

Designing a Sustainable Field Research Station for Skidmore College's Off Campus Properties



By: Marcus Goldbas, Gwyn Harris, Lily Alverson



Senior Environmental Studies Capstone Project



Fall of 2012 and Spring of 2013

INTRODUCTION

Green architecture is a new and innovative way to approach sustainability. Sustainability is currently being implemented at all scales, from national laws and incentives to local community initiatives. However, there are obstacles to implementing sustainable practices, and traditional building and design methods and technologies are considered better known and less expensive than innovative sustainable design techniques. We aim to challenge these architectural and social norms. The goal of our project is to design a sustainable field station that will generate its own supply of renewable energy and minimize its environmental impact. This structure will be designed to serve various purposes for a multitude of users. The newly conceived spaces would allow more activities and labs to be completed directly in the field and could serve as a storage space for materials and equipment. With the implementation of this design, more research, classes, and recreational activities can utilize the protected forested landscapes owned by Skidmore College. Our objective is to develop the best architectural design for a field station that will increase the use of Skidmore's forested properties for teaching, learning and outdoor activities, while implementing sustainable design strategies to limit the environmental impact of these structures on the surrounding landscape.

What does it mean to implement sustainable design?

Sustainability can be defined as the ability to meet today's needs without compromising the ability of future generations to meet their own needs (EPA). We aspire to design a sustainable structure that implement's proper water management strategies, and provides energy and heating using completely renewable sources such as solar or wind, without disrupting the natural landscape. Before we begin planning Skidmore's future field station, we must consider sustainable architecture and design in a global context. The general idea of sustainable design derives from the need to improve environmental quality, reduce environmental degradation and lessen the world's dependence on nonrenewable energy sources. A sustainable field station will act as a model for the 'green' architecture principles it employs. In addition, it will serve as an educational tool for students and local community members to learn about how these features work and why they are important in a broader context.

Buildings take up the majority of the United States' energy consumption (Figure. 1) (EIA). These structures will address the global issue of unsustainable materials and energy use in buildings by demonstrating implementation of long-term, local, and practical solutions (Clarke, 2012). This multi-use structure will serve a variety of different functions, including discussion based classes, labs, and summer research. Our goal is to accommodate these uses in a sustainable, practical, and economically feasible way. This is one of the exciting challenges about our project, which will be influential in determining the success of our final design.

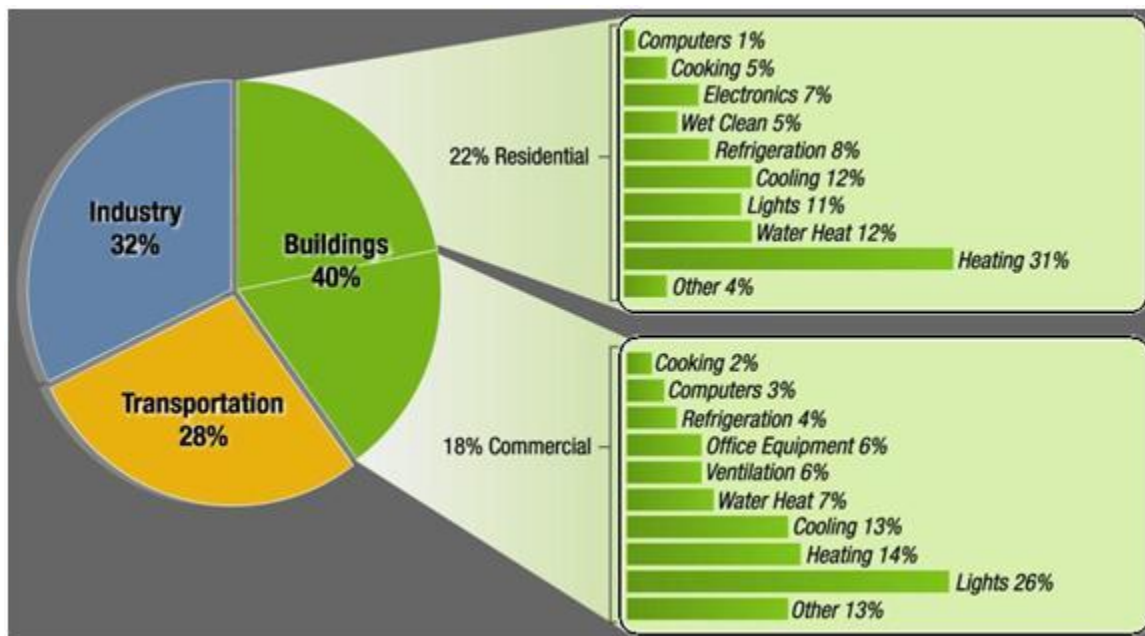


Figure 1. The U.S. Energy consumption by sector (United States Energy Consumption, EIA, 2011).

Why is it important?

Field stations have supplied students with a space to enhance their learning outside of the classroom by providing more first-hand experiences, especially pertaining to science studies (Hiram College, 2012). A field station could host a variety of desirable uses. For example, the building itself can act as a teaching tool to educate visitors about its sustainable operations, (Pilloton, 2007) as well as a research and education facility to better utilize both on and off campus properties. The Leslie Shao-ming Sun Field Station at Stanford University's Jasper Ridge Biological Reserve was designed with a goal of zero net carbon emissions for its annual energy budget (Stanford University, 2012). They achieved this goal through impressive use of renewable energy sources (passive solar design, photovoltaic panels for electricity and heating, and sustainable materials) and minimal energy and water consumption. Cornell University, Juniata College, and Bard College all have field stations in the upstate New York area. Skidmore would be joining this competition and improving its sustainability initiative. This is something that the school values but also that many students consider important. These field stations exemplify well-designed and highly functioning sustainable practices that Skidmore can learn from to start planning its own research facility.

Based on communication with Skidmore students and professors across the disciplines, the field station will be designed and catered to fit as many needs and desires as possible for those who are interested in using it. The station will allow students to not only explore Skidmore's newest property but also act as a retreat or for use as a secondary classroom. Depending on our designs and the features we decide to include, the research center would be able to accommodate classes for multiple uses, based on the feedback we get from the department interviews. Its sustainable design and location can motivate and offer inspiration to students from not just science courses but other sects of the student body, such as art students.

Groups like the Outing Club, Equestrian Team, and Art Club, would also benefit from the Stable Woods Field Station due to its multipurpose functionality.

Site Locations:

The field station will be located in the properties behind the Van Lennep Riding Center, a site that requires more transportation (car, bus, and bike) and/or time to utilize fully. Skidmore's off campus properties are used very little and largely unknown to a wide number of Skidmore's community members. We expect the latter site to be more appropriate for labs, workshops, and retreats. One main component of green architecture and sustainable design is to utilize the landscape and its characteristics. A full analysis of the properties is necessary to identify the most environmentally favorable locations with the easiest accessibility and renewable energy capacity.

Objective:

The goal of our project is to design a field station to increase the use of Skidmore's wooded properties and enhance students' learning experience, while addressing as many sustainable design strategies as possible. However, such an exhaustive study is beyond the scope of this capstone project, and not all of the strategies would be relevant and/or feasible for a field station of this scale. Recognizing these constraints, we will consider siting, orientation, climate, access/transportation, solar energy, passive solar heating, storm water management, rainwater catchment, day lighting, and materials (Lechner 2009; Brown and DeKay 2001). It is very important that our design is site specific and considers the particulars of regional climate and resource availability (Lechner 2009; Brown and DeKay 2001; Dvorak and Volder 2010; Racusin and McArleton 2012; Getter et al. 2007). Once we have sampled a broad range of perspectives and have developed a clear, detailed program, we will begin to synthesize this information into appropriate design elements and strategies. We will prioritize some of the sustainable design strategies listed above and eliminate others.

METHODS

Pre-Design Phase:

Practicing architects follow the same basic sequence of project phases that we describe here, from pre-design through construction (Brophy and Lewis 2011). In the pre-design phase, we gathered data and conduct groundwork research to create a clear vision to focus and direct our design process.

Stakeholder Analysis:

We identified stakeholders, including both faculty members and students, by emailing a list of people we thought would be interested in using either a field station or an outdoor classroom. We asked each person we talked to if they knew anyone else interested in such a project, and our list grew (Appendix A). Then they either participated in an interview with us or took an online survey about how they might use a field station and/or an outdoor classroom, and what types of spaces and amenities they would need to accommodate these uses (Appendix B). We used random sampling to select 100 students to complete our online survey. We wanted to get a variety of majors and social groups. We spent between 20 and 30 minutes for the interviews with faculty members. This information became the skeleton of our structural design.

Site Analysis and Access:

One of the main goals in sustainable design is to utilize, implement, and examine the particular landscape characteristics of a site. Thus, personal observations, scientific analysis and a GIS model was developed to determine the most appropriate sites within Skidmore's off campus properties for a sustainable field station. The model was created in ArcMap10 and ArcScene10. The model incorporated mapped variables including proximity to trails, proximity to water, aspect, elevation, critical habitat, soil type, watershed, and slope within the properties and their surrounding landscapes. Using these variables, we created a Raster equation in ArcMap10. Within each variable, their data points were grouped and valued on a scale of 0-10 based on the effect that they would have on the sustainable design. For example: areas that are highly elevated and south-west was given a value within the eight or ten range due to their high solar energy capacity. Within the equation, each variable was multiplied by chosen integer based on their significance to the characteristics of the landscape, accessibility, and energy capacity. Using this equation, each 10 by 10 meter land parcel was given a particular value.

The most highly valued locations was areas close to trails, near to water bodies, contained high elevation, and on a slight south-west facing slope. Locations directly adjacent (within 15 meters) to water were less desirable due to concerns about possible contamination, flooding, soil and bedrock structure, and possible habitat disruption. Locations far away from water were also less desirable. Areas surrounding the north side of water bodies allow for greater solar capacity and visibility due to the lack of canopy cover, south facing slope, coniferous tree density, and reflected light off of the water's surface. Thus, intermediate distances within 15 to 50 meters from water were valued most highly. We assigned values from one to ten for each of these variables, ten being most preferable, zero being least preferable. For example, locations within 30 meters of a trail were assigned a value of 10, locations between 30 and 45 meters, and between 45 and 60 meters from the trail were assigned values of 9 and 8, respectively. Locations between 60 and 75 meters, and 75 and 90 meters from the trail were assigned values of 7 and 6. Locations beyond 90 meters from water were issued a 0.

We then weighted each of these variables based on their importance to stakeholders (see below); these preferred conditions include low environmental impact, solar capacity, and the sustainability of our design, with proximity to trails and aspect being most important, followed by proximity to water, and slope being less important. Our suitability index can be calculated based on the following parameters and relationships:

$$\text{Parcel value} = 3(\text{proximity to trails}) + 3(\text{aspect}) + 2(\text{proximity to water}) + 1.3(\text{High elevation}) + (\text{slope}) + (\text{proximity to critical habitat}) + (\text{coniferous tree density}) / 7$$

This equation assigned each point on the map an average value that ranged from 0 to 10, higher values being more preferable to lower values. By mapping all of these values, we could easily see which sites would be most suitable for our field station, given these parameters.

We also considered the accessibility of locations, in terms of construction, parking, trail characteristic, and travel time to reach various sites. Currently, Skidmore only has access to these properties through the Van Lennep Riding Center on Daniels Road. In many cases, however, it would be much faster to access the properties from Maple Avenue, specifically through the Fire Station's parking lot. A formal agreement that would grant Skidmore students access to Skidmore's properties via the Maple Ave Fire Station requires presenting our plans to the Board of Fire Commissioners' monthly meeting and approval from the District Secretary.

The off-campus properties were visited on multiple occasions. Here, our model was then compared to our personal observations. We observed particular habitats, watershed characteristics, sun visibility, tree density, and access points. Areas with the largest amounts of highly valued parcels were visited most frequently and in each season. By combining the Raster Model with personal observations, three sites were chosen that had the lowest environmental impact, the most favorable and aesthetically pleasing location, and contained the highest solar energy capacity. The sites were plotted using a Garmin GPSMAP 60CSx that were then uploaded to ArcMap10.

Climate Analysis:

We used Climate Consultant 5.3 Beta software and weather data from Glens Falls, NY to conduct our climate analysis. The model generated a “comfort zone” to describe a comfortable range of humidity and temperatures given the amount of clothing a person is wearing and how actively they are working. Based on the results of our surveys, the field station will be used primarily for outdoor labs and research. As such, we assumed that students and faculty would dress appropriately for the weather. We assigned a clo value (clothing value) of 1.3 (a heavy sweater or fleece and pants - more than just a long-sleeve shirt and pants, but less than a winter coat) during the winter, and a clo value of 0.5 for the summer (shorts and a t-shirt) (Figure 2). We assigned an activity level of 1.5 mets, which is a rounded average of active laboratory work and sedentary desk work (Figure 3). The program used the weather data and these parameters to recommend the most effective design strategies for our field station, given its location and function.

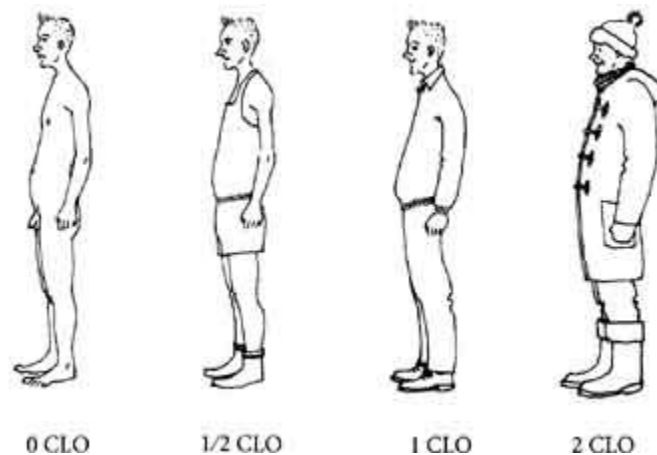


Figure 2. Illustrative description of clo values ranging from 0 clo (no clothes) to 2 clo (heavy socks, boots, pants, sweater, winter jacket, scarf, gloves, and hat). Clo values describe the average amount of clothing a person is expected to wear given different conditions. For example, very few people wear 2 clo indoors, even in winter. As a result the indoor space must be heated to maintain a comfortable temperature. These clo values are used to define an appropriate comfort zone for a building based on who will be using the space (<http://www.faryal.net/eco-ren-2-3.html>).

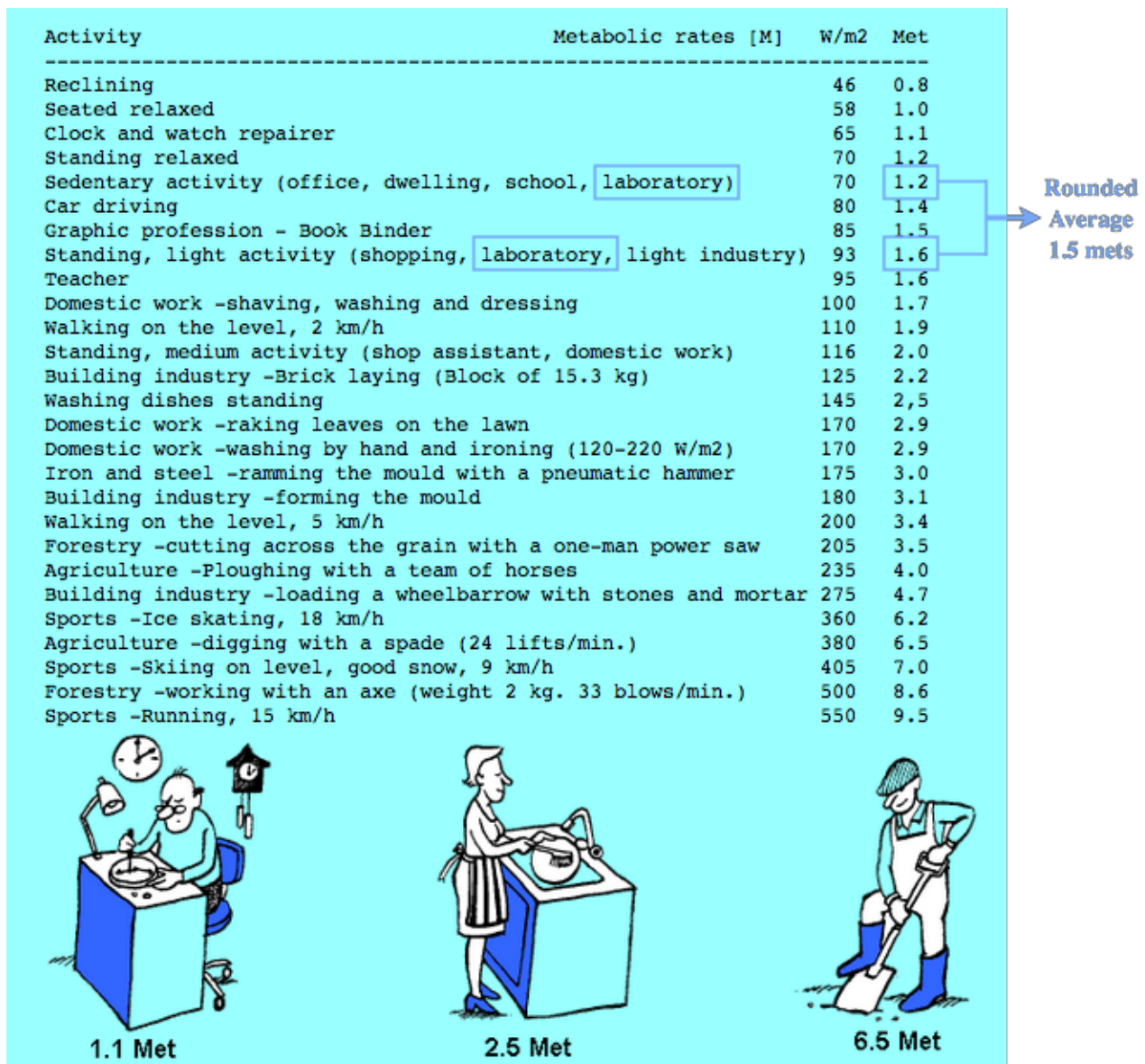


Figure 3. Activity level values for a variety of activities. A building designed to accommodate more active functions requires a lower range of temperatures and a building designed to accommodate more sedentary work requires a higher range of temperatures. For example, a gym, where people are working out is much more comfortable at cooler temperatures. These activity values are used to define an appropriate comfort zone for a building based on how the space will be used (<http://www.blowtex-eduair.it/DOWNLOADS/Thermal%20Comfort.htm>).

Solar Analysis:

To support our goal of providing energy to the field research station that is both sufficient and renewable, we assessed principles of passive solar designs, electrical solar designs (battery and grid tied), solar hot water designs, and day lighting designs (MacKay, 2009). We researched the strategies behind each of these sustainable practices to determine the most practical systems

to implement in our building's design. These systems were further analyzed based on the annual weather conditions, atmospheric conditions, ecosystem dynamics, location, and solar cycle that are particular to our sites.

Environmental and landscape factors such as elevation, peak sun hours, site latitude location, annual cloud cover, yearly radiation, humidity, ozone, atmospheric pressure, and optical depth all affect the amount of electricity that is created. Design factors specific to the site location such as the panels' angle (tilt), size (meters), product irradiance, product irradiation, and aspect angle (direction facing) need to be quantified to maximize the amount of electricity that is created.

Schematic Design Phase

The schematic design phase develops spatial and technical relationships between the objectives. While designing the field station, we will consider several fundamental questions. Which spaces should be adjacent? Which should be separated? What is the most logistically sensible placement of plumbing and electrical fixtures? How does the building relate to the site? We developed two designs for the field station and two for the outdoor classroom. We generated sketches and conceptual models using Sketch-up to describe the shape and size of the building/outdoor classroom, as well as the arrangement of spaces and features inside. The scope of this project did not allow us to fully refine our design, but there is potential for students to continue this project in the future.

Design Strategies

Passive Solar

Passive solar designs incorporate a large amount of thermal mass, which is strategically located in areas of the floor and walls. Thermal mass materials, such as concrete and adobe, absorb radiation from the sun and re-radiate that energy as heat when the temperature in the room drops below the temperature of the thermal mass. Thermal mass is strategically located such that direct sunlight coming through the windows is absorbed. Passive solar designs are most effective in areas with large diurnal temperature ranges, such as the American Southwest. During the summer in the deserts of the Southwest temperatures are very hot during the day and fairly cool at night. The vernacular adobe homes absorb the sun's heat during the day, keeping the buildings cool, and then re-radiate the heat at night to warm the space. Implementing passive solar designs can improve energy efficiency and dramatically reduce the heating and cooling cost in buildings. We decided not to design for passive solar because the large amount of concrete required has a lot of embodied energy and involves lots of heavy machinery that would be very difficult to get out into the woods, where our sites are.

Exterior Shading

Exterior shading allows direct sunlight to enter the building in the winter, but blocks direct sunlight during the summer. This helps to warm the building in the winter and keep the building cool during the summer. The sun's minimum angle (altitude) in the winter and maximum angle in the summer are determined based on the latitude of the site. These angles are used to calculate the length of the roof overhang (Figure 4). (Lechner, 2009)

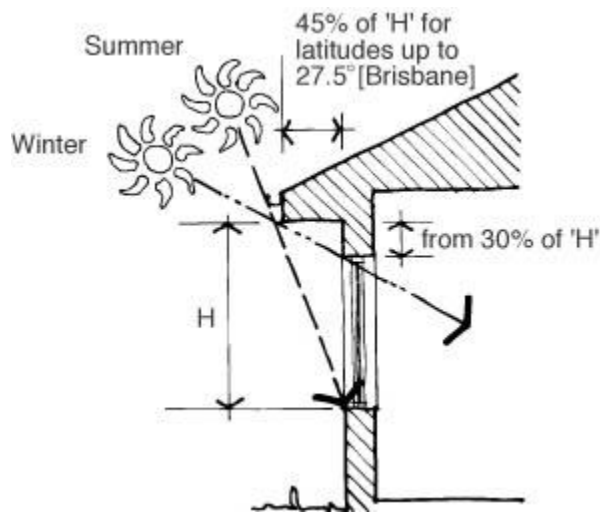


Figure 4. This cross-section demonstrates how shading can be used to block the higher angle of the summer sun, while allowing the lower angle winter sun to enter the building. These cross-sectional diagrams are used to calculate the length of the overhang using basic trigonometry. (<http://www.yourhome.gov.au/technical/fs44.html>).

Natural Ventilation

Natural ventilation involves an arrangement of operable windows that allow fresh air to circulate through the building, without creating uncomfortable drafts. (Lechner, 2009)

Solar Thermal Radiant Floor Heating

Evacuated solar tubes on the roof use the sun's energy to heat water or ethylene glycol which is then pumped through tubes in the floor. The hot liquid heats the thin concrete floor which then radiates heat into the room. This system is much more efficient than a conventional hot air system because less energy is required to heat water and ethylene glycol than to heat air. In a solar thermal system, that energy is being supplied by a sustainable source. Radiant flooring also requires less maintenance than a wood or pellet stove which must be restocked with fuel (Bokalders et al., 2010).

Day lighting

Incorporating many windows and skylights helps to maximize natural light entering the building. Day lighting helps to reduce energy consumption and utility costs by reducing the need for artificial lighting. Windows and skylights also create a sense of openness so that students working inside feel more connected to the surrounding environment. Day lighting has also been demonstrated to have a plethora of health and wellness benefits for building occupants (Lechner, 2009).

Green Roof

A green roof is essentially a layer of vegetation on top of a regular roof. It can be as thin as moss or grass, or as big as trees and shrubs. As long as the roof has the appropriate weatherproof layers, there can be many possibilities for what goes on a green roof. They can benefit both the environment and the building itself in many positive ways. Besides being aesthetically pleasing, green roofs increase the lifetime of a roof because they protect the roof

underneath. They also help with storm water management by preventing excess runoff water from entering local water sources. This is especially important in areas that have acid rain, like upstate New York, because green roofs can flush out toxins, nitrogen oxides and sulfur oxides (NO_x and SO_x), found in acid rain. Green roofs absorb carbon dioxide to improve air quality, and add a layer of insulation to the building (Green Roofs for Healthy Cities, 2013). In essence, they help lower the environmental impact a building has on its site.

Building Materials

There are many lumber suppliers in Vermont that get their materials from both reclaimed wood or from deconstruction projects. For example, ReNew Building Materials & Salvage Inc, in Brattleboro, VT, sells used hardwood flooring materials that comes from deconstruction projects, and is often of better quality than materials found in stores specific to new floors (ReNewSalvage.org). Other lumber companies, like Champlain Hardwoods in Essex Junction, VT, sell FSC Certified Wood (Forest Stewardship Council, 2013) from responsibly managed forests (ChamplainHardwoods.com) and use primarily tree species native to the Northeast.

Composting Toilet

Composting toilets use decomposition to evaporate and recycle human waste. Because 90% of the waste is water, which has a ventilation system to evaporate, the remaining solids slowly decompose and then can be used as fertilizer in soil. When properly composted, (with the right balance of heat, moisture, oxygen, and organic material) human waste will not contain any pathogens or viruses because the bacterial breakdown destroys them (LetsGoGreen.com).

Weather Station

A weather station includes tools such as an anemometer, thermometer, hygrometer, barometer, and a rain gage. In order to have all of these tools, a wireless weather station costs between \$300 and \$400. An example of an adequate weather station for the field station is the Davis Instruments 6250. At \$356, this system's features include sunrise/sunset and moon phase, heat index, dew point, wind chill, wind direction and speed, rainfall and rain rate, barometric pressure, humidity, temperature, and a solar-powered sensor (WeatherShack.com)

RESULTS

Stakeholder Analysis

Faculty Interviews

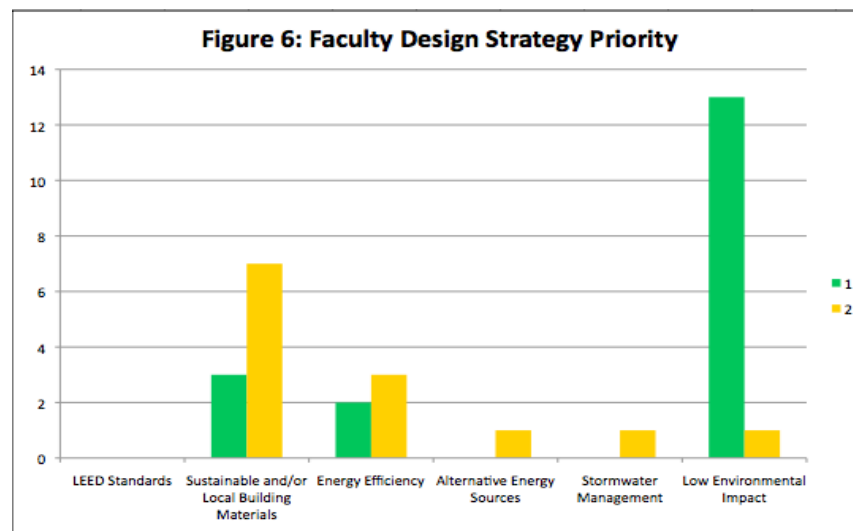
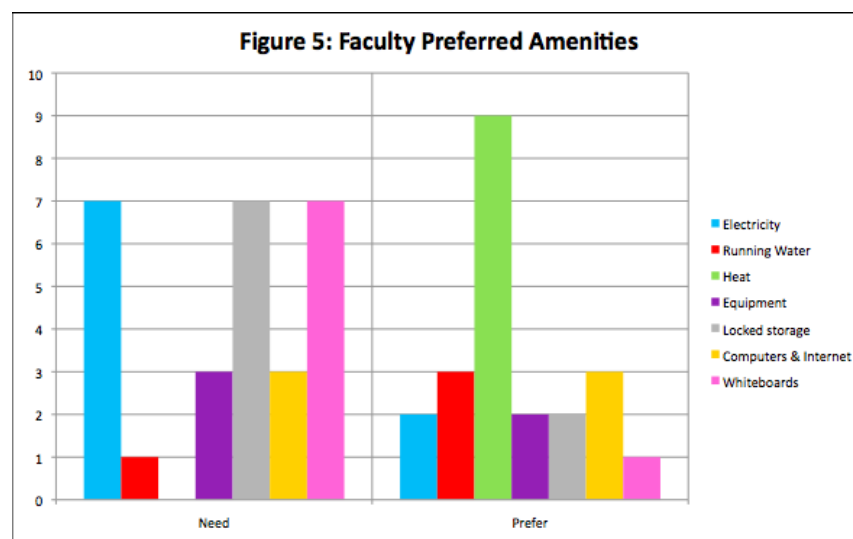
About half of the faculty members we interviewed said they would use the field station. As expected, the strongest response was from the science departments. We interviewed a total of 18 faculty members, including the 5 who opted to take the online survey instead of an in-person interview. The difference between the professors who said they would use the field station and the ones who didn't is primarily whether or not they teach long classes or have labs.

The primary use of the field station would target more of the longer, 3-hour science lab classes and would primarily be used for research. The field station was open to many possibilities among the faculty members. Denise Smith, a professor in the exercise science department, said she would use the field station as a base for her search and rescue class obstacle courses, and for her "lost hiker" simulations. A few teachers mentioned bringing their

independent study students there to do either a summer research program or an academic-year research project.

In terms of the physical construction of the field station, the majority of the science professors who would be using the space for labs and field research said they would need electricity and locked storage and would prefer heat in the winter (Figure 5). Other amenities like running water were not as desired.

From these interviews, we also determined that the most important sustainable design strategy to most of our interviewees is low environmental impact on the site (Figure 6). Though this is not necessarily a tangible part to a building, it guides our design process to make the field station blend in with the surrounding woods. Sustainable and/or local building materials was the second most popular item, influencing our research on where to obtain the materials necessary for the construction of the field station.

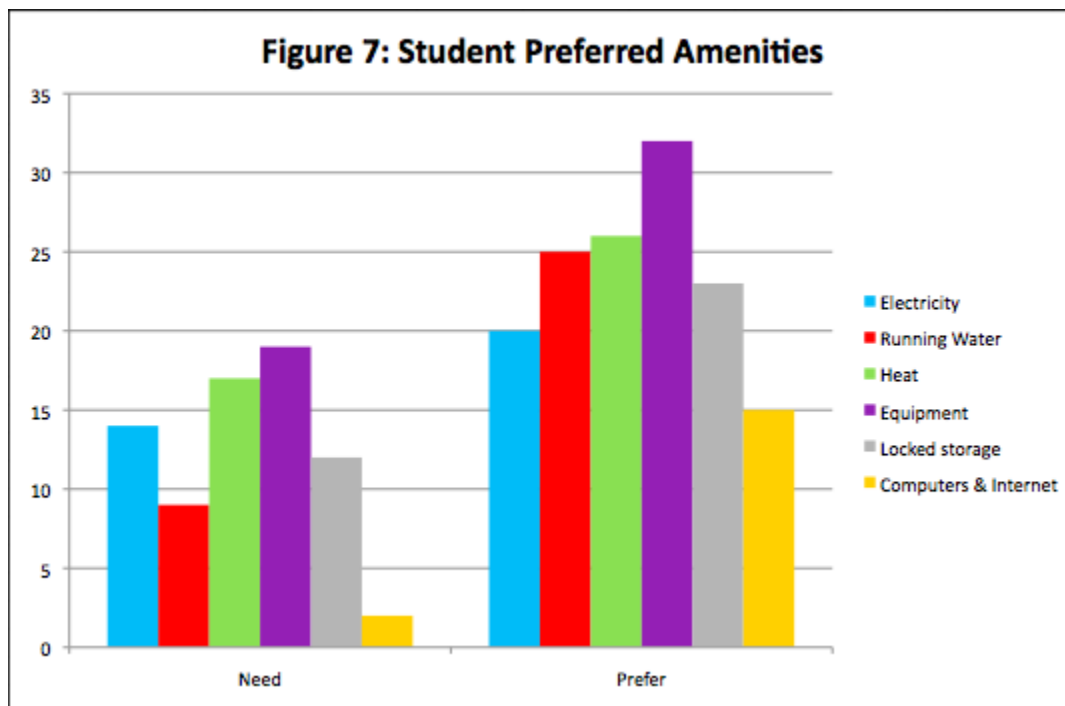


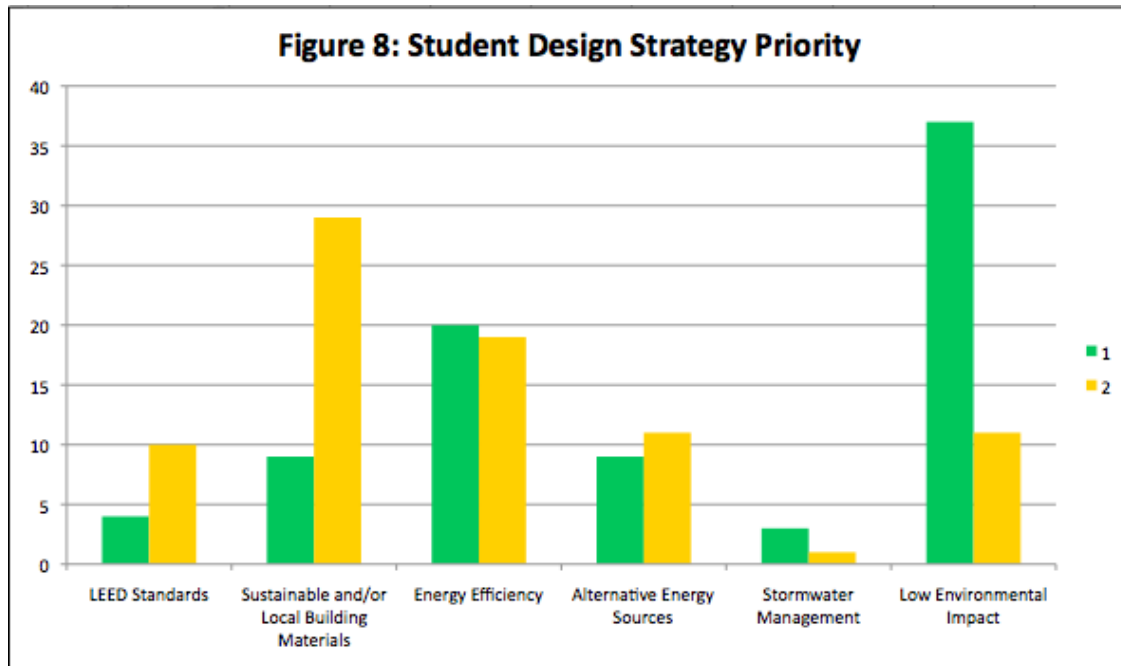
Student Surveys

92% of the students we surveyed said they would be more likely to take a class if it had some kind of outdoor component. We then focused the rest of our results on the students who said they take lab classes. Out of those 82 students, the majority of them “preferred” certain amenities instead of “needing” them, and even then equipment was the top preference, rather than electricity (Figure 7). Computers and internet were the least desired. The difference in the answers between the professors and the students probably happened because the faculty interviews were more focused on the physical construction of the building and the student surveys leaned more towards how they would use it. So professors were thinking about whether or not they need electricity to do their labs, and students were thinking about how they would do their labs in the woods.

The student surveys did turn up the same results as the faculty interviews for the sustainable design strategy priorities, however. Most students agreed low environmental impact on the site is most important, and that sustainable and/or local building material’s is the second most important strategy (Figure 8). Though faculty feedback is more important to us in terms of the design of both the outdoor classroom and the field station, student feedback has the ability to influence what the professors think is important to have in such a facility.

Students were full of positive reactions, as well as negative reactions towards regular classroom learning. “Labs would be able to do field work more easily and art classes could draw inspiration/materials from the surroundings.” There were many students who mentioned labs being more hands-on. Other students said they would be more willing to participate and share ideas in a more relaxed atmosphere. “The informal setting could lead to more enlightened conversation,” and “it would take away the boredom of classrooms.”





Climate Analysis

Based on these assumptions, the software determined that comfortable indoor winter temperatures range from 56.2°F to 68.2°F, and in summer, up to 76.5°. The Climate Consultant program then generated a psychrometric chart, with the comfort zone highlighted in blue (Figure 9). Each of the data points describes the hourly temperature and humidity data for an average year in Glens Falls, NY. All of the points in green are within the comfort zone. By adding design strategies from the list on the left, we can expand the comfort zone to include more of these weather points. If you were working at a moderate level outside wearing appropriate clothing (as defined by our designated clo values) in Glens Falls, NY, you would be comfortable 21% of the time.

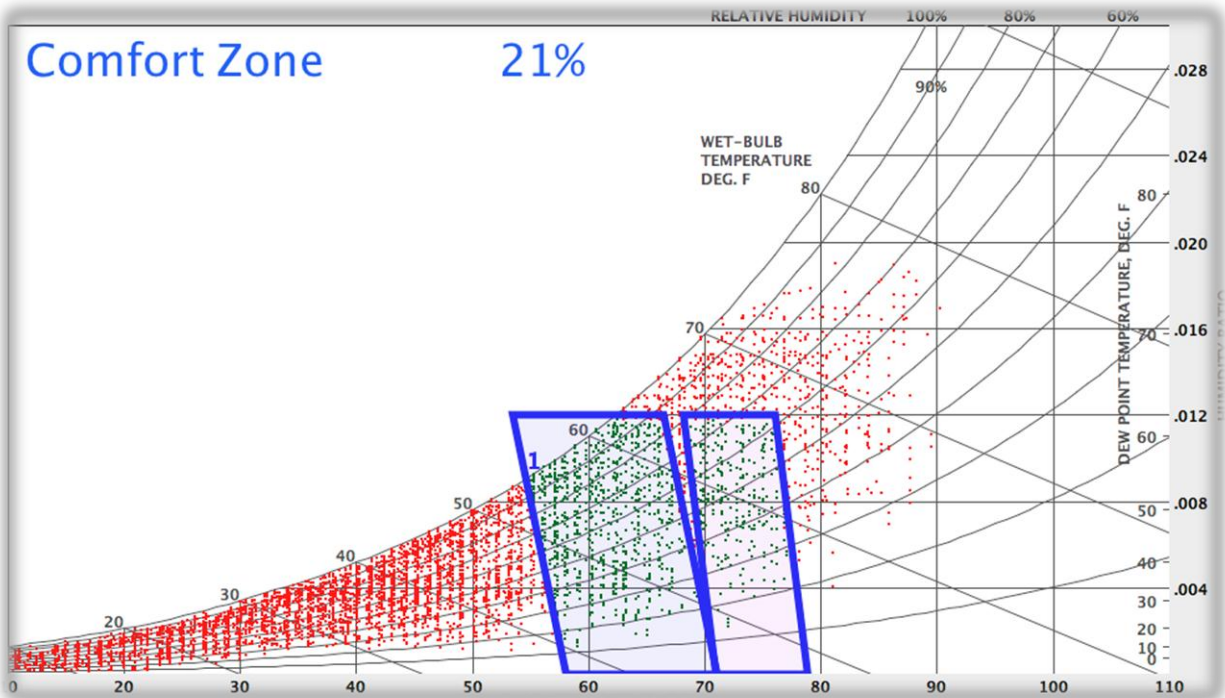


Figure 9. Comfort Zone based on weather data from Glens Falls, NY (Climate Consultant 5.3 Beta 2013).

The Climate Consultant analysis determined that heating the building would address an additional 54%. By implementing heating, shading, natural ventilation, internal heat gain and passive solar we can make our space comfortable 84% of the time, with the only uncomfortable times being the peak of summer, which is bound to be hot and sticky anyways (Figure 10). This analysis shows that heating is absolutely essential, even though it may require additional energy inputs; without it, the field station would be uncomfortable and therefore less likely to be used for most of the year.

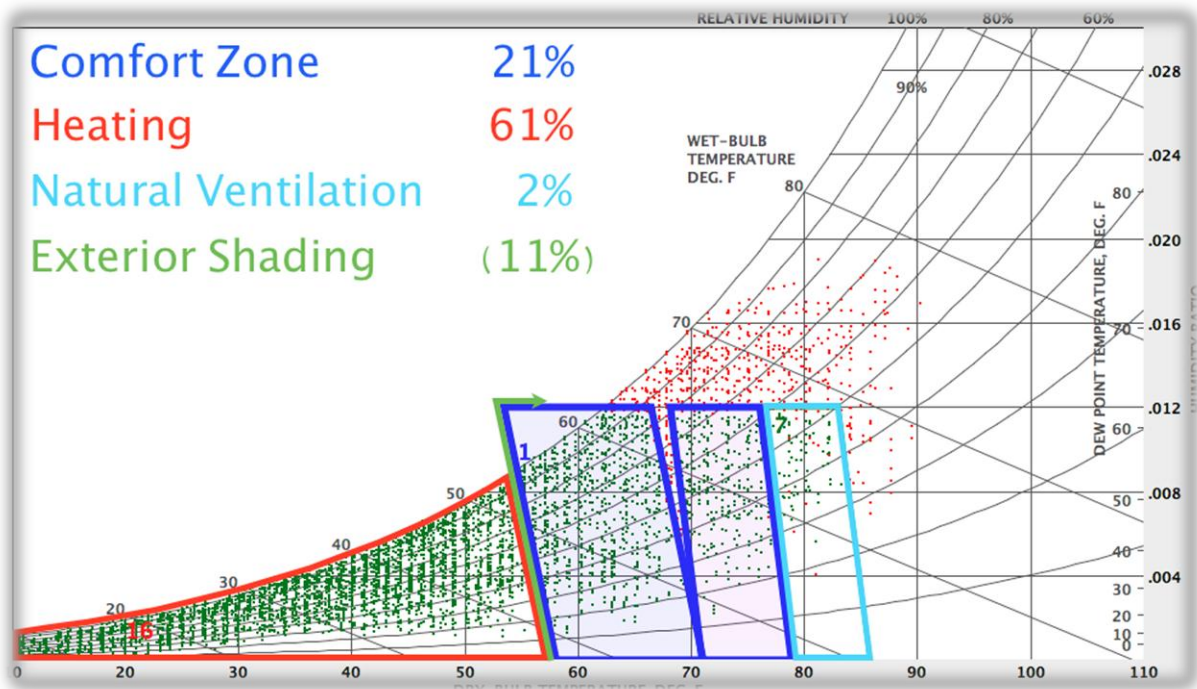


Figure 10. Improved Comfort Zone, implementing heating, natural ventilation and exterior shading, based on weather data from Glens Falls, NY (Climate Consultant 5.3 Beta 2013).

Site Analysis (GIS)

The following map shows the best locations in green and the least suitable locations in red (Figure 11). The black dots indicate 3 sites with the ultimate conditions based on site visits, critical habitat, low environmental impact, and the model's Raster score value.

GIS Raster Siting Model for the Field Station based on aspect, proximity to pathways, proximity to water, slope, and elevation.

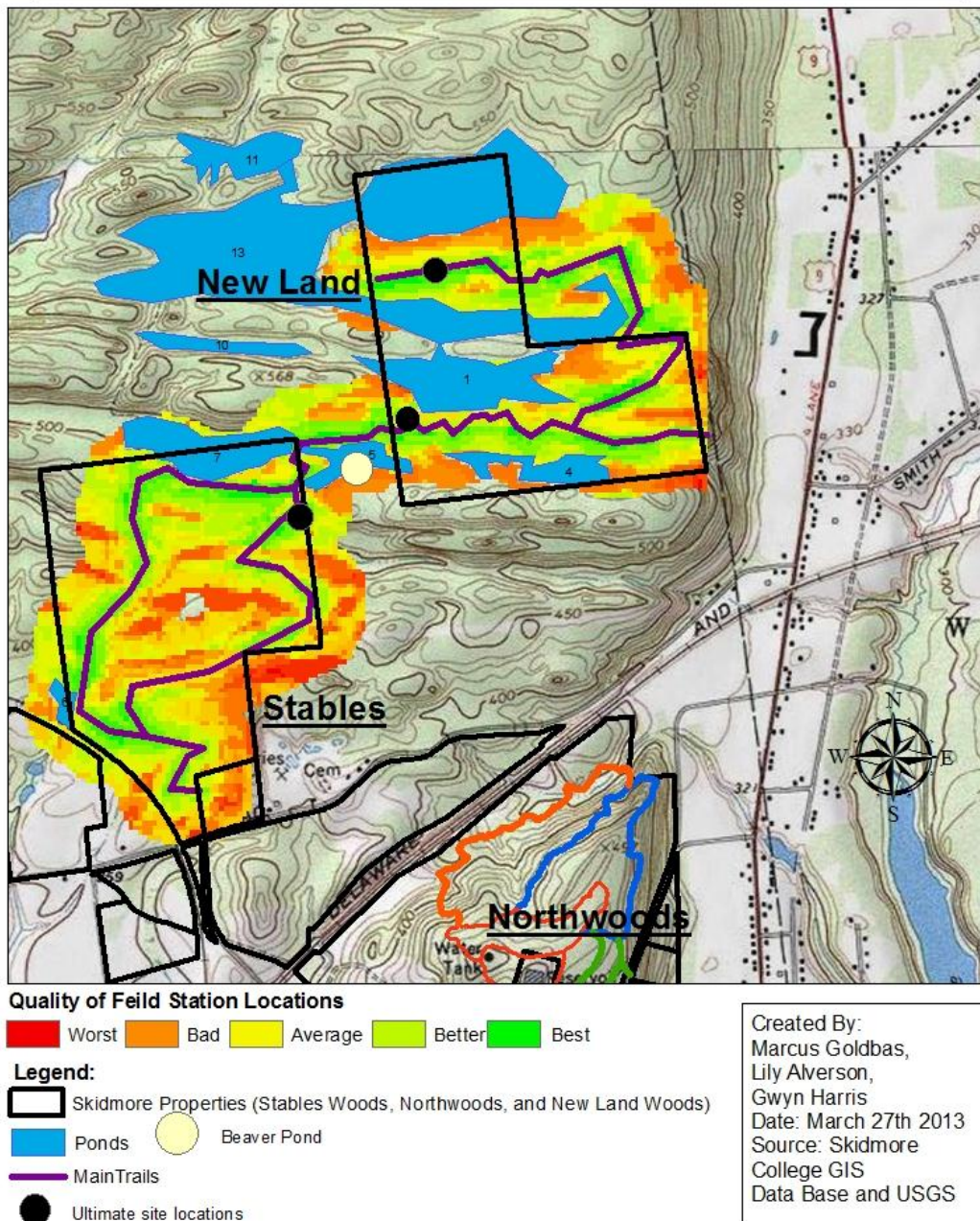


Figure 11. Arcmap10 GIS raster model of Skidmore's properties determines the ultimate site locations for the field station based on the implemented design strategies. The black dots indicate the ultimate location based on site visits and raster output score.

Site 1, Sits atop a hill at 521 feet above sea level within the Stables woods property on the south facing slope at an aspect tilt of 14° west (Figure 12). The high elevation disallows any shade from nearby landscapes to block the sun. The south-west facing slope gives high solar energy capacity by maximizing the sun's seasonal high and low arcing movement east to west. This location is located south of a beaver-created pond, outside of its watershed, but close enough for easy scientific research and environmental analysis. This site is located away from the beaver's habitat to rule out any possible forms of disruption to the habitat. This site is located 15 meters from the mail trail. This site location has a large path; large enough for a truck or tractor that leads to a smaller path roughly a half-mile from its location. The intersection between trails also bisects power lines that could be another potential access point.

Site 2 is also on southwest facing slope at a high elevated location (Figure 13). It sits atop the highest point in both properties at 542 feet above sea level within the New Land woods to the north side of the beaver pond overlooking it. This unique water body provides potential for scientific research and environmental analysis. This site is very unique in its ability to utilize lighting properties such as reflection and refraction off of the large water bodies' surface that increases solar energy capacity and natural day lighting techniques. This large water body also contains less tree density. The beavers and their ecological engineering processes assist in the sunlight availability due to lack of tree density and canopy cover. The site also overlooks the beaver pond but is far enough away to limit disruption. Site 2 is directly off of the main trail, is located 400 meters from Site 1 and 0.78 miles from an entrance beside the Fire Station on Daniels Rd.

Site 3, is located in the northern part of the New Land woods (Figure 14). Site 3 sits at an elevation of 523 feet above sea level just off the New Land woods back trail, 1.3 miles from a trail entrance off of Daniels Rd. This site is very similar to Sites 1 and 2 in its south-west facing slope and high elevation. Site 3 has similar characteristics to Site 2 in its placement on the northern side of a water body. However, it differs in the ecosystem habitat as its location overlooks a large marsh water body.

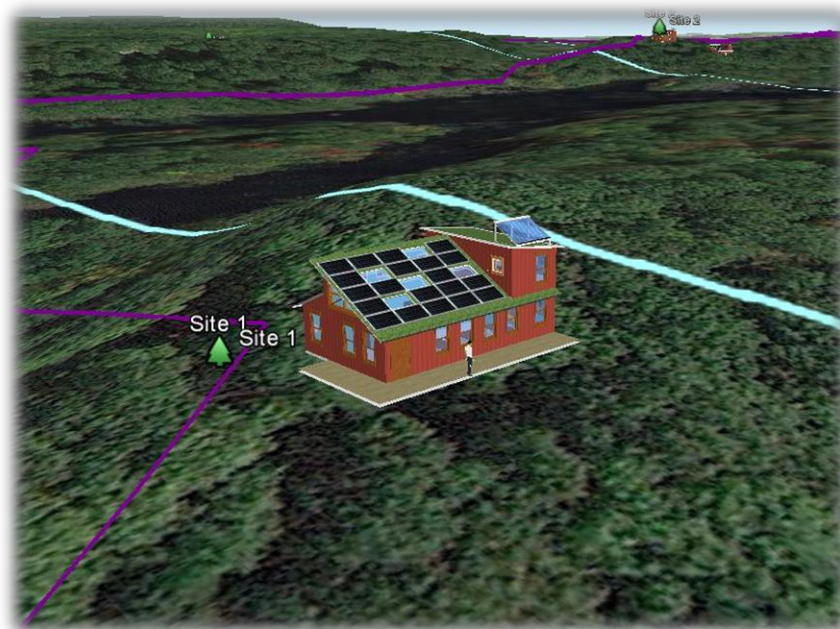


Figure 12. Site 1's Google Earth photo with the implemented field research Google SketchUp design to scale in the sites exact location.



Figure 13. Site 2's Google Earth photo with the implemented field research Google SketchUp design to scale in the sites exact location.

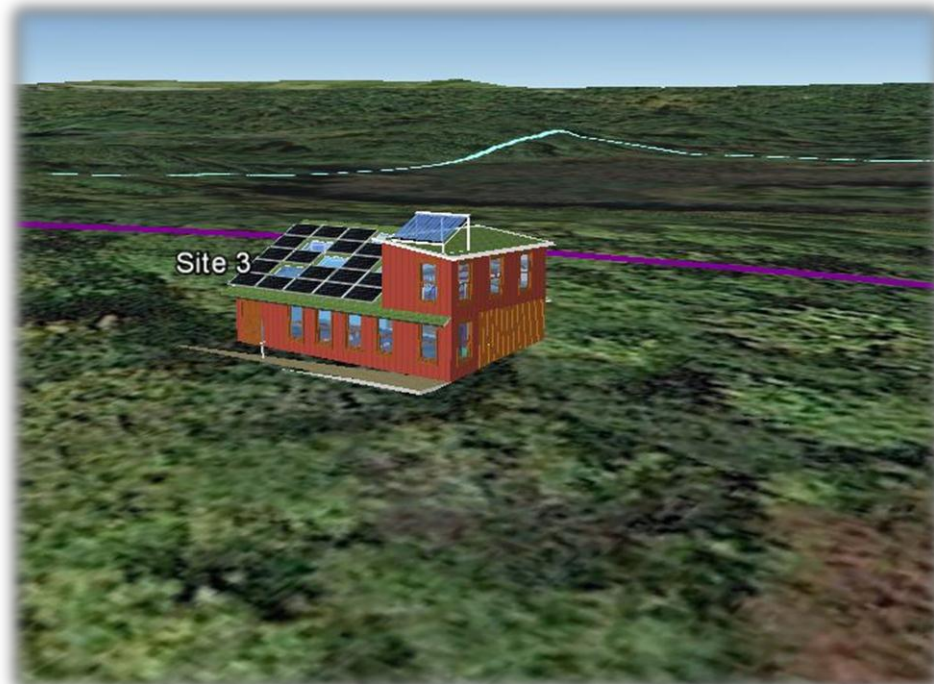


Figure 14. Site 3's Google Earth photo with the implemented field research Google SketchUp model to scale in the sites exact location.

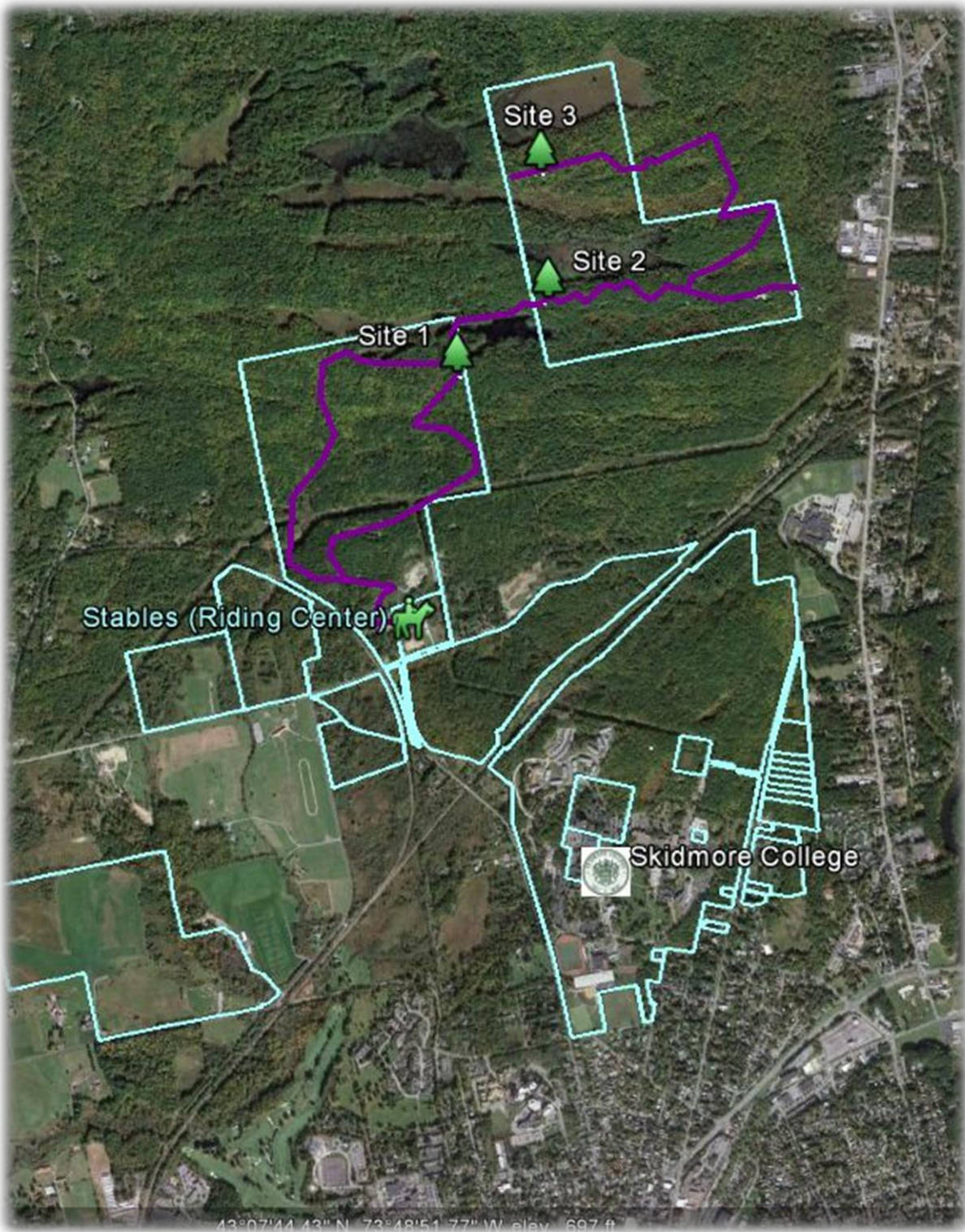


Figure 15. Google Earth satellite surveillance at 19,100 feet of Skidmore's Properties, nearby roads, nearby landmarks, late summer landscape characteristics, and selected sites.

Solar Electric & Solar Thermal Analysis:

Our sites are located at 43° 07' 53.04" W latitude due to the identified GPS locations. In the Northern hemisphere, more specifically the Capital Region of New York, solar designs are created so the angle of the panels is tilted to maximize the amount of electricity (kWh/meter squared/day) produced. The tilt of the panels is equal to the latitude point minus 15°.

$$(43.07^\circ) - (15^\circ) = 28.07^\circ$$

Therefore, the average annual output of electricity equaled 4.3 kWh/m²/day, SD= +/- 0.9 (Figure 16). A wide range of electrical output was found between months. The lowest occurred in December with an output of 2.1 kWh/m²/day, SD= +/- 0.9. The highest occurred in July with an electrical output of 6.0 kWh/m²/day, SD= +/- 0.9 (Figure 16) (NREL, 2012).

Tilt (°)		Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Year
0	Average	1.8	2.6	3.6	4.7	5.5	6.0	6.1	5.2	4.1	2.8	1.7	1.4	3.8
	Min/Max	1.2/2.1	2.1/3.3	3.1/4.1	3.9/5.4	4.5/6.4	5.1/6.9	5.4/6.6	4.6/5.8	3.2/4.6	2.2/3.6	1.4/2.0	1.2/1.6	3.6/4.1
Latitude -15	Average	2.7	3.6	4.4	5.0	5.5	5.8	6.0	5.5	4.8	3.7	2.4	2.1	4.3
	Min/Max	1.8/3.4	2.6/4.9	3.4/5.1	4.0/6.0	4.5/6.5	4.9/6.8	5.0/6.6	4.4/6.2	3.3/5.5	2.6/5.1	1.8/2.9	1.6/2.7	3.7/4.7
Latitude	Average	3.0	3.9	4.5	4.9	5.1	5.4	5.5	5.2	4.8	3.9	2.6	2.4	4.3
	Min/Max	2.0/3.9	2.8/5.5	3.5/5.3	3.9/5.9	4.2/6.1	4.5/6.2	4.7/6.1	4.2/5.9	3.3/5.6	2.8/5.5	1.9/3.3	1.8/3.1	3.7/4.7
Latitude +15	Average	3.2	4.1	4.4	4.5	4.6	4.6	4.8	4.8	4.6	3.9	2.7	2.5	4.1
	Min/Max	2.1/4.2	2.9/5.8	3.4/5.2	3.6/5.5	3.8/5.4	4.0/5.4	4.1/5.3	3.8/5.4	3.1/5.3	2.7/5.5	1.9/3.4	1.9/3.3	3.5/4.4
90	Average	3.1	3.7	3.5	3.1	2.7	2.6	2.8	3.0	3.3	3.2	2.4	2.4	3.0
	Min/Max	2.0/4.1	2.5/5.4	2.6/4.2	2.4/3.8	2.3/3.1	2.2/2.9	2.3/3.0	2.4/3.3	2.3/3.9	2.3/4.6	1.6/3.0	1.8/3.2	2.6/3.3

Figure 16. The variation of solar electrical output across months in New York State. (NREL, 2012)

Due to magnetic declination, the face of the array needs to be face south facing at 14° to the west to maximize solar energy capacity during all four of up-state New York's seasons (Figure 17)(IGRF, 2004).

The solar electrical output for upstate New York was also measured by the National Renewable Energy Laboratory. This measurement of daily solar radiation includes several different environmental factors: Cloud cover, optical depth, perceptible water vapor, ozone, and atmospheric pressure, via satellite. Saratoga Springs has an insolation percentage of 16.6, 1000W/m² PV standard, meaning that a meter-squared surface absorbs 16.6% of the solar radiation directed towards it. Saratoga Springs has an average electrical output of 4.0-4.5 kWh/m²/day (Figure 18) (NREL 2004).

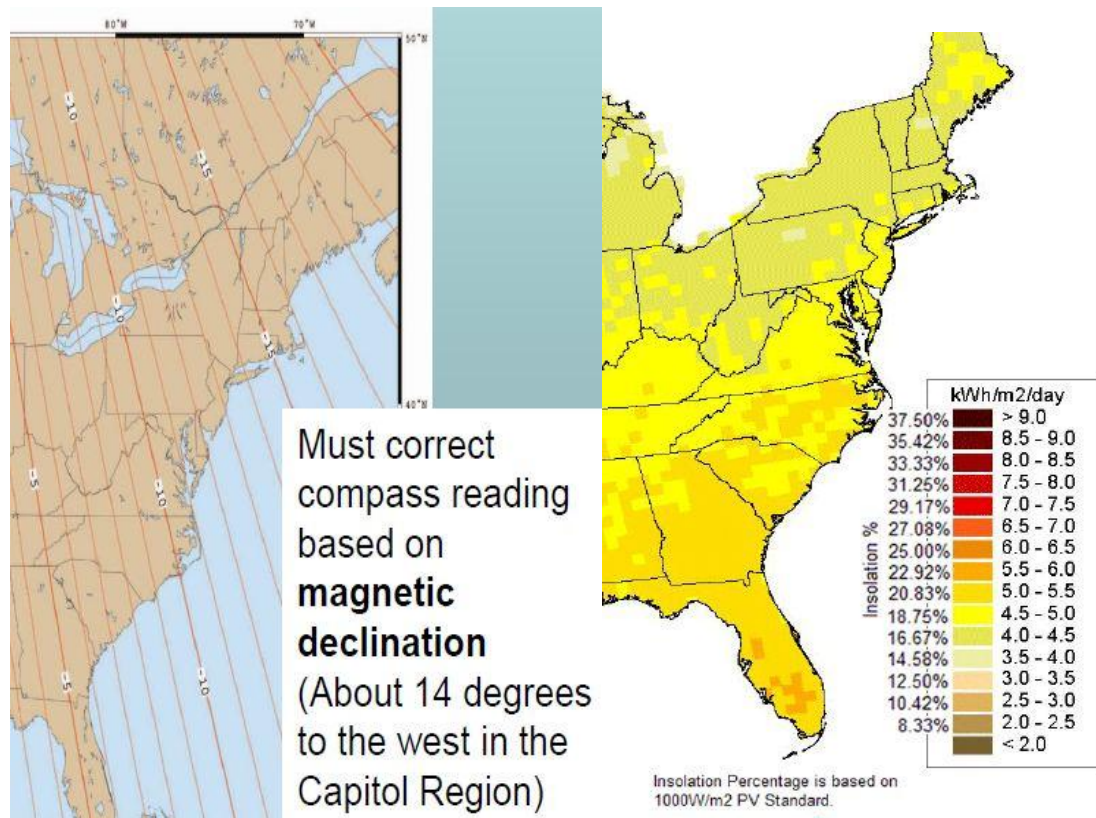


Figure 17. (upper left) The significance of magnetic declination for the direction of the solar array (IGRF, 2004).

Figure 18. (upper right) The distribution and variation of insolation and annual electrical generation (NREL, 2004).

In terms of aspect, the capital region of New York has specific variables to maximize the solar capacity of the system. At the site of our station, the panels need to be south facing at 14° west due to magnetic declination and the sun's azimuth angle. Each panel, together creating an array, will run east and west to maximize the amount of solar energy that is contacted with a solar system during all of New York's four seasons and their variation in the sun's altitude angle and sun availability.

Peak solar hours span from 9am to 5pm annually. Even though the sun may still be shining before or after the peak sun hours during particular seasons, it does not create enough energy to fully power the system to its capacity. In siting the location of a solar system, elevation is important for two reasons. The closer to the sun an array is, the greater irradiance the array will absorb. The higher a location is, the less likely it is going to be blocked within the peak solar hours by surrounding landscapes, trees, buildings, and other form of mass.

Due to the sites locations in the woods, a grid tied electrical solar system would be impractical. Grid tied solar systems are most commonly found in residential or commercial installations that allows the solar systems to produce electricity to reduce the amount of energy taken from the power companies. Grid tied systems reduce electrical usage through sustainable, renewable energy but still relies on non-renewable sources. Grid tied solar systems can earn tax credits, can sell solar created electricity back to the utility company, and have the potential to

significantly reduce a utility bill depending on the size of the solar array on a given house or business.

Our off-grid solar battery system uses Phono Solar Diamond Series 190W-210W panels. This system creates an average annual daily projection of 4.34 kWh/m²/day, that creates an average of 4501 kWh per year. Each panel is 62.2 inches in length, 31.8 inches in width, and 1.8 inches in depth. The estimated cost for the entire system would equal \$19,090 before tax credits, NYSEERDA financial incentives, Federal incentives, an average yearly energy created value of \$957.14, and grants.

Our Solar Battery PV System is comprised of the following components:

- (20) 190-210 Watt Solar Panels
- 2 Array Combiner w/ Breakers
- 2 45 Amp MPPT Controller w/ Meter
- Prewired Backplate Assembly
- (24) 250 Amp-Hour Batteries
- Complete Wire Kit and framing = \$650.00
- 3.9 kW or 3900 W system

Grid-tied systems are most cost effective in residential and commercial areas that do not fit within the scope of the field stations locations. Wiring and transmission boxes would need to be installed through the wooded properties to the proposed sites. Battery systems are all inclusive with no required contact to the National Grid system. This contained battery system creates and stores all of its energy sustainably from a renewable resource without any forms of carbon emissions. Grid-tied solar systems use a combination of sources besides the solar array, which do not define sustainability such as the building of dams and reservoirs for hydropower, nuclear generation, or the burning of fossil fuels.

Solar Heating

The Seido5-16 Sunda evacuated tube collectors (Figure 19) are an entirely different approach to solar water heating. Instead of many water-filled copper pipes, these collectors use multiple vacuum-filled glass tubes, each with a mix of water and antifreeze (propylene glycol) hermetically sealed within a small central copper pipe. When heated by the sun, this antifreeze converts to steam, rises to the top of the tube, transfers its heat to a collector header, then condenses back into liquid and repeats the process.

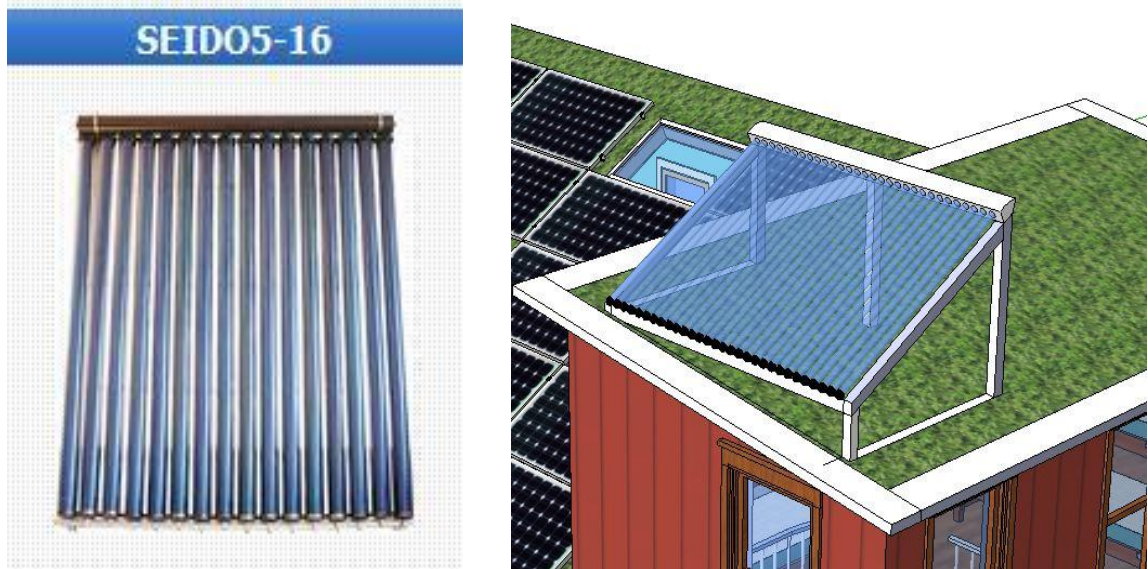


Figure 19. Seido5-16 Sunda Evacuated Tube System (left), positioned on the bunk room roof (right).

Because thermal energy doesn't easily transfer through a vacuum, the heat stays within the evacuated tube and passes to the collector header. This is a huge advantage because a standard flat plate collector radiates much of its accumulated heat to the surrounding atmosphere like any other hot object.

The evacuated tubes are also completely modular. Although not necessary, one or more tubes can be removed and replaced without affecting the other tubes in the array. There is no actual liquid transferred from the evacuated tube to the collector header, just heat. Evacuated tubes also start absorbing heat earlier in the day than flat plates due to their convex design, and antifreeze within the tube is freeze protected down to -50°F below zero.

Designing a solar thermal system depend on location and seasonal variation. In cold climates and high temps, characteristics of upstate New York, pressurized closed loop, evacuated tube systems are most effective and are 90% efficient (NREL, 2012). Hydronic radiant floor systems pump heated water from a storage tank through tubing laid in a pattern underneath the floor. An individual thermostat regulates the flow of heated water through a solenoid valve and manifold to each room in the house. The simplest is to pump the heat transfer fluid from the solar collectors directly through the tubing in the floor. Extreme care must be taken to avoid under or overestimating the system's collector area-to-storage mass ratio (Figure 21).

Below is a picture of the battery PV and solar thermal evacuated tube arrays on the field station model (Figure 20). This image resembles the sun's path at 2:32 pm in late June.



Figure 20. The design outlay of the solar PV array and solar thermal system on the sketchup model.

Radiant Flooring

Within a radiant flooring system, the under-floor materials include:

- 1600 ft. of 7/8" PEX heat exchanger tubing
- 350 heat diffusion plates, (1) 1000 sq. ft. roll of radiant reflective barrier
- (1) 2-loop slab manifold
- (8) brass adapters
- (4) brass couplings.

Mechanical components include:

- (2) Zone Control kit (thermostats and relays)
- (1) 1 " Expansion and Purge Kit (expansion tank, air eliminator, fill and drain valves - pressure gauge, and pressure relief valve)
- (2) Grundfos 3-speed cast iron circulator pumps
- (1) 2-zone manifold (factory assembled supply and return manifolds, including all check valves, ball valves, pump flanges, drain valves, in-line thermometers, and misc. mounting hardware).



Figure 21. A closed loop solar thermal radiant floor system.

Table 1: Cost analysis of radiant heating system and its components.

<i>Under floor material total costs</i>	<i>\$2,031.00</i>
<i>Mechanical component total</i>	<i>\$1,313.00</i>
<i>Sunda Seido evacuated tubes total</i>	<i>\$1873.00</i>
<i>Radiant heating system total</i>	<i>\$4,657</i>

Additional Costs

Excluding labor, the other costs we took into account were recycled barn wood for walls, the green roof, and concrete floors. According to a Pennsylvania based reclaimed wood dealer, it would cost approximately \$5000 to use recycled barn wood for the walls of our building (Barn Wood Connection). A green roof costs about \$15-\$20 per square foot (LID Urban Design Tools). So for our building's roof size, a green roof would cost approximately \$8790. An 80 pound bag of concrete mix costs \$3.99 (Lowes). For our floor size, we would need 177 bags, approximately \$705 (Concrete Network). The weather station, as mentioned above, costs \$356 from the WeatherShack.com.

The Final Design

Our field station is 1078 square feet. It is made out of recycled barn wood and features a green roof, an intensive battery powered PV system, and an evacuated tube solar thermal system (Figure 22). Natural daylight fills the classroom through the skylights and the clerestory windows, and makes people happier and generally more productive (Figure 23). The green roof covers all visible roof space (Figure 24). We provided a large classroom space to accommodate classes up to 16 students (Figure 25). For the desire for locked storage both inside and outside, we created a large storage closet in the room with the PV batteries (Figure 26). We also created a large exterior storage closet big enough to hold kayaks and other kinds of outdoor equipment (Figure 27). The outdoor storage is not heated and not completely closed, designed intentionally so that if things are wet they can dry out and the space does not get stuffy. There is an upstairs bunk room with 6 beds for overnight capacity (Figure 28).



Figure 22. View of the field station from the south west, showing the PV panels on the south facing roof at a pitch of 28 degrees. The skylights on the roof are arranged to mimic the effect of dappled sunlight filtering through a leafy canopy.

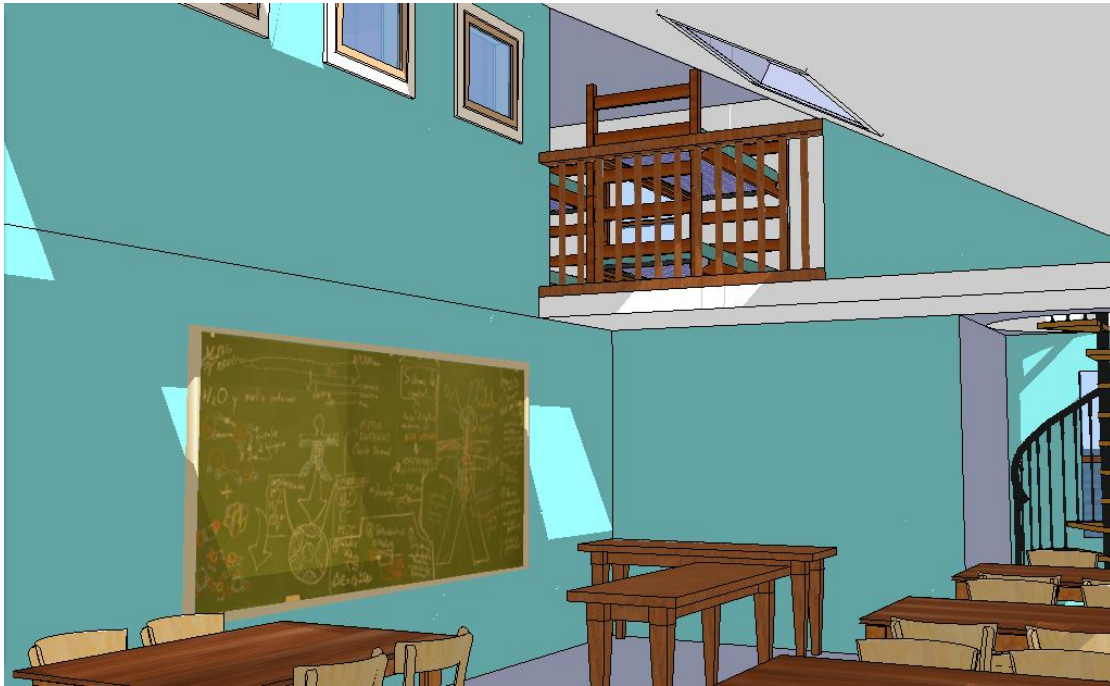


Figure 23. Light from the skylights moves across the room over the course of the day, creating interesting patterns. Daylight reflects off of the light colored wall surfaces and into the room as diffuse light, rather than harsh, direct light, which can create glare.

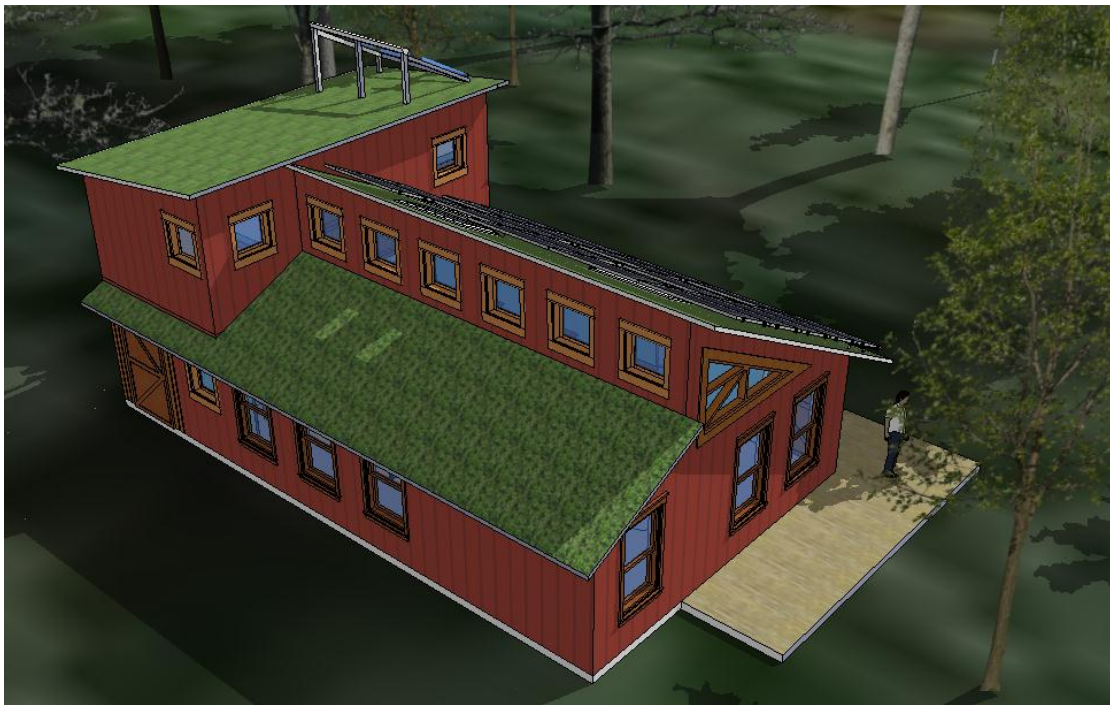


Figure 24. Green roofs will help to visually integrate the building into the surrounding landscape and prevent any contaminated runoff from entering the surrounding ecosystems.

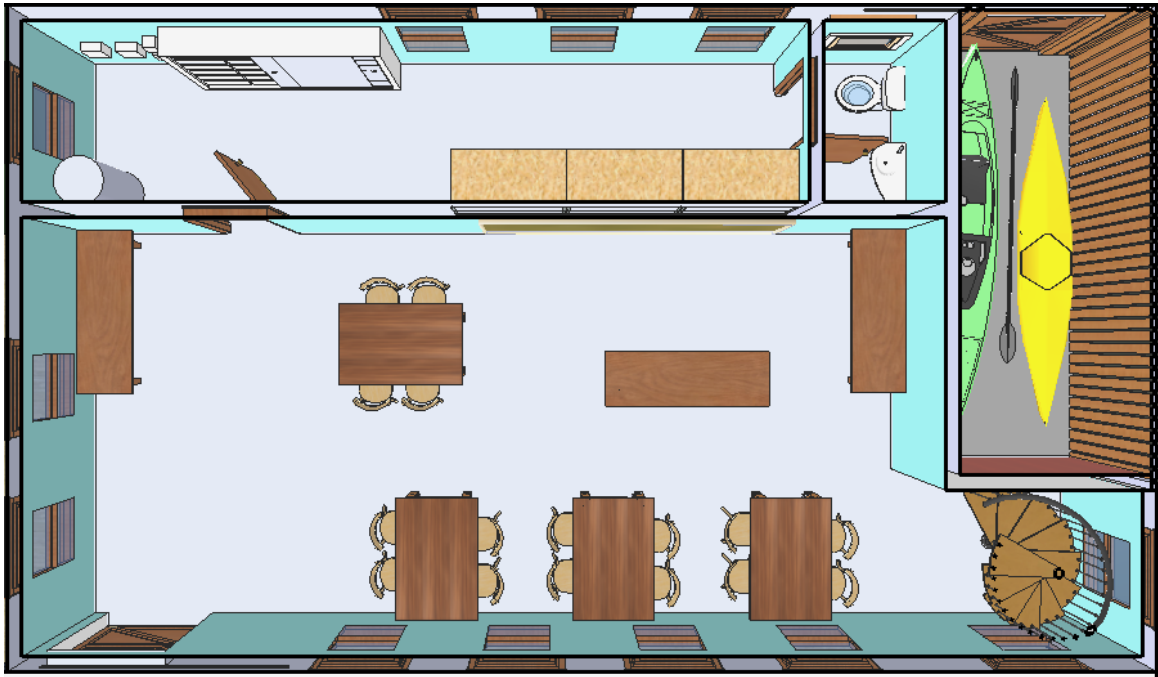


Figure 25. An overhead, plan view of the field station, showing the classroom, indoor storage and outdoor storage.



Figure 26. This section view from the west shows the open classroom space, indoor storage space to the left and the bunk loft overlooking the classroom.

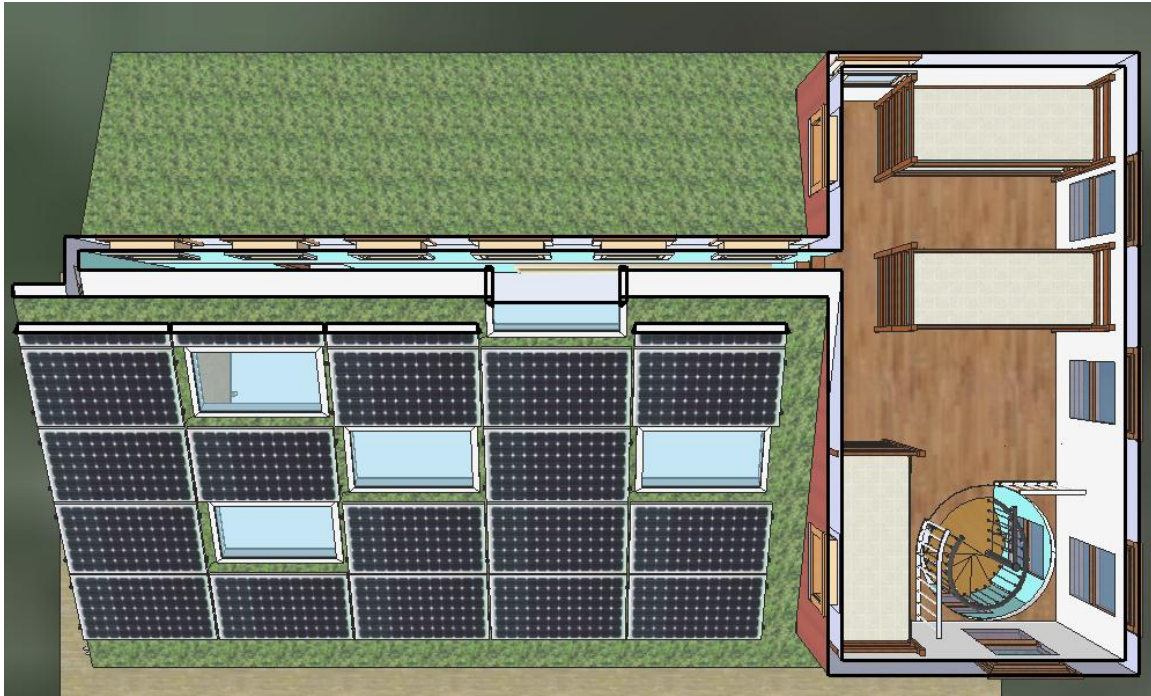


Figure 27. The second floor bunk room will accommodate overnight stays, which will be especially useful for summer research and early morning bird watching.

DISCUSSION

Evaluation of Design

Our proposed design for a sustainable field station addressed the top sustainability concerns cited by stakeholders: low environmental impact on the site, local and sustainably sourced building materials and energy efficiency. We decided to use a battery tied PV system rather than a grid tied system to avoid the disruptive impact of installing power lines on the site. We designed a green roof system to absorb and filter rainwater, which prevents contaminated runoff from entering the surrounding environment, particularly the nearby bogs and beaver pond. We decided not to design for passive solar because of the volume of concrete needed for thermal mass. Concrete has high embodied energy, meaning it is very energy intensive to produce. In addition, pouring concrete involves heavy machinery which would degrade the site. Because we determined that it would be necessary to heat the building even with the passive solar design, we decided that passive solar was redundant and would have an unnecessarily high environmental impact. The heating system we designed involves much less concrete than a passive solar design. Both the heating and electric systems are completely self-sufficient, require no fuel and have no emissions. The solar heating and PV systems make our building much more energy efficient than a conventional building. We found local sources to supply recycled barn wood for the exterior building envelope. Any virgin lumber for framing would come from local sustainably logged sites. If possible we would use reclaimed windows and other building fixtures. All of these design decisions helped achieve our objective of low environmental impact on our site.

We also considered specific amenities, spaces, and features that stakeholders said would make the field station most useful for a variety of activities. We included indoor and outdoor

locked storage, which was a high priority for faculty. Most of the faculty said they would take classes of 16 students to the field station. We designed a large, open classroom space with movable furniture accommodate 16 students and to maximize the flexibility of the space for a variety of uses. A few of our interviewees expressed a strong interest in full overnight capability for the field station, including sleeping cabins and a kitchen. We incorporated a sleeping loft in the design, but not a full kitchen. The field station is more likely to be used overnight by small groups of students conducting summer research than by a full class of sixteen students. For this reason the bunk room is only designed to accommodate six beds, and a full kitchen seemed beyond the scope of the project. It would be very easy to store a camp stove in the field station for such occasions. We were also unable to address one faculty member's request for an astronomy viewing platform. Because the tree cover at the sites was tall and dense the platform would have to be elevated higher than the roof of our building to achieve good visibility. The astronomy platform was simply too complex and involved to incorporate in the scope of our design.

Many of the faculty we spoke to thought that the length of the hike to the sites (45-60 minutes) would limit the field station's usability. It seemed too far for a standard three hour lab, and not quite far enough to justify frequent overnight stays. We considered that it might be more valuable for Skidmore to build a field station in the Adirondack Mountains with full overnight facilities to facilitate a more in depth and intensive experience. Many other colleges in upstate New York and surrounding states have built successful field stations with positive feedback. However, time constraints prevented us from fully exploring this idea. If our field station was built and became used more frequently than expected, more sleeping space and a kitchen could be added, or Skidmore might consider looking for property in the Adirondacks to implement a more intensive type of field station.

The Next Step

For future capstones, a viable next step would be to present our plan to the Board of Fire Commissioners to determine whether or not Skidmore could access their property through the Maple Ave fire station parking lot. Once a plausible access point can be determined, we would have to present the plan through the process similar to what the current renovation to Dana is going through. Our costs are based on a rough estimate from our research, and future students would have to look into more detail about the real possibilities of this field station's potential.

Appendix A: *List of stakeholders and their perceived role:*

Michael Marx (ES and English, Literature and the Environment)
Mary Crone-Odekon (Physics, Astronomy)
Kyle Nichols (Geoscience)
Karen Kellogg (Environmental Studies, Assoc. Dean of Faculty for Infrastructure, Sustainability, and Civic Engagement)
Josh Ness (ES and Biology, ES 205)
Denise Smith (Exercise Science dept. chair)
Alex Chaucer (GIS)
Andrew Schneller (ES faculty)
Anne Ernst (ES faculty)
Nurcan Atalan-Helicke (ES faculty)
Greg Gerbi (Geoscience and Physics Departments)
Rodney Wiltshire (ES faculty, Engineering and Sustainable Energy)
Alison Barnes (English, Environmental Art)
Rik Scarce (Environmental Sociology)
Richard Chrisman (Religious/Spiritual Life)
Riley Neugebauer (Sustainability Coordinator)
Corey Freeman-Gallant (Biology, Assoc. Dean of Faculty for Academic Policy and Advising)
Katrina Smith (Counseling Center/Meditation)

Appendix B:

Student Survey:

1. What is your (anticipated) major?
2. Which types of classes do you think would benefit from an outdoor learning environment? Check all that apply
 - a. Labs
 - b. Discussions
 - c. Lectures
 - d. Arts
 - e. Meditation/Yoga
 - f. Other (please specify)
3. Can you please describe how one of the experiences in question 2 would change in an outdoor setting?
4. Would you be more likely to take a class that has an outdoor lecture/activity component?
 - a. Yes
 - b. No
5. Would you use these spaces for other purposes outside of class?
 - a. Yes
 - b. No
 - c. Please explain
6. To support these activities would you need... (Need/Prefer/Doesn't matter)
 - a. Electricity
 - b. Running Water

- c. Desks/tables/chairs
 - d. Heat
 - e. Equipment
 - f. Storage space
 - g. Computers/internet
 - h. Other (please explain)
7. In your opinion, which of the following sustainable design strategies are the most important? Please rank 1-6 (1 being the most important)
- a. LEED standards
 - b. Sustainable and/or local building materials
 - c. Energy efficiency
 - d. Alternative energy
 - e. Storm water management
 - f. Low environmental impact on the site

Professor Survey:

1. Would you use...
 - a. An outdoor classroom in North Woods?
 - b. A field station in the property behind the riding center?
2. What sorts of activities would you use these spaces for? Check all that apply
 - a. Lectures
 - b. Labs
 - c. Studio Art
 - d. Creative Writing/Poetry
 - e. Meditation/Yoga
 - f. Storage for supplies and equipment to be used in the woods
 - g. Research
 - h. Other (please specify)
3. Please indicate the importance of the following amenities... (Need/Prefer/Doesn't matter)
 - a. Electricity
 - b. Running water
 - c. Heating/cooling
 - d. Furniture
 - e. Equipment
 - f. Locked storage
 - g. Computers/internet
 - h. Whiteboards
 - i. Other (please specify)
4. What size should the outdoor classroom/field station be?
 - a. About the size of a classroom (16-24 students)
 - b. About the size of the Spa's Saratoga Room (25-40 students)
 - c. About the size of Dana Atrium (40+ students)
5. When would you use the outdoor classroom/field station?
 - a. Spring term
 - b. Fall term
 - c. Summer

- d. During the day
 - e. Overnight
6. In your opinion, which of the following sustainable design strategies are most important?
(Please rank 1-6, 1 being most important)
- a. LEED standards
 - b. Sustainable and/or local building materials
 - c. Energy efficiency
 - d. Alternative energy sources
 - e. Storm water management
 - f. Low environmental impact on the site

REFERENCES

Assisted Home Performance Program with ENERGY STAR." Assisted Home Performance Program with ENERGY STAR. New York State Energy Research and Development Authority, n.d. Web. 29 Oct. 2012. <http://www.nyserda.ny.gov/FundingOpportunities/Current-Funding-Opportunities/Assisted-Home-Performance-Program-with-ENERGY-STAR.aspx>>.

Bokalders, Varis, and Maria Block. *The Whole Building Handbook: How to Design Healthy, Efficient and Sustainable Buildings*. London: Earthscan, 2010.

Brophy, Vivienne, and J. Owen. Lewis. *A Green Vitruvius: Principles and Practice of Sustainable Architectural Design*. London: Earthscan, 2011.

Brown, G. Z., and Mark DeKay. *Sun, Wind & Light: Architectural Design Strategies*. New York: Wiley, 2001.

Brunner, Marci. "Solar Thermal Incentive Program." www.nyserda.ny.gov. New York State Energy Research and Development Authority, 10 Dec. 2010. Web. 29 Oct. 2012. <<http://www.nyserda.ny.gov/Funding-Opportunities/Current-Funding-Opportunities/~media/Files/FO/Current%20Funding%20Opportunities/PON%202149/2149summary.pdf>>.

Clarke, Fred W. "The Architect's Role in Urban Regeneration, Economic Development, and Sustainability." *Pelli Clarke Pelli Architects*. N.p., 2012. Web. 02 Nov. 2012. <<http://pcparch.com/firm/bibliography/essays/the-architect-s-role-in-urban-regeneration-economic-development-and-sustainability>>.

"Concrete Calculator." *ConcreteNetwork.com*. The Concrete Network, 2013. Web. 06 Apr. 2013. <<http://www.concretenetwork.com/concrete/howmuch/calculator.htm>>.

Current Funding Opportunities, PONs, RFPs, and RFQs." Current Funding Opportunities, PONs, RFPs, and RFQs. New York State Energy Research and Development Authority, n.d. Web. 29 Oct. 2012. <<http://www.nyserda.ny.gov/funding/>>.

Dvorak, Bruce, and Astrid Volder. "Corrigendum to "Green Roof Vegetation Findings for North American Ecoregions: A Literature Review" [Landscape Urban Plan. 96 (4) (2010) 197–213]." *Landscape and Urban Planning* 97.2 (2010): 146.

"Ecological Aspects." *Eco Plan Architecture*. N.p., 2012. Web. 28 Oct. 2012. <<http://www.ecoplanarchitecture.com/ecological/>>.

"Elemental Materials." *First Light House*. Victoria University of Wellington, 2011. Web. 29 Oct. 2012. <<http://firstlighthouse.ac.nz/the-house/elemental-materials/>>.

"Flooring." *ReNew Salvage*. N.p., 2012. Web. 17 Apr. 2013. <<http://renewsalvage.org/>>.

Getter, Kristin L., D. Bradley Rowe, and Jeffrey A. Andresen. "Quantifying the Effect of Slope on Extensive Green Roof Stormwater Retention." *Ecological Engineering* 31.4 (2007): 225-31.

"Green Roof Benefits." *Green Roofs for Healthy Cities*, 2013. Web. 12 Apr. 2013. <<http://www.greenroofs.org/index.php/about/greenroofbenefits>>.

"Green Roofs Costs." *Urban Design Tools*. Low Impact Development, 2007. Web. 06 Apr. 2013. <http://www.lid-stormwater.net/greenroofs_cost.htm>.

"How Do Composting Toilets Work?" *Let's Go Green*. N.p., n.d. Web. 17 Apr. 2013. <<http://www.letsogogreen.com/how-composting-toilets-work.html>>.

Laylin, Taflin. "Playful Westborough Primary School Renovation Halves Annual Carbon Emissions." *Inhabitat.com*. Inhabitat, 7 July 2011. Web. 29 Oct. 2012. <<http://inhabitat.com/playful-westborough-primary-school-renovation-halves-annual-carbon-emissions/>>.

Lechner, Norbert. *Heating, Cooling, Lighting: Sustainable Design Methods for Architects*. Hoboken, NJ: John Wiley & Sons, 2009.

"Leslie Shao-ming Sun Field Station." *Jasper Ridge Biological Preserve*. Stanford University, 2012. Web. 03 Nov. 2012. <<http://jrpbp.stanford.edu/fieldstation.php>>.

MacKay, David J. C. *Sustainable Energy: Without the Hot Air*. Cambridge: UIT Cambridge, 2009. Print.

"Magnetic Field Calculators." *NGDC Geomagnetic Calculators*. NOAA, 07 May 2013. Web. 07 May 2013.

New York Solar Rebates and Incentives." Distributed Generation. Clean Energy Authority, n.d. Web. 29 Oct. 2012. <<http://www.cleanenergyauthority.com/solar-rebates-and-incentives/new-york/ny-distributed-generation>>.

New York Solar Rebates and Incentives." Personal Income Tax Credit. Clean Energy Authority, n.d. Web. 29 Oct. 2012. <<http://www.cleanenergyauthority.com/solar-rebates-and-incentives/new-york/income-tax-credit>>.

New York Solar Rebates and Incentives." Power Naturally Incentive Program. Clean Energy Authority, n.d. Web. 29 Oct. 2012. <<http://www.cleanenergyauthority.com/solar-rebates-and-incentives/new-york/power-naturally-program>>.

New York Solar Rebates and Incentives." New York Rebates and Incentives Summary. Clean Energy Authority, n.d. Web. 29 Oct. 2012. <<http://www.cleanenergyauthority.com/solar-rebates-and-incentives/new-york/new-york-rebates-and-incentives-summary>>.

New York State. New York State Energy Research and Development Authority. *The Training and Education Center for Semiconductor Manufacturing and Alternative and Renewable*

Technologies. N.p., 15 Oct. 2012. Web. 28 Oct. 2012. http://www.nyserda.ny.gov/Saratoga-Technology-and-Energy-Park/STEP-News/STEP-Announcements/2010-Announcements/TEC-SMART.aspx?sc_database=web

New York (State). Division of Code Enforcement and Administration. *Building Code of New York State*. Washington, DC: International Code Council, 2010.

Nico, Saieh. "Mountain Dwellings / BIG with JDS." *ArchDaily.com*. ArchDaily, 11 Mar. 2009. Web. 28 Oct. 2012. <<http://www.archdaily.com/15022/>>.

"Northwoods Field Station." *Hiram College Field Station*. Hiram College, 2012. Web. 28 Oct. 2012. <<http://www.hiram.edu/academic-support-services/field-station/northwoods-field-station>>.

NREL: Renewable Resource Data Center Home Page." *NREL: Renewable Resource Data Center Home Page*. N.p., 8 Nov. 2012. Web. 07 May 2013

Pilloton, Emily. "California Academy of Sciences Green Roof." *Inhabitat.com*. Inhabitat, 28 July 2007. Web. 29 Oct. 2012. <<http://inhabitat.com/california-academy-of-sciences-green-roof/>>.

"Pine Lake Institute." *Hartwick-Pine Lake Institute*. Hartwick College, 2012. Web. 29 Oct. 2012. <<http://www.hartwick.edu/about-us/centers-and-institutes/pine-lake-institute>>.

"Price List." *The Barnwood Connection*. N.p., 2009. Web. 06 Apr. 2013. <<http://www.barnwoodconnection.com/index.htm>>.

"The Products." *Champlain Hardwoods, Inc.* N.p., 2013. Web. 17 Apr. 2013. <<http://champlainhardwoods.com/product.html>>.

"QUIKRETE 80 Lbs Setting Post Concrete Mix." *Lowe's.com*. Lowe's, 2013. Web. 06 Apr. 2013. <http://www.lowes.com/pd_10385-286-110180>.

Racusin, Jacob Deva, and Ace McArleton. *The Natural Building Companion: A Comprehensive Guide to Integrative Design and Construction*. White River Junction: Chelsea Green, 2012.

"Residential Financing." Residential Financing Program. New York State Energy Research and Development Authority, n.d. Web. 29 Oct. 2012. <<http://www.nyserda.ny.gov/Residential/Programs/Existing-Home-Renovations/Low-Interest-Financing.aspx>>.

SUNDA Solar Water Heater." *SUNDA Solar Water Heater*. SUNDA, 11 Mar. 2012. Web. 07 May 2013. http://www.sundasolar.com/product_waterheaters.html

"Sustainability Information." *Sustainability*. Environmental Protection Agency, 2009. Web. 02 Nov. 2012. <<http://www.epa.gov/sustainability/basicinfo.htm>>.

"The Weather Station." *WeatherShack.com*, 2013. Web. 17 Apr. 2013.
<<http://www.weathershack.com/static/ed-the-weather-station.html>>.