

Project Chinook Final Design Report

Team BZERCX

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ABSTRACT

The goal of Project Chinook was to create a renewable source of energy for people while they are traveling. Team BZERCX set about achieving this goal by creating a portable turbine that is able to be mounted onto any vehicle and generate electricity while driving. A rapid prototype at the beginning design stages provided an overall idea for the turbine. After this overall idea was formed, the product required many prototypes of each main component (energy generation, mounting, housing, and battery storage) to reach a satisfactory standard for the product. At the end, all of the finalized components were assembled together into a finished product. Team BZERCX found that the turbine successfully fulfilled the goal of Project Chinook. When driving at around highway speed (around 70 mph), the turbine produced about 5 watts of power. This rate of charging is similar to what is expected of a phone charging through the use of an outlet and is ideal for the product. The turbine also fulfilled the goal of being able to produce this energy while people are traveling. The mounting system onto the car proved to be both efficient and safe. The magnet mounting system is easy to take off of the car and will not leave any scratch marks on the vehicle. After testing and analyzing the magnets, it is found that the magnets will hold the turbine up to 125.553 mph, well over the speed at which people are supposed to drive. Overall, Project Chinook can be considered a great success. All of the goals laid out at the beginning of the project were fulfilled, and the final product exceeded the expectations of Team BZERCX. As for future work, it is important to remember the benefits of actively reaching out for support from those who are willing to provide it. A huge aid to the creation of this product was the help that the team received from people who provided their applicable knowledge of the product. Team cohesion and communication also allowed for this project to advance smoothly and was vital to the creation of the product. Open communication prevented any resounding team conflicts from being created, which would have slowed down the project.

I. INTRODUCTION AND BACKGROUND

Mission Zero¹, an organization seeking to reduce anthropogenic climate change through student-driven innovation, tasked Team BZERCX with the objective of creating a product that will reduce the amount of carbon pushed into the atmosphere. Within the past few decades, human-induced climate change, particularly the unprecedented increase in global temperature, has come to the forefront of global issues due to the various problems it creates for both humans and the environment, some of which are ecosystems being destroyed, weather becoming more extreme, disease vectors spreading to farther regions, and fertile land decreasing.² The greatest factor contributing towards this historic climate change is the emission of greenhouse gasses into the atmosphere through the burning of fossil fuels.³

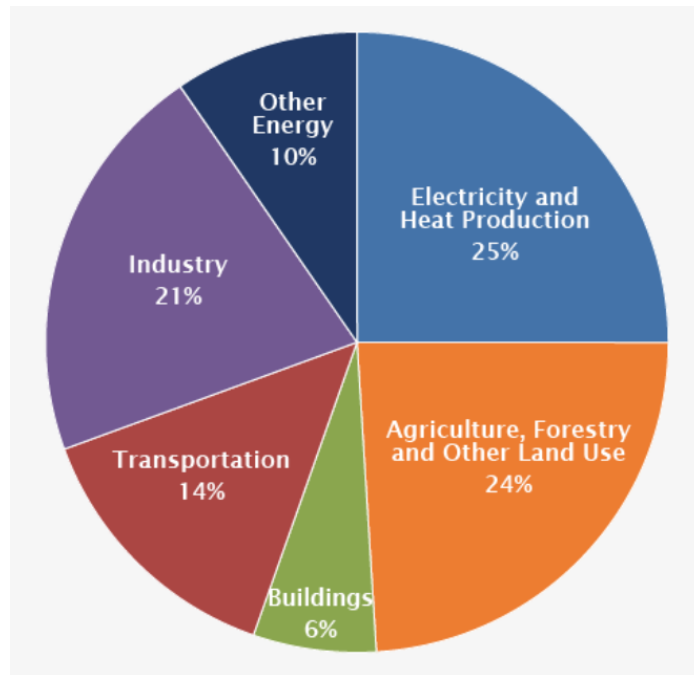


Figure 1.⁴ The percentage of global greenhouse gas emissions by economic sector.

As can be seen in Figure 1, the largest sector contributing to the burning of fossil fuels involves electricity and heat production. To solve the growing problem of climate change, reducing the use of these fuels in the electricity and heat production sector is necessary. This can be done by looking towards renewable energy to produce electricity and heat at a large scale to replace fossil fuels. Many different renewable energy sources are being incorporated into society that provide electricity and heat for human activities. Some examples are turbine farms, solar farms, and hydropower plants. The problem is the rate at which fossil fuels are being replaced by these clean energy alternatives. In 2020, only 19.8% of the energy produced in the United States was renewable.⁵ The speed at which fossil fuels are being replaced by clean energy is currently too slow to prevent the permanent and dangerous effects that climate change will have on the globe. Smaller scale operations must be incorporated to provide renewable energy as well. Some solutions in the market right now are solar panels put on houses and smaller turbines that can be placed in backyards. While these solutions solve part of the problem of fossil fuel consumption, there is still a glaring issue: people need electricity while traveling as well. People are constantly driving, and many find themselves without an available clean electricity source. For example, many people will find themselves in situations where they won't have access to electricity. These people will use energy provided by fossil fuels instead; for example, the idling of an engine to charge a battery. Solar panels and small-scale turbines for homes are not portable, so they do not provide a solution to this problem. This is where Project Chinook comes into play. Team BZERCX decided to launch this project with the goal of reducing the amount of carbon burned to charge portable chargers, which people use when they are traveling. The proposed product needs to be able to provide a source of clean energy for those who are traveling with their

automobiles. The clients of Project Chinook are any of those that drive, since they will be able to create a source of clean energy for themselves to use in the place of fossil fuels. This device would be specifically effective for those who find themselves in a situation where they don't have a source of clean electricity, campers for example. Team BZERCX's solution provides what solar panels and at-home turbines cannot, an environmentally friendly way for people to charge their devices while on the go.

II. DESIGN REQUIREMENTS

When Team BZERCX initially undertook development of what would later become Project Chinook there were obviously several immediate requirements for the design. The first and one of the most crucial aspects of the design was the energy generation as well as the efficiency of the turbine blade. The most glaring requirement for this section of the project was that the energy generation system needed to be able to produce sufficient power without demanding outrageous and illegal speeds of the vehicle. Furthermore, some other immediate design requirements were the necessary adhesion mechanism to the vehicle and the need for that mechanism to be able to sustain high speeds, as well as some indication system to allow the user to know that the device is working and give some indication if the device has stopped working and needs replacement or fixing. Finally, one of the most crucial design requirements was the aesthetics and size of the device the team was tasked with finding the perfect size to generate power but also not being unwieldy. The device also had to be aesthetically pleasing, preferably looking for a sleek and streamline design. Listed above are the initial and most crucial design requirements that were discussed by the team before the start of Predator typing or any further development.

III. DESIGN ALTERNATIVES AND PROCESS

Two of the biggest decisions of the project came from the mounting and housing components. With a component like mounting, there were countless different options to attach the turbine to a car. Some of the ideas the team came up with included rubber bands, spring loaded clips, bicycle rack clamps, magnets, and even an attachment to wedge in between the window and windowsill. Spring loaded clips were used in the rapid prototype (Figure 2), and bicycle rack clamps were number one on the list of preferred mounting methods (Figure 3).



Figure 2. Rapid prototype where a mouse trap was used as a clip that would attach to the cross beams of a car.



Figure 3. Bicycle rack clamps that also attach to the cross beams of a car. This item would have been purchased.

However, this limited the number of possible clients to those with cross beams on their roof, as well as increased our cost per unit significantly. With a little bit of hesitation, every member began working on testing and prototyping a magnetic mounting system. The problem with magnets is that with the right amount of pressure, in the correct orientation, magnets can be almost effortlessly removed. Mathematical equations and models were developed to demonstrate its possibility. The team attached three magnets to a wooden plate to test their strength in real life situations (accelerating, breaking, cross winds etc.) while keeping the real product out of harm's way. After many drives with both the wooden model and real thing, there was no doubt that magnets would be safe to use in the final product.

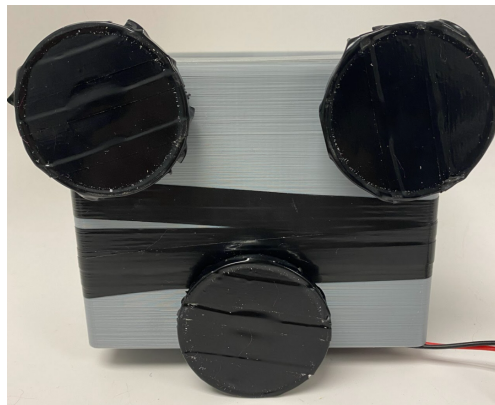


Figure 4. Magnets and magnet orientation for the final product. Three neodymium magnets enveloped in electrical tape to protect the paint on the car and increase grip.

The next step was designing the housing. This portion of the product will keep the battery and electronics safe from wind, rain, and any sort of debris. First, the housing was built from pieces of scrap wood (Figure 5), which was easy to work with and strong. Unfortunately, this type of material will warp under many outdoor conditions. Next, the housing was integrated with the turbine to promote a more sleek and aerodynamic design. This new alteration reduced the amount of space available for the battery and electronics, but was still more beneficial than harmful.

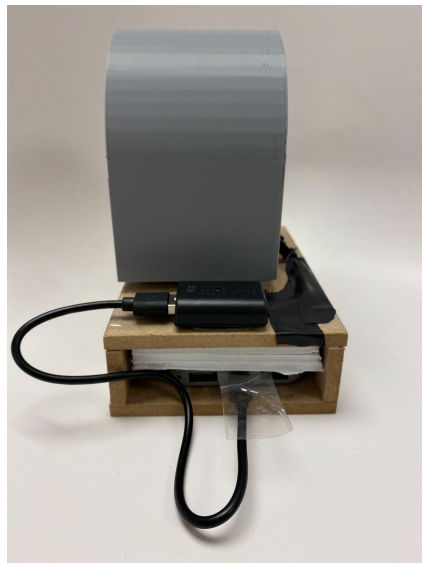


Figure 5. Wooden housing that kept the battery in place via pressure fit.

What came next was one of the most challenging decisions of the entire project. How do we make an easily accessible, water resistant, and visually appealing door to get a hold of the battery? Multiple hours were dedicated to brainstorming and designing different doorways into the housing, which included rubber bands, latches, and even more magnets. The result was a simple sliding door with magnets in both the end of the door, and one side of the door frame where the two will meet and create a magnetic connection. Such a design allowed for a simple installation during manufacturing, as well as an easy-to-use panel to access the battery for the consumer.

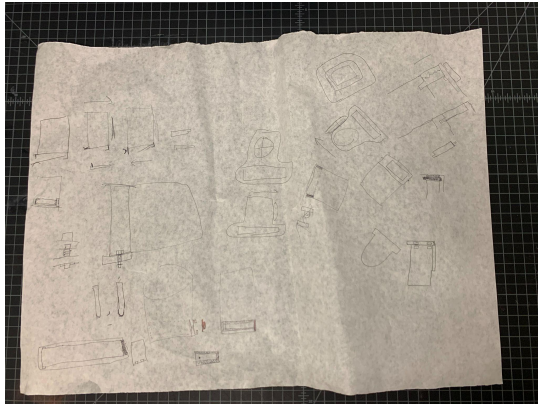


Figure 6. Housing door sketches.

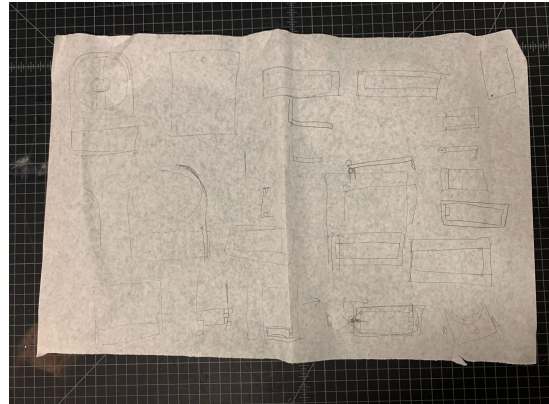


Figure 7. More housing door sketches.

IV. FINAL DESIGN

The final design of the Chinook was mainly all 3D printed. The base and the housing for the turbine was printed in PLA on a TAZ Workforce printer and the turbine was printed on a Markforged Onyx Pro Printer. The only parts that weren't 3D printed were the magnets and the electronics. Pictured below is the final product that team BZERCX took to the expo.



Figure 8. Final Design

Turbine Blade:

The turbine is a 6 blade design and is 4 inches in diameter. The base has a hole in it slightly bigger than the size of the axle of the 6V DC so it is press fit. The team decided on the 6

The ho

The housing is a cylinder that has a mount to hold the motor and a compartment to house

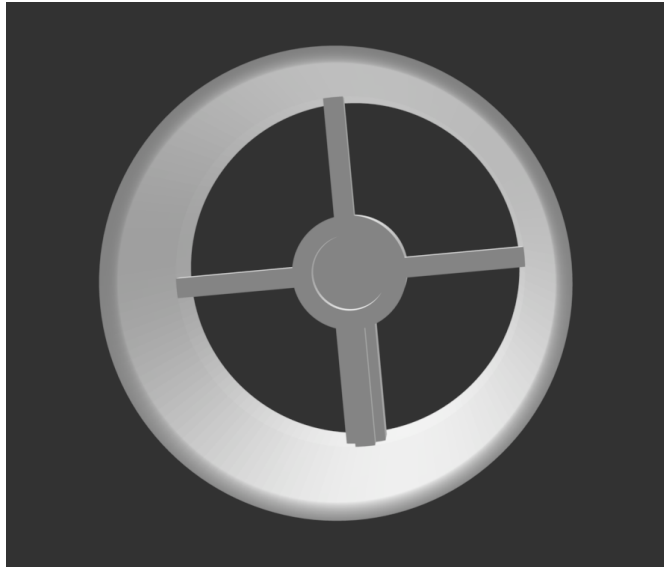


Figure 10. Top half of the housing design

The base has a cup shape on top that the housing can be placed into, and a rectangular base that has an area for the electronics to be housed. On the bottom of the cup is a hole that leads into the square base. When you attach the housing to the base the two holes need to be lined up. On the inside of the opening in the base is a slot for neodymium magnets to be placed. The magnets should be placed inside and glued down so they don't pop out. Pictured below is a CAD model of the base.

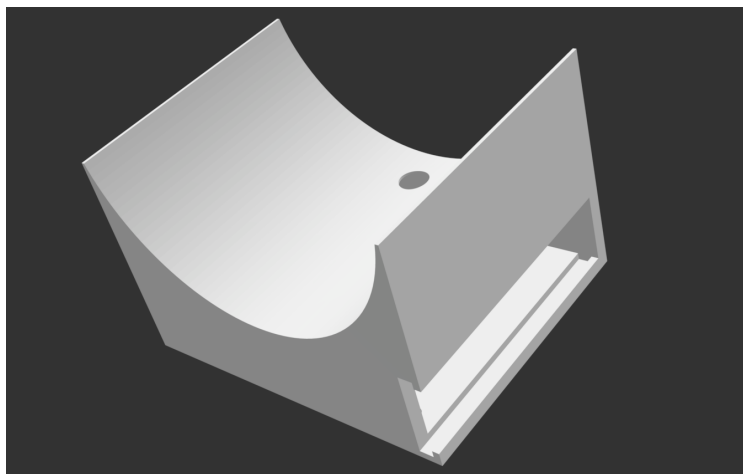


Figure 11. Bottom half of the housing design

The base door goes into the ridges in the base pictured above. It's a rectangular prism printed out of PLA. At the edge of the door is a slot for little neodymium magnets. The magnets were placed into the slot and glued down. The point of the magnets in the base door and the base

is to keep the door in place when it is shut. The door also has a small slot for your finger so you can have leverage to pull it out. Pictured below is a CAD model of the base door.

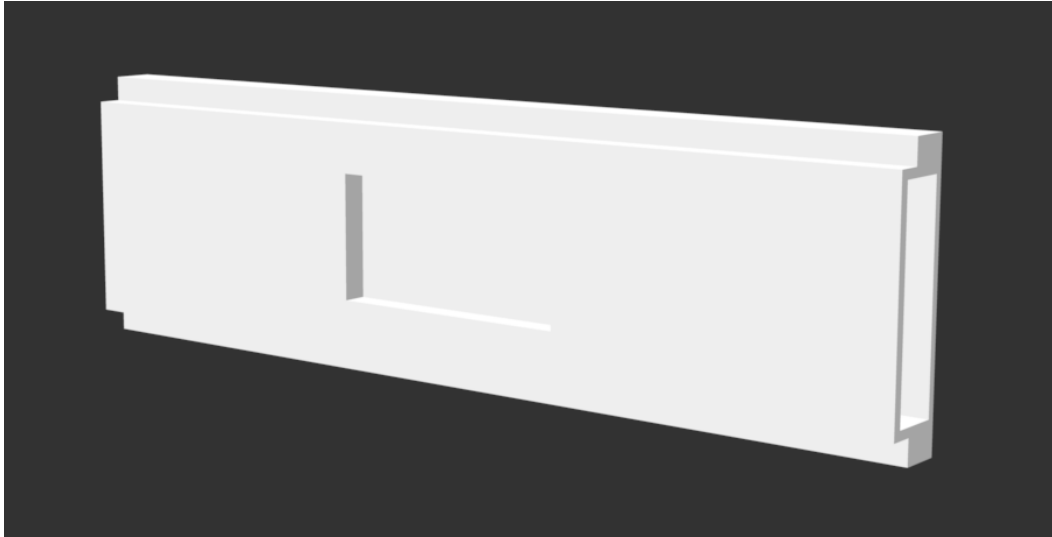


Figure 12. Housing Door

Electronics/Mounting:

The electronics consist of a few simple parts. A 6V DC motor is connected to a capacitor diode circuit which is then connected to a portable battery.

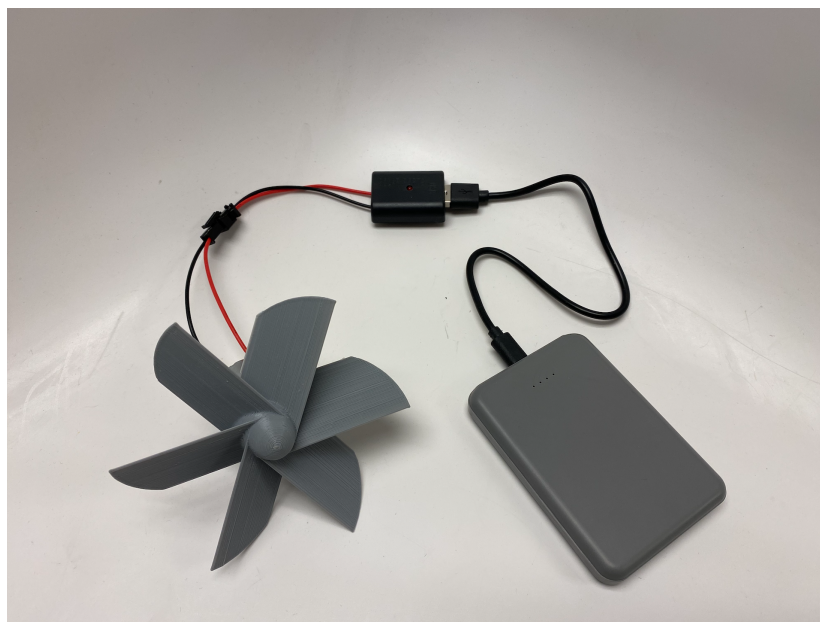


Figure 13. Electronic components of the Chinook

The mounting that Team BZERCX used are magnets. The Chinook has three magnets(each with a pull force of 35lbs) mounted to the base. The magnets are situated with two in the front and one in the back so it's easier to remove the Chinook from the roof of a car. The magnets are mounted by drilling holes in the base and securing the magnets in with nuts and bolts.

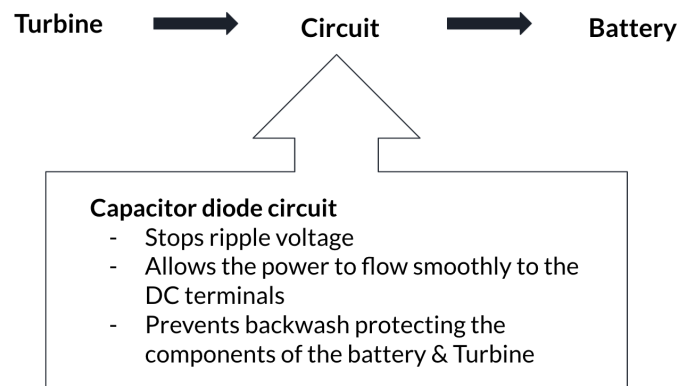


Figure 14. Electronic components block diagram

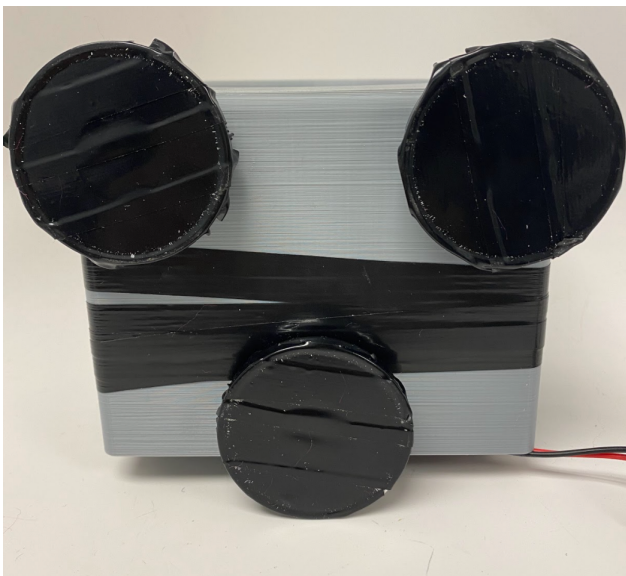


Figure 15. Magnets on the bottom of the Chinook



Figure 16. Magnet attachment to housing

Assembly:

To assemble the Chinook, take the housing and the base and line up their holes. Apply super glue in between the housing and the base and glue them together. After they are securely together, place the 6V DC motor in the mount in the housing. Then, wire the motor through the

holes to the base. Place the capacitor diode circuit into the base and hot glue it to the walls of the base. Hook up the wires from the motor to the capacitor diode circuit in the base, and then hookup the capacitor diode circuit to the charging cord for the battery pack. Slide the base door into the base and make sure the magnets click into place. After that, seal all of the cracks between the housing and base with epoxy to help waterproof and prevent air from getting in between the housing and the base. Once the epoxy has completely dried, apply multiple coats of spray paint to the Chinook.

V. TESTING

The first critical feature is the energy generation component, which consists of the turbine blades and motor. The component required many different iterations of testing until the power production proved satisfactory. Initially, the blades and generator were tested using an air compressor as a proof of concept to verify that the system could produce enough power to charge a battery. This was done by connecting a portable charger to the power generation component while testing with the air compressor. When the blade began to spin due to the air compressor, the blue LEDs lit up on the portable charger indicating that it was charging. After the success in initial testing, the turbine blades and motor were tested while driving in a car without a housing to enclose or mount the turbine. During this test, the blades proved to be a robust part that can handle driving speeds, and the generator proved to be capable of consistently producing power.



Figure 17. Initial energy generation component testing. The turbine blade and motor are connected to a battery, which lights up when it begins to charge.

The energy generation component was then implemented into a housing with a place to store the battery and circuitry, as well as magnets to mount the turbine to the top of a car. With the complete housing and mounting, the turbine was connected to a voltmeter for a more rigorous round of testing. As the testing vehicle drove around at set speeds in increments of 10 mph, the voltmeter read the values of the voltage and amperage. These values were then recorded and were useful for later analysis of the performance of the turbine.

Speed (mph)	Voltage (V)	Current (A)
20	2.7	0.3
30	4.7	0.4
40	5	0.6
50	5.3	0.7
60	5.4	0.8
70	5.4	0.9
80	5.5	1
90	5.7	1.1

Table 1. Values of voltage and amperage listed at different speeds in increments of 10 mph.

The second critical feature is the mounting component, which is composed of three magnets lined with electrical tape at the bottom. The testing for the magnets consisted of pulling on a spring scale attached around the base of the turbine.



Figure 18. Testing for the mounting component in action. Tether is threaded around the base of the turbine and hooked onto a spring scale.

This test was done to determine the amount of force required to move the product after it was mounted onto the car using the magnets. The force required to move the turbine was found to be 16.5 lbs, under the assumption that all of the drag force is applied around the base of the turbine, which is reasonable since the majority of the surface area and mass is located towards the base. The drag equation (Equation 1) was then used to make an estimate for the amount of drag that the turbine would experience when a car is traveling at 100 mph.

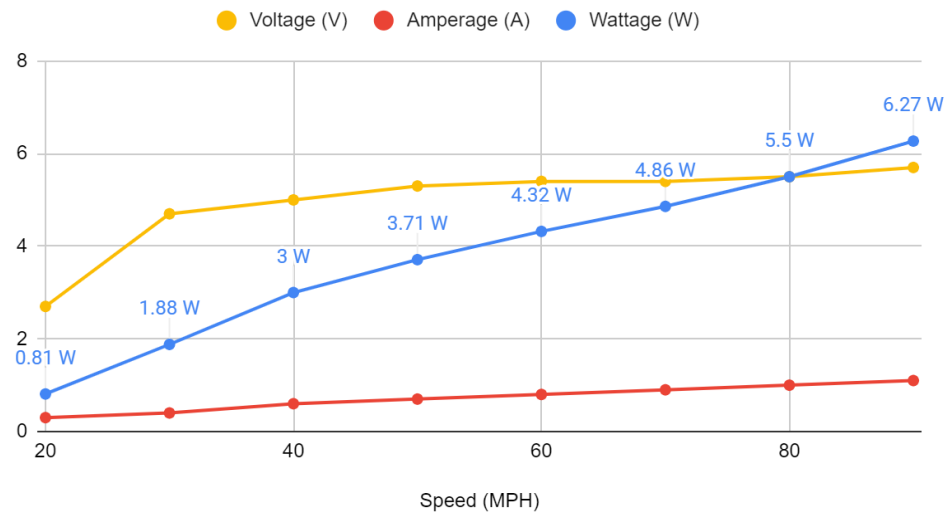
$$F_d = \frac{1}{2} \times \rho \times v^2 \times A \times c_d$$

(1)

The drag equation (Equation 1) is a function of the density of the fluid the object is passing through (ρ), the velocity of the object (v), the surface area of the object (A), and the drag coefficient of the object (c_d). The speed of the object was chosen to be 100 mph since this speed is quite above what people are expected to drive at. The approximate surface area of the turbine was found to be 0.2068 ft². The coefficient of drag was chosen to be that of a long plate (1.98), since a long plate has a greater coefficient of drag than the turbine, which means the calculated drag would be much more than what the turbine is experiencing. The density of the air was chosen to be at sea level (0.0765 lb/ft³) for the same reason. The estimation of the drag force using a long plate was found to be 10.47 lbf, which is 63.5% of the maximum force required to move the turbine. One aspect of this estimate that must be considered is that skin friction drag was not taken into consideration. This skin friction drag will increase the overall drag the turbine experiences, but the overall drag should still be far less than the maximum force needed to move the turbine, especially since the values in the drag equation were excessively exaggerated. Since the calculated drag force is an overestimate of the actual drag force the turbine experiences, and the calculated drag force is still well under the force required to move the turbine found through the spring scale, the mounting component in theory should hold onto the car extremely safely. This was verified through experiment when the turbine was tested on the streets and highways, where it held in place on the car.

VI. ANALYSIS

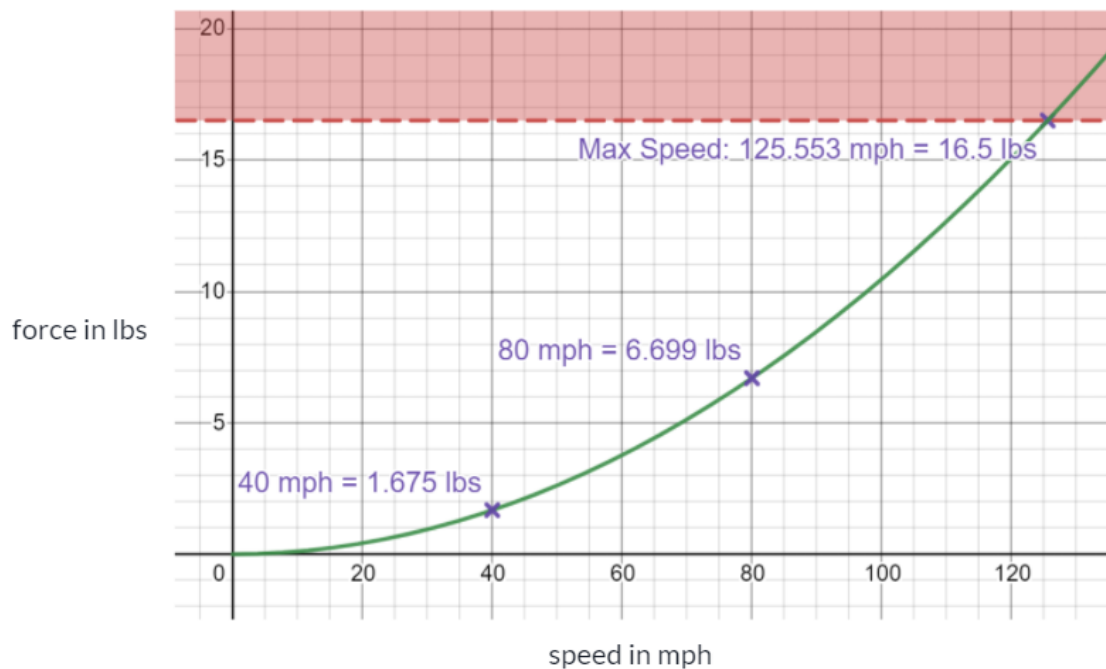
To analyze the energy generation component, the values of the voltage and amperage found in testing (Figure 1) were used to derive the power output at different speeds using power = voltage x current.



Graph 1. Graph of voltage (volts), amperage (amperes), and resulting wattage (watts) output of energy generation components at different driving speeds.

Graph 1 makes it clear that the power production of the turbine blade and motor component is more than sufficient to charge a battery. The wattage achieves a charging speed similar to that of a typical wall charger at 70 mph, so the power production was at an optimal level to charge the battery at a reasonable rate during a reasonable drive. Given the wattage derived from this testing, it would take anywhere from 1 to 3 hours to produce enough power to completely charge a phone from 0-100% at highway speeds. This large variability in charging time results from a variation in the size of phone batteries in the market, and a variation in highway speeds, which can range from 55 to 85 miles per hour. Regardless of this wide estimate, the critical component has shown to produce an ideal amount of power while travelling at highway speeds.

For the analysis of the mounting component, a graph was made to compare the calculated force of drag to the speed the car is traveling.



Graph 2. Graph of mounting calculations. Plot of drag force (y-axis) as it changes depending on speed of the car (x-axis).

This graph was created by taking the same values for density, surface area, and coefficient of drag that were used to calculate the drag force in testing (Figure 4) and solving for drag force, the dependent variable, using a varying speed, the independent variable. The graph helps depict the amount of drag force that is to be expected at different speeds. The graph displays the relationship between drag and mass flow rate; as mass flow rate increases, the drag increases as well. The graph is also insightful because the relationship between the change in estimated drag force of the turbine and the change in speed can be seen. Since the graph rises exponentially, the amount of drag increases at a faster and faster rate at very high speeds. To reach higher and higher speeds, an exponentially greater magnet force is required for the turbine to stay in place. This analysis of the pattern of the graph helps with future design implementations for the mounting component. The graph also helps determine the maximum speed that a vehicle can travel (assuming no wind) before the drag force exceeds the 16.5 lbf that begins moving the turbine. The speed was found to be 125.553 mph. This upper limit provides a definite maximum speed threshold that shouldn't be approached for the safety of the mounting component.

The power the turbine was able to provide was adequate for the charging of a phone, but design modifications must be made if the turbine is to charge something else. The design of the blade must be optimized to capitalize on the amount of power that can be produced from driving at different speeds. If the size of the turbine is to be scaled up, changes must be made to the mounting system, since the turbine would experience more drag due to increased surface area. This could be done by using stronger magnets. To reduce the amount of friction experienced by

the turbine, a smoother material can be used. Another consideration is to use an alternative to 3D printing, like machining, to see if improvements can be made on the efficiency or safety of the product. Incorporating some kind of mesh at the front and back of the turbine to protect the blade, motor, and cross-section from potential flying projectiles from flying and breaking the turbine should also be considered.

VII. CONCLUSIONS

The goal of this project was to combat climate change by tackling a problem where customers might idle the engines of their vehicles to charge their devices. Project Chinook sought to tackle this problem by providing a clean and easy way to produce electricity on a road trip. The design goals followed this directive, as the turbine needed to be able to charge a smartphone at a reasonable rate, so the power production goal to charge the battery was 5W. Furthermore, the Chinook had to be versatile and easy to use so that a wide market of people could employ the Chinook to reduce their carbon emissions.

After rigorous testing, the analysis showed that the turbine had met many of the necessary requirements to achieve the ultimate goal of reducing carbon emissions. The power production met a 5W charging speed at highway speeds, which showed that a phone could be charged after a reasonable driving time of 1-3 hours. Furthermore, the magnet mounting system showed that the turbine could safely be mounted to most cars using only magnets, while still achieving a factor of safety above industry standards.

To continue work on the production of the Chinook, many production alternatives need to be explored. The current design of the product satisfied all of the testing requirements, but the challenge of producing the Chinook on a large scale remains something that needs to be tackled. Processes such as injection molding should be considered for the production of the plastic parts of the Chinook, and a more elegant solution for the placements of circuitry components needs to be explored.

The core motivating factor to create the Chinook was to make an impact on the climate, so sustainability was inherently important to the design process for the product. In the early stages of prototyping, recycled materials were used in places such as the wooden box in the first version of the housing. As the quality of the prototypes improved, the primary material used was PLA printed plastic, which was not recycled. Even though using more sustainable materials was not entirely possible, the impact of printing parts was reduced by reusing many parts throughout the prototyping stages. For example, the turbine used in the second prototype was reused for every prototype iteration up until the final prototype, where the turbine was printed with a higher quality 3D printer. Even the final prototype iteration features reused parts from previous prototypes, such as the upper half of the housing which was stripped from the previous iteration and the motor, circuit, and battery, all of which were present in the second prototype. Additionally, if the Chinook were to be produced and sold, it would reduce carbon emissions made by those who bought it, as outlined in the goal of the project.

VIII. BUDGET/BILL OF MATERIALS

Item	Price
Power Generation	
High definition blade print	\$6.18
Motor	Free/Donated
Circuitry	Free/Donated
Battery	\$8.70
Housing/Mounting	
PLA filament ~ 1000g	\$25.00
Magnets for mounting	\$17.87
Magnets for door mechanism	\$11.25
Aesthetic/Adhesion	
Spray paint	\$5.99
Primer	\$5.99
Epoxy	\$4.84

Table 2. Budget/Bill of Materials

IX. TIMELINE

Necessary objectives

- Propeller design and Manufacturing
- Housing design and Manufacturing
- Electronic Hardware Manufacturing
- Software development
- Testing
- Revisions

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- [1] Mission Zero Webpage: <https://missionzero.io>
- [2] Climate Change Facts from the United Nations:
<https://www.un.org/en/climatechange/science/key-findings#physical-science>
- [3] Effects of climate change from the National Aeronautics and Space Administration (NASA): <https://climate.nasa.gov/effects/>
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<https://www.epa.gov/ghgemissions/global-greenhouse-gas-emissions-data>
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