Team Wind EnGen: Portable Turbine

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Motivation: Capture Waste Energy

Objective: To develop a vertical-axis wind turbine that is portable, inexpensive, and easily constructed with a focus on sustainability

Other Motivations: off-grid energy access, renewable source, affordability

Design Model: Original Concept

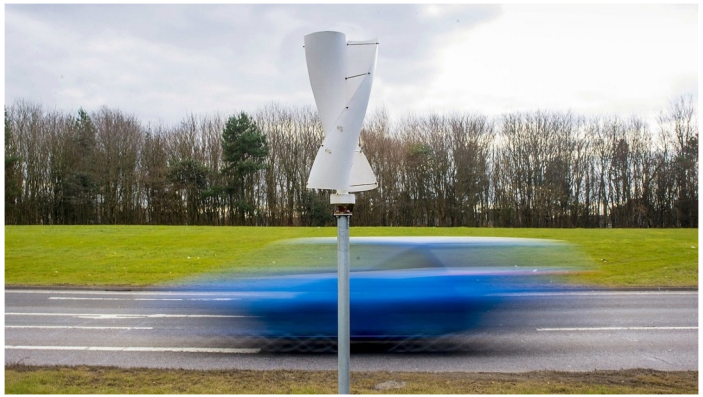
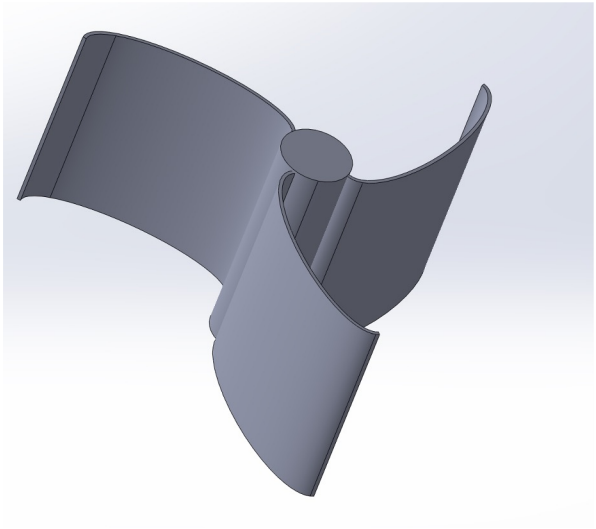
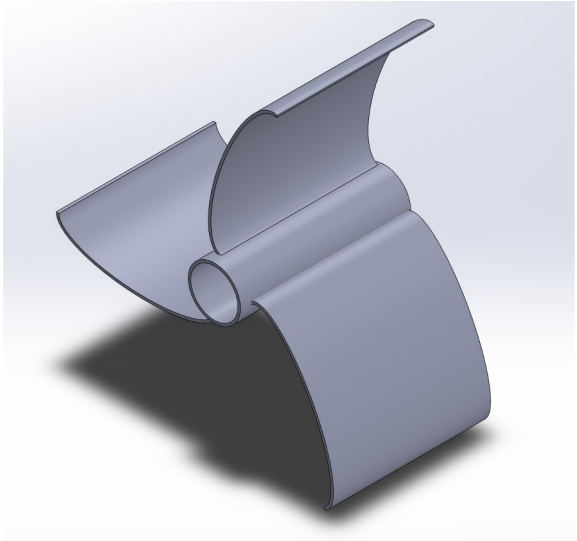


Table 1. Pugh Scoring Matrix for Turbine Blade Configuration Selection

	Resource Requirement (hrs)	Power Output (kW)	Capital Cost (≤ $)	Durability	Scalability	Safety	Total
(weight)	*0.2*	*0.2*	*0.15*	*0.1*	*0.15*	*0.2*	*1*
Savonius	7	3	8	6	7	8	6.45
Helix	3	8	5	7	7	8	6.30
Darrieus	6	5	6	7	7	6	6.05
Horizontal	2	8	3	6	4	5	4.65

Design Model: CAD

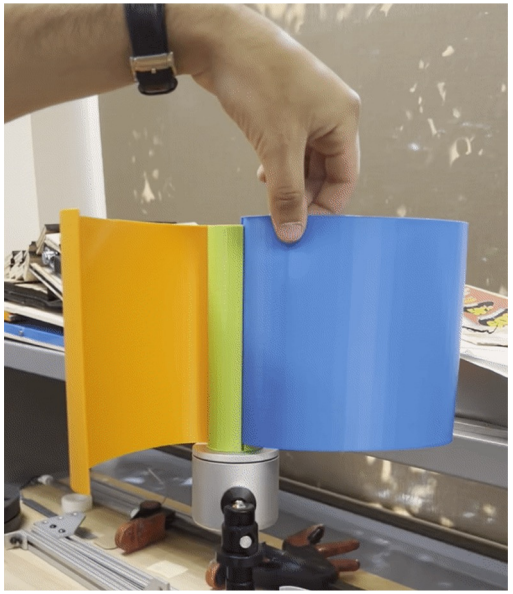




Model Iterations

Prototyped Model: PLA

GIF of turbine generating



GIF of blade insertion

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Prototyped Model: Updated PLA

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Proof of Concept & Application

Wind Power: $\frac{1}{2}\rho A v^3$ Usable Power: $\frac{1}{2}C_p\rho A v^3$

Given average losses, wind speed of 15 mph, Savonius efficiency of 15.5%, and blade dimensions of 6" wide by 6" tall (original) for compactness and portability:

Wind EnGen $power_{out} \approx 1.33$ W (original)

Wind EnGen $power_{out} \approx 0.67$ W (updated)

TexEnergy $power_{out} = 7.5 - 10$ W

TexEnergy Model

(Extrapolated) Application: Charging a mobile phone

- Phone requires 5 V

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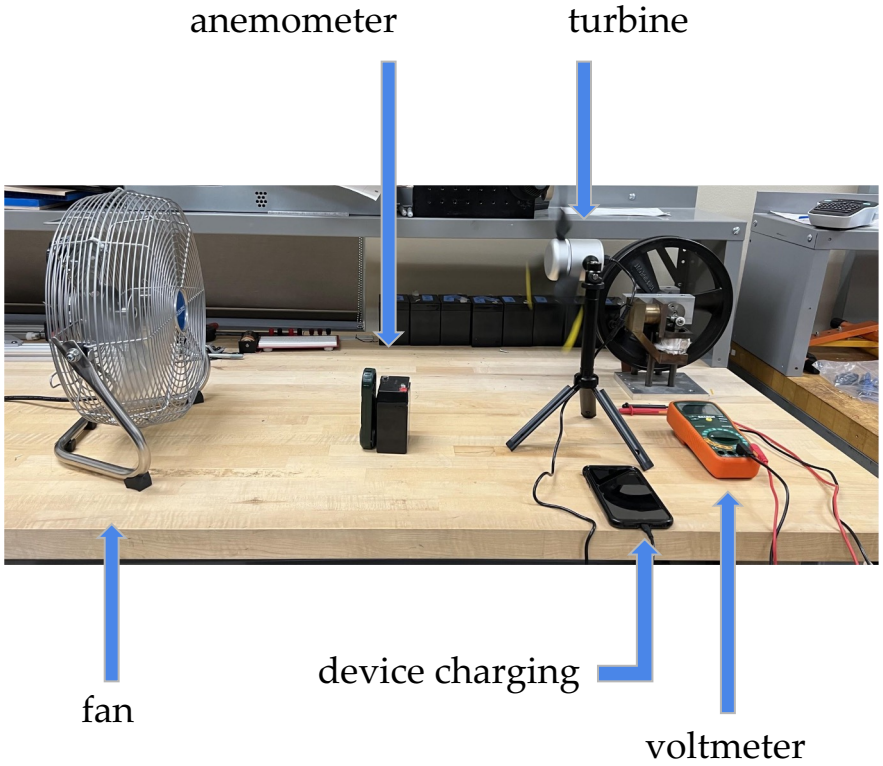
Testing Procedure

1. Measure various grid locations with an anemometer to determine wind speeds
2. Center turbine with fan and fix at a distance of known wind speed
3. Connect positive and negative terminals of turbine with single conducting wire to a breadboard
4. Use another set of wires to connect resistors in various configurations (parallel, series) to breadboard
5. Turn on fan at determined speed setting and measure voltage or RPM with a multimeter or laser tachometer, respectively

Testing Setup



Independent Variable: Blades & Shaft

- TexEnergy
- PLA
- (Updated) PLA

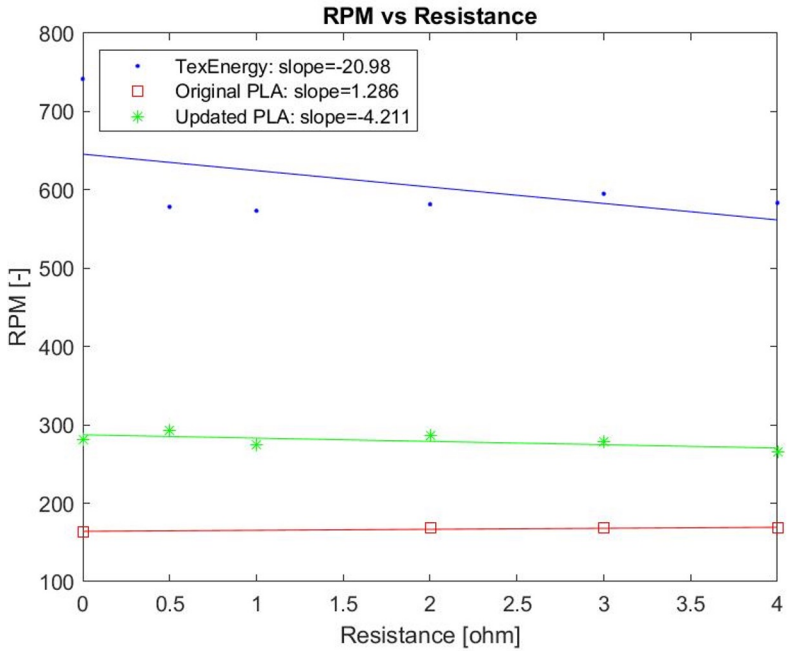
Equipment:

- Industrial Fan
- Voltmeter
- Anemometer
- Laser Tachometer (not shown)

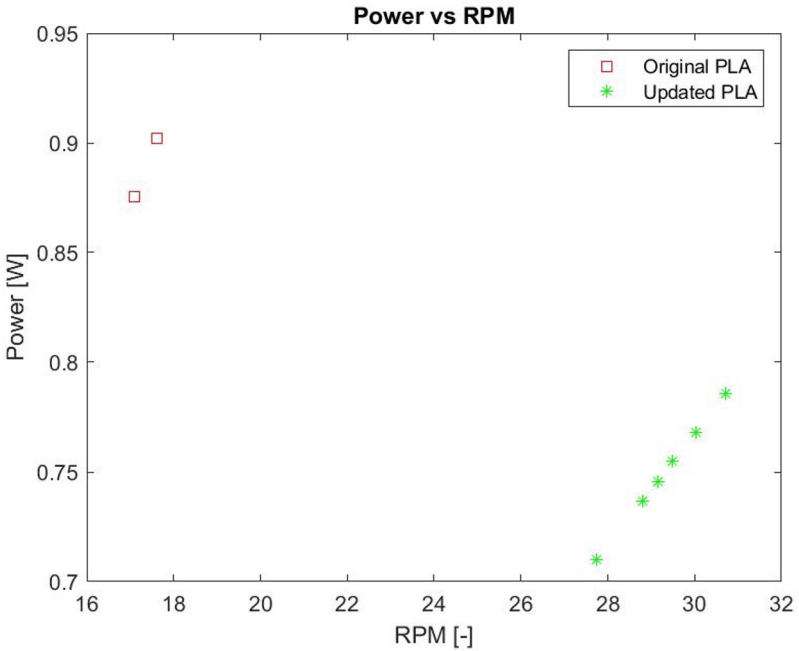
Environment:

- Gendell Lab

Results



RPM Vs. Resistance for All Models Tested



Power Vs. RPM for All VAWT Models Tested

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Discussion & Future Considerations

- Difficult to determine ideal load
- Original to Updated PLA: jump from under 200 RPM to 300 RPM (about 54% of TexEnergy's RPM)
- Original PLA model power stagnated while Updated PLA increased
    - Updated model more efficient
- Improvements
    - Blade shrouds → optimize structure & material
    - Blade curvature

Environmental Benefit Analysis

- Offsetting the carbon footprint for electricity generation
- North Carolina generates power at 282.1 gCO_2/kWh
  - Charging the 3227 mAh battery of an iPhone 13 generates 3.84gC02
  - Can range up to 10 gCO_2 per charge
- Car chargers or power bank dependency
- Recyclable PET filament

Material	Printability	Flexibility	Durability	Weight	Recyclability	Cost	Total
	0.2	*0.1*	*0.1*	*0.2*	*0.3*	*0.1*	*1*
PLA	8	2	4	6	8	8	6.6
TPU	5	9	8	5	1	3	4.3
PET	8	7	7	5	9	7	7.6

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Social Benefit Analysis

- Portable charge carrier mitigates dependency on low-efficiency chargers
  - Backpacking community
  - Ecotourists
  - Off-grid populace
- Emphasis on portability and durability
- Minimizes weight and maximizes the storage capacity
  - net weight 410g
- Emission offsetting help offset health repercussions of emissions

Target Group & Competition

- Texenergy, Shine, Bayoung Electronics

Travelers	Off-grid Populace
• Ecotourism • Backpacking community	• Researchers • Fishermen

• Socioeconomic background
  ○ Education
  ○ Budget
• Age
  ○ Between 24 and 54 years old
  ○ Technology experience
• Environmental awareness
	• Fuel scarce conditions

Basic Business Plan

- Emphasis on final product price
  - most recent estimate of $155
  - Potential to be lowered down to $62
- Distribution partnership with brand resellers
  - Camping gear resellers
    - *REI, Camping World,* or *Dick's Sporting Goods*
  - Technology and general stores
    - *BestBuy, Target, or Walmart*
- Renewable energy fairs and conferences
  - Startup and innovation competitions
  - Sustainability government grants

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Additional Considerations

- Portability
- Durability
- Ease of use
- Sustainable materials

Measuring Success

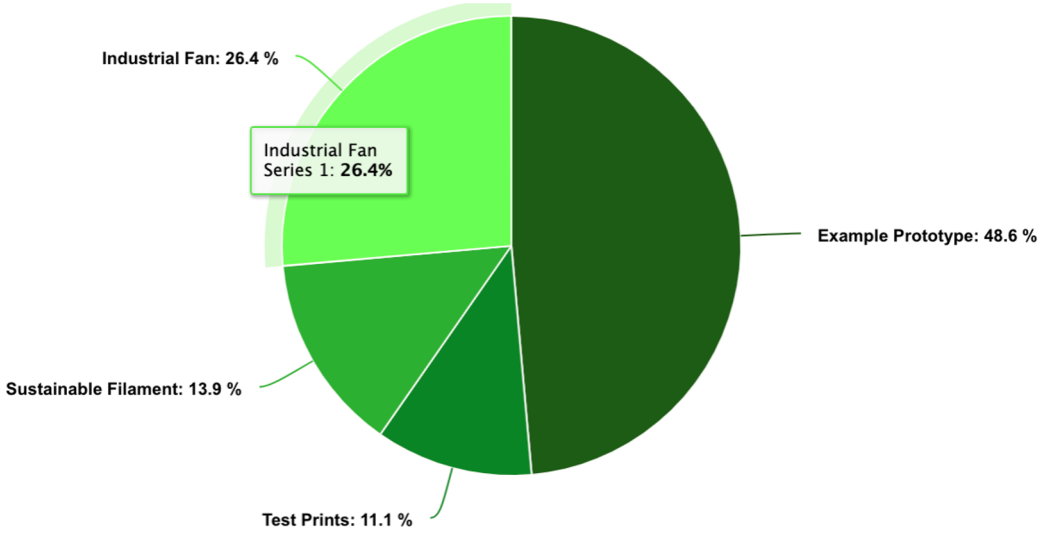
- Fully collapsible and durable wind generator 
- Ability to measure voltage difference across terminals & RPM 
- Data analysis on power output 
    - Information about optimal blade configuration, suggestions for commercialization, best use of generated energy, etc.

Project Budget

- Example Prototype **$175**
- Test Prints (CoLab)* **$40**
- Filament (PLA) **$50**
- Industrial Fan **$95**

Used **$360**

Remaining budget **$1140**



*** Materials not actually purchased but provided through university resources**

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Conclusions & Summary

- Feasible design but room for improvement
    - Further testing → more precisely determine ideal load
    - Goal of achieving great power output
    - PET prototype in the making
- Foundation for future development of portable, durable, sustainable VAWT (including but not limited to Savonius configuration)
- Low-cost energy prototype with large potential in the market

Thank You!

Questions?

References

3Dnatives (2019) *Is PLA filament actually biodegradable?*, *3Dnatives*. Available at: https://www.3dnatives.com/en/pla-filament-230720194/ (Accessed: 30 March 2022).

Apple (2022) *iPhone 13 and iPhone 13 mini - Technical Specifications*, *Apple*. Available at: https://www.apple.com/iphone-13/specs/ (Accessed: 30 March 2022).

Carvajal, M. and Alejandra, M. (2013) 'Ecotourists : profile and implications for the marketing strategy', p. 272.

CIA World Factbook (2022) 'United States', *The World Factbook*. Central Intelligence Agency. Available at: https://www.cia.gov/the-world-factbook/countries/united-states/#energy (Accessed: 31 March 2022).

EIA (2021) *North Carolina - State Energy Profile Overview - U.S. Energy Information Administration (EIA)*. Available at: https://www.eia.gov/state/?sid=NC#tabs-4 (Accessed: 30 March 2022).

Hamzah, I. *et al*. (2018) *Effect of blades number to performance of Savonius water turbine in water pipe*. doi: https://doi.org/10.1063/1.5024105

Møller Jensen, J. and Hjalager, A.-M. (2019) 'Travel motivations of first-time, repeat, and serial backpackers', *Tourism and Hospitality Research*, 19(4), pp. 465–477. doi:10.1177/1467358418781440.

Motive Power (2021) *The United States Electricity Mix*, *Motive Power*. Available at: https://www.motive-power.com/npuc-resource/the-united-states-electricity-mixas-featured-on-visual-capitalist/ (Accessed: 30 March 2022).

Pakkanen, J. *et al.* (2017) 'About the Use of Recycled or Biodegradable Filaments for Sustainability of 3D Printing', in Campana, G. et al. (eds) *Sustainable Design and* Manufacturing (2017) Cham: Springer International Publishing, pp. 776–785. doi:10.1007/978-3-319-57078-5_73.

Papiewski, J. (2022) *Horizontal Vs. Vertical Wind Turbines.* Available at: https://education.seattlepi.com/disadvantages-wind-turbine-4473.html

Scientific American (2008) *The Environmental Impact of Corn-Based Plastics*, *Scientific American*. Available at: https://www.scientificamerican.com/article/environmental-impact-of-corn-based-plastics/ (Accessed: 30 March 2022).

TexEnergy. *Infinite Air - Portable Off-Grid Wind Turbine*. Available at: https://www.texenergy.com/collections/portable-wind-turbines/products/infinite-air

US EPA, O. (2020) *Data Explorer*. Available at: https://www.epa.gov/egrid/data-explorer (Accessed: 30 March 2022).

Wight, P.A. (1996) 'North American Ecotourists: Market Profile and Trip Characteristics', *Journal of Travel Research*, 34(4), pp. 2–10. doi:10.1177/004728759603400401.

Zemamou, M., Aggour, M., and Toumi, A. (2017) *Review of savonius wind turbine design and performance*. doi: https://doi.org/10.1016/j.egypro.2017.11.047

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