GNG2101

Deliverable C -Conceptual Design and Project Plan

Submitted by

Team 1.1

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ABSTRACT

Our team met together to generate general idea concepts for solutions to help build a system for the client to generate enough power through human movement to power a set of grow lights for a suitable duration of time. This meeting started with a brainstorm for our functional development charts for both the user flow chart and system flow chart. All group members shared ideas to generate a creative and inspirational list of potential solution possibilities. All solutions were then evaluated using a weighted metric with our target specifications previously stated in Deliverable B. Calculations of power output and light output are also provided. In the end, a chosen concept of a pedaling system was developed, evaluated and an early design process generated.

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1 INTRODUCTION

The purpose of this deliverable is to functionally decompose the problem of creating a human-powered lighting system for plants. The problem was decomposed into basic functional subtasks. Afterwards, concepts were generated in order to produce potential solutions for accomplishing these tasks. The generated concepts were then analyzed and evaluated against the target specifications presented in Deliverable B. The rationale behind the evaluation is discussed and the chosen concept is presented. Finally, the preparation for the next client meeting is outlined. This deliverable provides the necessary information and baseline for the development of the first prototype.

2 FUNTIONAL DECOMPOSITION

The following section will describe the functional decomposition that was conducted for this project. The overall function of the system is to power lights that will be used to grow plants. Furthermore, the energy used to power the lights must be human powered. Therefore, decomposition of the system is as follows: human/mechanical energy will be converted to electrical energy. The electrical energy that is converted will be stored for later distribution. The stored energy must be distributed to the lights and finally the lights must be actuated to apply light energy to the plants. Figure 1 shows a block diagram of the overall function of the system, decomposed into sub tasks.

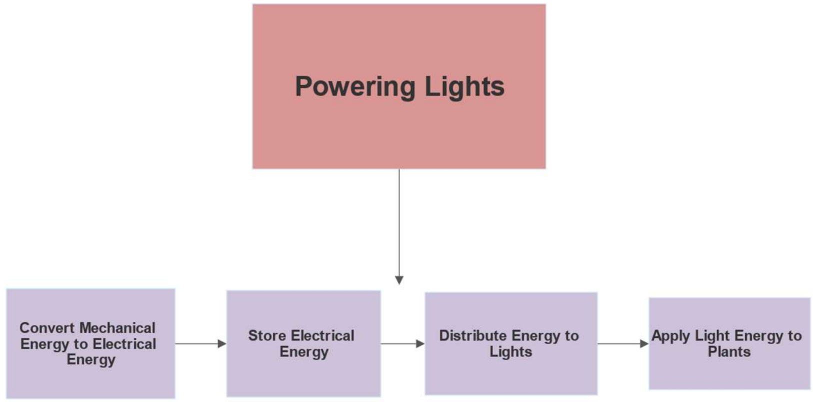


Figure 1: General Functional Decomposition

The user's interaction with the system is described with the flowchart in Figure 2. The rationale for the decision blocks is as follows. One of the customer requirements is that the system should not require an excessive amount of time to operate. Therefore, if the user is tired, the user will stop. Furthermore, if the energy storage is full, the user should stop for safety reasons.

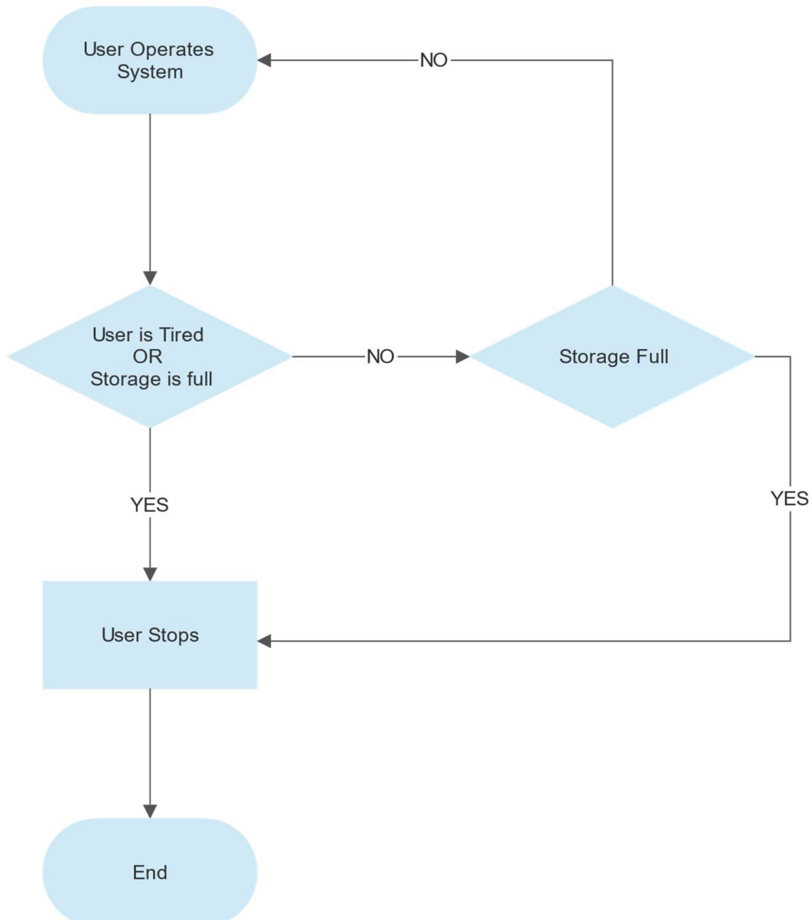


Figure 2: User Flow Chart

The overview of the system's operation is as follows. While the user is operating the system, the user's output will be converted to electrical energy and then stored. If it is not appropriate to actuate the lights, the system will do nothing. If it is appropriate to actuate the lights, the system will check if the energy levels are adequate. If the energy levels are not adequate, the system will not actuate the light to protect the energy storage. Finally, the system will turn off the lights when operation is no longer needed.

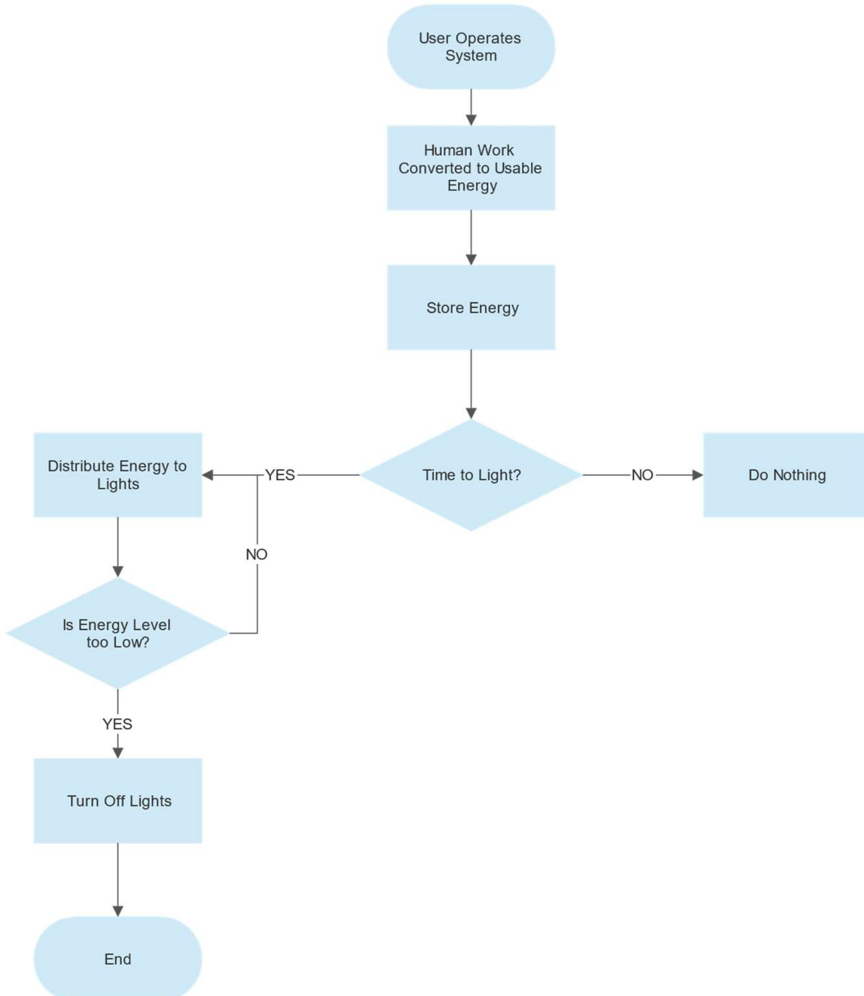
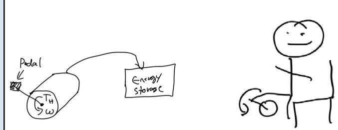
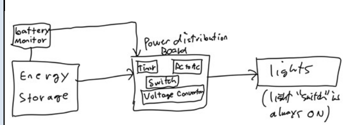


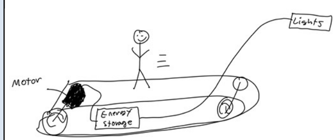
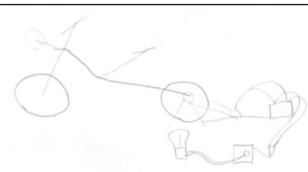
Figure 3: System Flow Chart

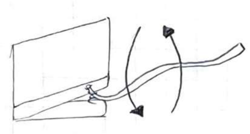
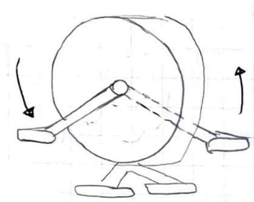
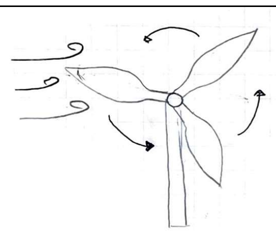
3 CONCEPT GENERATION

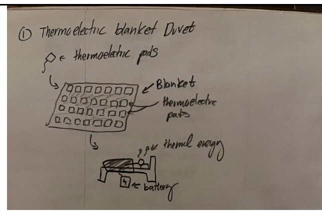
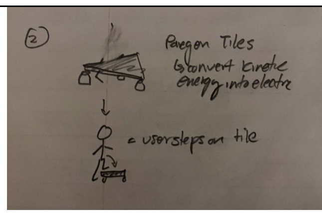
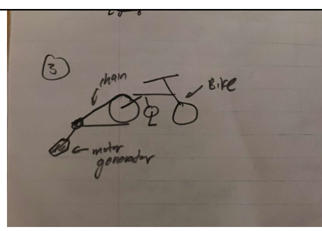
To promote diversity and creativity after an initial meeting where the functional decomposition occurred each group member was responsible to generate 3 minimum concepts. These concepts could address any part of the functional decomposition. The concepts including a sketch and a brief description outlining the advantages and disadvantages is recorded in the table below

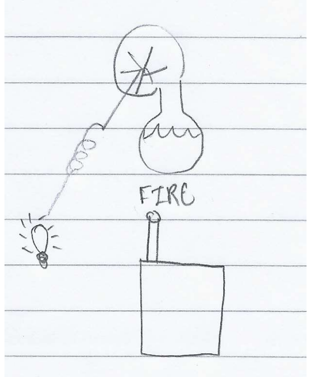
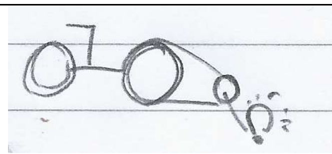
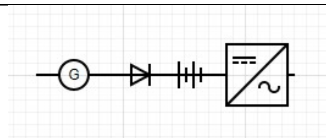
Table 1: Concept Generation

Concept #	Sketch	Description (Advantages/Disadvantages)	Group Member
1		Human Unicycle Generator: The user would be sitting on the chair and pedal only using one foot to generate and store power. The pedal would be attached to a small motor that is mounted on the ground. This has the advantage of being a simple design and therefore more cost effective since less components are needed. However, this design is somewhat inefficient as the user may find it difficult to generate enough power for a sustained period since the user is only using one leg.	Amit
2		Automatic Power Distribution System: This concept is designed for the subtasks of distributing energy to the lights and applying light energy to the plants. With this design, a custom electronics board would be built with a DC to AC converter (power for the lights), a switch (actuation for the lights) and a timer (apply light energy to the plants for an appropriate amount of time. This design has the advantage of having a high degree of control with respect to energy consumption	Amit

		and would allow for less system operation time.	
3		Human Treadmill Generator: This concept uses a treadmill to spin a generator. The user would use the treadmill as an exercise machine while charging the energy storage. This design has the advantage of providing a source of power that is not too time consuming. However, this design has the disadvantage of having a high cost and the power generation may not be sufficient if the user walks on the treadmill.	Amit
4		Recumbent cycle generator: Bicycle and bicycle derivates remain the most efficient way of generating power from human work. Despite this, it is still not enough to power a moderately-sized array of grow lights without making changes to ergonomics and comfort. The recumbent bicycle would allow the client to perform work while in a lying position, distributing body weight over a larger area, which could help alleviate discomfort from cycling for a long duration. A large foam seat could further help with comfort. A recumbent design would also grant a mechanical advantage since the client would be cycling faster with the legs forward.	Josh
5		Thermoelectric harvester: One or two thermoelectric pads can be used to generate electricity from the heat of the client. This effect is greater when the client is undergoing rigorous physical activity, such as running. The pad(s) are attached to a power bank or battery. However, a cursory analysis indicates that one hour of activity would only power the lowest-powered grow light on Amazon for half an hour, so this is not feasible.	Josh

6		Human-sized hamster wheel: An alternative to motor-powering human activity would be to build a wheel large enough for the client to run on. There are many issues pertaining to safety and large footprint, amplified to the lack of experience from the team required to build a reasonable prototype. This, coupled with its poor efficiency, means this idea is relegated to a novelty.	Josh
7		Sewing Pedal. The user repeatedly presses their foot up and down on the pedal. This method transforms the mechanical kinetic energy of the foot into electrical energy. A large drawback is doing this for too long will cause the user pain. To partially alleviate this issue the user can switch the foot pedaling to give each foot a break. Additionally, this is not an effect method of transferring energy and would require a lot of time. Due to the small size and that no hands are needed the client could be generating energy as she works through the day	Carly
8		The most abundant solution of human powered devices currently available was biking. The rotational motion has kinetic energy which is transferred to electrical energy. Biking a mode of power is used worldwide. Benefits to this concept specifically is by just including the pedals the client could place this under her desk and use it while she works.	Carly
9		This concept combines human powered element and the popular green energy solution of a wind turbine. This idea is a breath powered turbine. This method has breath creating a rotational motion of the blades which is converted to electrical energy. This method has major drawbacks	Carly

		which include not efficient it would take the client a lot of work and could risk hyperventilation. A large advantage to this concept is that it would cause no joint pain as there is no repetitive joint movement	
10		Thermoelectric pads are organized and placed inside a heavy duvet blanket. User sleeps with the blanket overnight and the thermal energy radiated during the 8 hours of sleep charge the thermoelectric pads and is stored in a battery. This would be an effortless way to generate electricity consistently using human power.	James
11		Inspired by Pavegen, tiles that convert kinetic energy into electric energy. Pavegen has been researching into converting the energy of an office working sitting in a chair on a tile into electrical energy. User steps on the tiles on the prototype, and the step causes the vertical displacements in the generators, which causes the internal coil to start spinning and generate electricity.	James
12		Bike generator, user pedals on a stationary bike which will power a generator with help of a chain belt and back wheel the back wheel. Requires more physical effort. It would be interesting to see if the required effort to pedal bike can be reduced with an implementation of extra in chain belts. (Much like how adding pulleys reduces the effort required to lift an object up)	James

13		Collecting food scraps to harvest biogas, combusting the biogas using a Bunsen burner and using the heat to boil water to power a steam turbine and spin a generator to get electrical energy and power the lighting system.	Alison
14		Removing the rear bike tire and attaching a V-belt to the client's pre-existing bike. The V-belt can then be attached to a generator to harvest mechanical energy.	Alison
15		Using a generator, diode, battery, and inverter in sequence to get electrical energy.	Alison

4 ANALYSIS AND EVALUATION

4.1 Target Specifications Evaluation

Using Deliverable B, the target specifications were used to evaluate the generated concepts. Table 2 lists the target specifications including the ideal and marginal values. Table 3 groups the concepts that are encompassed by a pedal concept and evaluates them against the target specifications. Table 4 uses a decision matrix with weights added to the target specifications to further evaluate the concepts.

Table 2: Target Specifications

Metric ID number	Metric Description	Unit	Marginal Values	Ideal Values
1	Footprint	Feet (ft^2)	<20	16
2	Light	Lumens (lm)	500-1600 lumen	1000 lumen
3	Speed	Revolutions per minute (RPM)	<159	61
4	Time (lights)	Hours (Hr)	>6	8-14 (mimic natural daylight)
5	Time (power generation)	Minutes (min)	<90	45
6	Cost	Canadian Dollar ($)	<100	80
7	Weight	Kilograms (kg)	<50 kg	<30 kg

Table 3: Pedal System Evaluation with Target Specifications

Pedal system	Footprint	Light	Speed	Time (lights)	Time (power)	Cost	Weight	TOTAL
Unicycle	5	3	1	2	1	3	5	20
Sewing Pedal	5	3	2	2	2	3	5	22
Recumbent cycle	2	4	3	3	4	2	2	20
Stationary bike	2	4	4	3	4	4	2	23

Table 4: Decision Matrix with Weighted Target Specifications

Pedal system	Footprint	Light	Speed	Time (lights)	Time (power)	Cost	Weight	SCORE
Weight	**0.05**	**0.15**	**0.15**	**0.25**	**0.25**	**0.10**	**0.05**	
Unicycle	0.25	0.45	0.15	0.50	0.25	0.30	0.25	2.15
Sewing Pedal	0.25	0.45	0.30	0.50	0.50	0.30	0.25	2.55
Recumbent Cycle	0.10	0.60	0.45	0.75	1.00	0.20	0.10	3.2
Stationary Bike	0.10	0.60	0.60	0.75	1.00	0.40	0.10	3.55

Footprint: The unicycle and sewing pedal had the smaller footprints compared to the two bicycle designs. However, the client allocated enough space to fit the latter designs, hence why this target specification was given a minimal weighting.

Light: Out of the four designs, the recumbent cycle and stationary bikes would have the greatest light output and would power the lights at greater lumens. The unicycle and sewing pedal, though compact, were given a lower rating due to their comparative inferiority in terms of producing a sufficiently bright light.

Speed: The speed at which the client turns the wheel and turns a motor is the key metric to determine mechanical efficiency. The unicycle fared the worst out of the four designs as that would be too unwieldy for the client to use for an extensive period of time. The sewing pedal ranks low in this matter. The recumbent cycle sought to work out optimizations in cycling speed, but in the end the stationary bike would be the most efficient design in terms of cyclical power.

Time (Lights): The time for the lights to be illuminated is weighted the heaviest out of all the target specifications, as it is the necessity for which the client's grown vegetables need to grow and survive. The unicycle and sewing pedal will likely have a low power output, and thus can only power the grow lights for a few hours before depleting, far less than what is needed for the plants. The traditional bicycle designs fare better and meet the marginal values for the time required if the client uses grow lights that require low power.

Time (Power): The time required for the system's user to provide mechanical energy to the system. The recumbent bike and stationary bike were the superior choices in this category as they used the most human muscle groups and allow the systems user to input the most energy in the shortest amount of time. The unicycle and the sewing pedal did not fare as well as they use smaller muscle groups so the user will need to spend more time to achieve the desired energy output.

Cost: The stationary bike had the best rating for cost because the client already has a bicycle and the only costs needed would be towards the electronic system and for building the stationary portion of the bike. The recumbent cycle had the lowest rating because the team would have to buy a whole new system as it isn't logical to build one. The sewing pedal and unicycle also had good ratings because there would be little cost to building the systems. The cost for these systems that put it back behind the stationary bike was the cost in time it would take to sketch, design, and build the system.

Weight: Weight was not weighted as much as the other target specifications as the client implies the design will remain stationary in her apartment. The unicycle and sewing pedal weigh significantly less than the bulkier bicycle concepts.

Of note is the importance of conducting a weighted decision matrix. Despite the recumbent cycle ranking second in the weighted matrix, it was ranked tied for last in the evaluation without the weights. The unicycle may be an interesting design if the client requested a compact and portable power generator, but with the weights that were determined, it would not be the best one to execute.

4.2 Sample Calculations

Power generated with rotation can be defined with the following equation.

$$\dot{W}_{ideal} = T\omega$$

Where T is torque and ω is angular velocity. In reality, the power exerted by the user on the system will not be equal to the energy outputted by the lights. This is due to losses in the drive train, energy conversion from mechanical to electrical energy, and distribution to the lights. The efficiency of the system can be defined as the following.

$$\eta = \frac{\dot{W}_{actual}}{\dot{W}_{ideal}}$$

The power outputted by the lights can then be expressed as the following.

$$\dot{W}_{actual} = \eta \times \dot{W}_{ideal}$$

It is nontrivial to determine an efficiency at this stage in the project as the efficiency is dependent on a variety of factors based on the components used. Therefore, actual efficiencies will be determined based on what components will be used in the future. This is essential for determining the required runtime for adequate plant lighting. Furthermore, the next client meeting will be used to estimate the client's preferred torque and angular velocity based on their current cycling gear selection. Figure 4 shows sample calculations for how the light bulbs will be arranged.

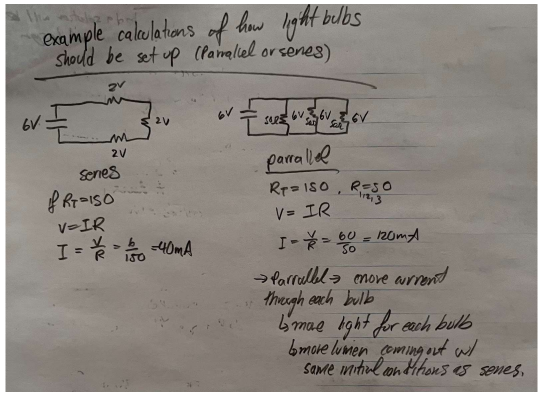


Figure 4: Sample Calculations to Determine How Light Bulbs Should be Aligned

5 CHOSEN CONCEPT

The chosen concept is to take the client's pre-existing bike and attach a system that can be used to harvest mechanical energy and power her lighting system. This will be executed by removing the rear tire and using a V-belt in its place. The V-belt will be connected to a generator where the rotation of the bike will be used to power the generator. The generator that will be used is a DC motor. The rear wheel will also be replaced with a smaller wheel, so the generator experiences more revolutions. The electrical energy created by the generator will then be distributed to the lights bulbs aligned in parallel using an automatic power distribution system. The automatic power distribution system will consist of a DC to AC converter (to power the lights), a switch (the actuator) and a timer (to apply light energy to the plants for an appropriate amount of time.

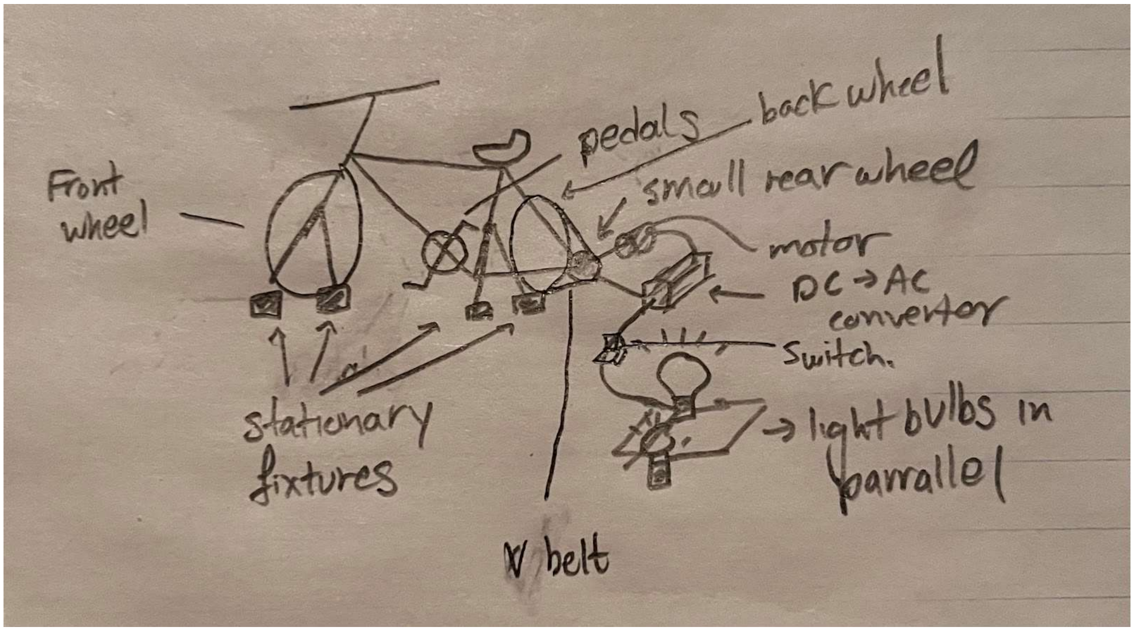


Figure 5: Chosen Concept Sketch

6 CLIENT MEETING PREPARATION

Now that an idea has been selected, client feedback is very important to refine it prior to creating the first prototype. The concept will first be presented to the client

6.1 Present Concept

The following prompts must be hit during the client meeting regarding the chosen concept:

1. The presentation will begin by presenting all the potential pedaling systems that were conceived. Client input and preferences on her preferred pedaling system should be collected.
2. The client will then be informed on the frequency, intensity, and duration she will need to power the system for.
3. In addition, the client will also be informed of the projected size and weight of the system.

4. Consultation with the client on the ideal number of plants that the system will accommodate will follow.
5. The clients experience with low maintenance plants will then be evaluated.

6.2 Ask Further Questions

After the concept has been presented, a set of questions will be asked to gauge how the client feels about it:

1. How do you feel about biking?
2. Is biking for 30-45 min manageable for you?
3. What would you consider a reasonable length of a bike ride?
4. How much do you find yourself exerting in a bike ride? (Do you really go hard or is it more of a leisurely ride?)
5. Do you have downstair neighbours that may be disturbed by the act of biking?
6. Since you have a degree in electrical engineering and are probably more knowledgeable in this topic, is there any adjustments you would suggest for the current design?
7. If you currently own a bike what are the dimensions of the tire, the weight etc.?

6.3 Assign Roles

For the meeting to run smoothly, roles are assigned to each group member. Each member is responsible for a specific aspect of the meeting.

Table 5: Client Meeting Roles

Role	Member	Description
Introduction/Conclusion	Carly	Greet the client and reintroduce the group. Thank the client at the end for their time.

Presenter	Josh	Present the chosen concept. Outline all important details, making a connection to the discussion held in the previous meeting
Questioner	Amit	After the concept is presented, this member is responsible for asking questions to prompt feedback on the concept as well as to ask questions to provide the group with information that is still missing.
Recorder	James	Record all of the client's answers given verbally. Post the client statements to the group drive so all members have access
Observation of Behavior	Alison	Record observations on how the client acts, record what excites them or what makes them visibly uncomfortable.

7 CONCLUSION

In this deliverable, the functional decomposition of the human powered light system was presented. Generated concepts were analyzed and evaluated to converge on a system that uses a pre-existing bike to which the system will attach to and harvest energy from. Based on the chosen concept, an initial prototype can be generated in the future. Further information about the problem is required, therefore the questions that will be asked at the next client meeting were outlined in this deliverable. Based on the information that will be gathered in the next client meeting, the initial prototype detailed design and bill of materials will be developed.

8 Appendix A: Concept Generation Process

The group concept generation meeting yielded a lot of creative, innovative, and interesting ideas which our group could take to solve the problem statement of designing a human-powered energy capture system capable of providing enough energy to power grow lights to grow a variety of indoor plants and vegetables. Outside the box ideas such as thermoelectric blankets, harvesting biogas, and human hamster wheels were generated to explore all possibilities, but the idea that all group members had was the idea of using a pedaling system to generate power. Pedal systems such as unicycles, recumbent cycles, sewing pedals, and stationary bikes were presented and expanded upon. Below are the pedal systems, along with their rating based on the group's criteria rating out of 5 (Where 5 is the best and 1 is the worst).

Table 66: Pedal Systems vs Group Criteria Rating

Pedal system	Manufacturability	Easy to use	Durability/ reliability	Ergonomics/ safety	Efficiency
Unicycle	3	2	4	3	1
Sewing pedal	4	4	4	4	3
Recumbent cycle	2	4	3	4	4
Stationary bike	5	5	3	2	5

Manufacturability: The stationary bike had the best rating for manufacturability because the client already has a bicycle at home that can easily be altered to a stationary bike. The other bikes such as the unicycle and sewing pedal require designing, planning and required more work to build from scratch. The recumbent cycle on the other hand would require most work to build because of how large the system is. The only feasible way to integrate a recumbent cycle into the project is to buy one, which would put the team over budget.

Easy to Use: The stationary bike had the best Usage rating because of how natural and accustomed the client is to bike on her own bike. The stationary bike allows for more pedal power to be generated in a seated, hunched over position. This would also help the client transition naturally to outdoor biking in the summertime. The Unicycle was the lowest rated idea because restricting the usage to only one foot would make it more tiresome, uncomfortable, and unnatural for the client. Although it is simple to use one foot, the trade in comfort and further unbalanced restriction of movement is not something that is ideal. The sewing pedal and recumbent cycle both offer the option for the user to sit and lean back while pedaling, making it more comfortable for the user.

Durability/Reliability: The sewing pedal and unicycle both had the best rating for durability and reliability because of how low impact the systems are. Sewing pedals require very little impact from the user, and the unicycle only has one pedal as opposed to two from the other system, allowing it to be more durable. The stationary bike and recumbent cycle are more reliable than durable. Both systems require two pedals being pushed at high impact.

Ergonomics/Safety: The sewing pedal and the recumbent bike had the best ratings for ergonomics. This doesn't come as a surprise because the recumbent cycle allows the client to lean back and cycle, and the sewing pedal allows the client to sit at a desk and effortlessly push the pedal. The stationary bike had the worst rating because of the need for a stationary system to keep the bike in place when biking, open way to more potential risk than the other systems. There is a chance that the stationary part of the bike falls apart and causes an injury to the client.

Efficiency: The stationary bike had the best rating for efficiency, this can be explained because the client is already familiar with the system, and the biking position is ore natural and mechanically generates more pedal power as opposed to if the user was sitting on a chair or leaning back. The unicycle had the worst rating because the system is unnatural to use and inefficient with only using one foot. The recumbent bike had a good rating, but the unnatural position of being seated and leaning back put it behind the stationary bike. The sewing pedal system was also lower because you can’t generate as much power sitting down on a chair as you can on a bike.