Team Gatekeepers

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Table of Contents

Table of Figures

Table of Tables

1 Problem Formulation

1.1 Background

Although many students and staff at Cal Poly Humboldt commute to and from campus using alternative modes of transportation, there is still a limited number of appropriate areas to charge and safely store electric bikes on campus. With only a dozen situated in one area of campus, there is limited use of these charging stations by those who may rely on their electric vehicles for mobility. Furthermore, the security, maintenance, and efficiency of these charging stations are a priority to ensure the safety of students and their property on campus. Team Gatekeepers is partnering with the Campus Center of Appropriate Technology (CCAT), a nonprofit, student-led organization at Cal Poly Humboldt, to design and digitally model a solar-charging bike cage to be potentially implemented throughout campus for use by students, faculty, and community members.

1.2 Objective

The objective is to design, test, and digitally model schematics for a solar-charging bike station fitted with solar panels and a battery to store and output electricity. The station should be able to safely store bikes in a sheltered post situated outside the CCA. Not enough solar powered electric bike charging stations on campus.

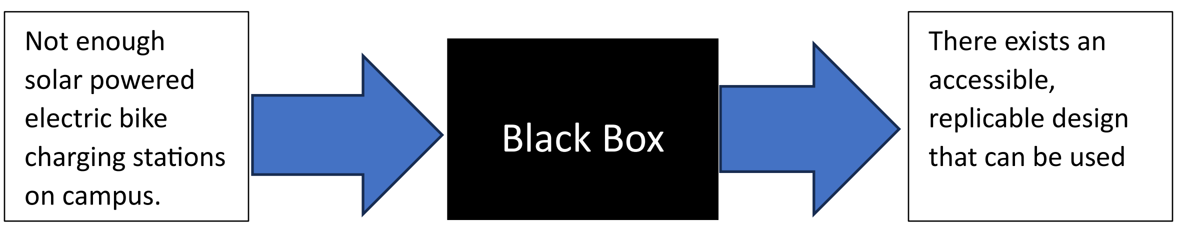

Figure 1-1: Black Box model used for Team Gatekeeper's problem formulation.

2 Problem Analysis and Literature Review

This section covers background information on the client, construction materials, photovoltaic systems, E-bikes, storage, security, and location. This section also covers the client's criteria and discusses the associated constraints.

2.1 Specifications

This section includes key details of the project that will outline the parameters of completion, such as:

- The client - CCAT (Campus Center for Appropriate Technology), a student-led initiative for sustainable technology and applied knowledge at Cal Poly Humboldt.
- The project - a bike station with 100% solar charging capability for electronic bikes available for use by students, faculty, and community members.

- The location - a plot of land along the street-facing side of CCAT.
- The budget - theoretically, will range from $25,000 - $50,000, but the scope of this project model will range from $40 - $100.
- The maximum allotted space - standing 10 feet tall on the 11 ft by 12 ft plot of land outside of CCAT.

2.2 Considerations

This section covers what needs to be considered in the procedure and implementation of the project, such as:

- The accessibility and structural integrity of the final design ensures safety and ease of use for end users.
- General demographics of the end users, specifically students, faculty, and community members that travel to and from campus using e-bikes, with special consideration for individuals working and living within CCAT.
- The climate of Humboldt County during periods of use, consisting of high precipitation and humidity necessitating appropriate weatherproofing
- The cost and sustainability of materials used during the construction of the final design, as well as the longevity and future maintenance costs.
- The visual aesthetic of the final design will conform with the CCAT house and the surrounding area.

2.3 Criteria and Constraints

This section will a list of Team Gatekeeper's main criteria and constraints (Table 1) covering bike storage, charging capacity, cost, ease of use, security, safety, longevity, and aesthetics can be found below.

Table 2-1: Table of criteria, constraints, and weight of importance.

Criteria	Constraint	Weight/Measurements (0-10)
Bike storage	The structure must be able to store 4-6 e-bikes at minimum	8
Charging capacity	The solar panels must produce enough power to charge 4-6 e-bikes	7
Ease of use	Users must be able to freely and easily store and charge their e-bikes	9
Cost	The overall project cost must not exceed the budget of $20,000	5

Security	The structure must include security measures to prevent theft	8
Safety	The structure must be stable, well-lit, and be able to secure 4-6 e-bikes	10
Structural integrity	The structure must be durable and able to withstand harsh weather and seismic activity	10
Longevity	The structure must be able to last for long periods of time	9
Aesthetics	The structure must be aesthetically pleasing to look at, with a recognizable and inviting outward appearance	8

2.4 Usage and Production Volume

The project will be used by students, faculty, and community members daily, particularly during the weekdays throughout the academic school year, stagnating in the summer months when school is out of session. Users should be able to store and charge their e-bikes fully for a few hours while on campus. If the project is reproduced, Team Gatekeepers anticipates that a half-dozen should be added to various areas on campus, particularly near the Cal Poly Humboldt library and the Gutswurrak Student Activities Center where many students spend time for leisure and food between classes.

2.5 CCAT

CCAT is a student-managed, student-funded live-in demonstration home and educational center for appropriate technology and resource management. It is a non-profit organization where students must live and manage a house using sustainability methods such as solar panels, rainwater catchers, and greenhouse and gardening technology. CCAT uses less than 5% of the energy consumed by the average household and produces almost no waste. CCAT aims to "educate through example" through sustainable technology that considers the social, economic, and environmental impact of introducing new technologies.

2.6 Introduction to Materials

A variety of materials will be considered for use in constructing the station. Materials will be assessed by durability, weather resistance, cost, availability, sourcing, and sustainability.

2.6.1 Steel Beams

Steel is an alloy of iron and carbon. Steel is one of the most commonly used materials in engineering and construction. It has a yield strength between 30,000 psi - 50,000 psi. Steel is an extremely durable material made by adding a small amount of carbon to iron, strengthening and hardening it to steel. The United States' 2021 steel consumption was around 98 million metric tons. Steel was used in 55% of the construction sites worldwide in 2022 (World Steel, Statista). Steel beams are $6 to $18 per square foot or about $100 to $400 including installation. **Figure 2-1** shows examples of steel pipes

Figure 2-1: Steel pipes (World steel)

2.6.2 Aluminum

Aluminum is a silvery, lightweight, and durable metal commonly used in engineering, manufacturing, and construction. Aluminum is widely used for its natural resistance to corrosion and its abundance as the third most common element in the Earth's crust. It has a natural corrosive layer because of the aluminum oxide on the surface of the metal. Aluminum weighs about one-third of steel and is three times lighter than iron. Aluminum is a "green metal," meaning it can be reused and recycled infinitely (Aluminum Leader, Howard Precision). Aluminum is typically less than $2 per pound.

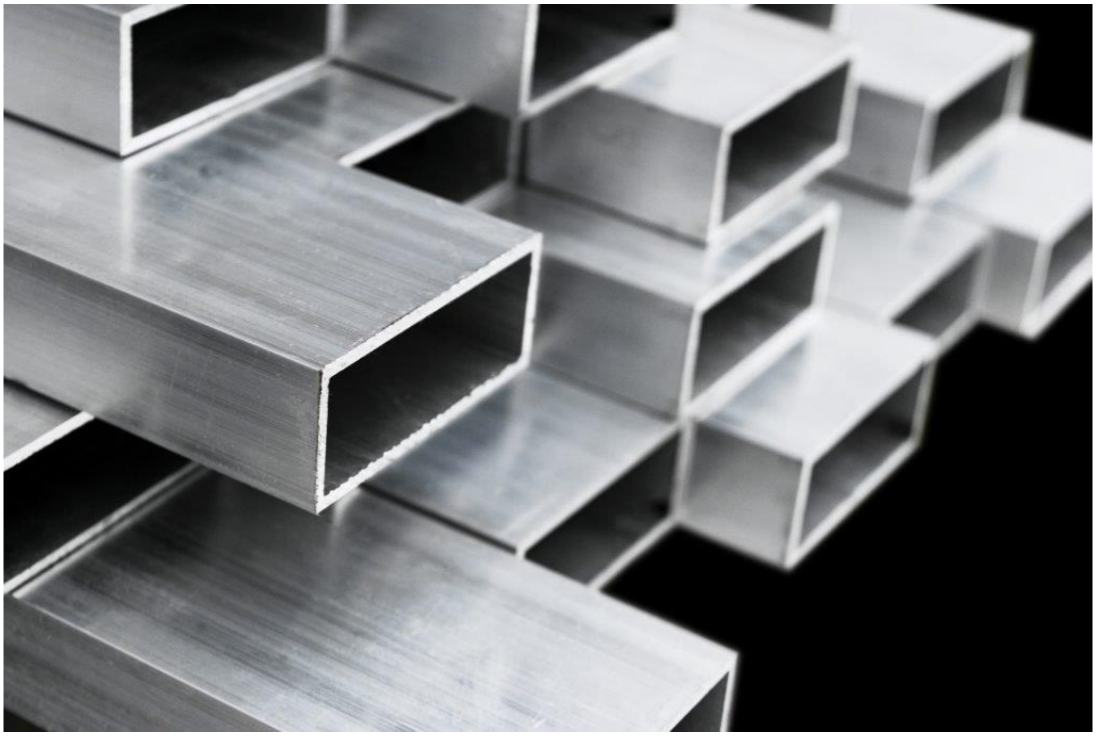

Figure 2-2: Aluminum (Millenium Alloys)

2.6.3 Plastic

Plastic is a material that contains synthetic or semi-synthetic organic compounds. Due to this, it can be molded into different solid shapes and provides permanent deformation without breaking. Some plastic types, such as polycarbonate, can withstand forces nearly 200 times stronger than steel. Strong types of plastic can be used in construction and modeling. Plastic can be recycled for a near-infinite number of times. This prevents the product from being wasted in construction (3ds, Miller Plastics). Polycarbonate plastic is typically $2 per pound.

Figure 2-3: Plastic trash (By Fusion)

2.6.4 Douglas Fir

Douglas fir trees are evergreen trees that keep their small leaves year-round. Douglas fir is the dominant forest type in Humboldt in elevations of 500-2,000 ft. There are two distinct species: Coast Douglas fir and Mountain Douglas fir, with different growth rates, habitats, and physical traits. Douglas fir is classified as a softwood, which makes it easy to damage (National Wildlife Federation). Douglas fir is typically $24 per foot.

Figure 2-4: Douglas Fir (Forest Products supply CO.)

2.6.5 Coast Redwood

Coast redwood is a coniferous evergreen type of timber tree and is the family of the Cupressaceae. This family is one of the tallest families of new trees. Redwood trees are endemic to northern California and southwestern Oregon. Redwood trees take about 400-500 years to mature, they are a type of softwood and are notable for their resistance to decaying. Redwood is much lighter than plastic composite and is five times greater than plastic decking products. Redwoods are a renewable resource and can withstand temperatures of 800 degrees. (Britannica, 2013)

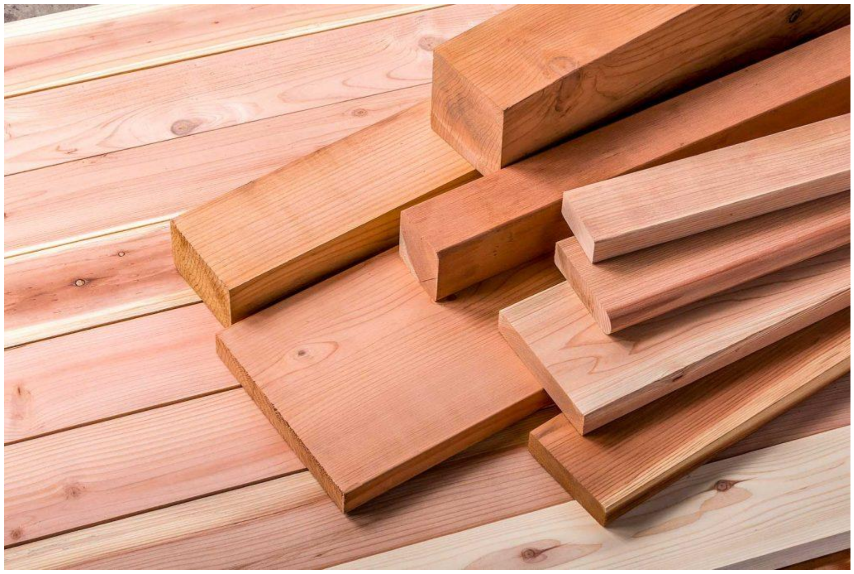

Figure 2-5: Redwood planks (Redwood Northwest)

2.6.6 Laminated Glass

Laminated glass is created from two pieces of tempered glass sandwiched between polyvinyl butyral (PVB). Laminated glass provides screening from UV radiation, can become soundproof, can be tinted or transparent, and can protect structures from harsh weather, intruders, and pests. Laminated glass is about five times stronger and 100 times stiffer than standard glass. Laminated glass may have a complex installation, but it is easy to upkeep even with minor damages. Laminated glass costs about $10-20 per square foot. (US Window & Door)

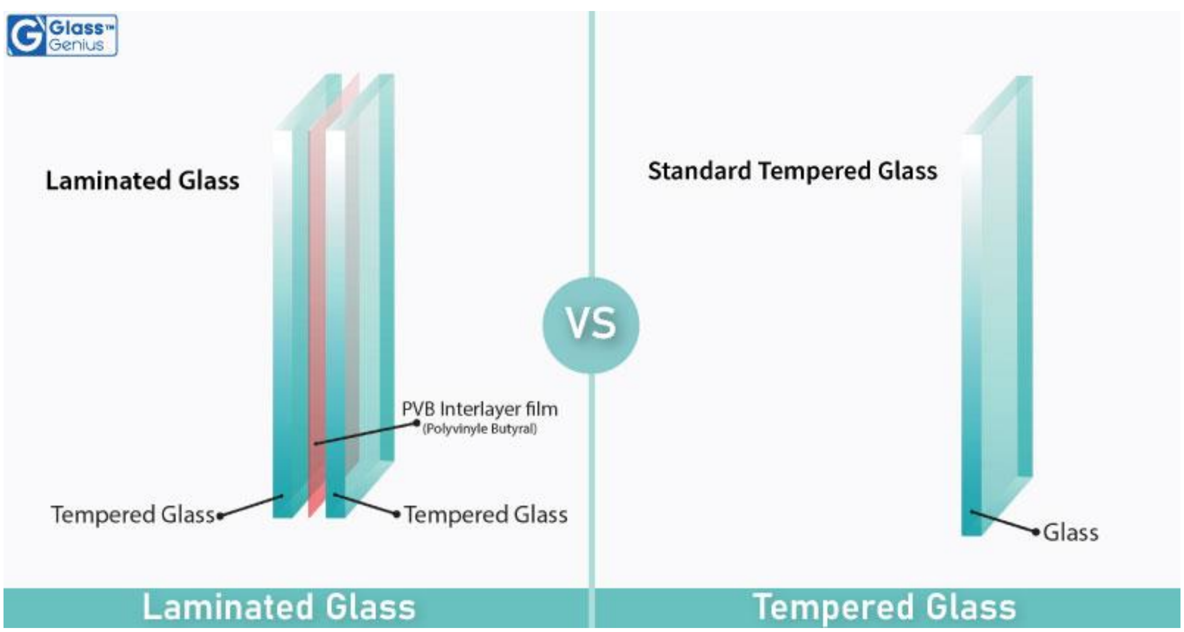

Figure 2-6: Laminated & tempered glass (Glass Genius)

2.6.7 Hempcrete

Hempcrete is a bio-composite made by mixing the inner wood core of hemp with a lime-based binder. A hemp's core is called "shiv" which has high silica content and allows it to mix well with lime. Hemp is a plant that has less than 0.3 percent THC. It grows faster than trees or other crops and can be used to make products like clothing or paper. Hempcrete is used in construction for walls, roofs, and screeds. Hempcrete is an eco-friendly and more sustainable alternative to concrete. Hemp products can also be recycled, are biodegradable, and help reduce global warming by taking large amounts of carbon dioxide per acre (Healthline, 2023). Hempcrete is typically priced at $3 per pound. **Figure 2-7** shows an example of hempcrete bricks being laid down to create a wall.

Figure 2-7: Hempcrete bricks being placed down to raise a wall (Rise)

2.7 Introduction to Photovoltaic Systems

Photovoltaic (PV) systems work to convert energy from sunlight into usable electricity in commercial and residential settings. There are a variety of components in an operational PV system that produce solar-generated electricity. These systems consist of solar panels, mounting structures, and batteries. To accommodate these systems for charging, inverters and charge controllers must be added to the system to charge electronic devices safely.

2.7.1 Solar Panels

Solar panels convert sunlight into electrical energy using PV cells which capture energy from moving electrons. The most common type of PV cell used in solar panels are made of silicon, with 95% of commercial models using silicon. A standard solar panel used in residential solar arrays consists of around 60 PV cells linked in chains surrounded by protective materials such as glass and plastics. These arrays are connected to an electrical grid which can power many electrical needs (Zaidi, 2018). A standard recreational solar panel produces 100 watts of electricity per 10 square feet, or about 1kW/h of electricity per day, depending on the amount of exposure to sunlight the panel receives (Gregor, 2023). Monocrystalline solar panels are ideal for smaller areas for solar panel coverage, as they produce more electricity on a smaller scale (about 400W per panel). Monocrystalline solar panels are more expensive than others, averaging about $1 to $1.50 per watt. Their lifespan ranges from 25-40 years, making monocrystalline panels suitable for greater returns on investment.

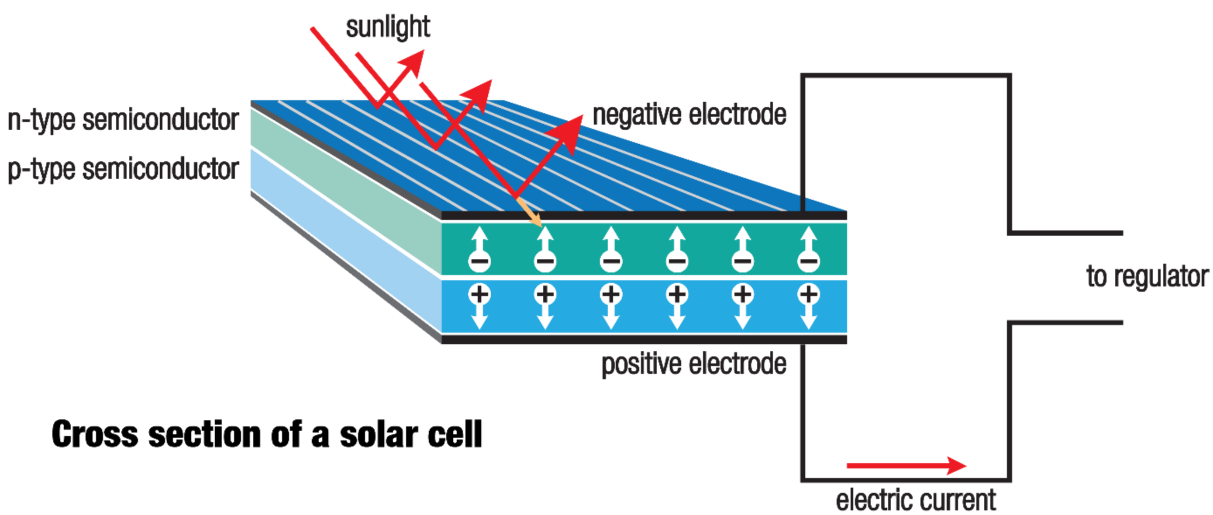

Figure 2-8: Diagram of a PV cell (Desjardins, 2017).

2.7.2 Mounting Structures

Solar arrays must be mounted on stable, durable structures (such as rooftops) that withstand wind, rain, hail, and corrosion over many years. To obtain the highest annual energy output, the PV array is tilted at a fixed angle determined by the structural orientation and local latitude (pointed due south, in the northern hemisphere). Rack mounting is currently the most common method because it is sturdy, versatile, and easy to construct and install. Additionally, implementing tracking mechanisms that automatically align panels with the sun provides more energy and higher returns on investment (Energy.gov, 2023).

2.7.3 Batteries

Batteries are used in an electrical system to store electricity to be used later. In a rechargeable battery, electrons and ions move back and forth through a circuit and electrolyte to either store or output electricity. Lithium-ion batteries are commonly used in modern systems because of their higher and longer-lasting power density (Clean Energy Institute, 2024). Lithium-ion batteries are typically $469 per KW/h, making them more expensive than other batteries. A 10KW/h lithium-ion battery is required to power a household of four people (Large.net, 2021).

2.7.4 Inverters

Inverters convert electricity from a direct current (DC) to an alternating current (AC) which transfers the electricity to grid systems and household power. DC electricity can be stored in batteries and be output as DC through chargers to power electronic devices (Earley, 2013). Generated electricity must be converted to AC to maximize efficiency via an inverter to incorporate a solar panel system into a grid system. To power a non-incorporating charging station, AC is preferred. Typically, inverters cost around $400 - $1,000 depending on the model.

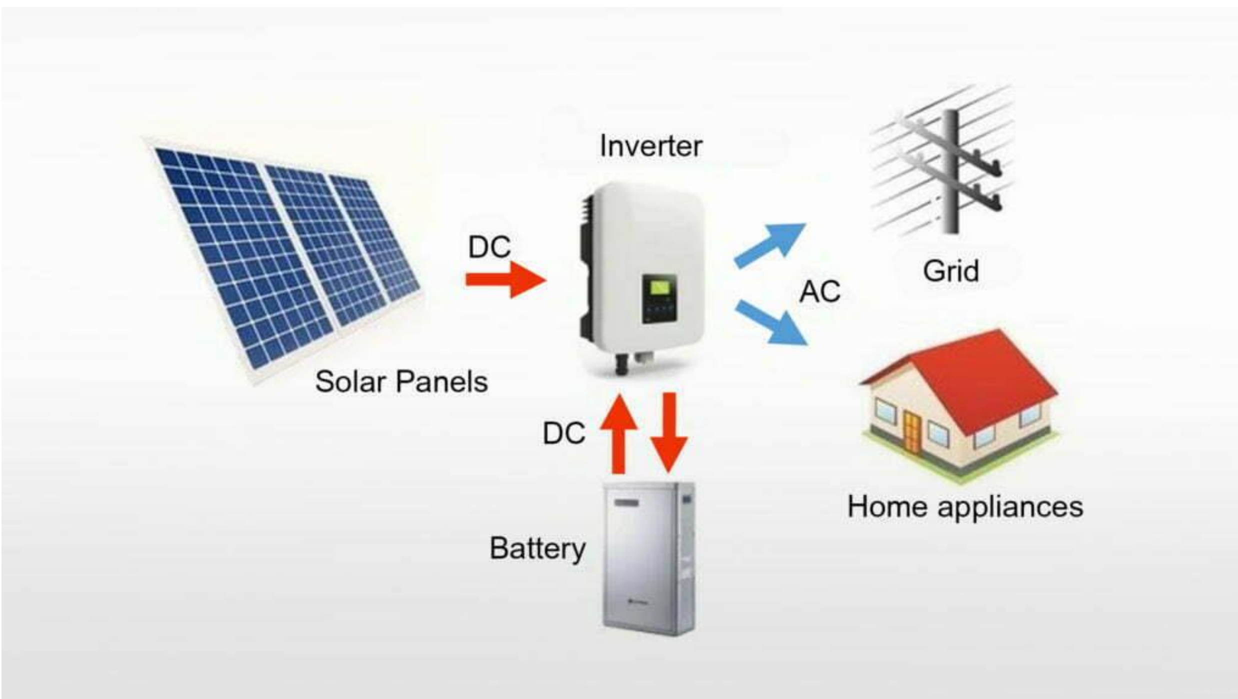

Figure 2-9: Inverter converting DC to AC to transport electricity through a PV system (Abgaryan, 2020).

2.7.5 Charge Controllers

Charge controllers regulate the current flow from the PV system to the battery and protect the battery from overcharging and from deep discharges. This improves the battery life and longevity of the electric system. As the charging nears completion, the charge controller tapers and disrupts the battery's ability to receive a charge, ensuring that the battery can continue cycling in a way that reduces its ability to charge over its lifespan (Usher & Ross, 2020). A standard 12 Amp – 12v/24v solar charge controller costs around $100 -$500 depending on the brand.

2.7.6 Wiring

The two most common materials used for wiring in residential and commercial buildings are copper and aluminum. Copper has a higher conductivity than aluminum, meaning it can carry more current than aluminum at the same size. Thus, copper wire is typically more common in residential and commercial electrical systems (Hede, 2023).

2.8 Climate

The use of solar panels necessitates a more in-depth analysis of the climate in Humboldt County. This analysis should account for geographic location and weather patterns that influence the effectiveness and lifespan of PV systems.

2.8.1 Geography and Weather

Humboldt County's geographic features can prove challenging for the development of utility-scale PV. Primarily, the northern latitude of the county is between 40° N and 41.5° N, and the high amount of annual rainfall can limit the amount of sunlight PV systems receive. Additionally, there is a considerable amount of coverage that Humboldt Bay receives from fog and a variety of conifer and hardwood forests. The largely mountainous landscape of Humboldt County leaves little flat land to use for wide-scale PV system usage (Avcolli, 2018). Moreover, the lack of exposure that Humboldt County receives from weather and geographic coverage must be accounted for to maximize the efficiency and annual yield generated from PV systems.

2.8.2 Seismicity

Humboldt County is located within two of the highest seismic risk zones specified by the Uniform Building Code (UBC), requiring a near-source seismic factor to be used in building design. The outlined design requirements in Humboldt County can substantially increase building strength and costs (Humboldt County Library, 2017). Cal Poly Humboldt sits on top of the Mendocino Triple Junction, leaving it prone to seismic activity and necessitating precaution when designing and building infrastructure.

Figure 2-10: Geographical picture of the Mendocino Triple Junction (Bird, 2003).

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2.9 Introduction to Electric Bikes

An electric bike, or e-bike, is a bicycle that is automated and powered by a battery or exterior power source. An e-bike contains a motor and a battery which help power the bike and reduce the need for physical peddling. Riders can use the pedals and the motor, or in conjunction to power the bike, making e-bikes a versatile form of transportation. An e-bike moto must be rated below 750 watts due to federal regulations. E-bikes can reach up to 28 miles per hour and typically carry up to 300 pounds. Prices of e-bikes can range from $300-$10,000 depending on the materials used and model. E-bikes can weigh from 30-80 pounds and have a frame size ranging from 19-24 inches long.

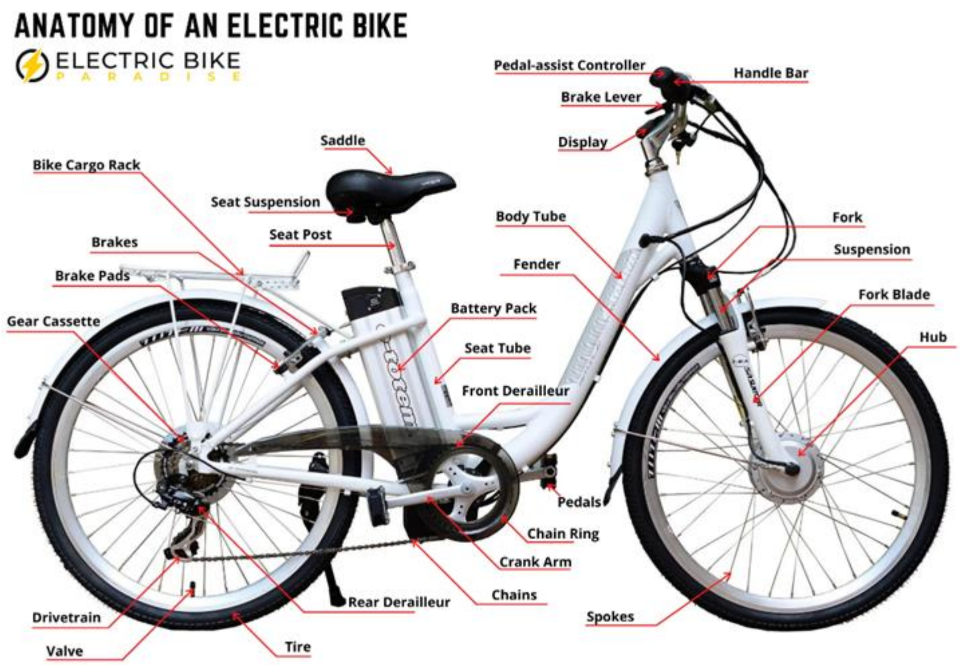


Figure 2-11: Anatomy of an e-bike (Electric Bike Paradise, 2019)

2.9.1 Classifications and Models

E-bikes are organized into three different classifications:

- Class 1: Maximum speed reaches up to 20 miles per hour. The motor may provide power while the rider is pedaling (pedal assist). There are no age restrictions in most states.
- Class 2: Maximum speed reaches up to 20 miles per hour. The motor may provide power independently of the pedals. There are no age restrictions in most states.
- Class 3: Maximum speed reaches up to 28 miles per hour. The motor and the pedals are used simultaneously. Must be older than 16 to use in most states.

E-bikes have different designs and models:

- Off-road: Designed for riding on a variety of different terrains such as dirt, gravel, sand, etc. Typically comes with thicker tires, hydraulic brakes, and heavier load capacities.
- Cargo & utility: Designed to carry large and heavy cargo. Typically built for more length and durability. Typically has payload capacities ranging from 200-500 pounds.
- Folding: Designed to fold and unfold for ease of storing and transportation.

Figure 2-12: Cargo e-bike and folding e-bike models (Rad Power Bikes, 2007)

2.9.2 Batteries and Bike Ranges

Most e-bikes contain 36V or 48V batteries with lifespans between 3-5 years. The battery is removable and can be detached from the bike. The battery is also rechargeable by connecting it to a charging station via a charging port. Battery capacity is measured in watt-hours; the more watt-hours a battery has, the larger the e-bike's range. Calculating watt-hours is done by multiplying an e-bike's amp hours by voltage (Electric Bike Basics, 2023). Charging time varies depending on battery capacity, charger, and other factors. Typically, most models will take 1.5-2 hours to get a majority charge and about 4-5 hours for a complete charge (Rei Co-op, 2022). There are three main types of e-bike batteries, lead-acid batteries, lithium-ion batteries, and lithium iron phosphate batteries.

- <u>Lead-acid battery:</u> Heavier and less capacity than lithium and nickel batteries. Lead-acid batteries don't have great capacity and are best for cyclists planning short commutes (Electric Bike Basics, 2023). They typically have a capacity of 15-amp hours and a range of 20 miles, with a battery capacity of 300 watt-hours.
- <u>Lithium-ion battery:</u> Moderate capacity and weight, allowing for sufficient range. More expensive than traditional lead-acid alternatives (Electric Bike Basics, 2023). Models typically have a capacity of 20-amp hours and a range of 50 miles, having a battery capacity of 1000 Watt-hours.
- <u>Lithium iron phosphate battery:</u> Has a longer life span and better charge efficiency than most batteries but is more expensive. Usable across a range of temperatures and weather conditions (Electric Bike Basics, 2023). Models typically have a capacity of 20-amp hours and a range of 68 miles, having a battery capacity of 1360 watt-hours.

2.9.3 Bike Storage

E-bikes can be stored on the floor or vertically using floor bike racks or wall-mounted bike racks. It is advised to store e-bikes indoors to avoid damage from harsh weather and corrosion. E-bikes can be difficult to store due to their larger size and weight and must be properly maintained to ensure longevity and performance. E-bike batteries must also be properly stored and maintained to prolong their lifespan. Avoid storing them in extremely hot or cold temperatures which can damage the battery (Gear Hooks, 2023).

Figure 2-13: Floor and wall bike racks (ebike24, 2023)

2.9.4 Safety and Maintenance

Most e-bikes must not be capable of going faster than 20 miles per hour on a level surface due to some state regulations. Due to their large size and weight, it is advised to take caution when mounting and dismounting the bike. Batteries must be kept away from extreme temperatures and moisture to avoid damage. The wheels must be checked and maintained regularly by checking PSI (pounds per square inch) levels and replacing or tightening the spokes. Regular checks on the brakes and cleaning and lubricating the bike chain also increase the performance. Letting batteries charge overnight or for long periods is not advised because some systems may keep charging even if the battery is fully charged. This can damage the battery in the long term (Rei Co-op, 2022).

2.10 Introduction to Security

Installing surveillance cameras and locking mechanisms in bicycle storage facilities plays a vital role in preventing theft and vandalism. Data indicates that approximately 1.5 million bicycles are stolen yearly from college campuses in the United States. Implementing cameras and locks act as deterrents against bike theft, providing a sense of security to cyclists. Additionally, surveillance footage becomes a valuable tool for law enforcement notifying perpetrators. Locks range from robust U-locks securing the bicycle to a stationary object to more discreet methods of concealing the entire bike.

2.10.1 Slick Locks

Slick Locks, manufactured by Slick Lock LLC, are made of steel alloys and plastics that are impact-resistant, flexible, and resilient against potential damage from drilling, cutting, and picking. Slick Locks resist outdoor conditions, such as severe weather conditions and corrosion. They come in various sizes and are customized to fit many vehicle models and door configurations. Slick Locks protects unauthorized access by utilizing a sliding slick cover adding an extra layer of defense. While primarily intended for vehicle security, Slick Locks can be adapted for alternative entry points such as doors through diverse installation techniques like welding or drilling. Moreover, Slick Locks provide versatility and efficacy in lock and security systems.

Figure 2-14 (left): Components of a Slick Lock and various options (countylocksmithinc.com, n.d.).

Figure 2-15 (right): A custom lock option welded onto a car to place a Slick Lock (Zaniolo, 2011).

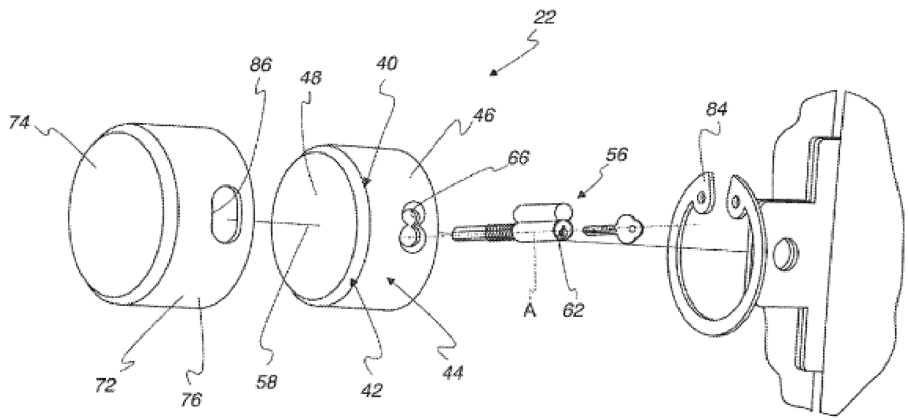


Figure 2-16: Diagram showing the mechanisms of a Slick Lock (*Ryan, 2021).*

2.10.2 T2 DL2700 Electronic Door Lock

The T2 DL2700 electronic door lock, developed by GOKEYLESS, operates without a physical key. Instead, it relies on the use of a personalized passcode for access. Notable features of the T2 DL2700 include remote access control, programmable scheduling capabilities, and automatic locking and unlocking. The lock is 8 x 3.25 x 1 7/8 inches and weighs 7.5 lbs., making it suitable for doors with a thickness ranging from 1 5/8 to 1 7/8 inches. Holding a capacity for 100 codes and a battery life of 120,000 cycles, the T2 DL2700 lock offers extensive convenience, functionality, and longevity. Manufacturers recommend complementing the lock with surveillance cameras and alarm systems to enhance security. Moreover, the T2 DL2700 is best used to increase security in commercial and residential settings.

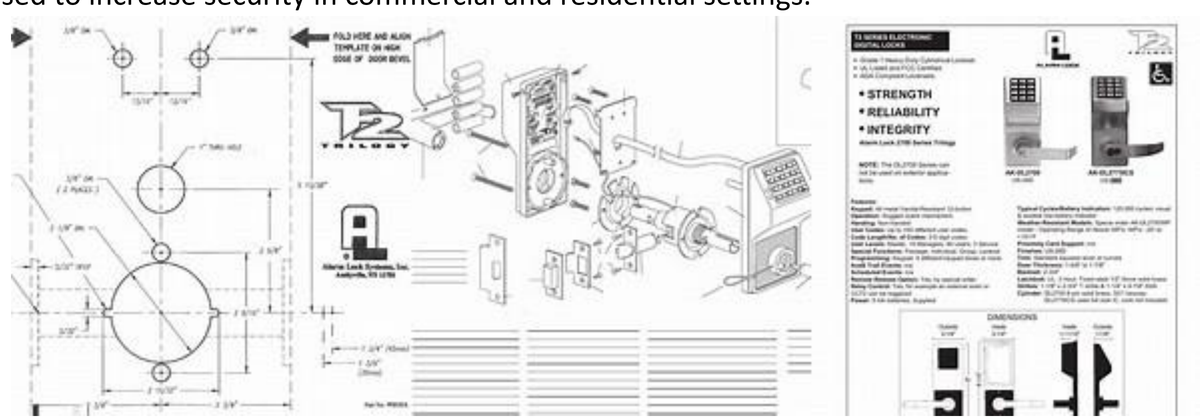


Figure 2-17: Diagram of components and mechanisms of the T2 DL2700 electronic door lock (James, 2023).

2.10.3 Amcrest Analog 5MP Night Color Security Camera

The Amcrest Analog 5MP Night Color Security Camera provides high-resolution video footage suitable for indoor and outdoor surveillance requirements. Models include the as exemplified by models such as the A5TN28-W which utilizes a 5-megapixel resolution (2592x1944 pixels), this camera offers sharp and detailed images, ensuring clear visibility of the surroundings. It can generate detailed images even in low-light conditions, surpassing the capabilities of traditional infrared night vision cameras. Despite potential challenges with installation wiring, the camera's analog design allows for integration with a DVR system and LAN cable, enabling real-time broadcasting and convenient monitoring capabilities. In conjunction with its robust housing and weatherproof construction, these specifications contribute to a secure and efficient security system and make it a preferred option for comprehensive security solutions. These cameras are available to purchase on their website for about $99.99 -> $64.99, or from online retailers, such as Amazon or eBay.

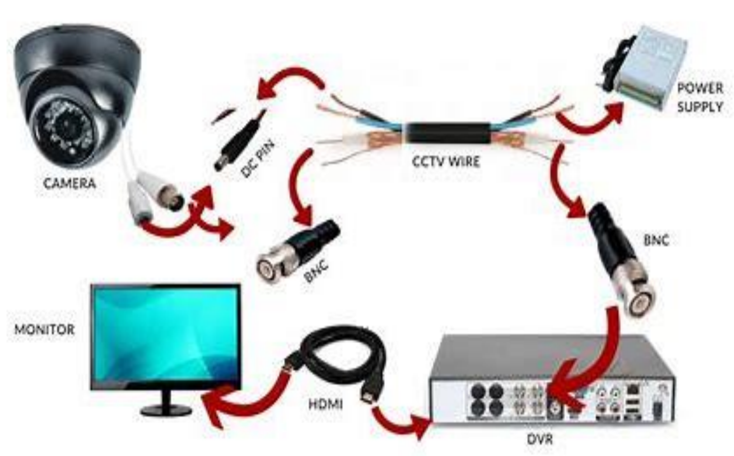


Figure 2-18 (left): Proses needed to connect place an analog camera (Arsh, 2018).

Figure 2-19 (right): The Amcrest Analog 5MP Night Color Security Camera (Amcrest.com, 2023)

3 Alternative Solutions

3.1 Brainstorming

For brainstorming, we used a free-for-all technique (writing down multiple random ideas) to think of designs for the bike cage. We began writing down random ideas that could be input into our design and then crossed out any unrealistic and unrelated ideas to the client’s criteria. Based on the measurements of the area where the bike cage would be, we combined our ideas and the measurements of the area to design our bike cage.

3.2 Alternative Designs

This section will introduce alternative designs proposed by members of Team Gatekeepers and a brief description of each design.

3.2.1 Building Design #1 – Side and Frontal View

Building Design #1 is a solar-covered bike cage design that is a 13ftx13ftx10ft building standing on a 3ft tall concrete foundation located on a plot of land along the street-facing side of CCAT, which meets the client's specification for the size of the building and its location. It has a 5ft long ramp that leads to an 8ft tall and 10ft wide doorway with a garage door for ease of use and security. It has three 2ft wide and 1.5ft tall windows on the side walls that can be opened for ventilation and light. It has a gable roof design that is 15ft long and 9ft wide with about a 2ft overhang on both sides. It has a solar panel located on the left-hand side of the roof that is 11ft long and 6ft wide, which provides power for the entire building and meets the client’s specification for the building to be 100% solar powered.

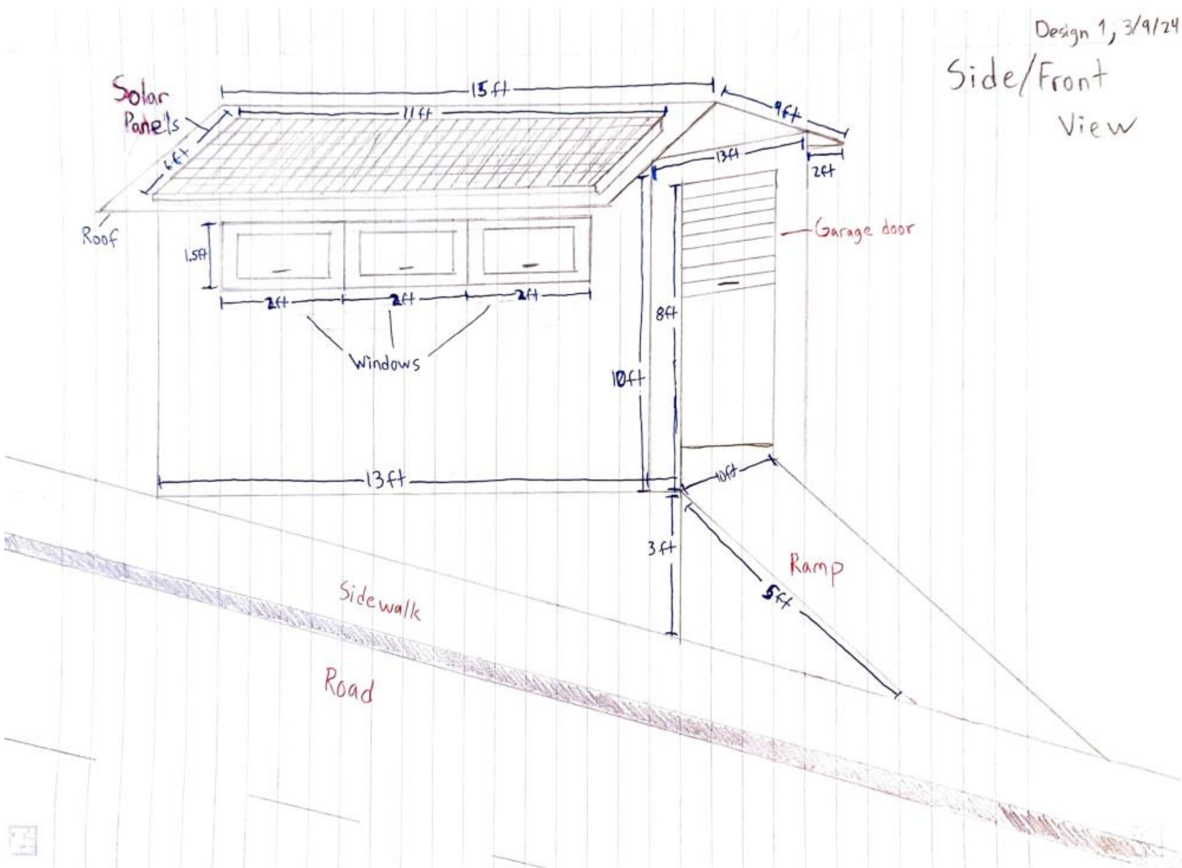


Figure 3-1 Building Design #1 sketch (side/frontal view).

3.2.2 Bike Coop #1 – Top and Inside View

Building Design #1 has walls that are 0.5ft thick and are divided into two rooms, the bike storage room and the solar battery storage room. The bike storage room is 9ft long and 12ft wide, with an area of 108ft^2 (33m^2). The purpose of the bike storage room is to store and charge multiple e-bikes using only solar energy. In total, six wall-mounted bike racks with two located on the side and back walls. The bike racks are about 2 feet apart and can be adjusted to different heights to accommodate different bike sizes. An outlet is located in between each pair of bike racks. A light switch located near the entrance on the right-hand side connects to a hanging lightbulb in the center of the room. The windows are located 2ft above the bike racks to avoid damage and can be opened for ventilation. The solar battery storage room is 2.5ft long and 12ft wide with an area of 30ft^2 (9m^2). The purpose of the solar battery storage room is to store the energy the solar panels produce, house the breaker box, etc. A 2ft wide door connects the two rooms. A light switch is located to the left of the door that connects to a hanging lightbulb in the center of the room.

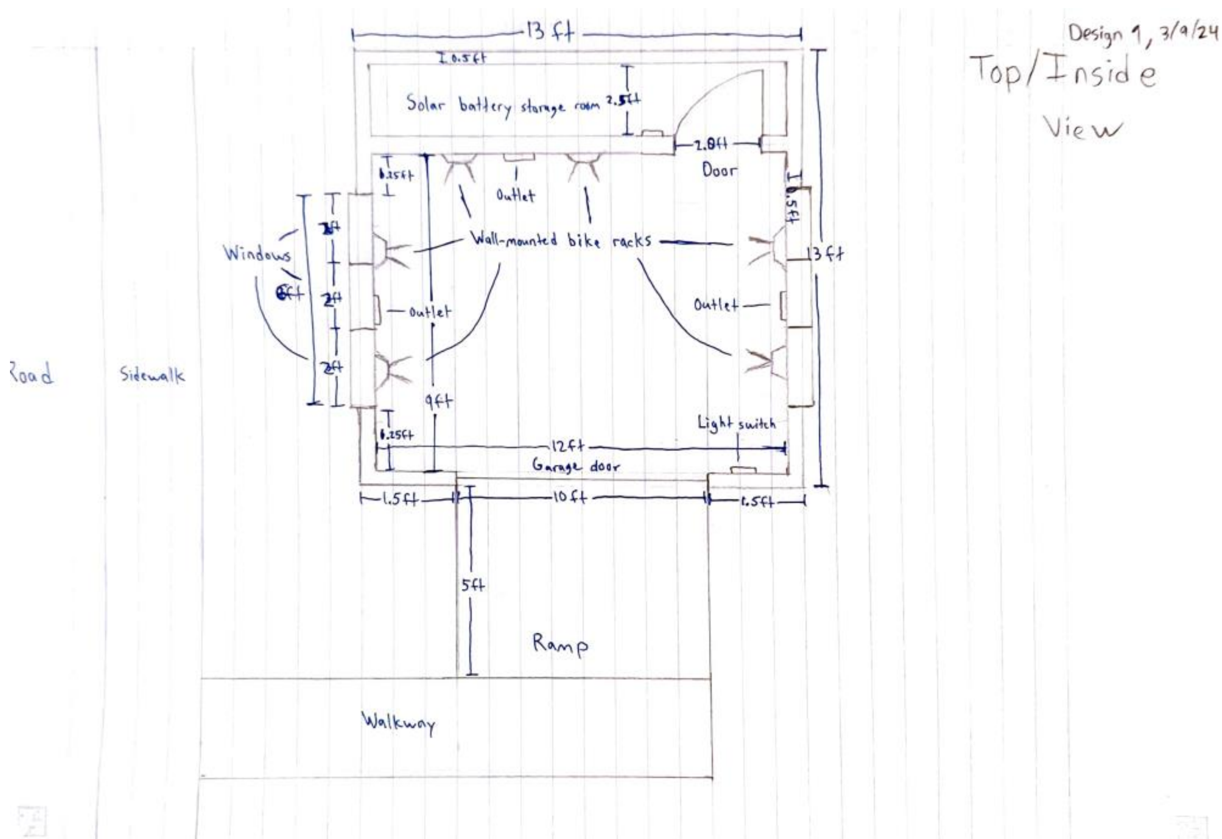


Figure 3-2: Building Design #1 sketch (above/inside view).

3.2.3 Bike Coop #2- Front View

Building Design #2 is a solar-covered bike cage design that is a 13ftx10ftx10ft building standing on a 2ft tall concrete foundation with a 13ft long and 6ft wide side-platform extension. It is located on a plot of land along the street-facing side of CCAT, which meets the client's specifications for the size of the building and its location. It has a 5ft long ramp that leads to a 7ft tall and 6ft wide doorway with a garage door for ease of use and security. It has three 2ft wide and 1.5ft tall windows on the left-hand side wall that can be opened for ventilation and light. It has a hip roof design, 15ft long and 9ft wide with about a 2ft overhang on both sides. A solar panel is on the left-hand side of the roof and another panel f is 11ft long and 6ft wide and another panel is 3ft long and 5ft wide on the front side of the roof. These panels power the entire building and meet the specifications of 100% solar-powered charging. The side-platform extension is 13ft long and 6ft wide with a 7.5ft long angled roof and a 6ft tall pillar for support.

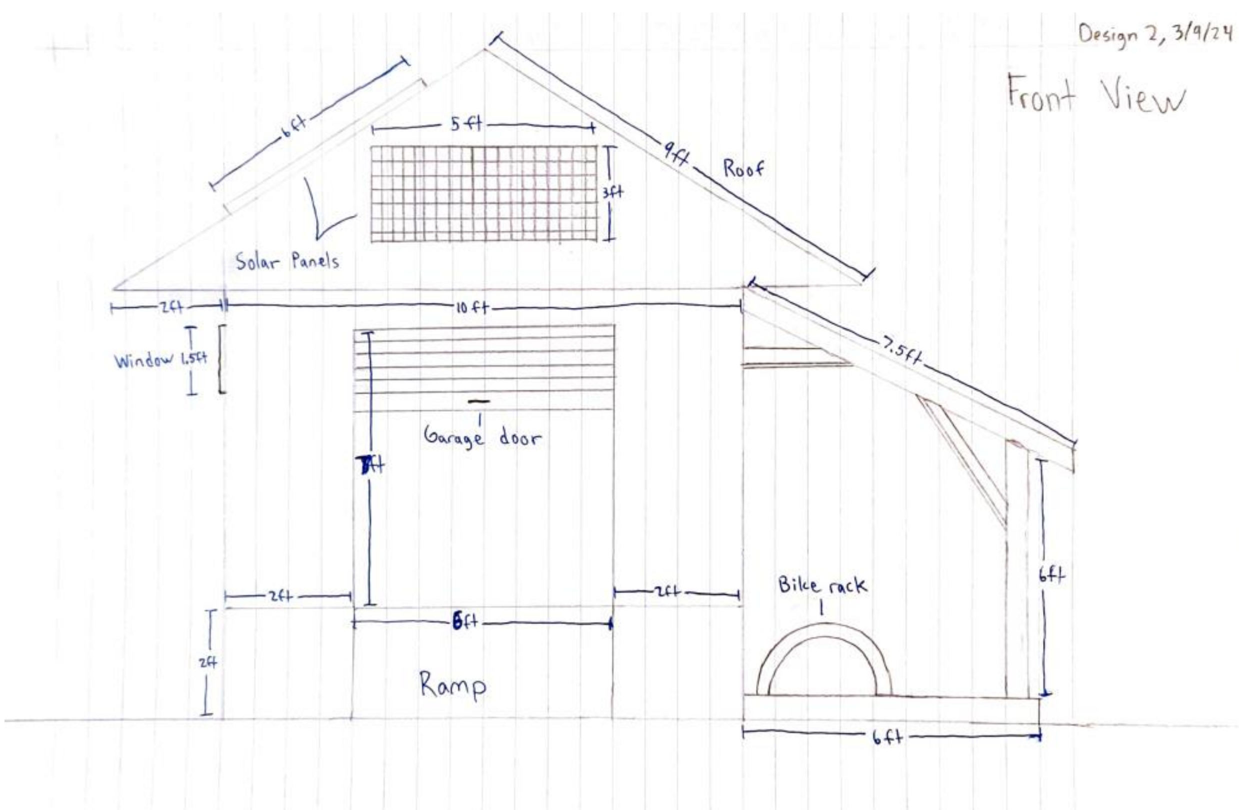


Figure 3-3: Building Design #2 sketch (frontal view.)

3.2.4 Building Design #2 – Top and Inside View

Building Design #2 has walls that are 0.5ft thick and are divided into two rooms, the bike storage room, and the solar battery storage room. The bike storage room is 9ft long and 12ft wide with an additional 3ft long and 2.5ft wide area, meaning it has a total area of 114.5ft^2 (35m^2). The purpose of the bike storage room is to store and charge multiple e-bikes using only solar energy. There are five wall-mounted bike racks with two on the side walls and one on the back wall. The bike racks are about 2ft apart and can be adjusted to different heights to accommodate different bike sizes. An outlet is located between each pair of bike racks and a light switch is located near the entrance on the right-hand side connected to a hanging lightbulb in the center of the room. The windows are located 2ft above the bike racks to avoid damage and can be opened for ventilation. The solar battery storage room is 2.5ft long and 6ft wide with an area of 12.5ft^2 (4m^2). The purpose of the solar battery storage room is to store the energy the solar panels produce, house the breaker box, etc. A 2ft wide door connects the two rooms and a light switch is located to the left of the door connecting to a hanging lightbulb in the center of the room. The side platform is 13ft long and 6ft wide and is an additional bike storage area. The area contains 5 bike racks that are 2.5ft long and 2in wide placed about 2.5ft apart from each other.

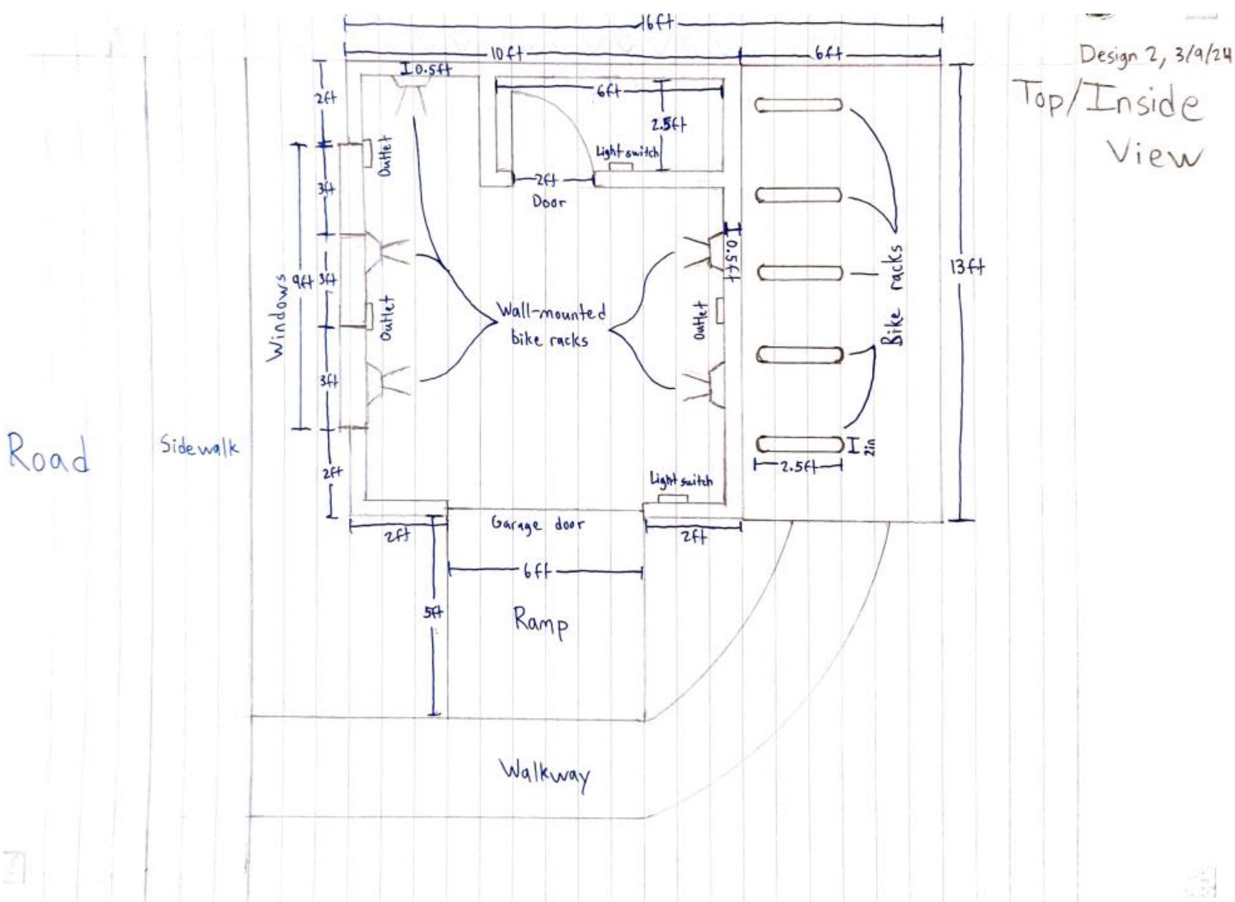


Figure 3-4: Building Design #2 sketch (top/inside view).

3.2.5 Bike Shed #3

Design #3 features a roofing design with a 45-degree angle, optimized to capture maximum sunlight for the solar panel. The bike cage dimensions are 13 feet in length and width. In the rear of the cage, there is a 2-foot space designated for a storage area to conceal solar batteries, wiring, and other components. A power breaker is situated outside the cage, with the option to locate it inside for added safety. Within the building, a locker is available for bike users to store valuables. Security measures include a surveillance camera and a digital lock system requiring a key code for access. The cage incorporates two bike wall racks and a versatile bike fence accommodating 4 to 7 bikes. A manual light is centrally located for convenience. The building features walls constructed of hempcrete with embedded glass bottles to allow natural light, creating a visually appealing aesthetic and aiding in insulation. Solar panels can be mounted on a separate panel wall for increased energy efficiency, supported by concrete pillars and metal stands. Conveniently located outlets near each bike rack and fence allow for the charging of electric bikes.

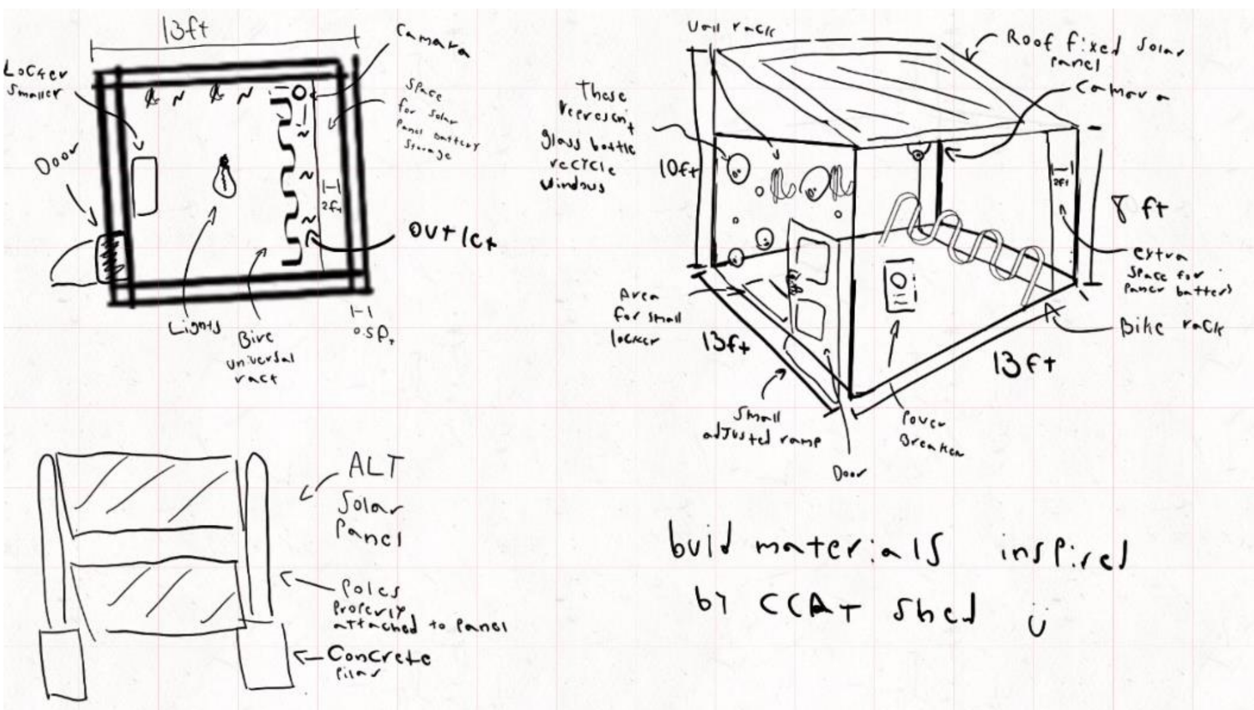


Figure 3-5: Building Design #3 sketch.

3.2.6 Bike Shed #4

Building Design #4 features an open wall with a garage door that can slide from side to side or be pulled down. This design choice was made to provide access to individuals who may not have access to the bike cage during the day. The structure includes a tent or roof extending to the end of the side wall to protect the bikes from rain and provide shade. The building is supported by pillars 1 foot wide and base, with .5-foot walls creating a gap that extends the building up to 10 feet. This gap allows for 2 feet of roof storage where wiring, solar storage, and other necessary items can be housed out of sight. There are two entrances - a door on the right side with a smart lock featuring a digital key code, and a front garage/sliding door that can be accessed even when the public cage is closed. The garage door will be secured with a slick lock. The design includes space for 5 universal bike fences, slanted for maximum storage efficiency, with outlines to guide users. In addition to bike storage, the interior will contain a power breaker, a security camera, and a large locker with a lock. The flat roofing includes a water drainage system and ample space for multiple solar panels, with a potential solar panel wall for increased energy production efficiency.

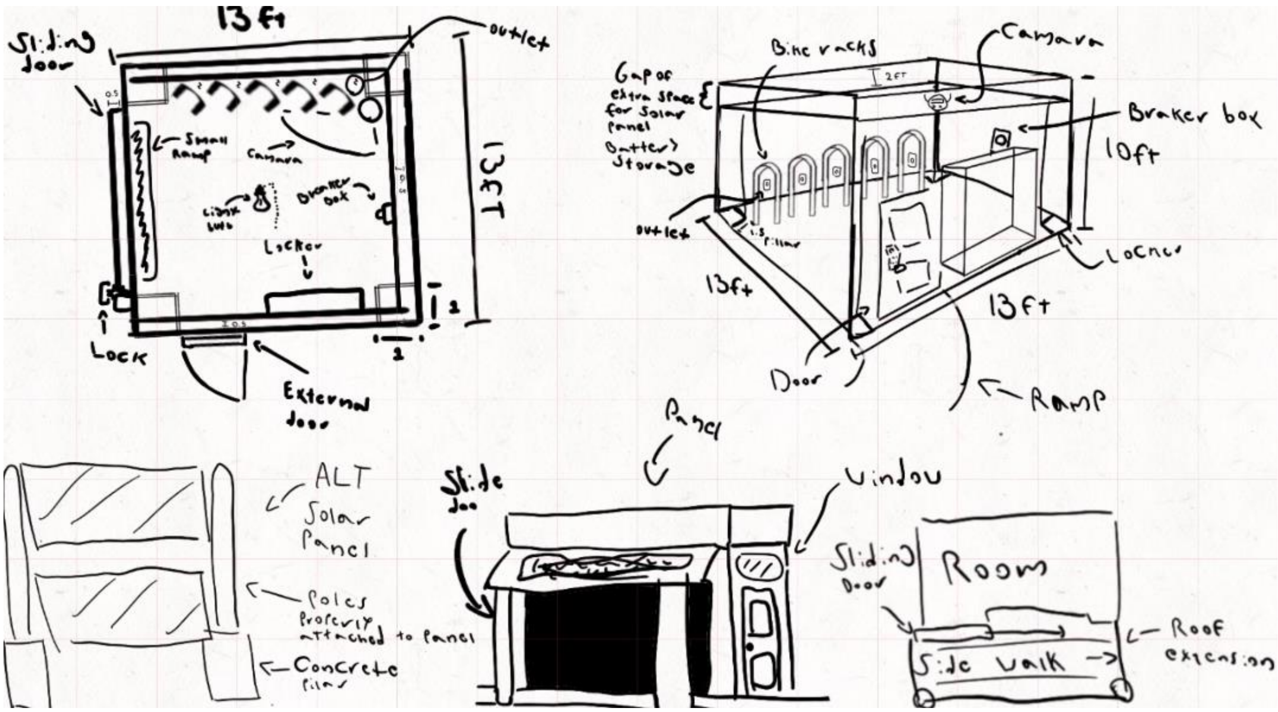


Figure 3-6: Building Design #4 sketch.

3.2.7 Building Design #5

Building Design # 5 is a solar-covered bike cage design. It is a 13ft x 13ft x 13ft building with two solar panels on top and two additional solar panel strips along the front and side of the building. The two solar panels on the roof will be 8ft x 8ft and the strips will be 13 feet long and 2 to 3 feet wide. Instead of a front door, it will have a sliding glass door. The sliding door will be made of laminated glass instead of regular glass. It will have a window for airflow in and out of the building. Inside the building, two bike racks with charging outlets line each wall.

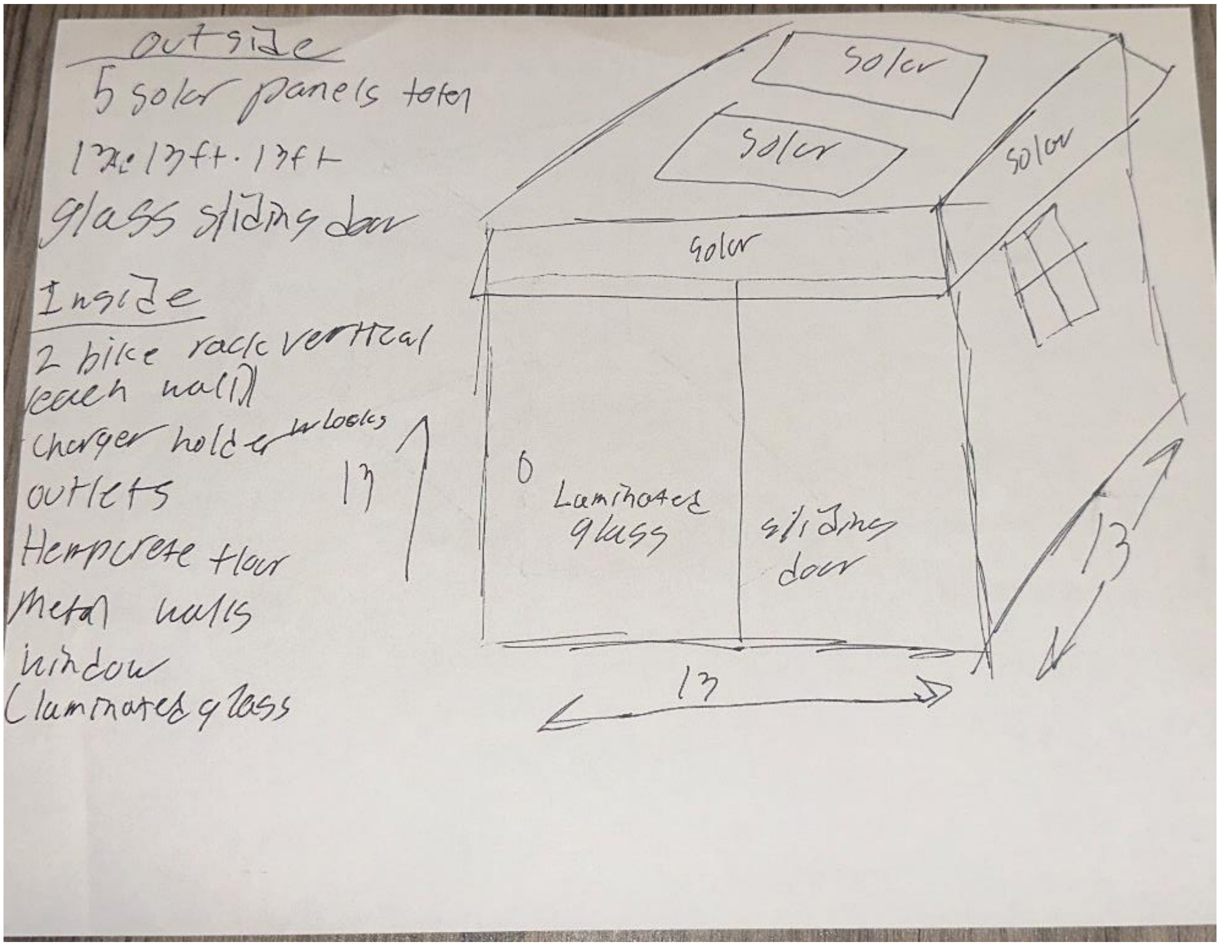


Figure 3-7: Building Design #5 sketch on white board.

3.2.8 Building Design #6

Building Design #6 is for the inside of the covered solar cage design. The laminated glass sliding door is 10ft x 10ft. The foundation of the building will be made of hempcrete. The walls will be 1 foot thick and made of hempcrete. There will be two bike racks on each wall. There will also be three outlets (one for each wall) and two charger holders for each bike. Then in the other will be a small locker/stand to put their helmet in.

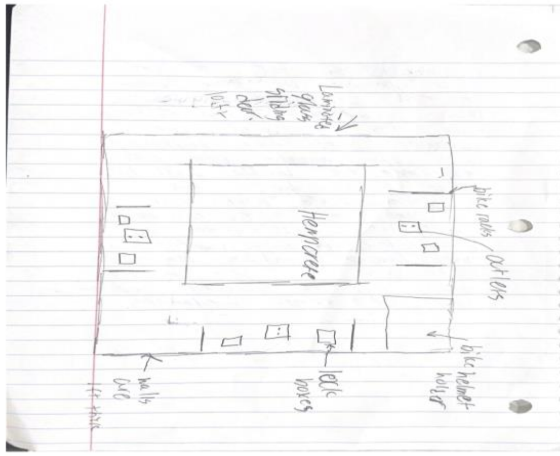


Figure 3-8: Building Design #6 sketch on paper.

3.2.9 Solar Panel Design #1

Standard solar panel design incorporating two residential-size solar panels, 5.5x3 ft, linked together and fixed on a steel mounting structure. The mounting structure is adjustable to accommodate different mounting angles to maximize exposure to sunlight. Given the location and global latitude, solar panels will face due southeast and angled at 32° from the horizontal to maximize exposure to sunlight. These parameters will apply to all alternative solutions to account for the system to be used primarily during the fall and spring semesters. The final design incorporates two to three linked panels (4 to 6) mounted atop both roof sides. Each panel can generate 250-400 watts of electricity for 3 hours daily or about 1.2-1.5 kW/h of energy per day.

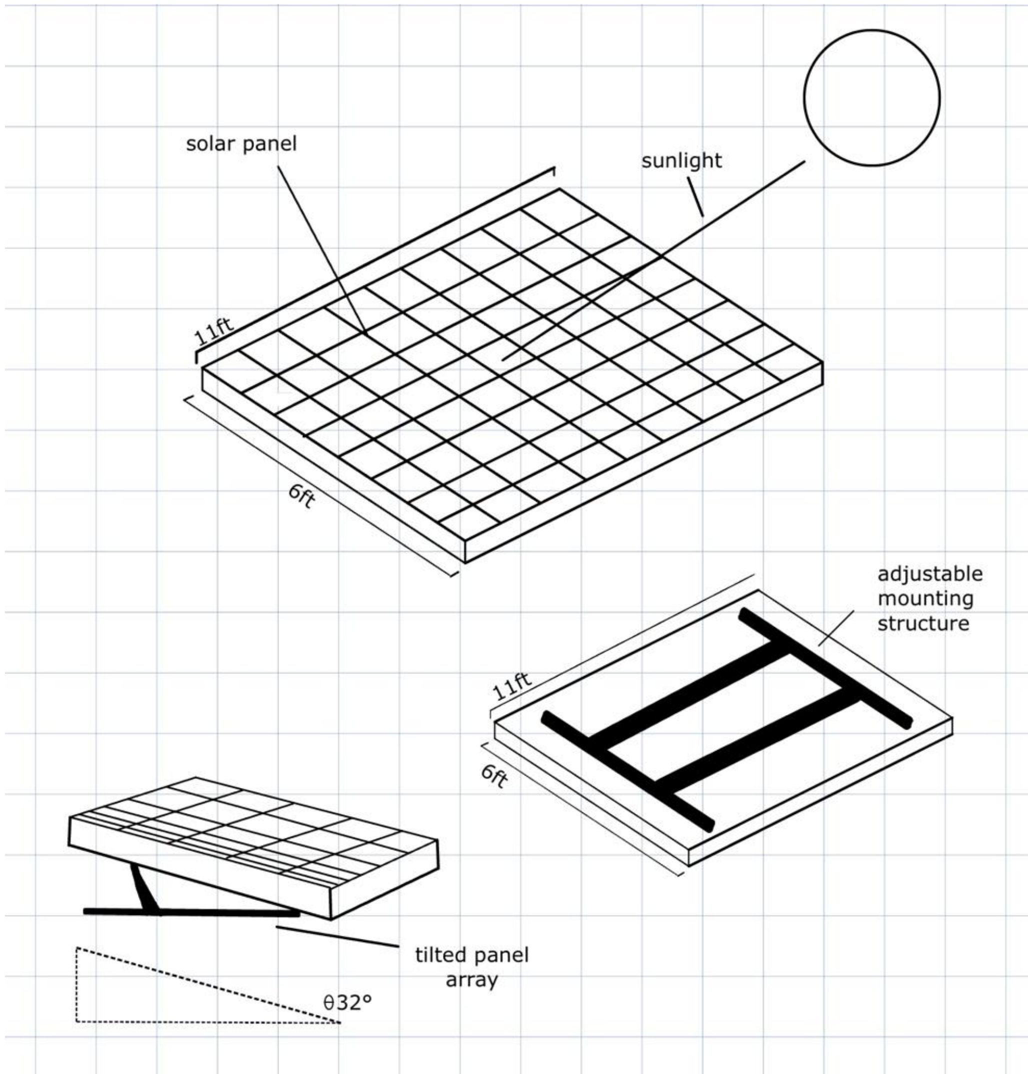


Figure 3-9: Solar Panel Design #1

3.2.10 Solar Panel Array Design #1

Alternative solar panel array design that employs smaller solar panels linked together and curved inwards, using mirrors to reflect light onto the solar panels. In conjunction, the solar array pointed due south and angled at 32 degrees from the horizontal will maximize efficiency year-round. The panels, 11 ft x 6 ft in dimension, are bolted down and mounted on the roof of our structure design. The steel mounting structure is sturdy and supports the solar panels against harsh weather conditions and seismic activity.

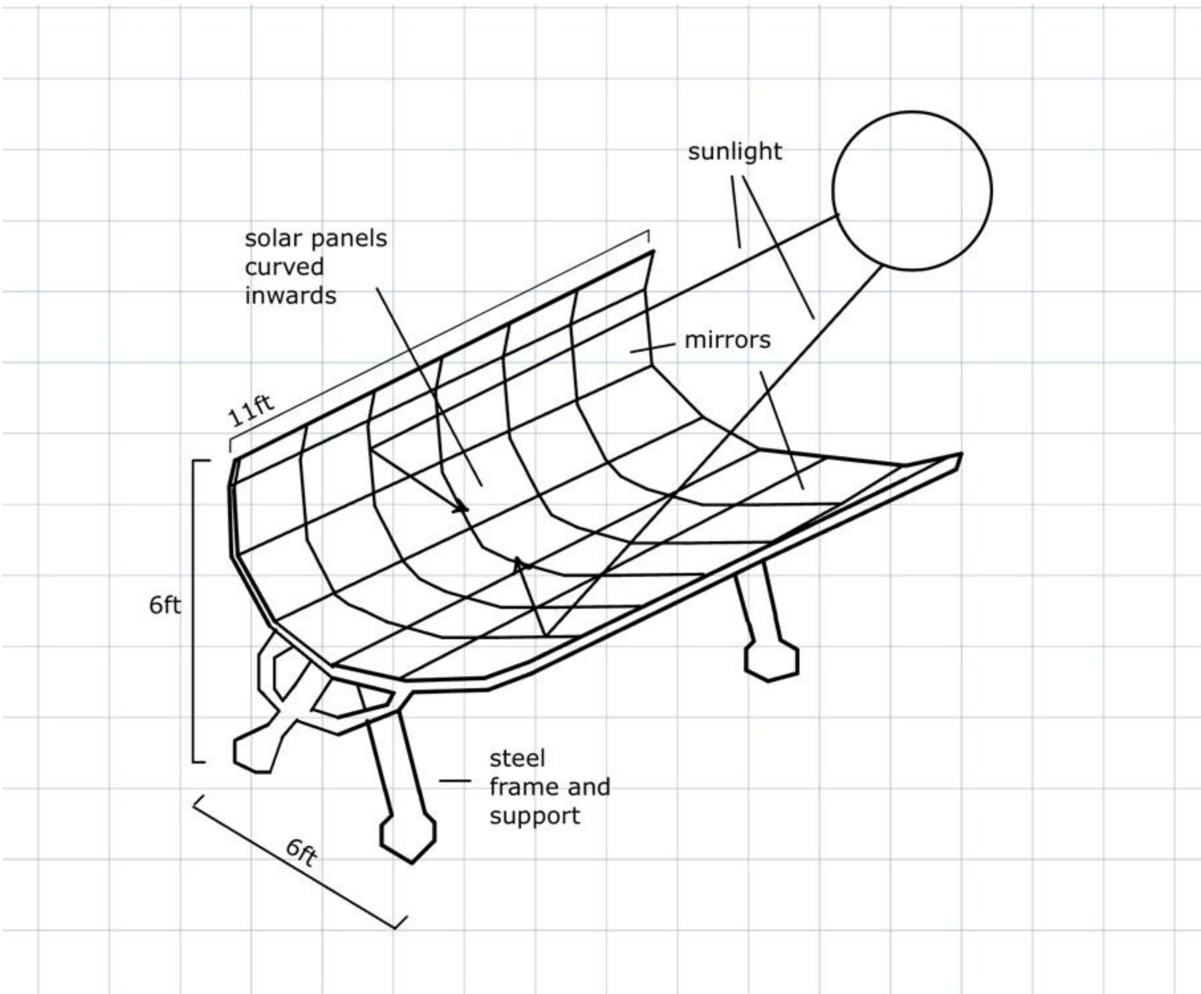


Figure 3-10: : Solar Panel Array Design #2 digital drawing.

3.2.11 Solar Panel Array Design #2 – "Solar Flower"

An alternative "sunflower-shaped" solar panel design incorporating triangular solar panels spreading outward from a central point to collect sunlight. Standing 4ft tall and including a 3x3 ft triangular solar panel array, this structure can be angled and modified to be mounted on rooftops. Other models may incorporate a taller and sturdier base, allowing for solar arrays to reach higher and collect sunlight for longer periods of the day. Additionally, this solar array provides aesthetic and visual cohesion with the natural landscape of the location.

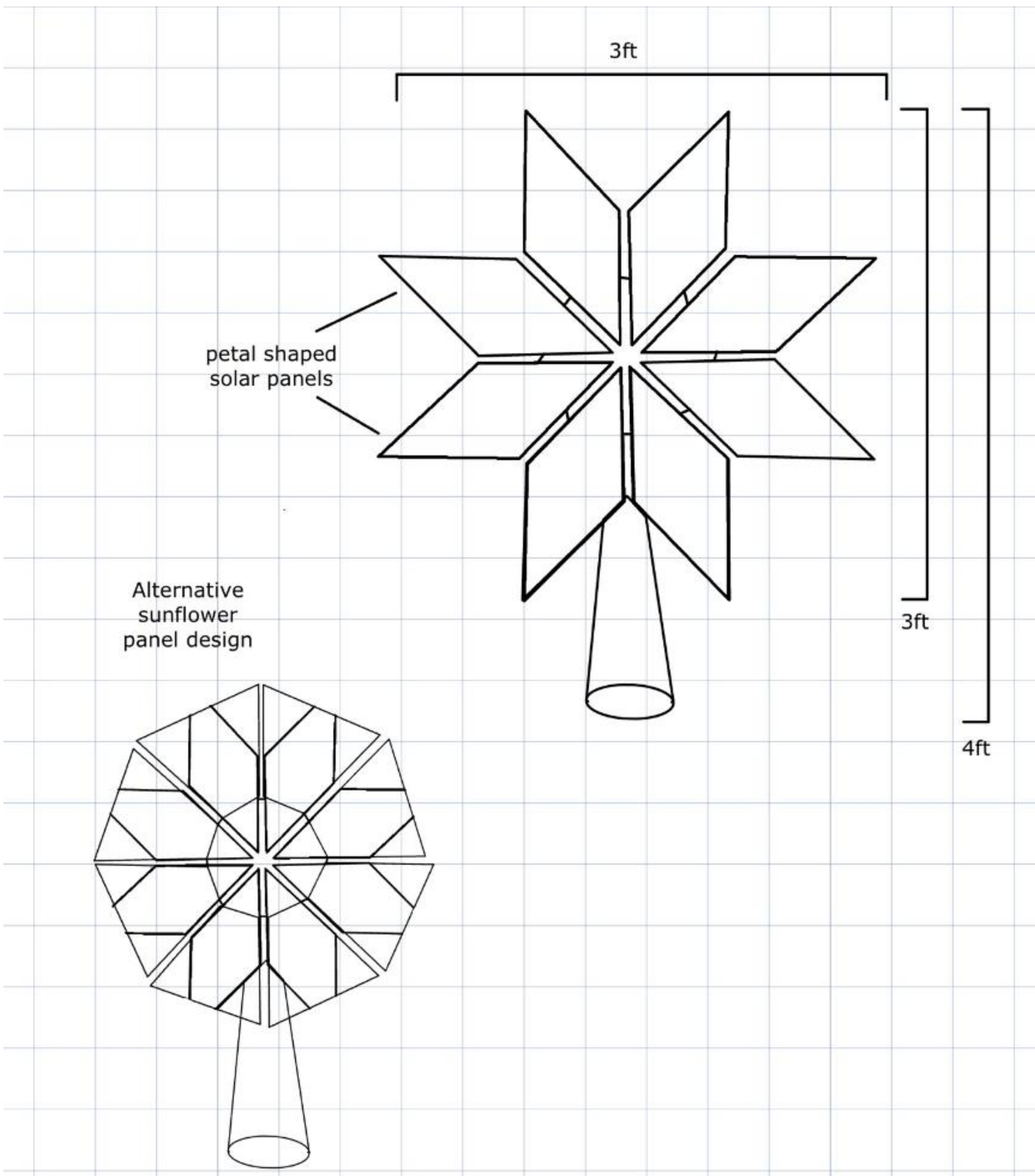


Figure 3-11: Solar Panel Array Design #3 – "Solar Flower" digital drawing.

3.2.12 Electrical System Design

This electrical system design incorporates copper wiring to carry DC electricity generated by the solar panels throughout the walls of the structure and distribute it to the bike charging stations, The wires run electricity through a DC ground fault interrupter which acts to interrupt the flow of electricity in case of contact with groundwater sources. From there, a charge controller controls the discharge of electricity supplied to the chargers to prevent overcharging the battery and devices. An inverter then controls the flow of DC towards the charging station and allows for the option of connecting the system to a grid system, such as the CCAT. The AC disconnect is an extra safety precaution to prevent overcharging or voltage hazards. Finally, the wires run through a distribution panel in the electric power breaker box which allocates and controls the flow of electricity throughout the structure.

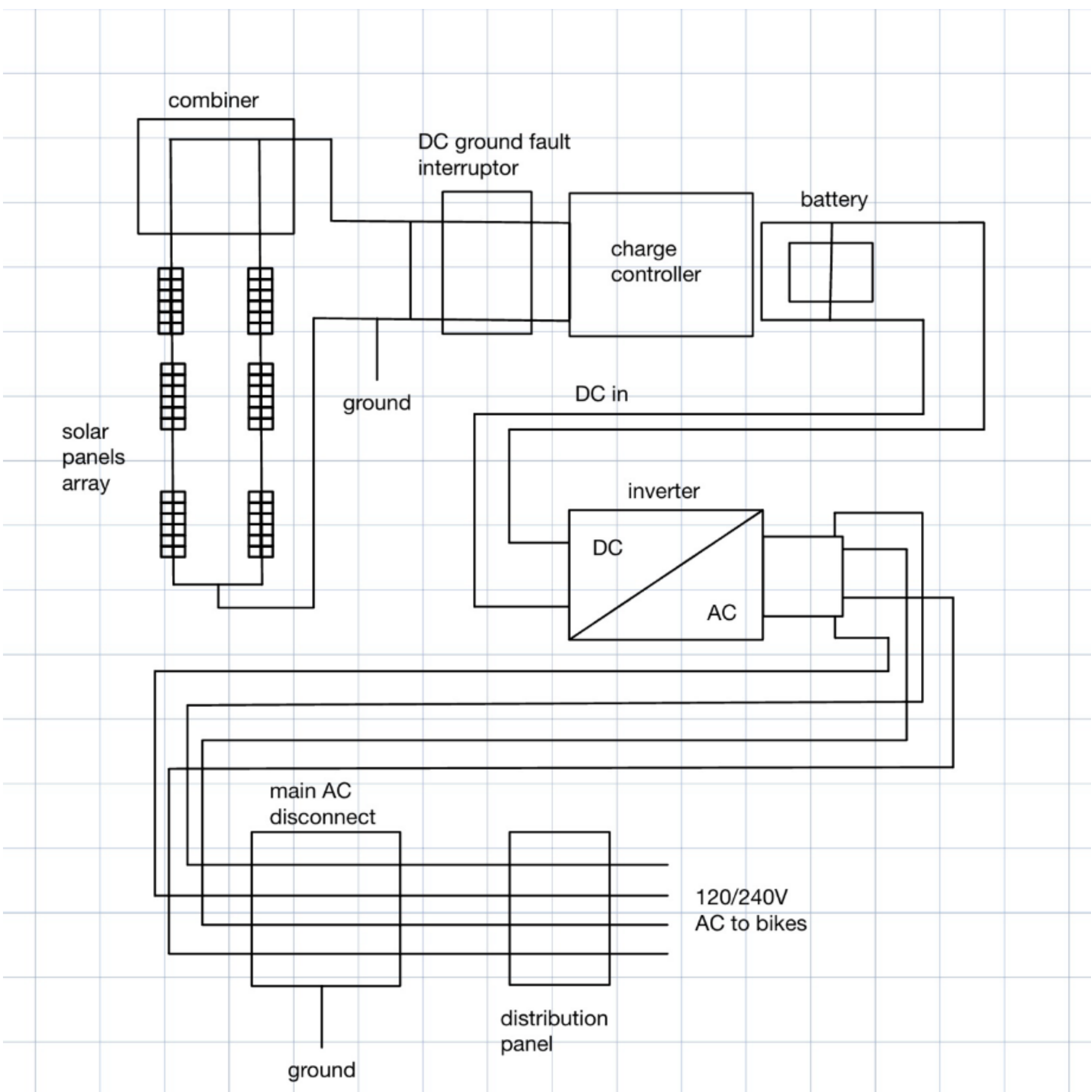


Figure 3-12: Electrical System Design digital drawing.

4 Decision Process

4.1 INTRODUCTION

This section covers the decision process for the final project design.

4.2 CRITERIA

Included below are tables for criteria weight and weighted scores for each criterion based on the feedback received from the client.

Table 4-1: Average weight of criteria for each team member

	Criteria Weight (0-10)				
Criteria List	Member 1	Member 2	Member 3	Member 4	Group
Bike Storage	10	10	8	10	38
Charging Capacity	10	9	9	7	35
Ease of Use	9	10	8	10	37
Cost	4	4	5	4	17
Security	6	7	7	7	27
Safety	8	9	8	9	34
Structure Integrity	8	9	10	10	37
Longevity	6	5	8	8	27
Aesthetics	6	5	6	7	24
Total	67	68	69	72	276

4.3 SOLUTIONS

Given the many different components of each bike cage design, Team Gatekeepers has chosen to assign scores to the “Bike Coop” and “Bike Shed” designs based on how well they complete each criterion.

Table 4-2: Scores based on weighted criteria for each alternative design.

Criteria		Solutions	
List	Weight	Bike Coop	Bike Shed
Bike Storage	38	8 304	7 266
Charging Capacity	35	8 280	4 140
Ease of Use	37	8 296	7 259

Cost	17	8 / 136	8 / 136
Security	27	7 / 189	9 / 243
Safety	34	8 / 272	9 / 306
Structural Integrity	37	9 / 333	9 / 333
Longevity	27	8 / 216	8 / 216
Aesthetics	24	9 / 216	8 / 192
	Total	2242	2090

4.4 DECISIONS PROCESS

Table 4-3: Step-by-step decision process

Step 1:	Step 2:	Step 3:	Step 4:	Step 5:
Draw design based on criteria	Build a model of the design out of cardboard	Show the client the model	Alter model based on client feedback	Discuss and finalize the design

When deciding which solution to choose from, we first discussed which design best suited CCAT's preference of what they wanted the design to look like. We then discussed which design met the most criteria and seemed the most plausible. We decided to go with the Bike Coop design for our solution because it had the highest score based on our criteria and we as a team and the client both liked the design.

4.5 FINAL DECISION SPECIFICATIONS

We chose the Bike Coop design for our final project because it provides the best balance of available bike storage (our primary criteria) with solar charging capability. The materials chosen for this design are durable and affordable, allowing the Bike Coop a longer lifespan and greater ease of maintenance. Using sustainable and environmentally conscious materials for the walls, floor, and platform for our structure and recycled solar panels is sustainable and coincides with CCAT's model for applied technology.

5 Design Specifications

5.1 Introduction

This section introduces the specifications of the final solution chosen from the previous section. It will include descriptions of specific features and overall purpose in fulfilling the criteria outlined in Section 2. A brief discussion will also explain why some features were chosen over others. Tables of costs have been included below displaying the team hours, section hours, materials specifics, cost of materials, etc. Finally, a guide for the construction, implementation, and maintenance of the final design is included.

5.2 Description of Solutions

5.2.1 Structure

The structure of the Bike Coop design will incorporate a Douglas fir wood frame with hempcrete brick walls and flooring. Hempcrete will also be used to raise a platform to level the structure along the slope of the hill next to CCAT. Hempcrete brick will be cut to 1ft X 0.5ft and placed in a standard "stretcher bond" brick laying pattern to raise four outer walls 11ft long and 9 ft tall. **Figure 5-1** shows an example of the hempcrete brick wall from a front-side view. For additional support, the Bike Coop design will have a wood frame made of Douglas Fir with a wood pillar at each corner standing 9 ft tall to support the roof of the building. **Figure 5-3** shows a drawing of the wood frame seen from the front. The Bike Coop will incorporate two fiberglass windows. One will be 5-7 feet wide and 2.5 feet tall on the upper left wall near the solar panels to provide light into the structure. A second window will be installed on the back of the wall at the top, 7 feet wide and 2 feet tall. The window provides additional light to the structure.

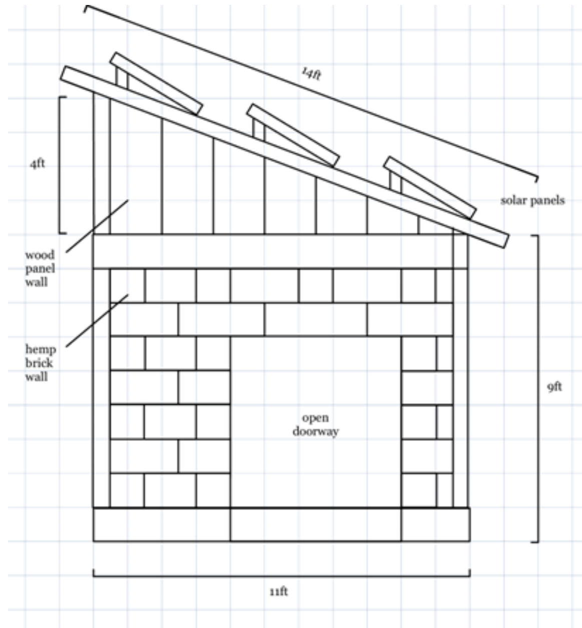


Figure 5-1: Hempcrete brick wall exterior of Bike Coop as seen from the front– digital drawing.

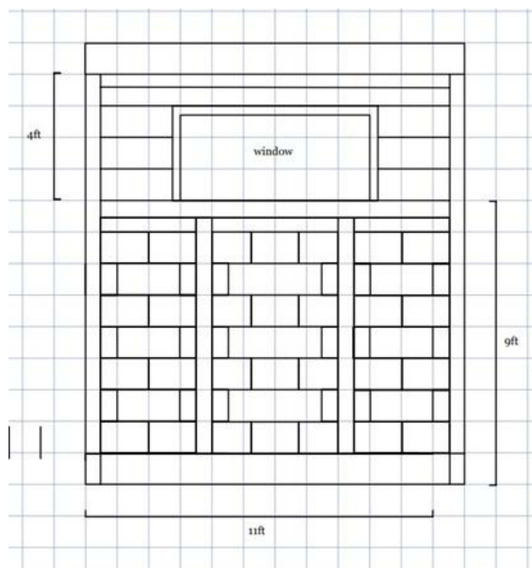
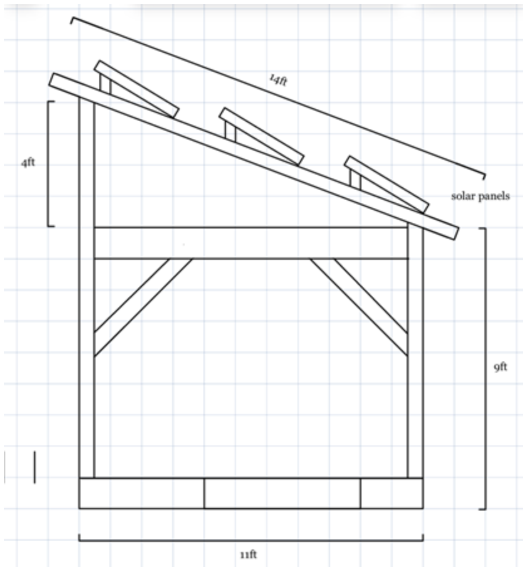


Figure 5-2: Hempcrete brick wall exterior and window of Bike Coop as seen from the left side – digital drawing.



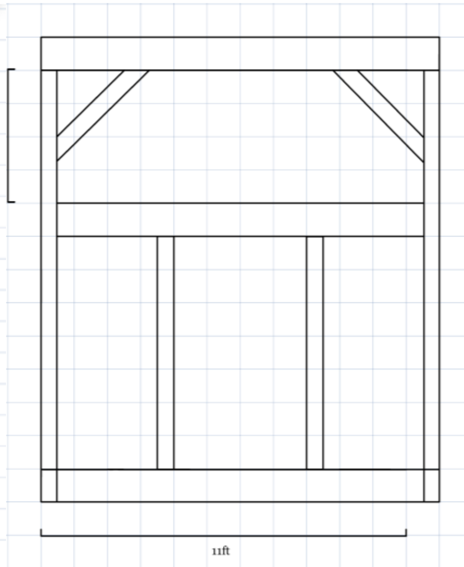


Figure 5-3 (left): Douglas fir wood frame of Bike Coop design as seen from the front - digital drawing.

Figure 5-4 (right): Douglas fir wood frame of the Bike Coop design as seen from the front - digital drawing.

5.2.2 Interior Layout

As seen in **Figure 5-5** and **Figure 5-6**, the interior layout of the final Bike Coop design is 12 feet wide x 11 feet long and the ceiling stands 9 feet tall. A doorless, 5-foot-wide entrance on the street-facing side of the structure allows for easier access for end users. The structure houses six circular steel bike racks: three racks angled 45 degrees along the left wall and three more perpendicular to the back wall which supports bike charging. The interior is divided into two levels, with the upper 4-foot-tall attic space hosting the battery storage compartment directly above the distribution panel on the first level. Three 12 V 2.5 kWh lithium-ion batteries are in the attic space locked in a battery storage compartment. The second floor of the structure can be accessed via a ladder. Two hanging light panels and two security cameras are mounted to the ceiling, providing lighting and safety measures for end users. There are bike storage lockers placed near the entrance for the convenience of end users, which will bring personal padlocks.

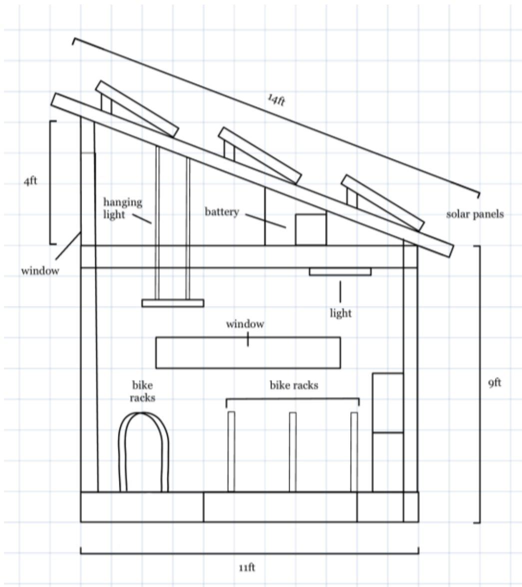


Figure 5-5: Interior of the Bike Coop design (open front view).

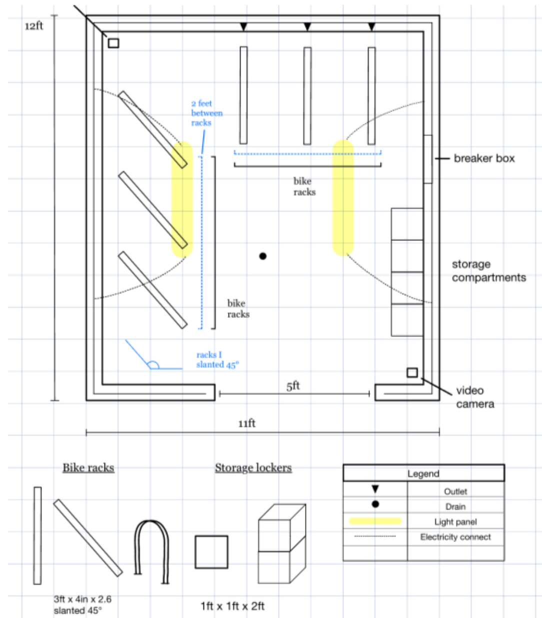


Figure 5-6: First-floor interior of the Bike Coop Design (frontal aerial view).

5.2.3 Bike Racks

The Bike Coop design will host six circular steel bike racks, 35'' long x 2.5'' wide x 33' tall. These racks will line the inner walls of the structure with a minimum of 2 feet between each rack to maximize space and allow for greater accessibility. Three bike racks will be angled 45 degrees along the left wall and the other three will line the back wall perpendicularly. The bike racks are made from galvanized steel and have a capacity of 2 bikes, one on each side.

Figure 5-7: Circular steel bike rack (ULINE, 2014).

5.2.4 Security System

5.2.4.1 Camera

The Bike Coop design will utilize Amcrest's 5MP Analog Camera Turret A5TN28-W for camera surveillance. Maintenance of these cameras involves cleaning the lenses, looking for wear or damage, and updating firmware on the camera. This will be purchased from the official Amcrest website or other internet merchants, such as Amazon or B&H Photo Video. This 5MP analog camera is frequently used for monitoring applications. Depending on the demands for surveillance, it can be mounted indoors or outside. The camera will be connected to a compatible DVR (Digital Video Recorder) to record activity around the Bike Coop. Two 5MP analog cameras will be used in our design, one camera will be standing in the very back on the (left hand back wall when facing the entrance) facing the entry and out to the street, while the second camera faces the bikes, right by the entry.

Figure 5-8: Amcrest's 5MP Analog Camera Turret A5TN28-W

5.2.4.2 Power Supply

The SPT 12-Amp, 9-Port CCTV Power Supply costs $78.18 at Lowe's. This power supply doesn't require much maintenance other than the occasional inspection for loose connections or dust accumulation, power supply boxes usually require little maintenance. To avoid overheating, make sure there is enough ventilation. You may purchase it online or at Lowe's hardware shops. This Power supply can use Up to nine CCTV cameras and can have their power distributed centrally by using this power supply box. It is usually connected to a power source close to the surveillance system setup. The CCTV system can then power on by plugging the power wire from each camera into a connector on the box. The power supply can be positioned in the upper storage compartment of the bike cage design.

Figure 5-9: SPT 12-Amp, 9-Port CCTV Power Supply

5.2.4.3 DVR

Pricing for the Dahua 4-Channel 5MP Pentabrid DVR (XVR5104H-S2 USA Version) varies depending on the reseller, although DeluxeCCTV used to sell this DVR for about $119.00. Updating software, verifying recording storage capacity, and proper ventilation to prevent overheating are necessary for maintenance. Software is obtained via approved Dahua distributors or the DeluxeCCTV website. Surveillance camera footage is recorded and stored on this DVR, or Digital Video Recorder, pictured in **Figure 5-10**. The DVR has multiple recording modes, including scheduled, continuous, and motion detection recording, and supports up to four channels. An analog, HD-CVI, HD-TVI, AHD, and IP camera can be linked to it, giving setup versatility for surveillance systems. It can also be viewed and played back remotely via the internet in real-time. This can be placed in the upper storage compartment.

Figure 5-10: Dahua 4-Channel 5MP Pentabrid DVR

5.2.5 Solar Panels

As seen in **Figure 5-9**, the solar panel design of the Bike Coop will incorporate six 6 ft x 3.25 ft monocrystalline solar panels arranged in three rows angled perpendicularly from the street-facing wall. Two of these solar panels will be linked together and mounted to the roof with a steel mount at an approximate 38-degree angle from the horizontal to maximize exposure to the sun during the spring and fall seasons. The roof will be angled at approximately 21 degrees from the horizontal and the mounts will add a 17-degree tilt, indicated by blue in **Figure 5-11**.

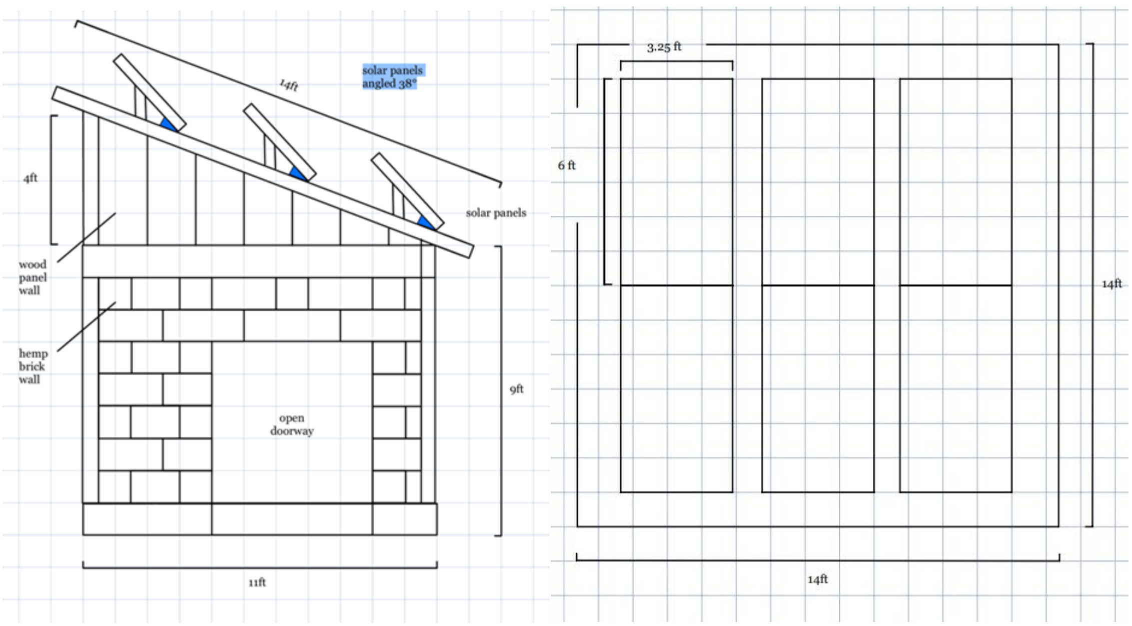


Figure 5-11:: Front view of solar panel orientation and angle indicated in blue - digital drawing (left).

Figure 5-12: Frontal aerial view of the Bike Coop design's solar panel array - digital drawing (right).

The solar panels will be sourced from online retailers such as Renogy 400 Watt 12 Volt Solar Panels (Figure 5-10) or similar 12V models with a maximum yield of 400W of electricity per panel. The Renogy 400 Watt 12 Volt Solar Panels retail for around $450.00 per four panels on Amazon.com, so we estimate the total cost for panels will be approximately $700.00. The solar panels must be mounted to a sturdy steel mounting rack such as the Samlex 28" Adjustable Solar Panel Tilt Mount [ADJ-28] (Figure 5-11). Each mount costs approximately $130.00 and supports one panel, totaling $780.00 approximately for all six racks.

Figure 5-13 (left): Renogy 400 Watt 12 Volt Solar Panels

Figure 5-14 (right): Samlex 28" Adjustable Solar Panel Tilt Mount [ADJ-28]

5.2.6 Electrical System

The Bike Coop's electrical system design will utilize standard monocrystalline solar panels mounted to the roof of the main structure with adjustable steel mounts. The mounts can be angled to maximize the amount of exposure the panels receive during the fall and spring semesters where usage of the bike chargers will be the highest. The electricity generated by the solar panels will travel through copper wire and water and heat-resistant conduit throughout the structure of the design. This charge controller will safely administer electricity to the battery. From there, the inverter will convert the electricity to AC suitable for charging devices such as e-bikes. Finally, the electricity runs through one last safety disconnect in case of emergency before reaching the distribution panel that the client can use to control when and where the electricity will be delivered.

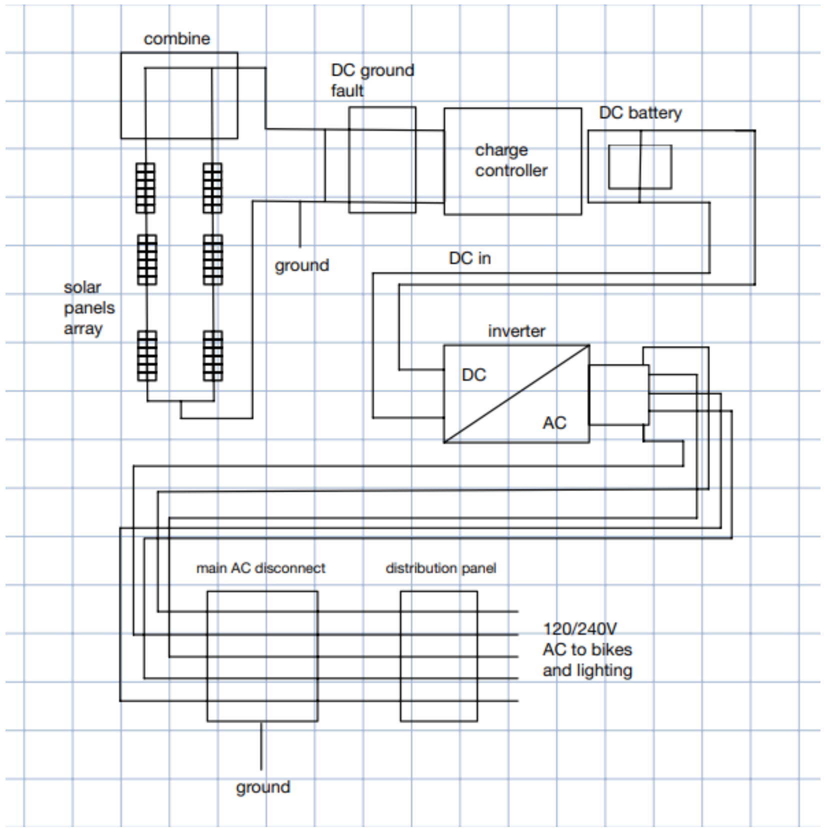


Figure 5-15: Bike Coop design's electrical system, including solar panels, charge controller, batteries, AC/DC inverter, ground disconnect, and distribution panel.

5.3 Costs

5.3.1 Design Costs

The total combined number of hours each member of Team Gatekeepers has put into designing this project is 241 hours. **Figure 5.5** is a pie graph of the total combined project time in hours for each section of this design project. The preponderance of hours spent on this project goes to Phase 5 – Specifications, which include brainstorming, decision process, final decisions, designing, prototyping, limitations, and results.

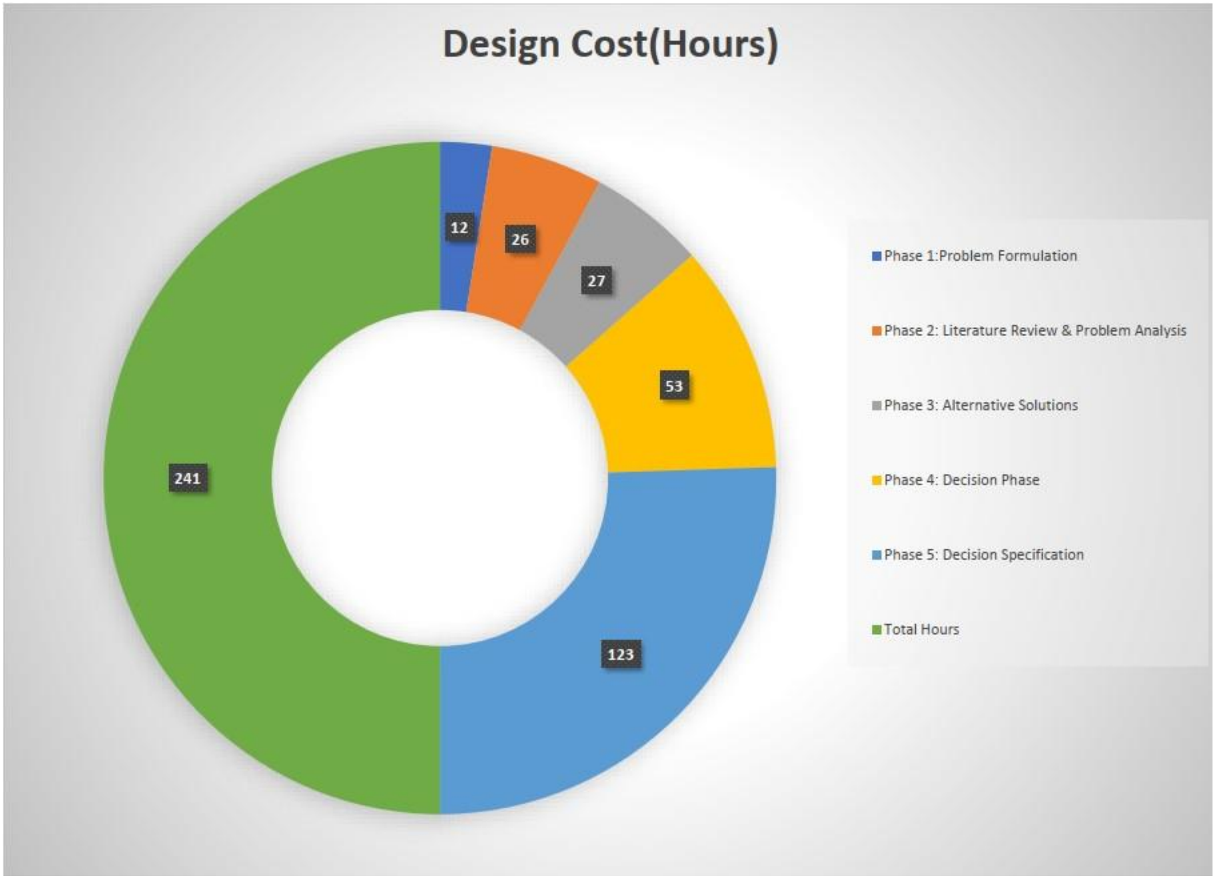


Figure 5-16: Design Cost pie graph for hours spent on each section

5.3.2 Material and Implementation Costs

The costs of materials and labor for implementation that will be used to construct the Bike Coop are shown in **Figure 5-17** and **Table 5-1**. The total cost to complete this project is approximately $48,000. However, volunteer labor and donated or recycled materials may reduce this cost by about $9,000, depending on the available volunteers and time constraints.

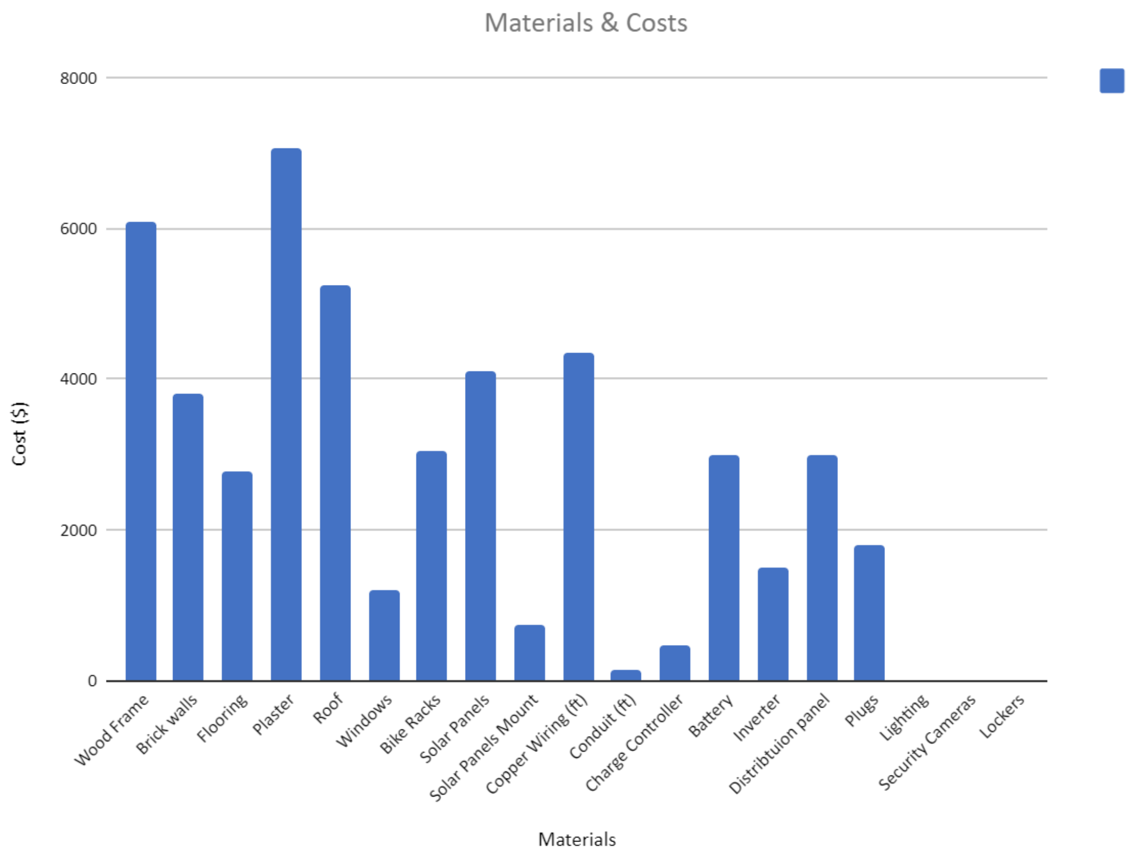


Figure 5-17: Bar graph of project materials and costs.

Table 5-1: Table of materials and costs

Items	Material	Amount	Cost	Cost of Materials	Cost of Labor / Implementation	Total	Maintenance (yearly)
Wood Frame	Douglas Fir (sq. ft)	150	$14.00	$2,100.00	$4,000.00	$6,100.00	$0.00
Brick walls	Hempcrete (sq. ft)	40	$15.00	$600.00	$3,200.00	$3,800.00	$0.00
Flooring	Hempcrete (sq. ft)	132	$15.00	$1,980.00	$800.00	$2,780.00	$0.00
Plaster	Hydraulic lime plaster	132	$41.45	$5,471.40	$1,600.00	$7,071.40	$0.00
Roof	Composite shingles	132	$14.00	$1,848.00	$2,400.00	$5,248.00	$1,000.00

Windows	Fiberglass	1	$1,000.00	$1,000.00	$200.00	$1,200.00	$0.00
Bike Racks	Steel	6	$460.00	$2,760.00	$300.00	$3,060.00	$0.00
Solar Panels	400W 12V monocrystallne panel	6	$400.00	$2,400.00	$500.00	$4,100.00	$1,200.00
Solar Panels Mount	Steel	3	$250.00	$750.00	$0.00	$750.00	$0.00
Copper Wiring (ft)	8 gauge copper / aluminum	90	$2.00	$180.00	$4,000.00	$4,355.00	$175.00
Conduit (ft)	Electrical non-metal tubing	90	$1.62	$145.80	$0.00	$145.80	$0.00
Charge Controller	100A 12V-48V charge controller	1	$480.00	$480.00	$0.00	$480.00	$0.00
Battery	48v 100Ah lithium-ion	3	$1,000.00	$3,000.00	$0.00	$3,000.00	$0.00
Inverter	12V AC/DC inverter	1	$1,500.00	$1,500.00	$0.00	$1,500.00	$0.00
Distribtuion panel		1	$3,000.00	$3,000.00	$0.00	$3,000.00	$0.00
Plugs		6	$300.00	$1,800.00	$0.00	$1,800.00	$0.00
Lighting		3	$5.00	$15.00	$0.00	$15.00	$0.00
Security Cameras		1	$40.00	$40.00	$0.00	$40.00	$0.00
Lockers		1	$400.00	$400.00	$0.00	$400.00	$0.00
				Total	**$9,600.00**	**$ 48,845.20**	**$2,375.00**

5.3.3 Maintenace Costs

The total maintenance cost of this design is $2,375 yearly. Yearly maintenance on solar panels, electrical wiring, and roofing will be necessary to ensure safety and longevity. Typically, the solar panels will be replaced every 25 years. The roofing will need to be replaced every 20 years. **Figure 5-18** contains a bar graph of our projected yearly maintenance costs.

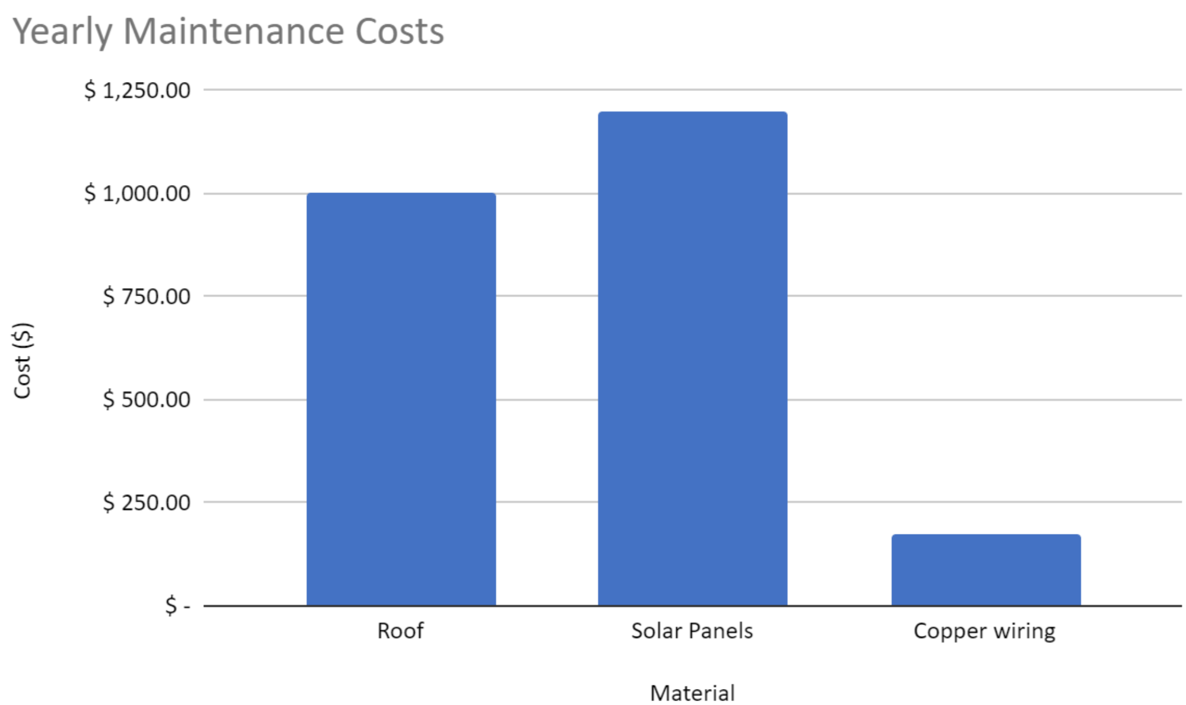


Figure 5-18: Bar graph of yearly maintenance costs.

Table 5-2: Table of maintenance costs

Material	Maintenace Yearly Cost
Roof	$ 1,000.00
Solar Panels	$ 1,200.00
Copper wiring	$ 175.0 0
Total	$ 2,375.00

5.4 Prototyping

Prototyping the Solar Powered Bike Cage demonstrated the dimensions, overall layout, and logistics of the design in application. This section portrays the evolution of prototype designs through photographs as we continued to assess and experiment with different design features.

5.4.1 Bike Coop- Prototype #1

This is the first prototype of the bike coop design. The interior is separated into two rooms, the bike storage room, and the solar energy storage room with a door between the rooms to allow access to both rooms. The bike storage room has two windows on each sidewall with a garage door that can be lifted upward to open the entrance. There are 7 wall-mounted bike racks for the storage of bikes. It has a gable roof design with 3 solar panels, one in front and two on the side. The result of this prototype is that the client liked the storage design but wanted to change the roof, walls, entrance, window, and room design.

Figure 5-19: Bike Coop Design #1 (front view).

Figure 5-20: Bike Coop Design #1 (above view).

5.4.2 Bike Coop – Prototype #2:

This is the second prototype of the bike coop design. Based on what the client said about the first design, the design changed from a gable roof design to a shed roof design for maximum panel coverage. There is a ramp that leads to the entrance with no door for ease of access. There is a single solid wall on the left side while the back and right walls are made of a layer of fencing and clear plastic for lighting. There are two wall-mounted bike racks on the left wall and two racks on the floor for bike storage.

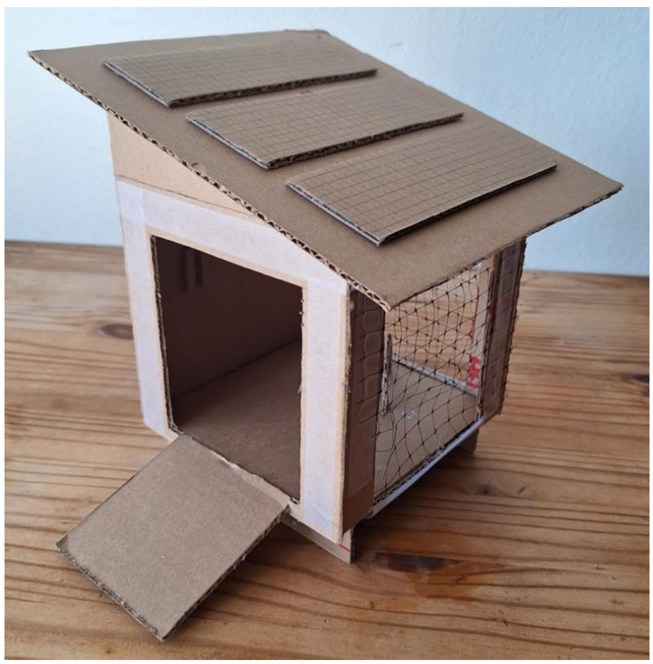


Figure 5-21: Bike Coop Prototype #2 (front)

Figure 5-22: Bike Coop Prototype #1 (above)

5.4.3 Bike Shed – Prototype #1:

This is the first prototype of the bike shed design. It is 12ft x 11ft x 9ft tall and is constructed from hempcrete walls, a wood frame, and an open gable roof. One sliding fiberglass door opens into one central room for bike storage. This design incorporates a connected outside breaker box / shed that houses the electrical system of the structure. This feature was removed in later prototypes because of a lack of space surrounding our structure.

Figure 5-23: Bike Shed Design Prototype #! (front)

Figure 5-24: Bike Shed Prototype #1 (back)

5.4.4 Bike Shed – Prototype #2

This is the second design of the bike shed design. Like the previous bike shed design, this design incorporates wood and a window fence design for aesthetics. Additionally, the sliding door is present and covers the entire street-facing wall for a wider opening for users to walk in and out of the structure. The door proved difficult to effectively implement.

Figure 5-25: Bike Shed Prototype #2 (front side)

Figure 5-26: Bike Shed Prototype #2 (side)

5.5 Instructions for Implementation and Use

For implementing our project, we must dig at least a 1.5ft deep hole that is 12ft long and 11ft wide for the foundation and then implement a ramp into it against the sidewalk. Then we will start building the walls and support pillars out of hempcrete and concrete with the walls being about 0.5 ft thick, and the support pillars being about 1ft in diameter. While building the walls, we will outline the windows which are 1ft tall and 5ft wide and are made of fiberglass and the doorway which is 6ft tall and 5ft wide. Afterward, we will start building the roof made from Douglas fir and implement the solar panels. Then we will attach a shelf near the ceiling to hold the solar batteries and then add the cables, charge controller, and DC/AC inverter next to the batteries on the back wall. Then we will drill in 6 bike racks into the floor and arrange them at an angle for optimum storage. We will then install the lights, camera, motion sensor, outlets and all the wiring and connect them to the electrical system. Finally, we will add 6 storage lockers on the right-side wall and a sign near the outside entrance saying "Public E-Bike Storage" to let people know that they can use the building to store their bikes. To use our project, people must first walk their bikes into the building and then park and lock their bikes into one of the 6 bike racks available, three of which will have charging capabilities. There are also storage lockers available for people to use but they must provide their own personal locks to use them unless they don't care about security. To maintain our project, we must clean the solar panels and check the batteries, DC/AC inverter, and all the electrical components within the building to make sure all are working correctly and are not damaged or worn down.

5.6 Results

5.6.1 Final "Bike Coop" 3D Model

The results from our testing and feedback from our client were very positive. However, since this project is limited to designing and modeling a bike cage, testing the final design is not currently possible. Moreover, our projections for costs and charging capability, in conjunction with overall positive feedback from the client, are reassuring. Our bike cage is successful in design and functionality because it can store 6-8 bikes and provide charging capability for e-bikes through 100% solar-generated power.

5.6.2 Overall Design Efficiency

We anticipate that in the 10 months that our design will be most used (August to May, fall and spring academic semesters), our design will generate approximately 1.4 MW of electricity. This will provide enough electricity to power nighttime lighting, 24/7 camera surveillance, and 3 hours of standard e-bike charging daily.

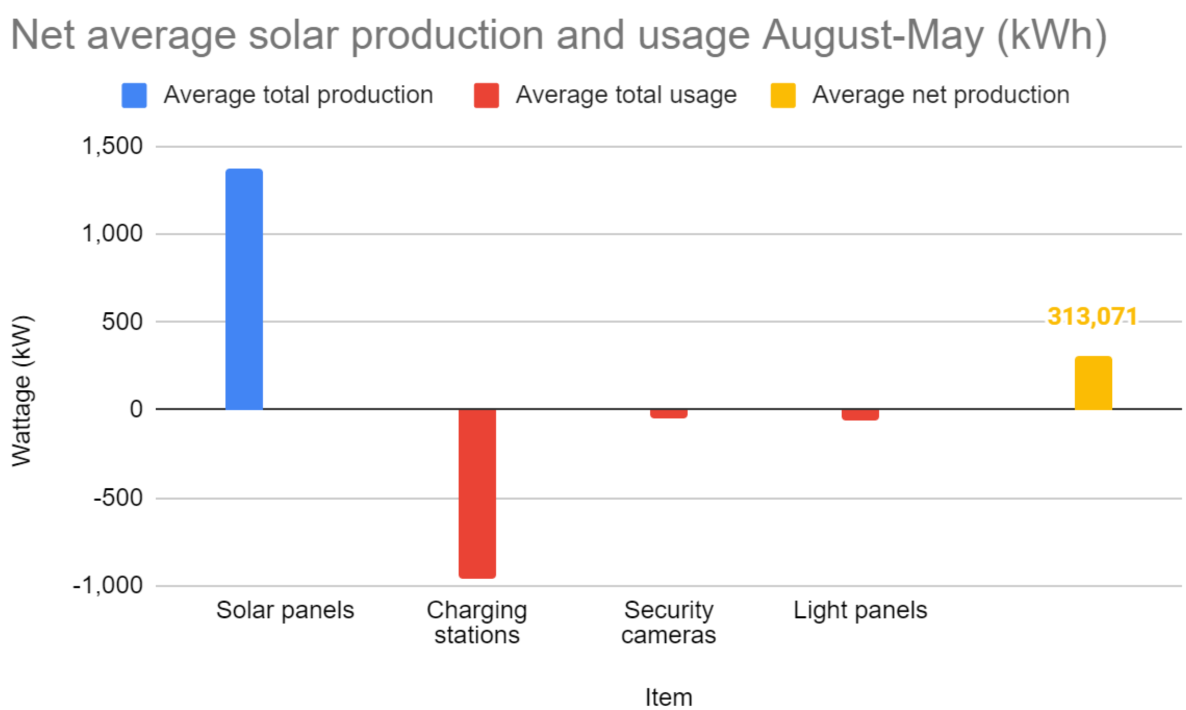


Figure 5-27: Bar graph of net solar production and usage.

5.7 Limitations

Parts of the final "Bike Coop" 3D model are scaled incorrectly due to the available 3D printer's inability to print smaller objects. The final 3D model also lacks finer details, such as the lights, outlets, cables, batteries, and cameras from our drawings due to the 3D printer's inability to print smaller objects. Our specifications in this document do include all these features.

5.8 Conclusions

Our "Bike Coop" design for the "Solar Powered Bike Cage" ENGR 205 Spring 2024 final project was overall successful because the project criteria were fulfilled.

6 Appendix

6.1 References

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