James Madison University

Business Plan & Wind Turbine Technical Report

NEIGHBORING WINDS

Renewable, Residential.

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1. Executive Summary

Individual wind energy consumers face two important unmet needs: high up-front capital costs and long payback periods. Neighboring Winds (*NW*), located in Denver, Colorado, will satisfy those needs by offering consumers wind energy through their contracted developers. In return for *NW* products and services, society will gain greater environmental sustainability, contracted developers will gain tax benefits, and the housing developers will gain a differentiation strategy to market to interested consumers.

Neighboring Winds will promote a niche strategy specifically marketing residential developers in CO building communities of 20+ homes in suburbs that surround highly populated cities, with an average wind speed above 7 m/s, at a competitive cost. *NW* consumers differ from the purchaser and can be characterized as environmentally conscious homebuyers with interest in new construction that have a positive outlook on wind energy. These consumers can utilize an application developed for iPhone and Android phones (offered by *NW*) allowing them to monitor their energy consumption and savings. This app will be marketed as a differentiated competitive advantage.

Marketing efforts will stem from the relationships made with the consumers due to a strong sales force, as well as business to business to business, relationship, direct, and targeted marketing in hopes of reaching the best developers for Neighboring Winds products and services. Specific efforts are described in the following plan.

Neighboring Winds revenue stream will mostly consist of the sale of the turbine, $271,490 per 50 kW turbine, and the fee charged for maintenance and replacement, $45 per month. Most costs will be variable due to the different needs of various developers. According to the financial analysis and factoring in both variable and fixed costs, it is expected for *NW* to breakeven in year one.

The turbines will be installed by Neighboring Winds employees to ensure developers' preferences are met and aid in building a trusting relationship with the developers. A strong set of quality control measures will be instilled in each installation to guarantee perfection.

The startup team will consist of a CEO, CFO, CMO, COO, and CTO. The CEO has previously worked in the real estate industry, while the CFO has experience in business and finance. The CMO's previous internship work consisted of face-to-face marketing. *NW*'s COO has a tremendous amount of customer service skills, and the CTO has previous studies and experience in engineering and electronics. In all, the combined experiences, skills, and education will lead to great success.

Due to a low-cost structure implementation, *NW* will find $100,000 in expenses during its startup year. We are projecting to take on one project within the first year which will result in an inflow of $271,490. Due to an estimated 10% market penetration, in year five it is expected of *NW* to be valued at $89 million, in specific with sales of approximately $19 million. Neighboring Winds is seeking $400,000 from investors at the beginning of year two for approximately 10% ownership of the company.

The market turbine is tailored to power around 50% of the developments energy needs. The Aeolos-H 50 kW turbine was selected based on specifications best suited for the company's particular use pertaining to Colorado, making use of simulations performed through System Advisory Model using historical wind speed data. The key specifications of the turbine include: 3 blade rotor, 17.6 m diameter rotor, direct drive generator, aerodynamic and hydraulic braking, and the hub height options of 18, 24, and 30 meters. The market turbine varies from the test turbine because of the differences in their objectives. The Engineering team built the test turbine which was split into two sub-teams. The objective of the test turbine was to maximize energy output with the given constraints and requirements from the Collegiate Wind Competition. The test turbine contained various handmade components which included, but not limited to, the generator, blades, nacelle, and vane. Similar to the market turbine, the test turbine had 3 blades, and a direct drive generator with permanent magnets.

2. Table of Contents

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3. Business Plan

3.1 Business Overview

3.1.1 The Company and the Concept:

For decades, homeowners have not been able to gain access to renewable energy because of high up-front costs, extremely long payback periods, and most renewable applications are only viable through the utilization of grants and tax incentives. Developers have an opportunity to differentiate their residential communities through targeting a fast growing, environmentally-friendly niche. This benefits homeowners through lowering utility bills and benefits the environment through the increase in wind-powered energy usage. The advantages of wind energy permits a clean way to generate electricity, while simultaneously avoiding the harmful effects of fossil fuels that lead to environmental and economic damage.

Neighboring Winds' LLC. (*NW*) objective is to provide access to renewable energy for homeowners in new housing development communities at a competitive cost. The deployment of our product will allow consumers to take advantage of wind energy resources while increasing the value of these residential homes introduced in the housing market. This will be done by marketing our product in a way that separates the primary purchaser of the turbine from the consumers who use the energy to power their homes. Our market entry point is targeted at residential home developers who will purchase our product to supply electricity to homes within their developing community. Community residents will pay a monthly "sustainability fee" that will cover all maintenance and replacement costs over the lifetime of the project at a significantly lower rate than the amount residents save on their utility bill. Structuring our target market towards contracted developers eliminates the initial investment concerns and risks faced by individual homeowners. Moreover, developers have access to undeveloped land, which facilitates the planning phase and eliminates potential project complications. Developers stand to benefit through green community marketing as an important point of differentiation.

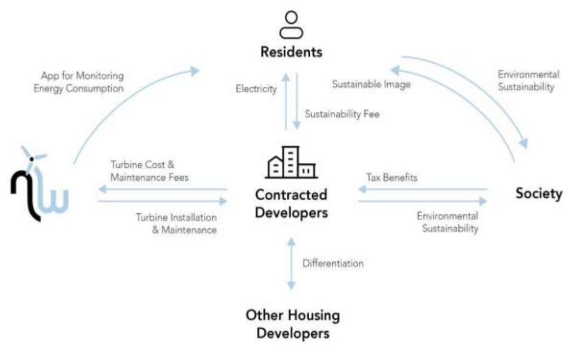

Figure 1. Neighboring Winds Company Overview

Neighboring Winds will be based out of Denver, Colorado and will begin operating in the spring of 2019. Colorado not only has reliable wind resources, but a favorable sociocultural environment for *NW* communities to expand. *NW* offers a cost-conscious and effective way for single homeowners to purchase wind energy and cover the inevitable cost of repair and replacement at the end of the turbine's lifecycle. A bottom-up approach is applied to enable home-owners access to renewable energy through housing communities. *NW* makes it possible for homeowners to supplement their traditional energy with wind energy at a competitive rate. A benefit for these communities consists of making renewable energy sustainable for the life of the community by issuing a monthly sustainability fee.

3.1.2. The Product and Service Mix:

Neighboring Winds provides a 50 kW wind turbine, along with turbine maintenance and a mobile application that will allow residents to monitor the wind energy that their home is utilizing. By offering housing developers the option to supply their residents with "green" energy prior to development, we can supply our consumer base through the developer. This bypasses the need for individual homeowners to front the capital for their own personal wind turbine and diminishes the financial burden for the user. Our strategic position in the market supplants us as a middleman between the wholesale vendor and the developer purchasing our product that we sign an exclusive contract with. A positive relationship with these two stakeholders will make it easier to generate growth beyond our initial sale of the product to individuals versus housing developments.

This unique entry point allows for smooth scalability in product deployment as we introduce hundreds of consumers to a market that relies on a single individual customer.

In addition to the initial cost of the product, the consumer will pay for the installation and maintenance services that cover product conception until eventual decommission. These additional services will be recouped in the form of an additional monthly sustainability fee. It is important to note that these homeowners will be saving on their monthly bills with this product and revenue model. The average electric costs are approximately $83.35-$146.09 for a single-family home. For example, a homeowner living in a Neighboring Winds community, that is supplementing 50% of their energy, will be able to save approximately $45 per month using wind energy after paying for *NW*'s sustainability fee.

COST-BENEFIT ANALYSIS	YEAR 1	5 YEAR SAVINGS
HOMEOWNER BENEFITS		
AVERAGE ELECTRICY EXP.	$ 1,351.08	$ 6,755.40
COST SAVING VIA TURBINE	$ 1,013.31	$ 5,066.55
TOTAL BENEFITS	**$ 1,013.31**	**$ 5,066.55**
HOMEOWNER COSTS		
MONTHLY FEE	$ 540.00	
TOTAL COSTS	**$ 540.00**	$ 2,700.00
NET BENEFIT	**$ 473.31**	**$ 2,366.55**

Figure 2. Data of home owners' cost

An additional product that Neighboring Winds will provide for the residents' community is a mobile application that provides real-time information about the turbine powering their community. This interactive component of the "green" community allows residents the ability to view the energy capacity, wind direction/speed, maintenance issues, and other elements of the wind turbine. This app will be utilizing and reporting out to the residents the same information that *NW*'s control center would already be collecting. Modern turbines have remote monitoring capabilities through the internet or GPRS which allows for around-the-clock monitoring of key turbine components, and could efficiently be synced to an app. By tracking component performance, maintenance activities can be coordinated across several turbines servicing multiple communities; service calls can be combined; and operators can take advantage of planned shutdowns to service multiple turbines simultaneously through the known machinery conditions from monitoring. These elements will contribute to efficiencies for our operation and gives the residents in the community a sight into their energy supply.

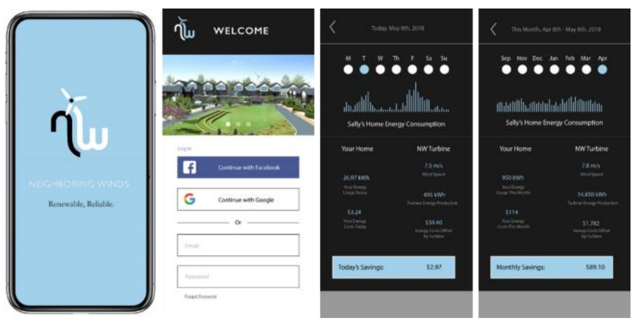

Figure 3. Image of NW Mobile Application

3.1.3. Entry, Growth & Exit Strategy:

Neighboring Winds' initial entrance into the market will be located at the headquarters of Denver, Colorado. Due to the significantly high wind resources Colorado has to offer and the favorable sociocultural environment, we intend to expand within the state, becoming familiar with Colorado while building reputation and brand awareness. After the first five years *NW* will look to either grow within the Western United States region given the wind resources in that area or sell the company due to secular shifts in the market. The expansion would be able to provide the company with the similar wind resources we started with, while diversifying our portfolio of customers and consumers. It is the company's objective to expand the business to offer accessible wind power to various commercial industries such as industrial farming, amusement parks, government buildings, schools and new business-startups. By January 2024 (end of Year 5), *NW* founders plan to exit the venture through the selling of the company to a larger wind energy corporation. This will allow the company to expand to more markets, potentially going global, while leaving the original management team with a sustainable profit.

3.2. Market Research and Analysis

3.2.1. Market Research Highlights

To fully understand the market that is being targeted by Neighboring Winds, it is important to carry out primary and secondary research on the buyers of the turbine as well as the consumers of the turbine's energy production. For primary research, the team conducted phone interviews with Colorado development companies, surveyed Colorado Real Estate Agents, and surveyed the local homeowners/homebuyers. These three segments of primary research were needed to fully understand the different stakeholders. There were multiple developers interviewed, and the results showed 43% interested in the business with most developers curious for details. Some asked about potential savings associated with less utility lines, and shared concerns for the noise as well as the siting aspect of wind turbines. The different developers believed that an associated increase of $5,000-$25,000 per home seemed reasonable, but they needed to see the results of the first project before fully buying into the concept. The surveys of Colorado Real Estate Agents received responses on behalf of 243 new homebuyers each year with an average price-point of roughly $530,000. This led to the homebuyers seeing a home worth, with an average of $12,453 more (at an average $530,000 price-point), when as little as 5% of electric cost is saved. That is a 2.35% average increase of the home's value at 5% savings, so the 50-100% savings is expected to have a much larger impact. 100 participants consisting of local homebuyers between the ages of 20 and 70 years old were surveyed to determine their current energy usage and interest in wind energy. Majority of the participants were moderately to severely concerned about their current electricity expenses, and approximately half of the participants pay more than $100 per month. 96% of participants find sustainable energy/being "green" important, and after introducing the concept of *NW* to our participants, around half responded saying they are willing to pay between $25-$50 for a sustainability HOA fee.

3.2.2. Relevant Market, Customer Overview, & Size/Trends:

The target market for Neighboring Winds comes in the form of Residential Real Estate Developers who build communities of 20+ homes. This is a targeted market since the turbine size used could power 100% of all 20+ homes. While these developers are the buyer, the homebuyers are the end-user that eventually purchase the properties within these communities. Both the buyer and consumer of the product will also be in suburban and rural environments.

According to the National Association of Home Builders, there were 41,911 building permits issued in Colorado from January 1, 2017 to December 17, 2017. The number of building permits has doubled since 2009 and is expected to rise by more than 7% each year. According to a collaboration between the U.S. Census Bureau and the U.S. Department of Housing and Urban Development, in 2017 the percentage of residential building permits that included 5 or more housing units was 32.48% of the total. By using this percentage, we estimate that the number of building permits within our market segment is equal to 13,611 communities in 2017 for Colorado. In terms of trends, if we assume that the 9% increase in Colorado's new construction permits is the average, and the United States' 2.6% decrease in 5+ unit permits is also consistent, then it is assumed that residential community developments have an average increase of 1.7% each year.

3.2.3. Buyer Behavior:

The easiest entrance for supplying wind turbines on the residential scale comes when you can supply energy to multiple houses and have some freedom to site the turbine. This makes selling to residential housing developers extremely appealing. A few things to keep in mind when developers are your first-line buyer is the importance of signing an upfront contract with them before their housing project begins. This is essential since developers need to plan for the location and infrastructure that wind turbines require. After speaking with developers there were a number of potential benefits that were seen. The first benefit came when a developer specializes in what they called "ultra-green" communities. While many developers use energy efficient materials and appliances to get tax benefits, there are others which go to the extreme with green communities. Some developers saw the benefit of gaining affordable housing tax credits due to the use of renewable energies. As it stands most of these credits are given to energy efficiency, but after speaking with CHFA, the organization that regulates these credits, it is not outside the realm of possibility for renewables to be included in the future. For those developers that do not take their communities to this degree, the different survey responses showed that homebuyers saw an increase in the value of the home which meant that they would be willing to spend 2.35% more for an identical home when 20% is saved due to renewables. Finally, different developers believed that there could be associated savings from decreased utility lines as well as faster sales periods, but could vary depending on the project and location. While the initial product is bought by the housing developer, the consumer of its benefits is the future homebuyer of those properties. Considering this, there is a service offered after the initial sale that comes in the form of maintenance and a refurbished turbine when it is needed. This offering is attractive to developers because of the opportunity that is being missed to raise the ROI of their projects, and it is attractive to homebuyers/homeowners because of the cost savings that comes from this offering.

3.2.4. Marketing Segmentation and Targeting:

While residential developers that build 5+ housing units can benefit from Neighboring Wind's turbines, as the community grows their benefits grow with it. This means that a more specific target market comes in the form of large developers. Developers who consistently build communities with at least 20 homes will be able to offer as much as 50-100% of the housing electricity needs with one turbine, which allows for a greater price increase on the homes because of the increased savings for the eventual homeowner. Due to the fact that a developer benefits more as the community they build grows, this is the ideal way to create different market segments.

Table 1. Target Market in Colorado

Priority:	Segment:	Value of 1 community Turbine Sales & Sustainability Fees:***	Estimated Target Size:	Market Potential:
1	Developers of communities with 20-49 housing units	$271,490 - $1,085,000 (sale) $1,100 - $2,695 (mo. fees)	1,361*	$369,497,890 - $1,476,685,000 (sale) $1,497,100 - $3,667,895 (mo. fees)
2	Developers of communities with 50+ housing units	$1,085,000+ (sale) $2,750+ (mo. fees)	408**	$442,680,000+ (sale) $1,122,000 (mo. fees)

*It is assumed that the portion of permits that include 20+ houses is 10% of the total 5+ living unit permits.
**It is assumed that the portion of permits that include 50+ houses is 3% of the total 5+ living unit permits.
***The monthly charge per household for communities is $45

3.2.5. Competition and Competitive Edges:

The main competition to our product/service comes in the form of substitutes rather than direct competitors. The main alternatives to Neighboring Winds is the use of natural gas generators, low cost electric (or essentially doing nothing), and the use of solar energy. By doing nothing, this gives houses access to typical electricity and is the most viable option for developers. This fails to differentiate their communities and does not allow them to market the vast advantages to their consumers. Following this option, solar energy is the closest substitute. Creating a community that utilizes solar energy to offset utility costs gives some of the same benefits that wind energy does, but land is a limited resource meaning that solar is unable to generate as much energy by minimizing that land resource. The final main substitute would be buying a natural gas generator. However, this approach fails to give the homeowner clean energy which does not provide the same identity that renewable energy gives to the developer.

3.2.6. Estimated Market Share and Sales:

As mentioned above, Neighboring Winds is differentiated because we make the developer unique in the eyes of the consumer. This product allows the developer to give themselves an identity which is seen as extremely valuable in the eyes of a homebuyer. It is for this reason that *NW* will be able to penetrate the market. The initial contract will be the most difficult because it acts as a proof of concept. As the proof becomes apparent and relationships with developers become more solidified, sales will drastically increase. Over the course of the first year, *NW* can generate one deal. After speaking with different Colorado Developers, this first deal will be the most time consuming to generate. After this first year, the yearly sales will increase with the number of salesmen the company hires. Each salesman is responsible for a different county but will work closely with each other.

3.3. Economics of the Business

3.3.1. Revenue Drivers and Profit Margins

The major revenue drivers for this business are the sale of the turbines and the monthly sustainability fee for maintenance and replacement. The turbine will be 50 kW in terms of size. The actual sale of the turbine will contribute to the majority of Neighboring Wind's total revenue in the beginning at 98.8%, while the monthly sustainability fee will contribute a larger portion of the revenues as the company progresses accounting for 66.6% of the revenue in year 5. The initial sale of the turbine has a profit margin of 45% after the purchase, installation, and commission. At the same time, the monthly sustainability fee will create substantial profits depending upon the amount of maintenance, lifetime of the turbine, and the number of homes per community. These factors influence the profit margin of the fee, making it range between 41% to 71% profit.

3.3.2. Fixed, Variable and Start-up Costs:

The variable costs for the business will consist of the turbine's purchase price ($96,140), its shipping/customs duty ($14,668.14), the turbine's installation cost ($29,000), and sales commission (5%). A 50 kW turbine is used for each project with the costs taken directly from the desired manufacturer, Aeolos. The shipping and transportation costs vary based on the location of the project, but shipping to most areas in Colorado for a 50 kW turbine is approximately $11,000. There are also fees associated with customs duty estimated at $3,668.14 from Simply Duty's import calculator. The installation of the turbine will also vary based on location and may take longer depending on different obstacles but was quoted by independent contractors. Finally, the last variable cost comes in the form of the sales commission to the employees. The main Identified fixed costs are the cost for office space, salaries, and marketing. The five-year fixed costs for the venture can be found on the income statements in the financials section. The business has very low operating leverage because of the nature of sales. The cost structure for this business is predominantly variable. Total start-up costs will be $62,780 and the detailed cost summary can be found in the table below.

Table 2. Operating Costs

Item	Cost
Application development	$50,000
Legal formation of company (insurance, license, etc…)	$6,500
Website creation	$1,000
Down payment of rent for office	$2,280
Used furniture for office	$3,000
Total initial investment	$62,780

3.3.3. Profit Durability:

The profit stream of this venture is solid because of the relationship-based sales as well as the monthly sustainability fee. As past turbine deals increase, the monthly sustainability fee becomes the largest driver of profit. Interviews with developers saw this fee as necessary to their home buyers because it gives them a type of insurance. This fee also allows the business to sustain profitability whether a deal is done or not, making it an extremely durable business model.

3.4. Marketing Plan

3.4.1. Marketing Strategy

The focus of our business will be selling our product to residential home developers. This means directing core efforts towards creating strong relationships with our customers. *NW* marketing strategies will include relationship marketing to reach the best customers for our product by utilizing sales representatives.

3.4.2. Positioning Statement/Unique Selling Proposition

Neighboring Winds has a unique business model that targets residential homeowners in a manner that has never been done before. *NW* is doing this by selling turbines to developers. Many home developers are aiming to differentiate themselves by providing green energy options to their clients. *NW* is a unique energy development system that will enable homeowners to save a significant portion of their electric bill through the generation of wind energy. This technology will allow home developers to generate more revenues through capitalizing on the trend that is renewable energy. Convincing home developers to offer renewable energy options is a win-win since this is an upgrade. *NW*'s turbines will be extremely cost effective and will allow our customers to reap outsized returns on their deployed capital. Similarly, this allows homeowners to utilize cost effective energy and hence lowers their monthly energy bills. The biggest advantage of *NW* is our sustainable business model: *NW* home owners will pay an extremely low monthly fee that will pay for any future repairs and the future replacement of the turbine at the end of its life. This ensures that *NW* communities will be powered by wind energy for the entirety of the life of the community. In the past, one of the biggest disadvantages of wind energy is the payback period for investors. *NW* has solved this problem for everyone involved: developers will be able to receive a substantial and quick return on their investment, homeowners will be able to save money from the use of wind energy, and *NW* will be able to sustain its business model through low monthly payments that will insure quality service for years to come.

3.4.3. Pricing

The pricing strategy is a convenient and market-based cost strategy that will lead the industry. New developers will be charged $278,826 per 50 kW turbine. This cost is $6,170 - $13,575 per home (compared to a $12,453 average added value, based on the 298-homebuyer survey), depending on the size of the community. This allows for Neighboring Winds to install the turbine as well as any other additional variable costs that may be incurred. After the initial cost of the turbine to the developer, the homeowners will be charged $45 per month to pay for any repairs and the eventual replacement of the turbine itself.

NW is maintaining a low monthly charge that is expected to help increase market share. The greatest thing about the sustainability fee is that *NW* will be constantly generating a steady stream of cash flows with little to no overhead. After a certain amount of years, *NW* will replace all the turbines with an upgrade to keep customers satisfied, and to stay on top of the competition. The replacement costs for new turbines is included in the monthly charge.

3.4.4. Sales Tactics

For the first year, the owners of Neighboring Winds will be the sales force conducting the sales. This is prudent since the owners will be well versed in the product and how it works. The plan is to hire only one sales representative in year one. After year one, the goal is to expand the sales force regionally which means hiring two additional salespersons in neighboring counties.

The sales management plan/strategy will be coordinated as follows: First: Sales Foundation/Planning where Neighboring Winds will be developing the product and hiring the sales reps, who will be exclusively *NW* employees. *NW* wants to hire reps with at least two years of experience in the real estate industry or industries related to the product and service. The sales representatives will be on the front line representing the company and its green energy option. These representatives are one of the most important aspects regarding company growth and will be professional and well-trained and versed in green technology. This will include becoming familiar with the company, the technology and understanding everything about the pros and cons of our product and service including local ordinances, and relevant marketing strategies.

Because of the time required to build a development, we anticipate that our sales reps will close around two developments a year. We believe that an effective strategy for the sale of our product is going to the developer and showing them how *NW* would have affected their previous developments. This gives them a unique perspective that they would not normally have, as well as showing the validity of the product in multiple situations. *NW* will also come to the developer with some areas that are believed to be primed for wind communities based on the wind resource, the legal atmosphere, and the sociocultural environment. As stated earlier, one of the biggest benefits to *NW* is the flexibility that the business plan allows. *NW* can be given potential projects and can site these places to show the potential benefits and costs of its product.

There are 3 marketing opportunities that will be taken advantage of due to the relationship-based sales:

1. 4 days a week we will host a different company's meeting. This is a conventional approach in the Real Estate market. It costs roughly $150 to cater a lunch and in return you get face-time with the company and 10 minutes to pitch yourself.
2. We will create a professional brochure that compares past developer deals to what the deal would have looked like if they used our company. We do this for 10 top prospects a month, sending 5 brochures to each, at $50 each.
3. 5 days a week we will invite someone from the different companies to coffee/lunch. This is another major marketing strategy in Real Estate and has a higher return to get that face-time and understand people's businesses.

3.4.5. Advertising and Sales Promotions

The advertising objective early on will be "Informative" because of the need to enlighten/inform the market of who *NW* is are and what they do. *NW* will switch to "Persuasive or Reminder" advertising in the later years depending on competition and maintaining customer relationships. This advertising execution strategy will be the Scientific Evidence strategy because we can give numerical and scientific evidence of the amount of money that developers can make as well as how much homeowners can save.

3.4.6. Warranty or Guarantee Policies:

One of the most unique attributes of the product is the lifetime warranty and guarantee policy. Neighboring Winds' sustainability fee will allow each development to reap the benefits of wind energy for the life of the community. It is one of the many values that is given to customers with their sustainability fee payment. This warranty and guarantee policy is not only what makes *NW* competitive in the market place, but it permits the business to sustain operations in an economic downturn. It is important to note that if a homeowner decides to move, the next homeowner will be responsible for *NW* monthly payments, and while the turbine is a part of the community, each home has a required payment in order to reap the proper benefits. Through these small monthly payments *NW* can deliver the highest quality products and services to our clients. For example, if $45 a month is collected from 20-100 houses we would receive $900 - $4,500 a month. Their core competency is delivering the highest possible quality products and services, and this low-cost leasing structure will give *NW* the ability to sustain its competencies for years to come.

3.5. Management Team

CEO: Brett Danielson will take the position of Chief Executive Officer due to his connections in the real estate industry and natural sales ability. Our CEO is responsible for strategic planning of the company and recruiting new developers to Neighboring Winds projects. It is important that our CEO has experience in the real estate industry because it is a very unique space requiring an in-depth understanding of what goes into each project.

COO: Bennett Conlin will take the position of Chief Operating Officer due to his significant sales and customer service experience. Our COO is responsible for all supplier logistics, day-to-day operations. Responsibilities will also include human resource management which is crucial in a sales relationship based company.

CMO: Jessie Richmond will assume the role of Chief Marketing Officer to oversee all of *NW*'s marketing efforts and manage the team of sales reps. She has extensive experience in face-to-face marketing through her past internships.

CFO: Lawson Evans will take the position of Chief Finance Officer due to his experience in business and finance. Our CFO is overseeing the coordination of the manufacturing companies, the financing of turbines, and the total budget of all projects. The CFO will report on current and future economic projections to accurately make decisions and keep stakeholder interest.

CTO: Neth Gardner will take the position of Chief Technical Officer due to his engineering and electronics experience. Our CTO is the primary point of contact for any turbine research and development and will make decisions on turbine size and manufacturer. Neth will coordinate directly with the home developers, discussing what turbine is viable and most efficient within the area of development. The CTO will also oversee maintenance operations.

Sales Representatives: Once developers have been identified for our projects it will be the job of sales reps to work intricately with them and our wind turbine manufacturer, monitoring quality control and maintaining exceptional customer service. Because our core competency is customer service, extensive training will be given to our sales reps. The sales reps will be acting as a CSR as well due to the minimal amount of sales they will make per year. They will also be conducting check-ups and be responsible for all customer service activities.

Board of Advisors: Neighboring Winds is entering a very complex industry that will require the strategic advice of experienced professionals to maintain the firm's' success. The following advisors are well trusted by the management team and have been associated with the company from its founding. They will serve a part-time role as senior consultants and have offered their services and expertise at no charge to the organization.

Dr. Stephen Holland, a professor at James Madison University, will serve as the Technical Strategic Advisor. Dr. Holland served as the Vice President of Research and Development for Avir Sensors, LLC. At Avir Sensors, Dr. Holland coordinated the research, product design, development, and technical aspects of product commercialization.

Roger Beale, a retired IT engineer and renewable energy enthusiast has been an external advisor to the team since our inception and will remain in this position. Roger has built his own 100 ft wind turbine in his Virginia backyard and teaches students of all ages about the battery storage and grid options of wind energy.

Dr. John Miles, a senior research associate and professor at James Madison University, will serve as the Chief Strategy Officer. Dr. Miles is the Director of the Virginia Center for Wind Energy at JMU and has significant experience in the renewable energy industry.

Dr. CK Lee, a professor at James Madison University, will serve as the Corporate Strategic Advisor. Dr. Lee brings to the team over seven years of management consultant experience and numerous degrees in Entrepreneurship. His role will be to assist in creating the vision for the firm, amending the business plan as operations continue to grow and advising for a successful exit strategy.

3.6. Development & Operations

3.6.1 Operating Model and Cycle:

Figure 3. Operation Flow Chart

Neighboring Winds is responsible for R&D on different types of turbines that would best suit our target market, whereas most of operations will be utilized by outsourcing contracts. The operation process begins by the COO and consultants coordinating with the homebuilder, alongside the HOA, to determine logistics for each development. The CFO or CEO then orders the turbine from the manufactures based on size and power output needed. Shipping ensues with coordination between Maersk and the manufacturer. The turbine is shipped directly to the home development site and installation is performed by *NW*. Maintenance checks are conducted quarterly by *NW* to ensure systems are to standard and repair any damages. Some outsourcing of minor maintenance activities may need to be done depending on the time and resources needed to travel to a site for minor maintenance. From the time of ordering the turbines to the end of installation, approximately two weeks of time to elapse.

Neighboring Winds will be partnering with Maersk Line, one of the largest shipping companies in the U.S. this allows a lower cost compared to distributing ourselves with the number of customers we have. Secondly: it is very convenient, can reach any customer, delivers quickly, and takes good care of their customer's products that they are shipping. The reason that *NW* choose Maersk is because they provide large commercial shipping containers that can accommodate the size of the turbine parts.

Potential shipping delays or issues with weather at the housing complex could increase lag time, although major delays aren't anticipated. To adjust for seasonal fluctuations, the management team needs to be in constant communication with the supplier to meet increased demand. The concern of bottlenecks takes shape in the ordering stage. Shipping delays lead to delays in the whole process, considering the process relies on receiving the turbines in a timely manner to get them to the location to begin installation. Working the delays into each project schedule alleviates the concern. Adding a week or two onto the expected completion date accounts for potential shipping delays.

In terms of quality control, installation is the biggest concern. To ensure consistency, each installer undergoes training. The training consists of going to installation sites with current employees to learn how to properly install a turbine up to our standards.

3.6.2. Operations Strategy:

The turbines will be delivered to each housing site where they will be installed, with CTO Neth Gardner leading the process. This comes after the turbines are shipped to our facility from our manufacturer. This ensures that Neighboring Winds installs the turbines exactly to the preferences and specifications of the housing complex. The relationship with the complex allows *NW* to become the most trusted installer of wind turbines for housing complexes.

Quality control measures, namely training installers thoroughly, sets Neighboring Winds apart in that the housing complexes will not have to worry about constant maintenance issues and can have peace of mind knowing that their investment is a safe one. Little to no inventory keeps *NW* flexible, while also keeping costs down. The turbines will not only fill a need for these housing complexes, but also be of the highest quality time after time. Focus on the installation and needs of the housing complexes allows *NW* to narrow down our competitive strengths and provide complexes with satisfactory experiences on a regular basis.

3.6.3. Risk Recognition and Management

NW is aware that utility companies which sell power do not have any incentive to allow these communities access to their transmission lines to provide power to the community. This could be seen as a substantial risk for our communities and results in either commission from the utility company that cuts into profits, or the establishment of extra infrastructure to distribute electricity. Fortunately, Colorado has a renewable energy standard which mandates utility companies have a percentage of total consumption come from distributed energy resources. Given that utility companies need renewable energy credits in order to meet government mandated standards, Neighboring Winds will give these credits to the utility company in exchange for access to the transmission lines.

Another risk comes in the form of what happens when the grid goes down and the turbine runs in islanding mode. To respond to this situation, when the grid is experiencing power outages the turbine will be shut off and is inoperable until the grid is back online.

3.7. Overall Schedule

To better visually depict the operational aspects of Neighboring Winds, the chart below divides the business cycle into 3 Phases: Pilot Phase, Growth Phase, and Expansion Phase. The Pilot Phase encompasses all start up activities, relationship establishment ventures, and marketing/sponsor events; luncheons, brochures, etc. This first phase also encompasses *NW*'s first sale in Boulder County Colorado and the components of operation within, as displayed in yellow. *NW* first enters Boulder County because of its proximity to the city of Denver and extensive visibility at 294,567 residents, as well as the fact that its residents are generally middle-upper class income. Moving into the Growth Phase entails the entrance into Denver and Colorado Springs in the Expansion Phase, which both have great wind resources and population density. The last step of the Expansion Phase is to continue growth throughout 20 additional counties in Colorado based on their population density, including; Arapahoe County, Jefferson County, Adams County, El Paso County, Weld County, Pueblo County, Mesa County, Larimer County, Douglas County and other counties.

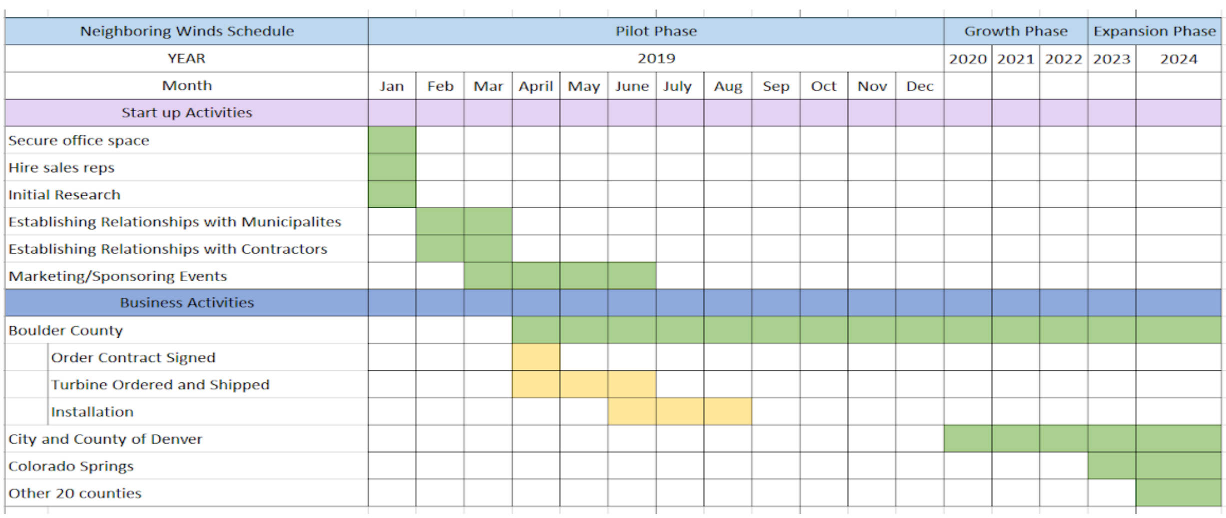

Figure 4 Neighboring Winds Schedule

3.8. Financial Plan and Proposed Company Offering

Neighboring Winds financial plan consists of a low-cost structure only accruing around $100,000 in expenses the first year for startup. The reason for this is because *NW* doesn't have to retain inventory or deal with many fixed costs, other than salaries, rent, and other general administrative expenses. In the first year, we only expect to take on one project due to experience with connections and reputation. This may seem off putting however, with a selling price of $278,826, revenue ($282,126) will be more than enough to make a positive profit in the first year. The sales structure is set up based on an estimated market penetration rate, so that during year 5 we will have done 25 projects (10% of the market) summing to $19.5 million in revenue with a profit of $6 million. The company will also remain cash flow positive throughout the first 5 years of operations with only the help of roughly $200,000 in common stock and no long-term debt. This will allow *NW* to have the ability for investment and financing for future growth.

Table 3. Five-year income statement plan

5 Year Income Statement					
Years	**Yr 1**	**Yr 2**	**Yr 3**	**Yr 4**	**Yr 5**
Sales (a)	$282,126	$1,457,491	$3,545,163	$7,616,911	$19,503,221
COS	141,349	734,243	1,839,773	4,108,485	10,841,934
Gross margin	**140,777**	**723,249**	**1,705,390**	**3,508,426**	**8,661,287**
Expenses:					
Commissions	13,941	69,707	139,413	209,689	348,533
Utilities/phone	556	556	2,166	2,166	2,166
Salaries	36,000	108,000	216,000	360,000	540,000
Rent	13,680	13,680	60,000	60,000	60,000
Marketing	39,600	118,800	237,600	396,000	594,000
Total expenses	103,777	310,743	655,179	1,027,855	1,544,699
Income Before Tax	36,999	412,506	1,050,210	2,480,571	7,116,588
Income Tax	11,165	61,876	157,532	372,086	1,067,488
Net income (loss)	**$ 25,835**	**$ 350,630**	**$ 892,679**	**$ 2,108,486**	**$ 6,049,100**

Table 4. Five-year Cash Flow statement plan

5 Year CF Statement					
	Yr1	**Yr 2**	**Yr 3**	**Yr4**	**Yr5**
Net income (loss)	**$ 25,835**	**$ 350,630**	**$ 892,679**	**$ 2,108,486**	**$ 6,049,100**
(Inc) Dec in receivables	(660)	(120,798)	(173,973)	(339,312)	(990,526)
(Inc) Dec in inventory	(141,349)	(165,279)	(378,119)	(1,122,242)	(3,537,524)
Inc (Dec) in payables	1,549	151,765	189,059	561,121	1,768,762
Cash from (used) in operations	**(114,626)**	**216,319**	**529,647**	**1,208,053**	**3,289,812**
Financing sources:					
Personally Invested Capital	200,000				
Partner Invested Capital	0	400,000			
Cash from Financing activities	**200,000**	**400,000**	**-**	**-**	**-**
Total source (use) of cash	85,374	616,319	529,647	1,208,053	3,289,812
Beginning cash	-	85,374	701,693	1,231,340	2,439,392
Ending cash	**$ 85,374**	**$ 701,693**	**$ 1,231,340**	**$ 2,439,392**	**$ 5,729,204**

Table 5. Five-year Balance Sheet statement plan

5 Year BS Statement					
	Yr 1	Yr 2	Yr 3	Yr4	Yr5
Cash	$ 85,374	$ 701,693	$ 1,231,340	$ 2,439,392	$ 5,729,204
Accounts receivable	660	121,458	295,430	634,743	1,625,268
Inventory	141,349	306,629	684,747	1,806,989	5,344,513
Total Assets	**$ 227,384**	**$ 1,129,779**	**$ 2,211,518**	**$ 4,881,124**	**$ 12,698,986**
Accounts payable	$ 1,549	$ 153,314	$ 342,374	$ 903,494	$ 2,672,257
Owner Equity	200,000	600,000	600,000	600,000	600,000
Retained earnings (deficit)	25,835	376,465	1,269,144	3,377,630	9,426,729
Total liabilities and equity	$ 227,384	$ 1,129,779	$ 2,211,518	$ 4,881,124	$ 12,698,986

At startup, we are asking for $400,000 from a venture capital for approximately 10% share. This startup capital will be utilized until we reach Series A and can tap into venture capital funding. Neighboring Wind's exit strategy is planned to be carried out after year five via sale of the LLC. Projected sales in year five are approximately $76 million. With sales of this magnitude and the payments we receive from prior contracts/sales, this is a strong time to sell. The purchasing members or company will incur all payments from HOAs and prior contracts, as well as relationships with the general contractors. With that being said, this adds to the valuation of the company. At the time of exit *NW* is valued at $89 million. This high valuation will result in $8.9 million being paid out to the original investors.

4. Technical Design

4.1.1. Market Turbine Objectives

4.1.2. Identifying the Need

Environmentally conscious homeowners considering the adoption of renewable energy systems, especially wind energy as a product of proximity to high wind regimes, encounter considerable initial investment concerns inherent to wind energy project completion. Having to pay large upfront costs to install renewable systems detracts proprietors from possible opportunities involving wind energy. The significant capital necessary for wind turbine acquisition and installation is alleviated through distributed wind energy generation, Neighboring Winds manages by way of developer contracted proxy to administer clean power to new communities. Currently, there are limited options for homeowners to move into residences with renewables offsetting some or all of their energy expenditure.

4.1.3. The Solution

Neighboring Winds offers a convenient way for homeowners to utilize wind energy without considerable upfront costs and complications that come with installation and selling. In partnering with developers, Neighboring Winds provides communities with grid connected wind turbines that supply a portion of power demands to residents. Our monthly "sustainability fee" allows residents to reap the benefits of clean energy, while avoiding large initial investment concerns associated with wind turbine installation. This fee also covers maintenance and eventual replacement of the products we are providing at the end of their 20-year design life. Sustainability fees come complementary to amenities provided by the community such as swimming pools and playgrounds, the wind turbines are similarly an added amenity to the community.

4.2. Market Turbine

4.2.1. Constraints and Requirements of our Turbine

Wind turbines will be established within the boundaries of our neighborhood and as a result, land must be allotted within these confines to accommodate the towers before development. The hub height will be adjusted according to clearance needed for project completion, with market turbine hub heights varying between 12 to 30 meters tall. County zoning with regards to tower height will be taken into consideration on a case-by-case basis. This variable tower height is dependent on local laws and regulations, with conventional regulatory frameworks mandating a 1:1 ratio between total height and nearest standing structure. Higher wind classes as well as a more stable wind resource are typical of higher altitudes, making increased hub heights optimal for larger communities. The proposed market turbine presents scalability opportunities necessary for distributed electricity generation, while also meeting optimal design standards intended for silent and reliable electricity generation adjacent to residential homeowners. During neighborhood development, Neighboring Winds will assess the sites and install wind turbines in areas with the most reliable wind resources available on a case-by-case basis in collaboration with developers. Turbine installation procedures are expected to be resolved prior to residential move-in deadlines, so that fully operational systems are active before residents move into their homes. Neighboring Winds uses a horizontal axis three blade rotor system with a 50 kW generating capacity, and size decisions are made depending on the requirements of the neighborhood. The size of the generator and number of turbines are also associated with the amount of energy consumed by neighborhood residents.

4.2.2. Market Turbine Technical Specifications

Neighboring Winds outsources the manufacturing of wind turbines from Aeolos. The Aeolos-H 50 kW offers excellent power generation, even in low wind speed environments, capable of functioning at a cut-in-speed as low as 3 m/s. The rated wind speed is 10 m/s with a rated rotor speed of 80 rpm. The turbine has an estimated lifespan of 20 years. The overall weight of this turbine is 3,700 kg. The rotor is 17.6 m in diameter, which gives the rotor a swept area of 243.2m^2. The gearless direct drive generator has an estimated 95% efficiency and alleviates various operational and maintenance concerns through the application of permanent generator magnets, as opposed to coil driven designs. The turbine employs a mechanical pitch control system that alters the degree angle of the blades to ensure exceptional power production in low wind regimes. The pitch control system also stabilizes the power output in higher wind speeds, as well as protecting the turbine in extreme wind speeds by feathering the blades. The active yaw control system allows the turbine to trace wind direction and alter the nacelles orientation upwind, thereby maximizing performance. The active yaw system will also turn the rotor out of the wind to prevent damage from extreme wind speeds. In the case of either of these systems failing, the turbine is equipped with a two-spindle hydraulic brake as well as an electrodynamic braking circuit to stop the turbine during emergencies. The auto grease lubricator keeps bearings within the nacelle lubricated, offsetting the possibility of mechanical failure and deterring the necessity for routine maintenance. The hub and the nacelle are molded using a material with high tensile strength, called EN-GJS-400-LT, the same material utilized in megawatt scale wind turbines. There are several tower options available from our manufacturer, including a 12, 18, 24 or 30m monopole as well as an 18 or 24m hydraulic tower. The low noise profile achieved through fiberglass blade design mitigates many consumer concerns without significantly impacting overall performance. The Aeolos-H 50 kW turbine is rated at 55 dBA noise output from 40m, roughly the sound of a humming refrigerator at clearance distance from residential homes pertaining to our market entry point in Colorado. During the deployment process, turbines are installed as far from homes as possible to curtail community noise disturbance.

4.3. Test Turbine

The ideal turbine varies based on the intended purpose and performance objectives. The market turbine and the test turbine have similar subsystems, including a generator, blades, yaw, and power conversion electronics. The test turbines deviations from the market turbine are due to the objectives of the turbines. The test turbine's design decisions were driven by the objectives to produce maximum power between 5 m/s and 11m/s wind speeds, regulate the power produced to meet the specifications the components used, safety, durability, and the constraints set by the competition rules. During the process of designing and building the test turbine, the biggest constraint the JMU Collegiate Wind Competition (CWC) team faced was time. Although JMU competed in the 2014 CWC event, the competition requirements have changed significantly since then. The majority of the subsystems of the turbine had to be redesigned. Thanks to financial support from the JMU colleges of Business, Engineering, and ISAT, as well as external sponsors such as anonymous donors and the Department of Energy, funding has not been a major concern in subsystem redesign as prototype iterations are produced. Contextualization processes such as benchmarking, qualitative modeling, stakeholder interviews, literature review, and reviewing codes and standards were used to understand the objective, constraints, the inputs, outputs, and transformations of the system. After the system was well understood, concept generations methods such as directed search, TRIZ, and design by analogy were used to inspire creativity and to generate a broad spectrum of concepts. Absolute criteria and analytical decision-making tools were applied to narrow down to the final decision

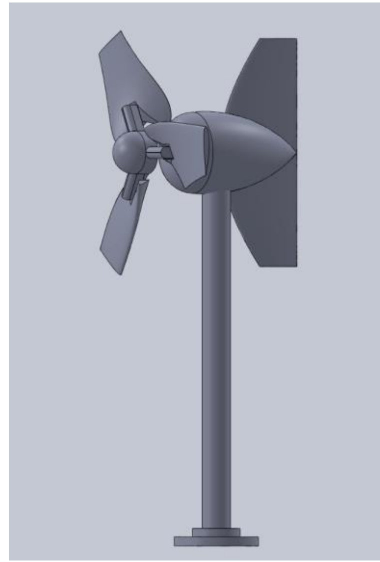

Figure 5 Test Turbine

4.3.1. Blades

The blades are the subsystem of the wind turbine that convert linear kinetic energy from the wind into rotational mechanical energy that spins the generator to produce electricity. A horizontal axis turbine design decision was made in place of vertical axis designs due to higher achievable tip speed ratio(TSR). To meet generator RPM and torque requirements, iterations were made until a blade was constructed with a low Reynolds number, TSR of 4, high lift to drag ratio, and a 20% increase in power output compared to production at the generators rated RPM. A single NACA 2413 airfoil was selected for blade design over ten different identified alternatives. Numerous blade element momentum (BEM) theory simulations were performed using QBlade, an open source wind turbine blade modelling package. A three blade 0.45 m rotor with blades attached to a 2-inch hub were selected in order to maximize the swept area of the blades while maintaining a hub size similar to the dimensional requirements of the 4 inch diameter generator.

Figure 6 Final Blade Design

The Markforged Mark 2 printer was chosen because it provides the capability to print using nylon reinforced carbon fiber material. This material has high tensile strength and is light weight making it a suitable material selection for the blades. Further, the printer provides precise, smooth prints which is essential for wind turbine blades. The theoretical performance of the final blade design is shown in the figures below.

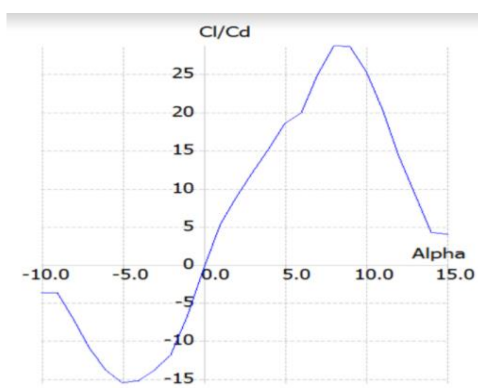

Figure 7 $C1/C_d$ Alpha

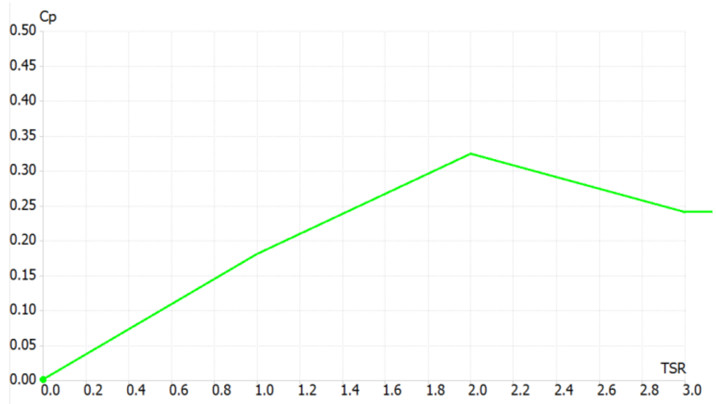

Figure 8 Cp vs TSR

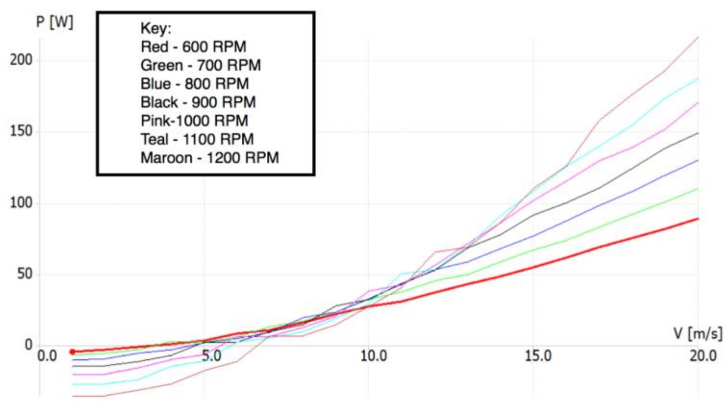

Figure 9 Power vs Wind Speed at Various RPM

4.3.2. Generator

The first step in the design was selecting the generator type. An axial flux permanent magnet generator was chosen because it's low cogging torque is appropriate for micro-turbine application. For an axial flux generator, the rotors are flat disks of magnets rotating on both sides of a flat stator of coils. The generator was designed to be wired to three-phase with a magnet-to-coil ratio of 4:3 for each phase. The three phase is wired in star configuration so that at lower RPMs of the generator the voltage output is higher which allows for the Arduino to power on earlier to monitor and control.

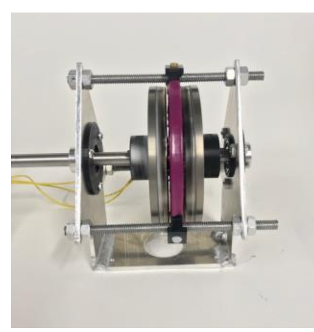

Figure 10 Generator Design

4.3.2.1. Rotor Design

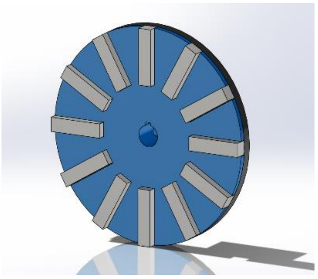

Figure 11 Isometric View of Rotor

Blue: plastic
Grey: agents
Black: cast Iron

Neodymium magnets were chosen because they are the strongest permanent magnets available. During the early stage, circular D82-N52 magnets and rectangular BX044-N52 magnets were considered based on the chosen generator size. When comparing the magnets, the rectangular BX044-52 magnets are better suited to maximize area of the coils. An iron plate backing was added behind the magnets to increase the magnetic flux. Since a design objective was to minimize the required torque for the system to rotate, the amount of iron backing was minimized while making sure that the magnetic flux density did not decrease. Since the only iron backing needed was directly behind the magnets, the remaining area of the rotor was replaced with 3D printed ABS plastic material as can be seen in Figure _. Additionally, the iron plate thickness was reduced to 3/16" from the previous ¼". This reduction in thickness showed no apparent decrease in magnetic flux.

4.3.2.2. Stator Design

Several factors were taken into consideration during the stator design process, such as wire material composition, number of turns per coil, coil area, and stator thickness. Calculations using Excel were executed to identify the ideal coil gauge and number of turns per coil within the stator. Through these calculations, a 28-gauge wire with 300 turns per coil was selected. To maximize the available area, each coil was hand wound into a teardrop shape. The stator thickness controls the gap between rotors and greatly affects power production as a result. To reduce the stator thickness, coils were compressed and molded using fiberglass resin which can be seen in Figure _.

Figure 12 Stator Mold

4.3.2.3. Generator Prototypes

The power output performance for each generator prototyped can be seen in Table _. All tests were done using a handheld drill and the RPM was measured with a tachometer. The voltage and current output was measured using a digital multimeter.

Table 6. Generator Prototypes

Prototype	Magnet	# of Magnets	# of Coils	Wire Gauge	# of Turns per Coil	Testing RPM	Voltage (Volts)	Current (Amps)	Power (Watts)
1	D82-N52	12	9	26	200	1414	22.68	0.24	5.11
2	D82-N52	12	9	28	250	1055	13.71	1.02	13.96
	BX044-N52	12	9	28	250	1048	15.61	1.01	15.69
3	BX044-N52	12	9	28	300	1280	40.22	1.27	51.08
4	BX044-N52	12	9	28	300	1260	47.98	1.47	70.53

4.3.3. Structural Design

The frame containing nacelle components was constructed with the intention of being strong, lightweight, easily adjustable, and nonmagnetic. The design features two vertical aluminum plates made to support a roller bearing, the drive shaft, and three additional aluminum rods. The purpose of the three aluminum rods is to hold the stator at a fixed position. The structure can be seen on Figure X.

4.3.3.1. Yaw

Unlike the market turbine, the test turbine utilizes passive yaw to maintain its orientation into the wind. The passive yaw system is comprised of an inner and outer aluminum tube, two roller bearings, base plate, and a nacelle connector plate. The passive tower was machined and welded at JMU. The protective rubber caps were removed from the bearings to decrease friction and increase sensitivity. Yaw movement results from 3D printed ABS plastic wind vane on the downwind side

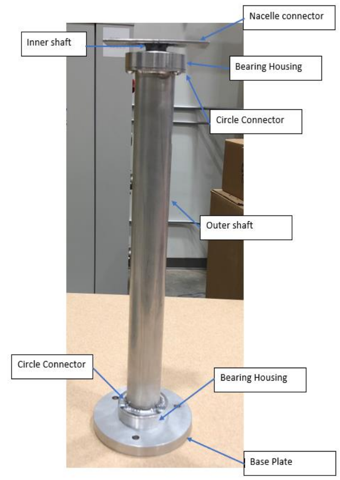

Figure 13 Yaw Design

4.3.4. Power Regulation & Control Systems

The power regulation system is comprised of a three-phase rectifier, DC-DC converters, and the load. Three phase AC from the generator is rectified to DC using a Schottky diode rectifier. The power regulation system converts this DC power into forms necessary to power electronics and control turbine output within constraints set by the CWC competition rules. The control system utilizes an Arduino Mega microcontroller system to control the braking, sense generator RPM, current, and voltage, and control the behavior of the turbine for its safety, durability, and power optimization.

4.3.4.1. Engineering Schematics

The electrical schematic in Figure 14 illustrates the power regulation and control systems. The relays allow for switching as the demand of the task varies. The load and the 5VDC regulators are attached to the same relay. The load is attached to the normally closed side and the 5VDC regulators for the durability task on the normally open side so that switching is simple following the safety tasks. With a simple signal to the Arduino Mega, the turbine can switch from normal operation to the durability task which requires a 5VDC to the competition load. The nacelle houses the generator and RPM sensor. All wires from the generator pass through the center of the yaw system with slip ring with flange, allowing the turbine to yaw without damage to the wires. Everything besides, the load, generator, RPM sensor, and the capacitive energy is housed in a NEMA box.

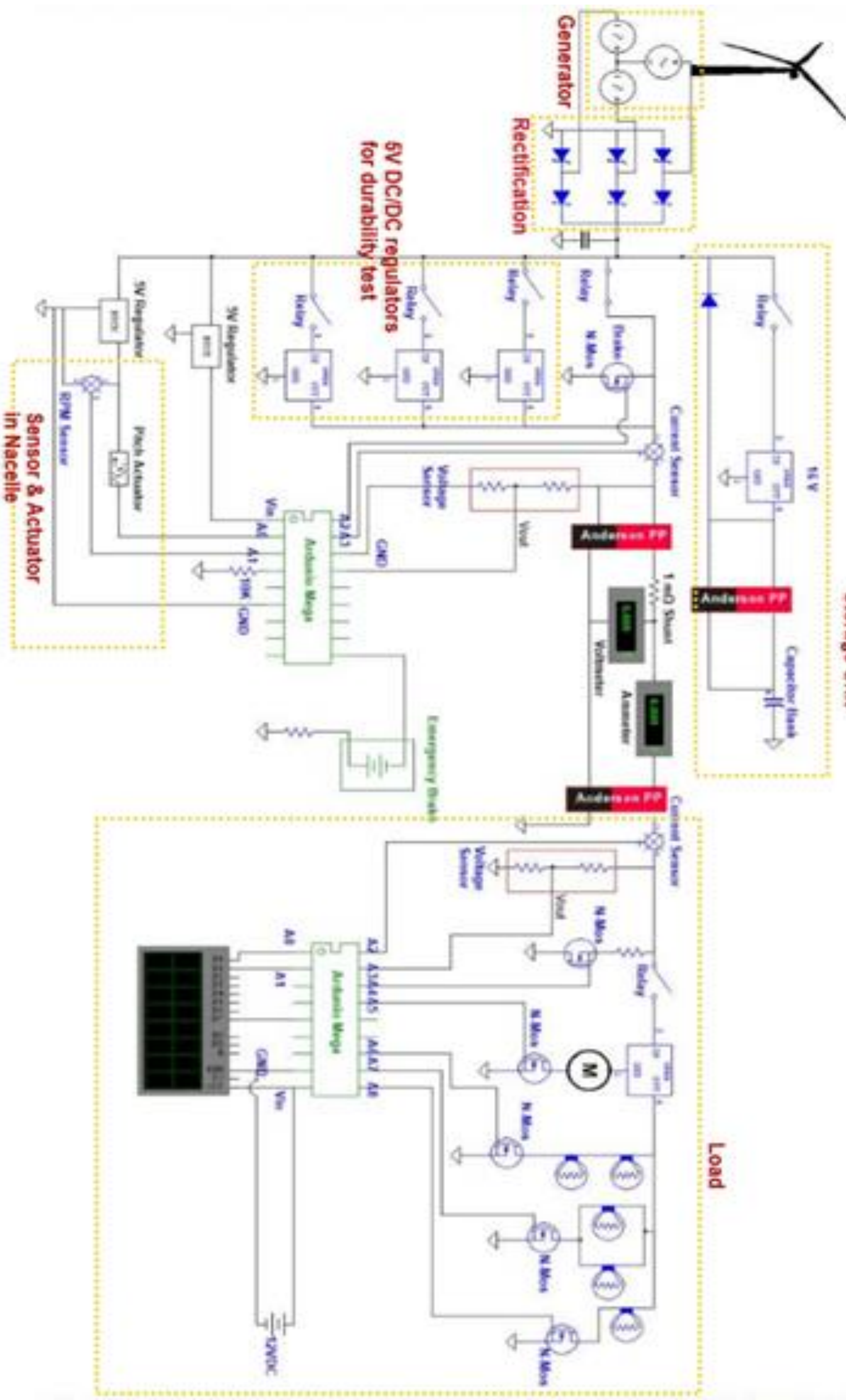

Figure 14 Electric System Diagram

4.3.4.2. AC/DC Rectification

Since the output from the generator is in three phased Alternating Current, it is then converted to Direct Current by a rectification circuit to meet the CWC competition requirement and provide usable energy to run the system. A three-phase rectifier was built using Ideal Bridge Diodes chips (LT4320-1) and N-MOSFETS for the purpose of maximizing efficiency. This circuitry board achieved a 97% efficiency due to the voltage drop of 20 mili-volts across a N-MOS, meanwhile a silicon diode has a voltage drop of 0.7 V. When choosing a power rectifier diode, it is important to select the most efficient design with a low voltage drop. However, after testing the LT4320-1, the circuit board failed due to its high sensitivity and ability to damage easily due to an excessive supply of voltage. At the end stages of the design process, a generator capable of producing 79 watts was designed and the Ideal Bridge Diode board cannot handle over 48 volts. Therefore, the backup option of using Schottky diode was selected to proceed into the final design. Although the Schottky diode rectifier is 89% efficient, this subsystem is best able to operate with the overall system.

4.3.4.3. Voltage Regulation

After the power is rectified to DC, the voltage must be regulated to the correct voltage for the Arduino Mega and RPM sensor, voltage sensor, current sensor, and the capacitor bank. The generator built currently is producing approximately 42V at the load this far exceeds the limits of the components and must be regulator for the load during the durability test. The Arduino Mega powered by a 5V low dropout(LDO) voltage regulator powers the voltage and current sensor, relays, and MOSFET. The RPM sensor and the linear actuator are powered from another 5V LDO regulator because during pitching the linear actuator draws a significant amount of current that it must be powered from a separate LDO. Since both the linear actuator and the RPM sensor are housed in the nacelle both and the RPM sensor draws a negligible amount of current, both are powered from the same 5V LDO. 16V LDO is also used to maintain the required voltage to charge the capacitor bank provided. The LDO were used for these components because of the low voltage dropout and minimal effect on the startup of the generator. However, they have an 85% efficiency which is a significant amount of power lose when considering a high amount of power is called for as in the load for the durability.

During the durability testing the output voltage to the provided load must be as close to 5V as possible. Because the generator can potentially produce 45V, three LT8073 switching regulators are used in parallel. Each rated for continuous at 5V and 3.5A will be used to divide the current and maintain the voltage output at 5V. The LT8073 through testing showed an efficiency of 91% which was why great efforts were made to make it work. The first challenge faced with these regulators is that the apparent resistance of each regulator to the generator is very low; this loads down the generator as if the brake is applied. When all three are placed in parallel this further increases the load applied to the generator. Through testing it was seen that the apparent resistance of the switching regulator varies as the input voltage varies. At very low input voltages the apparent resistance of the three regulators in parallel was less than 1 Ohm. At low wind speeds this caused the generator to barely turn. To prevent this from happening, relays are set in in series with each of the switching regulators. This will allow the generator to pick up momentum and build up voltage at which point the relays can be closed to allow voltage to the switching regulators because the input voltage is higher it will have a large apparent load. The regulators will be turned on by the relays as the current drawn by the load exceeds the limits of the regulators to divide the current.

4.3.3.4. Load

Currently, a load is being worked on that will be used to support the business plan by having a visual representation of what a community with Neighboring Winds turbine would look like. The model community is powered by the test turbine. Because the load affects the performance of the generator, an Arduino is placed on the load side to vary the apparent load as well as a voltage and current sensor to adjust the apparent load to optimize the power output through the PCC. The voltage output to the load is stepped down to power the light bulbs and the motor which serves as the resistive load. The Arduino Uno is powered externally as well as a display screen which will display the current power output. The load is increased and decreased by turning on or off lights as needed through a MOSFET. The first thing to be powered is a small DC motor which will look like a small wind turbine that powers on the community.

4.3.5. Control System

On the turbine, the control system monitors and controls the performance of the turbine through sensing and processing the voltage, current, and RPM. Feedback loop is used to continuous adjust the load and brake. Voltage division with large resistors is used to sense the voltage. The brain of the system is an Arduino Mega which process the voltage output, current output, and RPM. The voltage division is used to ensure that the voltage input into the Arduino Mega does not exceed the 5VDC input limit into the Arduino pins. Large resistors are used to reduce the amount of power dissipated.

4.3.5.1 Braking

The ability of braking is critical for a turbine's safety. Braking is achieved through electrodynamic braking by shorting the generator on the DC side of the power. The Arduino Mega sends pulse width modulated signal to the gate of a MOSFET which shorts the generator producing a high back EMF. The Arduino varies the applied brakes by varying the duty cycle as needed. This insures that the rated RPM and power are not exceeded. The voltage output is regulated through braking because the voltage output is a function of the RPM of the generator which allows for the voltage output to be regulated by the braking system to ensure the voltage output does not exceed the 48VDC. Electrodynamic braking was chosen because it has no mechanical moving parts. Rated for 30A, 60V, and rated for 5V logic level the RFP30N06LE NMOS is used for braking. This gives a safety factor of 1.5 for voltage and a safety factor of 30 for the current rating.

4.3.5.2. Maximum Power Point Tracking

Maximum power point tracking is achieved through a feedback loop by varying the load and measuring the power output. To achieve maximum power point tracking, information gained from the power curve is used to vary the load up and down and the power measured until maximum power is achieved.

4.3.6. Testing Tasks

The test turbine was designed to perform well for the scoring matrix set by DoE. To achieve low cut-wind speeds, the load applied is set at a low load to minimize the current back to the generator to reduce the back EMF. For MPPT, feedback loop is utilized that will achieve maximum power as the wind speed varies by varying the apparent load to the generator. The safety task is achieved by constantly monitoring the current output to the load. So that when the load is disconnected, the Arduino Mega reads zero current and an RPM greater than 10% of the rated RPM at which point the brakes are applied until the RPM of the generator are under 10% of the rated RPM. This shutdown process still keeps the Arduino powered on to monitor the system. For the emergency braking a 5V signal is connected to the emergency brake signal which switches the signal from high to low. This signals for the Arduino to apply the brakes. The turbine is able to achieve the durability task through three parallel 5VDC 3A switching regulators, a responsive yaw, and an effective wind vane. These with the aid of the capacitor bank that allows for the turbine to successfully withstand the stresses of the durability test. The storage unit allows for dumping and drawing power as needed.

4.3.7. Pitch Control

The pitch system was first investigated by benchmarking the designs and decisions made in past competitions as well as research done in scholarly articles. At first, several designs were developed using SolidWorks and were 3D printed to look at their functionality. After seeing too many degrees of freedom within the designs, a decision was made to explore small scale rotor head designs that are already being manufactured for different applications. After narrowing down the search, the "TREX 550 Rotor Head" from the company Align was selected as the chosen pitch system to be integrated into the test turbine. This rotor head is traditionally manufactured from Align to integrate into a small RC helicopter. One aspect that had to be adapted in that rotor head was a swashplate that allowed the three blades to pitch at different angles. Since the test turbine needed to have all three blades pitch to the same angle, an adapter was made in SolidWorks to be 3D printed and combined with a rotary and linear bushing to connect to the swashplate and prevent it from pitching the blades unequally. To move the 3D printed swashplate, a linear actuator was chosen and assimilated with the calculated dynamic thrust. Unfortunately, the weight of the pitch system started compromising the potential of the power produced from the generator. Through testing, it was decided to remove the variable pitch subsystem from the test turbine in order to remove the weight from the driveshaft, thus bringing the power of the generator back to its full potential.

4.3.8. Testing Data

Due to lack of a wind tunnel that can occupy the full-size test wind turbine, the data collected for the power curve, cut-in, maximum power, and rated RPM do not accurately represent the full size turbine. For testing in the wind tunnel at JMU, the blades were made to be 6 cm shorter than the actual 45cm just to fit the blades. However, the system was tested regularly to make improvements. The response of the braking system was able to be tested at several wind speeds and RPM of the generator. The maximum power point tracking ability of the turbine was also tested by varying the input wind speed and allowing the Arduino to vary the load to search for max power through feedback loop. The cut-in wind speed was improved through modification in the air gap of the magnets. The safety and the durability of the turbine was able to be tested. From testing, the final cut-in wind speed was established to be 2 m/s. With the smaller rotor diameter, a power curve was developed with a max rated power output of 50 watts.

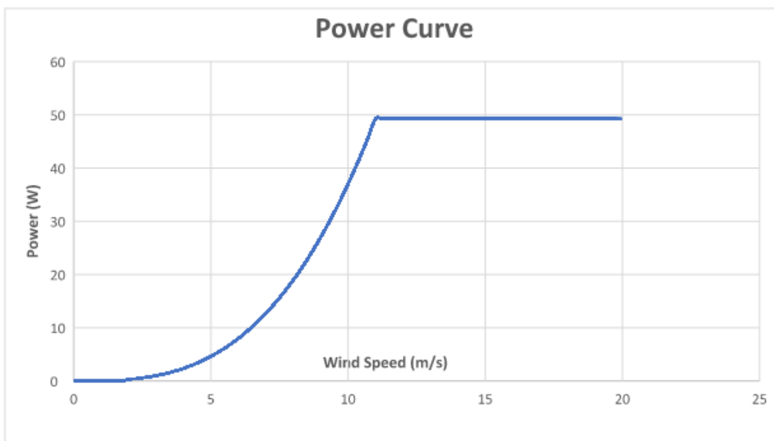

Figure 15 Power Curve

4.4. Justification of Differences

The market turbine is designed to power many homes whereas the test turbine designed to perform well in the tests being conducted in the wind tunnel. Because of this, the market turbine will deviate from the test turbine. The elements with major deviations include the yaw system, pitch control, rotor diameter, braking system, and blade materials. The market turbine has an active yaw system to track the wind direction in order for the turbine to align with the wind precisely, which ensures maximized power output. While the test turbine utilizes a passive yaw system due to its simplicity, the power demands of an active yaw system, and time constraints. The market turbine has an active pitch control to optimize the blade angles to achieve power output at lower wind speeds. After prototyping three unsuccessful pitching methods, it was finalized that a fixed pitch would be used for the test turbine. The market turbine has a 17.6 m rotor diameter to acquire the maximized desired output of 50 kW. The largest rotor diameter possible for the competition was chosen for the test turbine (0.45 m) to maximize the turbine's power and torque capability. Mechanical braking causes consistent fatigue on turbine components, which altered the design decision toward employing an electrodynamic braking system in the test turbine. The market turbine utilizes a combination of aerodynamic and mechanical braking. The primary braking system applied by the market turbine is done aerodynamically through active pitch control and active yaw systems. The secondary braking system of the market turbine is a mechanical braking system employing hydraulic brakes. Since the test turbine has a passive yaw system without the capability of furling and the blades are fixed, aerodynamic braking cannot be achieved. An electrodynamic braking system was selected for the test turbine due to fewer moving parts and precision in the amount of braking applied to the system. Material discrepancy is a significant difference in blade composition between test and market turbines. The test turbine blades are composed of nylon reinforced carbon fiber. This material selection was made based on its high tensile strength, light weight, and ease in accessibility to 3D print continued design iterations as necessary. The market turbine blades are configured with fiberglass, a rigid material that offers structural strength as well as being a cost-effective alternative to carbon fiber blade compositions that lead the industry in blade construction.

Table 7: Compares the specifications of the market turbine and the test turbine

	Market Turbine	Test Turbine
Power	50 kW	4.2 W
Cut-In Wind Speed	3 m/s	2.5 m/s
Rated Wind Speed	10 m/s	11 m/s
Rated Rotor Angular Frequency	80 RPM	1200 RPM
Weight	3700 kg	
Rotor Diameter	17.6 m	0.45 m
Generator Transmission	Direct Drive	Direct Drive
Magnet: Coil Ratio	4:3	4:3
Pitch Control	Active	Fixed
Yaw System	Active	Passive
Braking System	Electrodynamic & Hydraulic Braking	Electrodynamic
Monopole Tower Height	12 m, 18 m, 24 m, 30 m	-
Hydraulic Tower	24 m, 30 m	-
Hub & Nacelle Material	EN-GJS-400-LT	-

5. Conclusion

For the business plan, this venture will be successful because of how it responds to the difficulties of wind energy at the household level, the primary market research supporting its assumptions, the proven marketing plan, as well as the strong financial model. To begin, while wind energy has been difficult at the household level due to the high investment and long payback period, selling the initial turbine to developers allows for the investment to be minimized across multiple homes while recouping the investment with the initial sale of the home. Secondly, the assumption that this plan is viable in the market is also backed by credible market research. Roughly 20% of developers said that they would be interested in this model and believed it could increase the value of their community. The surveys of Colorado Real Estate Agents also received responses on behalf of 243 new homebuyers each year with an average price-point of roughly $530,000. These responses showed that homebuyers seeing a home worth with an average of $12,453 more (at an average $530,000 price-point) when as little as 5% of the electric is saved. That is an 2.35% average increase of the home's value at 5% savings, so the 50-100% savings is expected to have a much larger impact. The relationship marketing plan, customized for Neighboring Winds, has found a tremendous amount of success in the Real Estate industry and has become the standard. Finally, creating a financial model that is supported by ongoing sustainability fees, rather than just a one-time sale, allows for significant profit margins with less risk as more deals are done.

6. References

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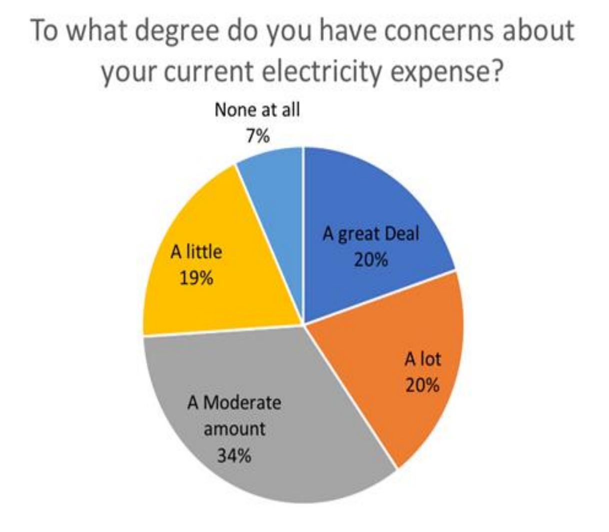
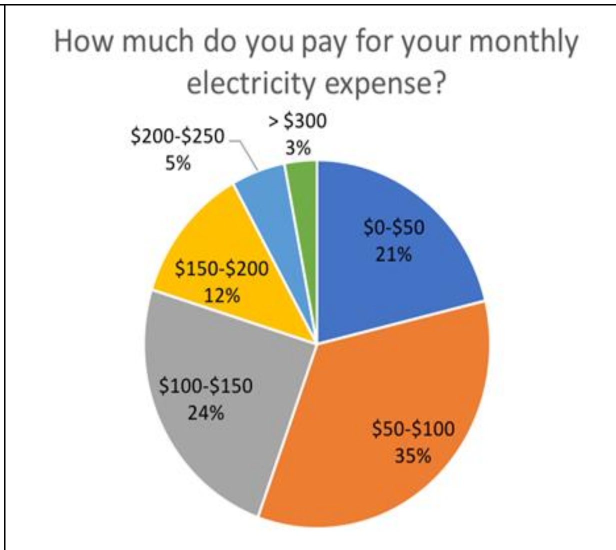
7. Appendices

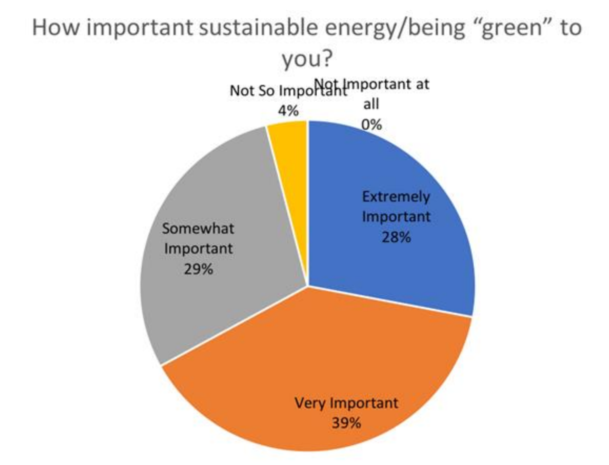
[Appendix 1: The interview list of Housing Development Companies]

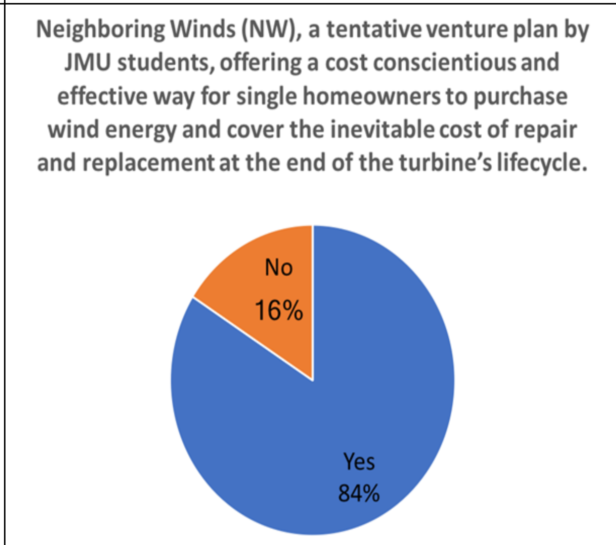
Housing Development Companies Interviewed			
AEA Enterprise LLC	Reliance Builders of Colorado	Colorado Association of Home Builders	Koelbel & Co
Anthem Colorado	Richmond American Homes	Confluent Development LLC	L C Fulenwider Inc
Arlington Designer Home Construction	Saddletree Homes	Continuum Partners LLC	McWhinny
Beckett Development	Sage Brush Companies	Copperleaf Homes	Mile High Development
Brookfield Residential Colorado	Shea Homes Colorado Division	Craddock Columbine Realty Co	Nor'wood Development Group
Bush Development	Tebo Development	Cushman & Wakefield Colorado	Oakwood Home Colorado
C-M-H Developers Inc	Thrive Home Builders	Enterprise Community Partners Inc.	Olive Real Estate Group Inc
Campbell Homes	Toll Brothers Colorado	Gibraltar Companies	Inland Pacific Colorado
Casa Verde Commons	University Village Developers	Gold Fill Mesa	Western Development Group
Central Colorado Builders Inc	Vintage Co	Home Builders Association of Metro Denver	Classic Homes

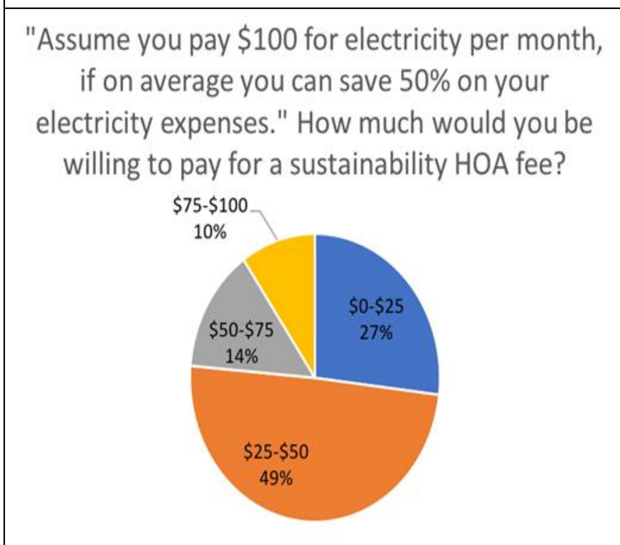
[Appendix 2: Survey Result for Potential Home Buyers]

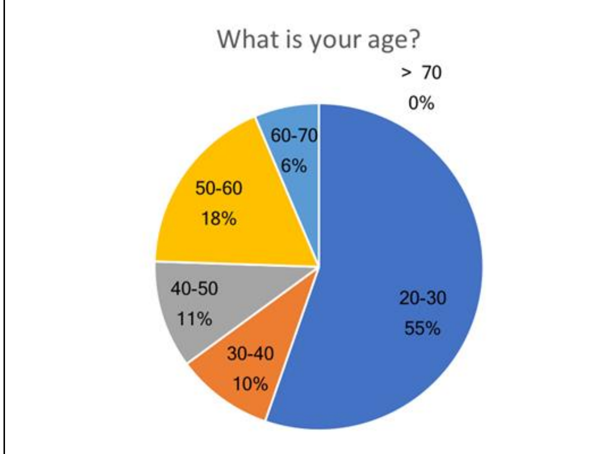








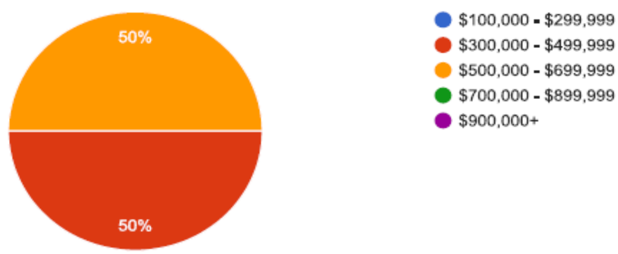




[Appendix 3: Survey Result for Real Estate Agents]

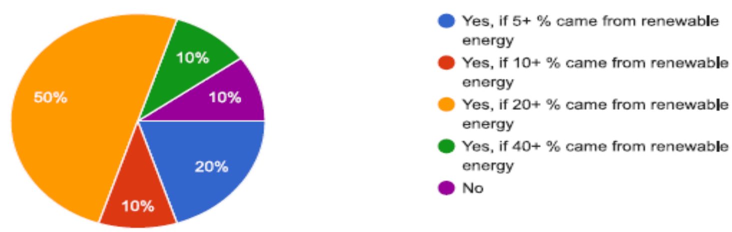
What is the average price-point of your area?

10 responses



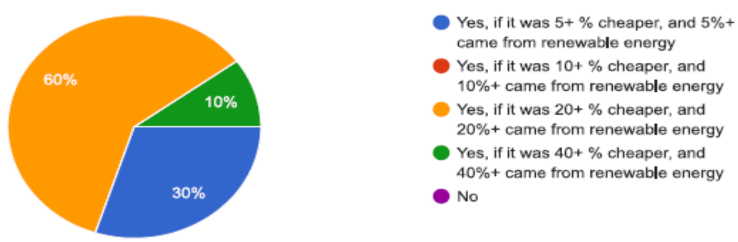
Would a homebuyer be more interested in a home if it got its electricity from renewable energy sources?

10 responses



Would a homebuyer be more interested in a home is it had cheaper monthly utilities because of its use of renewable energy sources?

10 responses



If a homebuyer was looking at 2 identical homes but one of the homes had a cheaper utility bill because it used renewable energy, how much more would that home be worth than the other? (use your above answers as the base price point and 50% as the extent of savings/renewable energy for your answer)

9 responses