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DEVELOPMENT OF A BUSINESS PLAN FOR PORTABLE WIND TURBINES

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ABSTRACT

In 2014 the Department of Energy sponsored a Collegiate Wind Competition challenging interdisciplinary teams of students to design a portable wind turbine and develop a business plan for the product. This thesis focuses on the business plan portion of The Pennsylvania State University's team, Remote Wind PSU, and investigates whether a market niche similar to those enjoyed by portable solar panels and diesel generators can be captured by a portable wind turbine. In order to evaluate a portable wind product, market research was conducted to determine the most opportune market and a financial analysis was performed to test the success of the product. The findings suggest that a portable wind turbine can be a viable product in the natural disaster aid market if the appropriate amount of funding is available and if product developers can navigate the bureaucracy of disaster relief agencies quickly. Remote Wind PSU has a projected NPV of $5.86 million after paying investors a five to one return on investment and an IRR of 2,294%. However, deviations from expected costs and investments could impact the success of the product. A sensitivity analysis was conducted to determine the robustness of the findings. Of the variables tested, NPV and IRR were most impacted by production cost variations. A 20% increase in production costs created a negative NPV of -$598,000 and an IRR of 12% while a 20% decrease generated a NPV of $9.6 million and an IRR of 2,312%. This research will hopefully spark interest in developing a commercial, portable wind turbine and contribute to the Collegiate Wind Competition.

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Chapter 1

Mobile Power Market

As the demand for energy grows and some conventional fuel supplies increase in cost, scientists look to develop new methods of energy production. Stand-alone technologies have been growing in popularity in areas without electrification. Some of these technologies have been developed on a portable scale. However, a portable wind turbine has not yet been developed that captures market attention on the scale of other portable technologies.

In this context, the Department of Energy (DOE) has developed the 2014 Collegiate Wind Competition (CWC) that poses the challenge of designing a small-scale, portable wind turbine with the purpose of charging small electronics. The Pennsylvania State University's team, Remote Wind PSU is composed of 30 undergraduates studying Aerospace Engineering, Communications, Energy, Business, and Finance, Energy Engineering, and Mechanical Engineering. In addition to the design portion, there are business plan development and financial analysis components to the competition which challenge students to determine a market and analyze the financial viability of a business in the market. Figure 1 displays the two primary teams of Remote Wind PSU, the Market Turbine Team and Business Plan Team, and their relationship to each other.

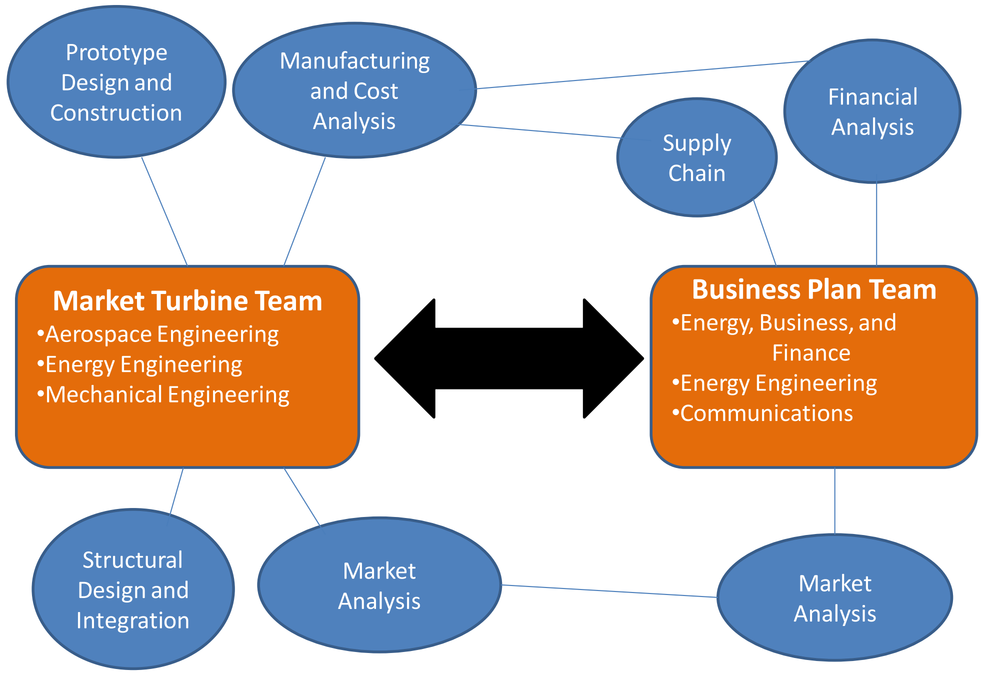

Figure 1: Remote Wind PSU Team Organization

Under each team heading is a list of the academic backgrounds of the students on the team. The two-sided arrow indicates the influential relationship between the two teams. The ovals denote the sub-teams and the focus of each. The arrows between the ovals show which tasks required input outside of team lines. For example, the Market Turbine Team has to fulfill certain requirements per CWC guidelines which influence the Business Plan Team's market selection process. The market analysis that the Business Plan Team conducts then impacts the final design of the market turbine so it suits the selected market. The manufacturing cost research that the Market Turbine Team conducts influences the supply chain organization and financial analysis. After the Business Plan Team uses the data provided by the Market Turbine Team, they analyze if the cost specifications allow for a sales price that covers costs and a profit margin while staying with the potential customers' price range. If the cost specifications are too high, the Market Turbine Team would need to revise its design and material decisions.

This thesis presents the key components of the market analysis and business plan that I developed as a team leader in the competition. It is organized in the following manner. Chapter 1 provides an overview of the mobile power market. Chapter 2 surveys potential markets and determines the best fit for this product. Chapter 3 presents the product design details. Chapter 4 describes production and distribution methods. Chapter 5 presents a financial analysis to test the market viability of the product. Chapter 6 concludes with a summary of the main points of the thesis.

Mobile power possesses a variety of meanings and is not always the same as stand-alone power. For example, mobile power can refer to supplying electricity for portable devices such as electric cars and cell phones rather than in terms of a portable producer (Starner &Paradiso, 2004). Alternatively, some scholars have explored the potential for electric cars to be used as power supply for other applications (Williams & Kurani, 2007). For the purpose of this thesis, mobile power is defined as power generated by portable products independent of an electricity grid connection. Portable is defined as able to be carried by two people.

Mobile power technology, which owes its roots to stand-alone technologies, is relatively new to energy markets. There are a few recognizable products within this market, but each has features limiting its utilization. Thus, these products have faced difficulty in capturing market share while in competition with grid-supplied electricity. Not all stand-alone applications are viable for scaling to portable devices. The remainder of this chapter focuses on stand-alone technologies, particularly those with the ability for portable development.

Micro-hydro power (MHP) and biomass gasification are common types of stand-alone technologies. MHP takes advantage of water pressure in downhill flowing bodies of water by transforming it into mechanical energy that can then be converted into electricity. Biomass gasification involves harnessing solar energy produced during photosynthesis from organic matter. Both have low operational costs and high capital costs due to infrastructure needs. Neither technology is well suited to portable adaptation due to equipment, feedstock, and site requirements (Kishore, Jagu, & Gopal, 2013). Some technologies could also be portable. These include solar photovoltaics (PV), wind turbines, and diesel generators.

Solar PV absorbs photons from sunlight and then converts them into energy via semiconductors. This method of energy production is growing in popularity and has received focus for technological development. PV modules have varying generation capacity from 5W to 200W and are often coupled with a battery for power storage (Energy Efficiency and Conservation Authority (EECA, 2010).

PV has high capital costs due to installation, orientation, and permitting fees (EECA, 2010). In 2012, PV for residential installations, which are on a scale of less than 10 kilowatts (kW), cost approximately $5.30/Watt (W). The capital costs estimated at the end of 2012 for residential installations in 2013 is $3.69/W (Feldman et al., 2013). Portable solar products do not require installation, orientation, and permitting which removes the costs associated with those processes. However, due to the small size of portable PV, there is likely a higher cost per Watt for those products since there are fewer Watts over which the cost can be distributed.

SunShot, a DOE initiative, seeks to reduce PV module prices by 75% from 2010 to 2020 in order to make PV more attractive. From 2011 to 2012, prices of residential PV decreased by 14%/W and are expected to continue decreasing. Module average sale prices are estimated to decrease to $0.55/W to $0.75/W by 2014 (Feldman et al., 2013). The decreasing cost of PV is increasing its attractiveness as a method of energy production.

Portable PV devices include lamps, radios, flashlights, and battery, phone, or laptop chargers. These products vary in price, but are usually offered on the scale of a few hundred dollars ("Earthtech Products," 2014.). A 400 W solar charger runs for $600 to $1,425 ("Complete kit 400W. . .," n.d.); "Grape solar 400 Watt off-grid solar panel kit Home Depot," n.d.). Compared to other renewable and portable energy sources, portable PV appears to have found a niche in basic consumer electronics and lighting.

While sunlight is the most abundant renewable resource and PV is exempt from fuel or feedstock costs, solar energy does have disadvantages which lessens its viability as an energy source in some applications. Sunlight is an intermittent resource that cannot be tapped into at night or during overcast weather. Any kind of shading from the sun such as trees or buildings can significantly reduce generation (EECA, 2010).

Diesel generators are often the go-to product for back-up generation when electricity grids lose power. Diesel generators are durable and reliable in addition to offering a quick response time ("Diesel Generators: A Reliable Source of Power," n.d.).

Due to its reputation for reliability and the ease of transporting and storing fuel, consumers tend to look at diesel generators as the first option for off-grid power.

Although portable diesel generators are viewed as reliable and are the top technology for portable power, there are downsides and risks associated with the use of diesel generators. Diesel generators are fuel dependent so there are operational costs that must be taken into account. As of March 24, 2014 the cost of diesel fuel was $3.988/gallon ("Gasoline and Diesel Fuel Update," 2014). A portable generator with a capacity of 1 kilowatt (kW) has a tank the size of a half-gallon to a gallon ("2014 Best Portable Generators," 2014). Storing fuel would be necessary, although generally inexpensive. Additionally, improper set-up and use of a portable generator can cause fire and carbon monoxide poisoning ("Portable Generator Hazards," 2012).

Wind energy is also growing in popularity as a renewable resource. Wind turbines capture energy from the wind by converting the rotational energy of the turning blades into electricity. Micro turbines for residential use typically have a capacity of 0.3 kW to 20 kW. Like solar panels, wind turbines have high investment costs and low operational costs at the margin since there are no fuel or feedstock expenses. Wind is also an intermittent resource in which proper siting is important for generation; however, unlike solar, wind energy can be available during the day and night (EECA, 2010).

Drawbacks of wind energy include the site specific nature of the resource and high initial investment costs which may include site assessment, installation, and the turbine itself. On average, small scale turbines cost approximately $4.08/W (Pacific Northwest National Laboratory, 2013). Turbines also incur maintenance costs throughout product life (EECA, 2010).

Through the CWC, our team considered the design of a portable turbine with an ultra-small scale of 375 Watts – enough to charge simple consumer electronic devices such as cell phones (Remote Wind PSU Design Team, 2014). Turbines at this scale do not require installation or site assessment. Similar to solar, energy storage is necessary, and site placement may be a consideration. Portable wind energy has not yet found a niche market to capture as PV and diesel technologies have. This investigation focuses on whether a similar market niche could be established for a portable wind turbine.

Chapter 2

Market Selection

As part of the work of the business plan team in the CWC, several markets were reviewed to determine which would be suitable for a small-scale, portable turbine. Due to the restrictions set regarding product design by CWC guidelines, the potential markets from which to choose are limited to those in which grid-supplied electricity is not readily available and portability would be useful or necessary. Conversely, market selection plays a role in the design process. Depending on the selected market and its needs, product features may be altered to enhance utilization. Each market candidate was reviewed based on its expected demand and entrance barriers. The following markets were under review.

Natural Disaster Aid

A major issue in the aftermath of a natural disaster occurs is power supply. A portable wind turbine can provide communities the opportunity to charge small devices such as cell phones, laptops, and batteries while the electricity grid is down. This turbine would be used as a community turbine that approximately five individuals can utilize simultaneously until power is restored (Remote Wind PSU Design Team, 2014).

The target customers for this market are organizations that deliver aid in emergency situations. These include local and state police and fire departments, municipalities, relief organizations such as the American Red Cross, and community and religious centers. Ideally, these organizations would purchase a supply of turbines in advance of a disaster occurrence.

While introducing a portable turbine into the natural disaster aid market has several benefits, there are also many disadvantages. The strongest incentives for purchasing this product include its portability, collective use ability, and renewable energy use. Since the turbine is portable and designed to have multiple charging outlets, the product's benefits can be spread over multiple users. Dependence on renewable energy allows a portable wind turbine to provide energy over an extended period at different locations without need to refuel. In times of disaster, fuel for generators is in short supply and at a high cost compared to non-disaster periods. For example, in the aftermath of Hurricane Sandy in 2012, power outages caused fuel distribution problems which led to fuel shortages and increased prices. While demand for some fuels waned during the period of power outages, demand for vehicle and generator fuels did not decline ("How Hurricane Sandy Affected the Fuels Industry", 2014).

Although fuel can be stored, a disaster that causes extended power loss may require fuel beyond stores. At that point, cost of fuel and transportation may lessen the attractiveness of a diesel generator. Without dependence on fossil fuels, customers can reduce variable costs and the waiting time for power use. In disaster response, technology decisions depend upon the severity and length of impact.

The most pertinent disadvantage to address is difficulty of breaking into the market. Competitive products, such as generators and solar panels, can be used in natural disaster situations. Generators have a history of use and reliance, albeit are fuel dependent, which will make introducing a new product that relies on an intermittent resource difficult. The potential resource unavailability of wind energy detracts from the value of the turbine. Many of the disaster responders likely rely on back-up generators and it may prove difficult to incentivize these customers to try a new product especially when dependability is crucial in times of emergency. Additionally, using this product in an urban landscape, where a population density and power demands are large could prove challenging.

Remote Area Use

A portable wind turbine can supply small-scale power in rural areas where grid-provided electricity is not available. Target customers include frequent campers, organizations that promote outdoor living, scout troops, ranchers, and farmers. Additionally, this turbine can be marketed to individuals or organizations that travel to areas without reliable electrification.

Due to its portability, this product can be an attractive asset to those who travel extensively to rural areas. While this product has the ability to supply power that would be needed in these specific areas, the competition and existing infrastructure would be difficult to overcome. Many campgrounds provide convenient charging stations. In instances in which charging stations are not available in rural areas, solar panels are a lighter-weight option. If the weather does not permit the use of solar panels, then a portable wind turbine could potentially be useful. However, the weight of the turbine would likely trump its usefulness. Unfortunately, in this market, a portable power supply is useful and may even be necessary, but there are better options than a wind turbine.

Small Businesses in Developing Countries

In areas without reliable electrification in developing countries, small businesses can suffer substantial losses due to power outages. Power outages may force a business to close until power is restored which can result in loss of profit and inventory. A portable wind turbine can alleviate the stress of power outages for both small business owners and their customers.

Target customers are small businesses such as convenience stores and grocery stores that rely on electricity to sell products. In this market, the customers have a great deal to lose if the power goes out. The wind turbine can cater to a need rather than serve as a product that can be useful, but is not necessary to livelihood.

While a portable turbine would alleviate losses and may prevent a store from closing due to power loss, there are significant problems with choosing this market. First, marketing the product to the target customers without stable electrification would prove difficult. As a startup company, Remote Wind PSU does not have the resources or contacts to connect with the customers. Second, the amount of electricity that a single turbine produces may not be sufficient to supply power to a small business. In addition, given the intermittent nature of wind, there is no guarantee that the business can rely solely on the turbine's generation to provide power. Third, these small businesses likely cannot afford a turbine with the aimed market price that is being projected. Another mobile power product that has already acquired a customer base at a lesser cost may prove to be better suited for this market.

Specialized Industry Use

For companies performing technical work in rural areas, a portable wind turbine can provide power to charge equipment. Target customers include film crews working on projects in remote areas such as Greenpeace or Discovery Channel in addition to documentary teams or news stations. An application for the turbine would be to charge equipment at night so that it is ready for use the following day.

This is a small niche market that requires a specialized product development. More intensive development and higher grade components than the other potential markets are needed and therefore, require a greater initial investment. Considering this is a unique market that is accustomed to technical equipment, product development and component costs may be offset by charging customers a higher market price. Unfortunately, such a specific and small market would be difficult to enter especially without creating a presence in another market first. Additionally, lightweight solar PV is a strong competitor in this field due to its ease of portability. This market is a potential candidate for a secondary market.

International Humanitarian Aid

Portable wind turbines could be used to provide electricity in troubled areas without electrification or reliable grid access outside of the United States. The wind turbine can provide lighting in the aftermath of natural disasters or to conduct procedures to help people in these remote areas. While the use of this product is similar to the Natural Disaster Aid market, the intention is that the turbine will be utilized for a longer period of time in areas where grid supplied electricity is not an option because infrastructure costs are too expensive to extend the grid.

Target customers are organizations with a global aid perspective. These organizations may include Red Cross, UNICEF, Doctors without Borders, Engineers without Borders, and the Peace Corps. These organizations can use the turbine to conduct work in rural areas where power is scarce.

While a turbine may prove useful to these organizations, competitive products would likely occupy too great of a market share for a portable turbine to enter the market. For conducting work in remote areas, lightweight equipment that requires little assembly and maintenance is of the utmost importance. In this category, solar power is more useful than wind power (K. Mehta, personal communication, March 4, 2014).

Selected Market

The selected market for this portable wind turbine is emergency response. Of the markets surveyed, this is the most defensible market for business plan development of a portable wind turbine. Additionally, it offers the greatest potential for capturing market share.

A portable wind turbine can fill a market gap left by the two strongest competitors in this market: diesel generator and solar power. Back-up generators are often purchased in case of power outages. However, a generator's dependence on fuel makes a wind turbine a more attractive product. In times of emergency, fuel sources are in high demand and short supply, which causes high prices for customers and long waits to receive fuel. A wind turbine relies on renewable energy that removes high operating expenses for fuel.

Solar PV also relies on a renewable source of fuel. However, since solar panels can only be used when the sun is shining, the potential for power generation is eliminated at night and reduced on cloudy days when electricity is most needed. Energy storage is necessary for both solar and wind products, but solar PV generation may be more difficult than wind generation in urban areas due to the solar shadows that tall buildings create.

Now that a market is established for the product, the design must be developed.

Chapter 3

Product Design

The product has been designed according to the challenge posed by the DOE's CWC while keeping the selected market in mind. The product must be a small-scale, portable wind turbine with the ability to charge small electronic devices. The design teams of Remote Wind PSU conducted all design work and drawings. The design team was tasked with creating a test turbine that will be demonstrated at the competition in order to test methods of design. They also developed the commercial product which will be the focus of this section. I will present design challenges faced in creating a marketable product and how the design team addressed each.

The first problem involves designing a wind turbine that can generate enough power to charge small electronics while remaining portable. The solution to this problem is dependent upon design and materials selection. Keeping in mind the portability requirement, materials must be limited to a certain size to allow for easy packaging and transport. Power is related to the area of the blades, but the length of the blades is limited. Given the scale of the product, target efficiency level, and estimated wind conditions, the target rated power for the turbine is 400 W (Remote Wind PSU Design Team, 2014).

Small electronics are defined as the range of devices from batteries to laptops. A laptop requires about 400 Watt-hours (Wh) to be fully charged. This charge contributed to selecting the battery to provide sufficient energy storage. In order for the turbine to be portable, it must be lightweight and designed in such a way that it can be packaged to a manageable carrying size. Table 1 presents the design specifications for both the prototype and market turbine (Remote Wind PSU Design Team, 2014).

As Table 1 indicates, the rated power for the market turbine is 375 W instead of the target 400 W. This is an example of the need for a flexible design in the beginning stages of development to create an optimal product. The decision to choose a generator with a lower capacity was a tradeoff for lower costs and better efficiency (Remote Wind PSU Design Report, 2014).

Table 1: Design Specifications

	Test Turbine	**Market-Scale Turbine**
Rated Power (W)	21	375
Rated Wind Speed	13	13
Rated Speed (rpm)	2759	815
Rated Torque (N-m)	0.07	4.4
Rotor Diameter (m)	0.45	1.52
Type	Downwind rotor with stall regulated control	
Rotation Direction	Clockwise looking upwind	
Blades	Solid Concepts PolyJet HD	Fiberglass reinforced composite
Max Tip Speed (m/s)	70.5	80
Alternator	AMMO GPMG5225	MOOG AG-5250-C-1ES
Yaw Control	Passive	
Battery Charging	5V	12V
Braking System	Electronic Stall Regulation with Relay Switch Controls	
Cut-In Wind Speed (m/s)	3.5	4
Survival Wind Speed (m/s)	20	25
Tower Type	N/A	Guyed Tubular
Tower Height (m)	N/A	3.81

In the turbine design process, the design team had most freedom in creating the blades and tower structure as well as the packaging. The design team used a blade optimization method called “evolutionary strategy” to determine the best blade design, depicted in Figure 1, for a target cut-in wind speed and efficiency level (Remote Wind PSU Design Team, 2014).

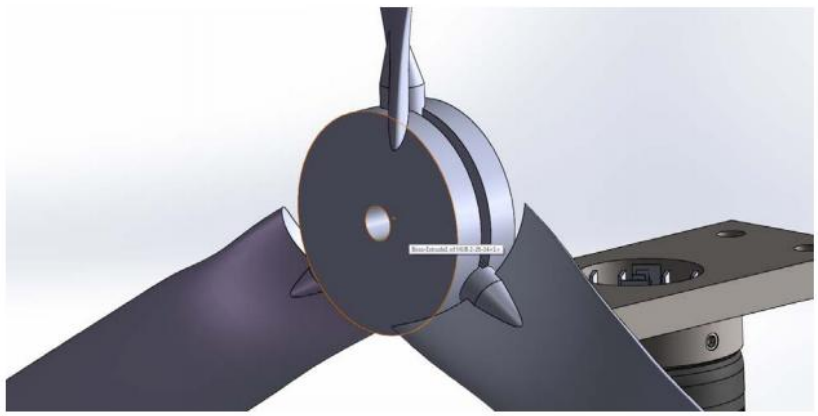

Figure 2: Blade Design

One of the most unique parts of the turbine design is the tower which is displayed in Figure 2. The turbine design has a telescoping tower for ease of portability. The tower has five equal sections and once assembled it reaches a height of approximately 3.8 meters. These sections nest inside one another for efficient packaging (Remote Wind PSU Design Team, 2014).

Figure 3: Assembled Tower

The second problem involves designing the turbine to be attractive in the targeted market. In the natural disaster aid market, durability and reliability are of utmost importance. The turbine must be able to withstand harsh weather conditions. Again, addressing this problem depends on the design and materials selection. After designing the turbine, the design team conducted a “Simple Load Model” analysis following the International Electrotechnical Commissions design requirements for small wind turbine to test loads at high safety standards (van Dam, 2011). The design team used this analysis to test various factors including fatigue, yaw, maximum rotational speed, maximum thrust, shutdown braking, and parked wind loading. The design team concluded that the blades and rotor shaft are durable and can withstand the expected conditions they would encounter throughout the product's operation (Remote Wind PSU Design Report, 2014). Figure 3 shows the assembled prototype turbine.

Figure 4: Assembled Prototype Wind Turbine

The biggest weakness in manufacturing a durable product is the telescoping tower because it is composed of five sections and the loads of the tower must be transferred across all sections. This is addressed by having a significant overlap of 15.2 centimeters between tower segments while also using shunts to help provide stability for the spacing between the various tower segments (Remote Wind PSU Design Team, 2014).

Since the product may be difficult to use in certain areas due to structural blockages to the wind or simply low wind, the turbine has been designed to have a low cut-in wind speed of 4 m/s. Since wind is an intermittent resource, a low cut-in wind speed increases the opportunities for generating power (Remote Wind PSU Design Team, 2014).

A 12 volt (V) battery is used in the design to charge devices. In the prototype of the turbine, this battery is connected to a charge controller which has two 12 V DC connections as well as a direct USB connection as output options. Via the 12 V connections, a variety of adapter plugs can be used to provide power to multiple loads at once (Remote Wind PSU Design Team, 2014).

Packaging is important in keeping the turbine components safe as well as portable. In order to reduce components, the carrying device doubles as the base of the turbine. Figure 4 depicts how the components would be packaged inside the carrying device.

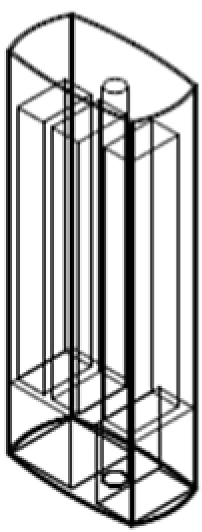

Figure 5: Packaging Organization

While the design team has not yet come to a decision on the carrying device, two materials are under consideration: cloth and carbon composite material. Both have merits and disadvantages. A cloth carrying device would be lighter and allow for additional pockets for storage, but the components may be too heavy for the cloth or become damaged during transportation. On the other hand, a composite structure would protect the turbine parts well, but may add a significant amount of weight that could reduce portability (Remote Wind PSU Design Team, 2014). I predict that the carrying device will likely be a combination of the two materials: a cloth bag and handle with a carbon composite lining. Figure 5 displays the carrying device.

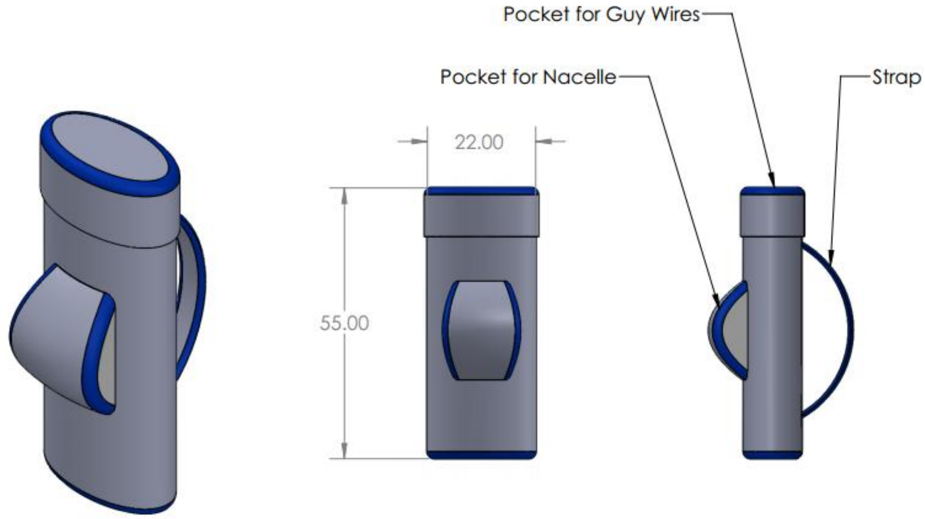

Figure 6: Carrying Device (Dimensions in Inches)

Third, the turbine must be manufactured at a price that allows for a profit margin large enough to attract sufficient investment capital. This is highly dependent upon component selection and method of manufacturing. In Table 2, the cost of parts is shown. Each purchase price is the least costly bulk order estimate for individual parts from a list of manufacturers that Remote Wind PSU has deemed credible. By taking advantage of the companies' specializations and economies of scale, Remote Wind PSU can purchase these parts at a lower price than the cost of manufacturing them in-house.

Table 2: Cost of Components

Components	Target Bulk Cost
Pole Sections	$100.00
Generator	$100.00
Electrical integration	$99.62
Controller	$75.00
Blades	$70.00
Base structure	$50.00
Battery	$40.00
Nacelle	$28.00
Rectifier	$15.00
Nacelle Attachment	$15.00
Spinner (Hub)	$10.00
Guy Wires	$7.00
Structure	$4.70
Total	$614.32

The component material selected and the amount of technical work needed to craft the material into a component influence the price for each component. The turbine was designed to be simple with the least expensive material that can be utilized without reducing durability significantly. The tower, which is the most expensive component, has five parts and is made of aluminum. The majority of the remaining parts are made from plastic. The cost of labor and raw materials increases the price of the generator, electrical integration, and controller. The blades, although made from plastic, require a design mold specific to this turbine (Remote Wind PSU Design Team, 2014).

Chapter 4

Supply Chain and Risk Management

After finalizing the product design, the next step for analysis is the production method. A wind turbine is comprised of a multitude of components required for proper functioning. Remote Wind PSU plans to use contract manufacturers to create the components. As displayed in Figure 6, Remote Wind PSU is responsible for the assembly, packaging, and storage of the finished product.

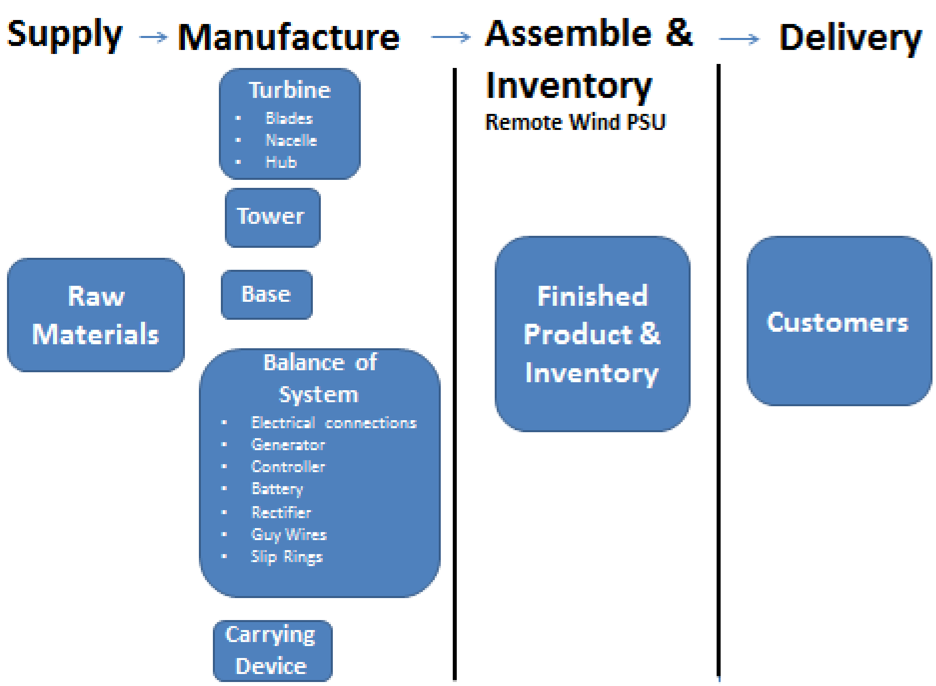

Figure 7: Supply Chain

Manufacturing companies that are specialized in a particular process can take advantage of economies of scale during production whereas a start-up company does not have the experience or production ability. Remote Wind PSU can take advantage of bulk ordering to further reduce prices. These components will be delivered to Remote Wind PSU's facility to be assembled, packaged, and stored until purchased.

Another crucial component is method of product delivery. Remote Wind PSU will likely develop an online retail store from which product information can be viewed and the turbines ordered. As for delivering the turbines to customers, Remote Wind PSU will hire a delivery company.

Since the supply chain is a crucial part of production, it is necessary to evaluate potential risks associated with the supply chain and develop a risk mitigation plan. According to Talluri, Kull, Yildiz, & Yoon (2013), there are three general risk categories associated with supply chains: delay, disruption, and distortion. Delay is a frequently occurring, short term risk related to schedule variations for transportation and production. Disruption is a break in the supply chain due to unavailability of materials, production, transportation, or holding space. Distortion occurs when received orders do not match expectations or estimations of needs such as size or quality of the order (Talluri et al., 2013).

Using the groupings of risks found in Talluri et al., (2013), potential risks that can occur during each phase of the supply chain will be examined and risk strategies developed to mitigate impacts. There are two main strategies for risk mitigation: redundancy and flexibility. Redundancy strategies rely on procuring backup supplies, suppliers, and finished products in the event that problems arise. Flexibility strategies involve increasing a company's ability to perform functions that will allow the finished product to reach the customer even if another link in the chain is primarily responsible for those activities (Talluri et al., 2013). Given the nature of the selected market and the infancy of the company, flexibility may not be a viable option in many cases so we focus on redundancy strategies to reduce risk exposure. Before delving into the categories of risk, allow me to note that the first phase of the supply chain is the transportation of raw materials to the manufacturers. The second phase involves the manufacturing of components and their delivery to the assembly facility. In the third stage, the components are assembled and packaged and then shipped to customers or placed in inventory.

Delays that can occur during the first phase between the raw materials supplier and the manufacturer are centered on delayed delivery of materials due to weather, accessibility of materials, or transportation issues. This initial delay can cause a delay in the remaining two legs of the chain. Obviously, late delivery to customers may lead to loss of business and a negative reputation. In a market that is based on natural disaster relief, time and reliability are crucial. Ideally, the wind turbines will be ordered in advance of natural disasters, but this may not always be the case.

The short-term nature of delay risks, meaning that the time between the realization of the problem and the time by which a solution must be found is short, indicates that it may be best solved through contracts and inventory accruement. Once a delay is realized, it may be too late to outsource the job to a secondary supplier even if the secondary supplier has already been thoroughly researched and chosen. Including additional incentives for on-time deliveries in a supplier contract could increase reliability of services. Also, increasing inventory stocks at the assembly facility can increase flexibility and reduce risks of late delivery to customers.

Disruption can occur if raw materials are unavailable or if their prices fluctuate greatly. Manufacturers can take financial steps to secure materials for production such as purchasing futures at certain prices to hedge against potential increases in prices. The company assembling the parts may choose to use secondary suppliers to reduce the burden on primary suppliers if they are not able to accumulate enough of the materials. This risk can be mitigated through use of secondary suppliers to reduce burden on primary suppliers. Additionally, the manufacturers can increase inventory levels of certain goods.

Third, distortion can be caused by unforeseen changes in demand by customers. In this category, for the assembly facility stockpiling supplies and the assembled wind turbines is the best strategy. However, if demand is too low, how can this risk be mitigated? One method to address this risk is to ensure that a certain percentage of the turbines is already accounted for by customers when ordering supplies. The manufacturers can take on the same strategy. Additionally, previous sales data and projections of sales can be utilized.

Finally, before entering a contract with a supplier, thorough research must be conducting on the supplier and their practices. While low prices are important for start-up companies, reliability is necessary. Limiting potential suppliers to those who meet International Standard of Organization (ISO) 9001: 2008 standards is a first step to ensuring suppliers offer reliable services and quality products. ISO 9001: 2008 offers quality management standards that follow eight basic principles: customer focus, leadership, involvement of people, process approach, system approach to management, continual improvement, factual approach to decision making, and mutually beneficial supplier relationships (“ISO 9000 – quality management,” n.d.). Another standard that can be utilized is the Global Reporting Initiative rating system which focuses on triple bottom line rating. Companies evaluate their sustainability according to guidelines that inspect economic, social, and environmental impacts of business actions. By using these guidelines and rating system, Remote Wind PSU can ensure that contracts are entered with reliable suppliers (“Reporting framework overview,” 2013).

Chapter 5

Financial Analysis

CWC guidelines require pro forma financial statements including cash flow statements, balance sheets, and income statements until the breakeven point to test Remote Wind PSU's viability in the selected market (U.S. DOE, 2014). The financial statements provided in this analysis cover five years of operation for Remote Wind PSU although the analysis finds breakeven times within two years. CWC provided a list of assumptions about costs. Those and additional assumptions are described below.

DOE requires assuming operating expenditures are equal to 50% of the cost of production per turbine (U.S. DOE, 2014). While the term "operational costs" was not defined by DOE, operational costs typically include expenses associated with the sale of goods and administrative activities (Wild, Shaw, & Chiappetta, 2009). I assume that operating expenditures include all costs that Remote Wind PSU incurs outside production costs.

The cost of production encompasses cost of materials and manufacturing components. Remote Wind PSU plans to utilize contract manufacturing for the production of components. This allows Remote Wind PSU to work with manufacturers that specialize in the production of certain products in order to take advantage of economies of scale. Remote Wind PSU will conduct assembly, packaging, and storage. The costs associated with these processes are included in operational expenditures.

After contacting suppliers such as Coleman Air, Ginlong, Tessco, and BatterStuff for bulk ordering costs of design components, the cost of production is determined to be approximately $615 per turbine (Remote Wind PSU Design Team, 2014). Thus, the operational cost is $307.50 per turbine. I assume a profit margin of 30% which brings the sale price to $1,317.86 per turbine.

As discussed in Chapter 2, the selected market is the natural disaster aid market. The target customers include local police departments, fire departments, local governments, religious centers, and Red Cross offices. Data is provided by the most recent U.S. police department, fire department, and government censuses and the American Red Cross's tally of their U.S. offices ("National fire department census quick facts," n.d.; Reaves, 2011; "Search Red Cross locations," n.d.). Religious centers are estimated to be equal to the number of township governments. Table 3 indicates the estimated market size.

Table 3: Market Size

Target Customer	**Number of Offices in the United States**
Local Police Departments	48,800
Fire Departments	12,501
Municipalities	19,519
Township Governments	16,300
Religious Centers	16,300
American Red Cross	519
Total	114,059

I assume market capture in the first year of production to be 3% of the total number of customer offices which equals 3,422 turbines. I also assume an annual growth of 1.5% or approximately 1,700 turbines per year. Table 4 displays the projection of sales.

Table 4: Sales Projections

Year of Production	Number of Turbines Sold	Growth Projections
2	3422	
3	5133	1.50%
4	6844	1.50%
5	8554	1.50%
6	10265	1.50%
Total	34218	

For the following discussion, look to Figure 7 which displays a timeline of activities for Remote Wind PSU.

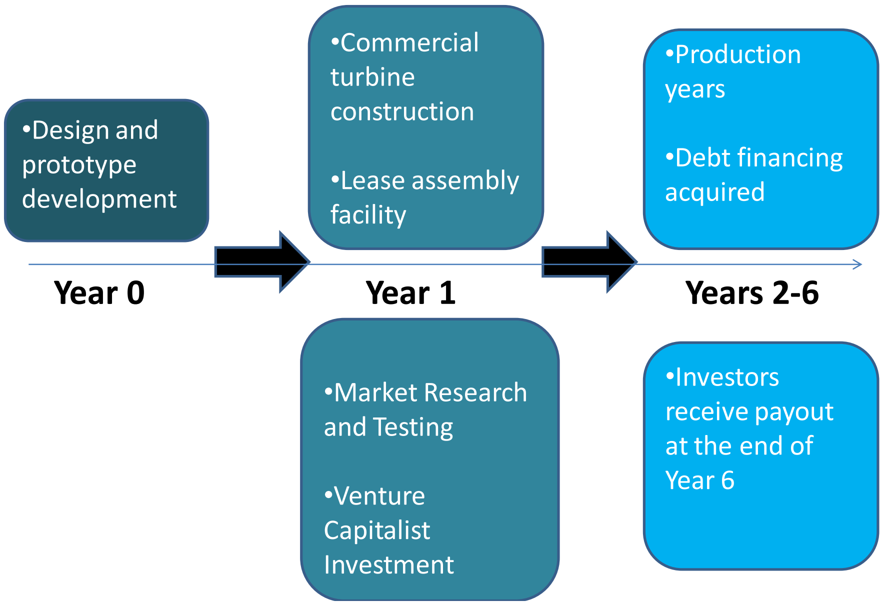

Figure 8: Timeline of Activities

Financing to facilitate initial production is assumed to be obtained through venture capital injections. The offer to investors is a maximum of 30% ownership and a five to one return on investment after five years of production in return for a total investment of $3.5 million. Based on future cash flow projections, $3.5 million is approximately 30% of Remote Wind PSU's value. Investor ownership is limited to 30% to ensure that Remote Wind PSU can request additional investment if required while allowing the owners to maintain a majority stake in the company.

In order to supplement the investments, Remote Wind PSU plans to apply for the Keystone Innovation Network program in Philipsburg, Pennsylvania where the assembly facility is located. The Keystone Innovation Network program provides grants in the form of tax breaks as well as tax credits to small businesses. The tax credits present an additional source of revenue since they can be sold to other companies if not used by Remote Wind PSU. The worth of the tax credits received equals 50% of the increase in growth of gross revenue each year ("Keystone Innovation Network," 2013). Remote Wind PSU will begin selling the tax credits during the second year of production.

Additionally, Remote Wind PSU plans to acquire debt financing. Remote Wind PSU will apply for a loan from Ben Franklin Technology Partners during the first year of production and a loan from the Small Business Administration in the following year. For startup companies, Ben Franklin Technology Partners can provide $50,000 to $150,000 in debt financing. Remote Wind PSU receives a loan of $100,000 in Year 2 ("Frequently Asked Questions," n.d.). The average loan offered by Small Business Administration in 2012 was approximately $337,730 ("7a Loan Amounts, Fees, and Interest Rates," 2013). During the second year of production, Remote Wind PSU obtains a $300,000 loan from them. Loan payments are covered under the mandated margin for operating expenses.

Investments will be used to pay for production and operating expenses during the first year as shown in Table 5 for the cash flow statement.

Table 5: Statement of Cash Flows

Remote Wind PSU							
Statement of Cash Flows	Pre-Production Phase		Production Phase				
	0	1	2	3	4	5	6
Operating Activities							
Sales	0	0	$ 4,509,404.04	$ 7,020,738.80	$ 9,360,985.07	$ 11,701,231.34	$ 14,041,477.61
Tax Credit Sales				$ 1,255,667.38	$ 1,170,123.13	$ 1,170,123.13	$ 1,170,123.13
Total Sales	0	0	$ 4,509,404.04	$ 8,276,406.19	$ 10,531,108.21	$ 12,871,354.47	$ 5,211,600.74
Cost of Goods Sold			$(2,104,388.55)	$ (3,156,582.83)	$ (4,208,777.10)	$ (5,260,971.38)	$ (6,313,165.65)
Operating Expenses (rent, wages, etc)			$ (1,052,194.28)	$ (1,578,291.41)	$ (2,104,388.55)	$ (2,630,485.69)	$ (3,156,582.83)
Total Cost	0	0	$(3,156,582.83)	$ (4,734,874.24)	$ (6,313,165.65)	$ (7,891,457.06)	$ (9,469,748.48)
Investor Payout							$ (17,500,000.00)
Net Cash Flow from Operating Activities			$ 1,352,821.21	$ 3,541,531.95	$ 4,217,942.56	$ 4,979,897.41	$ (11,758,147.73)
Investing Activities							
Prototype/Design Development	$ (145,500.00)						
Capital Expenditures							
Web Design		$ (50,000.00)					
Facility Lease		$ (26,000.00)					
Furniture/Equipment		$ (4,000.00)					
Market Testing Turbine		$ (5,000.00)					
Net Cash Flow from Investing Activities	$ (145,500.00)	$ (85,000.00)					
Financing Activities							
Cash Investments by Owner							
Debt Financing (Ben Franklin Technology Institute, Small Business Loan)			$ 100,000.00	$ 300,000.00			
Venture Capital Investment		$ 3,500,000.00					
Net Cash Flow from Investment Activities		$ 3,500,000.00	$ 100,000.00	$ 300,000.00			
Net Increase (Decrease) in Cash	$ (145,500.00)	$ 3,415,000.00	$ 1,452,821.21	$ 3,841,531.95	$ 4,217,942.56	$ 4,979,897.41	$ (11,758,147.73)
Discount Rate		0.09					
Net Present Value	**$5,862,747.46**						
IRR	**2294%**						

The facility lease cost incurred in Year 1 is an estimate based on rent and utility costs in Philipsburg, PA where the assembly facility is to be located to take advantage of the Keystone Innovation Network program (J. Helke, personal communication, December 5, 2015). The remaining investment activity costs incurred in Year 1 are assumptions based on the type of equipment and supplies needed for the facility, approximate web design costs for start-up companies, and cost of developing a commercial product and conducting market testing with 40 turbines. These costs are embedded in operating expenditures once production years begin.

As noted in Table 5 under investing activities, at the end of the fifth year of production, investors will receive $17.5 million for their investment. The payment results in a negative cash flow in Year 6, but Remote Wind PSU will retain a net present value (NPV) of approximately $5.86 million. The internal rate of return (IRR) of the cash flows is 2,294%. This is an exceptionally high rate of return. However, in this case, IRR is modeled as a yield which includes both the return for the investors and the Remote Wind PSU owners. Additionally, due to low pre-production costs and high operational costs which are embedded in the unit sale price per DOE’s instructions, Remote Wind PSU breaks even during its first year of production. While turning a profit in the first year of operation is uncommon, Remote Wind PSU’s largest hurdles are receiving the requested investment to support production activities and meeting sales projections. The IRR projections are highly dependent upon my assumptions of market capture which may be aggressive.

Tables 6 and 7 present the income statement and balance sheet for Remote Wind PSU. The income statement provides data on the revenues and expenditures of Remote

Wind PSU over the five production years. As noted in the income of the first year, Remote Wind PSU makes a profit. The balance sheet provides an estimation of the assets and liabilities of Remote Wind PSU. Since the value of the assets and liabilities are combined in the 50% margin for operational expenditures, the value of a few main assets were estimated. The cash value is equal to the ending balance on the cash flow statement each year. The facility value was estimated by the rent and utility expenses used in the cash flow statements. Finally, the inventory is equal to the value of one month of turbines. Since the majority of the operational expenditures are considered liabilities, I set the liabilities equal to the operational costs for each year. Since it is unknown how the company will withdrawal and inject cash on an annual basis, the equity shown in each year is the amount necessary to maintain balance between Remote Wind PSU's assets and liabilities.

Table 6: Income Statement

Remote Wind PSU					
Income Statement					
	Production Phase				
Year	2	3	4	5	6
Revenue					
Sales	$4,509,404.04	$7,020,738.80	$9,360,985.07	$11,701,231.34	$14,041,477.61
Increase in Gross Revenue		$2,511,334.77	$2,340,246.27	$2,340,246.27	$2,340,246.27
Tax Credit Revenue		$1,255,667.38	$1,170,123.13	$1,170,123.13	$1,170,123.13
Total Revenue	$4,509,404.04	$8,276,406.19	$10,531,108.21	$12,871,354.47	$15,211,600.74
Expenses					
Cost of Goods Sold	-$2,104,388.55	-$3,156,582.83	-$4,208,777.10	-$5,260,971.38	-$6,313,165.65
Operating Expenses	-$1,052,194.28	-$1,578,291.41	-$2,104,388.55	-$2,630,485.69	-$3,156,582.83
Investor Payout					-$17,500,000.00
Total Expenses	-$3,156,582.83	-$4,734,874.24	-$6,313,165.65	-$7,891,457.06	-$26,969,748.48
Net Income	$1,352,821.21	$3,541,531.95	$4,217,942.56	$4,979,897.41	-$11,758,147.73

Table 7: Balance Sheet

Remote Wind PSU					
Balance Sheet					
	Production Years				
Assets	2	3	4	5	6
Cash	$1,452,821.21	$3,841,531.95	$4,217,942.56	$4,979,897.41	-$11,758,147.73
Inventory	$375,783.67	$375,783.67	$375,783.67	$375,783.67	$375,783.67
Facility	$26,000.00	$26,000.00	$26,000.00	$26,000.00	$26,000.00
Total Assets	$1,854,604.88	$4,243,315.62	$4,619,726.23	$5,381,681.08	-$11,356,364.06
Liabilities					
Accounts Payable (Operating Expenses)	$1,052,194.28	$1,578,291.41	$2,104,388.55	$2,630,485.69	$3,156,582.83
Loans	$100,000.00	$300,000.00			
Total Liabilities	$1,152,194.28	$1,878,291.41	$2,104,388.55	$2,630,485.69	$3,156,582.83
Equity					
Equity	$802,410.61	$2,665,024.21	$2,515,337.68	$2,751,195.39	-$14,512,946.89
Total Equity	$802,410.61	$2,665,024.21	$2,515,337.68	$2,751,195.39	-$14,512,946.89
Total Liabilities and Equity	$1,854,604.88	$4,243,315.62	$4,619,726.23	$5,381,681.08	-$11,356,364.06

Figure 8 displays the variations in cash flow during the pre-production and production years. In Year 1, there is a relatively sharp increase that represents obtaining investment from venture capitalists. By the end of Year 2, cash reserves decline due to the beginning of production. During Year 3, Remote Wind PSU obtains debt financing to allow for continued production. The large decrease at the end of Year 6 represents Remote Wind PSU's payout to investors.

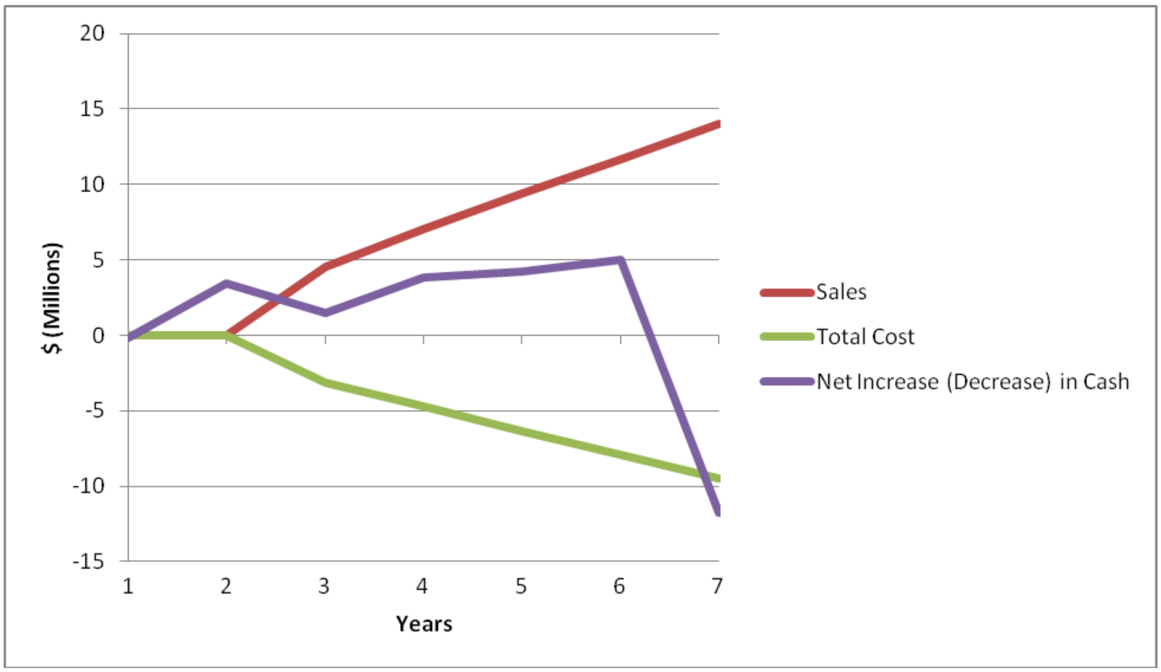

Figure 9: Cash Flow Variations

Sensitivity Analysis

I conducted a sensitivity analysis to determine the robustness of Remote Wind PSU's financial performance to changes in various market assumptions. Three variables, cost of production, cost of prototype development, and level of investment, have the potential to impact the success of this business. Figures 9 and 10 display the impact these variables on the Remote Wind PSU's NPV and IRR.

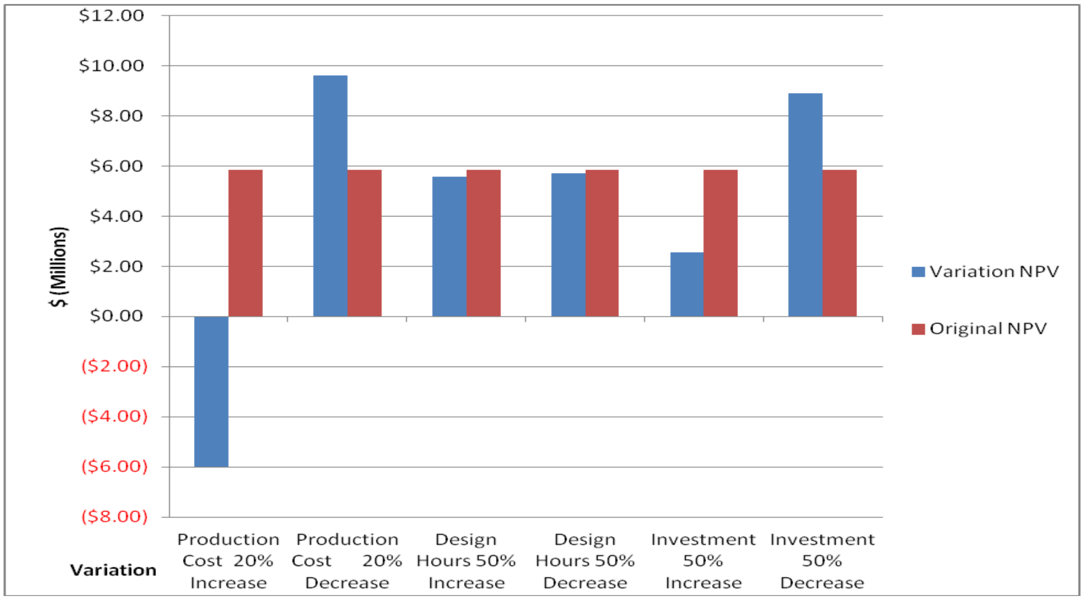

Figure 10: Sensitivity Analysis, NPV Comparison

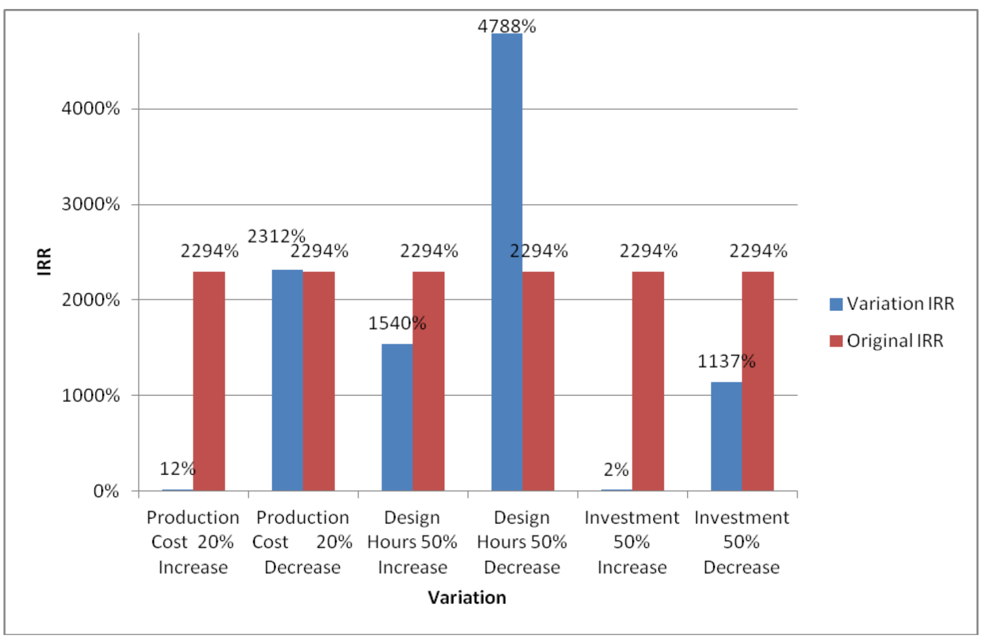

Figure 11: Sensitivity Analysis, IRR Comparison

For the first variable, I increased and decreased the cost of production by 20% to determine how this would impact the cash flows. After increasing the cost of production by 20% and holding the sale price per unit constant, Remote Wind PSU cannot afford to pay the investors a five to one return on investment. The IRR decreased from the original 2,294% to 12% and the NPV is approximately -$598,000. On the other hand, by decreasing the cost of production by 20%, Remote Wind PSU enjoys a NPV of $9.6 million which is a $3.7 million gain from the original NPV of $5.86 million. The adjusted IRR is slightly higher than the original at 2,312%.

The second parameter for sensitivity analysis is the number of hours needed to develop the prototype. Originally, 30 engineers worked five hours a week for six months for a total of 3600 hours. Each hour was estimated to be worth $40. The effects of a 50% increase and decrease of total hours was examined. The variation in either direction had a small effect on the NPV and IRR. The 50% increase of hours decreased the NPV by almost $300,000 and the IRR reduced to 1540%. Surprisingly, the 50% decrease in hours caused a slight decline in NPV by approximately $144,000 while the IRR rose to 4,788%. The IRR increase may be due to the high operational costs and sales which do not seem to reflect the appropriate amount of pre-production costs to warrant such quick growth.

The third parameter is the size of the initial investment. The requested investment covers the expected expenses during the first year of operation. The sensitivity analysis measures the effect of a 50% increase or decrease in investment. The 50% increase in initial investment to $5.25 million resulted in a NPV of $2.55 million and an IRR of 2%. This suggests that the promised five to one return in this scenario may be too high for

Remote Wind PSU to fulfill and may reduce the benefits of a larger investment. That being said, a larger initial investment would provide more security during the initial stages of production.

The 50% reduction in initial investment to $1.75 million resulted in a NPV of $8.989 million and an IRR of 1137%. While the NPV is greater than the original NPV, this is largely due to the smaller investor payout cost incurred at the end of the fifth year of production. Without an investment that can support the production and operating costs, Remote Wind PSU would not be able to sell the anticipated number of wind turbine without seeking additional investment.

After conducting sensitivity analysis for cost of production, product development costs, and initial investment, I recommend that Remote Wind PSU focus on reducing production costs. The reduction in costs resulted in the largest improvement in company value. That being said, recall that CWC parameters require operating expenditures to be equal to 50% of production costs. Therefore, a 20% reduction in production costs also results in a 20% decrease in operating costs. While operating expenditures would decrease by a certain amount when production costs decrease, many of the costs included in operating expenditures are fixed costs which would not normally be impacted if CWC's requirement did not exist. Therefore, this scenario likely overestimates the reduction of costs and valuation of the company. Alterations in the remaining parameters decreased the value of the company, did not provide a significant benefit, or created in an unrealistic outcome while other factors were held constant.

Chapter 6
Conclusion

The purpose of this investigation is to determine if a small-scale, portable wind turbine can be a viable product. Portable diesel generators and solar panels have enjoyed success in markets that require a portable energy producer, yet a portable wind turbine of this nature has not captured consumer interest in a similar manner. This thesis presents key points that a start-up business should consider when constructing a business plan to capture investor interest

This investigation placed a large emphasis on market selection. A small-scale, portable wind turbine is a specialized product that satisfies a particular need. Target consumers must be determined to evaluate interest in a product of this nature and to curb the design to fit market needs.

Six markets were surveyed to determine potential consumer demand, target customers, and barriers to market entry. The markets selected for review include natural disaster aid, remote area use, small businesses in rural areas, specialized industry use, and international humanitarian aid. I chose the natural disaster aid market because it presented the greatest need for a portable wind turbine with several identifiable customers that provide aid in the aftermath of natural disasters. Although portable diesel generators and solar panels are strong competitors that present barriers to market entry due to pricing and market experience, a portable wind turbine fills needs that portable solar and diesel do not cover. A portable wind turbine operates without fuel which reduces the operational costs and the waiting period for fuel transportation that diesel generators experience. Solar panels cannot operate without sunlight which limits its utilization.

During the design process, the design team took the market and purposed use of the wind turbine into account in developing the product. They focused on creating a product at a low cost while preserving efficiency, durability, and target power output. Material and component selection played a large role in keeping the turbine to a portable size.

An important consideration for a business that is entertaining the idea of entering a business is the supply chain and its risks. For this business model, I propose that Remote Wind PSU use contract manufacturing for individual components to take advantage of the specialization and economies of scale that manufacturing companies possess. Remote Wind PSU will conduct the assembly and storage stages of the supply chain.

Remote Wind PSU must be careful of three types of risk: delay, disruption, and distortion. The primary risk management strategies incorporate redundancy measures which involve increasing inventories, employing secondary manufacturers, and ordering components after a certain percentage of turbines are claimed by customers. In addition, it is recommended that manufacturers be evaluated according to ISO 9001 and GRI reporting guidelines.

In order to begin production, Remote Wind PSU hopes to capture the attention of venture capitalists. The company offers a five to one return on investment after five years and a maximum of 30% share of the company in return for a $3.5 million investment. The investment would be used to support production and operation costs during the first year of production. Due to the high costs of production and operation, which are embedded in the retail price and low pre-production costs, Remote Wind PSU generates a profit during its first year of production. After the fifth production year, the investors would receive $17.5 million with remaining value of $5.86 million for the owners of Remote Wind PSU.

After performing a sensitivity analysis that tests how variations in the cost of production, product development hours, and initial investment would impact the success of Remote Wind PSU, a 20% increase and decrease in cost of production was found to have the greatest impact on the value of the company. With a 20% increase, Remote Wind PSU cannot meet the five to one return on investment promise and obtain a positive NPV. With a 20% decrease in cost of production, Remote Wind PSU obtains an NPV of $9.6 million which is almost a $4 million increase from the original NPV.

The results of this investigation indicate that there is potential for a portable wind turbine to capture consumer interest. However, the success of a business such as Remote Wind PSU is largely dependent upon receiving sufficient initial investment and capturing consumer interest early in the production phase. Without sufficient investment, there is little chance of success. Additionally, success is dependent upon CWC's assumptions as well as mine, both of which may be aggressive.

The investigation would benefit from further analysis using a more specific estimation of operating costs and pre-production costs. Additionally, feedback from target customers of potential markets would provide support for market choice. It is my hope that this thesis benefits future research in the development of portable wind technology.

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ACADEMIC VITA

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EDUCATION

The Pennsylvania State University, Schreyer Honors College — Graduation: May 2014
Bachelor of Science in Energy, Business, and Finance
Bachelor of Arts in International Politics — Minor in Chinese (Mandarin)

RELEVANT COURSES

- Graduate Course: Electricity Markets
- Energy Economics
- Risk Management in Energy Industries
- Technical Writing
- Global Management for Earth, Energy and Materials Industries

RELATED EXPERIENCE

- Business/financial consultant for PSU team in DOE Collegiate Wind Competition **2013-2014**
  - Develop a business plan and financial analysis for small-scale wind turbine product
- Conewago Creek Initiative/Penn State Extension Intern **Summer 2013**
  - Performed extensive technical writing, community outreach, event planning, water sampling, and data analysis
- CHANCE Fellow **Summer 2013**
  - Conducted conservation research with Smithsonian Tropical Research Institute Ph.D. Candidates in Panama
- Faculty Assistant for Schreyer Distinguished Honors Faculty Program **2011-2013**
  - Planned logistics and facilitated 100 discussion forums and trips per year;
- Hess Corporation Course - Case Studies Analyst **Fall 2012**
  - Conducted and presented financial analysis for energy company development strategies
- Research Assistant for Political Science Department **Summer 2012**
  - Furnished critical analyses on journals exploring religion, civil war, and culture.
- Environmental Analysis: Deep Water Horizon Course **Fall 2010**
  - Explored causes, effects, and potential remedies of 2010 Gulf oil spill per engineering, environmental, ecological, geological, business, ethical, legal, and media perspectives.

LEADERSHIP

- Honor Society of Phi Kappa Phi Council of Students NE Regional Rep. **2012-2014**
  - Planned and implemented national leadership conference for 70 members
- Schreyer Orientation Mentor and Team Leader **2011-2013**
  - Organized "Afternoon of Service" for 150 scholars to increase involvement in PSU community; Faculty/staff liaison for the creation of presentations and networking
- Schreyer Honors College Day of Service Team Leader **2012**
- Team Service Project - "Middle Eastern Cultural Enrichment Event" **2010**
  - Planned and implemented a fundraiser to promote awareness of Middle Eastern cultures and intercultural acceptance through education, discussion, and experience.

SKILLS

- Computer: Microsoft Office, extensive experience with Excel, foundational C++ and Matlab
- Language: Proficient in Mandarin

ACCOLADES

- Hess Scholarship in "Global Management for the Earth, Energy and Materials Industries" **2013**
- Academic Merit Awards: Marie Radomsky & Vernon Ellzey, Joseph & Margaret Nesbit Hunt Scholarships; Chevron Corporation Environmental Systems Scholarship; **2012, 2013**