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Vertical Axis Windmill

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Abstract Engineers and environmentalists are pursuing the utilization of renewable energy in lieu of ever the increasing demands for electricity. Our generation has inherited the charge for finding a solution to society's growing needs. Capturing wind energy was first conceptualized in 1888 by Charles. F. Brush, and has evolved into large scale wind turbines and generators known today. However, a small scale system for exploiting wind energy has eluded mass production, when it could realistically be implemented into our everyday lives. Through our daily tasks, society loses kinetic energy to the environment; a small scale wind turbine will streamline energy efficiency from a renewable source. Our goal is to design a propeller that will suit an aesthetic residential sized wind turbine that will perform well in a non-commercial environment and be easy to expand to a whole system.

Keywords: *vertical axis windmill, renewable energy, wind powers*

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1. Introduction

1.1. History

Wind powers uses have dated back as early as the first sailboats to navigate vast seas and oceans in the worlds early ages of exploration. The United States entered the industry in 1854 with the first manufactured windmill designed by Daniel Halladay [1]. His work was heavily relied on during Westward expansion, when water required for steam engines was scarce. More than 6 million windmills were installed between 1850 and 1970 in the United States.

1.2. Mariah Windspire

The Mariah Windspire is an attempt at redesigning the classic windmill design. It features a tall and slender vertical axis, mounted on a short tower. There are three vertical blades shaped similar to airplane blades, which rotate about the center axis. Although the idea was ingenuitive, the Windspire could not deliver the required output to justify itself as anything more than an aesthetic accessory [2].

1.3. Quiet Revolution

The Quiet revolution vertical axis wind turbine (VAWT) features three airfoil blades in a helical twist design. The unique design distributes the torque evenly over the revolution to negate destructive pulsations. The early poor performance of the QR5 has been credited to poor placement [2].

1.4. Windbelt

The device harnesses wind power by intentionally inducing aeroelastic flutter. Wind belt is designed to work under low wind speeds of three to twelve meters per second. The device is designed to provide power to remote locations in the developing world. A scaled down version, called the microbelt, is up to ten times more efficient and planned to be used to power IOT devices [3].

1.5. Dragonfly

The Dragonfly is a compact wind turbine, designed by an Italian Architect who was inspired by the physics of a dragonfly. Its unique two blade design can harvest winds blowing as slow as four miles per hour. The traditional turbine use either specifically designed blades that stall at high systems or computerized systems that have wind speed sensors that modulate the angle of the blade in response-which is too expensive to offset costs associated. The dragonflys design is ultra lightweight, allowing it to harness the slightest of breezes [4].

1.6. SheerWind Invelox

This wind turbine is capable of producing 600 times the power of a normal turbine. It is designed to take ground level winds and funnel them inward. This process accelerates the wind speed so it can function at times of low wind. Being a simpler design than most windmills it is also cheaper to build than most of its competitors [5].

1.7. Wind-Hydro Hybrid

The wind-hydro hybrid is a wind turbine that combines the power of wind and hydroelectricity. This is the only turbine that could generate power when there is no wind because of the electricity that comes from the hydro part of the turbine. The first ones are set to be located in the forests of Germany and will have a capacity of about 13.6 megawatts [6].

1.8. Darieus Wind Turbine

Darrieus wind turbine - A darrieus wind turbine can spin at many times the speed of the wind hitting, hence the turbine will create only less torque than a savonius but it rotates much faster. The Darrieus wind turbine is a type of vertical axis wind turbine used to generate electricity from the energy carried in the wind. The turbine consist of a number of curved aerofoil blades mounted on a vertical rotating shaft [7].

1.9. Vortex

The Vortex wind turbine has a straw shaped bladeless design. The turbine is designed to harness energy by exploiting the aerodynamic effect vorticity. The vortex uses the vibrations caused by vorticity in conjunction with a base of repelling magnets to generate electricity. The device in theory should have low maintenance costs because there are very few moving parts. The turbines can be placed closer together than conventional turbines are totally silent and cost less to manufacture. Vortex is also no danger to birds [8].

1.10. Typhoon

The Typhoon is an eggbeater shaped wind turbine designed to harness the massive amount of energy potential of typhoon storms. It is much more durable than conventional three blade turbines because of how compact it is. The design utilizes the Magnus effect and allows for wind from any direction to be harnessed. The device is designed to fit the energy needs of Japan, a country regularly hit by typhoons [9].

1.11. Makani Airborne Wind Turbine

This airborne turbine can reach stronger and more consistent winds not available on the ground. It could be deployed over the mainland us or over deep offshore waters. which could lead to access to a renewable energy resource four times greater than the entire country’s electrical generation capacity [10].

1.12. Compound Rotor System

US Patent 8777557 Introduced a compound rotor system to increase the capabilities of wind turbines. The second rotor allows for the system to efficiently generate electricity from low wind speeds [11]. This increased capability allows for the system to be effectively deployed in a larger array of locations [14].

1.13. WhalePower

WhalePower has redesigned the props for typical wind turbines to mimic the bumps (tubercles) found to the bumps on a humpback whales fins. This evolutionary feature found in the wild helps whales to prevent a stalling effect with their fins as they glide through the ocean. The steeper the tilt on the blade, the more there is potential for power generation. Steeper angles however also increase the risk of stalling. Studies show that implementing bumps into a prop could increase the production for wind farms by 20 percent [12].

1.14. Mageen Air Rotor System (MARS)

It is a high altitude wind turbine that stays a float with helium-filled airship like body. It can be tethered up to 1000 feet in the air. MARS rotation generates electricity, which is transferred down the power line, which doubles as its tether, to the ground. MARS is still being tested [12].

1.15. WePOWER

It is a vertical-axis wind turbine that operates quietly and performs well in low speed winds. Unlike many turbines which either rely solely on lift or drag, WePOWER uses a combination of both. Its unique airfoil lets its produce power at low wind speeds. WePOWER turbines are mainly used in wind farms, homes, cell towers and buildings [12].

1.16. Spiral Drag Wind Turbine

The vertical axis turbine uses drag propulsion to push the blade that is designed as an involute spiral. The turbine uses aluminum vanes formed into an involute spiral giving the blade extremely high surface area to capture wind and rotate. This design is still in developmental stage [12].

1.17. Helium Filled Floaters

The world’s first airborne wind turbine launched in 2014 over Fairbanks, Alaska. Held aloft by helium like a giant cylindrical blimp, built by MIT startup Altaeros Energies to float 1,000 feet in the air and capture wind currents five to eight times more powerful than the breezes at ground level. Since its this high it can transmit WiFi, and cell signals during the bad weather [13].

1.18. Wind Harvester

This reciprocation motion based turbine uses horizontal aerofoils similar to those on airplanes. It is noise free, works at relatively low speeds, and easy to install. It will also be operational at higher wind speeds than current wind turbines [13].

1.19. Windstalk

Within each hollow pole is a stack of piezoelectric ceramic discs. Between the ceramic disks are electrodes. Every other electrode is connected to each other by a cable that reaches from top to bottom of each pole. One cable connects the even electrodes, and another cable connects the odd ones. When the wind sways the poles, the stack of piezoelectric disks is forced into compression, thus generating a current through the electrodes [13].

1.20. Windbeam

Windbeam is a micro generator capable of generating energy from wind speeds as low as two miles per hour. Vortex shedding and transverse galloping cause oscillations in a beam which are then harnessed through an electromagnet induction system. Windbeam is designed to work with low power devices such as HVAC duct sensors and other internet of things devices [15].

2. Methodology

The specific goals represented by our efforts are summarized in the abstract. Our extended goals focus on user profitability, positive environmental impact and self sustainability.

The design process begins with a **needs assessment:**

- Increase the quality of life by providing a source of renewable, clean energy.
- Improve on previous large scale wind turbines by creating a system used by the civilians.
- Provides commercial incentive for members of the public to invest in personal renewable energy, generated and used by them.

Once a need is discerned, the following **problem formulation** is in order. Large wind turbine systems lack mobility and are costly to fund, most of which are company maintained. A small scale version could go with the user, and the user would directly benefit from its use. The vision at hand is for an individual to be self sufficient, if not at least supplemented.

As we analyze the task at hand, we utilize the why-why diagram above to pursue why residential wind turbines aren’t more common.

2.1. General Goals

At peak performance, our product should pay for itself within 5 years. There are only a few moving parts involved, all of which would take an extremely out of place force to jeopardize the users safety. Our product will supplement electricity requirements for the user, laxing the reliance on fossil fuel-produced power sold by the power companies. At first glance, a spinning top perched on every roof on the street may seem contrary to popular aesthetics; we aim to overcome this as the windmill’s benefits outlast the cons. The rigid minimal design of the 3-D printed propeller will endure nature’s obstacles. The worst-case scenario would be a large tree limb falling on it, afterwards replacement parts shall be obtainable. With minimal moving parts, the only maintenance required would be an annual axle lubrication and electrical connection cleaning. In case of structural failure, the propeller could be special ordered. Until a prototype is constructed, the cost of production is inexact. The list of materials for our product is the cost of 3D printing the propeller.

Out of the four designs developed by our team, we had much to consider when weighing out the best option. To facilitate our decision, we utilized a design matrix shown in Figure 2 to rank our design goals, and grade each design without bias.

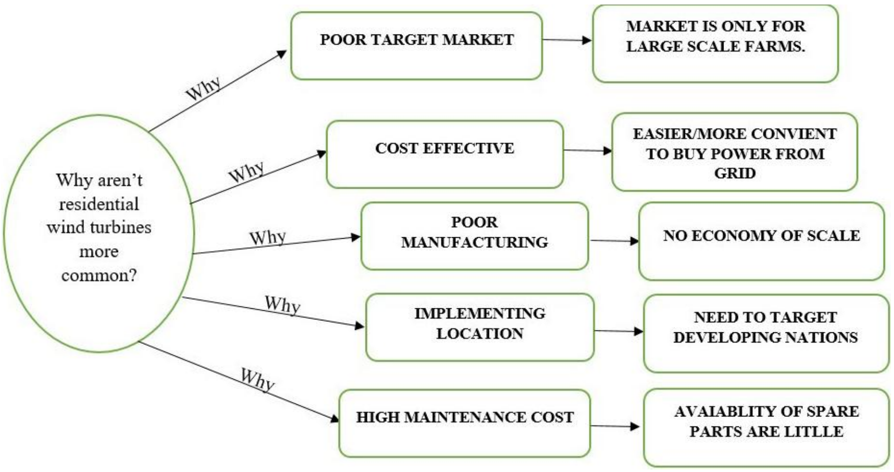
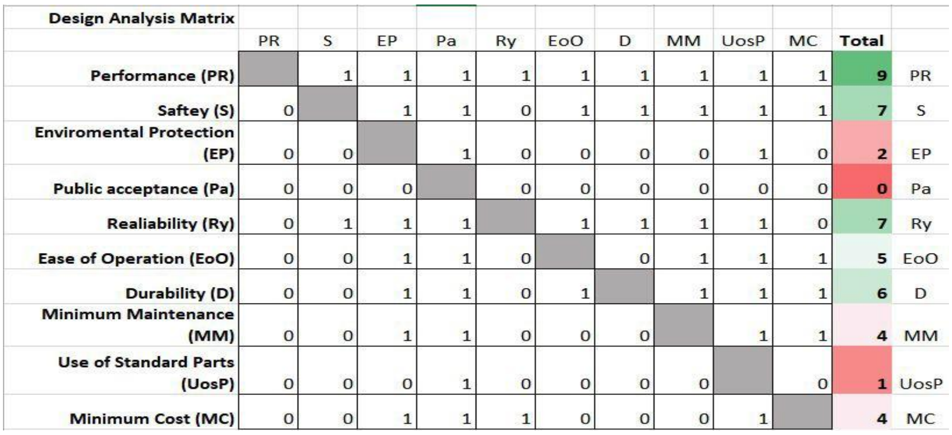
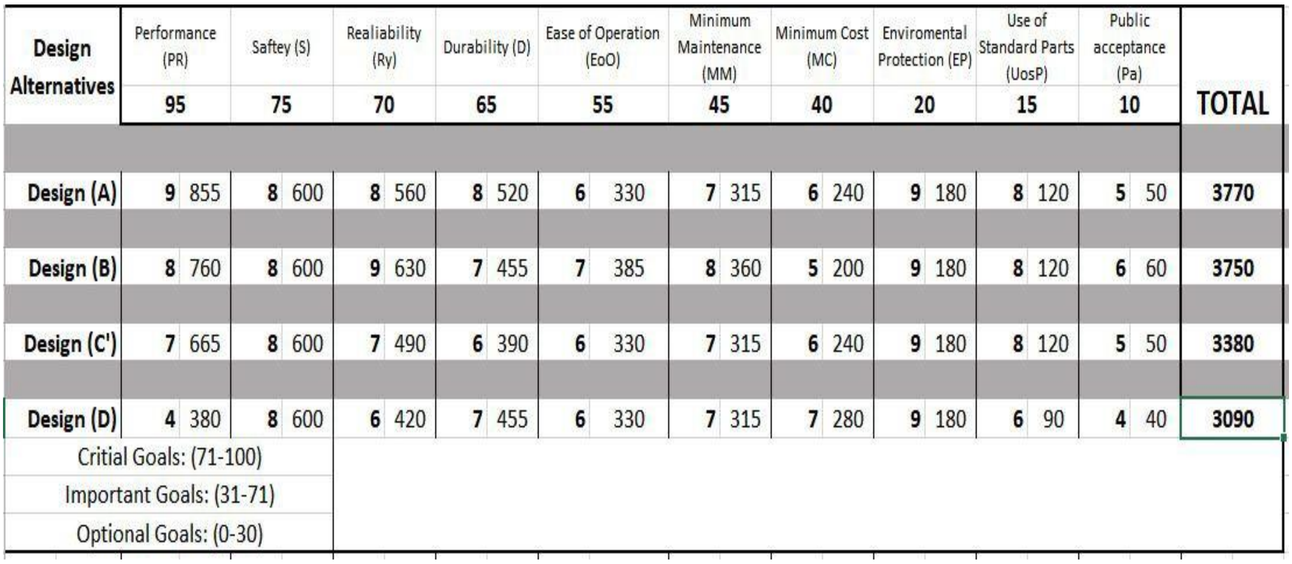


Figure 1. Why-Why Diagram



Design Analysis Matrix												
	PR	S	EP	Pa	Ry	EoO	D	MM	UosP	MC	**Total**	
Performance (PR)		1	1	1	1	1	1	1	1	1	**9**	PR
Saftey (S)	0		1	1	0	1	1	1	1	1	**7**	S
Enviromental Protection (EP)	0	0		1	0	0	0	0	1	0	**2**	EP
Public acceptance (Pa)	0	0	0		0	0	0	0	0	0	**0**	Pa
Realiability (Ry)	0	1	1	1		1	1	1	1	0	**7**	Ry
Ease of Operation (EoO)	0	0	1	1	0		0	1	1	1	**5**	EoO
Durability (D)	0	0	1	1	0	1		1	1	1	**6**	D
Minimum Maintenance (MM)	0	0	1	1	0	0	0		1	1	**4**	MM
Use of Standard Parts (UosP)	0	0	0	1	0	0	0	0		0	**1**	UosP
Minimum Cost (MC)	0	0	1	1	1	0	0	0	1		**4**	MC

Figure 2. Design Analysis Matrix



Design Alternatives	Performance (PR)		Saftey (S)		Realiability (Ry)		Durability (D)		Ease of Operation (EoO)		Minimum Maintenance (MM)		Minimum Cost (MC)		Enviromental Protection (EP)		Use of Standard Parts (UosP)		Public acceptance (Pa)		TOTAL
	95		75		70		65		55		45		40		20		15		10		
Design (A)	9	855	8	600	8	560	8	520	6	330	7	315	6	240	9	180	8	120	5	50	3770
Design (B)	8	760	8	600	9	630	7	455	7	385	8	360	5	200	9	180	8	120	6	60	3750
Design (C')	7	665	8	600	7	490	6	390	6	330	7	315	6	240	9	180	8	120	5	50	3380
Design (D)	4	380	8	600	6	420	7	455	6	330	7	315	7	280	9	180	6	90	4	40	3090
Critial Goals: (71-100)																					
Important Goals: (31-71)																					
Optional Goals: (0-30)																					

Figure 3. Design Rating Matrix

Performance ranked the highest among those considered, followed by Safety and Reliability. These became our critical goals. Following were our important goals: Durability, Ease of Operation, Minimum Maintenance, and Minimum Cost. Lastly the optional goals were Environmental Protection, Use of Standard Parts and Public Acceptance. Ironically, the motivation behind out project is to provide an alternative form of energy that will preserve the environment, and it is among our lowest goals. We attribute that to the underlying knowledge that Performance in directly related to Environmental Protection.

Now that we have determined a ranking system, we graded each design on how well it satisfied the goals. This is shown on the above Design Rating Matrix Figure 3.

All things considered, we concluded that our original propeller design would best satisfy our goals. Going forward, we delve into the CAD construction process.

2.2. Design Alternatives

Design Alternative B, see Figure 4 below.
Design Alternative C, see Figure 5 below.
Design Alternative D, see Figure 6 below.

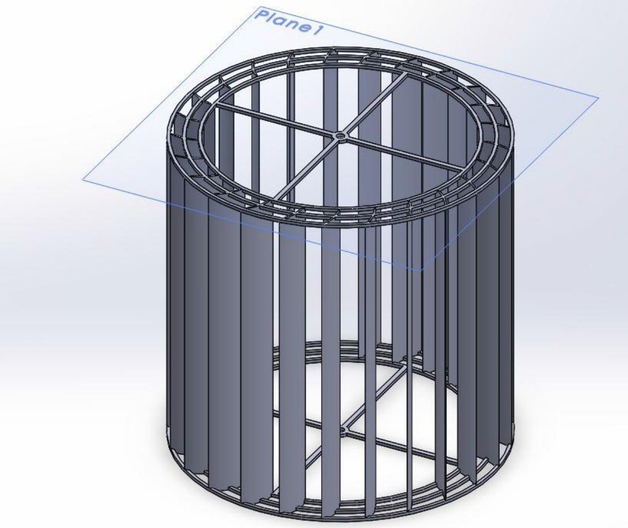


Figure 4. Alternative Design B

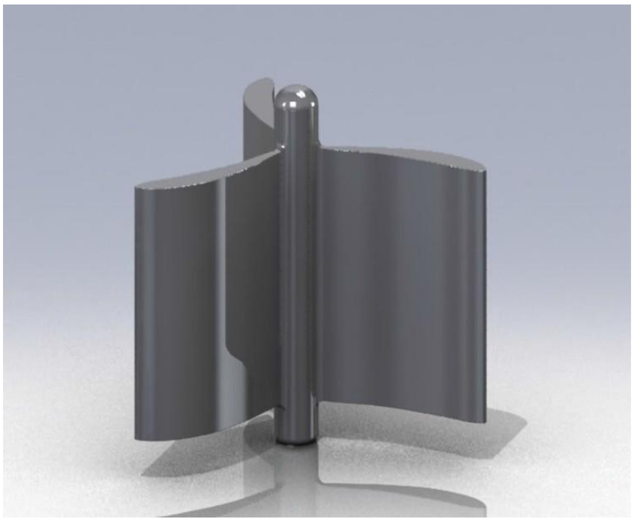


Figure 5. Alternative Design C

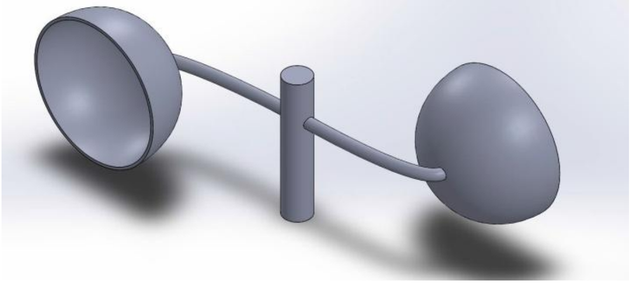


Figure 6. Alternative Design D

2.3. 5 types of Constraints

The devices prop shall be a foot tall, 10 wide at the widest. The yields of our product depend on the amount of wind available at a given point in time. Only through testing can we accurately estimate the output available. Our goal to make the product as cost effective as possible will encourage sales. The consumer should see logic in paying the upfront cost to yield long term savings. The user will need to check their local requirements for structures, particularly in suburban areas. Our device will be compact enough to mount atop a home, and should not result in any negative forthcoming. However, a permit may be required depending on local jurisdiction. The final product will be simple enough for the user to perform self maintenance, and not require a technician. We would offer a start up installation, and optional maintenance package if desired.

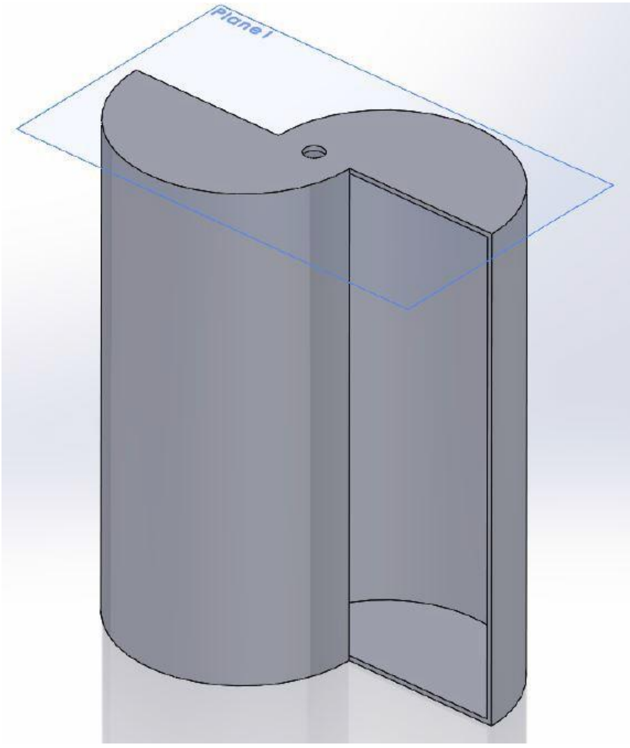


Figure 7. Final Propeller Design

3. Final Design

The final goal of designing a propeller to capture wind flow from any direction supplied required consideration of various aspects: First, the design of the prop ensures that contradicting wind directions would yield rotation of the prop. Traditional wind turbines must be turned to face the direction of the wind, whereas the vertical axis wind turbine is omni-directional, is not influenced at all by wind direction and is better in respect to the configuration and operation [17]. The additional versatility granted makes the turbine viable even in areas with less than constant wind flow in varying directions. The two circular openings opposing each other force air into the opening so that even distribution of wind will rotate the prop in one direction, creating a couple moment about the axis of rotation. Another design property was to stretch the openings out as far as possible without compromising structure of the prop. The further out from the center the wind can push, the more torque the propeller could output to the axle to result in more energy generation. Lastly, we designed the propeller based on a drag concept, as opposed to lift based. The shape of the prop was designed to accelerate the air as it spins into the prop, thus creating more force. The combination of aforementioned properties streamline propeller performance, ensuring optimum efficiency.

The final design for the propeller shown in Figure 7 will best satisfy the general goals outlined in the methodology, and be cost effective to produce.

4. Conclusion

Each of the five phases of design bred our final design, which will quench the need for an alternative energy solution available on a residential level. Looking forward, our windmill’s uses could be expanded to government highways, commercial high rise buildings, schools, beach fronts, etc. The possibilities are only as limited as the creativity of the user-wind envelops the human race daily. The solution to our energy supply worries has blustered mankind preceding electricity. America’s pursuit of wind energy began with large scale government wind turbine farms in the wild west, and now an individual can self-supplement at every street corner and cul-de-sack.

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