Renewable Energy Electric Bicycle

A Baccalaureate thesis submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

Christian Myers

April 2021

Thesis Advisor:

Professor Moise Cummings

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABSTRACT

As senior mechanical engineering technology students at the University of Cincinnati in the College of Engineering and Applied Sciences, we are required to complete a senior design project as a capstone to our years of studies. The senior design project must be a unique design that applies all the knowledge gained during our time as students and apply it to address a problem in society today. This project tasks students the responsibility of going through the entire engineering design process to address the problem and requires them to locate their funding independently to build the project. Our senior design project is a renewable energy e-bike. We intend to design, test, and manufacture a solar powered electric bike that also encapsulates normally wasted kinetic energy during braking, into electrical energy.

PROBLEM DEFINITION AND RESEARCH

PROBLEM STATEMENT

With the increased global use of energy driving gas prices to new highs, as well as the harmful environmental impacts caused from the by-product of combustion engines, new “green” alternatives to transportation are needed now more than ever. Our team has decided to tackle a segment of this increased energy consumption problem by applying modern technological advances in energy production to the bike industry. We intend to design, test, and manufacture a renewable energy powered electric bike that encapsulates normally wasted kinetic energy during riding along with solar energy, into electrical energy. We intend for our bike to be street legal and able to travel up to 20mph with a battery range of 25 miles with a price-to-build of around $1,000.

RESEARCH

BACKGROUND AND SCOPE OF THE PROBLEM

History of the problem

Modern automotive technology is leaning more and more toward green alternatives such as electricity, compared to combustion. For example, Toyota, who’s vehicles produce 80% of the hybrid vehicle global market, plans to make half of its vehicle sales electrified vehicles by 2025 [1]. Furthermore, emission regulations are getting more strict by the year [1]. Our bike plans to advance on this trend and provide a cost effective and energy efficient transportation method for small urban areas across the globe such as college towns, crowded cities where cars are too congested, parks, and street markets across the globe, all while cutting down on harmful emissions.

Why the Problem Needs Addressed

Currently 99.8% of global transport is powered by internal combustion engines (ICEs) and 95% of transport energy comes from liquid fuels made from petroleum [2]. Carbon Dioxide, carbon monoxide, sulfur dioxide, nitrogen oxides, and lead are a few of the products released into the atmosphere from combustion engines [4]. Carbon Monoxide is a component of motor vehicle exhaust, which contributes about 55 percent of all CO emissions nationwide [4]. Battery electric vehicles are a great catalyst to restrict the release of the harmful chemicals to our environment. Compact battery electric vehicles produce 15% CO2 emissions compared to a mid-sized combustion engine [4]. This is great data that points to why electric vehicles can be a healthy and short term fix to the environmental impact of transportation vehicles.

Not only is the environmental impact less strenuous with battery electric vehicles than it is with combustion engine vehicles, but also the maintenance savings related with battery electric vehicles is much cost effective. Battery electric vehicles have a 20% cheaper cost of ownership over a 20 year period. The price per kilowatt hour, tangled with the simplicity of electric drivetrains is an appealing trait to battery powered vehicles.

Solar Bikes have already been created, but they do not exceed long distances. There also not bikes which reuse kinetic energy which the bike gives off. With our idea we hope to take this next step in the electric bike industry.

To accomplish our goal our bike will be powered by 100% renewable energy, utilizing solar power from the sun and kinetic energy produced by the bike to supply power to the drivetrain. The magnitude of the problem includes creating a battery unit that is charged by kinetic energy and solar panels that are able to rotate along multiple axes to capture optimal sunlight. The goal is to be able to carry a 250lb load at a max speed of 20 mph for 25 miles on a single charge. To execute this build we will need to retrofit a current bike frame or create a new bike frame, create an adequate suspension system, configure a system to capture the kinetic energy of the bike and create an actuated solar panel system that rotates based off of where the most sunlight is coming from. Safety will need to be a top priority to ensure the driver is safe during travel. To do so, we will need to make sure our bike adopts all federal and local transportation regulations including brake lights, head lights, rear-view mirrors, and turn signals.

CURRENT STATE OF THE ART

E-Bike Current State of the Art

Bicycles have been around for centuries. It was only a matter of time for some sort of system that allowed for electrical assistance during biking to be invented. One of the earliest e-bikes was invented in France in the late 19th century, utilizing a hand-lever system to propel the bike[3]. Today, e-bikes are typically propelled by either hub motors or direct drive motors. Most models use a 7.5 lb, 48V, 14 Ah Lithium-Ion battery with a 30 Amp continuous Battery Management System (BMS) and genuine Samsung 35E cells, rated for 800 full charge cycles[3]. These batteries can be charged by typical outlets without the need of any adapters. These bikes also use a Pedal Assist System(PAS) where the user pedals with the motor. This helps with extending the life of the e-bikes battery. Some newer models have a regenerative braking feature which recharges the battery while the brakes are being applied. Inside the direct drive motor, copper windings are powered by the battery to drive an outer ring of magnets that spin the wheel, which puts the power in your pedal. When either the front or rear brake levers are squeezed (like when coming to a stop or riding downhill), a signal is sent to the motor controller, which changes the motor into a generator, quickly converting some of the momentum of the bike into electricity to charge the battery[6].

Figure 1: Rad Power Bike

The Rad Power RadMission1 uses a 500W gear hubbed motor that is powered by 48V 10.5 amp lithium-ion battery that gets 25-40 miles per charge, at top speed of 20mph and a charge time between 3-7 hours. The cost of this bike is $999.

Figure 4: E-Trek
Figure 2: Ecotric Seagull Mountain Bike

The Ecotric Seagull mountain bike uses a 1000W motor powered by a by 48V 13 amp lithium-ion battery that gets 35 miles per charge. Its top speed is 20mph with a charge time between 6-8 hours. The cost of this bike is $1259

State of the Art Chassis/Suspension

Currently there are not many solar powered e-bikes other then ones which people have designed for themselves. Most of the bikes created for personal use have solar panels connected to the bike, similar to a trailer. This is a good idea since you can have a large number of panels attached to the trailer resulting in faster charging and sustained charge while riding. Some of these bikes even claim to have unlimited energy on a nice day. The biggest downside to this model is the size of the bike. The bike now takes up too much room for storage and is not as practical.

Another model for a solar bike was where the solar panels were placed between the spokes of the front and rear wheels. Although this idea is very creative, there were many shortcomings thought of right away. For one, the wiring from the panels to the other systems on the bike would not allow the bike to receive any charge while the user is using the bike. As the wheels rotate, the wheel spokes would pull out any connections during transit. With the panels in the wheels, this would result in unconventional charging for the bike. The bike would either need to be laid on its side for charging during the day. The only time the bike could charge standing upright would be in the early morning or late evening.

Another solar bike model did not have solar panels attached to the bike at all. The bike frame looked similar to other electrical charging e-bikes in production today. The frame looked very similar to a typical road bike. The bike frame was built with a small compartment where the battery was placed and plugged in. The wiring of to the bike was also built into the frame to keep the wires out of the users way. The main downside to this model is that it doesn't fit the idea of our project. Although the bike is powered by solar energy, the panels are not directly attached to the frame. The user has to unplug their battery and attach it to a solar mount. Our solar bike is designed to be charged anywhere the bike is whether it's in transit or parked. We do not want our end user to be reliant on taking their bike back to a charging station. We want our bike to be able to be charged anywhere.

Capturing kinetic energy from the bike is where we have a lot of flexibility. The thought of adding propellers to the bike to convert wind energy to electric energy. There are not currently any wind powered bicyles in the market today. Only self-made prototypes people have made for themselves. One way to accomplish this is to mount propellers on the bike to charge the battery while the bike is in use. Testing will need to be done for this idea since we are unsure if the drag from the propellers will do more harm then good for the battery due to drag. Another idea similar to the solar panel, would be with external charging. To have a wind turbine set up with the intent to charge the bike when stationary.

Another way to capture this kinetic energy from the bike is to add another small wheel to one of the bikes tires. This would work like how gear systems work. As the bikes tires spin during use, the tire would turn this added wheel. This added wheel could then be used to add power to some additional unit which could capture this kinetic energy.

END USER

Our main subject for our design is for people who want a low-cost, energy efficient, and environmentally friendly form of transportation. Our typical end user is anyone who is old enough to drive a car and weighs less than 250lbs. Electric bikes have many benefits including cutting back on expenses such as gas and electricity. It also gives customers who do not typically ride bikes, to have an assisted ride. You don't even have to be home for the bike to charge, just anywhere the sun shines. This bike is trying to be the only solar bike that can run completely on solar without having to make nearly as many stops as bikes out there today. We want people to be able to travel from destination to destination and never have to worry about their bike losing its charge.

CONCLUSIONS AND SUMMARY OF RESEARCH

There are many great upsides to current models of solar powered e-bikes but the breakthrough in this technology has yet to be designed. Our frame will need to incorporate different aspects of previous designs in order to properly bring our problem statement to reality. Our bike needs to have solar panels attached directly to the bike without having a large attachment on the rear or top of the bike. Our frame will be like typical bikes but with an attached satchel above the rear wheel. We will use this rear frame to mount the panels to the bicycle. We can also drill into the frame of the bike to conceal the wires so they will be out of the way and unable to tangle when the bike is in use. After further research, we found that the wind generation seemed to have more downside than upside. We decided to use our additional wheel idea in order to capture the kinetic energy produced by the bikes tires while the bike is in use.

QUALITY FUNCTION DEPLOYMENT

CUSTOMER FEATURES

Although we may have thought we knew what the most important features of the bike were, we wanted to hear from potential customers. To do this, we created a survey and posted it to reddit. Below are the results of the survey. The first number is the number of people who thought that feature was important with the next number being the percent of the people in the survey who voted for that.

- Battery Life(Range) = 75 (98.7%)
- Cost = 72 (93.5%)
- Charge Time = 49 (63.6%)
- Durability = 42 (54.5%)
- Top Speed = 25 (32.5%)
- Appearance = 22 (28.6%)
- Weight =16 (20.8%)

ENGINEERING CHARACTERISTICS

- Travel Distance (Miles)
- Time to Recharge (Hours)
- Size of Motor (Watts/Hp)
- Price to Build (Dollars)
- Battery Life (Years)
- Battery Size (Amp Hours)
- Weight (lbs)
- Frame Load Capacity (lbs)

HOUSE OF QUALITY

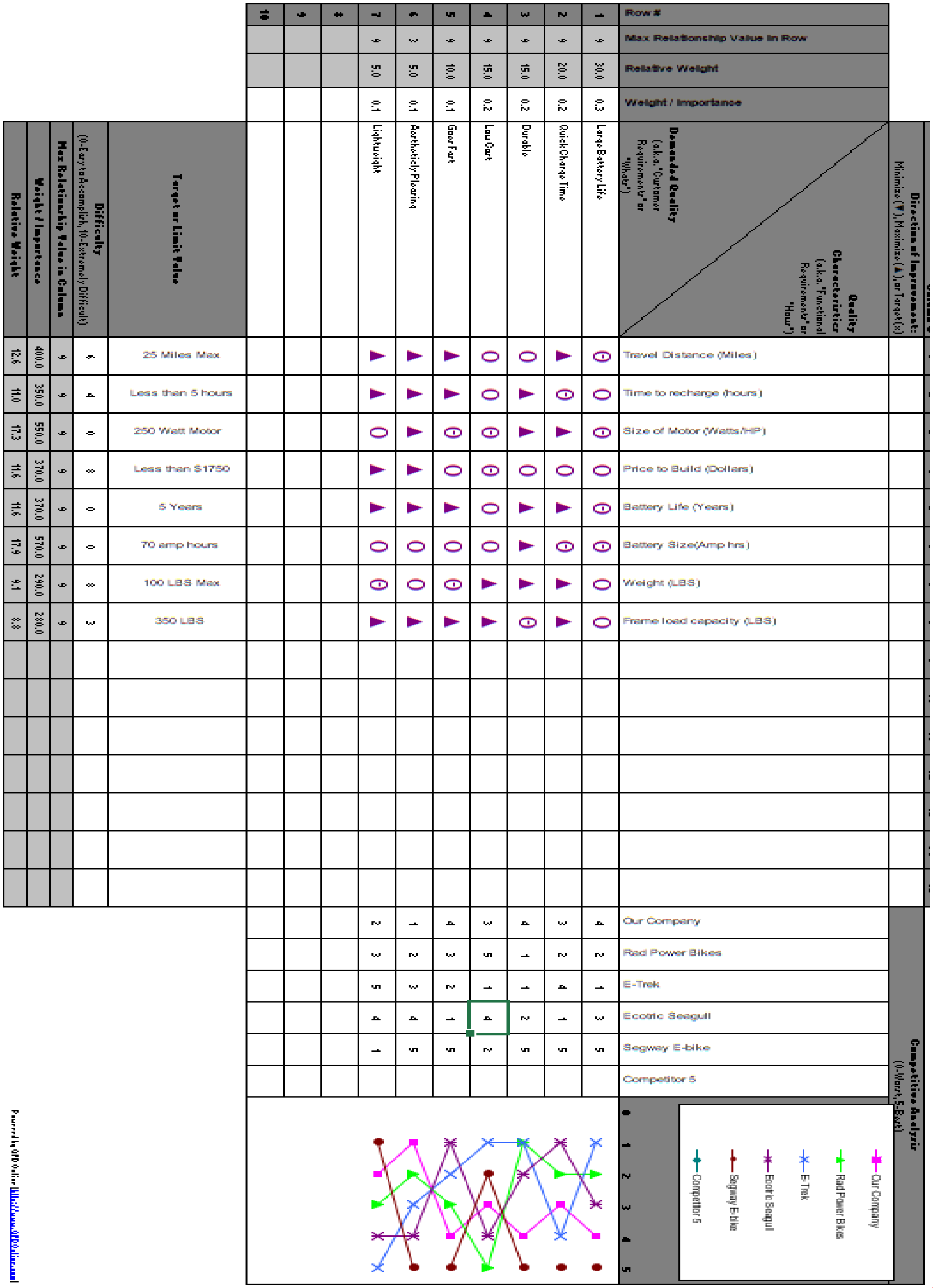

Figure 3: Product House of Quality

PRODUCT OBJECTIVES

- Battery Life(Range) = 75 (98.7%)

To achieve a long battery life, we will have to create as light as a vehicle as we can, in order to utilize a small and efficient motor for our application. The lighter the bike, the longer the battery will be able to power the electric motor.

- Cost = 72 (93.5%)

Cost is a factor that is tied to almost every engineering characteristic and customer feature associated with our e-bike. The higher faster we want to go-the more expensive the motor will be, the longer the battery life-the more expensive the battery will be, the faster the charge time-the more expensive the solar and wind power generation will be, etc.

- Charge Time = 49 (63.6%)

Charge time will be dependent on how much we are able to utilize solar, wind, and regenerative braking in our e-bike. Based on customer feedback, it seems that a quick charge time isn’t as desired as we’d expected (5+hours).

- Durability = 42 (54.5%)

With any quality product, durability is an essential characteristic of the design. Our team will have to utilize lightweight, and strong materials that are cost effective as well. Furthermore, our team will have to design for longevity by designing our e-bike to require minimal maintenance and easy of use.

- Top Speed = 25 (32.5%)

Based on our survey results, a speed of 25-35 mph is preferred. This will allow our bike to be street legal on most suburban roadways and also provide enough power to tackle off-road terrain and slopes.

- Appearance = 22 (28.6%)

Appearance will help our bike become more marketable. Other bikes on the market aren't as aesthetically pleasing and may not appeal to a wide range of audiences. Our team should browse creative ways to make our body appeal to our end user.

- Weight =16 (20.8%)

Weight is a large technical performance indicator involved with our project. We must be slim with our design concepts and create a drivetrain, body, and charging system that is lightweight and efficient as possible.

DESIGN

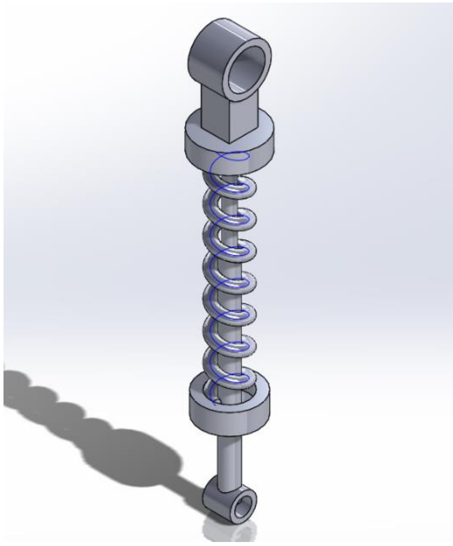
Figure 4: Suspension Design 1

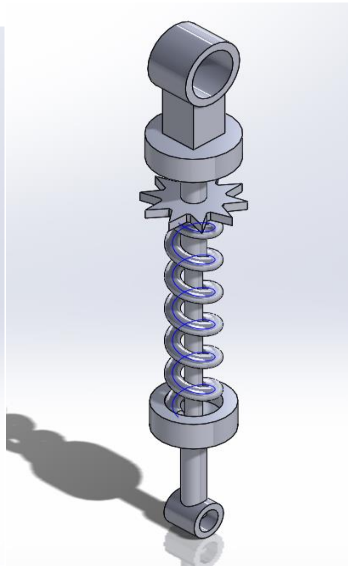
Figure 5: Suspension Design 2

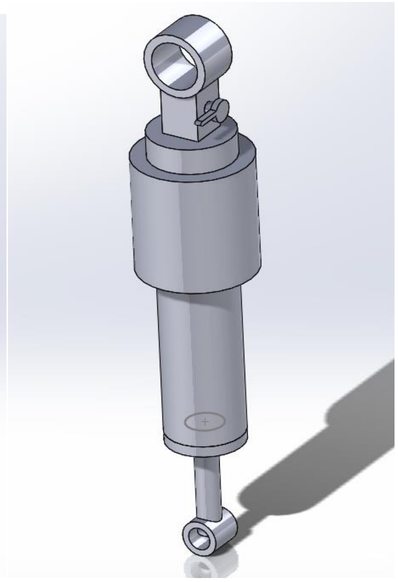
Figure 6: Suspension Design 3

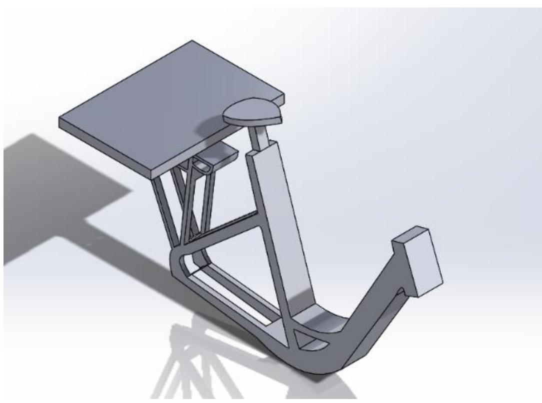
Figure 7: Frame Design 1

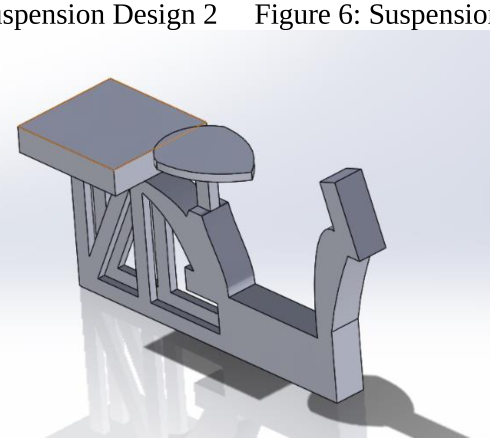
Figure 8: Frame Design 2

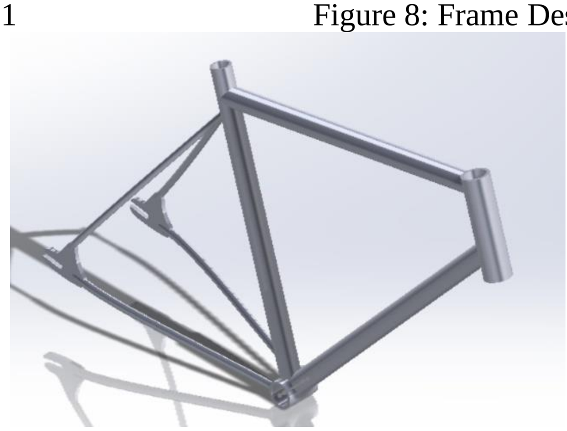
Figure 9: Frame Design 3

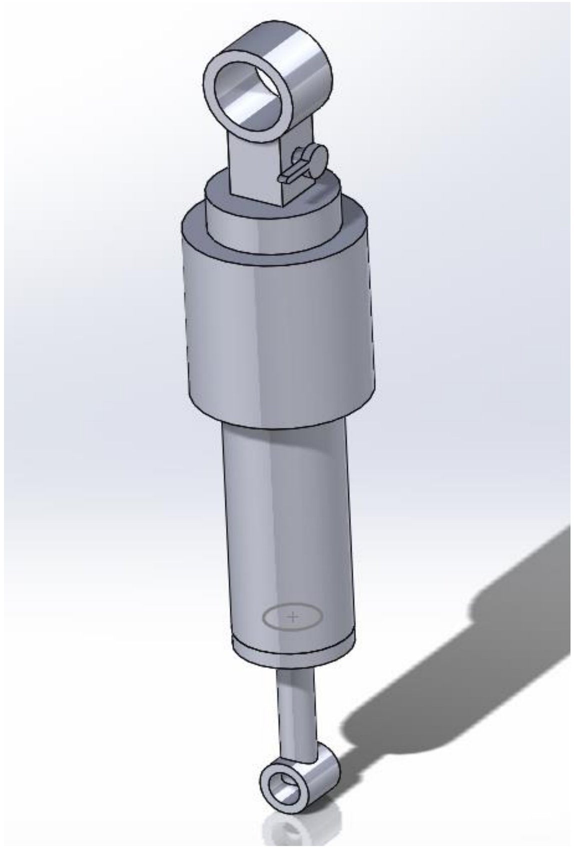

Figure 10: Final Suspension Design

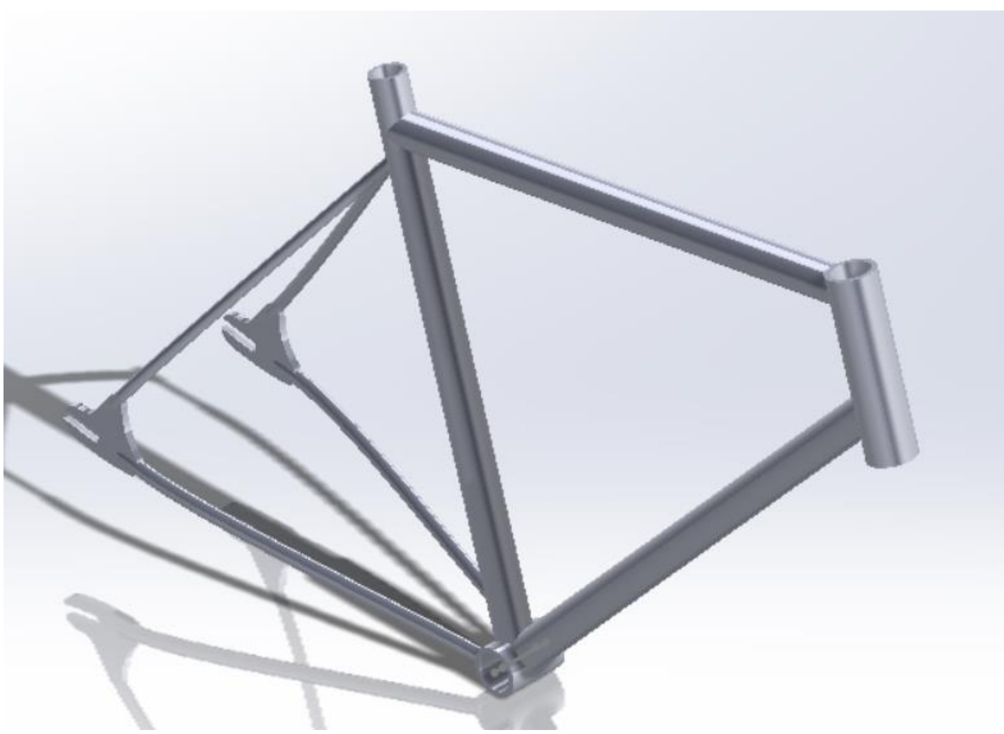

Figure 11: Final Frame Design

DESIGN ALTERNATIVES AND SELECTION

Criteria	Concept 1 (Coil Shock)	Concept 2 (Coil Shock with Adjuster)	Concept 3 (Air Shock)
Safety	10	10	10
Adjustability	1	8	10
All-Terrain	6	8	8
Comfort/Control	9	9	7
Low Cost	7	6	9
Design and Look	9	5	10
Total	42	46	54

Table 1: Suspension Design Decision Matrix

Safety (25%)
Safety is the most important factor when it comes to designing anything. The suspension of a bicycle is important to safety because the suspension is what keeps the rider in control. Little or no shock can add unnecessary strain on the rider. Our concepts will meet that need and consider the safety of the rider when implementing our suspension system.

Adjustability (20%)
Adjustability is important to our customers who will do more than just street riding. This gives the riders ability to tighten or loosen their suspension system to accommodate for the specific terrain. This is also appealing to people who will just use the bike for street riding as well. They won’t necessarily have to stick to the stock suspension purchased with their bike, but be able to adjust it to fit their comfort.

All-Terrain (15%)
All-Terrain and adjustability go together. In order for the bike's suspension to ride anywhere, it needs the ability to be adjusted. Although a bike with a coil suspension can ride on most terrains, the ability to adjust the suspension's stiffness will increase the comfort and more importantly the control of the bike.

Comfort/Control (20%)
The suspension is the driving factor when it comes to comfort and control. Without a solid suspension, the bike can lose its grip on the surface its riding on. Without contact to a surface, the bike loses all its control. The suspension is also responsible for the comfort
Cost (15%)
This is an important field since our survey reported that cost was important. Although most suspensions are similar in price, the air shock is the least expensive of the three.

Design and Look (5%)
This design and aesthetic look of the suspension should be appealing to customers. We want the bike and attachments to appeal to the consumers and be comfortable to them during the ride.

Criteria	Concept 1	Concept 2	Concept 3
Safety	9	8	10
Load Capacity	9	10	6
All-Terrain	5	3	10
Comfort	10	10	10
Control	8	5	10
Design and Look	8	6	10
Total	49	42	56

Table 2: Frame Design Decision Matrix

Safety (25%)
Safety is the most important factor when it comes to designing anything. This should be considered when we finalize the design for the frame of the bike. Our concepts will meet that need and consider the safety of the rider when implementing the frame of our project.

Load Capacity (15%)
The load capacity is important because our bike will have much more weight on it then a typical bicycle. The motor and battery will definitely need to be directly attached. The frame design could also change depending on if the solar panels and turbines are to also be attached directly to the frame.

All-Terrain (10%)
Our frame design will also depend on the types of terrain the rider may encounter. The larger bulky frame would be suitable for road riding but not for mountain bike trains since the rear has so much weight. The bike could easily lose contact with the front wheel and lose control.

Comfort (20%)
The comfort of the bike is also very important. Other than the bike functioning properly, comfort is arguably the next important trait. The rider needs to be comfortable while riding or they will not use our product.

Control (20%)
Control is very important because without solid control, the bike isn't safe. The bike will need to have proper weight distribution for concepts 1 and 2 in order to keep the rider in control. If the weight is not in proper equilibrium when riding, it may cause the rider to lose control if the rear is overweight. There is also the potential that the rider could fly over the handlebars and flip the bike if the front is too heavy. All this will need to be addressed when finalizing our design.

Design and Look (10%)
We want the finished product to be aesthetically pleasing to our customers while still being able to fulfill its other requirements.

Figure 12: Final Bike Design Side View

Concept Integration

Our group's bike frame concept will effectively accommodate all of our renewable energy bike's functions, including the selected electrical drivetrain. With the motor being located within the wheel itself, it eliminates the need for extra space under the driver's legs where a traditional motor would be located. This extra space reduces the weight of the frame while allowing the required space needed to be able to fit the battery and control system. With the bike frame selected, the back solar panel mount will mount underneath the seat frame, this will allow for a stable and sturdy mount to support the entire weight once the panels are added. The front mount will be applied to the steering column. The steering column will have enough support to be able to hold the solar panels and still allow for easing turning for the rider. The front mount is also a lower weight to ensure all riders do not have to put in extra effort to turn the steering column. The concept ideas for the solar panels chosen, will allow for the bike to receive as much energy as possible in order to maintain power with the battery and motor chosen. The solar panels weight along with the other mechanisms' weight will go hand in hand with the suspension system chosen. These air shocks will be able to maintain the operating load, while giving the rider a more comfortable and quieter ride. These shocks were chosen because they are lightweight, quiet, and durable. They will be able to be adjusted for any operational load while also working independently from one another to ensure the ride is as smooth as possible. Together integrated, these selected concept designs successfully encompass all of our team's product objectives.

ENGINEERING CALCULATIONS

Load From Battery

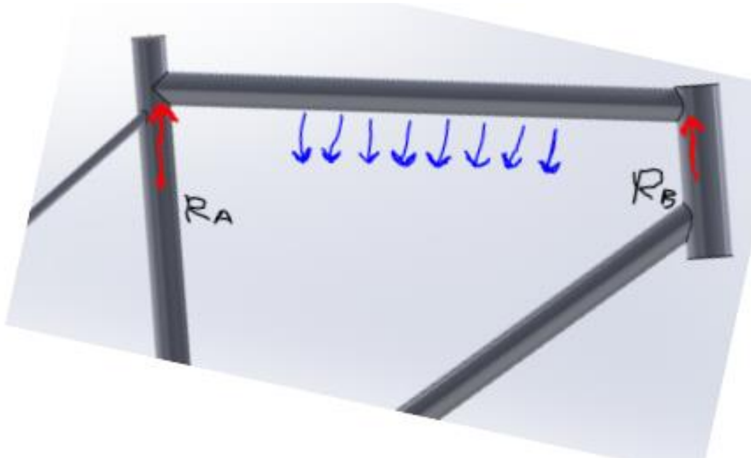

Figure 13: Side view of Frame

Force on Frame from Battery

Known: Battery is 18lbs

$$F = 18\ lbf$$
$$Distributed\ Load = F * L$$
$$Distributed\ Load = (18\ lbf) * \left(\frac{10.2\ in}{12\ in}\right)$$
$$Distributed\ Load = 15.3\ lbf$$

Bending Moment at A and B

$$\sum M_A = Force * Distance$$
$$\sum M_A = 0 = (R_A * D) + (R_B * D) - (DL * D)$$
$$\sum M_A = 0 = (R_A * 0) + (R_B * L) - (15.3lbs * \frac{1}{2}L)$$
$$R_B = \frac{(15.3lbs * 1/2\ L)}{L}$$
$$R_B = 7.65\ lbf$$
$$R_A + R_B - Load = 0$$
$$R_A = Load - R_B$$
$$R_A = 15.3lbs - 7.65lbs$$
$$R_A = 7.65\ lbf$$

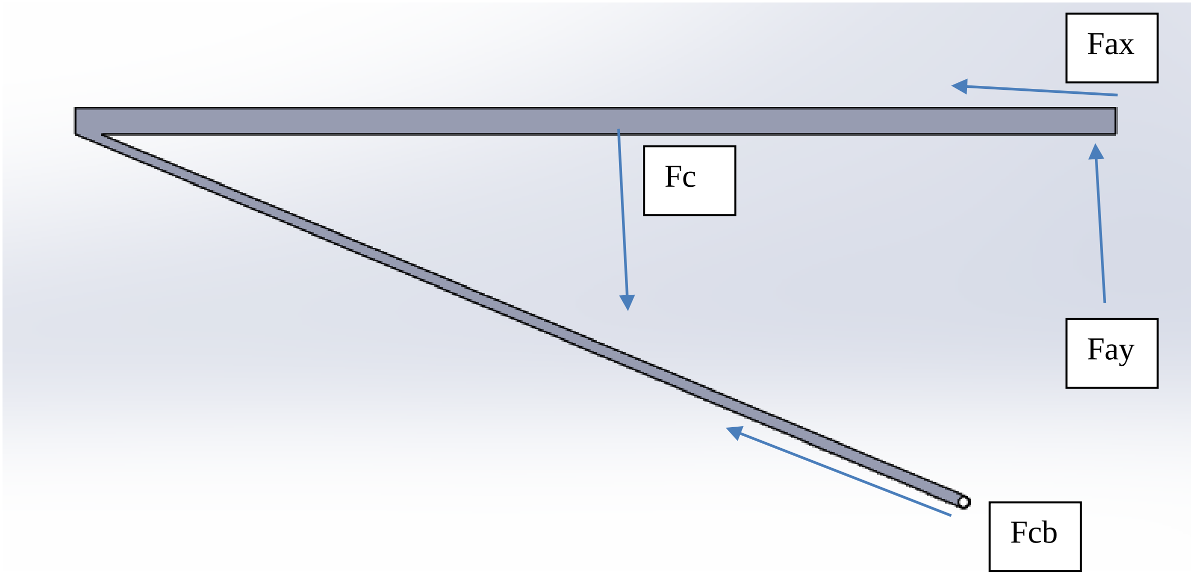

Figure 14: Solar Panel Frame

$$F_c = F_{Solar\ Panel} + F_{Rack} + F_{Generator} + F_{Converter} + F_{Charger\ Controller} + F_{Motor\ Controller} + F_{wood}$$
$$F_c = 15.8lbs + 15lbs + 4.5lbs + 0.5lbs + 1lb + 1.5lbs + 2lbs$$
$$F_c = 40.3\ lbf$$
$$M_a = 0$$
$$0 = sin\Theta F_{cb} L - F_c L$$
$$0 = \sin(60) * F_{cb} * 21in - 40.3lbs(21in)$$
$$F_{cb} = 46.6\ lbf$$
$$F_x = 0$$
$$F_{ax} = cos\Theta * F_{cb}$$
$$F_{ax} = \cos(60) * 46.6lbs$$
$$F_{ax} = 23.27\ lbf$$
$$F_y = 0$$
$$F_{ay} = F_c - sin\Theta * F_{cb}$$
$$F_{ay} = 40.3lbs - \sin(60) * 46.6lbs$$
$$F_{ay} = 0\ lbf$$

Suspension Calculations

$$\%\ Sag = \frac{Stroke\ Used}{Total\ Stroke\ Length}$$
$$10\% = \frac{Stroke\ Used}{120mm}$$
$$Stroke\ Used = 12mm$$
$$Stroke\ Used = 12mm \longrightarrow 75.95\ psi$$

Material Strength Calculations

$$Yield\ Stress = \frac{Force}{Cross\ Section\ Area}$$
$$CS\ Area\ for\ Pipe = \pi * r^2$$
$$CS\ Area\ for\ Pipe = \pi * 25mm^2$$
$$CS\ Area\ for\ Pipe = 0.1963m^2$$
$$Yeild\ Strength = \frac{31511\ N}{0.1963\ m^2}$$
$$Yeild\ Stength = 160\ MPa$$
$$Yeild\ Strength\ Aluminum\ 6061 = 240\ Mpa$$
$$Safety\ Factor = \frac{240Mpa}{160Mpa} = 1.5$$

BILL OF MATERIAL

QTY	Part Name	Supplier
1	48v 20A Battery	Amazon
1	100 Watt Solar Panel	Amazon
1	Bike Frame	Donated
1	Solar Panel Mounting Frame	Donated
1	Generator	Amazon
1	Solar Controller	Amazon
1	750 Watt Hub Motor Kit	Ebay
1	Step Up Converter	Amazon
1	15A Doides	Amazon
1	Battery Pouch	Amazon
1	Waterproof Junction Box	Amazon
1	Bike Seat	Amazon
1	Kick Stand	Walmart
1	Rubber Drive Roller	McMaster Carr
1	Braking Repair Kit	Walmart
N/A	Miscellaneous Items	N/A

Table 3: Bill of Materials

BUILD AND TEST

Figure 15: Finished Assembly of the Bike

Figure 16: Welding Points for Solar Panel Frame

To weld the frame to the bicycle, we had the frame welded to three separate points on the bike. We welded the top of the frame to just under the seat as seen in the top right image. We then attached a brace just above the rear wheel axel on both sides of the frame as seen in the image in the bottom right. These securely hold the panels frame in place and were able to mount the panel on top of it using screws attached to the frame of the panels itself.

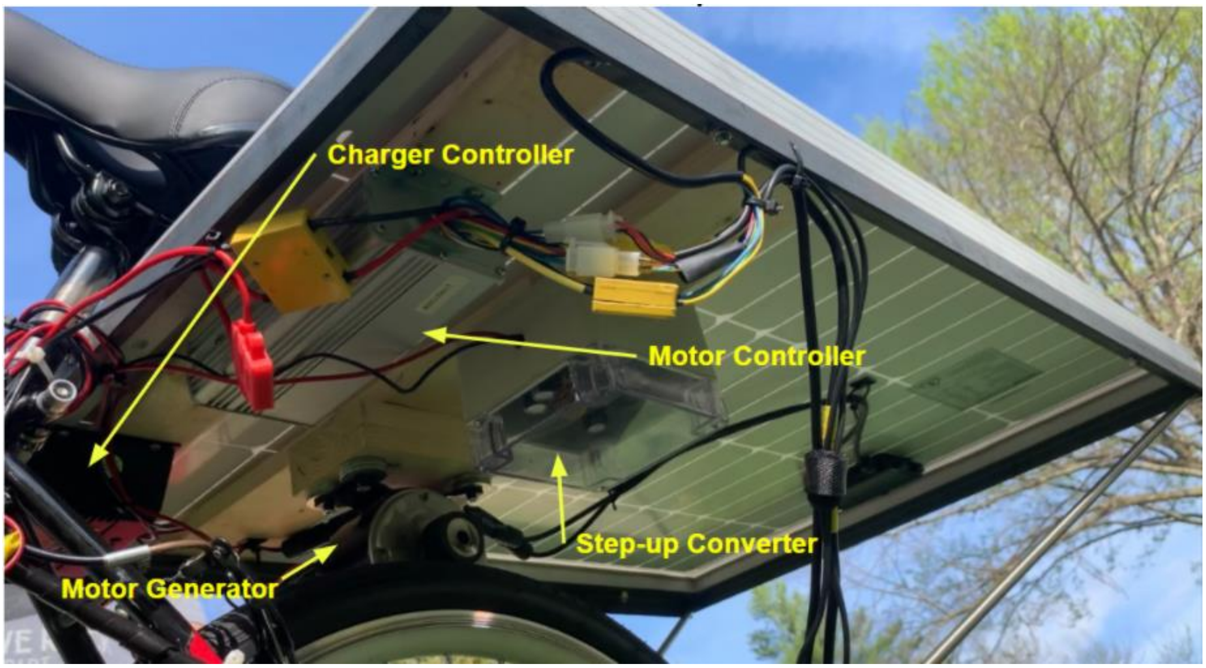

Figure 17: Controls Underneath the Bike

Underneath the panels' frame houses most of the controls for the bike. The motor controller attaches to the rear hub motor on one end with the other end first going through the battery and then to the twist throttle on the right handlebar. The outputs from the motor generator and solar panel are then wired in a series circuit to the step-up converter to not overload the charger controller. The step-up converter then connects to the charger controller. The charger controller is what charges the battery. It can be set to the desired amount of voltage and current you wish the battery to receive. It also has two additional USB ports so the rider can charge two additional devices all from the renewable energy produced by the bike.

Figure 18: Twist Throttle and Rear Wheel Generator

The twist throttle (Left) is what turns on and off the hub motor by the red push button. While on, it also reads the amount of power left in the battery. The twist throttle works in the same way a motorcycle does, where the more you twist, the faster the motor will propel the bike. The rear wheel generator (right) works by converting the kinetic energy produced by the wheel while the bike is moving. This small drive roller spins while the bike is in motion which in then converted to electrical energy by the generator.

Some additional parts not pictured but to improve the bike were the replacement of the bikes' brakes and a new seat. The seat was added because the stock bike seat was very rigid and made riding over rough terrain very uncomfortable. The improved bike seat can be seen on figures 16 and 17. The brakes were also replaced since the bike was older and we desired a short braking distance. No testing was done on the stock brakes but after replacing the brakes with new ones, we were able to beat our target braking distance at the beginning of the project.

TEST PROCEDURE AND CRITERIA

Maximum Speed

To test the top speed of the bike we used two method. We first used a 100-foot tape measure and a stopwatch. We used the time and distance to calculate the velocity of the bike at its top speed.

Maximum Load

The maximum load for the bike we used was 250lbs. We added a total of 40.6lbs to the bike with the modifications made. To test if a 200lbs rider could ride the bike we had a 200lb person ride the bike over different terrain for an extended period of time.

Braking Distance

To test how long it would take the bike to stop, we used a take measure to see how long it would take the bike to come to a complete stop from its top speed with its maximum load on it to see the longest possible braking distance.

Renewable Energy Generated

To find the renewable energy created by the bike we used a multimeter to measure the current and volage produced on a sunny day while riding at full speed. To do this we propped the rear wheel off the ground and used the twist throttle to fully power the rear wheel. The multimeter was then used to rear the voltage and current output from the charger controller. It was measured here because this is the amount of energy the battery would receive.

TEST RESULTS AND FINDINGS

Design:	Results
Max Rider Weight = 250lbs	Max Rider Weight = 200lbs
Max Speed = 20mph	Max Speed = 30mph
Range = 25 miles	Range = 40.96+ miles
Braking Distance = 20’	Braking Distance = 18’

The range is stated as “40.96+” because that is the range of the bike if the rider were to ride the bike at full speed without pedaling.

PROJECT MANAGEMENT

BUDGET, PROPOSED/ACTUAL

Category and Item	Item Notes	Budget	Actual	Difference
Total Project Budget		**$924**	**$750**	**$174**
Regenerative & Manual Braking	Alex Shelton	**$146**	**$54**	**$92**
Hydraulic Brake Set Kits Power Cut Off Electric Bike Brake with 160mm Disc Brake Rotors	cancelled	$90	$0	
1" Washers		$10	$8	
15 amp Waterproof Diode		$15	$15	
24V Electric Motor Brushed 250W 2650RPM Motor		$31	$31	
Powertrain	Alex Shelton	**$430**	**$532**	-$102
48V Rear Wheel Electric Bicycle Motor Conversion Kit 1000W Bike Hub		$180	$190	
VISET Ebike 48V 20Ah Battery Pack		$240	$333	
Weather-resistant Battery Pouch		$10	$9	
Solar Power	Ian Smith	**$185**	**$164**	**$21**
Solar Panel		$80	$90	
Rear Bike Rack	materials donated	$33	$0	
Split Connecters		$8	$8	
High Power DC to DC Boost Converter DC 12-60V to 12-80V Boost Module Board Step-up Transformer		$16	$16	
Charger Controller		$33	$35	
Waterproof Junction Box		$15	$15	
Frame & Suspension	Christian Myers	**$137**	**$0**	$137
Mountain Bike	donated	$0	$0	
Air Supsension	cancelled	$137	$0	
Bike Seat		$15	$15	
Safety	Christian Myers	**$26**	**$0**	$26
Headlamp & Turn Signals	not ordered	$8	$0	
Rear View Mirrors	not ordered	$18	$0	

SCHEDULE, PROPOSED /ACTUAL

	Task Name	Duration	Start	Finish
1	Purchase & Acquire Required Parts	3w	01/11/21	02/19/21
2	Manufacture Battery & Control Housing	1w	03/08/21	03/12/21
3	Manufacture Solar Power Frame	1w	03/08/21	03/12/21
4	Assemble Rear Wheel Assembly	1w	02/22/21	02/26/21
5	Assemble Solar Power Unit	1w	03/01/21	03/05/21
6	Assemble Front Wheel Assembly (regen braking)	1w	03/15/21	03/19/21
7	Test Weight Capacity	0.25d	03/22/21	03/22/21
8	Test Max. Speed	0.25d	03/22/21	03/22/21
9	Test Max. Acceleration	0.25d	03/22/21	03/22/21
10	Test Braking Distance	0.25d	03/22/21	03/22/21
11	Test Power Generated via Regen Braking System	1d	03/26/21	03/26/21
12	Test Power Generated via Solar Power Unit	1d	03/26/21	03/26/21
13	Formulate Final Report	3w	04/05/21	04/23/21
14	Formulate & Apply Changes Based on Test Result	2w	03/29/21	04/02/21

SUSTAINABILITY AND MATERIAL USAGE

One issue we faced was how back heavy the bike is. We tried to best attach all the controls between where the rear wheel contacts the ground and where the solar panel frame ends. However, that did not help as much as we would have liked. Another change would have been to use a more durable material other than wood to attach all the controls underneath the solar panel. We used wood because it was the cheapest option and also lightweight since we did not want to add more weight to the rear of the bike. It would still be able to carry out its purpose which is why we still selected it. In long term use the wood will begin to wear out faster than other lightweight materials. Lastly, the drive roller, which is in contact with the rear wheel and connected to the generator. The one we selected was made of rubber which will overtime will wear down enough so that it is no longer in contact with the wheel. Which would make it a part which would need to be replaced on a regular basis.

CONCLUSIONS

Overall, our project ended the way we had planned it to at the beginning of the fall semester. We were able to create an electric bicycle which is powered completely by renewable energy. It also either matched or surpassed specifications of electric bikes in production today. With our design our bike goes faster, for longer distances and produces more electrical energy than a typical wall outlet. There were some changes we had to make from our initial design intent. Our initial design had regenerative braking and the use of propellers to convert energy from the wind for another way of producing renewable energy. We decided to not include regenerative braking since the energy it would have produced was negligible compared to the other methods we used. Similarly, the propellers were also not included for a couple reasons. We found that drag produced from them would hurt the maximum speed the bike would be able reach. The propellers could also be a safety concern since where we would need to attach them would be close to the riders' hands or legs. At the beginning of the project, we thought that the suspension of the bike would also need to be upgraded because of all the added weight to the bike. As we moved further along in the project, we found that was not the case. The stock suspension was capable of a total rider weight of between 250-300lbs before it needed to be upgraded. Since our maximum rider weight is 200lbs, with the added materials, the total weight on the bike was only 240lbs. Also, most of the added weight was to the rear of the bike which would have a smaller impact on front suspension. From this, we decided not to change the bikes suspension. In conclusion, we were able to create an electric bike which was powered completely by renewable energy. We were able to take our customer features and make them a reality. They wanted a bike which could travel further distances, charge quicker and go faster then other e-bikes in the market. All while eliminating the harmful effects of combustion engines while also eliminating any conventional energy consumption. Our completely "green" electric bike will hopefully be inspiration for an alternative mode of transportation.

WORKS CITED

1. LEVIN, Tim, 2020, All the things carmakers say they'll accomplish with their future electric vehicles between now and 2030. *Business Insider* [online]. 28 January 2020. [Accessed 18 September 2020]. Available from: https://www.businessinsider.com/promises-carmakers-have-made-about-their-future-electric-vehicles-2020-1

2. LEACH, Felix, KALGHATGI, Gautam, STONE, Richard and MILES, Paul, 2020, The scope for improving the efficiency and environmental impact of internal combustion engines. *Transportation Engineering* [online]. 30 May 2020. [Accessed 18 September 2020]. Available from: https://www.sciencedirect.com/science/article/pii/S2666691X20300063

3. Guide to Electric Bike Motors, [no date]. *Rad Power Bikes* [online], [Accessed 18 September 2020]. Available from: https://www.radpowerbikes.com/blogs/the-scenic-route/guide-to-electric-bike-motors

4. Products of Combustion, [no date]. *Products of Combustion | EGEE 102: Energy Conservation and Environmental Protection* [online], [Accessed 18 September 2020]. Available from: https://www.e-education.psu.edu/egee102/node/1951

5. STARR, Michelle, 2015, Wind-powered motorcycle for a Mad Max world. *CNET* [online]. 25 June 2015. [Accessed 18 September 2020]. Available from: https://www.cnet.com/news/wind-powered-motorcycle-for-a-mad-max-world/

6. Ebike Basics, [no date]. *Ebike Basics – Rad Power Bikes Help Center* [online], [Accessed 18 September 2020]. Available from: https://radpowerbikes.zendesk.com/hc/en-us/categories/115000119874-Ebike-Basics

7. KIDD, Derek. Coil Shock VS Air Shock - Pros and Cons. *News & Press " Live to Play Sports* [online]. 3 March 2017. [Accessed 13 October 2020]. Available from: https://livetoplaysports.com/news-press/2017/03/coil-shock-vs-air-sho