A Thesis Presented to

The Faculty of Alfred University

Off Grid Tiny House: Green Wall

by

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Summary

The Tiny House project is a proposed 200 square foot off grid home sitting atop a 24-foot trailer. The concept of the tiny house is simply, “a social movement where people are choosing to downsize the space they live in. The typical American home is around 2,600 square feet, whereas the typical small or tiny house is between 100 and 400 square feet.” The square footage of the AU off-grid tiny house is 180 sq. ft. discounting wall width and the sleeping space in the loft. The loft is 6’10” by 10’ and contains a queen size bed which acts as the main sleeping quarters for the home. Beneath in the living room space is a multipurpose couch that can act as a sofa bed as well as a sitting area. Attached to the exterior of the home to extend the living space is a foldable deck. The deck also benefits the home as extra space for entertaining as well.

The engineering projects incorporated into the home included a water filtration and collection system, a methane digester, a green wall, a crank system for the deck, a solar array with battery bank system, a home automation system and an aerodynamic roof feature to protect the solar panels during travel. Each of the engineering projects were distributed to one or two senior engineers and a handful of undergrads for design, testing and implementation. Two marketing majors joined the project as well to better market it to prospective students, donors and faculty.

The project incorporates disciplines from all the different colleges at Alfred University and ties in several from Alfred State College. Within Alfred University, the project includes 29 Alfred University students primarily consisting of renewable and mechanical engineers. A collaboration has been set up with Alfred State College through Jack Jones, the building trades’ chairmen. The collaboration allows the house to be built outside the Alfred village lines to avoid any conflicts with local legislation. It also provides hands on experience for the building trades students and experience for the engineers to problem solve the complexities that arise between design and actual implementation.

The projected time line of the project was two years, one year for design and one year from prep and build. However, it has been since extended to the two and a half years due to delays in funding and paperwork. Construction was slated to begin at the beginning of the spring semester, however it began on April 30. The first step in construction was to prep the bottom of the trailer with geo-textile to protect it from sediment on the road and insulate the

base to prevent heat loss. Next, the framing will commence and for there, the construction will follow the standard home building timeline.

The overall budget for the project is $41,000 and has be accumulated through donations, grants, and various campus funds. The initial funding came from the Bill Rice Fund and the Student Life Enhancement Fund. This money was used to buy a trailer from specifically designed to bear the weight of a tiny house. The dean's office and the Inamori Fund also contributed funds for the Tiny House trailer that was used to buy the materials necessary to prep the bottom of the trailer and to begin framing. John L. Turner '64 donated $2000 and this was used to finish purchasing lumber and various items for the different engineering groups to complete their testing prior to the implementation phase.

The project itself came to fruition at the tail end of sophomore year and acquired an advisor and faculty support the following August. The team leaders from the project were Matt Finley, Zac Mapes and Jessica Scoones. First, a design was created based on the standard dimensions available for tiny house trailers. A tournament-style was then used to determine the design. The nine engineers working on the project were paired off with one group of three. Each pairing designed a layout and brought it to the following meeting. From there, each pairing combined theirs with another group's until one design remained. Since the final design was created in December of 2016, three major overhauls have happened based on design constraints with the engineering systems to be installed. An official final design was achieved in the spring of 2017 and sent on to Alfred State College Building Trades Program.

The purpose of the aerodynamics group was to design a roof feature to protect the solar panels from being ripped of the roof while traveling down the road. The winds the panels would face when traveling down the road at highway speeds could reach that of sustained hurricane level winds. It was thus necessary to design a metal roof feature that would direct the wind up and over the panels. The solar array and battery bank system are being designed to allow the home to be capable of remaining off the grid for six months at a time. The goal is to have a 15kW battery back up to store the excess energy created by the panels on sunny days. The home will also be designed to be grid tied, so the home will not be completely reliant on the solar panels.

The water filtration and collection system further adds to the off grid capabilities of the home. The goal is to collect rain water and filter it into water that is safe to use for showering and cooking. A gutter filter will be the first filter in the system and it will remove large pieces such as sticks and leaves from making it further into the system. The rain water will then go through three mesh filters, 100um, 500um and 1000um, each filtering smaller particles out of the system. It will then go through a ceramic filter before finally going through a UV filter and moving to a storage tank. The waste water or greywater will then be used to water the green wall as it cannot be re-filtered for use again.

A methane digester and composting system will be installed to use the food waste to create bio-fuel for a bio-gas stove top. The system will include a chute for food waste to be dumped into that leads to a tank set up outside the home due to the dangers of storing gas inside the home. This gas will then be pumped back into the home like a gas stove set up. However, this system will be designed to be disconnected from the home for travel to maintain the mobility of the tiny house.

Attached the backside of the house will be a deck that can be raised and lower for traveling. An electric winch system was designed to raise and lower the deck that would draw energy from the solar panels. The model of the home in Solidworks and then the decking portion of the model was tested in ANSYS to see how it would handle various loads without being structurally compromised. In Abaqus, a cube was created made of pine and of steel. This cube then had various forces applied to it and the behavior of the cube based on the material was compared.

The HVAC team tested the usage of a Mitsubishi Mini-Split heating/cooling system to provide a temperature-controlled climate for the home. The mini-split was chosen because it is ductless which is key due to the limited space within the tiny house. A wooden structure was built around the mini-split so that is could be tested and the efficiency of it could be determined. The HVAC team was also responsible for determining insulation for the home to ensure that the maximum amount of heat was retained. The chosen insulation is manufactured by Owens Corning as it is highly rated. This will help achieve the ultimate R-value of the home around R19 to R21.

The HVAC team has been working in conjunction with Home Automation to allow wireless control of the mini-split. The home automation team has worked to incorporate a variety of sensors into the home to maximize power usage efficiency. This includes motion sensors, smart outlets, the CREE Dimmable LED’s and a smart thermostat. This is all connected and controlled via a Samsung SmartThings Hub which can be paired with a variety of devices. The smart hub is synced with an app that can be downloaded on the phone of the user to control all the devices from anywhere when the phone is connected to Wi-Fi.

My specific role within the project was to create an effective design for the green wall that can be attached to the exterior of the home. This included performing porosity testing to ensure that the moisture barrier between the green wall and the home would not be compromised. If this barrier is broken, there is risk of mold growing on the house. The green wall will be a fabric green wall that is removable to reflect the mobility of the home. The consequence of using a fabric green wall is that the odds of the moisture barrier being compromised are higher. It is necessary then to line the back of it with a waterproof material that can prevent this.

I am also a leader for the project, so I be responsible for meeting with various Alfred State College and Alfred University officials, faculty and staff, keeping track of the budget and participating in public relations events held by the University. This includes attending luncheons with prospective donors and liaising between Alfred State College and AU. This role will be taken over by Arica Enders as the intended design of the project is for it to be continued for years to come as a consistent two-year time line senior project.

Abstract

Green walls provide a nature aesthetic to a tiny house as well as a mobile garden. While they may be beautiful from the front it is important to ensure the moisture barrier in the back is being maintained. This can be done by lining the back with a waterproof material. Gore-Tex was selected as the desired material to line the green wall due to its well-known abilities at being waterproof and the adhesive backs of the patches allows for easy installation.

An experiment was designed to test the Gore-Tex's waterproof capabilities and limits by placing five grams of water on a sample that is secured to a funnel allowing any water that gets through to leak down into a graduated cylinder below. This trial was ran for a variety of times (1min, 10min, 30min, 60min, 360min, and 1080min) and with two different types of water (DI water and tap water).

The weight of the dry graduated cylinder and funnel was compared after the water sample was left for each duration of time. There was a negligible variation after each trial proving the Gore-Tex was waterproof and thus useable. A single green wall pocket was then lined with Gore-Tex and violas were planted and watered to test the usability and effectiveness of the design. While the felt-like fabric of the pocket was wet, the Gore-Tex remained dry meaning the experiment was a success.

Introduction

The Off Grid Tiny House is multi-disciplinary project that fosters hands on and cooperative learning between the different schools within Alfred University and with Alfred State College. The goal is to create a self-sustaining home while implementing innovative solutions and problem solving. The project encompasses many of the elements of what it means to be an Alfred University student; the ability to work productively and cooperatively in a diverse group, develop problem solving skills, express ideas through written and verbal communication, and the use of logical reasoning. Within the Off Grid Tiny House project, there are seven different engineering projects. These include a water filtration and collection system, a methane digester, a green wall, a crank system for the deck, a solar array with battery bank system, a home automation system and an aerodynamic roof feature to protect the solar panels during travel.

The off grid tiny house is built on a 24’ by 7’6” trailer with an interior space of 23’4” by 6’10”. The home must contain certain features for livability and usability of the space. This includes electricity, heating, water, plumbing, waste management, sleeping quarters, food preparation, food storage, general storage for belongings, ergonomics, space to work and space to entertain. Each of these items are incorporated into the tiny house while maintaining the off-grid element of the home.

Involvement

My personal involvement within the project was split between the leading the project, keeping track of the budget and designing the green wall.

Problem

The purpose of the green wall is often to add an aesthetic to a structure. However, this is not its only use. One of the basic concepts of self-sustaining living is growing one’s own food. A garden forces a person to stay in a set location for a lengthy period. A green wall takes all the benefits of a garden and combines it with the mobility of a tiny house. With a green wall, the garden is attached to the house on hooks, so it can be removed for travel making it just as mobile as the house itself. Some of the obstacles involved in a green wall is what plants will grow in a planter, not creating too much weight on the exterior wall, maintaining the moisture barrier and the ability to reach each portion of the green wall with ease. The main concern is that if the moisture barrier is broken, then mold will begin to grow on the siding of the house and could eventually break the moisture barrier between the inside and the outside of the house.

Solution

By creating a detachable green wall, the accessibility element of the green wall is no longer a concern because it can be removed from the wall and the garden can be tended at a more reasonable height. Most plants that can be grown in a pot can be grown in a green wall, solving the question of what can be and cannot be grown in a green wall. Most commonly these are herbs and flowers such as spinach, oregano, etc. Plants that cannot be grown in a green wall include vegetables like pumpkins and potatoes because potatoes grow into the ground which is not an option for a green wall and pumpkins will become too weighty for the green wall. This means with the green wall will be ripped off the wall of the plant will be ripped out of the pocket.

The weight of the green wall will be negligible comparatively to the other elements weighing on the house. However, it will be necessary to ensure the screw hooks are placed in the studs to give the green wall extra support. A single pocket with fully grown planted flowers weighed _____. The major concern was maintaining the moisture barrier between the house and the green wall. The solution was to line the back of the green wall with a waterproof material that would prevent any moisture through the back. Gore-Tex was the initial material that came to mind because of its well-known waterproof qualities. It was then necessary to design an experiment to confirm that Gore-Tex would be completely waterproof.

Design

An experiment was designed to confirm the waterproof qualities of Gore-Tex material. The experiment required DI water, tap water, a beaker, a funnel, a graduated cylinder, a circular Gore-Tex sample with an adhesive back, a pipette and a scale. The funnel was first cleaned with DI water and dried completely. The Gore-Tex was then placed inside the funnel with the edges of the adhesive securing it as seen in Figure 1 and 2 below. Figure 1 is a birds-eye view of the secured adhesive and Figure 2 is a side view of the secured adhesive.

Figure 1: Birds-eye view of secured Gore-Tex Sample Patch

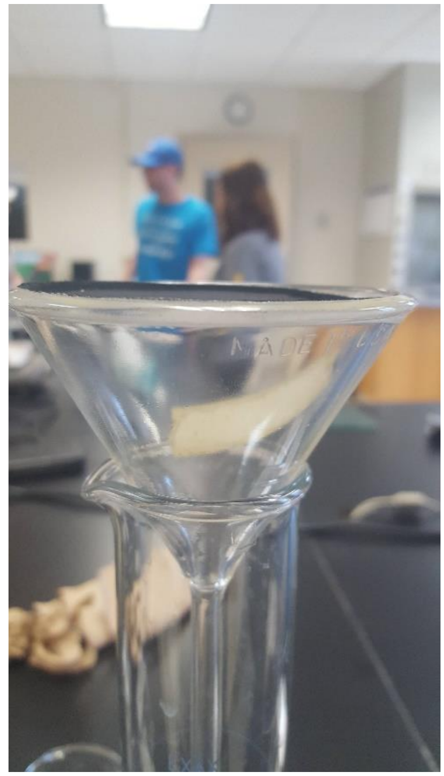


Figure 2: Side view of secured Gore-Tex Sample Patch

The funnel and Gore-Tex sample were then weighed to give a starting base line weight. This was repeated for the graduated cylinder. The funnel was then placed inside the graduated cylinder as seen in Figure 3. This would allow any water that made it through the Gore-Tex to be collected in the graduated cylinder and weighed. A beaker of DI water was placed on the scale and weighed. Five grams of water was then placed on the Gore-Tex as seen Figure 4. The water was then left on the Gore-Tex for different variations of time: 1minute, 10 minutes, 30 minutes, 60 minutes, 360 minutes (6 Hours), and 1080 minutes (18 Hours). The water remaining on the surface of the Gore-Tex was then removed with a pipette. The graduated cylinder and funnel with Gore-Tex was then re-weighed as seen in Figures 5 and 6 below. The results were then recorded and analyzed to determine if Gore-Tex would be an effective solution or if another material would need to be selected.

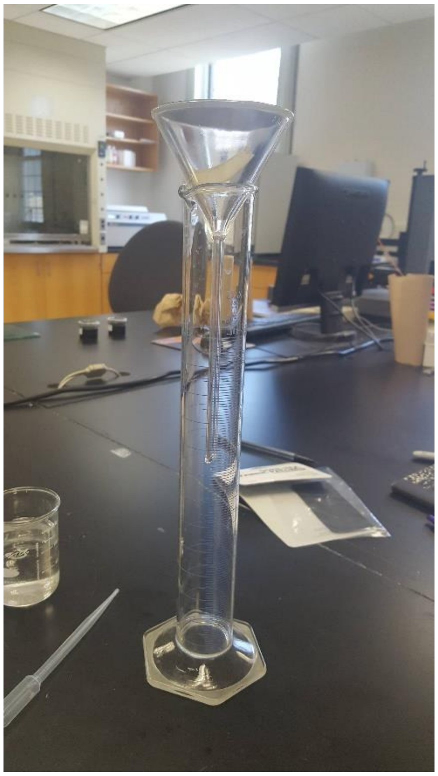


Figure 3: Complete set up with funnel Inserted into graduated cylinder

Figure 4: Five Grams of water placed on Gore-Tex

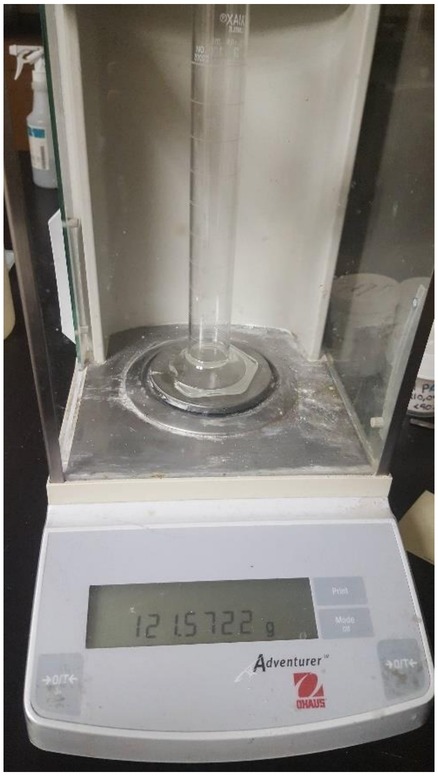


Figure 5: Re-Weighed Graduated Cylinder at 360 minutes of DI Water Test

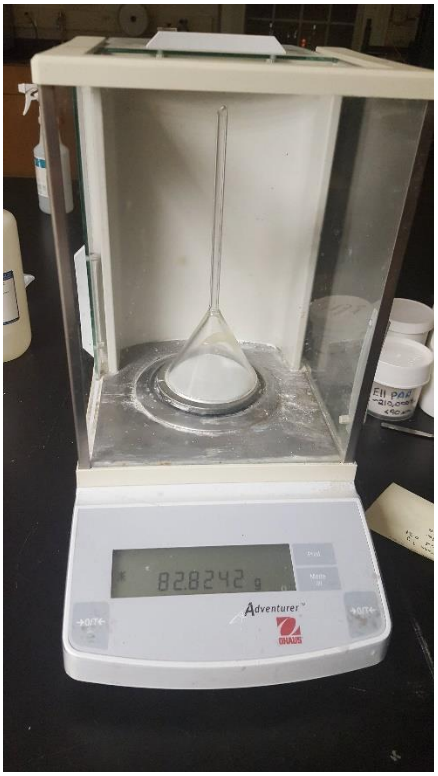


Figure 6: Re-We
360 minutes of I

Results and Analysis

The results of both the DI water test and tap water test were virtually the same and comparative to the base line values. There was little variation in the masses after each period had past. Figure 7 shows a slight darkening where the water sat on the Gore-Tex after 18 hours, but this did not add a noticeable amount of weight to the Gore-Tex and funnel sample mass. After each period, the water remained on the surface of the Gore-Tex as shown in Figure 8 below.

Table 1: DI Water Test

Time (min)	Item	Mass (g)	Amount of DI Water (g)
1	Graduated Cylinder	121.6915	5.0543
	Gore-Tex & Funnel	82.8242	
10	Graduated Cylinder	121.6824	4.9601
	Gore-Tex & Funnel	82.8321	
30	Graduated Cylinder	121.5754	4.9663
	Gore-Tex & Funnel	82.8184	
60	Graduated Cylinder	121.5771	4.9688
	Gore-Tex & Funnel	82.8201	
360	Graduated Cylinder	121.5722	5.0488
	Gore-Tex & Funnel	82.8242	
1080	Graduated Cylinder	121.5761	4.9542
	Gore-Tex & Funnel	82.8189	

Table 2: Tap Water Test

Time (min)	Item	Mass (g)	Amount of DI Water (g)
1	Graduated Cylinder	121.5714	5.0662
	Gore-Tex & Funnel	82.8185	
10	Graduated Cylinder	121.5721	4.9371
	Gore-Tex & Funnel	82.8142	
30	Graduated Cylinder	121.5743	4.9688
	Gore-Tex & Funnel	82.8206	
60	Graduated Cylinder	121.5744	4.9278
	Gore-Tex & Funnel	82.8223	
360	Graduated Cylinder	121.5749	4.9832
	Gore-Tex & Funnel	82.8269	
1080	Graduated Cylinder	121.5754	4.9603
	Gore-Tex & Funnel	82.815	

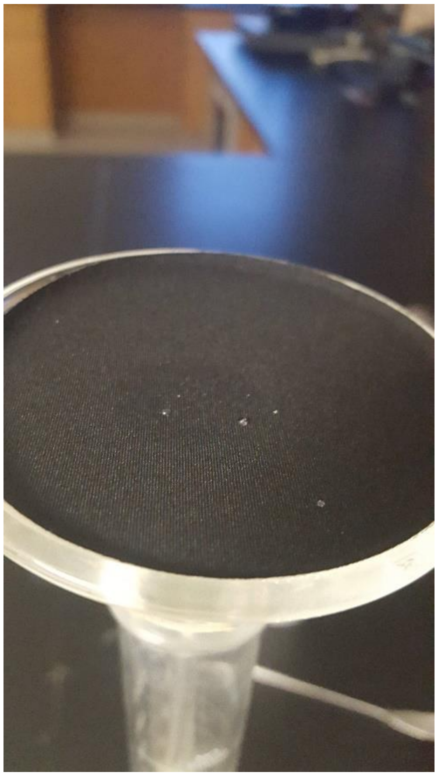


Figure 7: Slight Darkening at center
Of Gore-Tex sample

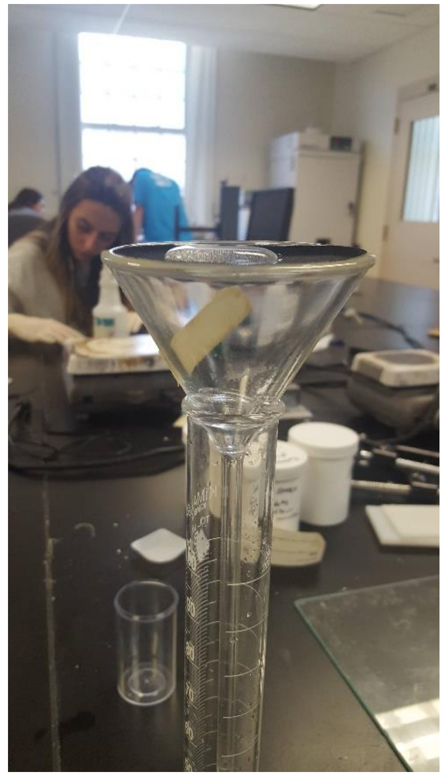
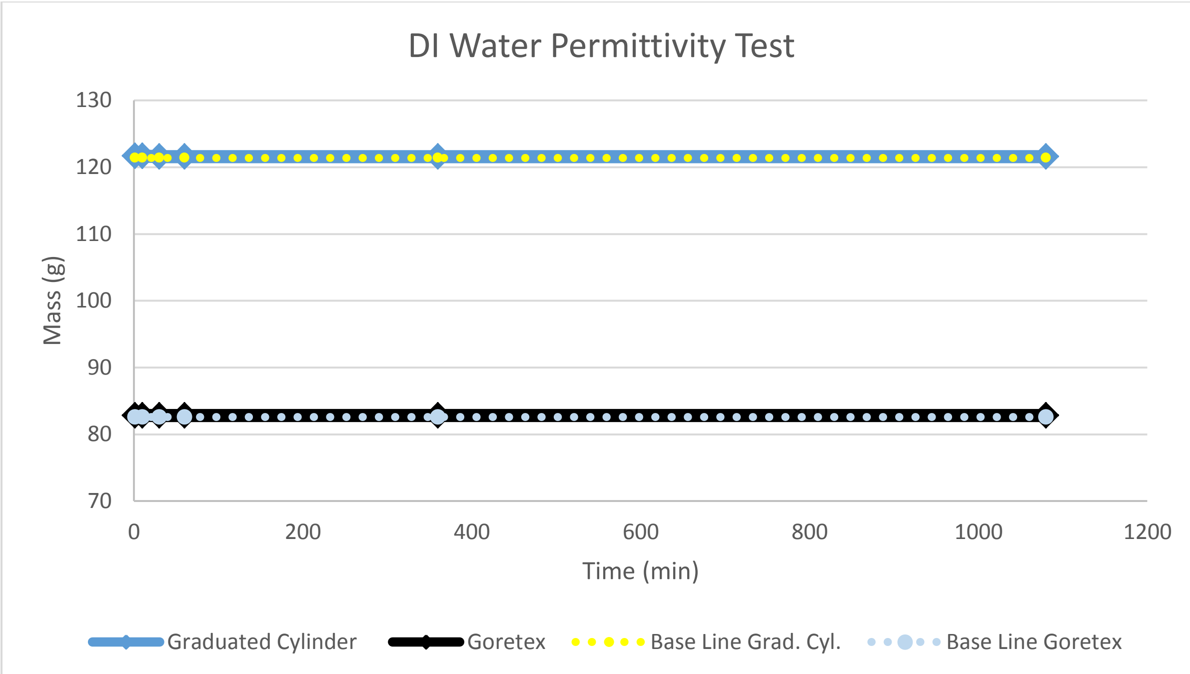
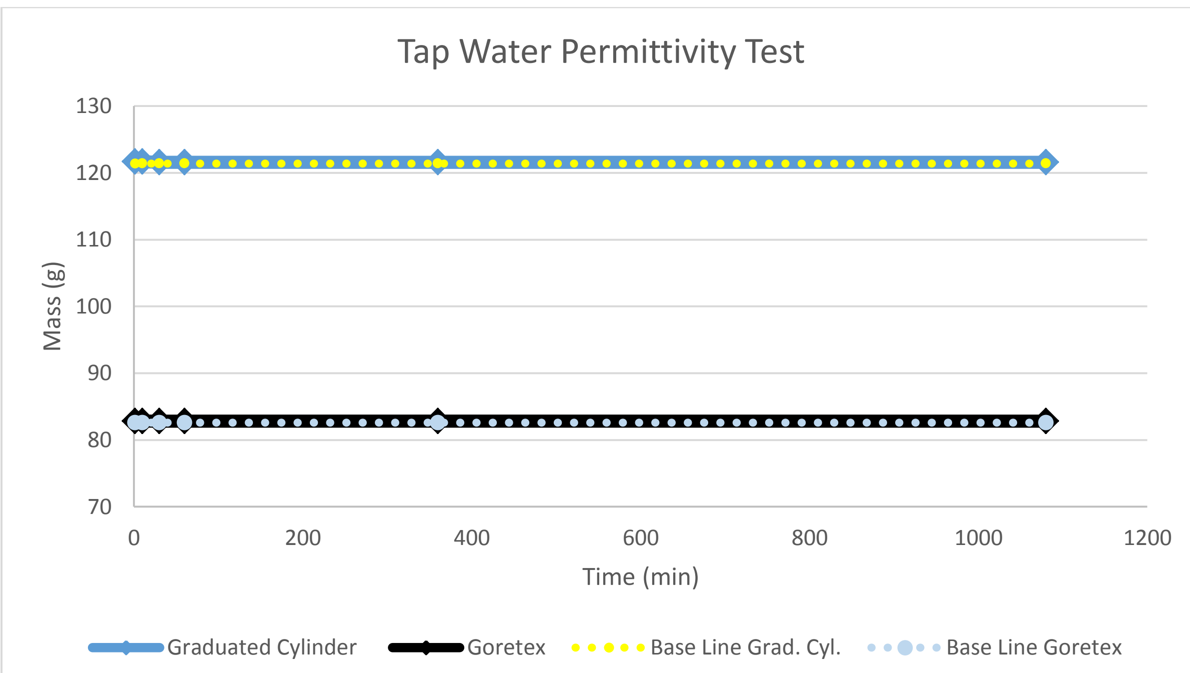


Figure 8: Water remaining after
the 60 min DI water test

When the data from Tables 1 and 2 are graphed against the base line as shown in Graphs 1 and 2, there is little to no variation in the line proving visually the experiment was a success. The next step was to test the Gore-Tex on actual green wall material. Two fabric green wall pockets made of the standard felt-like material were purchased from Amazon and lined with a mix of clear and black Gore-Tex patches. The patches were attached using the adhesive backing of the Gore-Tex samples. This can be seen in Figure 9. It is possible to see the moisture of the felt material due to the water being retained in the soil of the viola plant. However, to the touch it is dry, proving that the Gore-Tex makes a barrier that the moisture is unable to pass through. Along the bottom edge of the black Gore-Tex lining the very bottom of the green wall pocket, there is some moisture, but it is on a portion of the pocket that would not be in contact with the wall. It may be because the pocket is not hanging but resting on a surface preventing it from airing out properly.



Graph 1: DI water permittivity test results compared to the base line values



Graph 2: Tap water permittivity test results compared to the base line values

Figure 9: Green wall pocket lined with black and clear Gore-Tex samples

Budget

The budget concluding testing with the definitive answer of the effectiveness of Gore-Tex was roughly $171 as seen in Table 3 below. This is well with-in the original projected budget of $200 meaning the Gore-Tex lined green wall is also economically viable based on the predetermined Off Grid Tiny House budget.

Table 3: Budget breakdown based on Gore-Tex lining

Quantity	Item	Purchase Location	Unit Price	Total Cost
10	3"x20" Gore-Tex Roll	Amazon	$12.17	$121.70
2	Fabric Green Wall	Amazon	$11.99	$23.98
1	Potting Soil	Lowes	$15.00	$15.00
7	Assorted Seeds	Lowes	$1.35	$9.45
			Total	$170.13

The total cost of employment as an engineer making $25 an hour for the duration of the project when considering both designing and testing the green wall and leadership activities would be $7500 as broken down in Table 4. The three categories used were: Design & Experiment, General Leadership, and Meetings & Networking.

Table 4: Cost of Employment by hour based on experiment design and leadership activities

Work	Hours a week Averaged from Total	Total Hours (75 weeks)	Cost
Design & Experiment	1	75	$1875
General Leadership	2	150	$3750
Meetings & Networking	1	75	$1875
Total	4	300	$7500

Conclusion

The lining of the green wall with Gore-Tex adhesive patches is an effective way to guarantee a moisture barrier between the green wall and the tiny house siding. A source of error in the experiment is that the water was placed on the Gore-Tex side of the patch rather than the adhesive side of the patch which is opposite of how the water will attempt to seep through. This has not proven to be a problem, so far with the prototype green wall pocket.

Future work for the green wall would include comparing a lined green wall with an unlined green wall to confirm just how effective is the Gore-Tex barrier. Another experiment would be to grow the plant from seedling through full maturity to see if this influences the amount of moisture that possibly penetrates the Gore-Tex barrier. Due to weather conditions and time constraints, in the experiment only flowers with a fully grown root system were used.

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Appendix

Green Wall Pocket Details including recommendation to line backing with waterproof material:

Vtete

Vtete 2 Pcs 1 Pocket 15" × 11" Vertical Hanging Wall Planter Living Wall Grow Container Bags Green

4 customer reviews

Best Deal | Add to Droplist

Price: $8.90 ✓prime

Your cost could be $3.90. Eligible customers get a $5 bonus when reloading $100.

In Stock.

Want it Tuesday, May 1? Order within **14 hrs 59 mins** and choose **One-Day Shipping** at checkout. Details
Sold by Vtete and Fulfilled by Amazon. Gift-wrap available.

- Package includes 2 Pcs 1 Pocket 15" × 11" wall planters, Each pocket size is : Height = 11 inches; Width = 15 inches;
- Felt material to allow drainage and breathe, eco-friendly and non-toxic to producing superior plants; A unique, decorative, space-saving way to harvest fresh herbs from your wall
- Easily to use zip ties or hooks to attach planter metal holes onto railing or fence, or can use screws or nails to mount the wall planter to the wall or wallboard
- Can be used in the patio, rail, fence, balcony, sun room, gate or anywhere else you can find to grow flowers, succulents, herbs, vegetables and plants
- Avoid water drain to indoor wall, we recommend use waterproof backing or watering outside or use inlaid irrigation system

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Base Line Average Calculations:

Original Graduated Cylinder Weight (g)		121.6813
		120.7038
		121.5762
		121.5772
	Average (g)	**121.3846**

Original Gore-Tex and Funnel (g)		82.8196
		81.9403
		82.8109
		82.8156
	Average (g)	**82.5966**

Extra Summary Text:

After a design was decided upon, the engineering projects were decided upon and assigned to the various seniors based on their major. Aerodynamics was assigned to mechanical engineering underclassmen under senior, Matthew Derse. The solar array and battery bank group was led by Samuel DiRisio and Jackson Norwood with its own corresponding renewable energy engineering underclassmen. Water filtration and collection was led by Matthew Finley and Zac Mapes for the design portion with a mix of mechanical and renewable underclassmen as well as contacts with the ceramic engineering major. Composting and the methane digester is led by Sheldon Palmer from environmental science. The decking winch and beam bending was overseen by Kevin Volz and Matt Derse with several mechanical engineering underclassmen. HVAC for the home including insulation was overseen by Mike Nowak and Matt Roder. Home automation was led by Seneca Collins and the green wall was overseen by Jessica Scoones.