ducted turbine fed from a stream flowing down the mountain. Our power consumption consists of a large electric blower providing air for the forced air composting system, an off the shelf electric fence energizer, and a small submersible pump for aerating a compost tea system. While the fence energizer and the compost tea pump are running constantly, the large blower, which is the majority of the power consumed, operates for only 1-2 minutes per hour. The various components have power consumption ratings as follows. The blower draws 700 watts, but is only operating for 2 minutes per hour, or 1/30th of an hour. The electric fence energizer constantly draws one watt, and the bubbler for the compost tea draws an additional 1 watt of power. Over the course of the day, the total power consumption, plus 10 percent overhead for energy losses and other general inefficiencies, results in an hourly power usage of 28-watt hours. This works out to a daily power usage of 670-watt hours.

Having determined the power required for the system, we next looked at the cost of generating that amount of power via both hydropower and solar harvesting. The first thing we looked at was the maximum amount of power we could generate with a hydroelectric turbine given the flow rate (.5 L/s) and the head (elevation difference between the water inlet and the turbine) (114 ft). A turbine to fit this flow rate and head, such as the DCPAT-20 (http://www.nooutage.com/dcpat.htm) produces 28 watts under peak water flow conditions. While this is theoretically enough power to operate all of the power drawing equipment, there is little to no margin to account for fluctuations in water flow. Additionally, frequent heavy rainfall events in the area regularly damage the water channeling system on the farm. The potential for damage or loss of equipment, combined with the high cost of the turbine (400+ USD) was another major reason a hydroelectric solution was removed from consideration.

From the outset of the project, solar was seen as an attractive option, due to its relatively low cost, ease of setup, and low maintenance nature. Based on our sponsor's own estimates, the site of the farm receives roughly 7 hours of sunlight during the seasons in which the system would be in operation. Using a single 100-watt solar panel it is possible to generate 700-watt hours of power under ideal conditions. While this is enough to power the system for a full day, we ultimately elected to design a system using two panels in order to account for any potential energy loss, as well as to allow the system to continue to run even in the event that there are one or more cloudy days in a row on the farm. While our sponsor stressed that a short-term loss of power to the system was not a problem, the ability to operate in less than optimal conditions was considered worth the extra investment.

Appendix B - Setup Instructions

1. Inverter setup
    a. Follow provided instructions for installing/mounting inverter
    b. Ground inverter
        i. Install ground stake firmly into soil
        ii. Connect ground stake to inverter using green wire (use crimp on screw terminal for connecting to inverter)
    c. Connect battery to inverter
        i. Use provided .5-meter cables
        ii. Attach wires to inverter before battery
        iii. When attaching wires to battery, attach positive (red) terminal first.
2. Solar Panel setup
    a. Mounting and positioning
        i. Panels should be kept off the ground to allow for airflow and reduce wear
        ii. Panels should be mounted 20 degrees from horizontal, facing south
    b. Solar panels should be kept as close to the inverter as possible to reduce energy loss
        i. Cut 8-gauge wire to length and attach crimp terminals to each end
        ii. Connect wire extensions to solar panels
        iii. Connect each panel to the inverter separately. DO NOT connect the panels in series.
3. Connecting the blower
    a. Before connecting the blower
        i. Either manually charge the battery or allow the panels several hours to charge the battery. (Use the inverters meter or a multimeter to ensure the battery is not low)
        ii. Confirm the timer is functioning correctly (on for roughly two minutes every hour) to prevent the blower from running constantly and draining the battery.
            1. Consider using a low power device such as a phone charger to confirm the timer is working correctly.
    b. When connecting the blower
        i. Inverter should be switched on
        ii. Blower should be switched off
        iii. The timer should be between the inverter and the blower.
4. Connecting other devices (electric fence, bubbler)
    a. Connect other devices to the non-timer outlet, using a power strip if necessary.
        i. Avoid connecting other devices while the blower is running to reduce risk of over-current situations.

Appendix C - Safety

1. General Electrical Safety
    a. The solar panels / battery is 12-18V D.C., relatively safe
        i. Avoid situations where current could run through torso / heart
        ii. Avoid shorting the battery / solar panel terminals.
    b. The inverter produces 120V, or standard wall power.
        i. Observe standard electrical safety precautions
    c. The electric fence should be clearly marked as such
2. Safety considerations for construction
    a. If possible, all equipment should be elevated off the ground to reduce wear
    b. Aside from the solar panels, all equipment should be stored under cover to protect from rain / debris.
    c. The inverter should be securely mounted to ensure good connections are made and will not be damaged should storms occur.
    d. The battery can potentially release gas, so it should be stored in a ventilated area.
3. In the event of storm / flooding.
    a. If a storm is expected, shut off the inverter / power consuming devices and store loose objects such as solar panels so they will not blow away
    b. After the storm, first check for loose wires or obvious damage that could indicate danger
    c. If it is safe to do so, shut off the inverter if it isn't already before approaching the other equipment
    d. Check connections, especially to the battery and the electric fence
    e. Carefully inspect the electric fence to make sure the fence will not short upon startup.

Appendix D - Troubleshooting

1. There are two general categories that failures can fall under.
    a. A part of the power generation system has failed
    b. A device that uses power has failed
2. Determining where a failure has occurred
    a. If one device (fence, blower) has stopped working, the fault is most likely with that particular device. If this is the case, proceed to step 3.
    b. If none of the devices are working, consult the included inverter troubleshooting, then proceed to step 4
3. If one device has stopped working

a. Try plugging the device into a wall outlet. If the device still does not function, the device is likely irreparably damaged. Consider replacing the device with an identical or comparable version.
b. If the blower has stopped working, but operates when plugged into the wall, the timer may be damaged. Test the timer by plugging in a lamp or other low power device to wall power through the timer and seeing if it operates correctly.
c. If the devices all function correctly when connected to wall power, measure the voltage of the outlet on the inverter. If the voltage is low or zero, consult the inverter guide for troubleshooting steps. Proceed to step

4. If all devices have stopped working
    a. If none of the devices are working, the problem is with either the inverter or the power generation and storage systems.
    b. After consulting the inverter guide if the problem falls under the “Low input DC voltage” heading proceed to step 5.
    c. If the problem is not low input voltage and is not resolved by the inverter manual, the inverter is likely damaged, and should be replaced
5. Inverter is inoperative due to “low input voltage’
    a. If there has been several days of overcast skies, the system may simply not have had enough sun to run. Consider temporarily disconnecting the compost blower to reduce power consumption until the weather clears and the battery has had a chance to re-charge.
    b. Begin by checking wire connections to the battery and solar panels. Any loose connections should be tightened.
    c. Measure the solar panel voltage. Do this both at the end of the wire close to the panels, and at the end connected to the inverter. This should be done with good sunlight to ensure the panels are functioning correctly
        i. If the end close to the panels measures 15-18 V, and the end close to the inverter measures much lower (<10V), the wires are likely damaged. Check connections and replace any damaged wires.
        ii. If the end of the wire close to one panel measures significantly lower voltage than the other panel, the lower voltage panel is likely damaged. If both panels measure low, they are likely not getting enough sun.
    d. Measure battery voltage
        i. If the battery voltage is below 11V, it may be permanently damaged. This also indicates that the inverter may be damaged, as the inverter is supposed to prevent the battery from discharging to dangerous levels.
            1. The battery may be recharged, using a wall ‘trickle charger’ this process may take 8+ hours, and may not be successful
            2. If the trickle charger does recharge the battery, the inverter should be replaced, as the charge circuitry is likely damaged.
            3. If the battery will not hold a charge it should be replaced. Monitor the battery voltage of the system for the next week.

            If the new battery maintains good voltage (>12V), the problem was likely isolated to the old battery. If the new battery voltage continues to drop, disconnect it before it reaches 11.5 V. This indicates the inverter is failing and needs to be replaced as well.

    ii. If the battery has good (>11V) voltage
        1. Check the connections from the battery to the inverter. Repair or replace any damage cables with ones of appropriate gauge.
        2. If everything else is functioning correctly, the problem is likely the inverter, which must be replaced.

Appendix E - Maintenance

1. Daily
    a. Inspect system visually - look for obvious signs of damage
        i. Broken wires
        ii. Cracked solar panels
    b. Check inverter
        i. Inverter LEDs indicate approximate battery voltage
        ii. Inverter will be making alarm noises if there is a problem
2. Weekly
    a. Measure battery voltage with a multimeter to confirm inverter functionality
    b. Check solar panels
        i. If dirty, clean with cloth / water to prevent efficiency loss
3. Monthly
    a. Re - orient panels to follow track of the sun better
    b. Consider shutting the blower off for 2-3 days to allow the battery to fully charge. This can help preserve battery health / longevity.
4. When putting equipment away for the winter
    a. Make sure all equipment is stored somewhere dry
    b. All equipment should be off and disconnected
    c. The battery(ies) should be fully charged
    d. Consider bringing the batteries to your house and storing them indoors
    e. Use mothballs to keep rodents away from wiring. If possible, put wires in a container with a quantity of mothballs
5. When setting up the system in the spring
    a. Follow the initial installation instructions
    b. Check equipment for signs of wear
        i. Pay special attention to electrical wires - look for cracked / missing insulation

Appendix F - Expansion

1. Solar panels
    a. The inverter has capacity for one additional 100-watt solar panel, a 50% increase in power generation.
        i. This additional solar panel will provide enough power for a second blower to be installed
2. Inverter
    a. The inverter can power an additional blower, but for safety reasons, alternating when they run is advised.
        i. As an example, one blower might be run at the top of every hour (ex 9:00 to 9:02), while the other blower runs half an hour later (ex. 9:30 to 9:32).
    b. With 2 100-Watt solar panels, an additional 3 compost tea bubblers may be added.
        i. If a third panel and second blower are added, a fourth additional bubbler may be added.
3. Battery
    a. The provided battery should provide enough power for even an expanded two blower 3 panel system
    b. If long cloudy periods are frequently fully discharging the battery, there are two options
        i. A larger battery may be purchased to replace the current one
        ii. A second identical battery may be purchased and wired in parallel with the first battery.
4. Electric fence
    a. The electric fence energizer is rated to cover over a mile of fence. The single energizer should provide enough power for any possible fencing solution at Field 2.