UMass MinuteWind

Presents

The Oasis

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I. Executive Summary

The UMass Amherst Collegiate Wind Competition (CWC) Team, aptly named UMass MinuteWind, has conceptualized, designed, and analyzed a unique and compelling product to revolutionize water decontamination and desalination. Our product—the Oasis—is a wind turbine equipped with a water purification unit designed to provide clean and plentiful drinking water in areas affected by natural disasters as well as refugee camps. In both scenarios, regular access to water supplies has been disrupted, denying the affected population one of the most fundamental components of human health and well-being. The Oasis is able to address these critical issues in addition to supplying affected areas with an array of benefits that no other solution offers. The wind turbine is easily deployable to target areas within two weeks of the event, and the installation process can be completed within twelve hours. The turbine powers a reverse-osmosis water purification unit that can sustainably provide communities with water in considerable excess of the United Nations' standards on water supply[1] (United Nations, 2010). UMass MinuteWind has designed this off-grid wind turbine to maximize the impact on the surrounding community, while ensuring a successful and sustainable business model. Ultimately, the team is pleased to present this impressive and versatile product, which has tremendous potential to leave a lasting impact on the two markets identified.

The UMass MinuteWind CWC Team is organized in a similar fashion to a startup company, with several domain expert groups operating under the class's leadership structure. The two faculty advisors, Matthew Lackner of the Mechanical Engineering Department and Birton Cowden of the School of Management, oversee the activities of the class and provide guidance when necessary. However, the intent of the course is for the students to guide the development of the project. Justin Calderara is the student leader of the course; his responsibilities include organizing the team into subgroups with particular foci, overseeing and assisting in all aspects of the project, and keeping each facet of the project on course. In addition, Jessica Murphy and Pavel Grigorash serve as the business and engineering leads, respectively. Both roles involve direct coordination with the team members to ensure effective progress is being made. The engineering team is divided into the four main portions of the technical turbine design: 1) rotor; 2) mechanical systems; 3) electrical and control systems; and 4) load. Similarly, the business team is divided into two subcategories: 1) business planning and 2) finances. Each subgroup consists of a team leader, as well as group members. This structure offers the best opportunity to divide the work evenly among each individual's strengths.

Identifying the appropriate problem to address with off-grid wind energy involved an extensive period of research for the UMass MinuteWind Team. Ultimately, the team arrived at water purification in disaster relief scenarios and in refugee camps as the problem that was both critical to solve as well as well-suited for an off-grid wind turbine. To reach this conclusion, the class was separated into groups that researched a unique problem that could potentially be solved with off-grid wind energy. The teams investigated forest fire prevention, waste removal, remote power, and water purification among other topics. After a rigorous and collaborative evaluation process entailing numerous expert interviews and extensive research, water purification was shown to hold the most potential; it is both a pressing problem without a satisfactory solution, and well-suited to an off-grid wind turbine as the solution. With the focus narrowed, teams then began researching which markets held the most promise for this topic. It was quickly found that natural disasters frequently occur in remote, off-grid locations near bodies of water. In addition, refugee camps suffer from similar clean water accessibility challenges because of the socio-political elements present in camps throughout the world. In both cases, the most reliable source of clean water during times of need is bottled water, which introduces logistical issues in terms of supply chain interruption and shipping. These two markets hold unique promise in that both are perfectly suited for off-grid energy production and water decontamination technology.

[1] Standard water availability per person is based off of United Nations Resolution 64/292: *The Human Right to Water and Sanitation*.

The technical design of the Oasis product is tailored to the application of powering a water purification unit in both of the selected markets. The Oasis features an 18.3 m tall tower made of high-strength structural steel with three blades made of Douglas fir and a rotor radius of 3.1 m. The turbine, which is rated at 3.1 kW, is transported to its deployment site in an 8'x8'x20' (2.4 m x 2.4 m x 6.1 m) shipping container. The tower is erected from the customized shipping container via a motor-driven lifting mechanism that easily hoists six foot segments of the tower from within the container, which serves as the foundation of the turbine. The Oasis is installable within twelve hours by a team of two to four individuals. The turbine is designed to power a GenPro water filtration unit that is capable of producing the equivalent of 2,000 liters of clean water per day. This unit was specifically chosen because of its ability to filter contaminants from both fresh and salt water at 99.99% reliability. Since possible deployment locations are unknown ahead of time and may vary widely in terms of wind resource, the system is conservatively sized to compensate for the potential of low wind speeds sites or deployment periods in which low wind speeds occur. These features are discussed thoroughly in the market turbine design section of the business plan, and serve to ensure that sufficient water will always be supplied as per the standards outlined by the United Nations. With these features, the Oasis is a robust system that can serve hundreds to thousands of people throughout its lifetime.

To represent this design for the Collegiate Wind Competition (CWC), a scaled version of the turbine was built. The test turbine features slight, but notable differences from the market turbine, which is inevitable at such different scales. For example, the test turbine is designed to fit in the 45 cm cube to conform to the CWC wind tunnel, while still accurately depicting the main features of the market turbine. To achieve this goal and still yield acceptable power output, the airfoil shapes and distribution used on the test turbine differ from the market product. To protect the turbine in high wind speeds, a tail vane and furling mechanism is considered in the market turbine. The test turbine will feature a tail vane that serves merely as a visual representation of the market vane, but will not work as a furling mechanism. Also, the load powered by the test turbine is different from the market load. The test Oasis model features a pump that forces water through a two-stage filtration system that demonstrates the reverse osmosis GenPro system.

The business plan for the Oasis system is designed to offer an attractive product to its customers while creating a profitable business. The primary customers for Oasis will be non-governmental organizations (NGOs), with the secondary customers being refugee camps. Oasis is intended to be rented to its customers at competitive market prices, comparable to what they currently pay to ship bottled water and supporting agents. UMass MinuteWind will act as a full service organization, meaning that the product is rented to the customers while the maintenance, setup, and service is completed by the company. This makes UMass MinuteWind the only solution of its kind that offers full-service purification of both fresh and salt water in both markets. The large capital cost of the system will be covered by loans, angel investors, and venture capitalists. By renting the product out to customers for several months each year, the company will be in good health in five years as discussed thoroughly in the business plan. This is done without asking the customers to incur high and unreasonable costs per month. This unique cost structure differentiates UMass MinuteWind from the competitor products in this market and will allow the company to prosper behind Oasis.

UMass MinuteWind's Oasis is a revolutionary product in terms of its ability to purify different grades of water efficiently and economically in both disaster relief scenarios and refugee camps. The primary customers will be pleased with the affordable renting structure and full-service aspect of the product, while the company avoids assuming insurmountable debt. The chosen markets were found by the team to have the greatest room for improvement in their current methods of combatting clean-water accessibility. By relying upon shipments of bottled water, interruptions to the supply chain and shipping logistics can prevent entire communities from receiving adequate amounts of water. The Oasis product is robust and capable of producing more than enough water per individual as outlined by the United

Nations' standards. The turbine is easily installed, reliable to operate, and capable of satisfying the purification system power requirements even during non-ideal wind behavior. Overall, the UMass MinuteWind team presents a remarkable product in the Oasis that is primed to have a profound impact upon the two targeted markets.

II. Business Plan

II.1 Market Overview

Water is an invaluable resource and a fundamental component of human health. An individual needs 10 liters of water per day just for drinking and that number grows when taking into account cooking, cleaning, farming, and sanitation. After a natural disaster, a community's regular access to potable water may be rapidly crippled, by damage to infrastructure or contamination of the supply. The current method for supplying areas in need is transporting water in large tankards or pallets of bottled water. Although many communities have access to local water sources, they may lack a system that makes the contaminated water usable after a disaster, forcing them to rely on water shipments[2] (Dr. David Alexander, Personal Communication, October 19, 2015). Unfortunately, the process of supplying water requires extensive logistical planning, which is susceptible to breaks in the supply chain and relies on fossil fuels[3] (Dr. Nezih Altay, Personal Communication, October 12, 2015). Communities are left in a constant state of waiting for water and disruptions in the supply chain have devastating effects on end users.

II.2 Our Solution

MinuteWind addresses these concerns of limited and unreliable drinking water availability by providing an affordable and sustainable service with our flagship product, Oasis. Oasis is a wind-energy powered water desalination and purification system that can be shipped globally. As seen in our Business Model Canvas (Figure 1), we are in a unique position in the emergency drinking water distribution industry, as no other companies currently offer a sustainable and full-service solution to address drinking water concerns. Our goals are centered around a triple bottom line: ecological, societal, and financial. MinuteWind strives to be the company of choice for NGOs who are looking for a renewable, reliable, affordable and safe solution to meet their water needs in times of disaster or in locations where clean drinking water is a limited resource.

II.3 Our Methods

Over the course of the year, MinuteWind has done extensive research to identify a significant need for Oasis. Utilizing the Lean Launchpad methodology, we have conducted over twenty interviews with academics, turbine production companies, current players in the water distribution market, and potential end users. Through constant customer contact, we were able to determine a market gap and need for our product.

II.4 Vision, Mission & Values

Vision: To be a leader in providing potable water to those in desperate need, sustainably, efficiently, affordably, safely, and reliably.

Mission Statement: We aim to provide access to clean drinking water for communities in need with a high quality, customer focused service that uses renewable wind energy. MinuteWind is dedicated to upholding our values of innovation, sustainability, reliability, customer service, and safety.

Value Proposition: The value proposition has been derived using the Business Model Canvas (Figure 1) and with a SWOT analysis (Appendix). Oasis is a highly valuable product for 5 reasons:

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[2] Interview with Dr. David Alexander, Disaster Relief Expert and Professor at University College London

[3] Interview with Dr. Nezih Altay, Professor of Operations Management at DePaul University and Expert on Supply Chain Management During Disasters

a. **Dependability:** Oasis can operate day and night to desalinate and purify 2000 L of drinking water per day (using UN standards for 200 people per tap at 10L per day, per person). With its independence from fuel sources, low maintenance design, backup battery supply, and water storage, individuals are provided with increased peace of mind knowing that their drinking water source is reliable and always available.
b. **Reliability:** Oasis is constructed from materials that meet or exceed MintueWind's strict quality standards. Oasis has been designed to be easily constructed and maintained; our technicians assemble, operate, and repair Oasis on site, while minimizing the risk of system failure.
c. **Independence and Sustainability:** Oasis reduces the need for shipments of bottled water or fuel for generator-powered water treatment systems, which promotes independence and sustainability. Currently, both bottled water and water shipments are logistically complicated, which can cause devastating effects for the end user when disrupted. Oasis produces clean drinking water without reliance on outside resources immediately after installation. Using renewable wind energy allows for independent operation, promotes sustainability, and reduces the environmental impact of plastic bottles and fossil fuels.
d. **Portability:** Oasis is completely contained inside a standard 20-foot shipping container, making it simple to deliver and deploy. This allows MinuteWind to distribute this product anywhere in the world in two weeks; this is ideal for disaster recovery situations and refugee camps where the immediate need for water is low, but the lack of established infrastructure calls for a mid- to long-term drinking water source. Due to its ease of assembly, maintenance, and disassembly, Oasis can adapt to a service timeline of a few months to multiple years.
e. **Versatility:** Full, secure, and reliable service from onsite MinuteWind technicians ensures that drinking water will be distributed fairly and the system will be operating efficiently. An internal battery bank and water storage allows clean water to be available even when the system is undergoing maintenance or when sufficient wind is not present. Closed circuit cameras and external lights improve site safety while an external UV water bottle sanitizer improves water safety, preventing the spread of disease in already unstable and dangerous locations.

II.5 Market Opportunity

Market Gap/Market Growth - Through our research, there is a clear need for a portable and sustainable solution that provides clean drinking water. Our product will target natural disaster relief groups, refugee camp coordinators, and various NGOs that aid the two groups. Especially in third world countries, MinuteWind's solution fills a life-saving gap for those affected by hardships and the organizations trying to help these people

Primary Market - Our primary customers are NGOs, such as Red Cross, FEMA, and humanitarian groups aiding in the rebuilding after a natural disaster. Drinking water can be extremely difficult to acquire reliably during the months of disaster recovery due to growing demand and hindered shipping logistics[4] (Dr. Michael Zakour, Personal Communication, November 8, 2015). Inaccessible roads, crippled communications, and damaged infrastructure after natural disasters make shipping and distributing resources from distant locations more difficult. Additionally, NGOs are constantly looking for more efficient solutions than bottled water[5] (Dr. David Reckhow, Personal Communication, October 6, 2015). Bottled water is guaranteed to be potable for communities in need, but disposing of used plastic bottles is difficult in countries with limited infrastructure. If the bottles are burned, harmful carcinogens are released, and transporting the bottles for proper disposal is rarely economically viable.

Because Oasis features a portable and fuel-independent design, we can overcome these challenges. Furthermore, Oasis yields clean water at a lower cost per serving than plastic bottled water, which is the

[4] Interview with Dr. Michael Zakour, Disaster Recovery Operations Expert and Professor at West Virginia University
[5] Interview with Dr. David Reckhow, Civil Engineering Professor at the University of Massachusetts, Amherst on Water Resources Research

predominant option for disaster relief drinking water. Additionally, included in each Oasis trailer is an ultra-violet (UV) sanitation device to reuse bottles and other water containers, which lessens plastic waste. When considering our market, small NGOs lack the funds to directly purchase and maintain high-volume water purification and desalinization systems. Large NGOs, like FEMA, are also inclined to rent out equipment instead of maintaining and storing their own items[6] (FEMA, 2016). By renting out our fully staffed Oasis system, smaller NGOs will be able to deliver sustainable, clean drinking water, while larger NGOs will still be interested in hiring our services.

Oasis will remain a relevant water supplier for areas affected by natural disasters. Natural disasters are an unfortunate, but common, global occurrence. According to a report made by the Norwegian Refugee Council and the Internal Displacement Monitoring Centre, over 19.3 million people were displaced by natural disasters across 100 countries in 2014. Since 2008, an average of 24.8 million have been displaced[7] (Internal Displacement Monitoring Center, 2015). This number is expected to grow as natural disasters caused by climate change may become more increasingly more commonplace[8] (NASA Earth Observatory, 2016).

Secondary Market - Our secondary market is international groups such as USAID, the UN, and others that aid in the management of refugee camps. Long-term refugee camps have become permanent homes for many individuals, which often lack essential resources in poorly governed locations[9] (Dr. Robert Rabil, Personal Communication, October 28, 2015). In addition to the availability of clean water, water sources in refugee camps are subject to corruption, as those in charge can sabotage, hoard, or limit the distribution as a means of obtaining power or revenge[10] (David DeArmey, Personal Communication, February 4, 2016). MinuteWind technicians help mitigate these issues by acting as an independent third party that fairly distributes clean water. The use of a sustainable system means that there is no dependence on fuel shipments, which are also susceptible to sabotage.

Looking towards the future, there is a growing need for Oasis at refugee camps. According to a 2015 report by the UNHCR, worldwide displacement of refugees is at all-time high; over 59.6 million people are displaced, with 13.9 million being new refugees[11] (UNHCR, 2015). The largest percentage (86%) of refugees are in developing areas. As the size of refugee camps grows in areas without transportation infrastructure, there is a clear need for a self-sufficient and sustainable product to provide access to potable water.

In most refugee camps, diesel generators are the main sources of power[12] (Dr. Robert Rabil, Personal Communication, October 28, 2015). Although seemingly reliable, diesel generators require a constant source of fuel. With refugee camps often located in areas that are difficult to access and rarely secure, drinking water reliability issues arise. Wind energy provides the opportunity to exploit an unused, on-site resource that is plentiful in supply and independent of external factors. In terms of renewable systems, the only major competitor to Oasis is portable, solar powered water treatment to supplement their diesel generators and bottled water.

Oasis in the Current Market – Currently, clean water is supplied through contracting with the bottled water industry and purchasing from companies that provide bladder tankards filled with water. Oasis would be able to compete with bottled water companies on a convenience, economics, and sustainability front, especially for long term water needs during the disaster recovery phase. For example, during the first year of disaster relief in Haiti, the Red Cross provided 678 million liters of water

[6] FEMA has a Schedule of Equipment Renting Rates that is used to determine compensation for renting of private, civilian equipment
[7] Facts from the IDMC Publication Global Overview 2015: People Internally Displaced by Conflict and Violence
[8] Facts from NASA Earth Observatory Website Article The Impact of Climate Change on Natural Disasters
[9] Interview with Dr. Robert Rabil: Professor at Florida Atlantic University and Expert on Foreign Refugee Camp Logistics.
[10] Interview with David DeArmey: Water for Good's Central African Republic Operations Manager.
[11] Facts based off of UNHCR's article Worldwide Displacement Hits All-time High as War and Persecution Increase
[12] Interview with Dr. Robert Rabil: Professor at Florida Atlantic University and Expert on Foreign Refugee Camp Logistics.

and spent $37 million while distributing this water to those affected[13] (American Red Cross, 2011). This leads to a cost of $0.0546 cents per liter of water or $0.55 per the recommended, 10 L daily serving. Oasis has the capability of providing 200 people with one 10 L serving per day. At our rental cost of $3300 per month**,** Oasis will provide water at a cost of $0.55 per 10 L serving, which is cost competitive with current methods.

There are many water treatment and desalination systems available on the market today; however, there are very few fully wind powered systems. Most units are fueled by diesel, solar, or a combination of solar and wind. A competitor, Trunz Water Systems, provides a similar product with a variety of solar powered systems for treating both freshwater and seawater sources. The Trunz Water Trailer is solar powered, easy to deploy, and produces 250 L/hour from a saltwater source and 1200 L/hour from a freshwater source[14] (Trunz Water Systems, 2016). However, the major downfalls of the Trunz Water Trailer are its minimal battery bank to be able to run overnight, and its small storage tank to hold excess treated water.

Oasis differentiates itself from other products on the market, including the Trunz Water Trailer, on several levels. By renting Oasis, the customer receives much more than the product itself. NGOs and governments rent both the product and the staff, guaranteeing end-users a high-quality product and service. Oasis also comes equipped with a UV sterilization unit, ensuring that our end users are drinking their purified water from a clean container. Also, within the shipping container is a 2000 L storage container for potable water. Unlike the Trunz Water Trailer, this storage container allows multiple consumers access to water at the same time, through the use of four self-serve taps. The use of multiple taps guarantees that the end users have minimal wait times and easy access to potable water. Finally, Oasis follows UN guidelines and supplies a maximum of 200 people with 10 L of drinking water per day.

II.6 Business Model Canvas

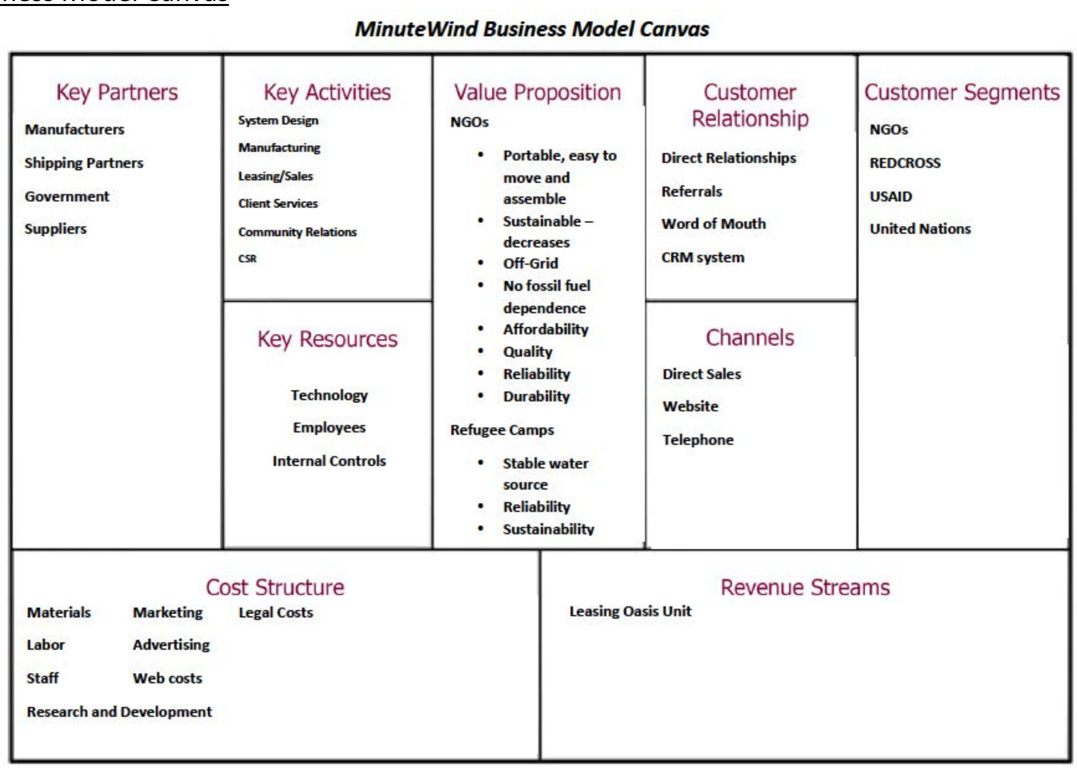


Figure 1: Business Model Canvas for MinuteWind

[13] Facts based off of the Red Cross's Haiti Earthquake Relief: One Year Report
[14] Trunz Water Trailer www.trunzwatersystems.com

a. **Value Proposition:** Across both markets, Oasis provides a dependable and sustainable product that reduces reliance on supply chains for water. Areas affected by natural disasters have the ability to move the product to areas of greatest need as it fluctuates. Refugee camps derive additional value from the MinuteWind service as a neutral third party to supply potable water.
b. **Channels:** We will implement direct sales by use of telephone and a customer oriented website where prospective customers can submit inquiries about the service. We will make constant connection with NGOs and other organizations as potential customers.
c. **Customer Relationships:** We plan to maintain constant contact with customers though a few different mediums in order to ensure high customer satisfaction. Sales representatives from MinuteWind will be aided by a Customer Relationship Management System, a software system that will have marketing and call center automation as well as help us to identify real sales prospects. It is also prudent to have a strong social media presence, so the company has already adopted a Facebook and Twitter account.
d. **Revenue Streams:** As a service company, we will have a single revenue stream; customers can rent both the product and service directly from MinuteWind on a monthly basis. This provides the convenience of having a water supply without needing to worry about staffing, maintenance, or storage.
e. **Key Resources:**
    - Technology, for both for the product manufacturing and the sales processes: we will focus heavily on a Research and Development division to ensure continuous improvement.
    - Carefully selected employees: workers will have experience in the green energy industry, a background in engineering or a related field, a passion for helping others, and strong problem-solving skills to make every employee of MinuteWind a vital asset to the company.
    - Proper internal controls: each facet of the company will perform as expected (internal auditing, corporate responsibility, innovating for the end user before profits).
f. **Key Activities:** To maintain a profitable company with a good reputation we need to maintain a few key activities.
    - We will continually innovate the Oasis design and technology, as well as the company as a whole, in order to maintain relevance and serve our clients and end users best.
    - We will maintain manufacturability, and continually seek to improve the operations and logistics of the processes involved.
    - We will have a sales department that is highly educated in both our product and the features that benefit each market. They will be fully immersed in the technology and maintain a strong customer service index.
    - We will hire a director of client services to acquire new clients and to ensure our customers are pleased with our product and properly educated about our services.
g. **Key Partners:** MinuteWind will establish relationships with its key partners in development, manufacturing, and sales. By establishing strong relationships with manufacturers of components and third party equipment, we will ensure that the products produced for MinuteWind meet our strict quality standards with economies of scale. Additionally, we will connect with dependable shipping partners to ensure that our product gets to our customers quickly and safely.
h. **Cost Structure:** Lastly, we have outlined our exact cost structure, as referenced in Table 2 of the Appendix. Operationally, we will increase profitability by decreasing costs for the greatest customer access. By maintaining a clear understanding of costs in relation to economies of scale, we will be able to create the most cost-effective product while still providing funding for future innovations.

II.7 Management Team

Justin Calderara: As the CEO, Justin oversees the enterprise and the general direction of the company. He keeps track of tasks that need to be completed and sets overall goals each week.

Jessica Murphy: As COO, Jessica oversees the business leads. She sets goals for each team to complete and gives tasks to the person who has the ability to complete them with the highest quality. She monitors the progress made and collaborates with engineering teams to get information needed for the business teams.

Pavel Grigorash: As CTO, Pavel oversees the engineering leads. He ensures that the teams collaborate to develop a fully functional product. Additionally, he assists the teams during testing to ensure that the tests collect accurate and applicable data and all the parts are designed in the most efficient way based on research and test data.

II.8 Company Milestones and Key Objectives

6 Months	• Develop training methodology for on-site MinuteWind technicians on how to erect and maintain the product • Focus: strategic growth
12-18 Months	• Develop relationships with various NGOs and Refugee Camp Coordinators to initiate our entrance in the market; maintain relationships to create goodwill and build a customer network • Focus: building a positive reputation, serving clients effectively
3-5 Years	• Breakeven and reaching ptofitability • Focus: improving efficient operation processes
4-10 Years	• Effective and effcient in generating customers • Focus: R&D for product improvement and potential new products

II.9 Manufacturing

Manufacturing Process and Buildability - To manufacture our product, we plan on purchasing the majority of the components directly at wholesale prices from our third party business partners. Although we are basing financial projections off single unit pricing, we expect to leverage our partnerships for a bulk discount on the water purification systems, UV sanitation units, safety and security features, and trailers. The wind turbine components, including the blades, nacelle, tower, and deployment/support system will be specially manufactured for MinuteWind by third party business partners. Specialized technicians will be responsible for final assembly according to the optimized trailer layout shown in Figure 2. This will ensure maximum shipping efficiency and safety while creating an easily accessible work environment during construction and deployment. The Gantt Chart of the manufacturing process in Figure 2 provides a timeline for the first Oasis production.

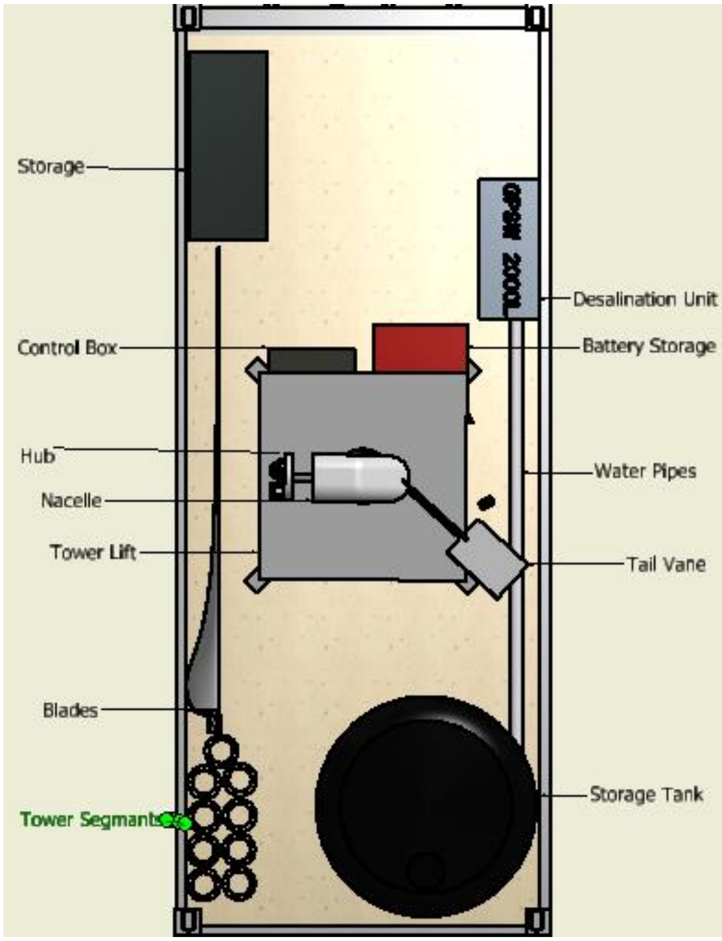


Figure 2: Optimized Shipping Layout of Trailer for Efficient Packaging and Onsite Assembly

Product Distribution - Once fully packaged in according to our optimized trailer layout, shown in Figure 2, Oasis will be shipped to our customers, where the product will be deployed and operated by our technicians for the entire duration of its use. Once Oasis is no longer needed, the system will be repackaged and shipped back to our warehouse for routine maintenance.

Technicians will repair any damage and install any replacement parts. Damaged components will be sent back to the original manufacturer for repairs. Once maintenance has been completed, Oasis will be ready for redeployment. Production will be an opportunity for growth, and we expect to improve with each unit produced. We will speak with our product partners to secure enough units for our operation, and develop a training methodology to ensure that both production and on-site technicians are able to complete their tasks effectively.

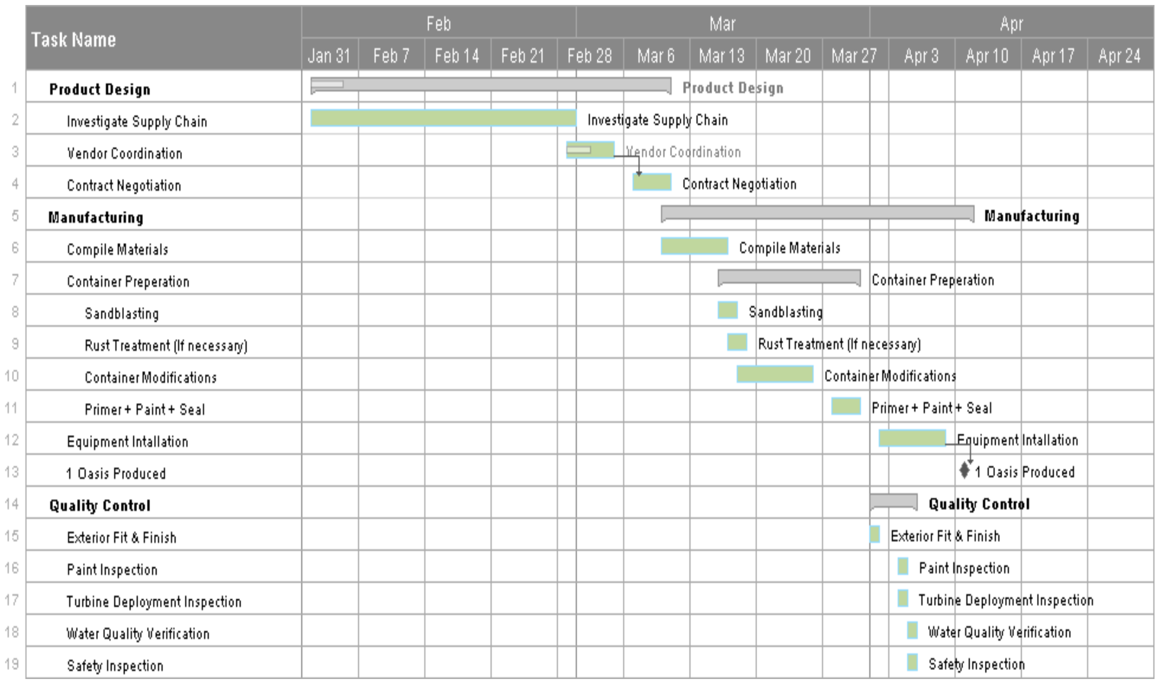


Figure 3: Gantt Chart for Unit Production

<u>II.10 Marketing</u>

Marketing Mission - MinuteWind's marketing mission is to introduce and educate NGOs, disaster relief groups, refugee camp coordinators and other niche groups about Oasis. By generating brand equity, our product will be easily recognized as an integral component of providing water in areas of need.

Marketing Objectives - As a new entrant in the industry, MinuteWind will first work to create a strong customer awareness for Oasis and the services we provide. We will appeal to NGOs and refugee camp leaders directly by communicating the effectiveness of the system, and the many features it delivers by implementing tactical marketing measures and actively advertising. Additionally, we will focus on publishing articles in humanitarian aid and NGO journals, highlighting the benefits and successes of our product. Once we have created a foundation, we plan on showcasing Oasis in trade show expositions. With enough interest, MinuteWind will attend high-profile events such as the World Wind Energy Association Conference and the UN DPI/NGO Conference.

Tactical Marketing Measures - To increase customer awareness of Oasis, MinuteWind will utilize the following measures:

- ***Journals and Magazines:*** Focusing on industry, peer-reviewed journals and magazines such as WORLD Magazine, Interpreter, Emergency Management Magazine, and Disaster Recovery Journal. We will print our company's mission and Oasis's impressive features. This will allow those involved with our target markets to learn about and obtain interest in our product.
- ***Surveys*:** We will continue market research by means of surveys, both Value and Lifestyle Surveys and Qualtrics, to NGOs and refugee camp officials in order to determine their needs and demands for drinking water production systems. This will illuminate purchasing motivators for the customers, and we can position the product in that direction.
- ***Trade Shows:*** MinuteWind will attend trade shows like the World Wind Energy Association Conference to showcase our product and develop a reputation for the promotion of green energy and sustainability. Also, attending and advertising in NGO and humanitarian aid conferences such as InsideNGO and the UN DPI/NGO Conference allows MinuteWind to

illustrate the functionality and benefits of our technology to a relevant audience, consisting of potential customer from various NGOs and humanitarian groups worldwide.

- ***Web Advertising:*** Although this will not be a primary form of advertising, we will create a user-friendly website that optimizes search engine marketing (SEM) though enhanced Search Engine Advertising (SEA) and Search Engine Optimization (SEO). The site will also be optimized for mobile device use as well as desktop devices for an intuitive experience.

II.11 Financial Analysis

Pricing - The materials cost of the Oasis system is broken down by part in the Appendix. The total part cost will amount to $29,600 (rounded to $30,000). Much of this cost is attributed to a few components. The water desalination system amounts to just over 30% of the total cost. The battery bank stores enough energy to run the system for 48 hours without wind, and amounts to $3500. The central structure to the deployment system is $3065, and ensures fast, safe, and easy erection of the turbine's 60-foot tower. The trailer and tower sections contribute about $3300 to the cost. We intend on renting this product with our service at a cost of $3300/month. This is an appropriate pricing model because it is competitive with the price of bottled water that our target market expects to pay.

Research and Development - Continued research and development (R&D) is necessary for success in the water treatment system industry. We will invest in R&D to ensure a future pipeline of products, which will remain relevant with contemporary technological advances. For example, the incorporation of solar panels to further exploit available, renewable resources represents a sustainable and complementary option when integrated with a wind power system.

We have initial allocations of $20,000/year for R&D, with expectations of increasing this value after MinuteWind becomes profitable. R&D costs will consist of improving components in Oasis, as well as developing more advanced, renewable energy water treatment systems. This will maintain our relevance and ensure our competitive edge in the market.

Labor Costs - The cost of labor is $50,000 monthly, or $600,000 yearly. This will increase each year, slightly. This accounts for labor costs in manufacturing, sales, and engineering, as well as executive and employee salaries. The onsite staffing cost per product is $4,500.

Production/Development Numbers - We are projecting to increase the production of Oasis water systems over time to decrease overall production costs through economies of scale. Starting in year 1, we plan to produce 9 units. Subsequently, we predict to be able to produce 24 units per year in year 2 through year 5. MinuteWind is only producing 9 units the first year because we would like to account for the time it will take to reach top manufacturing capacity. By year 5, we expect to have 96 units available to rent. 96 units can provide water for 19,200 people, only a miniscule percentage of those in need. As the amount of natural disasters as well as the population of refugee camps continues to rise, we expect a continuous demand for our product.

Health of the Company - In short, our 5-year plan will have MinuteWind in good health. Analyzing the following ratios, we get a better idea of the health of the company.

a. Profitability Ratios
- Return on Equity - This is net income over total shareholder equity. In Year 5 we project this to be 83%.
- Return on Assets - This is net income over total assets. In Year 5 we project this to be 44.2%.
- Profit Margin - This is net income over net sales. In Year 5 we project this to be 21.7%.

b. Leverage Ratios
- Assets/Equity - This is total assets over total shareholder equity. In Year 5 we project this to be 1.19 due to the amount of debt MinuteWind will take on to start the business. We would like this to be lower in the future, by relying less on debt, and paying off the interest in a timely manner.

c. Liquidity

- Current Ratio - This is the total current asset over total current liabilities. In Year 5, we project this to be 3.47. This puts us in a good position to begin paying off our debt in Year 6 because it means we are liquid enough to be able to pay off our short-term liabilities (notes payable, current portion of term debt, payables, accrued expenses and taxes) with current assets (cash, cash equivalents, marketable securities, receivables and inventory).

Financial Objectives - Our financial plan is to become profitable as early as possible. Currently, MinuteWind is on track to reach profitability in Year 4, as shown in Figure 4. We are expecting to take on debt to cover expenses from the start and for the first few years. Our financial plan includes efforts to decrease the expenses per unit as we become more efficient with better economies of scale. As start-ups require significant capital to run, MinuteWind plans to utilize many methods of funding. First, the US Federal Government offers grants for renewable energy. However, since there aren't many large grants, MinuteWind will apply for several smaller grants, which will add up quickly. Secondly, we will reach out to angel investors interested in investing in sustainable and socially conscious companies. As they will be looking for some protection, we will utilize US Federal Government loan protection to appease potential investors from losing all of their capital. Lastly, we will also attempt to sell equity of the company to venture capitalists who want a stake in the company to share our future successes.

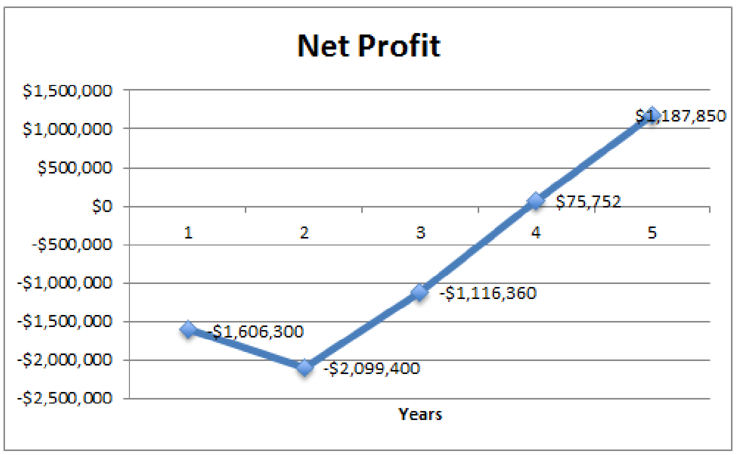


Figure 4: Projected Net Profit of MinuteWind over First 5 Years of the Company

Our financial goals are twofold: we aim to increase our profit margin by generating partnerships with our suppliers and to reduce the cost of producing our products by economies of scale. By Year 4, our profits will allow us to look into new technologies that increase efficiency while decreasing the costs of Oasis. The revenue of MinuteWind over 5 years is depicted in Figure 5. The profit and loss statement of MinuteWind over 5 years is shown in Figure 6.

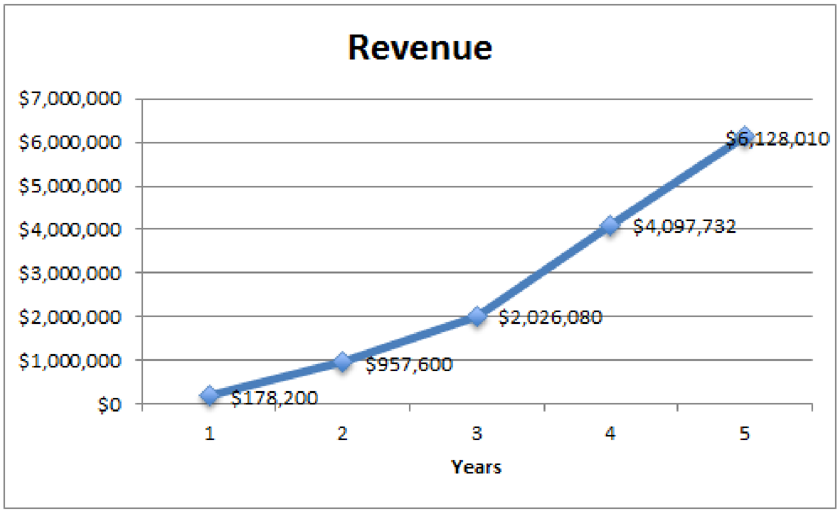


Figure 5: Projected Revenue of MinuteWind over the First Five Years of the Company's Lifetime

Profit & Loss Statement		Year 1	Year 2	Year 3	Year 4	Year 5
Revenue		$178,200	$957,600	$2,026,080	$4,097,732	$6,128,010
COGS		$270,000	$732,000	$1,488,000	$2,268,000	$3,072,000
Gross Profit		-$91,800	$225,600	$538,080	$1,829,732	$3,056,010
Operating Expenses		$1,234,660	$1,296,720	$1,389,480	$1,496,340	$1,617,600
Non-Operating Expenses		$279,840	$272,280	$264,960	$257,640	$250,560
Total Expenses		$1,514,500	$1,569,000	$1,654,440	$1,753,980	$1,868,160
Profit		-$1,606,300	-$1,343,400	-$1,116,360	$75,752	$1,187,850

Figure 6: Projected Profit and Loss Statement of MinuteWind over the First Five Years

Cash Flow Statement - The monthly cash flow statement for MinuteWind at the end of Year 1 and the end of Year 5 are shown in Figure 7 and Figure 8, respectively. The cash flow is based off of a cost of $35,000 per unit, which gives us a buffer to absorb costs not included in the original estimates and labor costs of $50,000 per month. In the later years, labor costs will rise marginally, however productivity will increase leading to a lower cost per unit for labor. In the first year, labor costs will be high as the project is progressing, at over $66,000/ unit. Starting in year 2, the labor cost will drop drastically to $38,000 per unit and will continue to fall as economies of scale starts working in our favor.

The debt and equity amounts and distribution were selected to ensure the company had enough operating cash, while also minimizing the costs associated with each funding source. The cash balance of MinuteWind over the first five years of operation is shown in Figure 7.

Statement of Cash Flow					Units Per Year	9							Year 1
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year End
Cash Position	$4,600,000	$4,434,100	$4,287,200	$4,140,300	$4,003,150	$3,866,000	$3,728,850	$3,601,450	$3,474,050	$3,346,650	$3,229,000	$3,111,350	$2,993,700
Sales	$0	$0	$0	$9,900	$9,900	$9,900	$19,800	$19,800	$19,800	$29,700	$29,700	$29,700	$178,200
Cost of Goods Sold	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$22,500	$270,000
Net Cash Flow From Operations	-$22,500	-$22,500	-$22,500	-$12,600	-$12,600	-$12,600	-$2,700	-$2,700	-$2,700	$7,200	$7,200	$7,200	-$91,800
Operating Expenses													
Labor	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	$80,000	
Payroll Tax	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	$7,280	
Rent	$8,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	$4,000	
Utilities	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	
Credit Card	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	
Insurance	$6,000	$0	$0	$150	$150	$150	$300	$300	$300	$450	$450	$450	
Equipment	$10,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	$1,000	
Advertising/Marketing	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	$5,000	
Maintenance	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	
Office Supplies	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	$100	
Lawyer	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	
Research & Development	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	
Other	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	$500	
Total Operating Expenses	$120,080	$101,080	$101,080	$101,230	$101,230	$101,230	$101,380	$101,380	$101,380	$101,530	$101,530	$101,530	$1,234,660
Non Operating Expenses													
Interest	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Other	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Total Non-Operating Expenses	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$23,320	$279,840
Net Cash Flow	-$165,900	-$146,900	-$146,900	-$137,150	-$137,150	-$137,150	-$127,400	-$127,400	-$127,400	-$117,650	-$117,650	-$117,650	-$1,606,300
Ending Cash Position	$4,434,100	$4,287,200	$4,140,300	$4,003,150	$3,866,000	$3,728,850	$3,601,450	$3,474,050	$3,346,650	$3,229,000	$3,111,350	$2,993,700	

Figure 7: MinuteWind's Monthly Cash Flow over the First Year of Operation

Statement of Cash Flow					Units For Year	96							Year 5
Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year End
Cash Position	$609,692	$624,169	$638,647	$653,124	$723,942	$794,759	$865,577	$992,734	$1,119,892	$1,247,049	$1,430,547	$1,614,044	$1,797,542
Sales	$424,358	$424,358	$424,358	$481,898	$481,898	$481,898	$539,438	$539,438	$539,438	$596,978	$596,978	$596,978	$6,128,010
Cost of Goods Sold	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$256,000	$3,072,000
Net Cash Flow From Operations	$168,358	$168,358	$168,358	$225,898	$225,898	$225,898	$283,438	$283,438	$283,438	$340,978	$340,978	$340,978	$3,056,010
Operating Expenses													
Labor	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	$100,000	
Payroll Tax	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	$9,100	
Rent	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	$4,400	
Utilities	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	
Credit Card	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	
Insurance	$8,850	$8,850	$8,850	$10,050	$10,050	$10,050	$11,250	$11,250	$11,250	$12,450	$12,450	$12,450	
Equipment	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	
Advertising/Marketing	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	$5,800	
Maintenance	$350	$350	$350	$350	$350	$350	$350	$350	$350	$350	$350	$350	
Office Supplies	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	$200	
Lawyer	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	$300	
Research & Development	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	$2,000	
Other	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	$600	
Total Operating Expenses	$133,000	$133,000	$133,000	$134,200	$134,200	$134,200	$135,400	$135,400	$135,400	$136,600	$136,600	$136,600	$1,617,600
Non Operating Expenses													
Interest	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	
Taxes	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Other	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	
Total Non-Operating Expenses	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$20,880	$250,560
Net Cash Flow	$14,478	$14,478	$14,478	$70,817	$70,817	$70,817	$127,158	$127,158	$127,158	$183,498	$183,498	$183,498	$1,187,850
Ending Cash Position	$624,169	$638,647	$653,124	$723,942	$794,759	$865,577	$992,734	$1,119,892	$1,247,049	$1,430,547	$1,614,044	$1,797,542	

Figure 8: MinuteWind's Monthly Cash Flow over the Fifth Year of Operation

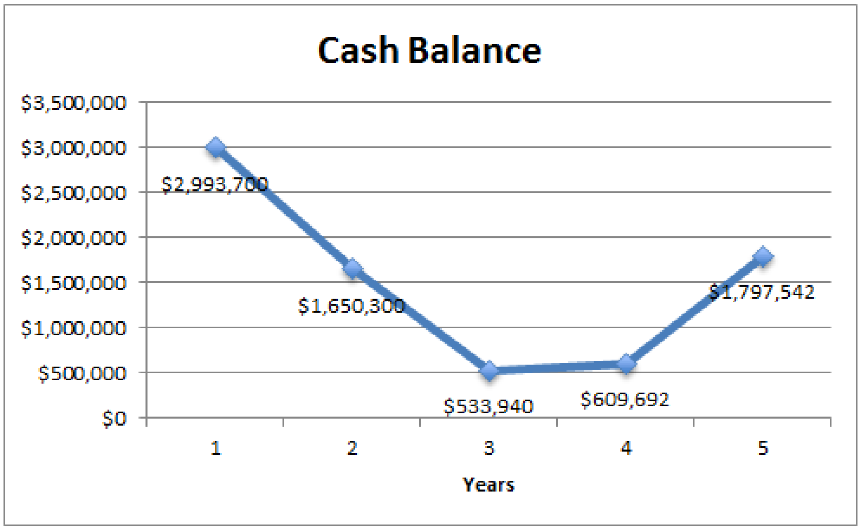


Figure 9: MinuteWind's Cash Balance Over the First Five Years of Operation

Deal Terms/ Stocks - To raise the money that is needed for this company, we will apply for a loan of $3.0 million and apply for grants worth $600,000. We also plan to sell equity in the company worth $1.0 million. We will keep these transactions private, to keep the number of investors to a small pool and to retain control of the company's decisions. When MinuteWind is applying for grants, we will apply for loan guarantees too. The loan protection will act as a backup when financing with angel investors. The angel investors know there is a high level of risk involved in start-ups involving a new product. The loan guarantee will offer protection that the angel investors will seek to hedge their risk.

MinuteWind's return on investment over the first five years is shown in Figure 10. Low debt to equity ratios show that the company is financed by investments and not loans. This is less risky than relying on debt. Return on equity shows how much net income is being generated relative to equity.

Ratio	Year 1	Year 2	Year 3	Year 4	Year 5
Lease Effeciency	100%	100%	80%	80%	70%
Gross Profit Margin	-52%	24%	27%	45%	67%
Net Profit	-901.40%	-140.29%	-55.10%	1.85%	19.38%
Debt:Equity	1.5	1.3525	1.202	1.05275	0.903
Return on Equity	-72.92%	-59.95%	-48.32%	13.43%	221.00%
Labor/Unit	$106,666.67	$42,500.00	$22,500.00	$15,833.33	$12,500.00
Return on Investment	-46.79%	-38.15%	-23.33%	4.32%	54.77%
Insurance/unit	$50	$50	$50	$50	$50

Figure 10: MinuteWind's Return on Investment over the First Five Years

II.12 Impacts

Environment - By deploying a sustainable, fuel-free desalinization unit as an alternative for bottled water, Oasis will reduce the dependence on fossil fuels and the amount of plastic consumption from water bottles. While water bottles require constant shipments and can cause damage and issues to airports during a disaster, Oasis is a one-time delivery, and would reduce air and water traffic coming into and out of disaster zones.

Social - Oasis's unique solution of potable water in water-deprived locations enables communities to gain stable access to clean drinking water at an affordable cost. Since Oasis serves 200 people, multiple systems can be deployed to provide proximal convenience, requiring less walking for the consumers.

Oasis also provides NGOs an easier to manage water distribution network that is unaffected by breaks in the shipping process, as Oasis does not need any additional equipment after deployment. Oasis provides a superior product to both the customer and the consumer.

Technical - The reliability and sustainability of Oasis can lead countries recovering from natural disasters to adopt wind energy when they begin to establish or re-establish the infrastructure of their electrical grid. In this way, Oasis can serve as a proof-of-concept and catalyst for the implementation of wind power in developing countries.

II.13 Market Turbine: Technical Design

Oasis is a safe, portable, sustainable, and reliable, green energy system that provides clean drinking water for disaster victims and refugees at a completive price. Since Oasis is completely self-contained, it can be deployed anywhere within 2 weeks, ideal for supporting disaster recovery and refugee camps. Oasis's fast, 12-hour maximum setup time, independence from third party fuel, and low maintenance design cuts costs, makes the system reliable, and promotes a renewable future. The health and well-being of disaster victims and refugees is dependent upon a reliable source of clean drinking water, and the Oasis provides an affordable, streamlined solution to meet those needs.

Oasis uses a 3.1 kW wind turbine to provide energy for a water treatment and desalinization system. Our fully collapsible, easy to maintain design is transported inside a standard 20-foot shipping container, making it a portable, renewable source of drinking water. The shipping container is retrofitted with our wind turbine and a third party water treatment system. All of the necessary parts of Oasis are efficiently packaged, as shown in the optimized trailer layout in Figure 2, ensuring safe transport and assembly.

The high-quality 3.1 kW wind turbine uses a Leeson DF100L generator to create the electricity needed to power the onboard water treatment system. This 18.3 m hub-height, horizontal axis wind turbine is anchored to the floor of the trailer and is supported by a structural steel tower that is shipped in 10, 6-foot segments for convenient storage and assembly. The 3.1 m turbine rotor radius has been chosen to meet the required output at nearly any site. Each blade is constructed from Douglas Fir wood, using a wood-epoxy saturation technique (WEST) that involves adhering layers of wood in varying directions. This is a common technique for Douglas Fir blades that allows for strength in all directions, a suitable strength to weight ratio, and better fatigue properties relative to fiberglass or carbon fiber.

Oasis is outfitted with a custom GP SW 550 GenPro Series water treatment and desalinization system that can provide up to 2,000 L of fresh drinking water per day from any water source. Water pumps carry water from the local source to Oasis through reinforced tubing. Once the water has been purified, it is sent to a collapsible storage bladder that holds enough drinking water to serve 200 people for one day. Also, Oasis has a unique, externally mounted UV light bottle decontamination system. This allows individuals to disinfect their containers, ensuring the health and safety while minimizing waste.

Since safety of the workers and those in the vicinity of Oasis is a priority, our system has a multitude of safety features. The turbine will experience high wind forces that could damage components and result in trailer instability. However, the wind turbine is designed with high-strength steel structures and wooden blades to withstand these large forces. To improve stability, 1.2 cubic meter compartments with collapsible storage bladders act as ballasts in each corner. These water storage ballasts are filled onsite to minimizing shipping weight. Guy wires will be employed as a safety measure to further reduce stress on the tower. For operational purposes, Oasis is constructed with a variety of safety features. At unsafe wind speeds, Oasis has an automatic electronic brake and a manual mechanical brake in case of electronic failure. Additionally, Oasis comes equipped with radio communication, internal and external lights for nighttime operation, and an external security camera system. Also, first aid kits and fire extinguishers come as standard safety equipment. Finally, the optimal trailer layout shown in Figure 2 allows enough space for technicians to work in the trailer without risk of injury.

Conservative Design Approach - Since drinking water is such a critical resource to disaster victims and refugees, Oasis has been designed using a conservative approach. Using assumptions for the aerodynamic, mechanical, and electrical efficiency of the turbine, the rotor radius and rated wind speed were chosen such that the Oasis is capable of producing the required energy for water treatment even in very low wind sites. The power curve of the Oasis, and the wind speed probability distribution (pdf) for three mean wind speeds are shown in Figure 11. Figure 12 shows the average power output of the Oasis (found by integrating the power curve and the wind speed pdf) versus the mean wind speed at a site. It also shows the required power for the water treatment system. Even at a site with a mean wind speed of 3 m/s, Oasis produces sufficient power to meet the water treatment needs. This conservative design for Oasis has been chosen because for a resource as essential as drinking water, we need to ensure that Oasis is always meeting drinking water demands.

To compensate for fluctuating wind speeds, Oasis is outfitted with a 20 kWh battery, allowing at least 48 hours of system operation when no wind energy is produced. At sites with high mean wind speeds, MinuteWind has developed two solutions. Since the GenPro water purification units are highly customizable, depending on the average wind speed at the location of deployment, a larger unit can be installed that can produce more drinking water. Similarly, a larger battery bank can be installed, which will allow for increased energy storage and even a charging station. By taking this conservative approach to designing Oasis, a sufficient amount of water is available even under low wind speeds while no energy produced under higher wind speed operation will be wasted.

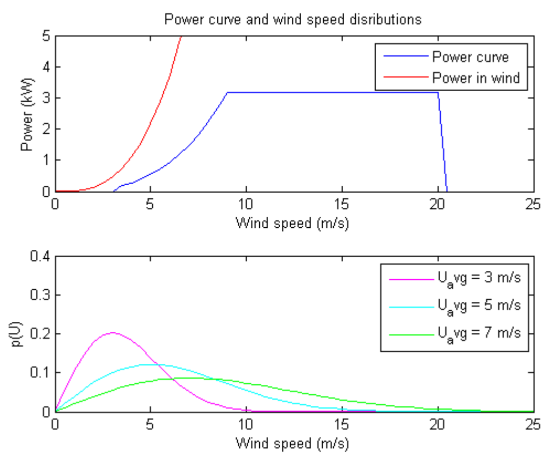


Figure 11: Oasis Power Curve and Wind Speed Distribution

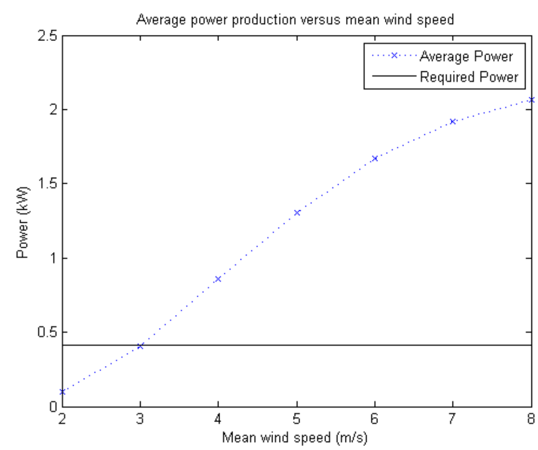


Figure 12: Oasis Average Power Output

III. Technical Design

The UMass MinuteWind team designed the Oasis product with the goal of safely providing 2,000 L of clean water per day (sufficient for 200 people) to both disaster relief scenarios and refugee camps. This turbine was designed with conservative assumptions to ensure sufficient production even in low wind sites. The Oasis system consists of a three-bladed rotor, a nacelle housing a generator and other electrical components, a steel tower, and a water purification system, deployed from a shipping container. Blades with airfoils appropriate for low Reynolds numbers were designed using an in-house aerodynamic analysis code, ensuring sufficient power output for the water purification system. The tower, rotor, and other critical components were tested via Finite Element Analysis to confirm the robustness of the model and the safety of the users. The control system has been optimized through experimental testing to yield maximum power output in below rated operation. A unique deployment system has been designed to enable rapid and convenient deployment at any site. An overview of the most important features of the design, and then a detailed discussion of all technical components follows. Please note that the specifications presented in the Technical Design section correspond to the test Oasis turbine, and the market product specifications are found in the Business Plan.

A 3-D CAD model and photograph of the current test turbine design can be seen in Figure 13. The design objective of the hub and blades for the rotor assembly was to maximize performance while maintaining low cost and ease of manufacturing. Research was conducted on airfoils that are efficient at low Reynolds numbers. The rotor diameter is 22.5 cm for the test turbine and 3.1 m for the market turbine, and the design tip speed ratio is 7; thus the anticipated Reynolds number for test turbine conditions is less than 50,000, and will be roughly 500,000 for the market turbine. The blades and hub were modeled in Solidworks before being manufactured with an Eden 3D Printer.

A bending stress analysis was conducted to determine the optimal dimensions of the tower. The baseplate was designed for compatibility with the base flange bolt pattern in the competition wind tunnel. The nacelle has an aluminum base to support all electrical components, including the generator, controller, and other circuitry.

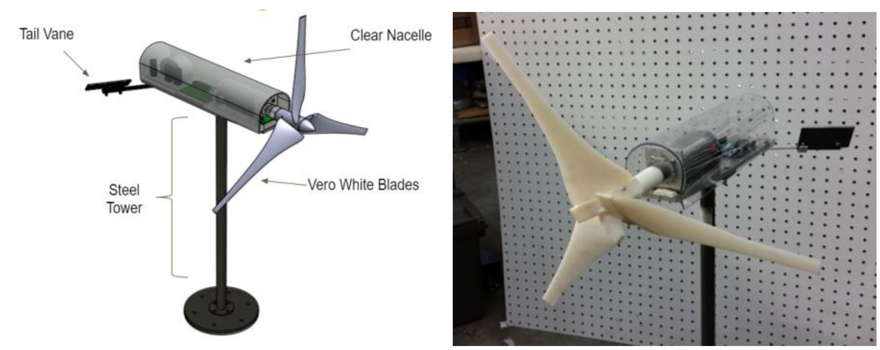


Figure 13: Final Prototype CAD model and Photograph

To control the power output of the turbine, a system was designed that converts the power provided by the rotor into electrical energy that can be used to power a specific load. This necessitates a control system, which maximizes power in below rated conditions, limits power and speed in above rated conditions, and controls the braking and shutdown mechanisms of the turbine. The general configuration shared by both the market and test turbine was a direct drive generator producing an alternating current that was then rectified so the resulting output was compatible with the load. A microprocessor acts as the control system, gathering information on current rotor speed and power output and then influencing the electrical system to obtain the desired output.

Research was conducted to define a load system for the market turbine as well as to create a way to visually represent the load during the wind tunnel testing the competition. For the market load, a reverse osmosis system was chosen with pre- and post-treatment. This will enable Oasis to work with any type of water and with little to no customization. For the test load, a water cleaning system was created that visually demonstrates the same principle, but without using a reverse osmosis system with a large power requirement.

III.1 Rotor Design and Static Performance Analysis

An in-house aerodynamic analysis code was created in MATLAB to enable airfoil selection, optimize rotor design, and conduct performance assessment. The code requires the lift and drag coefficients versus angle of attack for a particular airfoil, and the user can specify the rotor radius, airfoil distribution, number of blades, design wind speed, and tip-speed ratio. The code then creates an optimal blade chord and twist distribution using blade-element momentum (BEM) theory[15] (Manwell, et al., 2002). The blade is then analyzed using an iterative BEM solver to find the power coefficient (Cp) as

[15] The method employed is derived from *Wind Energy Explained*, by Manwell, McGowan and Rogers.

a function of the tip-speed ratio. The code was validated with the NREL code AeroDyn v14 and gave Cp values within 3% at a given tip speed ratio. The airfoils were chosen by analyzing a variety of airfoils that have been used for small wind turbines, or could perform well at low Reynolds numbers. These include the S822, S823, S824, E387, SG6040, SG6042, SG6043, FX63137, S833, S834, and S835. The SG6040 family of airfoils yielded the highest power coefficient, which was deemed the most important consideration. This allows for the blending of airfoils from root to tip without compromising the overall efficiency of the turbine. The thicker airfoil (SG6040) can be used at the root while the thinner airfoils (SG6042, SG6043) can be used at the tip to balance the strength and aerodynamic efficiency. Based on the Cp curves generated by the MATLAB code (Figure 14 and Table 1), the SG6040, SG6042, and SG6043 were identified as optimal for both the test and market turbines. However, due to fabrication limitations, the S834 airfoil was chosen for the test turbine blades due to the larger thickness to chord ratio. While this may result in a performance penalty in theory, in practice a thicker airfoil was needed to achieve an accurate fabrication of the ideal blade shape. In Figure 14, the nominal pitch angle (thetap) is 0 degrees, and for the S834 results, it can be seen that a 4-degree pitch maximizes Cp.

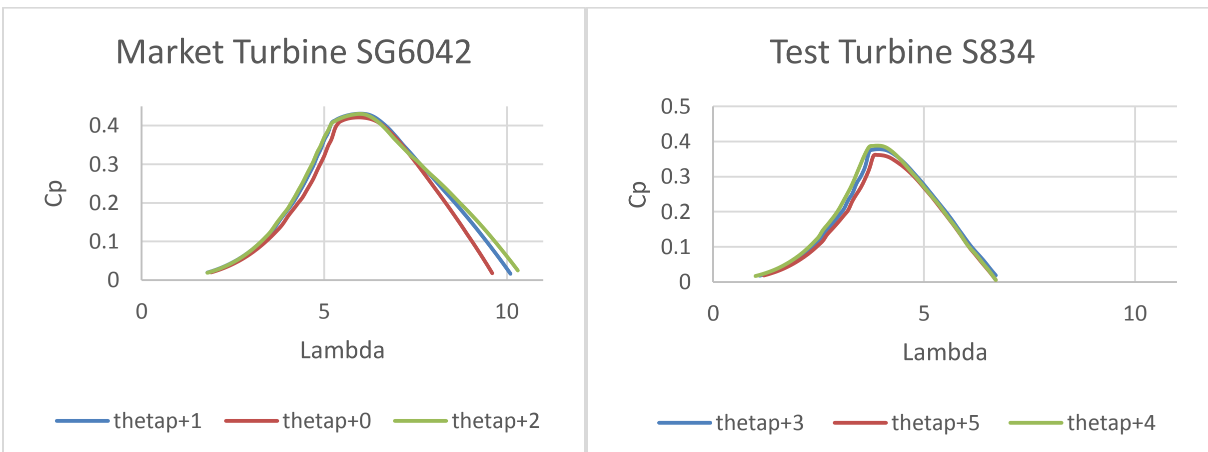


Figure 14: Sample Analysis for SG6042 and S834 Airfoil for Different Blade Pitch Angles (thetap)

Table 1: Maximum Power Coefficient for Candidate Airfoils

Airfoil	Maximum Coefficient of Power
S822	.3933
S823	.3966
S824	.3488
E387	.4148
SG6040	.4221
SG6042	.4337
SG6043	.425
FX63137	.4194

S833	.3904
S834	.3933
S835	.3551

Initially, the rotor analysis was conducted for a blade with ideal twist angle and chord distributions. Later, the manufacturability of the blades was considered. For ease of fabrication, the market turbine may need to have blades that differ from the ideal blade geometry, such that the chord and twist distributions vary linearly over the span of the blade. However, linear chord and twist distributions can significantly reduce the power production of the turbine. This is seen by the power coefficient reduction from the ideal blade to the more easily manufactured blade in Figure 15.

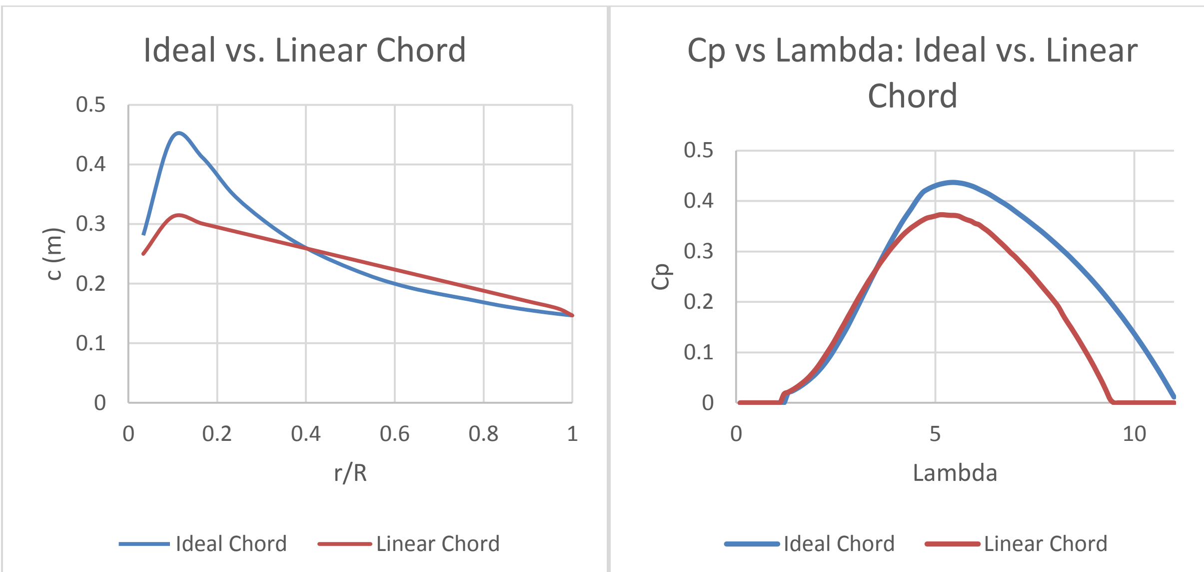


Figure 15: Ideal vs Linear Chord and Cp vs. Lambda Curve of SG6040 Airfoil

The number of blades was another consideration. The power difference between a two- and three-bladed design is relatively small, as shown in Figure 16 for the market turbine. In general the two-bladed turbine creates about 5% less power than the three-bladed turbine. A two-bladed turbine also necessitates a teetering hub, which is complicated to manufacture and may decrease system reliability. Thus, a three-bladed turbine design will be employed for both the test and market turbine. Figure 17 shows the final chord and twist distribution for both the market turbine and the test turbine.

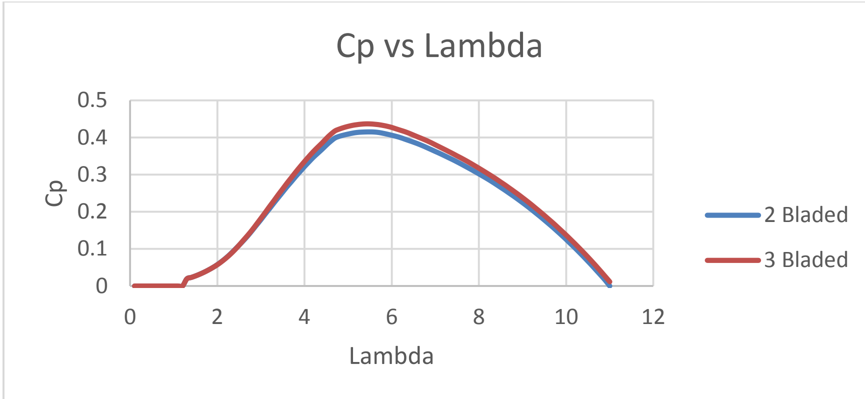


Figure 16: Cp vs. Lambda for Two- and Three-Bladed Ideal Rotor

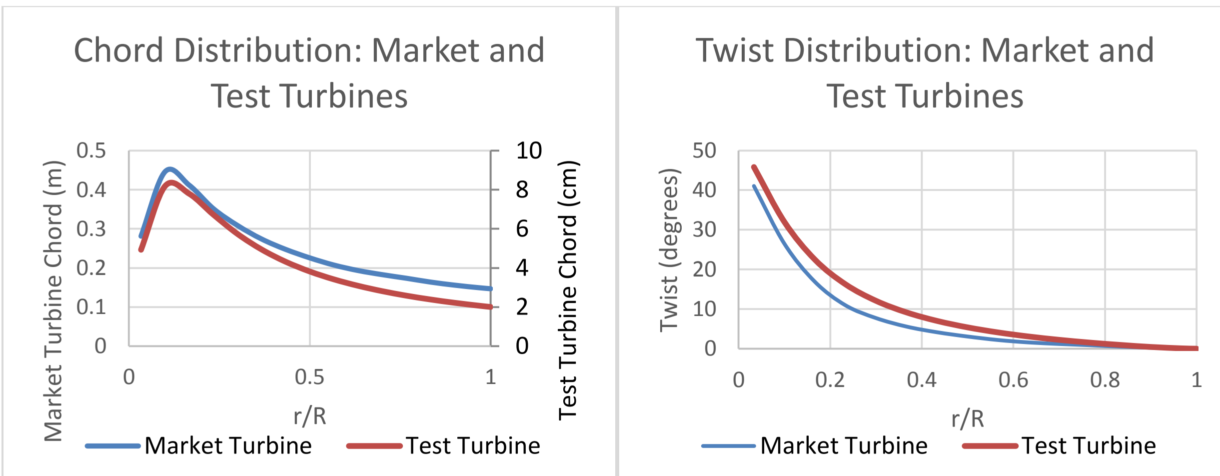


Figure 17: Chord and Twist Distribution for Market and Test Turbines

Manufacturing the test turbine required several iterations of prototypes before a final design was chosen. Due to the need for rapid prototyping, the test turbine blades were fabricated from ABS plastic using additive manufacturing technology (i.e. 3D printing). The advantages of 3D printing include simple customization and ease of manufacturing, making it a good choice for this application. The blades and hub were modeled in Solidworks before being manufactured with an Eden 3D printer (Figure 18). The ideal geometry of the blade was too thin to be printed, so an airfoil with greater thickness (S834) was chosen and then iterated with different chord lengths to find the blade planform that best balanced aerodynamic efficiency, manufacturability and cut in speed. It was determined that scaling the chord distribution up by a factor of 1.5 compared to the theoretical optimum enabled both a more accurately manufactured shape, and more cut-in torque at low wind speeds. A universal hub was 3D printed that allowed for rapid testing of different blade designs.

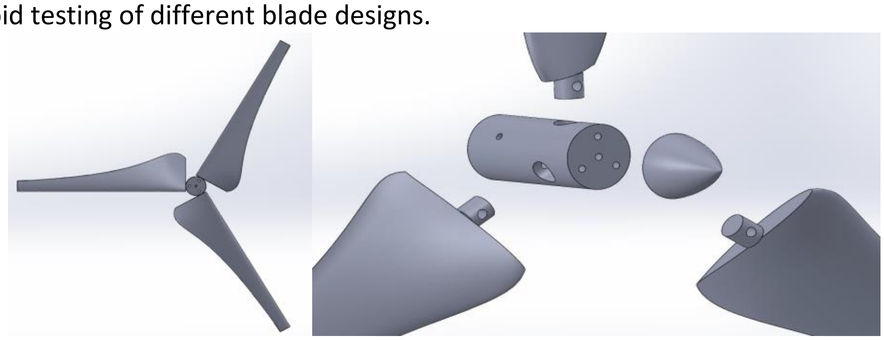


Figure 18: SolidWorks Assembled Rotor Model (Left) and Exploded Rotor Model (Right)

Wood will be used to manufacture the market turbine blades. The BEM code showed that for optimal performance, the chord distribution versus the span-wise position needs to be highly nonlinear. In comparison, when the code was altered and to produce a linearized chord and twist distribution, the performance decreased significantly. It was concluded that wood would be the easiest material to use to manufacture a blade that is as close to the ideal blade shape as possible. A composite (fiberglass or carbon) blade would require complicated molds and layup processes, which increase the cost of production. Optimally shaped wood blades can be manufactured from conventional milling machines. The benefit of having a blade as close the ideal shape as possible is shown by Figure 15. Slight changes to make the blade closer to the ideal shape (adding multiple linear sections) have a substantial impact on the power efficiency of the turbine, which is an important design consideration.

Wooden blades are generally crafted by using an epoxy to adhere thin layers together, which is known as the wood-epoxy saturation technique (WEST). Techniques like this involve laying adjacent layers in varying directions, since many woods naturally display anisotropy (varying properties with respect to strain direction). As a result, techniques such as WEST result in wood composites that are strong in all directions. Furthermore, wood generally has a suitable strength to weight ratio, and has better fatigue properties relative to fiberglass or carbon fiber. In addition, wooden blades are well suited for unsaturated polymer gelcoats that yield superior water surface protection and absorption rates to fiberglass and carbon fiber blades[16] (Kjærside, 2013). Lastly, Black Island Wind Turbines, a small scale turbine manufacturer in Hadley, MA, currently uses wooden blades in their turbines that are designed to withstand harsh arctic winds and weather. Since the location of deployment of the Oasis product is unknown ahead of time, it is possible that the turbine will experience adverse weather conditions, coastal environments with humidity and sea-spray, and wide temperature ranges that justify using wooden blades. A common wood chosen for wind turbine blades is Douglas Fir. Some of these material properties are seen in Table 2.

Table 2: Market Turbine Material Comparison

	Carbon Fiber	Fiber Glass	Wood
Cost w/ Treatments	$10/lb	$5/lb	$4/board foot
Youngs Modulus	240 GPA	80 GPA	10.9 GPA
Tensile Strength	1.6-4.1 GPA	2-4.7 GPA	
Process	Wrapped-Wound	Resin	Composite

The annual energy production (AEP) for the market turbine was evaluated as a function of mean wind speed, with values ranging from 2 m/s to 8 m/s, and the results are shown in Figure 19. In all cases, the rotor radius (3.1 m), cut-in wind speed (3 m/s), and cut out wind speed (20 m/s) were held constant, while the rated wind speed and the overall turbine efficiency (aerodynamic power coefficient multiplied by mechanical and electrical efficiency, i.e. Cp*eff) varied. The rated wind speeds analyzed were 8 m/s (solid lines), 9 m/s (dashed), and 10 m/s (dotted). The efficiency values analyzed are 0.2 (blue), 0.25 (red), and 0.3 (green). These efficiency values were based on the predicted Cp from the BEM code, and a reasonable estimate of mechanical and electrical efficiency. To calculate AEP, a power curve was created that was a cubic function of wind speed, scaled by the Cp*eff value, between cut-in and rated, and was constant between rated and cut-out (Figure 11). A Rayleigh distribution modeled the wind speed probability density function (pdf) for a given mean wind speed value, and the average power was then calculated by integrating the product of the power curve and pdf versus wind speed between cut in and cut out. The average power was then multiplied by 8,766 hours to obtain AEP. The output was compared to the necessary production to provide enough water from the water treatment unit (black

[16] Based off of article Surface Protection and Coatings for Wind Turbine Rotor Blades: Advances in Wind Turbine Blade Design and Materials.

line in Figure 7). It was assumed that seawater was being desalinated with a specific energy of 5 kWh/m^3, and that 2,000 L were produced per day. Figure 19 demonstrates that the Oasis turbine will produce more than enough energy to meet the water production requirements, except at sites with extremely low mean wind speeds.

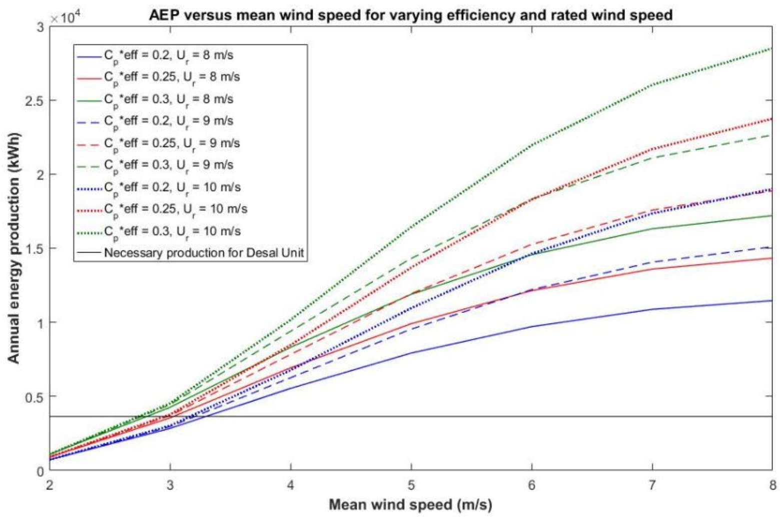


Figure 19: Annual Energy Production vs. Mean Wind Speed for a Variety of CP and Speed Values

III.2 Loads and Safety Factors

Ensuring a high margin of safety is an important aspect of this turbine, as the production of clean water as a component of disaster relief necessitates very high system reliability. Computational models were used to evaluate the response of the turbine components to loading. Using ANSYS Workbench 2012, a tool for finite element analysis, the turbine's structural response and dynamics were modeled. The geometry of the rotor was created using SolidWorks 2012, and imported into ANSYS. The material properties corresponded to the material used by the UMass 3D printers. The fluid for the simulation was air at standard temperature and pressure, given by ANSYS's material reference catalog. Static structural analysis was carried out with the specific geometries and material properties of the test turbine discussed above. A frictionless support constraint was placed on the downwind face of the turbine's rotor. A wind load and rotational velocity corresponding to rated wind speed (when rotor thrust is maximum) were applied to the assembly. The wind pressure was modeled by a constant pressure over the turbine's geometry in the negative z direction, simulating the direction of wind that would result in a maximum bending moment. These results are shown in Figure 20.

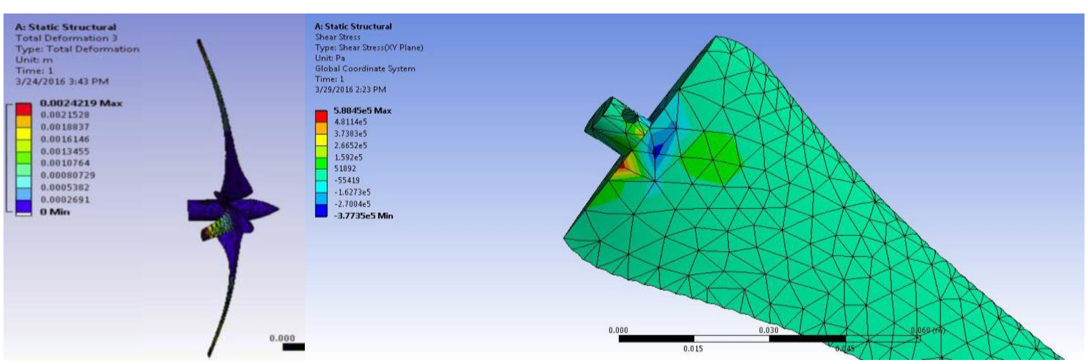


Figure 20: ANSYS Testing of Test Turbine Rotor Assembly (Left) and Blade (Right)

The results of the static structural test ensured a safety factor of 45 times the maximum allowable yield stress of the material. The blade experienced levels of stress that fell well within the tolerable ranges of the material used. The deflection of the blades was also found to be minimal, resulting in a 0.0025 meter maximum deflection.

ANSYS modal response was simulated on the rotor as well. ABS plastic yielded roughly an 11 Hz first modal frequency as shown in Figure 21. It is necessary for this not to resonate with the tower supporting the nacelle and rotor.

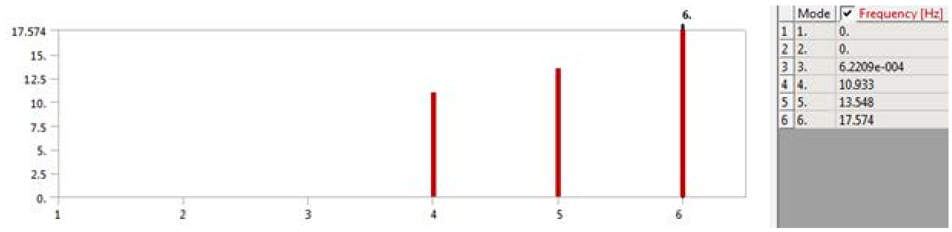


Figure 21: ANSYS Modal Analysis (X Axis – Blade Mode Number, Y Axis – Frequency (Hz.))

The preliminary tower analysis consisted of a bending stress analysis depicted in Figure 22 at maximum wind speed conditions, which served to determine the necessary radius and thickness of the tower tube. This analysis was conducted using bending theory by varying only the radius of the tower to determine the resultant bending stress. This analysis revealed that the radial dimensions of the test tower do not introduce a major design limitation, as the forces produced on this scale are low with a safety factor that exceeds 13 as shown in Figure 23. Also shown in this figure are bending stress ANSYS results for the market tower, which exhibit a high safety factor when loaded. Thus, the key design criteria for the tower was reaching the appropriate height and allowing internal clearance for the wiring to pass through the hollow center. This led to the selection of the hollow stock steel pipe depicted in Figure 1, which was selected due to its availability via McMaster-Carr and its price.

Test Turbine Bending Analysis

Ft = Thrust Force — d0 = outside diameter
ρ = air density — di = inside diameter
u = wind speed — $\sigma_{bending}$ = Bending Stress
R = rotor radius — $\sigma_{yieldAL}$ = Yeild Strength of Aluminum
x = hub height
Ct = thrust coefficient
h = hieght

$$F_t = \frac{1}{2} \cdot C_t \cdot \rho \cdot R^2 \cdot \pi \cdot u^2 \qquad a := \frac{1}{3} \qquad C_t := 4 \cdot a \cdot (1-a) = 0.889 \text{ (betz rotor)}$$

$$\rho := 1.225 \cdot \frac{kg}{m^3} \qquad u_{max} := 18 \cdot \frac{m}{s} \qquad R := 22.5 \cdot cm$$

$$F_t := \frac{1}{2} \cdot C_t \cdot \rho \cdot R^2 \cdot \pi \cdot u_{max}^2 = 28.055\ N \qquad \sigma_{bending} = \frac{M_{base} \cdot c}{I}$$

$$x := 5 \cdot cm$$

$$h := 38.53 \cdot cm + x = 43.53\ cm \qquad M_{base} := F_t \cdot h = 12.212\ N \cdot m$$

$$d_o := 1.25 \cdot in \quad d_i := 1 \cdot in \qquad I := \frac{d_o^4 - d_i^4}{64} \qquad c := \frac{d_o}{2}$$

$$\sigma_{bending} := \frac{M_{base} \cdot c}{I} = 3000\ psi \qquad \sigma_{yieldAL} := 40000 \cdot psi = 275.79\ MPa$$

$$\sigma_{bending} = 20.681\ MPa \qquad SF := \frac{\sigma_{yieldAL}}{\sigma_{bending}} = 13.335$$

Figure 22: Test Turbine Tower Bending Stress Calculations

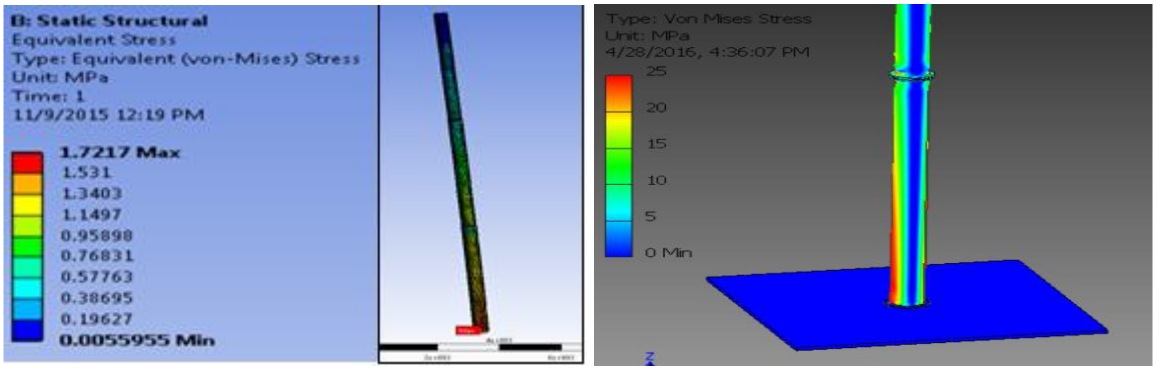


Figure 23: Tower Stress Simulation for Test Tower (Left) and Market Tower (Right)

The baseplate was designed to integrate with the base flange bolt pattern provided in the wind tunnel testing conditions as well as to allow for easy tower assembly through a threaded center hole. The baseplate, shown in Figure 24, went through several iterations, as documented below in the Iterations section.

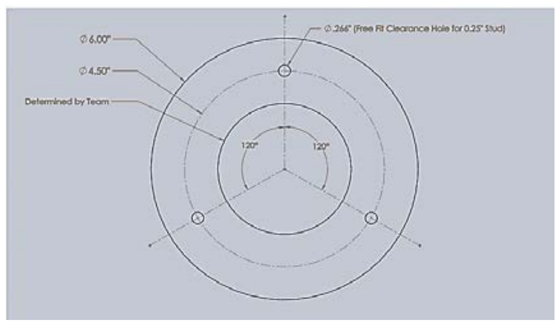


Figure 24: Baseplate layout as per DOE Wind Tunnel Spec Sheet

The nacelle was designed with an aluminum base supporting the electrical and mechanical components, covered with a 3-D printed transparent nacelle case to promote aerodynamics and to visually display the internal components.

III.3 Design Iterations

The first iteration of the test turbine was overdesigned and under-constrained. That is, its components were selected for immediate use in the wind tunnel at UMass Amherst (and thus did not align with the CWC wind tunnel specifications) in order to facilitate early blade and motor testing. Through each iteration, the test turbine was modified and improved. The first tower design that was used to begin testing in the wind tunnel proved to be unnecessarily strong. The three pieces which composed the tower included the base plate, tower shaft, and top plate. The two plate was much larger and thicker than was necessary. In addition, the tower's diameter proved to be too large and the tower did not comply with the rules of the competition as it was too short. The bottom of the nacelle was a rectangle cut from Aluminum 6061 stock with slots for half inch bolts that could be slid to move the setup forwards or backwards in the wind tunnel. This piece was connected to the top plate of the tower and was cut to dimensions of the electrical circuit design. A mount for the first motor used in the design, which was a 24V motor, was constructed from an L-shaped piece of Aluminum 6061. The motor was attached via three screws into its front face and a hole was made for the motor shaft to come through the bracket. A shaft coupler, two low-profile mounted ball bearings and a 6-inch long shaft with a 0.25-inch diameter, were purchased from McMaster-Carr. A mount was constructed for the two ball bearings by milling a stock piece of Aluminum 6061 to provide the shaft with extra support. The shaft was then attached to the 3-D printed hub via a set screw. The electrical components used in this iteration were left off of the nacelle and were connected to the motor from a separate test stand.

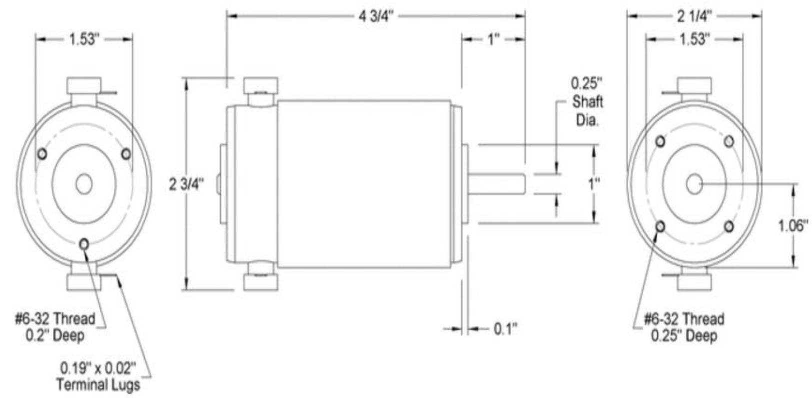
Figure 25: Previous Design Iteration of Test Turbine

In the second design iteration, a smaller aluminum plate for the bottom of the nacelle was constructed in an effort to better represent the third design iteration while it was being designed and then fabricated as displayed in Figure 25. 0.25-inch bolts with two washers and a nut were used to attach this smaller plate to the existing top plate of the tower. This plate left little room for electrical components. The previous bearing support was manipulated to support the motor shaft with a new motor brace that was fabricated to be used during the interim until the third design iteration was completed.

The third iteration utilized a thinner, taller steel tower to minimize material and raise the nacelle to the height required to function in the CWC wind tunnel. The bottom baseplate was eliminated in favor of a direct mount flange serving to couple the tower to the mounting platform without the interruption of a bulky aluminum block. The bearing was also eliminated upon the realization that it was unnecessary and decreased efficiency. Instead, a short, custom coupler/shaft extension was attached to the motor shaft to allow for hub clearance and the mounting of a tachometer. Finally, a new motor mount was fabricated to secure a smaller 12 V motor to the nacelle base plate. This mount featured faces on both the front and back of the motor providing two securable surfaces (whereas each of the previous design iterations had only one face to which the motor was mounted). The clear plastic nacelle features a custom fabricated base designed specifically to minimize space and drag while housing all of the necessary electrical components.

III.4 Electrical Systems Report

The first major decision pertaining to the electrical components of the test turbine was the choice of motor that would be used as a generator. Several different motors were considered. After experimenting with motor voltages ranging from 12 to 24 V and power ratings ranging from 60 to 120 W, it was determined that the ideal motor for the test turbine would be a 12 V, 60 W motor. This decision was based on a number of factors: 1) this motor and other motors similar to this model feature low torque constants (k_t), which enables the motor to start spinning at lower speeds; 2) complementing a low torque constant, the low initial startup torque of the motor of 21 oz.-in. allows for a lower cut-in speed for the turbine; and 3) the 60 W motor is closer to the maximum expected power output of approximately 40 W based on aerodynamic analysis. Ultimately, the motor chosen is shown below in Figure 26 and features ratings of 60 W, 3000 rpm, 4.9 A maximum, and 68% efficiency. Figure 26 depicts the motor specifications, while Figure 27 shows the torque-speed operating curve for continuous operation provided by McMaster-Carr.



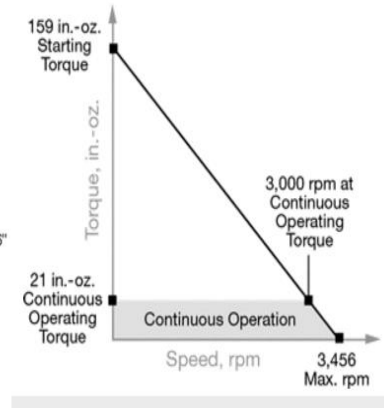


Figure 26: Motor Specifications **Figure 27: Continuous Operation Torque-Speed Curve**

Following the generator selection, the governing circuit depicted in Figure 28 was designed to maximize the power output of the turbine at various wind speeds and to allow for the rotor speed to be controlled in the various safety and shut-down tasks. The notable components are an inductor, shunt resistor, voltage divider, MOSFETs, an Arduino, an Adafruit Trinket Mini, a Schottky Diode, and a capacitor. Each component's function and integration into the circuit is discussed below.

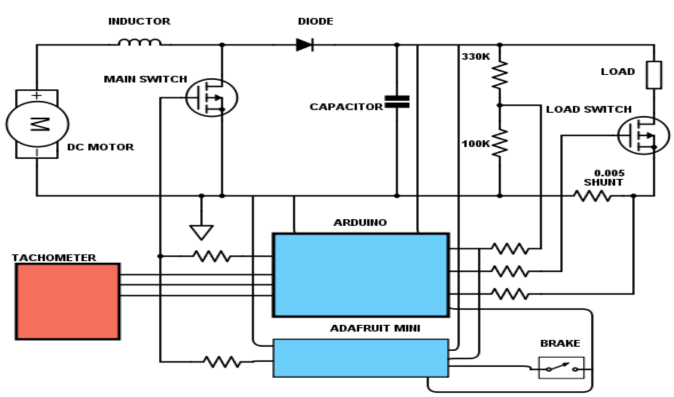


Figure 28: Circuit Diagram for the Test Turbine

The Arduino serves as the primary microcontroller for the system that enables the turbine control discussed below. In addition, an Adafruit Trinket Mini is used as a smaller microcontroller to control safety in low power situations. The Arduino has a 5 V operating voltage and while it can run with an input voltage between 6–20 V, it works best in the range of 7 – 12 V. The Adafruit Mini is built around an Atmel ATtiny85 chip that has an operating voltage of 3.3 V and pulls much less power than the Arduino's ATmega328. This lower operating voltage allows the Adafruit mini to stay on in low power situations to ensure the circuit is always controlled.

The circuit also features two IRF540 Power MOSFETs, which are used as switches to activate different circuit modes by controlling the flow of current throughout the circuit. Each MOSFET contains a drain, source, and gate, which are connected by the microcontrollers. Analog output from the microcontrollers can vary the gate voltage from 0 V to 5 V through pulse width modulation (PWM), which allows for control with the MOSFETs. These devices are used to expose the load and inductor at varying amounts throughout operation. Through a control algorithm explained later in this document, the Arduino can alter the gate value between 0 and 5 V. At 0 V, the gate is open and at 5 V, the gate is closed. To stop the blades from spinning, the primary MOSFET is made to behave like a closed circuit, effectively shorting the leads of the generator through the inductor and main MOSFET. The load

MOSFET is toggled after startup to ensure that the microcontrollers are able to turn on before power is sent to the load. When properly cooled, these MOSFETs can dissipate 150 Watts of power, which far exceeds the need of the load. It is necessary to cool the transistors; heat sinks are applied to each MOSFET in order to increase heat dissipation.

The 335 µH, 6 A inductor from Pulse Electronics Corp is paired with a MOSFET to vary the effective resistance shown to the motor. This allows for control over RPMs as well as power output and load side voltage. As the gate voltage on the connected MOSFET increases, the MOSFET transitions from cut-off to saturation mode. This allows current to begin to flow through the switch, and once the gate reaches 5 V the MOSFET is in full saturation and essentially acts as a short circuit. When used to brake the turbine, the MOSFET is sent into saturation and the motor is shorted across the inductor and MOSFET. This causes a dramatic increase in current and the blades are quickly slowed down.

A shunt resistor is placed between the load output and ground and is used as a current sensor. The voltage drop across the shunt is measured and then divided by the Ohmic value of the shunt resistor, resulting in the amount of current going through the load. The shunt resistor is a 0.005 Ω, 1 W device with 1% precision. A Schottky Diode is incorporated into the circuit to ensure that current does not flow backwards into the motor when the load voltage exceeds input voltage. A 1milliFarad capacitor is also included in the circuit to smooth the voltage ripple on the load side.

A voltage divider with high resistance values is placed in parallel with the load. This is because the Arduino can only read up to 5 volts, and the voltage across the load often exceeds that value. A 100k ohm resistor is used in series with a 330k ohm resistor from load(+) to ground. Voltage is measured between the resistors and multiplied by 3.67. High resistance values cause minimal loss in power through the voltage divider. The microcontrollers interface with the circuit at seven different points, the inductor and load MOSFETs, the shunt resistor, voltage divider, brake signal, power, and ground.

III.5 Control System

To meet the testing requirements in the competition, a control strategy was created involving the Arduino and the electrical circuit discussed above. This controller is designed to optimize the power output of the turbine while still powering the microcontrollers, as well as to meet the various competition performance metrics and tasks outlined by the CWC guidelines. The controller is summarized below in Figure 29 through the control states diagram.

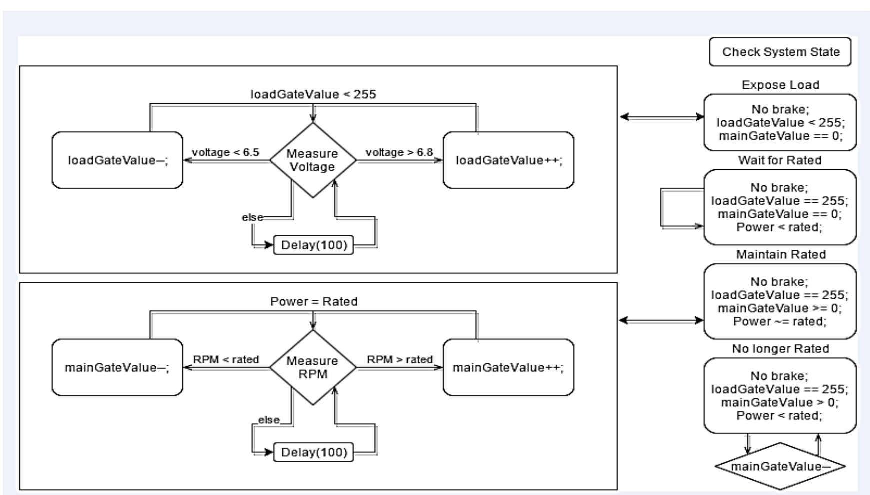


Figure 29: Control States Diagram

As shown in Figure 29, the controller executes different functions depending upon the operation scenario. To begin, the circuit must be in the optimal state to cut-in and send power to the controllers without any control. This was accomplished by designing a circuit where the zero power state of the MOSFETs require the lowest possible current from the motor and divert no power to the load. When the turbine cuts in, the power output is enough to power on the microcontrollers. Once the Arduino turns on, it raises the gate voltage of the load MOSFET, transitioning the MOSFET from cut-off towards saturation, and beginning to send power to the load. Some power is lost at very low wind speeds in order to maintain the minimal voltage required for the Arduino. We feel that the power lost at these low levels is outweighed by the utility of a larger microcontroller.

When the wind speed varies from 5 to 11 m/s, the Arduino maximizes the power diverted to the load while ensuring there is enough power to keep the Arduino on. A feedback loop that continually checks the voltage and then adjusts the gate voltage of the load MOSFET. The system maintains safety by monitoring the load as well as an emergency shutoff input. A load disconnect or low brake signal will cause the system to run a braking algorithm. A load disconnect is detected when the system is recording RPMs and has exposed the load but detects no output current from the load. When braking, the controller will bring the load MOSFET into cut-off (disconnecting the load) and then bring the inductor MOSFET toward saturation. This action increases the motor torque and quickly slows the rotor.

A challenge encountered when braking was ensuring that the load side voltage did not get too high or too low. A spike in voltage could damage the microcontrollers and a drop would cause them to turn off and lose control. Once the load is disconnected, the resistance increases dramatically, causing any current forced through inductor to raise the voltage much higher than if the load was connected. Careful programming was required to design a feedback loop that would quickly adjust the inductor gate voltage to maintain a safe voltage while the rotor speed decreases. Once the rotor has reached 10% of rated speed, the feedback loop adjusts the inductor gate value to maintain braking speed.

When braking at very low wind speeds the turbine could not extract enough power at 10% of rated speed to keep the Arduino on. This required adding the Adafruit mini, which runs at a lower operating voltage (3.7 V as opposed to 5.9 V for the Arduino). The Adafruit mini runs a simplified feedback loop monitoring voltage and the brake signal, maintaining braking speed and minimum voltage until the brake signal is restored. At this point the system will spin back up and the Arduino will power back on.

When the wind speed exceeds the rated value of 11 m/s, the controller must maintain the speed and power output of the turbine. The rated power for the turbine was calculated through testing and programmed into the Arduino. Without the ability to measure wind speed, the Arduino knows it has reached 11 m/s once it measures rated power from the load. The turbine will then increase the gate voltage of the inductor MOSFET to increase torque and slow down the turbine, inversely the gate value of the load MOSFET will be reduced in order to throttle power sent to the load.

III.6 Load

The load chosen to demonstrate the Oasis operation during the testing portion of the competition is a two stage filtration system powered by a pump. The load, shown below in Figure 31 features a pump, a 30 micron filter, and a 5 micron filter all connected by clear piping to demonstrate the filtration effects. The test load has two stages. The first stage simulates a charge controller that would charge the buffer battery system in the market turbine. The charge controller would adapt throughout this process to enable the maximum power absorption for the battery. In the test turbine, the charge controller is replaced with a resistive load for simplicity. Once the test turbine reaches rated power, the pump is activated by the MOSFET switch located in the control box. This enables the second stage of the load to begin. Directly powering the pump in above rated conditions for the test turbine was chosen in order to demonstrate the load in the competition, and because the impedance of the pump is well-matched to the output of the turbine in above rated conditions. Moreover, LEDs with intensities that change in proportion to the amount of power being created by the turbine are included in the test turbine to provide an elegant visualization of power output, in particular in below rated conditions when the pump is not running.

The filtration system consists of a 30 micron and a 5 micron filter. As unfiltered water is pumped, the larger particles are caught in the 30 micron filter while the smaller particles, between 30 and 5 microns in size, are caught in the 5 micron filter. As water passes through each filter, the waste is caught in the filter fibers. After a certain amount of time, depending on the size of the waste, speed of the water, and size of the filter, the waste begins to build up on the filters, requiring the user to clean off the filter or replace it if damage is substantial. To mitigate the need to frequently clean and replace filters, the dual step process was used, distributing the filtration burden over two filters.

The pump used is a Pentair SHURFLO REVOLUTION 4008 series pump that pumps water per the specifications listed in Table 3. At an operating voltage of 12 VDC, the pump will transfer water at 3 gallons per minute. The filters used are HDX Household Melt-B filters with specifications shown in Table 4. The 30 micron filter is used to catch larger particles that are to be expected in places with unclean water, such as sediment. The 5 micron filter, however, is used to remove smaller particle such as parasitic cysts.

Table 3: Pump Specifications

Pump Brand	Flow Diameter	Operating Voltage	Max Current	Max Internal Pressure	Fluid Flow Rate
Pentair	0.5 in	12 VDC	7.5 A	30 psi	3 GPM

Table 4: Dimensional Specifications

Equipment	Height	Length	Width	Quantity
Glass Tank	6 in	12 in	6 in	2
30 μm Filter	10 in	2.5 in	2.5 in	1
5 μm Filter	10 in	2.5 in	2.5 in	1

The load system is configured to minimize the occupied space and length of piping (Figure 30). As the length of pipe holds no benefit for the filtration process, a more compact configuration is preferred. This will reduce the space required to hold the test and market filtration system and will require fewer machines of industrial scale to set it up. Ideally, the market load system will be shipped fully assembled in the container with little to no technological background for use. A more compact filtration system will reduce required space and cost of materials as smaller piping features are typically cheaper.

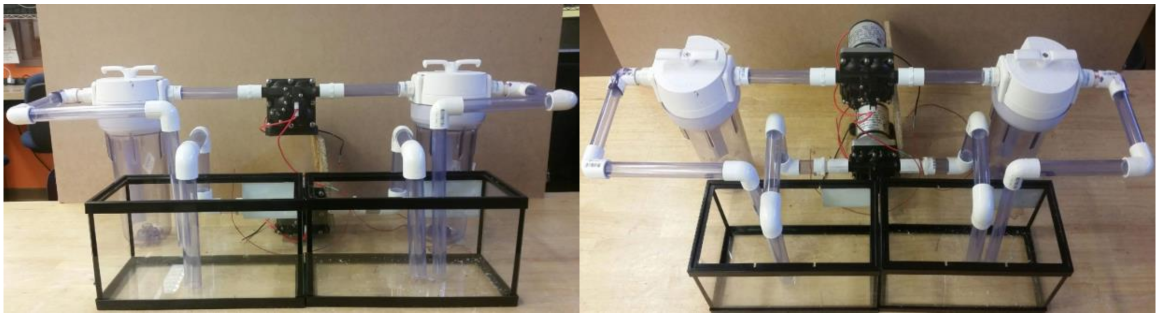


Figure 30: Front View (Left) and Top View (Right) of Load Configuration

<u>III.7 Test Data</u>

To optimize the test turbine performance at the CWC, we have conducted extensive wind tunnel testing using a wind tunnel on campus. The tunnel has a 1 m by 1 m cross section, and is capable of producing wind speeds up to 25 m/s. The three major objectives of the tunnel testing were to: integrate all components and ensure the system is operating well and meeting the competition specifications; evaluate different blade designs to maximize aerodynamic efficiency; test the controller under a range of testing conditions. This section shows a selection of test data obtained to date. In many cases the data was obtained with an obsolete rotor design, and thus the power output is low in some figures. Nonetheless, the testing data was invaluable or the team to better understand the system behavior and refine the controller and rotor design.

Figure 31 shows the power output of an early turbine design versus the rotor rotational speed. Various resistive loads were evaluated, and it is clear that the load impacts power output. This test clearly indicated that the controller should utilize pulse width modulation to expose the load to the generator at the right amount to achieve maximum output.

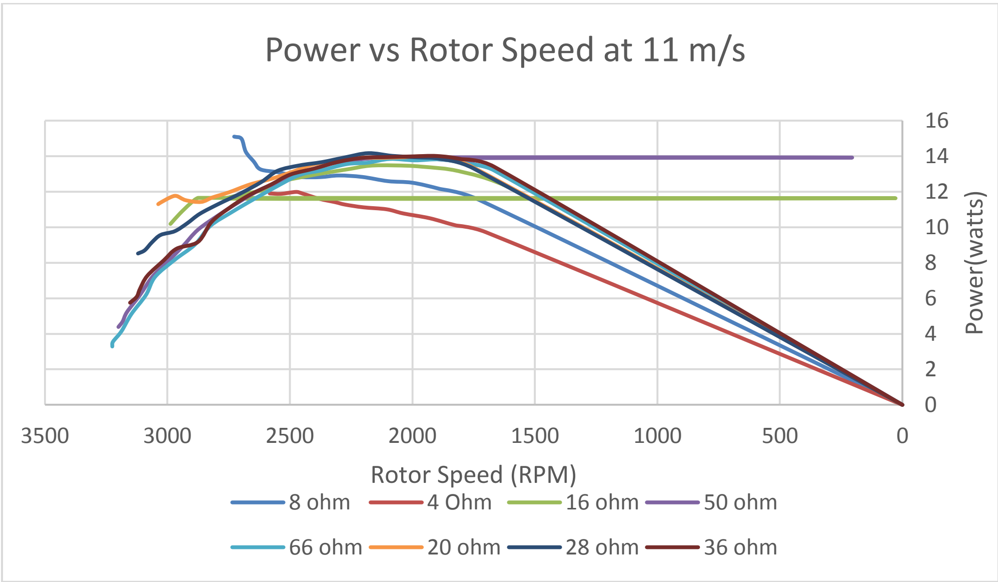


Figure 31: Power vs. Blade Speed at Varying Resistances

Figure 32 shows how power varies with the gate of the MOSSFET for various resistive loads. As the gate increases, the generator is short-circuited a higher percentage of the time, which increases the torque resisting the rotor rotation. The drop off at high gate is when the torque becomes large enough to brake the turbine. This test indicates how we can use the MOSSFET to control the gate and thus brake the turbine during shut down events.

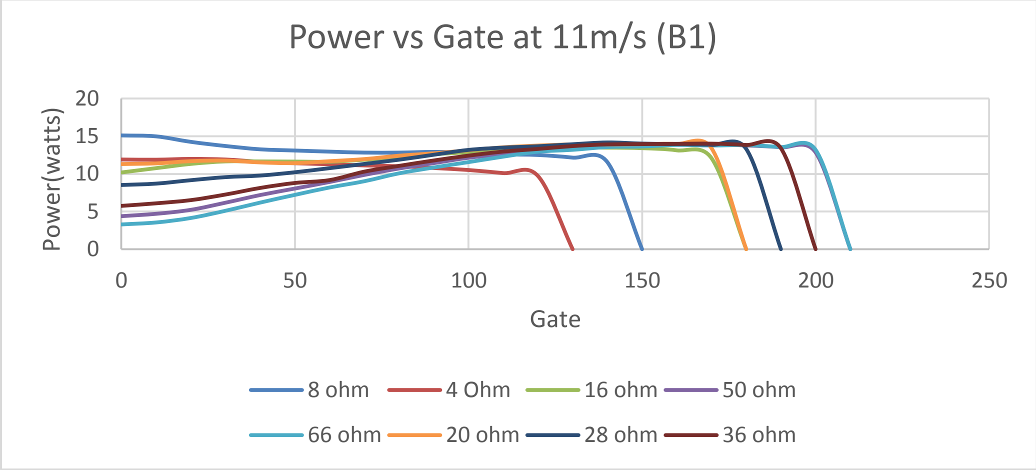


Figure 32: Power vs. Inductor Gate at Rated Wind Speed for B1 Blades at Different Resistances

Figure 33 shows the turbine power output versus tip speed ratio at a few different wind speeds. It is clear that the aerodynamic efficiency is maximized at a tip speed ratio of approximately 4.5. This result is interesting because the design tip speed ratio is 6. This discrepancy is likely due to some of the idealized assumptions in BEM theory for optimal design such as no drag. There could also be impacts from flow separation at the low Reynolds numbers of the system.

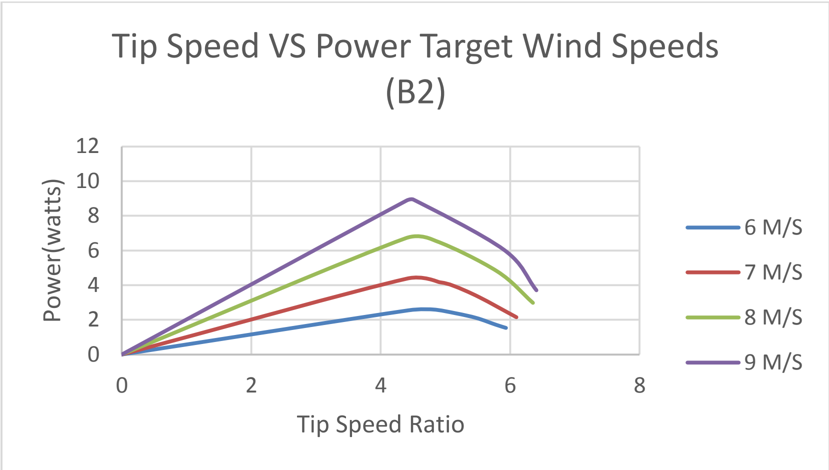


Figure 33: Tip Speed Ratio vs. Power at Different Wind Speed

Figure 34 shows the rotor speed versus the MOSFET gate value. As the gate increases, the generator is short circuited a higher percentage of the time, increasing the generator torque and reducing the rotor speed. This figure indicates that we can brake the turbine using this control approach.

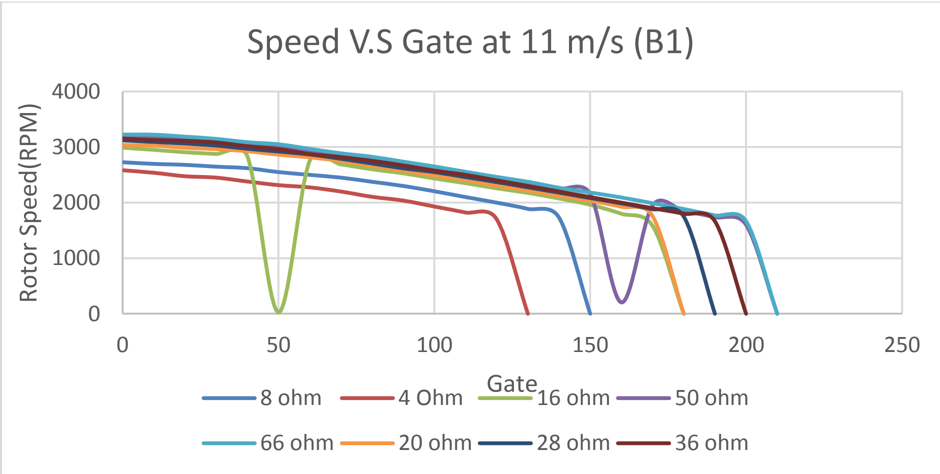


Figure 34: Rotor Speed vs. Inductor Gate Value for Different Resistances

Figure 35 shows our ability to control the rotor speed in above rated conditions for a few different blade designs. This was done by increasing the main gate value connected to the inductor. This in effect causes the circuit to approach a short circuit, which requires more current from the motor and effectively applies torque. This increase in torque is what slows the rotor.

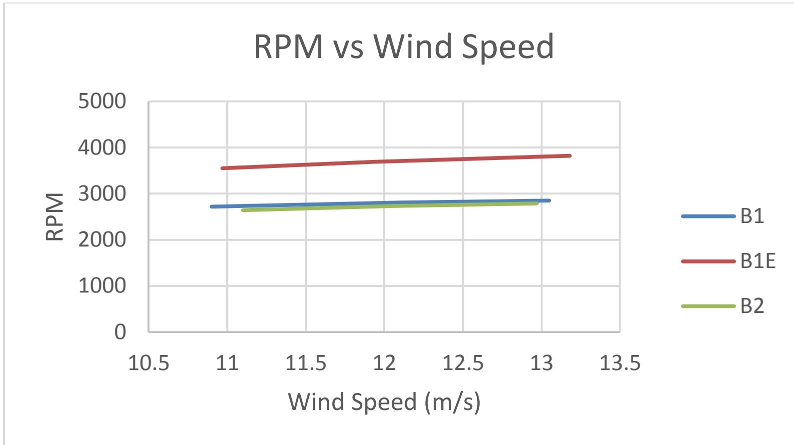


Figure 35: Controlling Rotor Speed vs. Wind Speed

Figure 36 shows how our system maintains rated power between 11 and 13 m/s. As the wind speed increases, the effective resistance that the load shows to the motor increases. This increase in resistance will draw less current through the load and therefore less power.

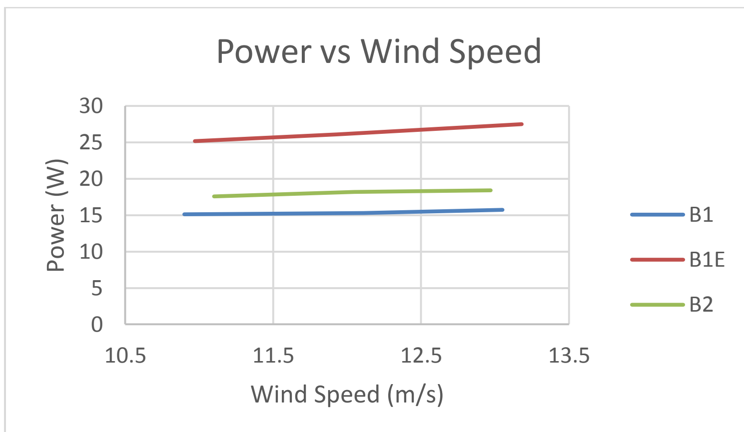


Figure 36: Controlling Power vs. Wind Speed

Figure 37 shows how RPMs are brought to under 10% of rated in under ten seconds. Braking is initiated at t=0 and then flattens out at 10%. This is done by drastically increasing the main gate which causes a short circuit. The blades quickly drop in RPMs and then the gate value is slowly reduced in order to maintain a flow of power as opposed to stopping the blades entirely.

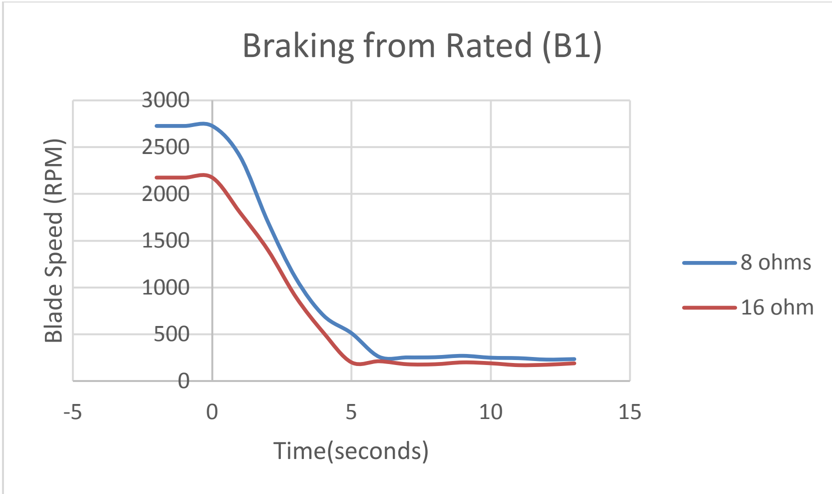


Figure 37: Turbine Braking Capability at Different Resistances

IV. Deployment Strategy

IV.1 Deployment Timeline and Project Life Cycle

Oasis will be shipped, assembled, and operated from a 20-foot shipping container. To begin manufacturing, MinuteWind requires a capital investment of $4M. These funds will be used to develop the Oasis name with NGO's, rent a warehouse for maintenance and fabrication of Oasis systems, establish relationships with third party suppliers, purchase components, and hire knowledgeable and passionate staff. The timeline for product construction is outlined in the Gantt chart in Figure 3. After transforming a shipping container into Oasis, the final product can be stored in the MinuteWind warehouse until it is needed. MinuteWind aims to minimize the time between producing and deploying an Oasis system by communicating with NGO's regarding their needs and requirements. Once an order is placed, MinuteWind will ship the required number of units to the deployment location where MinuteWind staff will assemble Oasis into its operational state and perform routine maintenance and safety checks throughout its deployment as outlined later in this document.

Oasis is designed for disaster zones in the recovery phase. A few months after a disaster, shipping bottled water is no longer efficient based on the scale of need, but clean water infrastructure has not been rebuilt. Oasis acts as an intermediate solution between these two stages of the recovery phase. In some places, this can be as little as six months to a year, while in places like Haiti, it can be upwards of five years. Contracts between the customer and MinuteWind are expected to last three to six months, but Oasis's mobility allows this time to be lessened and its durability allows this time to be lengthened. Similarly, Oasis's secondary market of refugee camps are designed to be temporary, but tend to develop into long lasting communities. If the camps dissolve, Oasis can be disassembled and sent back to a MinuteWind warehouse. Oasis serves as a low-risk investment for refugee camps due to its flexible project life cycle and its ease of mobility.

IV.2 Project Site Evaluation and Selection

When a disaster strikes or a refugee camp in need is identified, it is vital that MinuteWind is quick to assess potential operational sites according to their population density, average wind speed, and access to a local water source. This information will be provided through NGO's, local maps, publicly available research, and on site MinuteWind field studies.

a. **Number of Units:** The density and population of displaced refugees or people without access to potable water will help MinuteWind determine the number of Oasis products to deploy. By collaborating with local NGO's, we can determine their need and find suitable locations.

b. **Wind Resource:** Following potential site selection, the site will then be examined for a reliable source of wind. Oasis requires approximately 10 kWh per day to operate. MinuteWind purposely over-engineered Oasis, allowing it to produce sufficient energy even under low to moderate wind. Additionally, the 20 kWh battery bank provides a buffer between the turbine and the desalinization unit to reduce the impact of variable wind speeds.

c. **Water Access:** Site evaluations must show that the site has a nearby source of water. Without a source, Oasis is unable to provide water. This limits MinuteWind's operations to refugee camps and disaster areas near fresh or salt water sources. However, many natural disasters occur along the coast and there are many refugee camps close to bodies of water.

d. **Permitting:** The last element to address before deployment is permitting in the chosen site location. Due to the nature of Oasis, with a fully mobile 18.3 m tower, permitting will vary country to country. In countries where the government is disrupted after a large natural disaster or an influx of displaced people, their ability to permit may be infringed. However, we still expect to acquire permitting just as NGO's are required to when installing communication towers. MinuteWind will work with the commanding NGOs and local governments to determine the permits that are required for Oasis in order to receive them as quickly as possible. MinuteWind will acquire all necessary permits, for both ground and air space, before deploying.

IV.3 Deployment Case Studies

Case Study Disaster Relief - Following the 2010 earthquake in Haiti, more than 317,000 people were left without access to clean drinking water. In the first year, the Red Cross addressed this issue by decontaminating water on site at purification centers. Then, the purified water was trucked in to 87 distribution points at a cost of $0.54 per 10 L serving. This method was used for five years as the Red Cross attempted to implement more permanent infrastructure for Haitians' water supply[17](American Red Cross, 2015). A more efficient and cost effective solution would have been found with Oasis. By deploying Oasis products along the coast and near rivers and lakes, our product would have shortened transportation distance, simplified the supply chain, and provided a more convenient service to those in need.

Case Study Refugee Camp - There are several refugee camps that meet all of Oasis's site requirements. One fresh water example is Nakivale, Uganda. This refugee camp houses more than 61,000 refugees and is located near Lake Nakivale. Currently, UNHCR has established a water treatment plant that sources water from Lake Nakivale and has trained refugees to run the plant and distribute the potable water. Although the system is gaining popularity, many refugees are still needing to boil water and decontaminate their personal drinking containers[18] (UNHCR, 2014). By bringing in Oasis units, MinuteWind would work with UNHCR to provide a secondary source of water for displaced people that can relieve stress from the current system and reach out to those who the system could not help.

IV.4 Stakeholder Identification

The major stakeholders for MinuteWind are NGOs, wind turbine component manufacturers, and third party vendors. We will be targeting the heads and decision makers of NGOs and refugee camps in order to influence them into leasing Oasis. Other important stakeholders are different governments. Many local laws might prevent deployment in certain areas, or require documents before deployment. MinuteWind will follow regulations that will vary with each country that Oasis will be deployed in.

[17] Facts from the Red Cross Report Haiti Earthquake Response: 5 Year Update
[18] Facts from the UNHCR Uganda Nakivale Fact Sheet 2014

IV.5 Communication

People always need water, but ever changing markets requires a flexible product and an adaptable company. As a service, it is vital that both MinuteWind's customers and end users are consistently satisfied with the quality of our water and services. This means that constant communication is necessary both with our customers and end users. MinuteWind will conduct frequent field reports and NGO satisfaction surveys to grasp how we as a company are performing and thus serving our stakeholders. This constant communication helps us to continuously innovate to meet undiscovered needs.

IV.6 Installation and Maintenance

When shipped, both the tower and the blades are disassembled into ten separate tower components and three blades detached from the hub. Once the product arrives, a team of certified MinuteWind technicians construct and deploy Oasis in a safe, efficient manner. First, the liquid storage ballasts in the trailer will be filled to support Oasis from tipping under high winds. Afterwards, the wind turbine deployment system is constructed inside the trailer. The deployment system consists of a set of threaded steel rods attached to a moving platform (Figure 38). Using a chain driven motor and gear system, the rods are spun in synchronicit,y lifting up the tower segment on the platform. The platform gripping mechanism holds and carries each tower segment to about six feet, before the next section is slid underneath. The bottom tower segment is bolted into the base of the shipping container for temporary support, and the upper, lifted segment is then lowered onto the bottom segment where it is attached via flanges and bolts. Once fully connected, the gripping mechanism is released and attached to the lower segment. This process is repeated until the tower has been fully erected. Once the first section of the tower has cleared the trailer roof, the nacelle is attached to the top section, and the hub is aligned with the nacelle. Technicians then secure the blades and hub onto the nacelle.

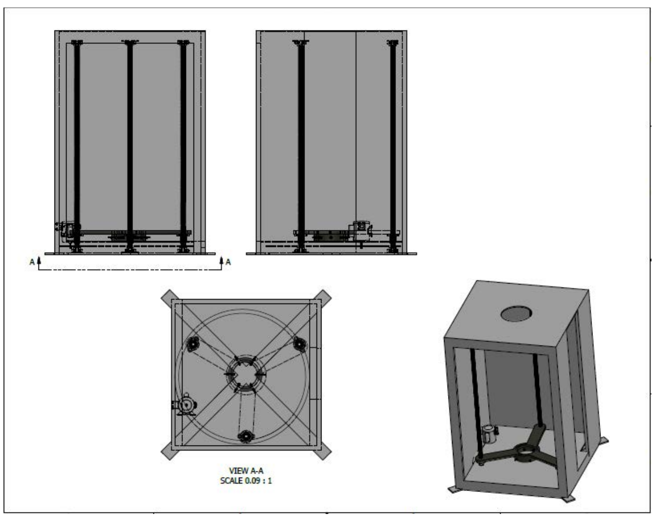


Figure 38: Chain Driven Deployment System for the Oasis Wind Turbine

When Oasis is fully constructed, technicians ensure that the construction is safe and secured before activating the turbine and water treatment system. Water purification will start once the technicians have connected all piping from the water source to the desalinization unit, regardless of the turbine's initial output. The 20 kWh battery bank comes fully charged allowing instant water production. MinuteWind's technician will continue to operate and maintain Oasis for the duration of its use. The technicians will repair any issues that arise, distribute the drinking water, and manage the operation of Oasis to ensure that a safe, reliable, and sustainable source of drinking water is available at all times. Once Oasis is no longer needed, the technicians will reverse the construction process, disassembling and repackaging the system into the shipping container. It will be shipped back to MinuteWind's repair center for additional maintenance before subsequent deployments.

IV.7 Reliability and Risk Management

To produce the 2000 L of water necessary for Oasis to serve its consumers, MinuteWind has taken extra caution to ensure adequate water production in less than ideal conditions. Oasis has been over engineered to ensure that it will produce the energy required to produce 2000 L of potable water from a saltwater source even under low to moderate wind conditions. Oasis's 20 kWh backup battery bank can store surplus energy during high winds and then use this excess energy for water purification in periods of suboptimal energy production.

MinuteWind acknowledges the detrimental effect of Oasis being non-operational for even a short period of time. From this, MinuteWind supports all extra costs and purchases only the highest quality parts from our third party vendors. The onsite technicians are aware of these priorities, ensuring that safety and reliability come first and profit comes second. All onsite staff will be properly trained in testing the quality of the water and performing routine maintenance as well.

In addition, three major safety issues must be addressed throughout Oasis deployment regarding quality of water and quantity of water. The quality of water will be tested daily to ensure it is meeting UN standards. MinuteWind will also constantly monitor turbine output to guarantee the production of the UN standard of 10 L per person per day.

IV.8 Conclusion

In summary, MinuteWind's product, Oasis, is a safe, sustainable, and durable product designed to meet global needs. By working with NGO's and local governments, we can rapidly deploy near any body of water to provide an intermediate source of potable water. Oasis's ease of deployment and mobility make it the optimal solution for short term use. Its durability and reliability promises a long-lasting solution in areas struggling to develop permanent infrastructure. Oasis strives to produce a high quality product and service for the betterment of many.

V. Appendices

Income Statement Depicting Net Income using Sales and Company-Wide Expenses

INCOME STATEMENT	Year 1	Year 2	Year 3	Year 4	Year 5
Revenue					
Sales	$178,200	$957,600	$2,026,080	$4,097,732	$9,200,010
COGS	$270,000	$732,000	$1,488,000	$2,268,000	$3,072,000
Gross Profit	-$91,800	$225,600	$538,080	$1,829,732	$6,128,010
Expenses					
Selling Expenses					
Advertising	$60,000	$62,400	$64,800	$67,200	$69,600
Shipping	$0	$0	$0	$0	$0
Total Selling Expenses	$60,000	$62,400	$64,800	$67,200	$69,600
General & Admin Expenses					
Salaries	$960,000	$1,020,000	$1,080,000	$1,140,000	$1,200,000
Rent	$52,000	$49,200	$50,400	$51,600	$52,800
Utilities	$6,000	$6,300	$6,600	$6,900	$7,200
Insurance	$8,700	$14,400	$37,800	$37,800	$127,800
Total G&A Expenses	$1,026,700	$1,089,900	$1,174,800	$1,236,300	$1,387,800
Other					
Research & Development	$24,000	$24,000	$24,000	$24,000	$24,000
Interest	$279,840	$272,280	$264,960	$257,640	$250,560
Total Other Expenses	$279,840	$272,280	$264,960	$257,640	$250,560
Income Before Tax	-$1,458,340	-$1,198,980	-$966,480	$268,592	$4,420,050
Income Tax Expense	$0	$0	$0	$0	$0
Net Income	-$1,458,340	-$1,198,980	-$966,480	$268,592	$4,420,050

SWOT Analysis

Oasis Market Turbine Cost Structure

1 x 20’ Trailer	$2,000.00
1 x 525 gallon water storage system	$396.80
3 x Blades	$2,000.00
6" SCH 40 (6.625 OD X .280 wall) A-500 ERW Structural Steel Pipe 6 feet long, 10 sections	$1,308.80
3 x 1 ½” Precision Threaded Rod, 6ft	$250.08
3 x Nut-Flange Assembly	$405.90
6 x 1 7/16” Flange Ball Bearing	$323.04
1 x ½ HP AC motor w/ 40-1 reducer	$291.95
1 x 15 ft ANSI 35 Roller chain	$157.35
3 x Sprocket w/ mounting assembly	$259.56
2 x Tower Gripper	$1,000.00
1 x Motor drive sprocket	$35.80
1 x 12 ft Stock steel	$291.14
Hardware	$50.00
1 x Nacelle	$475.00
1 x Low Speed Input/Output Shaft	$350.00
1 x Energy Storage System/Backup Power (20 kWh)	$3,500
1 x Generator/Motor	$422.00
1 x Electrics (Wires, Controllers, Circuit Components, etc.)	$150.00
1 x External Water Taps (Up to 4)	$60.00
1 x Water Purification/Desalination System (approximate cost of 2000 L system)	$11,100.00
1 (or more) x Water Pumps	$169.99
1 inch water tubing for source (100 ft)	$162.06
2 x Internal Overhead Lights (For nighttime operation.)	$80.00
2 x Onboard First Aid Kits (In case of worker injury.)	$25.00
1 x UV light Water Bottle Purification Systems (4 x UV Lights/UV Sanitizers)	$90.00
1 x External, Closed Loop Security Camera System	$1,500
4 x Water Bladders for Corners	$2,640
1 x 8 Foot Ladder	$100
Total	$29,594