WILDCAT WIND POWER

Kansas State University

Wind Turbine Business Plan and Technical Report

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2. Executive Summary

In this document, Monarch Energy, LLC. describes and supports an investment opportunity that can earn up to 3.4 times initial investment for investors and lead to a shift in how relief organizations provide disaster relief. Monarch Energy has seen and continues to witness the destruction wrought by Hurricanes Harvey, Irma, and Maria. Homes have been destroyed and lives have been put on hold by these disasters. In light of these recent occurrences, particularly in Puerto Rico and the U.S. Virgin Islands, it has become apparent that the ability to re-establish power is paramount when providing relief. Historically, bringing the lights back on has been a challenge with multi-ton diesel generators that are difficult to transport and expensive to operate. We at Monarch believe there is a better way, utilizing wind energy. Monarch Energy has prepared this report to discuss our solution.

Monarch Energy has developed a proprietary wind turbine that, when complemented by a battery storage system, will replace nearly all need for diesel generators in disaster mitigation projects. The design of this turbine is focused on providing a solution that is modular and consists of inexpensive components without sacrificing performance. We aim to provide a product with low initial cost that also minimizes annual maintenance costs and downtime for repairs. The turbine is designed so the rotor can be assembled on ground level. The rotor is then attached to the nacelle. After that, the nacelle and rotor are hoisted atop the collapsed tower. Finally, the tower is extended to its full height. All control circuitry is self-contained on ground level. This will keep almost all routine maintenance at ground level, and nearly all repairs are completed by replacing the part, thus minimizing downtime.

The remainder of the document is divided into two sections: Business and Technical, with figures and further details included in the appendices. The Business section will discuss the business model, vision, and a top-level view of the direction of the company. This section will also analyze the market as it currently exists and discuss how Monarch Energy aims to infiltrate it. Finally, the Business section will dive into the manufacture of our product, distribution, technical and economic constraints, financial analysis, and deployment. The technical design section goes into detailed descriptions of both the mechanical and electrical design components of the prototype wind turbine. Additionally, this section introduces a conceptual-level market turbine, which is influenced by the business plan as well as lessons learned from the prototype turbine. The Mechanical section is primarily concerned with nacelle, blade, hub, tail, yaw system, and tower design. This section also delves into the mechanical load and safety analysis of the the wind turbine. The Electrical section discusses the generator model, the load, and voltage regulation. This section will also describe the control circuitry designed by the team.

3. Business Plan

3.1 Business Overview

Monarch Energy, LLC. aims to improve the way relief organizations generate emergency power by using wind energy as a resource. Growth in the the small wind industry has gained substantial traction in the past decade as performance improves, costs decline, and value increases. This is at the same time that the Environmental Protection Agency, EPA, is attempting to push tougher and tougher regulations against the use of emergency diesel generators, limiting both the fuel they use and the hours they are allowed to run. Monarch Energy sees this changing political and economic atmosphere as an opportune time to penetrate the market with a new solution.

Monarch provides small-scale wind turbines for rent that can replace most small emergency diesel generators. These turbines are cleaner, cheaper, and easier to utilize than the diesel generators used today. Monarch has chosen Puerto Rico as our first target market. According to Army Corps of Engineers, 700 diesel generators have been deployed to Puerto Rico following Hurricane Irma and Maria as of November 27th, 2017. An obsolete infrastructure hinders Puerto Rico's recovery and needs a solution other than rebuilding around dirty, expensive fossil fuels. Realities like this make it apparent that there is a need for wind energy in disaster relief.

Monarch Energy will aim to partner with companies already in Puerto Rico such as Tesla and Sunnova. Tesla has made national headlines providing solar arrays with battery storage to a hospitals in San Juan. Sunnova, a solar company from Houston, TX currently has a 10,000-customer base in Puerto Rico and has made donations of solar panels as Tesla has. Both have made it apparent that they are keen on making their name known in this market in the same fashion that Monarch does. It is Monarch Energy's vision to bring emergency power relief to the 21st century with a focus on responsibility for our community both locally and globally.

Monarch Energy's wind turbine offers an inexpensive alternative to current backup power diesel generators. These generators are often cited as being loud, unreliable, and rampant polluters. Our turbine is cleaner since it doesn't burn diesel or natural gas. It is designed to produce power at low wind speeds to address the non-ideal wind resource available in Puerto Rico. Our turbine is designed to be inexpensive enough to have a competitive advantage over diesel. Monarch understands that we need to be able to offer value that diesel cannot. Additionally, these turbines are not designed to be a permanent solution. They are intended to be a means to provide emergency power while local utilities re-establish the grid. By keeping the needs of our market in mind, Monarch is capable of carving out a place for green energy in disaster relief.

3.2 Market Analysis

3.2.1 Target Market

Monarch Energy has chosen Puerto Rico as our first target market. The memories from hurricane Maria, as well as the continued need for backup power as utility companies rebuild, means that the demand for energy security in this region is still high. According to an August 2017 press release by Newswire, the power rental market is projected to grow 8.49% by 2022. This is thanks to increased power demand and a need to replace an ageing power infrastructure. Overall, diesel generator sales are projected to reach $20 billion by 2023. In addition, Puerto Rico's primary utility, Puerto Rico Power Authority (Prepa), had been suffering from billions of dollars in debt before Maria struck. According to [GALE] Prepa has been spending $1 billion per year on fuels (primarily oil and diesel) to provide power to the island, all while nearing federal pollution limits. Growing demand for uninterrupted power is driving growth in backup power globally as well. This globally growing demand paired with the obvious need in Puerto Rico makes for a perfect opportunity for market entry.

3.2.2 Competitors

In any market, there exists the threat of competitors. This includes the existing indirect competition such as Caterpillar, Cummins, Rolls-Royce, Mitsubishi, Yanmar, and Kohler, all of whom produce diesel generators that are used in emergency backup power. They are established and innovative within their space. These companies, among others, offer a large hurdle for Monarch Energy to clear in order to make room for ourselves in this market. Additionally, there are solar companies such as Sunnova out of Houston, TX that already do business in Puerto Rico. They, as well as Tesla and Sonnen, have leapt at the chance to grow their businesses and prove the feasibility of solar in the same way (?) Monarch attempts to accomplish with wind. If Monarch fails to develop a partnership with one or more of these companies, making headway in Puerto Rico could prove to be difficult. The natural gas industry also aims to make headway in this market leaning on its affordability and relative cleanliness compared to oil and diesel. Last, any number of small wind turbine manufacturers such as Gaia-Wind from the UK, Sonkyo Energy from Spain, domestic manufacturers like Northern Power Systems, Renewtech, Ogin, Primus, or Bergey could see our involvement in this market as a greenlight to get involved as well. Their established partnerships in manufacturing and distribution make each of them a formidable potential competitor.

3.3 SWOT Analysis

3.3.1 Strengths

Diesel and Natural Gas

In our target market, Monarch Energy has a list of strengths over our competitors in diesel generators and natural gas: our strengths include our cleaner form of energy, reduced lifecycle costs, and superior portability. Because the burning of fossil fuels can cause air pollution, wind is an inherently cleaner form of energy. Our product is also projected to be cheaper to own and operate over a lifecycle compared to a diesel generator. This in turn leads to a lower cost of energy which offers a better value to the consumer than that of diesel or natural gas. Last, diesel and natural gas generators require diesel and natural gas. This means that even after installation fuel needs to be relayed from port to the generator. The Port of San Juan was in disarray after hurricane Maria. On September 27th after hurricane Maria, 11 tankers were carrying 2.4 million barrels of fuel to the port that, upon arrival, was at capacity. “After ships reach shore, the real problems begin. Port operations are hampered by decimated infrastructure. Roads are flooded or covered by debris including trees and downed power poles,” (Malik, 2017). At a time when lives are at stake, and people are suffering, speed needs to be a priority. When ports are clogged with generators and fuel for said generators, food, water, and medical supplies are not reaching their destination quickly enough. Monarch has specifically designed our turbine to combat this issue. By being lightweight and collapsible, our turbine transports easily, and, once set up, does not need the regular shipments of fuel that fossil fuel based generators require.

Solar

Competitors in the solar industry, like Sunnova, work in a similar space as Monarch does. They aim to challenge diesel and natural gas through alternative energy. The strengths that our company have over competitors like Sunnova are the same strengths that wind typically has over solar. Wind energy works throughout the day and year round. Average wind speeds can fluctuate throughout the day and year, but the wind continues to blow at night. Solar panels are most effective in direct sunlight. Performance drops off when the sun is not at the right elevation or if there is any significant amount of cloud cover. Solar panels also don't work at night. Meanwhile, the wind will continue to blow. Solar power is also very dependent on surface area used. More power required means more panels means more area. True, wind turbines work in a similar manner. However, at ground level, turbines only need space for the tower and, in the case of our turbine, the guy wires for support. The guy wires can be navigated around, so the required area is negligible.

Wind

Monarch Energy also faces competition from small wind turbine manufacturers like Bergey and Sonkyo among others. Monarch believes that our strengths against these firms are in our focus and our design. Our focus is solely in emergency generation for disaster relief. Though this market segment is smaller than the small turbine industry at large, our design differentiates us from our competitors. Our collapsing, lightweight design is unlike any other large player on the market. This design gives us an edge in disaster relief for some of the same reasons that our turbines have an edge on diesel and natural gas generators. Our turbines can get on site quickly because of their size and weight. Other turbines are designed to take more time, money, and manpower to install. This leads to more resources taken away from other mitigation efforts.

Business Approach

As a manufacturing and rental company Monarch stands to benefit in this market. Wind turbines typically have a life of around 20-25 years. This obviously is much longer than the typical recovery project. Rather than selling turbines at the full initial cost, Monarch can essentially offer a discount to consumers needing emergency power. The costs are much lower for the consumer, but our company will be able to earn more revenue out of each unit by inflating rental price. For example, if a turbine costs $4500 to produce, we could sell the turbine outright for $5000. That extra $500 will go towards our net income. Now, assume the same $4500 turbine and instead charge $500/month for use. Suppose a typical lease agreement lasts 6 months and the turbine is put in warehouse and repaired for the other half of the year. Over the 25 years of the turbine that is $500/month x 6 months x 25 years = $75,000. Obviously, this is not realistic because there are extra risks incurred in the rental business. The point is that, by leasing our product, Monarch is able to obtain more revenue and ideally more profit than by selling them outright. In addition, the power rental market is projected to grow even faster than the other diesel generator markets because consumers desire the absence of liability on their end.

3.3.2 Threats and Weaknesses

Training Necessary

One of the initial concerns with the change in technology is the need for additional training by installers. According to Loch (2017) the Army Corps of Engineers recently recruited the help of over 500 local, Puerto Rican contractors to help install the diesel generators currently used for emergency power. These contractors are normally trained electricians and should have minimal trouble adapting to the new technology given that it is designed for ease of use and installation. In addition, the Monarch's design is intended to be collapsible with relatively easy assembly compared to our competitors in wind and solar. This additional requirement to the installation process will inevitably be more difficult than the basic wiring required to install a trailer-loaded diesel generator. This has been heavily considered in our design process with aims to minimize and eliminate it.

Inertia with Diesel Generators

Another weakness in our company is that infiltrating a market that is historically committed to fossil fuels is difficult. This market is looking to a quick, easy fix by either doubling down on diesel generators or transitioning to natural gas. In addition there already exists an expansive inventory of generators in warehouses and in use waiting for the next disaster. The logistics for getting fuel from the port to the generators have already been established. The resources necessary to address a situation can be easily estimated given the models, set data, and history that agencies like FEMA have with the existing arrangement with diesel generators. In addition, replacing the existing diesel generators with Monarch Energy turbines requires an immense initial cost. Though continued use of diesel and natural gas generators is expensive, these initial costs still need to be considered.

Natural Gas adoption

Building off of what was previously stated, these well-established companies in fossil fuel markets are catering to developed countries that are demanding increased backup power by transitioning to a cleaner alternative - natural gas. Though still a fossil fuel, liquified natural gas burns cleaner with considerably less carbon emissions and other pollutants. Large diesel generator companies already have the edge with existing consumer loyalty and technology. The shift from diesel to natural gas for them is relatively effortless. If Monarch is unable to gain some attention during this transition to natural gas, the likelihood of the business gaining traction is slim.

Sinking prices of crude and natural gas

Another related risk to the company is the threat of falling crude oil and natural gas prices. Crude in particular has prices that are subject to fluctuation thanks to OPEC and other political bodies. Recent policy in the United States favors domestic drilling to keep prices of crude and natural gas low. When these prices fall, pressure is put on renewables to prove their economic value. If crude oil and natural gas prices are low early in the life cycle of Monarch Energy, it will prove difficult to argue the value of renewables to buyers.

Potential Reliability Issues

Renewable energy has long been lamented as an unreliable primary source of electricity. The argument that, depending on the location of the disaster, wind or solar resources may not be abundant enough to be relied upon solely, can be hard to argue. It is difficult to rely on the wind to blow consistently. Power generation in a system entirely reliant on the weather also cannot step up depending on demand without help from some sort of backup generation or storage system. In addition, our target market of Puerto Rico has an abundant solar resource while having a low average wind speed. This makes having ample power output difficult to accomplish throughout the day and night. In other markets, pending future disasters, these locations may be farther from the tropics where solar radiation is less intense. These locations may also have a better wind resource. Our chosen target market is a particularly tough case, but if Monarch can succeed here, future markets can prove to be an easier sale to make.

3.3.3 Opportunities

PR's need to diversify energy portfolio in recovery

According to Malik citing the U.S Energy Information Administration, "almost half of [Puerto Rico's] power is generated by burning petroleum products and more than a third from natural gas" (2017). Another nearly 20% comes from coal according to the Puerto Rico Electric Power Authority Fiscal Plan (2017). Malik then noted that six days after Maria "just 11 of 69 hospitals [had] fuel or power" (2017). Puerto Rico needed 200 generators to relieve the damage, not counting those already on the ground post-Irma. As noted before, 2.4 million barrels of fuel were being shipped in on 11 tankers. Malik noted, citing the Energy Information Administration, that this supply of fuel may be enough for two weeks. A November 2017 report by Ana Campoy with Quartz paints a portrait of a recovery effort that is stagnant and listless. The authorities have been so troubled by repowering - more accurately, refueling - the grid that any hope of rebuilding has been all but lost. The Puerto Rico Electric Power Authority (Prepa) had for years proven to be in disarray before the storm arrived. This is a company that was $9 billion in debt and total assets of approximately $6.3 billion with power plants averaging nearly 50 years in age according to data provided by Campoy, citing the Prepa April 2017 Fiscal Plan. Just three months after that plan was released, Prepa filed for bankruptcy according to Hirsch and Brown with Reuters (2017). It is time for Puerto Rico to move on from their $1 billion/year fossil fuel dependence.

Solar companies like Sunnova and Sunrun have started moving to establish micro-grids to bring power back to consumers. Sunrun recently installed panels and batteries at a fire station in Barrio Obrero to keep communications running (Campoy, 2017). The question regarding whether renewables have a place in disaster relief is no longer "if". It is "when". According to Sunrun's public policy director, Chris Rauscher, "the demand is there and the infrastructure isn't." Tomas Torres, executive director of the Institute for Competitiveness and Sustainable Economy, says that Puerto Rico needs to move towards a model of smaller grids utilizing renewables. He claims that this would provide a more efficient and resilient network . Monarch sees this as an opportunity to enter the fray with our solution to PR's problems.

Increasing demand for low-cost energy security in developing economies

As developing economies continue to grow, so too will their demand for power. Many of this economy's load demands are growing at such a rate that infrastructure can not be updated in time to compensate. In turn, the grid becomes unreliable and demand for a solution arises. Diesel generator sales are projected to eclipse $27 billion in annual sales by 2023. This is a growth of just under $6 billion in the next five years. To reduce emissions and satisfy mounting environmental demands, many developed countries have begun adopting natural gas generation, which at the present moment appears to be filling the gap left by total sales growth. Large companies like Caterpillar, Cummins, Rolls-Royce, etc. have begun making moves to address this demand trend for clean backup power. Monarch too should see these trends as a chance to infiltrate and grow. These companies mentioned above are our competition, and when a company like Caterpillar sees an opportunity to grow in the generator industry, Monarch should also exploit it.

3.4 Value Proposition

Monarch Energy's offer of low-cost, renewable energy for disaster power generation stands apart from the competition because we offer the most value to our customer. Financially, our product does not require fuel, so customers can avoid the massive fuel costs associated with these disaster efforts. Logistically, Monarch's wind turbines are light and ship easily making them much easier to deploy than our competition in diesel and natural gas. In addition, by not needing to transport fuel to the recovery sites, emphasis can be put on other supplies. Environmentally, our product does not pollute as the competition. In today's political climate, avoiding a carbon tax gives our company a competitive advantage.

As a company, Monarch Energy wants to help people. Our goal is to positively impact the lives of all who receive our aid, work for us, or work with us. That goal drives us to manufacture a product that can help those in need after a disaster. That same mindset affects how we do business too. Manufacturing and assembly will always be done in adequate working conditions by fairly paid laborers. Our facilities will be committed to reducing waste and recycling what we can. Monarch Energy believes that profits should not sacrifice morality. By doing so, we believe that organizations will choose us.

To make an entrance into the market, Monarch Energy will provide five turbines to the community center in Orocovis, PR. This will serve as a proof of concept before an official roll-out of our product. As far as technical factors that our turbine has over competing small turbine manufacturers, Monarch's focus on low cut-in wind speed will prove to be a huge benefit in locations like Puerto Rico with non-ideal wind resource. Our circuitry is designed to continue to put power into the load as long as any is being generated from the wind. The turbine is designed to be simple, so the blade pitch is fixed, yaw is passive, and the circuit avoids power loss wherever possible. This gives Monarch Energy a large technical advantage over other manufacturers.

3.5 Management Team

President - Jacob Meyer is the President of Monarch Energy. He possesses a deep understanding of entrepreneurship and operations management. Supported by an unparalleled level of experience in the company, Jacob understands its inner workings better than anyone. His commitment to communication, perseverance, and respect makes him an ideal fit to lead this company. Jacob does this while holding an unwavering vision for the company that will keep Monarch moving in the right direction.

In the organization, Jacob will lead all major company decisions and will serve as the primary point of contact for investors. Major company decisions include ensuring that all other executive positions are filled by the most qualified individuals and guaranteeing that the goals of the company are being achieved. Monarch believes that his guidance puts us in the best position to succeed in our goals.

Vice President of Operations – Samuel Wilson serves as the VP of Operations as he oversees the day-to-day growth of Monarch Energy. Hard working and diligent, Samuel fills this position perfectly. Over the life of the organization, Samuel has proven capable of filling the roles of compelling leader and diligent partner to the President. This flexibility has proven to be invaluable to Monarch.

Samuel's roles in Monarch vary greatly depending on the season, the project, and the day. As VP of Operations, he establishes and ensures objectives are met that enable the goals set by the President. Samuel is also relied upon to develop relationships with business partners to aid the Monarch mission. His initiative and passion give Samuel the ability to help lead this organization.

Treasurer – Andrew Rieschick serves as the Treasurer of Monarch Energy. His role is oversight of the budget and managing expenses. This includes clearing all major purchases made by Monarch and regulating manufacturing costs.

Vice Presidents of Technology – Jacob McAfee and Tyler Kodonaz both serve as our lead Technology Officers. Their unique expertise in their respective fields make them irreplaceable in Monarch operations. Jacob and Tyler oversee design of the turbine from a mechanical and electrical standpoint, respectively. They both delegate work to the rest of the team and push to meet deadlines set by the Vice President of Operations.

Lead Project Manager – Justice Catron serves as Lead Project Manager. In this role, Justice oversees deployment for Monarch. Once the turbines are in the field, Justice's word is final. As Lead Project Manager, Justice is in charge of micrositing and turbine installation. This is a task that requires a depth of knowledge that is unmatched by the rest of the company. For this reason, as well as his strong sense of initiative and independence, Justice dutifully serves Monarch Energy as its Lead Project Manager.

Strategic Advisor – Dr. Warren White, Associate Professor of Mechanical Engineering at Kansas State University, has over 15 years in the field of wind turbine control. Dr. White has been with Monarch Energy since its inception dutifully offering guidance and expertise to the company. This experience with the team gives him a level of familiarity unmatched by any other person associated with the organization and makes him a valued mentor to the President and the rest of the team. Dr. White understands the vision of Monarch and helps guide the company toward its goals.

3.6 Development and Operations

In the following section, the development and operations of Monarch Energy and its products are described. This is done by discussing strategic partnerships and segmenting the lifecycle of the company into its initial three phases. In doing so, Monarch aims to clarify the decision making done by the management and illustrate the company vision. The segments listed are Phase 1-Launch, Phase 2-Growth, and Phase 3-Maturity. The reader should see that the focus of the company and the way it conducts business changes as Monarch grows.

3.6.1 Targeted Partnerships

Though it may seem counterintuitive to take the actions of a competitor as an opportunity, the products offered by Sunnova and Tesla are perfectly complementary to Monarch Energy. Sunnova and Tesla have both paved the way for renewables not just in Puerto Rico, but all over the developing and disaster stricken world. Sunnova has some 10,000 existing customers just in PR and has been donating solar panels and batteries to the island. Tesla has done the same thing, but with the typical bravado expected of an Elon Musk company. Many studies, including one by Abdullah Al Sharafi, indicate that solar and wind power generation working in tandem with battery storage lowers the cost of energy, by nearly $0.10/kWh in some cases, by allowing the strengths of wind to supplement the drawbacks of solar and vice versa (2017). In addition, this partnership would allow all entities involved to provide the best combination of wind, solar, and storage available to optimize performance and minimize total cost. By doing this our potential partnership would then be able to push and compete more aggressively against companies like Cummins.

Phase 1-Launch

In the initial year of existence, Monarch's goals will be to market to our core consumer segments, to improve our product, and to establish good business partnerships. During this stage Monarch Energy will develop its brand and try to appeal to consumers. Monarch's marketing strategy will rest heavily on special PR events, like those discussed in our value proposition. Orocovis, PR is a town in the mountains that has been neglected due to its distance from the coast. The community center that we are providing our turbines to has been housing oxygen-dependent elderly people who need reliable electricity. Monarch aims to gain name recognition through deployments like this.

In the launch stages, manufacturing will be held out-of-house. This decision was made to minimize initial facility costs. Monarch will be incorporated in the state of Kansas since it is the home state of most of our executives. Warehousing and facilities will need to be rented to house our inventory when it's not in use. Costs, taxes and depreciation will be handled in the financial analysis.

Phase 2-Growth

In the following year, Monarch aims to be in its growth period. In this year, it will continue to leverage its comparative advantages to attract new customers. New attention on our company will continue to improve sales and provide positive cash flow. With this, we expect to begin seeing profits as we pay off our initial costs. At this point, Monarch Energy will begin to prepare for expansion and go public. The freedom to raise cash for equity on the stock market was one of Monarch Energy's primary reasons for declaring as an LLC. Doing this will allow Monarch to insource manufacturing and make acquisitions and mergers that will benefit the company later on. Monarch plans to construct a permanent home in San Antonio, TX complete with manufacturing facilities and warehousing for our inventory. We made this decision for Texas' lack of corporate income taxes. This is favorable for a growing company trying to make a profit. San Antonio has a large workforce to support our corporation and is within an acceptable radius to the Gulf of Mexico and Sunnova, a potential partner of Monarch's. This is where most of Monarch's business will be in Phase 2.

Phase 3-Maturity

Following the Phase 2, Monarch will settle into the most profitable part of its life. Having utilized the successes seen in the growth period to make additional capital investments, Monarch can focus on making money and extending this period as long as possible. Possibilities for extending Phase 3 include making additional acquisitions and mergers, expanding into new markets, and infiltrating new industries.

As Monarch Energy matures as a company, it will need to continue expanding and changing to stay competitive. At maturity, Monarch anticipates having several direct competitors. Maintaining competitive prices and innovative products becomes paramount to keep an edge. Monarch also plans to expand into other markets such as Southeast Asia by this point. Backup generators have been a rapidly growing market there for several years as a number of economies continue to industrialize. This is also a region susceptible to typhoons and tsunamis which necessitates disaster relief power generation. At this time, Monarch will also begin new product development. This could be done either in developing new turbine concepts or by shifting into the microgrid industry. Sunnova and Sunrun are two companies that Monarch could in time acquire to shift our focus toward hybrid microgrid solutions. By doing this, Monarch would own all aspects of our disaster relief projects. Additionally, the development or acquisition of this technology would diversify our product portfolio. Above all, we plan to continue to strive for our goals and impact lives through improvement and innovation as an organization.

3.7 Financial Analysis

Taking into account the goals of our development and operations, our business plan started off with an initial investment of $500,000 to get the operation off the ground. This included ordering and manufacturing our first 50 turbines. In addition, we anticipate advertising, maintenance, and startup capital to become incorporated. Startup capital is $1645 in the state of Kansas.

4. Technical Design

4.1 Design Objective

The primary objectives of the turbine design include the following:

- **Minimal Deployment Effort:** The ability to quickly transport and set up the turbine.
- **Maximum Power Output:** Blade design was heavily emphasized in order to attain maximum power.
- **Low Cut-in Speed Operation:** Variable input resistance for lowering cut-in.
- **Reliability:** Minimal components required for market turbine.

Since, the wind turbine is being marketed towards a rental service for disaster situations, the turbine needs to be very mobile and easy to assemble, as well as be able to supply a large amount of power consistently. The market turbine's trailer will be in the form of a 10.5' long by 7' wide trailer that has a 30ft telescoping mast on top, which is commercially available for purchase. The market turbine can be towed to various locations and the telescoping tower can be winched down with a 1,000-lb hand winch to a height of 13 feet. The tower can withstand 125 mph winds and the trailer has 4- 1000-lb outriggers for stability. The blades were designed to produce maximum power and still generate power at lower cut-in speeds. The blades will be 11 feet in length and able to produce 5000 Watts at 8 m/s, the average wind speed in Puerto Rico. The blades were also designed for ease of manufacturing with fiberglass molds. The market wind turbine has a fixed-pitch hub machined out of aluminum to minimize moving parts. The fewer moving parts on the turbine will decrease maintenance and increase turbine reliability. Additionally, the blades can be detached from the hub and stored on the trailer for transport. Lastly, we will be utilizing a horizontal furling mechanism that is machined out of carbon steel, which is also commercially available for purchase. The furling system (detailed in Appendix A) allows us to make the braking system mechanical so we do not consume any power as you would with electrical overspeed and yaw control systems.

The major mechanical components of this year's test turbine design include twisted blades, a fixed-pitch hub, a twin-vane tail, and a lightweight base plate and tower. The airfoils for the blade were selected using a python program created by a member on the team. The blades were then optimized in QBlade by varying blade twist to allow for early cut-in as well as higher maximum power output. The tail design consists of a V-shape, which allows for more surface area to aid in yawing and a damping effect to prevent oscillations from the turbulent prop wash from the rotor. The base plate and tower were machined from aluminum to decrease weight. Lastly, the nacelle has been completely reworked to smoothly connect all other components while keeping the nacelle diameter as small as possible.

4.2 Difference Between Market Turbine and Test Turbine

A small-scale test turbine shown in Figure 1 was designed, built, and tested in order to prove the feasibility of achieving the design objective of the market turbine that can be seen in Figure 2. The test turbine differs in order to adhere to competition specifications and test facility limitations. The test turbine allowed the team to test multiple prototyped blade designs in order to find the maximum power producing model. The market turbine utilizes a furling mechanism for overspeed and yaw control whereas the test turbine utilizes back-EMF for overspeed protection and a twin-wing tail for yaw control. The market turbine furling mechanism uses an offset tail that is attached to a spring with a carefully selected spring constant. When the wind speed is outside the design wind speed range, the force on the tailfin will cause a strong enough moment to turn the tail away from the wind. The drag from the air will then slow down the blades, allowing for overspeed protection. Additionally, the orientation of the blades is no longer aerodynamically capable of increasing speed. When the wind speeds lower into the design range, the turbine will the return into the wind and its tail will act as a simple vane tail.

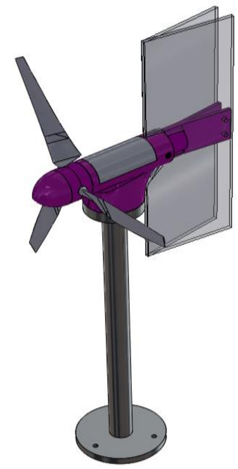


Figure 1. Test turbine model

Another major difference in our turbine design is tower construction. There is not a need for a telescoping tower at the testing scale so we used a light-weight aluminum tower and base plate. For our market turbine we will be purchasing a pre-fabricated trailer from Larson Electronics. The Larson Electronics Trailer comes with a 30' telescoping mast that extends into 5 sturdy steel sections with a locking mechanism. The tower can be hand-cranked into place or has powered extension capabilities. The trailer has 3/16" galvanized aircraft cables for guy wires and the tower is rated for 125 mph winds. However, the tower can be custom-reinforced by Larson for high-wind scenarios. A small fleet of high-wind trailer assemblies can be purchased for extreme circumstances. Our turbine will be easily mounted and unmounted from the plate at the top of each tower for easy maintenance and modularity. The trailer also comes with a solar panel that powers the electronic crank assembly if necessary and can supplement our battery storage system. The blades have been scaled appropriately in Q-Blade in order to generate our 5 KW target and are discussed in the next section.


Figure 2. Market turbine model

4.3 Static Performance Analysis and Blade Design

Blade analysis has been a large focus for the Wildcat Wind Power team. Our team has prototyped and tested four different types of blades: traditional, slotted, tubercle, and twisted. The base airfoil profiles for all of these blades were found using a python program developed in-house to filter through thousands of airfoil combinations for high lift-low drag airfoils to produce the most efficient blade. These airfoils were taken from AirfoilTools.com. Slotted and tubercle blades were modeled using the traditional blade as a base and modifying them based on information from Ibrahim, Alsultan, Shen, and Amano (2015) and Bai, Wang & Chen, 2016). Twisted blades were created using this same traditional profile and further optimizing it with QBlade by adding a twist of approximately 30 degrees.The profiles the blade is comprised of are the BE50sm and SA7024 airfoils, which are thin, high lift-low drag airfoils. The twisted blades were selected as they had the highest coefficient of power and the overall best power curve. The blades were then designed in SolidWorks and 3D printed for testing (Figure 3).

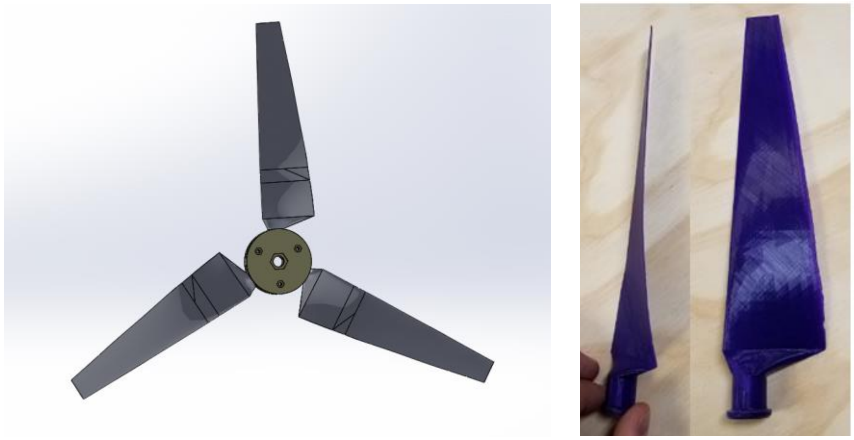


Figure 3. Twisted blades

The Q-Blade simulation results are included for both the test turbine (Figure 4) and the market turbine (Figure 6). A linear chord distribution was used; although not ideal, it reduces the cost to manufacture the blades.

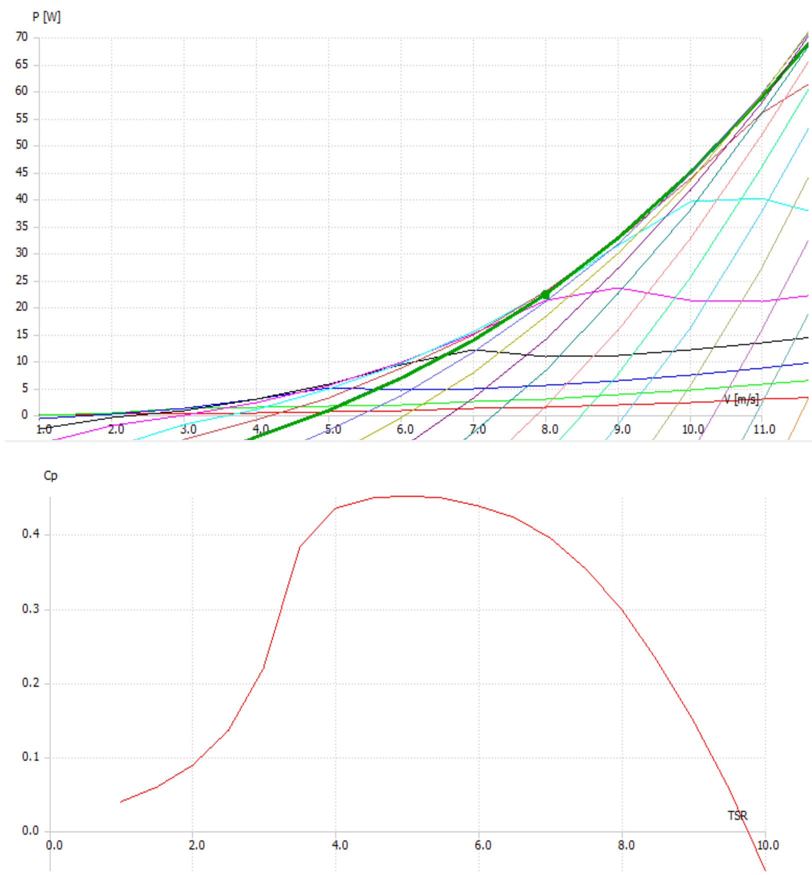


Figure 4. Test turbine QBlade graphs

The test turbine blades had a maximum coefficient of power of approximately 0.42. The number of blades was considered with the team originally opting for 5 blades. However, while 5 blades gives us a lower cut-in speed, the coefficient of power decreases which can be seen in Figure 5, and manufacturing costs for our market turbine increase .

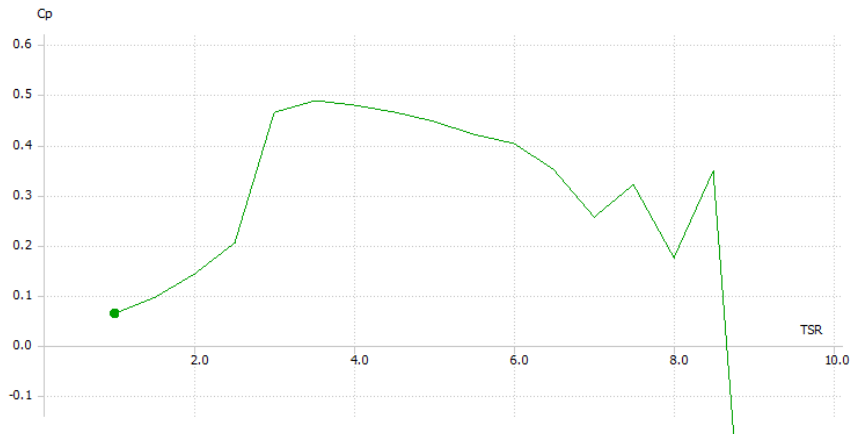


Figure 5. Test turbine Qblade graph for 5 blades

The blades for the test turbine included several iterations to develop a final design. Many blade designs were developed in SolidWorks: Traditional blades with no twist, tubercle, slotted and lastly the twisted blades. The twisted blades were selected as the final version of the blade and are thus the only design included in this report. All blades were fabricated with PLA using a 3D printer due to the ease of rapidly prototyping these blades. The tubercle blades and slotted blades could not be simulated in Q-Blade and real data had to be acquired through testing. A universal hub was then designed so all the blades would be able to fit in the hub and rapid blade testing could be done. After the twisted blades were selected, the blades were redesigned for the full scale turbine. Scaling the blades to 11 ft offered us the target range of 5 KW at 8 m/s, the national wind average at a height of 10 meters. This lets us provide the rated 5000 Watts of power at the national average wind speed.

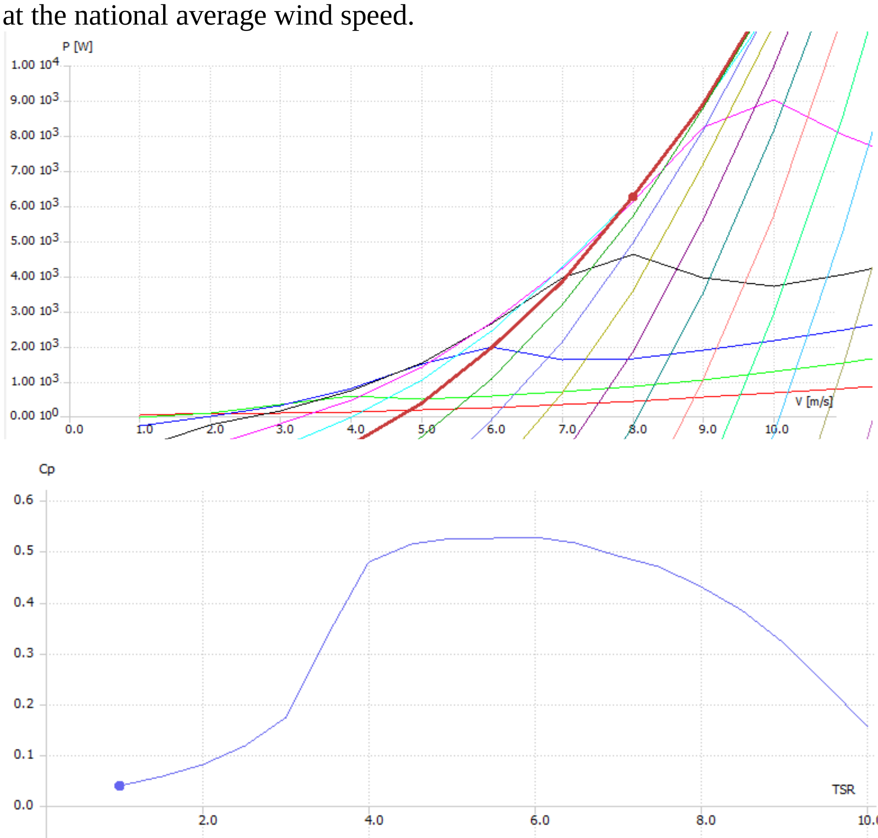


Figure 6. Market turbine QBlade graphs

The market turbine blades have a theoretical coefficient of power of 0.52 according to QBlade. After losses, we are going to assume the coefficient of power will be closer to 0.42. Figure 7 shows FEA analysis performed in QBlade on our twisted blades. If our blades remain rotating at the optimum tip speed ratio of 4, which gives us our maximum coefficient of performance, then the maximum stress that the blade will see is roughly 11 MPa. The breaking point would be located near the root of the blade, with a factor of safety of roughly 3.4, given that the ultimate tensile strength of PLA plastic is 37 MPa.

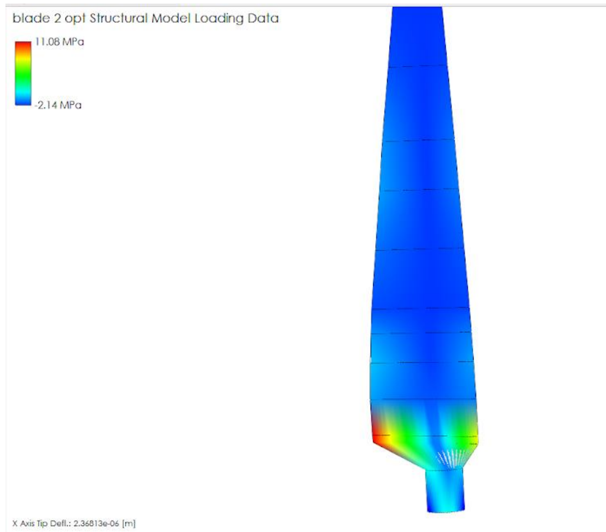


Figure 7. QBlade FEA analysis for twisted blades at TSR of 4

4.4 Mechanical Design

4.4.1 Nacelle

The nacelle will be discussed first since it is the central piece of the wind turbine that connects all other parts together. While simple in concept, it has fluctuated significantly in design due to the number of other pieces it must accommodate. On the bottom face of the nacelle, there are two recessed areas for two ¼-20 nuts, seen in Figure 8. These nuts fit into the recesses via an interference fit as well as glue, essentially making them permanent pieces of the nacelle. The outer ring of the bearing at the top of the tower has two holes for the bolts that go through this ring and into the nuts on the bottom of the nacelle, securing the connection between the tower bearing and the nacelle.

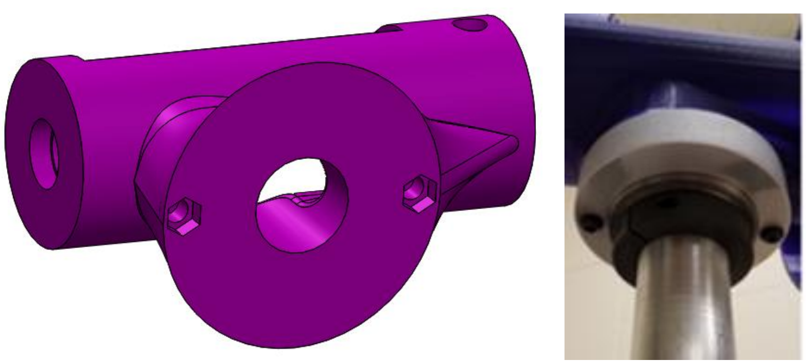


Figure 8. Tower connection to bottom of the nacelle

As you can see in Figure 9, the back of the nacelle is hollowed out, with the back wall of the nacelle featuring four slots that will accommodate generators with varying screw hole patterns, as long as these patterns have four screws. These must be screwed into the generator before the tail can be inserted. The tail is then inserted into the hollowed-out back section of the nacelle. There are holes for two ¼-20 bolts to be inserted through the sides of the nacelle, which then screw into the two nuts attached to the interior wall of the tail insert.

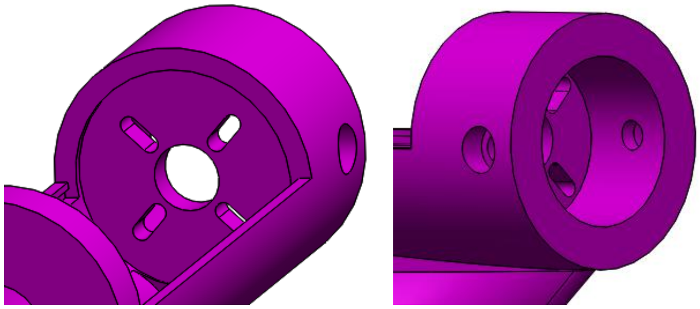


Figure 9. Generator and tail connection to the back of the nacelle

The front of the nacelle houses a single bearing for the shaft, which is held in place with an interference fit, seen in Figure 10. The shaft itself is coupled to the generator, with a flat notch on that end of the shaft to keep the shaft from slipping inside the coupling. The front of the shaft features M10 threads, seen in Figure 11. The length of these threads determines the location of the hub. Knowing this location along with the thickness of all components behind the shaft, the length of the main nacelle body was determined. The cover of the nacelle simply features a lip that fits inside a groove on the inside edges of the nacelle body, seen in Figure 12, allowing the cover to be popped on or off with ease.

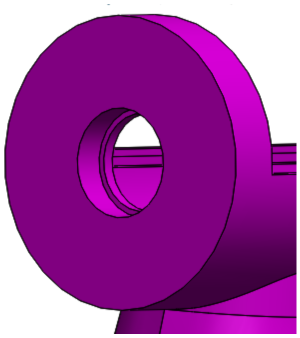


Figure 10. Shaft bearing housing in nacelle

Figure 11. Machined shaft

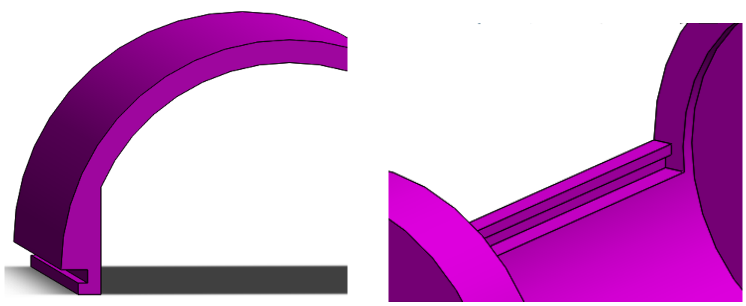


Figure 12. Nacelle cover and grooves

The main body of the nacelle was made as small as possible while still being able to house the generator, which resulted in an outside nacelle diameter of 60 mm. The bottom face of the nacelle was determined by the connection to the tower, which has a 90 mm diameter. This is one of the few things that our team wishes we would have designed differently – the tower connection is large and ultimately will have a slightly negative effect on power performance. To lessen this effect, the bottom face has a loft in an airfoil shape.

The front of this airfoil shape is located far enough back that there is no chance of blades hitting the nacelle, which can be seen in Figure 13. The inside of the nacelle is then partially hollowed out in the bottom to give more space for generator wires, shown in Figure 14.

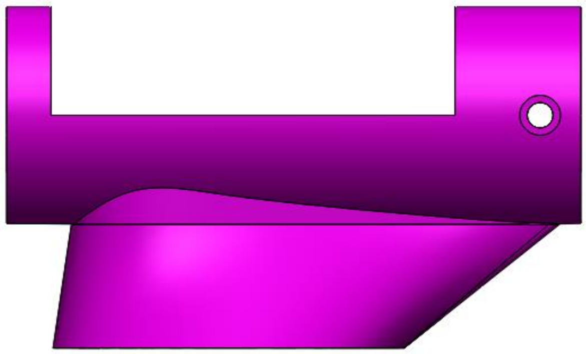


Figure 13. Side view of the nacelle

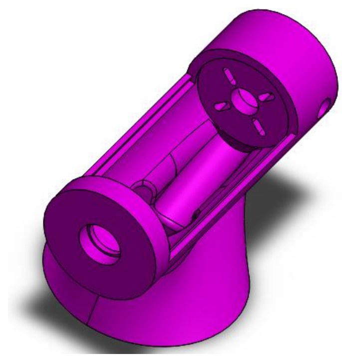


Figure 14. Extra wire space in the bottom of the nacelle

4.4.2 Yaw Control

Designing a yawing system has proven to be one of the more difficult tasks this year. We decided to move away from the shrouded tail from last year because it hinders power performance and is not feasible to manufacture on a large scale. Our team is only given the maximum angular speed, and a range for the wind speed, so there is no way to know exactly what values will be applicable to the actual test at the CWC. However, using approximations based on experience with previous competitions, it is possible to obtain an estimate for the tail area required. We start with the equation:

$$\theta = \theta_o + \omega t + \frac{1}{2}\alpha t^2$$

Where:

$\theta = final\ angular\ position$

$\theta_o = initial\ angular\ position$

$\omega = angular\ speed$

$\alpha = angular\ acceleration$

$t = elapsed\ time$

Substituting an angle difference of 180° per second and assuming that the turbine starts from rest – meaning the angular velocity begins at zero – the equation is simplified enough to give an angular acceleration of:

$$\alpha = \frac{2\Delta\theta}{t^2} = \frac{2(\pi)}{(1s)^2} = 2\pi\frac{rad}{s^2}$$

The next variable necessary is the dynamic pressure from the wind. Assuming that the maximum yaw rate will be performed at no less than the maximum cut-in speed:

$$q = \frac{1}{2}\rho V^2 = \frac{1}{2}(1.225\frac{kg}{m^3})(5\frac{m}{s})^2 = 15.31\ Pa$$

Our team then found an estimate for the inertia of our wind turbine from a SolidWorks model of the current turbine ($J = 0.03\ \frac{kg*m^2}{s^2}$), and estimated the boom length for the tail ($d = 0.162m$), which is the distance from the axis of rotation to the center of pressure for the tail. From there, if we assume a coefficient of lift of 1 for a flat plate, the force acting on the plate is then:

$$F = PA = qA$$

Since this is acting at the center of pressure of the plate, it produces a torque around the yaw axis:

$$\tau = Fd = (qA)d$$

Finally, recalling that the torque acting must be equal to the inertia multiplied by the angular acceleration, it is then possible to solve for the area required:

$$\tau = J\alpha = qAd$$

$$A = \frac{J\alpha}{qd} = \frac{(0.03\frac{kg*m^2}{s^2})(2\pi\frac{rad}{s^2})}{(15.31\ Pa)(0.162m)} = 0.076\ m^2 = 760\ cm^2$$

Twin-Wing Tail

The senior design team created rapid prototypes for both a flat plate and a twin-wing tail. The sizes of these tails were made to match as closely as possible to the area calculated, to achieve sufficient yawing. The flat plate was tested first and appeared to yaw well enough for competition requirements, but did experience some slight oscillation. The twin-wing tail was then tested. This tail yawed roughly the same as the flat plate, but appeared to experience even less oscillation than the flat plate due to the damping effect produced by the wedge shape (Ebert & Wood, 1995). The initial prototype included a tail insert into the back of the nacelle that then had two plates of balsa wood bolted onto it. To increase the strength of the tail, the team attempted to upgrade the balsa wood to Makrolon polycarbonate sheets, but a failure in the wind tunnel combined with the increased weight of the tail caused the adapter to break. To remedy this, the tail adapter was reprinted with 100% infill instead of the default of 20%. This should be the final revision of the tail, which can be seen in Figure 15.

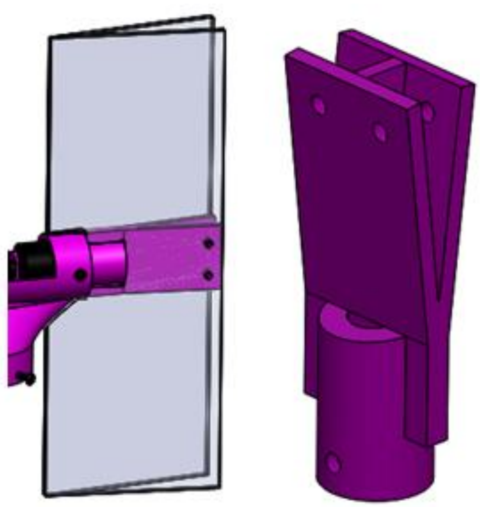


Figure 15. Twin-wing tail and adapter

4.4.3 Pitch Control

Fixed Pitch Hub

Given that our pitching system failed at last year's CWC, our team set out this year to design a new one. Several concepts for a passive pitching system were designed, but each one of them faced feasibility issues in some regard. We then turned towards an active pitching system using a servo and what was essentially the same as a helicopter swash plate. However, after evaluating blade performance and observing a fairly low cut-in with high maximum power output, the team decided a pitching system would not be necessary. Therefore, the team moved forward with a fixed pitch hub. Additionally, the team has used five blades in previous years versus three in the present design. The team performed analysis with three blades versus five, and came up with the graph seen in Figure 16. Ultimately, five blades performed just slightly better than three with a few watts of more power and a slightly earlier cut-in. However, because three blades means less 3D printing, quicker manufacturing of new blade sets, and more space within the hub for future changes, the team decided to use three blades.

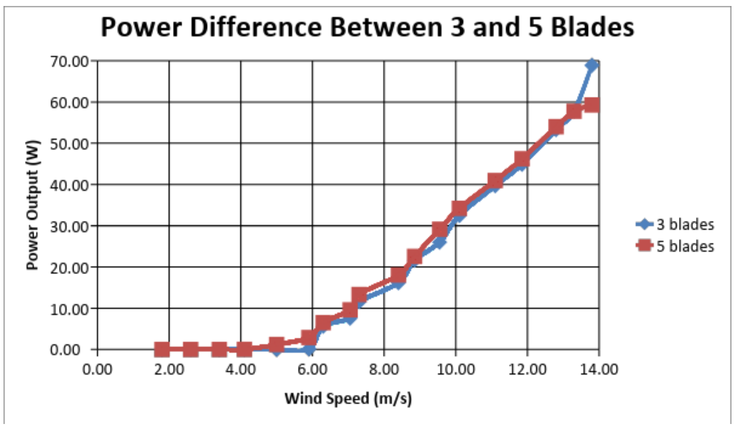


Figure 16. Graph of the power difference between three and five blades

Fixed pitch hubs of previous years simply had two halves that clamped around the blades. This normally worked fine, but there were concerns with blades changing pitch during testing as well as making sure that each and every blade was pitched exactly the same. To remedy this, our team moved the screw holes that hold the two hub halves together to go through the root of the blades, which can be seen in Figures 17 and 18. By running these screws through the blade roots, the team can control exact pitch angles of the blades. The only possible downside would be that we are then constrained to a single pitch for each set of blades that we print, but since QBlade gives us enough information to know the optimum pitch, this is not a serious issue. Additionally, to relieve some of the stress on the blade root where this screw passes through, the tolerances that hold the rest of the root were decreased to provide added friction across the entire root.

A nut that fits into one side of the hub is ultimately what translates rotation of the hub to rotation of the shaft. The nose-cone is then screwed on from the outside. During testing, the team noticed on several occasions that this nut could come loose from the hub and result in a loss of produced power. In order to keep this from happening during competition, the team decreased the tolerance for this nut recess so that it resulted in an interference fit, and also glued the nut into the hub so that there would be no possible way for this to happen during competition.

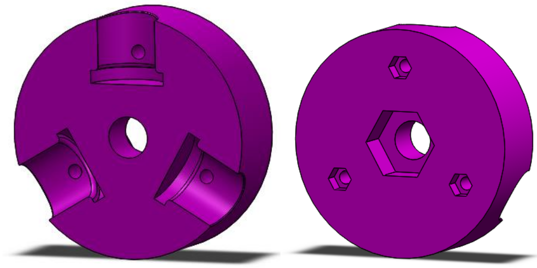


Figure 17. Nut side of the fixed pitch hub

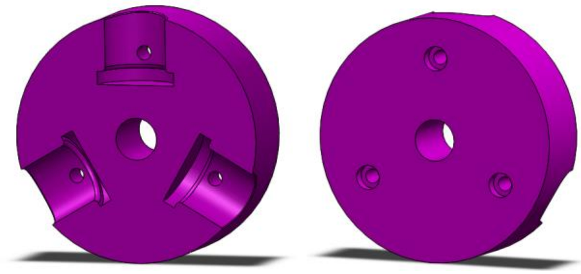


Figure 18. Screw side of the fixed pitch hub

4.4.4 Base Plate and Tower Analysis

The base plate and tower were very tightly constrained by CWC rules. This translates to few design decisions to be made by our team. The base plate and tower are made out of aluminum to reduce weight. Near the top of the tower, there is a split-ring shaft collar that a bearing sits on top of, seen in Figure 19. The outside of this bearing is forced into a larger metal ring via an interference fit. The larger metal ring then has two holes for the ¼-20 bolts that go into the bottom of the nacelle, fastening the two together.

Figure 19. Base plate and tower

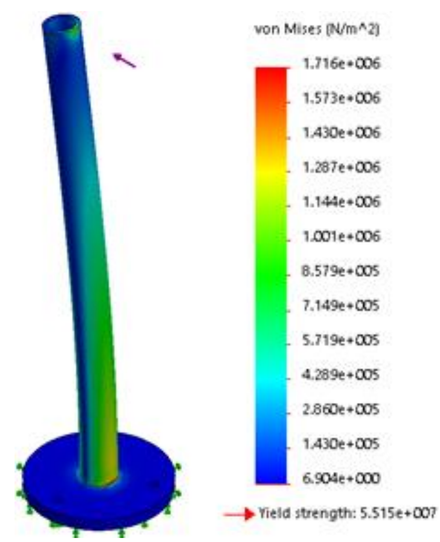


Figure 20. FEA analysis on tower

Through a finite element analysis (Figure 20), our team ensured that the structure would not break due to the force of the wind. The maximum force was calculated by the following equation:

$$F = \frac{1}{2} * \rho * A_s * v^2$$

Inserting the values for density of air, the area being swept by the blades, and the maximum speed that the turbine will be tested at, we obtained the following value:

$$F = \frac{1}{2} * 1.225 \frac{kg}{m^3} * \frac{\pi}{4} * (0.220\ m)^2 * (20 \frac{m}{s})^2$$

$$F = 9.32\ N$$

In simulation, this force was applied to the top part of the tower, where the nacelle sits. As a consequence of this force, the maximum stress was located at the part where the tower connects to the base, which is still not large enough to break the connection.

4.5 Electrical Analysis

The electrical system design consists of four main components: generator, rectifiers, DC/DC converters, and the load (Figure 22). These components are supplemented and controlled by an Arduino microcontroller (Figure 23). The generator converts the mechanical energy into three-phase AC power, which in turn is rectified into DC power. The DC power is regulated by a DC/DC converter and then supplied to a load.

Our team tested several generators to find the optimal generator for our application. Of the available generators tested, the team chose to use the LDPower MT4014 330 KV shown in Figure 21 below.
The MT4014 330KV provides the highest excitation voltage of all available generators and relatively low phase to phase resistance. Considering these factors led us to select this generator for our wind turbine. The kV rating of a generator relates to the number of stator windings and the gauge of wire used to wind the stator. As the kV rating increases, the generator has fewer stator windings. However, the wires are of a thicker gauge. We chose to go with a 330kV generator which is on the lower end of the kV values we tested. This lower kV allows the motor to generate higher voltages at a lower RPM, which is important for applications where it is connected to heavy fan blades. Higher voltage ratings require higher RPM to excite the same voltage, making it undesirable for wind turbine application.
The microcontroller will monitor the power output at each stage and control the function of the circuit in several ways such as breaking the generator using a back-electromotive force (EMF) and load detection.

Figure 21. Generator used in test turbine

With these processes, we are able to simulate and overcome challenges faced by industry-standard turbines such as steady power curves, controlled rotor speed and power output, minimized cut-in wind speed, sustained functionality, and safe shutdown methods.This section of the report will discuss the specifics of the turbine design by analyzing solutions to each of the challenges listed above.

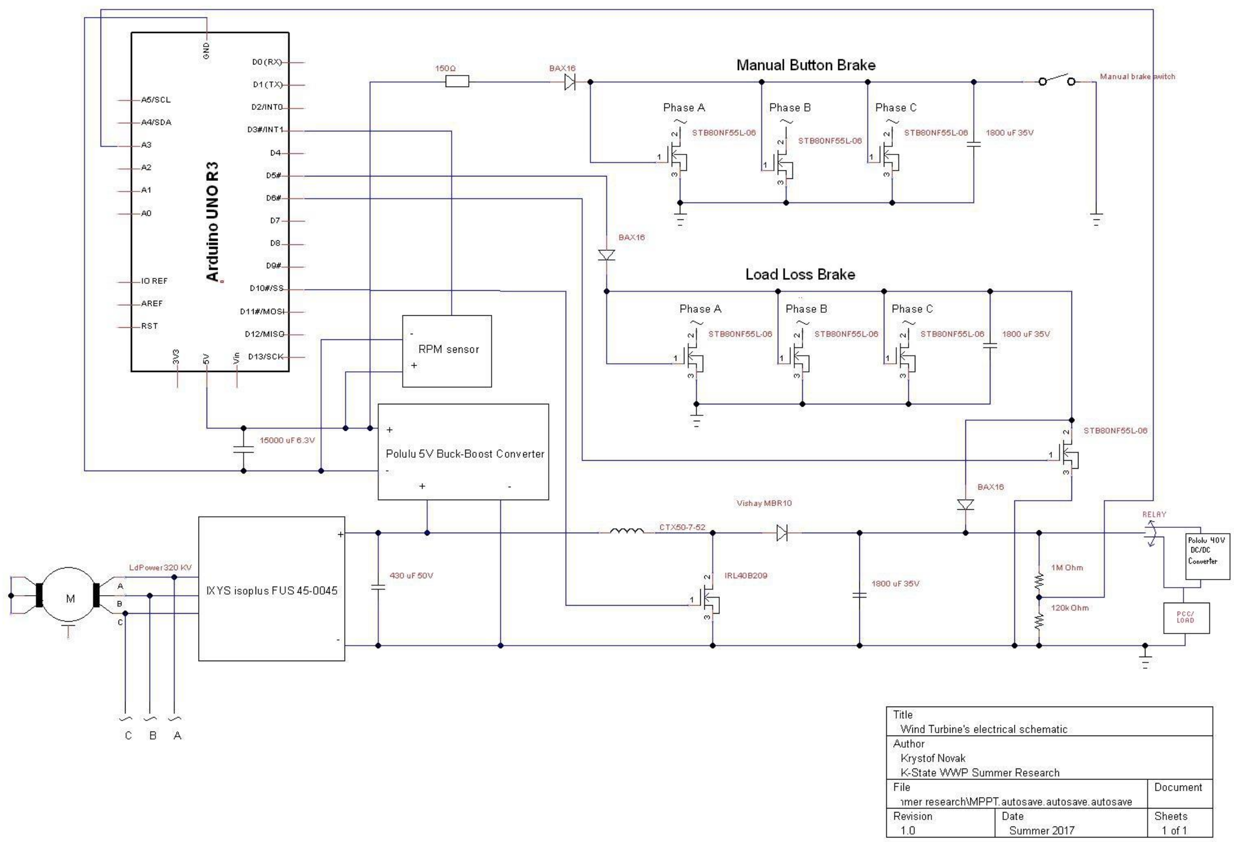


Figure 22. Test turbine circuit schematic

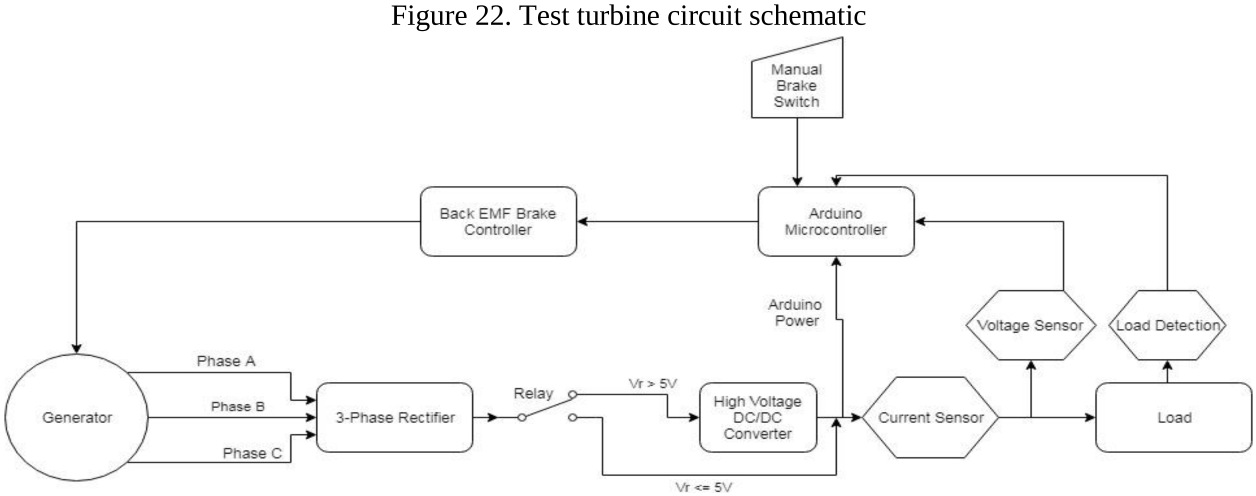


Figure 23. Box diagram showing power flow

4.6 Control Analysis

The control circuit uses a specific algorithm to control the torque of the generator, in order to maximize power output across a variety of wind speeds. Once we determine the optimal tip speed ratio for our particular blades, we can determine the torque necessary to maintain the that tip speed ratio (TSR) based on the equation:

$$\tau = K\omega^2 = \left(\frac{1}{2}\rho A R^3 \frac{Cp_{max}}{\lambda_*^3}\right)\omega^2$$

We can change the duty cycle across the DC/DC converter in order to change the resistance seen by the generator, which in turn affect torque. This behavior can explained with the equation below:

$$D = 1 - \frac{V_{in}}{\sqrt{R_{load}\tau\omega}}$$

Combining the two previous equation, we get our equation for optimal duty cycle:

$$D = 1 - \frac{V_{in}}{\sqrt{\frac{1}{2}R_{load}\rho A R^3 \frac{Cp_{max}}{\lambda^3}\omega^3}} \qquad \text{(Equation 4.1.1)}$$

We have used this equation to create an algorithm which calculates the optimum duty cycle every 800 milliseconds. This algorithm offers many advantages, such as optimal TSR at all wind speeds, rapidly reaching maximum power equilibrium, and power optimization independent of generator values.

In order to leverage our robust controls algorithm, we must gather a significant amount of information on the operation of the turbine. This duty cycle calculation requires the knowledge of some constantly changing variables; rotation speed, input voltage, and load resistance. Other constants; density of air, Cpmax, and TSR must also be known. With our implementation sensors and this control circuitry, we are able to quickly maximize our power production for a wide range of wind speeds. Additionally, with equation 4.1.1 being independent of the generator used, we can easily scale up this power optimization technique with our market turbine.

4.6.1 Control of Rated Power and Rotor Speed

High wind speeds are dangerous for wind turbines because the components are designed to operate in a certain range. In addition, turbines supply power to electrical power grids which may not be designed for large power spikes. For this purpose, it is important to be able to control the power output by turbines. The turbine we designed accomplishes this in two ways: first, by using EMF braking, we are able to slow the turbine and lower the power output. Second, mechanical systems such as pitch and yaw control can minimize or maximize the power output. When exposed to high-speed winds, both of these systems are necessary for total control of the rotor speed and power output by our turbine

4.6.2 Cut In Wind Speed

At low wind speeds, most turbines cannot produce an effective amount of power. However, wind at any speed has the potential to do work and produce electric power. Therefore, in order to maximize the efficiency of our turbine, we need it to operate at the lowest wind speed possible. This is done by allowing all the power produced at low wind speeds go straight to the load until enough power is being generated to run our microcontroller and begin extracting efficiency. This system ensures that as little power is wasted as possible.

4.6.3 Durability

Real turbines face a variety of wind speeds and need to provide sustained power throughout. Output power regulation is assisted by the rest of the electrical power grid: when the wind speeds are not sufficient to provide power, other sources including solar, hydroelectric, nuclear, fossil fuel, and stored energy make up the difference. The 58-Farad capacitor simulates power stored in the grid that can be used to maintain stable power levels during dips in wind energy productivity.

Our strategy for this task has 2 parts: charging and scoring. The primary goal is to charge the capacitor as quickly as possible. The charged capacitor will resist sudden voltage changes and provide auxiliary power to the load. Charging the capacitor quickly is accomplished by a low resistance accompanying the capacitor resulting in a low time constant. Second, during the scoring period, variable resistance loads will be applied to our circuit, resulting in power drawn from the capacitor and the turbine. Our new objective is to alter the duty cycle of our DC/DC converter. With careful control over our circuit, we can use the extra energy stored in the capacitor augment our generated power to maintain a consistent output voltage.

4.6.4 Safety

Safety is a major concern when it comes to wind turbines since there is no way to control the wind. During a dangerously high wind situation, we use back EMF to use the energy that the turbine is creating to slow down the rotation of the blades. This avoids an overspeed scenario where the turbine could spin up to a hazardous speed and potentially destroy itself and cause harm to anyone near it. The safety design also prevents overloading: if the load is either disconnected, or the current out to the load drops to 0 Amps, the turbine will shut down. After shutdown, if the conditions that caused shutdown are no longer true, the turbine will resume normal power production.

4.7 Test Results

The mechanical testing of the turbine was performed using the test circuit shown in Figure 24. The turbine was mounted in our wind tunnel, the three-phase generator wires were ran to a circuit which rectified the voltage to DC. This DC output was then ran across a resistor, and the voltage across this resistor was measured with a digital multimeter. The resistance was varied to produce an optimized power curve for our twisted blades. The power produced by the wind turbine can then be calculated using the equation:

$$P = V^2/R$$

Our team used resistances between 1 Ω and 5 Ω, and three blades with no pitch to obtain the power curve shown in Figure 25.At 5 Ω, we are able to cut in at roughly 4.0 m/s. Once we transition to 3 Ω we see roughly 14 W at 8 m/s. After again transitioning resistance, this time to 1Ω, we see roughly 39 W at 11 m/s.

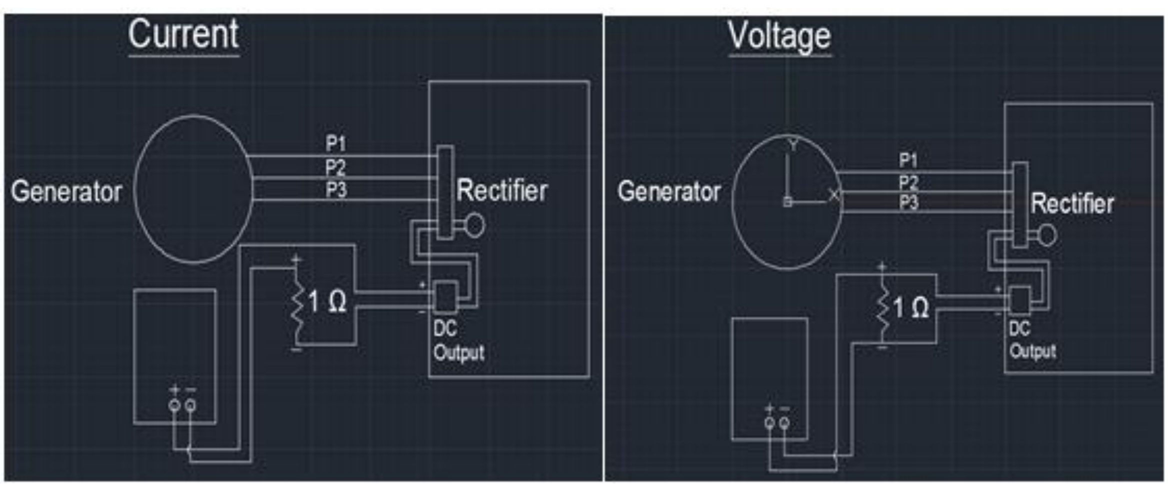


Figure 24. Wiring diagram for test set up

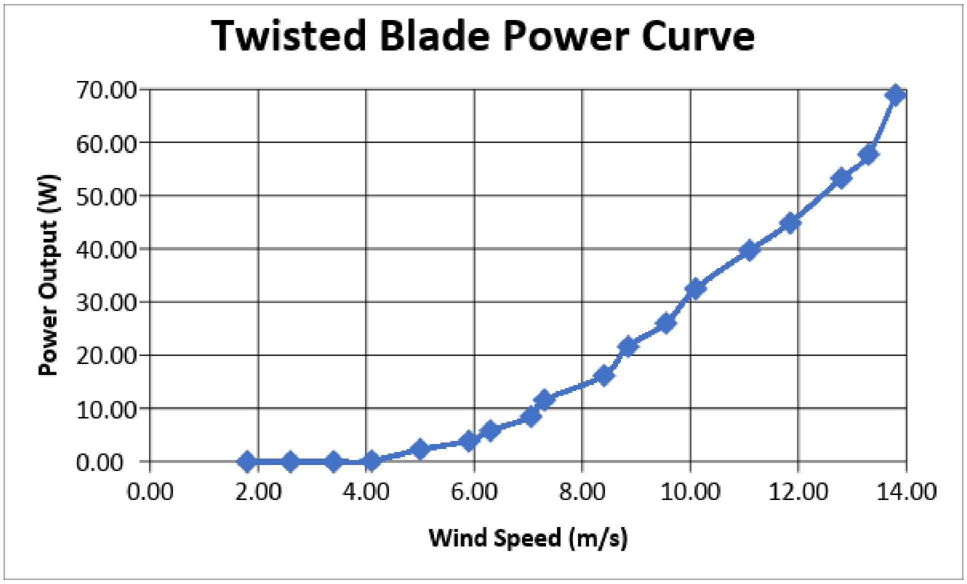
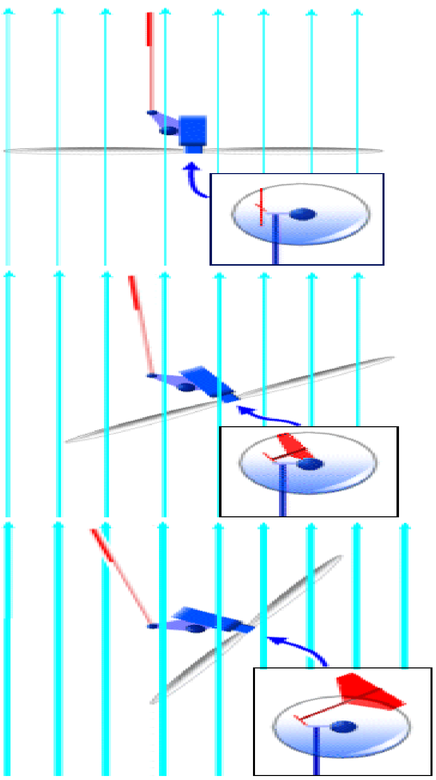


Figure 25. Twisted blade power curve

5. Appendix

Appendix A: Furling Mechanism



In this diagram, the vertical blue lines represent wind direction, the blue box represents the nacelle, and the red line represents the vane tail. Furling uses an offset tail that is attached to a spring with a carefully selected spring constant. When the wind speed is outside of the design wind speed range (which is what determines the spring constant), then the force on the tail and rotor will cause a strong enough moment to turn the rotor out of the wind. As wind speed decreases, the force of the spring overcomes the other forces, and the turbine returns into the wind.

Appendix B: Market Turbine Bill of Materials

Part Number	Part Name	Description	Vendor	Quantity	Unit Cost	Total Cost
1	Blades	Custom Fiberglass Molded to design	Gurit	3	$1,000.00	$3,000.00
2	Generator	5.6KW 3-phase C132T34FZ45A	Leeson	1	$1,770.00	$1,770.00
3	Telescope Tower and Trailer	30 ft. Telescoping Tower w/ trailer	Larson Electronics	1	$7,400.00	$7,400.00
4	Shaft	Nitride-Coated 1045 Carbon Steel 1.5" Dia - 18" Length	McMaster -Carr	1	$72.39	$72.39
5	Shaft Collar	High-Grip Clamping Shaft Couplings	McMaster -Carr	1	$96.41	$96.41
6	Nacelle	Machined aluminum	RAPID	1	$2,600.00	$2,600.00
7	Hub	Machined steel	RAPID	1	$400.00	$400.00
8	Furling Tail	Machined steel	RAPID	1	$1,200.00	$1,200.00
9	Bearing	SR24C-2RS/C3 NB2 1.5000 X 2.6250 X 0.5625 INCHES	Boca Bearing	1	$104.97	$104.97
10	Electronics	Rectifier/Wire/ Controllers	Mouser Electronics	1	$170.00	$170.00
					Total	$ 16843.77

Appendix C: Financial Statements

Monarch Energy			
Income Statement			
For the Year ended December 31, 2018, 2019, and 2020			
Revenue	2018	2019	2020
Investment	$ 500,000.00	$ 1,000,000.00	$ 800,000.00
Revenue from Sales	$ 60,000.00	$ 2,460,000.00	$ 4,860,000.00
(see pricing)			
(Cost of Goods Sold)	$ 842,188.50	$ 3,368,754.00	$ 2,695,003.20
(see BOM appendix B)			
Gross Profit	$ (282,188.50)	$ 91,246.00	$ 2,964,996.80
Operating Expenses			
Advertising Expense	$ 5,000.00	$ 10,000.00	$ 10,000.00
Maintenance Expense	$ 8,421.89	$ 33,687.54	$ 26,950.03
Utilities Expense	$ 20,000.00	$ 40,000.00	$ 50,000.00
Rent Expense	$ 100,000.00	$ 150,000.00	$ 150,000.00
Startup Capital Expense	$ 1,645.00	$ 300.00	$ -
Supplies Expense	$ 3,000.00	$ 5,000.00	$ 5,000.00
Building Depreciation	$ -	$ 7,692.00	$ 14,990.00
Payroll Expense	$ 80,000.00	$ 200,000.00	$ 230,000.00
Operating Income	$ (500,255.39)	$ (355,433.54)	$ 2,478,056.77
Other Revenues			
Gain on disposal	$ -	$ 5,000.00	$ 10,000.00
Income from continuing operations	$ (500,255.39)	$ (350,433.54)	$ 2,488,056.77
Income tax expense	$ (132,567.68)	$ (73,591.04)	$ 522,491.92
Net Income	$ (367,687.71)	$ (276,842.50)	$ 1,965,564.85

Monarch Energy			
Statement of Balance Sheets			
For the Year ended December 31, 2018, 2019, and 2020			
Year	2018	2019	2020
Assets			
Cash	$ 558,568.79	$ (1,361,835.58)	$ 1,445,160.47
Turbines	$ 842,188.50	$ 3,363,754.00	$ 2,685,003.20
Plant, Property, and Equipment		$ 300,000.00	$ 300,000.00
Accumulated Depreciation-PPE	$ -	$ 7,692.00	$ 22,682.00
Total Assets	$ 1,400,757.29	$ 2,294,226.42	$ 4,407,481.67
Liabilities			
Expenses			
Advertising Expense	$ 5,000.00	$ 10,000.00	$ 10,000.00
Maintenance Expense	$ -	$ 76.92	$ 226.82
Utilities Expense	$ 20,000.00	$ 40,000.00	$ 50,000.00
Rent Expense	$ 100,000.00	$ 150,000.00	$ 150,000.00
Startup Capital Expense	$ 1,645.00	$ 300.00	$ -
Supplies Expense	$ 3,000.00	$ 5,000.00	$ 5,000.00
Building Depreciation	$ -	$ 7,692.00	$ 14,990.00
Payroll Expense	$ 80,000.00	$ 200,000.00	$ 230,000.00
Total Liabilities	$ 209,645.00	$ 413,068.92	$ 460,216.82
Shareholder's Equity			
Common Stock	$ 1,000,000.00	$ 1,000,000.00	$ 1,000,000.00
Additional Paid In Capital	$ 500,000.00	$ 1,000,000.00	$ 800,000.00
Retained Earnings	$ (308,887.71)	$ (118,842.50)	$ 2,147,264.85
Total Shareholder's Equity	$ 1,191,112.29	$ 1,881,157.50	$ 3,947,264.85
Total Liabilities & Shareholder's Equity	$ 1,400,757.29	$ 2,294,226.42	$ 4,407,481.67

Monarch Energy			
Statement of Cashflows			
For the Year ended December 31, 2018, 2019, and 2020			
Year	2018	2019	2020
Cashflows from Operating Activities			
Cash from Customers	$ 60,000.00	$ 2,460,000.00	$ 4,860,000.00
Cash paid for Advertising	$ 5,000.00	$ 30,000.00	$ 50,000.00
Cash paid for Maintenance	$ -	$ -	$ -
Cash paid for Utilities	$ 20,000.00	$ 40,000.00	$ 50,000.00
Cash paid for Rent	$ 100,000.00	$ 150,000.00	$ 200,000.00
Cash paid for Startup Capital Expenses	$ 1,645.00	$ 300.00	$ -
Cash paid for Supplies	$ 3,000.00	$ 5,000.00	$ 5,000.00
Cash paid for Wages	$ 80,000.00	$ 200,000.00	$ 230,000.00
Taxes Paid	$ (111,367.68)	$ (31,591.04)	$ 570,791.92
Net Cash Flow From Operating Activities	$ (38,277.32)	$ 2,066,291.04	$ 3,754,208.08
Cash Flow from Investing Activities			
Turbines Purchased and Manufactured	$ (842,188.50)	$ (3,368,754.00)	$ (2,695,003.20)
Plant, Property, and Equipment	$ -	$ (300,000.00)	$ -
Net Cash Flow From Investing Activities	$ (842,188.50)	$ (3,668,754.00)	$ (2,695,003.20)
Cash Flow from Financing Activities			
Investment	$ 500,000.00	$ -	$ -
Cash received from stock issues	$ -	$ 1,000,000.00	$ 800,000.00
Net Cash Flow from Financing Activities	$ 500,000.00	$ 1,000,000.00	$ 800,000.00
Trial Balance	$ (380,465.82)	$ (602,462.96)	$ 1,859,204.88
Add beginning balance of cash	$ -	$ (380,465.82)	$ (982,928.78)
Ending Balance of Cash	$ (380,465.82)	$ (982,928.78)	$ 876,276.10

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