HARNESSING WIND ENERGY FROM RECYCLED MATERIALS

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Overview

- Project introduction
- Background information
- Design process and progression
- Final design concept
- Prototype
- Testing & Results

Project Motivation & Need

- Project Motivation: Major issue in underdeveloped countries is lack of electricity
  - People living far away from power production facilities or the electrical grid
- Project Need: People whom do not have access to power production facilities or the electrical grid are in need of electricity

Design Goals & Scope

- Project Goal: Design a home-sized wind turbine system that can be reproduced by those in need of electricity.
- Project Scope:
  - Inexpensive
  - Includes a turbine and an energy storage method
  - Powers both a light bulb and a fan for at least 5 hours/day
  - Portable and relatively easy to manufacture

Design Requirements & Constraints

- Requirements:
  - Provides at least 0.5 kWh per day
- Constraints:
  - Cost does not exceed $50
  - Built from common materials which are either recycled or otherwise sold at general hardware stores
  - Portable

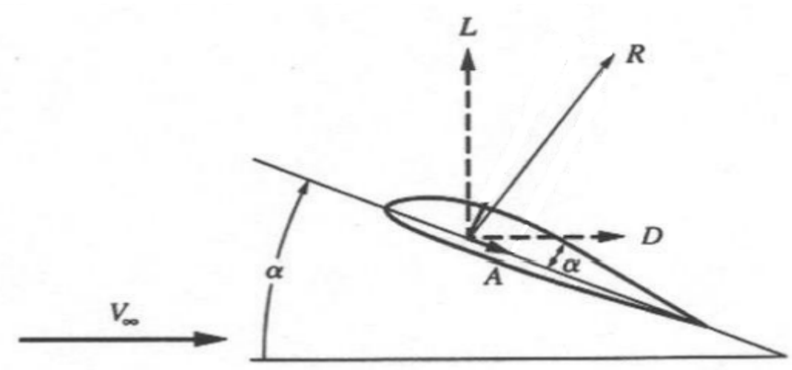
Research – Horizontal vs. Vertical Axis

- Axis about which the wind-powered spinning occurs

http://www.onpointpro.biz

Research – Turbine Axis Considerations

- Horizontal axis turbines:
  - Airfoil design relies on both lift and drag forces
  - Need to be pointed into the wind
  - Higher efficiency



Wind Tunnel Lab handout, ME 495L

- Vertical axis turbines:
  - Operation in any direction wind
  - Only allows for rotation by drag forces
  - Many different designs to consider

Horizontal Wind Turbine Analysis

http://www.windturbinezone.com

Power produced by a turbine:

$$P = \frac{1}{2} C_p \rho v^3 A$$

C_p = *coefficient of performance*

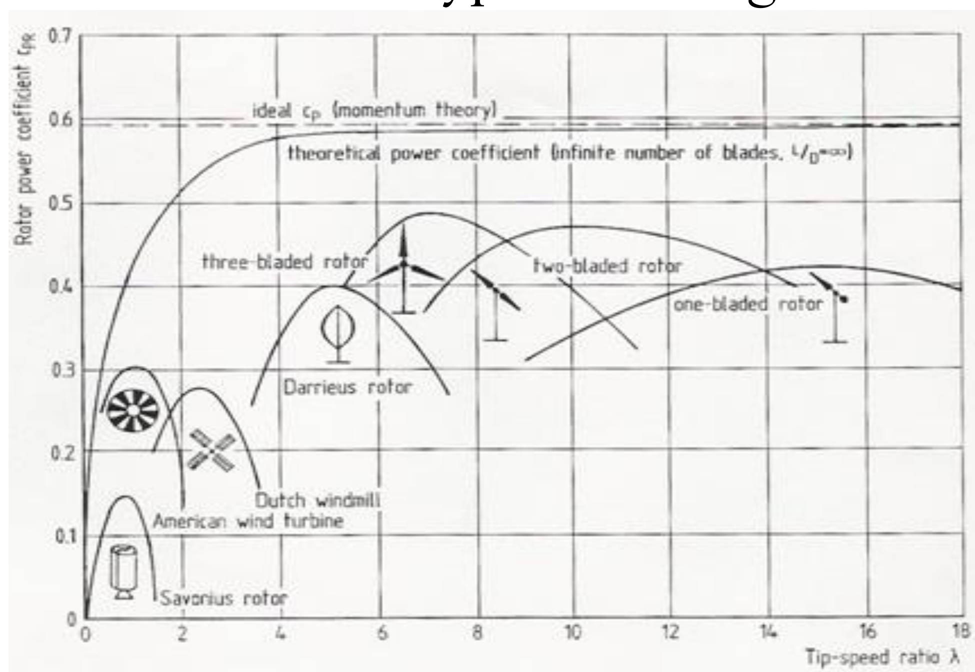
ρ = *density of air*

v = *velocity of air flow*

A = *swept area of turbine*

Coefficient of Performance

- $C\downarrow p$ = coefficient of performance
  - *ratio of kinetic energy in from wind/ power captured from turbine rotation*
- Performance is dependent on wind turbine type and design
- Also dependent on operating wind speed



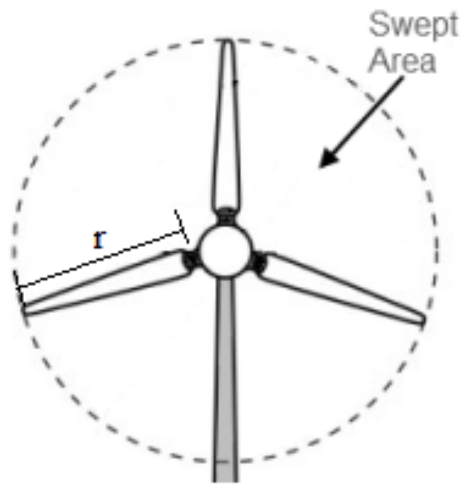
http://www.scielo.cl

Coefficient of Performance Limitations

- The true C_p of any design is restricted below the Betz Limit
- Betz Limit – maximum theoretical C_p for any horizontal axis wind turbine
  - Derived from fluid mechanics, and conservation of mass/ momentum equations
- Betz Limit = 59%

Swept Area Requirements

- Cross-sectional area that the airflow interacts with directly
- Dictated by turbine blade dimensions
- $A=\pi r^2$
  - r = radius = length of turbine blade



http://www.thebetterplanet.com

Swept Area Analysis

- Rearranging power equation:

$$P = \frac{1}{2} C_p \rho v^3 A \rightarrow A = \frac{2P}{C_p \rho V^3}$$

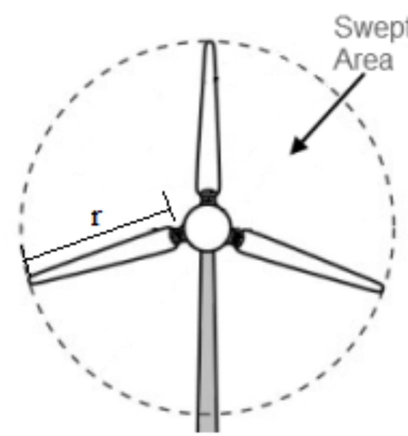
- Allows for calculation of necessary swept area
- Based on required power and estimated variables

Swept Area Analysis

- For analysis, the following assumptions were made:
  - Air density: $\rho = 1.2\, kg/m^3$
  - Average wind speed: $v = 5\, m/s$
  - Coefficient of performance (estimated): $C_p = 0.40$
  - Power required: $P = 55\ W$

$$A = \frac{2P}{C_p\, \rho V^3} = 1.83\ m^2$$

$$r = \sqrt{A/\pi} = 0.76\ m = 30\ in$$



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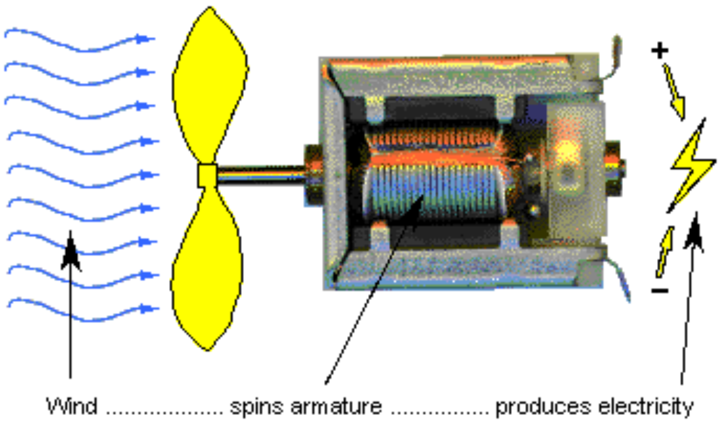
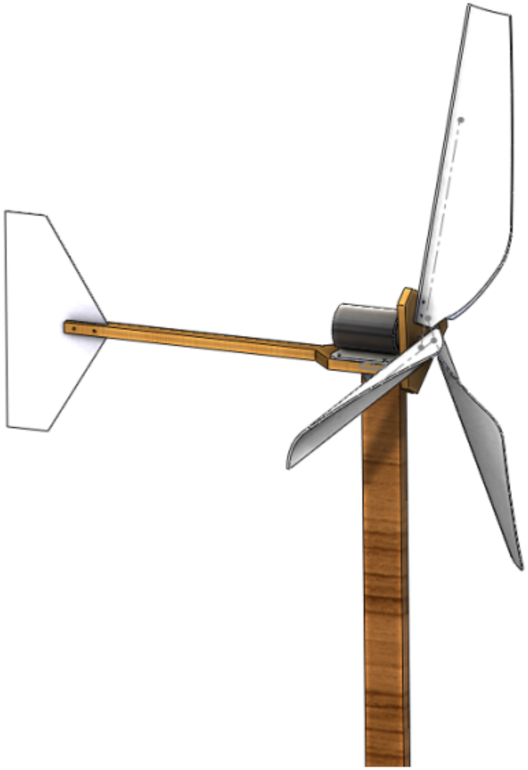
Generator Operation

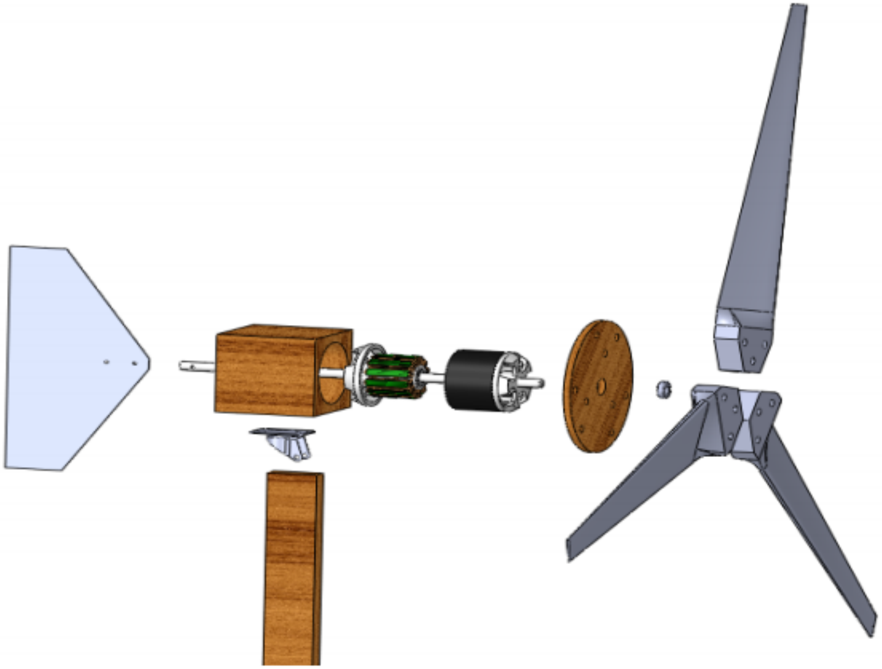
- Converts mechanical energy into electrical energy
- Rotation of the blades spins a magnet around copper coils
- Electromagnetic induction generates an electrical current



Initial Design Concepts

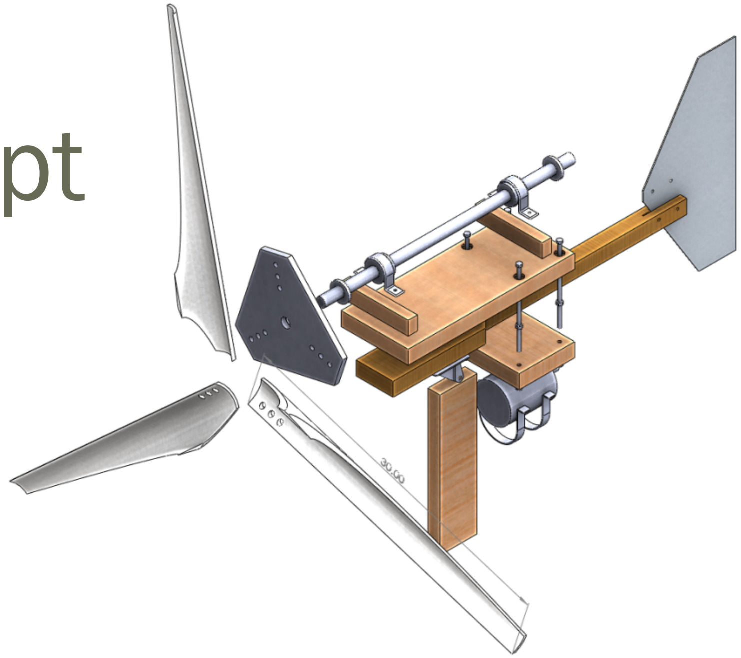
- Treadmill motor & motorcycle stator
- Assumed 1:1 Gear ratio

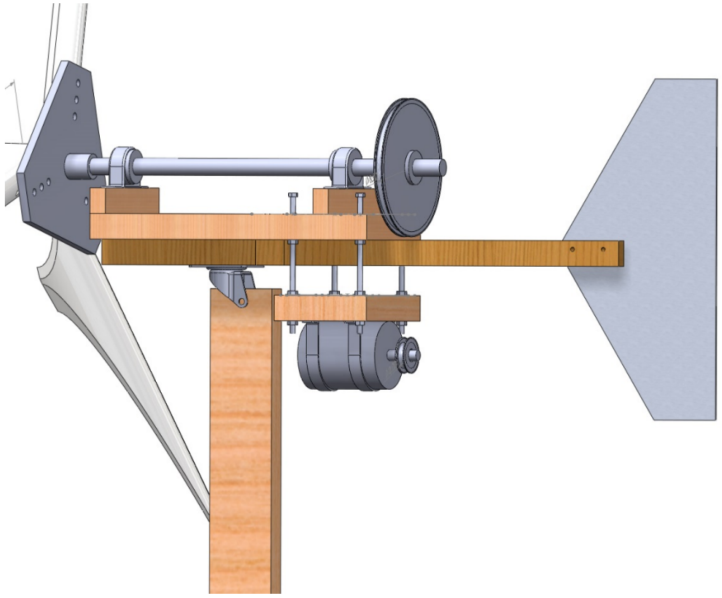




Final Design Concept

- Modeled in SolidWorks
- 30” PVC blades
- 4:1 Gear ratio
- Central shaft to transfer energy
- Caster wheel to pivot 180°
- Rear mounted DC generator for balance and flow





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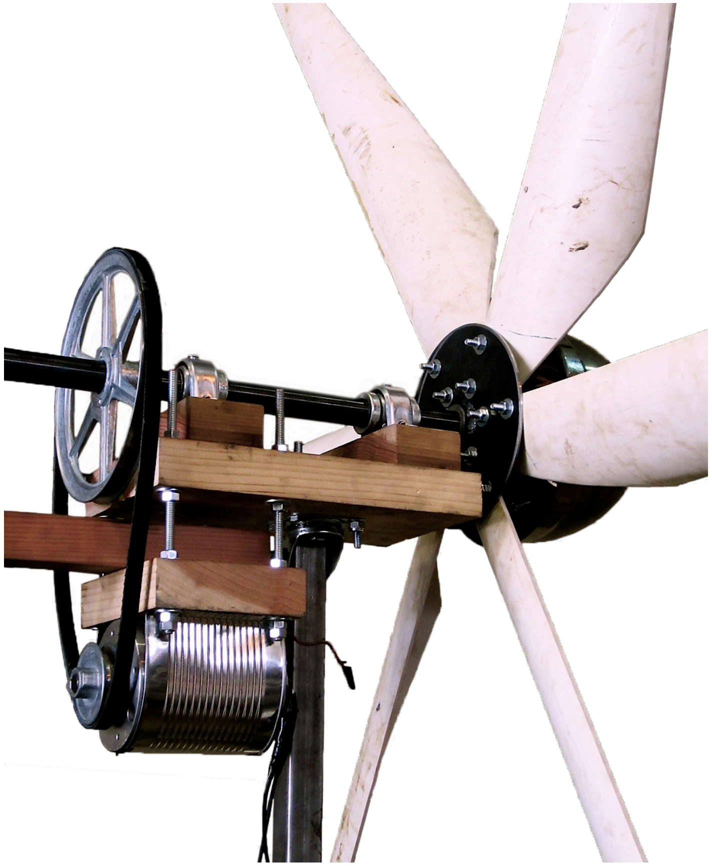
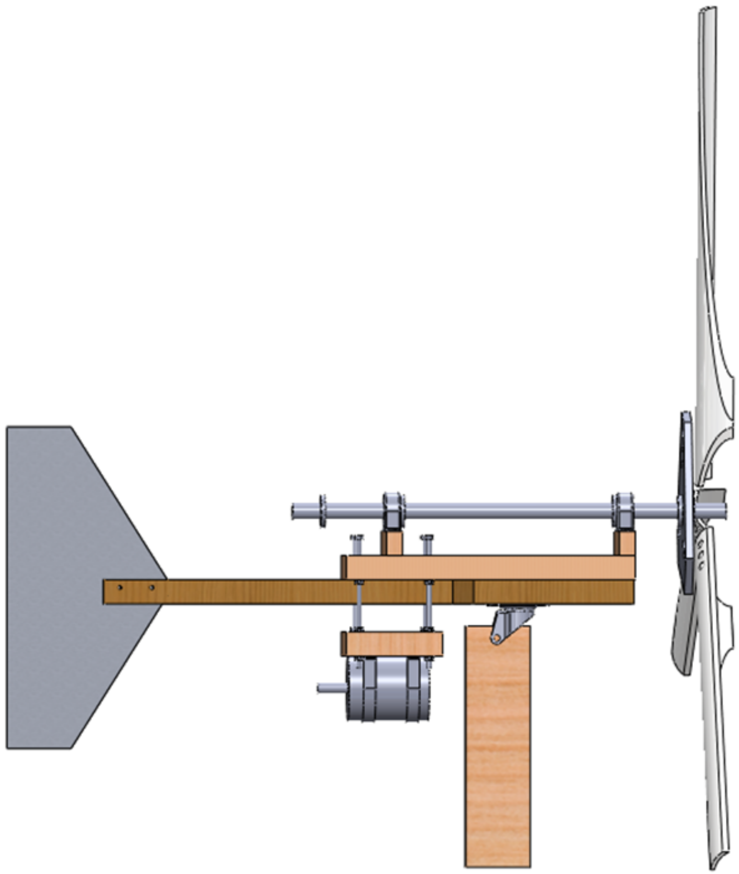
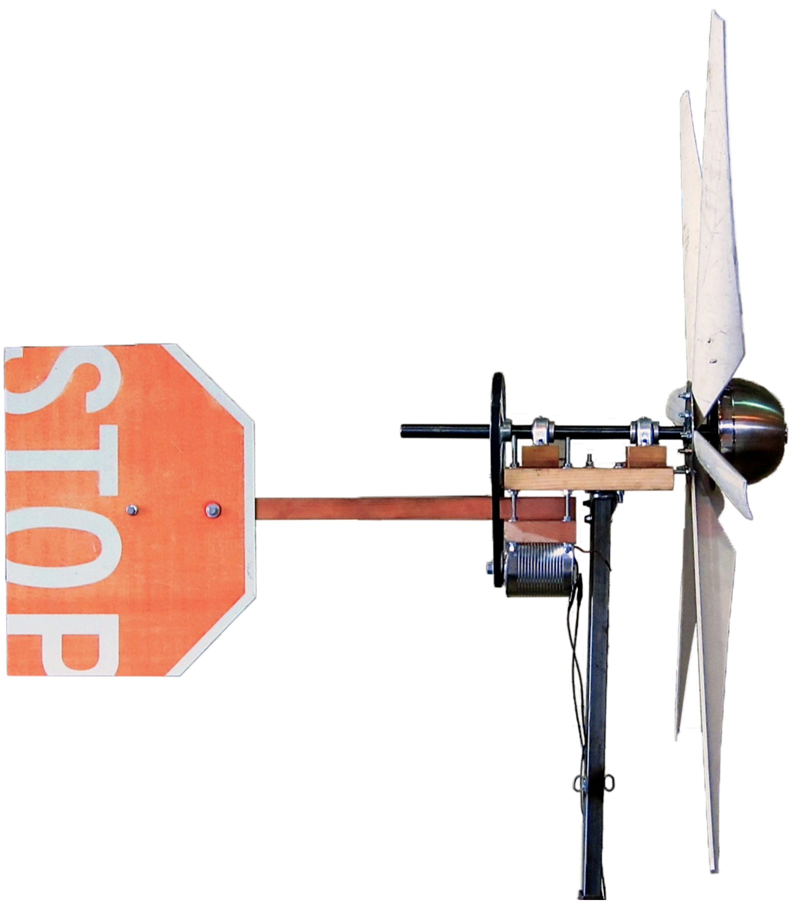
Blade Design & Pulley System

- Curved drag surface to create rotational energy
- Gear ratio to increase the power output of the DC generator and V-belt to reduce tension drag



Final Design Concept & Prototype

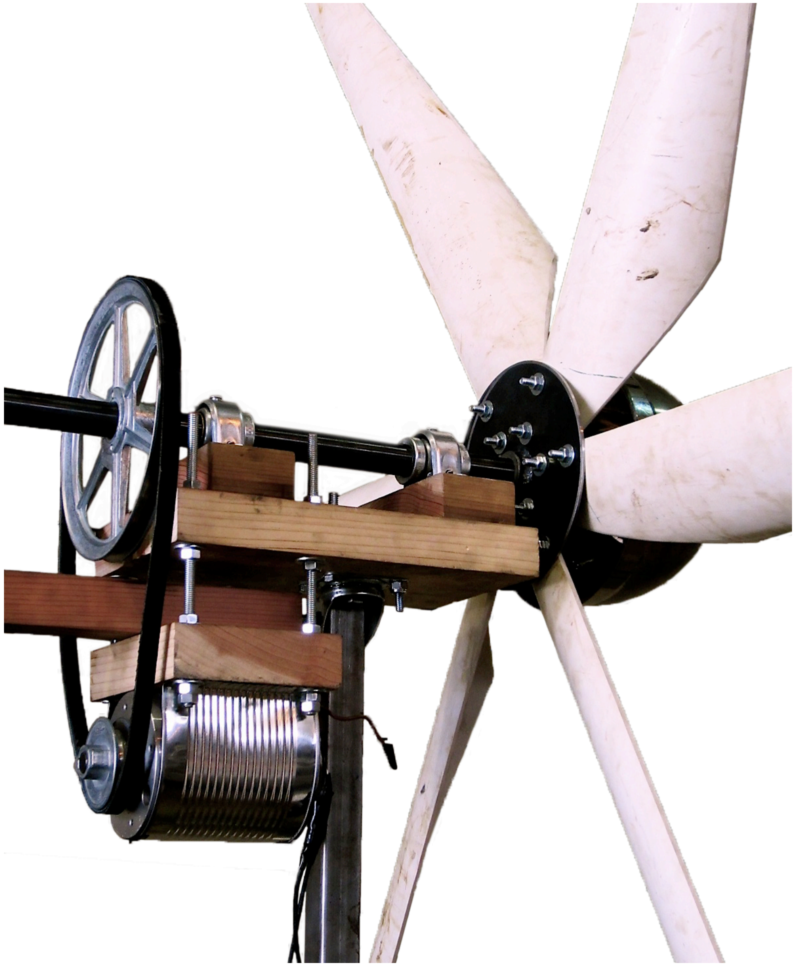




Prototype – Design Changes

- Function, aid in prototype testing
- 6 blade design; increased torque at low wind speeds
- Constructed stand for display and testing
- Added nose cone; aesthetics

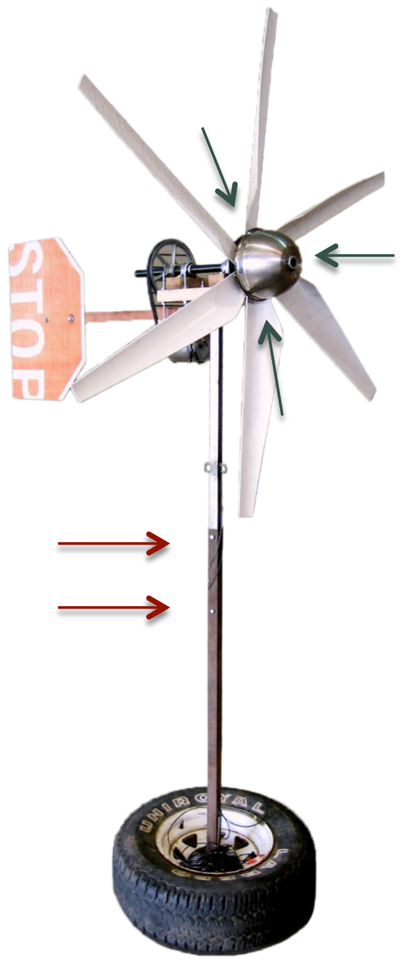
Prototype – View of mechanics



- Changed orientation of vertical tensioning system bolts; improved access
- Mounted tail shaft above generator block; increased clearance of large pulley

Manufacturing & Portability

- Attempted to use common hardware tools and techniques
  - Table saw, drill press/hand held drill, some welding, made templates
- Extremely portable
  - Disassembles into 4 components
  - 2 bolts (red)
  - 3 set screws (green)



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Cost Analysis

Table 1 – Bill of Materials	
Component	**Cost**
Generator	$64
Battery	$35
Pulleys	$27
Bearings & Shaft Collars	$25
Steel Bowl for Nose Cap	$16
Shaft	$10
Epoxy	$9
Electrical wiring components	$5
V-Belt	$4
Caster Wheel	Scrapped
PVC Pipe	Scrapped
Wood	Scrapped
Metal Posts	Scrapped
Sheet Metal	Scrapped
Car Tire	Scrapped
Solder	Scrapped
Total Cost	**$195**

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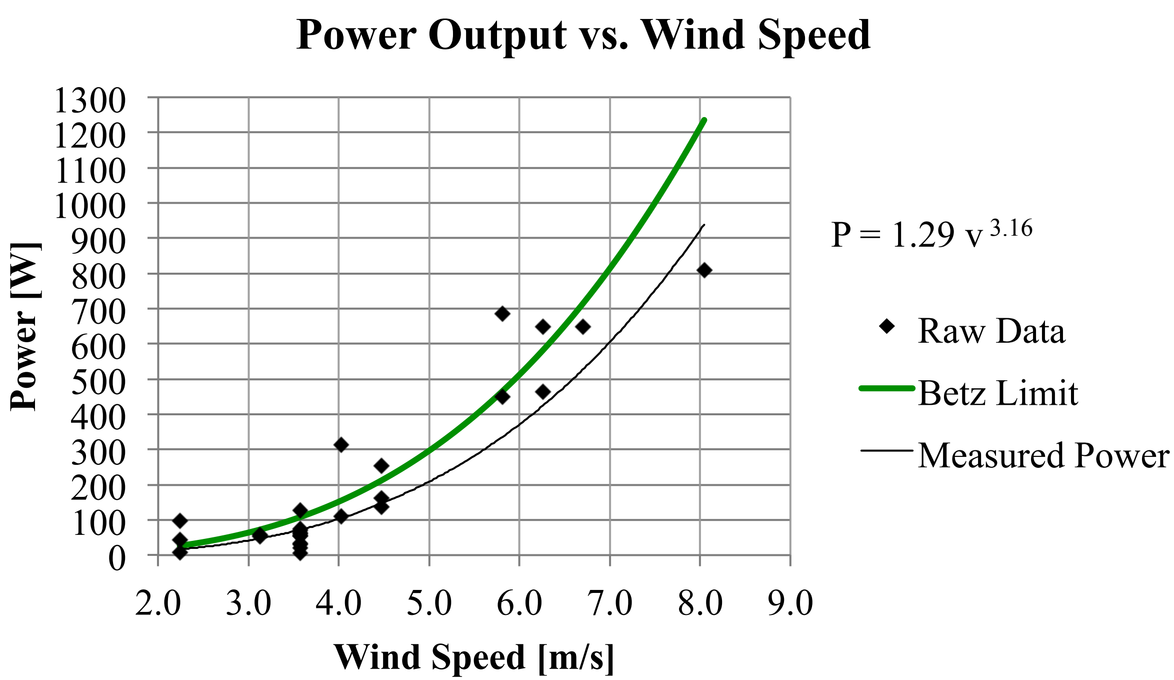
Prototype Testing

- Simulated wind: fastened turbine to truck bed and drove truck at various speeds
- Wind Speed: 4 to 18 MPH
- Voltmeter, ammeter and digital speedometer
- Video

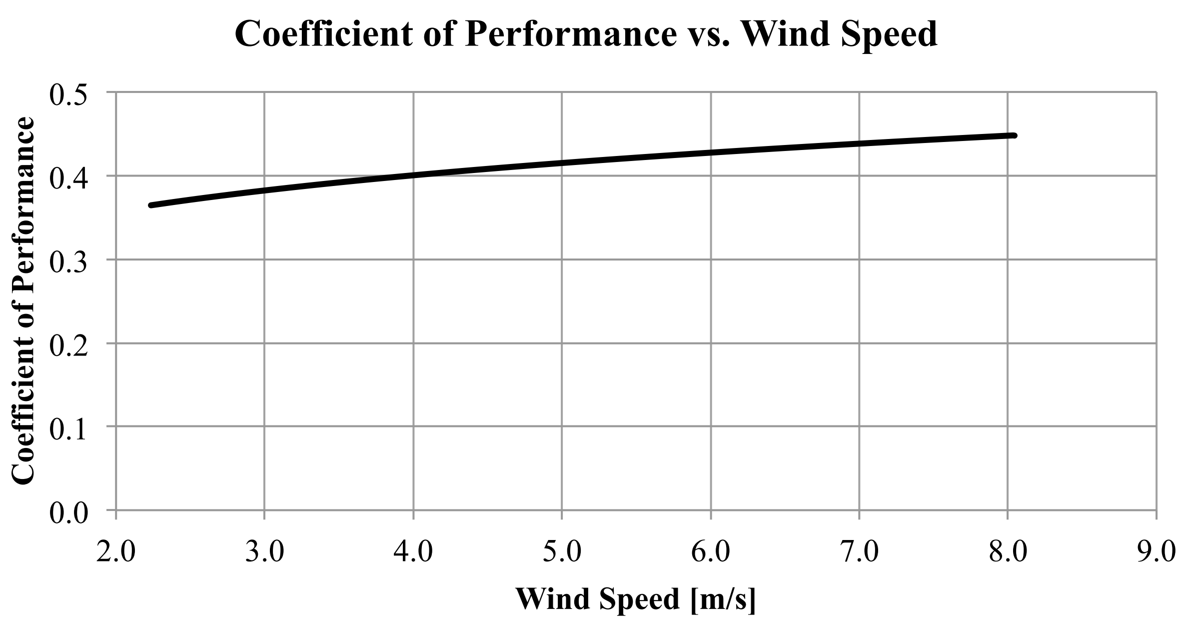
Results – Power Output

- Measured power follows expected trend
- Inaccuracy of testing procedure



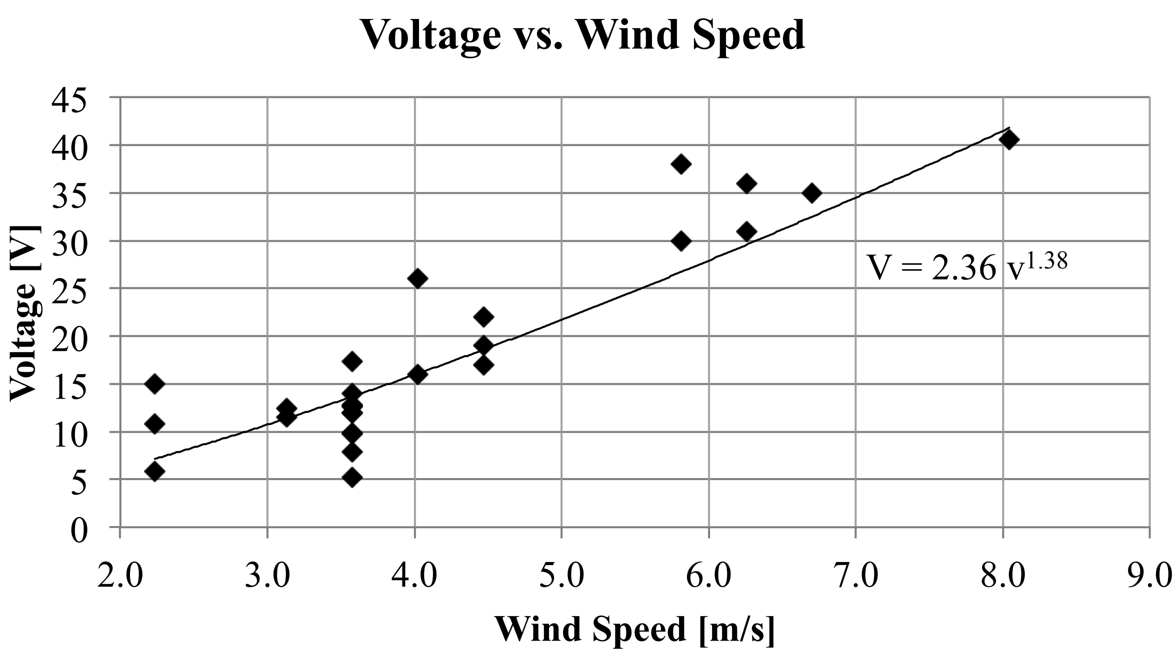
Results – Efficiency

- Efficiency: 35% to 45%
- Same range as commercial wind turbines



Results – Voltage Output

- Required voltage output: 14 V
- Wind speed needed: 3.64 m/s = 8.14 mph



Meeting the Project Scope

Requirements	Met? (Yes/No)	Comments
Produce at least 0.5 kWh per day.	Yes	Assuming a wind speed of 4 m/s for 9 -10 hours per day
Portable	Yes	Quick disassembly into four manageable pieces
Easy to manufacture	Yes	Used common hardware tools & techniques
Built from recycled/ common materials	Yes	
Cost less than $50	No	High expense for battery and generator

Conclusion

- Successfully built a portable, home sized wind turbine
- Cost greater than expected
  - Availability of generator and battery
- Only 3.64 m/s = 8.14 mph required to charge standard 12 V batteries

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Questions?