



ESW Build Day

Proposal for Ithaca Children's Garden
Siting Committee

Engineers for a Sustainable World Build Day Team

*Trisha Ray, Emma Payne, Stephie Lux, Sidarth Giddu,
Jay Chand, August Cudeck, Megan Tormey, Tarannum
Sahar*

Cornell University
November 7, 2018

Table of Contents:

Executive Summary	2
Objectives and Scope	2
Meet the Team	3
Research	4
Design	6
Well Design	6
Electrical Circuit	7
Placement and Support for Solar Panel	7
Hole Design and Support	8
Water-Use System	8
Work Plan	8
Progress	9
Materials and Costs	9
Funding	10
Build Day Logistics	10
Day-of Logistics:	10
Day-of Timeline:	10
Advertising for Build Day	11
Safety Concerns	11
Post Build Day Considerations	11
Appendix	12
Electrical Component Specifications	12
Preliminary Design of Well and Pump System	14
Close-Up of Well	15
Stress Analysis of Pergola Structure	16

Executive Summary

Our project for Ithaca Children's Garden (ICG) is a solar powered ground water pump system. The ground water pump will benefit ICG as it will provide a solution to their seasonal droughts and will simultaneously introduce the children to renewable energy. Many visitors come through Ithaca Children's Garden, so the visitors will see the solar powered pump and likewise learn about the benefits and relative ease of incorporating renewable energy into their lives.

The water pump's primary purpose is to replenish the water in the bioswale and rice paddy. As Jean Gerow and Daniel Wayne Krall explained to our group, the bioswale tends to dry out during the hot summer months of Ithaca, and the drought season is harsh on the plants in those areas. Additionally, the drought takes away from the children's ability to learn about wetlands and different ecosystems and ecological features. With the water pump, Ithaca Children's Garden (ICG) will be able to replenish the bioswale during any droughts. The water pump will take advantage of the high water table, which is about two feet below the ground at ICG and isn't currently being used to supply any water to the site. We were informed that ICG would prefer to use this groundwater water instead of purchasing more city water, due to the high cost of city water. The water pump is a cost-effective solution to watering ICG's wetland that enables Ithaca Children's Garden to make use of their water resource.

In addition to being cost-effective, the project with Ithaca Children's Garden will have several positive environmental impacts. First, it is a sustainable way to supply water to ICG's bioswale in the summer months. The water obtained is groundwater, and once it is in the bioswale it eventually seeps back into Cayuga Lake. Additionally, it will be very noticeable to the community of ICG visitors. The community can then become easily engaged with the concept of sustainability and renewable energy and be inspired to incorporate it into their own lives. Due to its utility to Ithaca Children's Garden, the overall Ithaca community, and its promotion of sustainable living, the ESW Build Day team proposes to build this project at Ithaca Children's Garden this coming Spring.

Objectives and Scope

Our team's goal is to design and implement a project which will shed light on the practicality of sustainable solar power in Ithaca, NY. While Ithaca may not be the most ideal location for solar generation, this does not imply that such practices are completely infeasible. We find that ICG would be the perfect place to implement such a solar powered system, as this is a popular place for the youth of Ithaca to play and learn about the natural environment in which they live. The objective of our project is to design and implement a working groundwater pump powered solely by sunlight, so that the bioswale in the Children's Garden remains at a full water level conducive to garden growth. Through our Build Day event, we hope to provide an fun and

enriching experience centered around sustainability and show that such practices are affordable and easy to implement.

Meet the Team

ESW Cornell Chapter is the original chapter of ESW, and since our founding we have worked hard to explore and create new and innovative projects that work to integrate sustainable solutions into our community. Our chapter consists of around 60 members where each member is a part of three main teams: Biofuels, Solar Powered Solutions, or Renewable Energy Design. Each of these main teams is further broken down into smaller project teams of 4-7 people, with each smaller project team working on a different project.

ESW Build Day is one of the project teams on Renewable Energy Design. Our current team consists of 8 students in a variety of different engineering disciplines. This team was created at the beginning of the 2018-2019 school year after being accepted into the ESW-HQ Build Day Program.

ESW-HQ is the leadership team that oversees all ESW chapters. The ESW Build Day program “is a collaborative project design and build initiative that brings together student engineers, technical experts, and community leaders to create local sustainable change.” Through this program, our Build Day team will receive funding and mentorship to help make this Build Day at Ithaca Children’s Garden possible.

Additional Information:

You can learn more about our ESW chapter and current projects on our website:

<http://esw.engineering.cornell.edu>.

You can learn more about ESW-HQ on their website: <https://www.eswglobal.org>

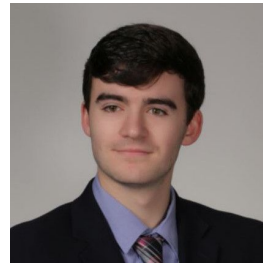
ESW Build Day Team Members:



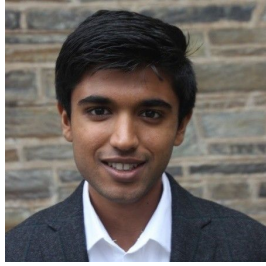
Trisha Ray
Class of 2019
Electrical and Computer
Engineering



Emma Payne
Class of 2021
Environmental
Engineering



August Cudeck
Class of 2020
Operations Research



Sidarth Giddu
Class of 2020
Electrical and Computer
Engineering



Stephie Lux
Class of 2021
Biomedical Engineering



Jay Chand
Class of 2021
Electrical and Computer
Engineering



Megan Tormey
Class of 2022
Environmental
Engineering



Tarannum Sahar
Class of 2020
Mechanical Engineering
and Economics

Research

Solar Research

Our solar panel is 37.5" by 74.5", giving an area of 1.778 m². The spec sheet gives data from the company's test conditions (Standard Test Conditions) when it tested the panel's output. The input power was given as 1000 W/m², and multiplying by the area of the solar panel, that is a total power input of 1778 W. The maximum output under these conditions and input is given as 285 W. Dividing 285 W / 1778 W gives an efficiency value of ~16%.

The efficiency of our solar panel lies well within the normal range of panel efficiencies, according to Standard Test Condition tests. However, the system we intend to build also faces losses in productivity from other factors such as unpredictable weather and lack of constant sunlight during the day. To avoid the problems of erratic power output, the panel will charge a

battery during the times of sunlight rather than being attached directly to the pump, so that the pump can draw power from the battery whenever the bioswale or the rice paddy needs to be refilled. The pump will be needed most during the summer, when solar panels can produce the most energy, which is why solar power is a fitting source to use for this project.

Pump Research

For our pump, we intend to use a small submersible pump with enough power to pump large amounts of water fully out of the hole (i.e. a couple feet) and then across several more feet to the bioswale. Although the exact volume needed to replenish the bioswale is unknown, the pump will offer sufficient flow rate to more significant volumes of water. The first pump we are testing can pump 880 gallons per hour and has 13 feet of head lift, so it should easily meet the pumping requirements. Additionally, the pump will need to be submerged at all times in order to pump properly, so there will be a control above-ground to switch it on and off as needed. The first prototype pump is small in dimension (5.1 in. x 5.1 in. x 3.1 in.), so keeping it submerged in the hole should be feasible.

The water entering the pump should be as pure as possible to avoid clogging the pump; we intend to keep the system as low maintenance as possible. A submersible filtration cap will be placed over the intake zone of the pump to keep particulate matter out of the pump.

Groundwater Research

This project is feasible due to the nature of the groundwater at Ithaca Children's Garden. Because the water table is so high, it is only necessary to dig down a few feet in order to submerge our pump in water. According to USGS data on groundwater, the water table measured in a well in Romulus, NY (the closest nearby data point) was recently at 3.89 feet. Although this will fluctuate slightly with season, aquifer use, and geography, it gives good reasoning to believe the water table in Ithaca is similarly high. This was in fact confirmed by digging a test hole at ICG, in which we hit water at less than one foot.

Another consideration is the purity of the groundwater. Because children will be playing around the bioswale, it is imperative that any water pumped in is safe. Much of Tompkins County gets water from Cayuga Lake, so it is reasonable to hypothesize that the groundwater in the Cayuga Lake watershed does not have severe contamination. We were able to definitively conclude that the water is safe by reaching out to Megan Wilson, who works in the city planning office.

Lastly we considered the rates at which we will be pumping water, to ensure that we will not overdraw the local source of groundwater. For this project, it is only necessary to pump around one thousand gallons of water over an extended amount of time, as the bioswale will only need to be replenished in the summer after the spring rainfall dries out. The recommended minimum pumping capacity for wells from the Water Well Board is 600 gallons over two hours. This need is met by household wells, and our "well" will be pumping at far below this rate. Additionally, bioswales naturally replenish groundwater, whereas in traditional wells the water is pumped out, used, and recycled into a wastewater system, rather than back into the aquifer. Therefore we conclude that water availability and overdraw will not be of concern in this project.

Design

Our solar panel will be attached to an adjustable mount. This is advantageous because we can angle the solar panel to receive the max amount of sunlight. Also, the battery, inverter, and charge controller will connect to the solar panel. The battery stores energy harnessed by the solar panel, and the inverter changes DC to AC so the battery can supply current to the pump.

Well Design

In order to safely cover the hole in which the pump will go, we plan to build a decorative well that can be placed on top of the hole. There will be a piece of plywood to cover the hole and then the well will be placed on top of the plywood. This is to ensure that no one can climb into the well and fall into the hole. For further safety, the top of the well will be covered with something aesthetic (e.g. a rock bed) so no one can climb into it. The well also has many practical purposes. It will house the electrical components such as the batteries, charge controller, the inverter, and the safety load. Also, the plywood will contain a small hole to allow the hose and pump to be removed from the system. The hole will have a trap door to ensure safety. We will make sure that the electrical components in the well are in a waterproof enclosing and that the components are easily accessible via a door. The door will also allow access to the pump and hose system, which will allow the pump and hose to be removed during winter.



Figure 1: Well CAD Design

Electrical Circuit

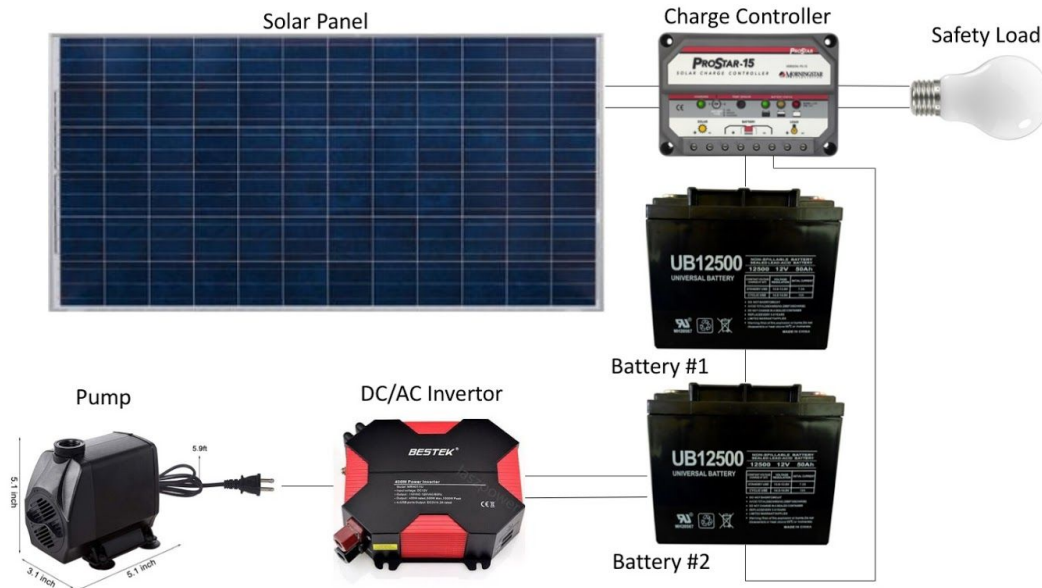


Figure 2: Electrical Circuit Diagram

As seen in Figure 2, the electrical circuit for this solar pump will require a solar panel, charge controller, safety load, two batteries, and a DC/AC inverter. We decided on a electrical system with batteries as opposed to a solar panel directly connecting to an inverter in order to increase reliability. Although there is a high chance that the bioswale and the rice paddy will face a drought during periods when the sun is strong, the battery provides an added layer of reliability to ensure there is enough power to use the pump whenever it is needed.

In terms of the physical location of the electrical circuit, the only part of the electrical circuit that will be in the hole is the pump and the extension cord that will lead up to the well where the rest of the electrical circuit, except for the solar panel, will be housed. We will enclose any long wires, such as the wire from the charge controller to the solar panel, in a PVC pipe for protection.

Placement and Support for Solar Panel

In order to maximize the efficiency of the solar panel it must be facing directly south, and must be positioned high enough to be above the nearby tree line. Therefore, we are inclined to place the solar panel on one of the already existing pergolas. The nearest pergola is less than 20 feet from the planned location of the well, so it will be feasible to have an electric connection from

the electrical components in the well to the solar panel. It is necessary however, to ensure that the pergola can support the weight of the solar panel. We performed a stress analysis of the pergola structure and concluded that the stress caused by the weight of the solar panel is less than the maximum stress of the oak wood structure (picture of methods in appendix). However, we still plan on reinforcing the pergola by adding additional wood slats across the top and an additional horizontal supporting beam. This extra reinforcement will provide the necessary certainty that this project is safe.

Hole Design and Support

In order to ensure that the hole will not cave in and will remain the correct size, we plan to place metal fire rings inside the hole to secure its shape. The idea is that we will stack these fire rings as we dig the hole.

The hole itself will be 5 feet deep and 4 feet in diameter. When digging the hole, the diameter of the hole might be larger to allow us to dig the hole, but once the metal fire rings are inside, we will fill in any excess space outside the ring. The soil and clay that is removed to create the hole will be put into the Anarchy Zone.

Our plan is to dig the hole before the winter sets in, or at the very least before the actual Build Day. This is because digging the hole itself will probably take around 4 hours.

Water-Use System

Our plan is to have our pump attach to an above ground spigot similar to the other ones found around the garden. While initial considerations were to also provide pipelines to the rice paddy and bioswale, we have found that a simple spigot system will provide the greatest utility. This avoids the possibility of pipes freezing or having to remove an elaborate hose system each winter. This should effectively reduce the yearly maintenance labor to removal and installation of the pump and a few feet of hose.

Work Plan

See the following link for the ESW Build Day Gantt Chart. This chart contains a general outline of our work plan for the year.

<https://docs.google.com/spreadsheets/d/1YIRjpf0PJFFf8NIRthWpJKdFfFB5u5RR74ybyToUKhk/edit?usp=sharing>

Progress

This semester, we have completed all of the preliminary research needed to build a solar powered pump system. This included analysis of local groundwater, research into wells, researching optimization of solar panels, and choosing an appropriate pump and hose system for our well. Additionally, we have been to Ithaca Children’s Garden several times to determine the location of the well and take any relevant measurements (e.g. distance from bioswale to well). Once we finished gathering data and information, we designed an electrical system (see Figure 1) and a model for the fluid pump system. The latter will begin with the pump at the base of the well, which will push water into a main hose out of the well. The hose will divert into two separate hoses (one for the bioswale, one for the rice paddy) to refill water at the desired locations.

Beyond planning the design and set up, we have begun preliminary work for the installation of the system. We have started digging the hole for the well because we wanted to finish this while the weather is warm enough for the ground to be soft. We are also concerned about mounting our solar panel safely, so we are currently analyzing the structure needed to hold it up. We started by examining ICG’s existing pergola, as this is a good height and size for our panel, and are still confirming whether the material is strong enough to support the weight. We are also working to make the system winter-proof (i.e. removable from the well) and as low maintenance as possible to make ICG’s long-term maintenance of the system fairly easy.

Finally, we have spent a lot of time working on the logistical side of Build Day. We have been in touch with ESW HQ to confirm the details of the project, meet their national Build Day standards, and discuss funding. We have also been working closely with ICG and Dan to confirm the exact needs and wants of ICG, and how we can best meet those needs. Moving forward with logistics, we have started to plan both Build Day itself and the advertisement of the event. However, these tasks will comprise a lot more of our future work as we get closer to the event. The rest of our work up until Build Day will include building the structures that cannot be made during the time we have on Build Day, and testing the electrical and mechanical components of the system for quality, safety, and efficiency.

Materials and Costs

Product	Price	Quantity	Cost
UB12500 Battery	\$99.99	2	\$199.98
Solar Charge Controller	\$89.00	1	\$89.00
AC-DC Inverter	\$39.98	1	\$39.98

Eoply Solar Panel		\$255.00	1	\$255.00
Copper Wiring (10ft)		\$10.70	1	\$10.70
Frame (material tbd)		\$200.00	1	\$200.00
Well pump (jet)		\$100.00	1	\$100.00
Push Button Switch		\$6.61	2	\$13.22
Waterproof Enclosure		\$160.00	1	\$160.00
Panel Cover		\$20.88	1	\$20.88
Hose		\$100	1	\$100
Galvanized Metal Fire Ring		\$45.00	4	\$180
Hose Connector		\$7	1	\$7
Total (Excluding Recycled Parts):				\$1375.76

Funding

This project is completely funded by ESW HQ, as Build Day is a concept sponsored by HQ. Earlier in the semester, we submitted a grant request to HQ, which they use to procure funding as a non-profit. We will send HQ a bill of materials which they will purchase on our behalf. Additionally, we will be reimbursed by them for any smaller purchases we have already made. Therefore Ithaca Children's Garden will not be responsible for any costs related to this project.

Build Day Logistics

Day-of Logistics:

On the day of the actual Build Day, the Build Day team as well as authorized staff of ICG will complete any tasks that are on the higher risk side. These tasks include:

- Placing the solar panel on the pergola
- Connecting the electrical system
- Placing water pump in hole
- Testing the entire system

We want to open the Build Day event to volunteers and guests. Volunteers will help with painting the well while guests can observe and partake in the end of event celebration.

Day-of Timeline:

Note: The exact time and day of the actual Build Day may be subject to change based on the

weather and ICG's availability, but this is our tentative timeline.

Build Day will take place on Saturday April 27th, 2019 from 12pm to 4pm. The Build Day team will arrive an hour before the Build Day event starts to set up. Setting up will involve organizing all the materials and tools for the build and blocking off any areas that are restricted to only the Build Day team and ICG staff. We want to open the Build Day event to volunteers, so set up will also involve organizing a table and sign-in sheets for volunteers.

Hour 1-2: The Build Day team will give a brief welcome speech and thank everyone who came to the event. Only some Build Day members will work on placing the solar panel in its permanent position and connecting the electrical circuit. Other Build Day members and volunteers will work on bolting together the well that will be placed on top of the hole.

Hour 3-4: As Build Day members and volunteers finish assembling the well, volunteers will work on painting the well. Once the electrical circuit is in place and attached to the pump, Build Day members will test the system with a hose and see if we can successfully transfer water to the bioswale and rice paddy. Once testing and painting is complete, we will have a small celebration at the end to conclude Build Day.

Advertising for Build Day

As mentioned above in reference to the logistics for Build Day, we will be looking for volunteers to assist with the construction of the well and other components of the project on the actual Build Day. We will put up advertising posters around town closer to the date of Build Day, Cornell and the Ithaca Children's Garden in order to gain the attention of community members interested in helping. In addition, we would like to use the Ithaca Children's Garden website and social media to gain interest from those involved in the ICG community already. While we may need to limit the number of volunteers based on the level of interest in the event, anyone is welcome to come down and throughout the day or especially at the unveiling at the end of Build Day.

Safety Concerns

In order to make the hole secure and safe so that no one at Build Day can fall into the hole, we are planning on placing a temporary fence or boundary that no one but designated Build Day members can cross to place the pump. The hole should also be covered for the majority of the Build Day after the pump has been placed inside the hole.

We will also provide all volunteers with necessary safety equipment including safety goggles and hard hats. Everyone participating in the Build Day will be required to wear closed-toed shoes and have their hair pulled back.

Post Build Day Considerations

During the winter, we need to make sure that water does not stay in the hose because water expands when it freezes. This can potentially break the hose in the cold months. When the pump is not in use, ICG can detach the hose from the pump to drain the excess water. ICG will also be able to remove the pump using the side door of the well.

To make sure our structure is durable, we must check if the pergola can support our solar panel. We also need to weatherproof all of the materials we will use.

This project will help ICG by teaching children how to use solar power and how bioswales work.

Appendix

Electrical Component Specifications

ProStar-15 PS-15 Solar Charge Controller:

Part Number: PS-15

Manufacturer: Morningstar

Voltage: 12 and 24

Amps: 15

Controller Type: PWM

Meter: No

Length: 6.01 IN

Width: 4.14 IN

Thickness: 2.17 IN

PDF-Datasheet:  [ProStar-ProductDataSheet.pdf](#)

PDF-Manual:  [ProStar-UserManual.pdf](#)

Solar Panel:

Part Number: EP156P/72-285W

Manufacturer: Eoply New Energy Technology Co., Ltd

Open Circuit Voltage: 44.21V

Short Circuit Current: 8.27A

Maximum Power at Standard Test Conditions: 1000 W/(m²) 285W

Maximum Power Voltage: 36.79V

Maximum Power Current: 7.76A

Maximum Series Fuse: 15A
Maximum System Voltage: 600VDC
Fire Resistance Rating: Class C
Weight: 26kg
Intended Load: 30lbs/ft²

Samlexpower 300 DC-AC Inverter Model PST-305-24A:

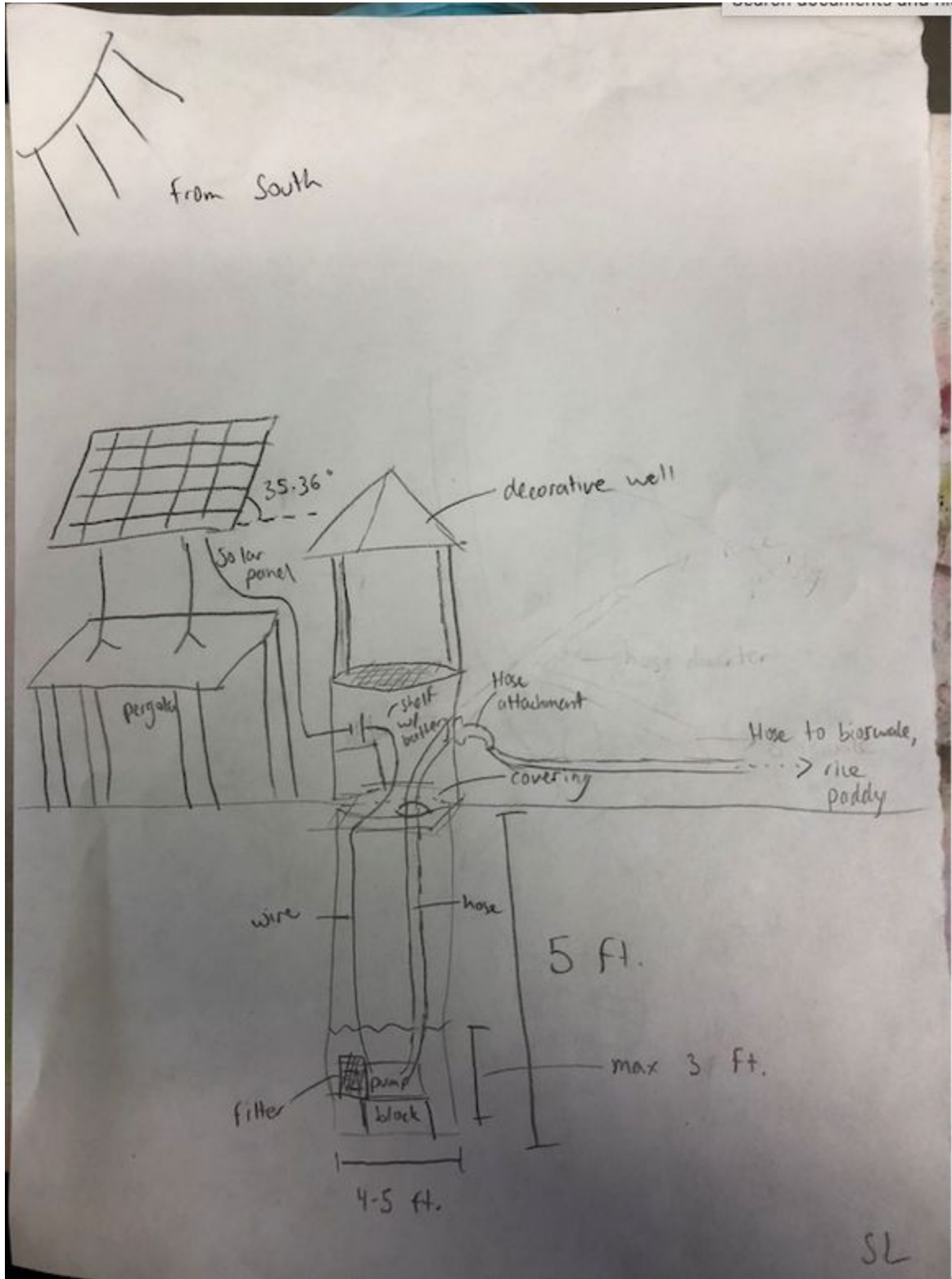
Power: 300 W
Input: 24 VDC
Output: 120 VAC

<http://www.samlexamerica.com/products/ProductDetail.aspx?pid=471>

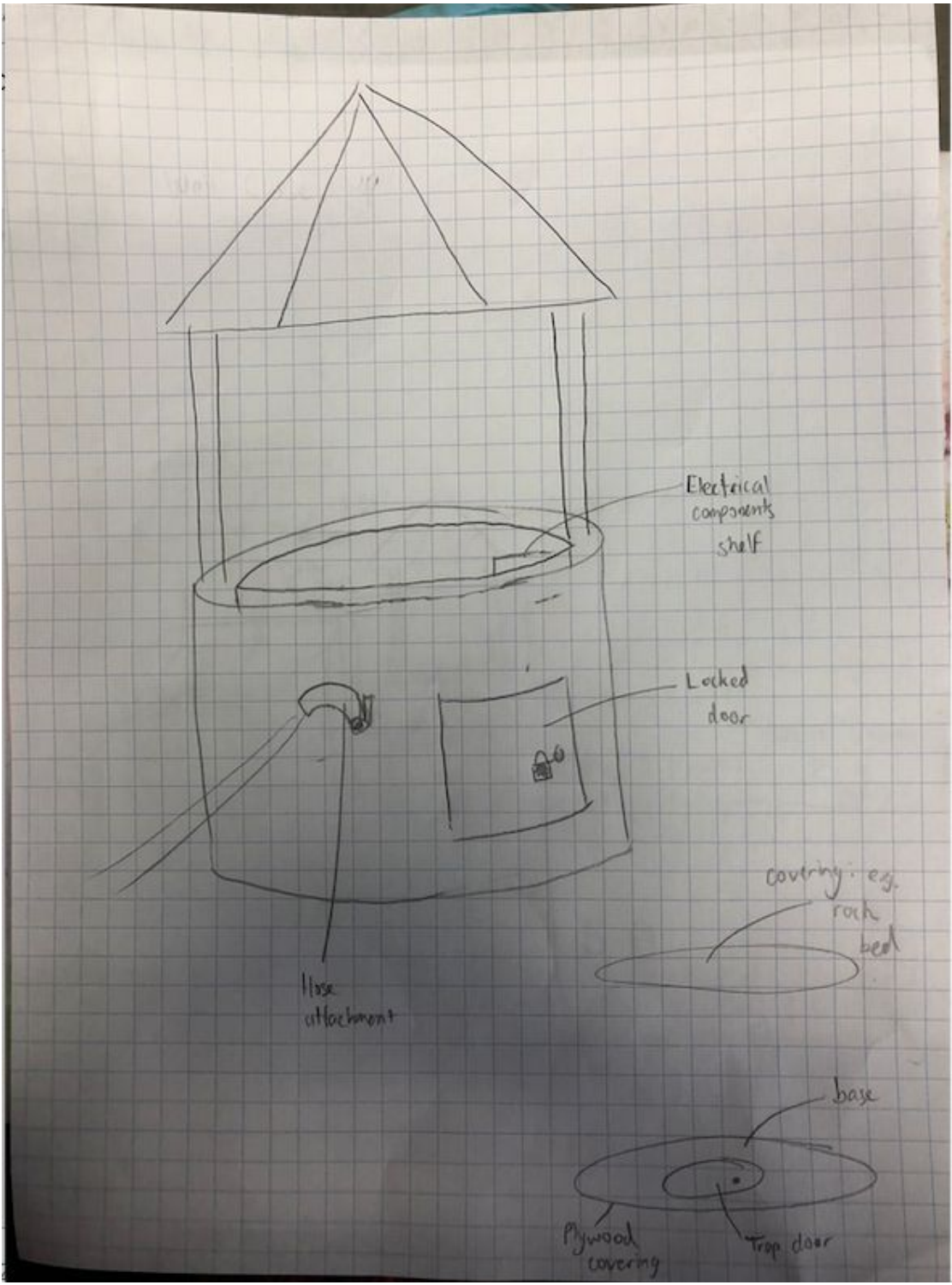
UB12500 Universal Battery:

Voltage: 12V battery
Discharge Rate: 50AH
Voltage Regulation: **Standby Use:** 13.6-13.8V
Cyclic Use: 14.5-14.9V
Initial Current: **Standby Use:** 7.5A
Cyclic Use: 15A

Preliminary Design of Well and Pump System



Close-Up of Well



Stress Analysis of Pergola Structure

Weight of solar panel = w_{sp}

Weight of the roof of pergola = w_r
 $w_r = n_b \text{ of wood bars} \times (L \times h \times w) \times \text{density of oak wood}$

Weight total, $w_T = w_{sp} + w_r$

Stress on the column, $\sigma_c = \frac{w_T/4}{w_2 \times L_2}$

$\sigma_{max} \text{ (compression)} = 1150 \text{ MPa}$ (check edge for dry wood parallel to)

If $\sigma_c > \sigma_{max} \rightarrow \text{Failure}$

Shear stress, $\tau_w = \frac{w_{sp}/4}{h_1 \times w_1}$

Max shear stress, $\tau_{max} = 1610 \text{ MPa}$ (check)

If $\tau_{max} > \tau_w \rightarrow \text{Failure}$