Power Generation through Recycled Materials

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Motivation

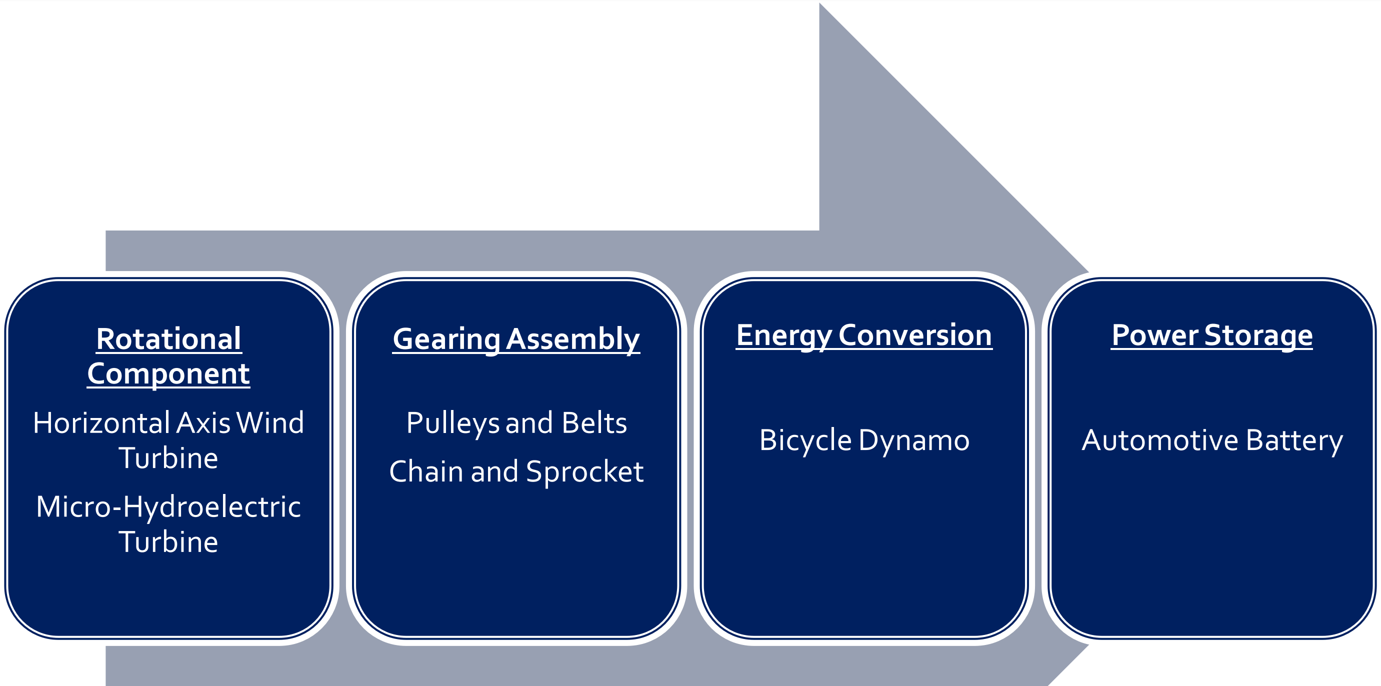
- **Current Problem:**
  In many countries around the world there are people with scarce means of acquiring power.

- **Solution:**
  A low cost power generator would be a very valuable commodity for them and would greatly enhance their standard of living. The goal of this project was to take readily available parts from the trash of the "developed world" and create an electrical power generator that runs off renewable resources. The project needed be very cost-efficient and reliable for everyday use. It was important to promote clean energy sources, and exploit the value contained within recycled materials.

Background Overview

- **Problem Statement:**
  - Design and construct a power generation device that implements the use of a renewable energy source and is composed entirely of recycled materials
- **Objectives:**
  - Must generate 100 W•h/day
  - Must store 300 W•h
  - Output must be 12 V DC
  - Must sustain severe weather
- **Constraints:**
  - Must choose three different geographic locations
    - 100 km away from the ocean, 500 km away from each other
  - Final product must cost under US $50.00

Design Layout

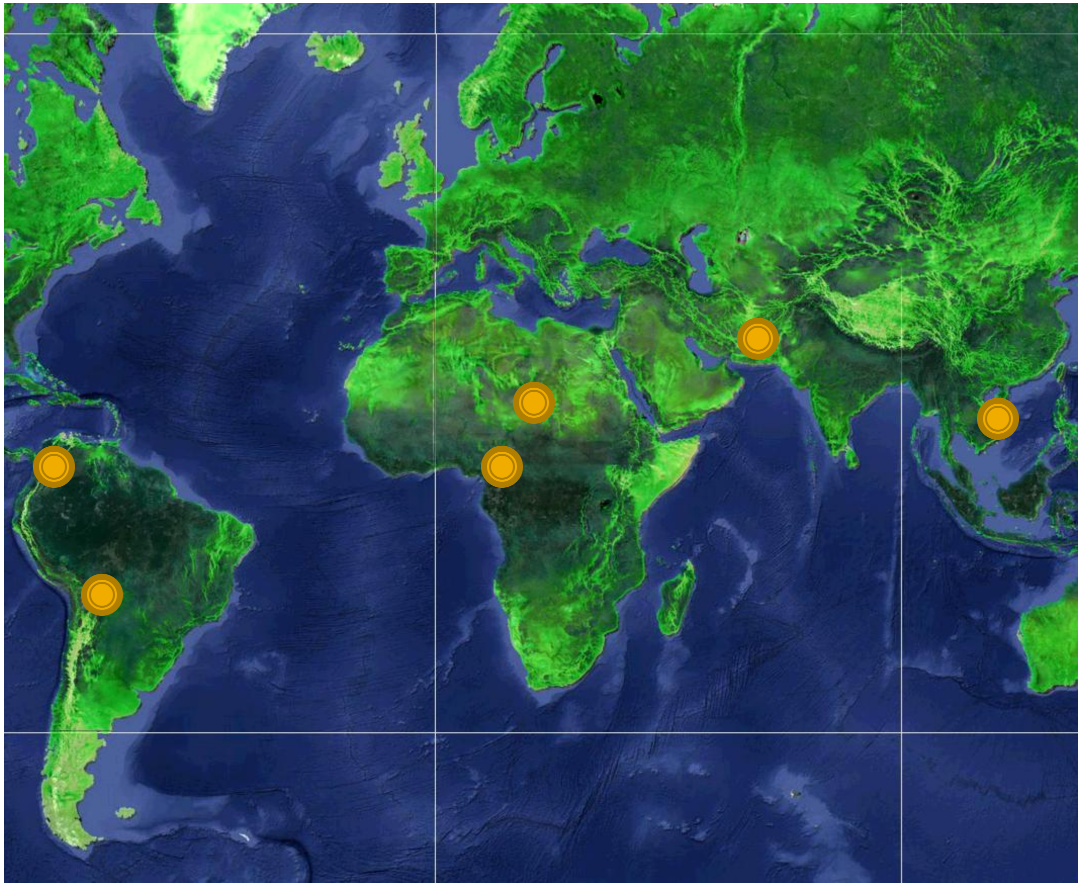


- **Functional Diagram**
  - Rotational Component (Energy Capture)→ Gearing Assembly (Energy Transfer)→ Energy Conversion→ Battery Storage
  - Simplicity with 4 main component layout

Geographic Locations

- **Wind Energy Locations**
  - **Faya-Largeau, Chad**
    - Average wind speed = 4.6 m/s ~ 10 m height
  - **Santa Cruz, Bolivia**
    - Average Wind = 3.9 m/s ~ 10 m height
  - **Sen Monorom, Cambodia**
    - Average Wind = 5.1 m/s ~ 10 m height

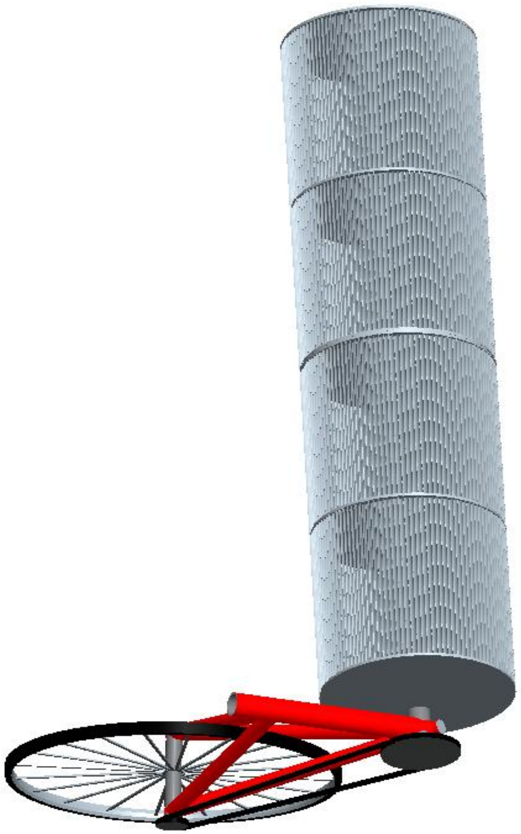
- **Water Energy Locations**
  - **Atrato River, Colombia**
    - Average Flow = $2.0 \cdot 10^6$ L/s
  - **Indus River, Pakistan**
    - Average Flow = $6.5 \cdot 10^6$ L/s
  - **Benue River, Cameroon**
    - Average Flow = $1.75 \cdot 10^5$ L/s



Preliminary Wind Design Concepts

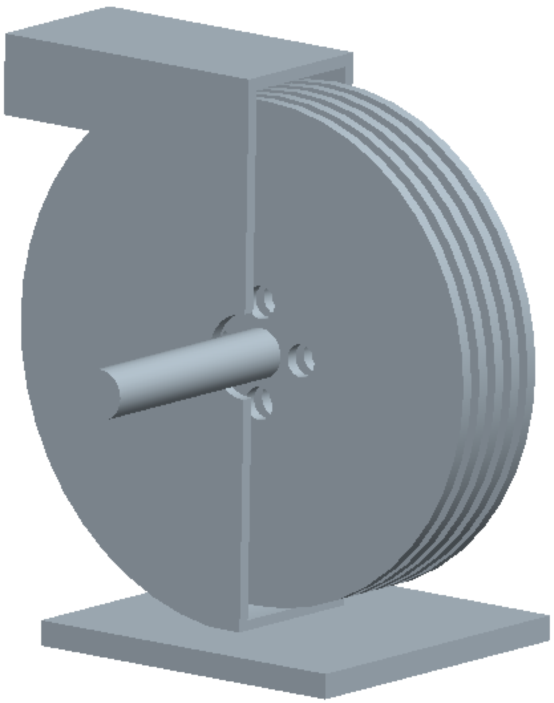
HAWT-HORIZONTAL AXIS WIND TURBINE

VAWT- VERTICAL AXIS WIND TURBINE

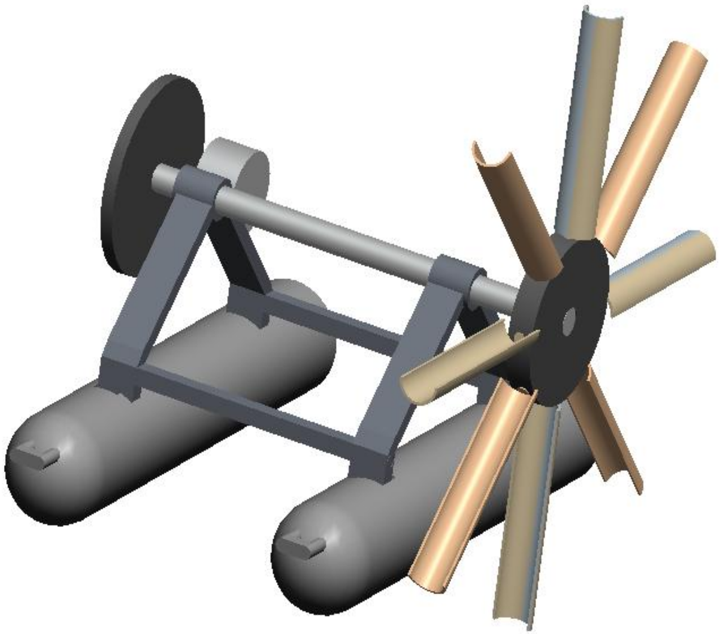


Preliminary Water Design Concepts

TESLA TURBINE



MICRO-HYDRO ELECTRIC



Decision Matrix

		Concepts							
		VAWT		**HAWT**		**Hydro-electric**		**Tesla**	
Specifications	Importance Weight	Rating	Weighted Scores	Rating	Weighted Scores	Rating	Weighted Scores	Rating	Weighted Scores
Durability	15%	5	0.75	3	0.45	3	0.45	1	0.15
Ease of Assembly	20%	3	0.60	5	1.00	3	0.60	1	0.20
Cost	40%	5	2.00	5	2.0	1	0.40	3	1.20
Maintenance	20%	3	0.60	3	0.60	3	0.60	1	0.20
Innovative	5%	3	0.15	3	0.15	3	0.15	5	0.25
	Score	**19**	**4.1**	**19**	**4.2**	**15**	**2.20**	**11**	**2.0**

Durability	10%	5	0.50	3	0.30	3	0.30	1	0.10
Ease of Assembly	15%	3	0.45	5	0.45	3	0.45	1	0.15
Cost	30%	3	0.90	3	0.90	5	1.50	3	0.90
Maintenance	15%	3	0.45	3	0.45	3	0.45	1	0.15
Efficiency	30%	1	0.30	1	0.30	5	1.50	1	0.30
	Score	**15**	**2.6**	**15**	**2.4**	**19**	**4.20**	**7**	**1.60**

HAWT – Theoretical Design Parameters

ARE442 WIND TURBINE (NREL)

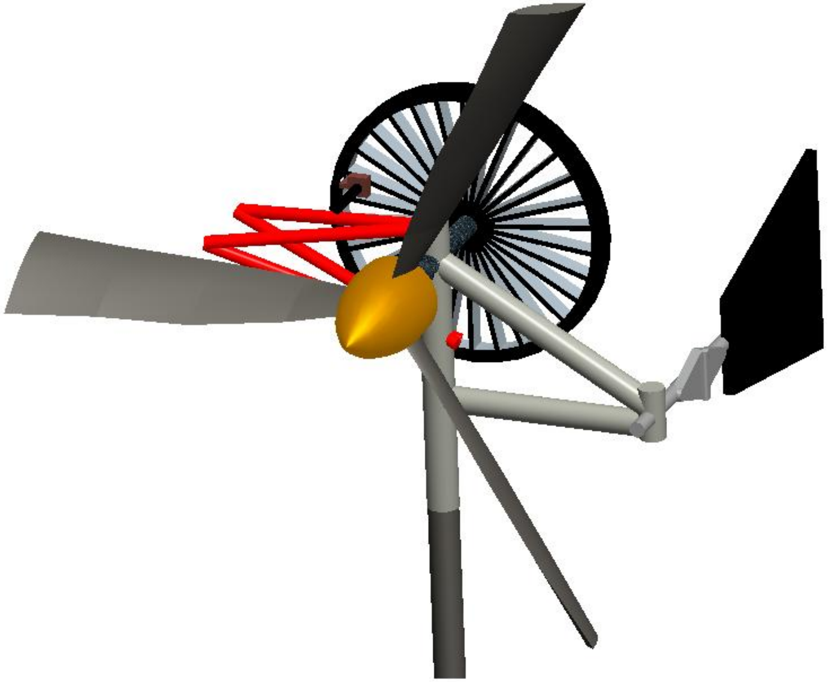
- **Power coefficient of Turbine**
  - 0.190
- **Minimum Rotor Area (4.2 W every hour)**
  - Area = 0.625 m^2
  - Diameter = 0.912 m
- **Design Specifications**
  - 3-blade Design
  - 7.2 m rotor diameter
- **Power Generated**
  - Gearing/pulley efficiency ~ 96%
  - New alternator efficiency ~90%
  - ~ 525 W

HAWT THEORETICAL DESIGN

- **Power Coefficient of Turbine (60% of ARE 442):**
  - 0.114
- **Minimum Rotor Area (4.2 W every hour)**
  - Area = 1.39 m^2
  - Diameter = 1.33 m
- **Design Specifications**
  - 3-blade design
  - 2.05 m rotor diameter
  - Area = 3.29 m^2
- **Power Generated**
  - Gearing/pulley efficiency ~ 85%
  - Refurbished alternator efficiency ~ 80%
  - ~ 10 W

HAWT – Final Design and Construction

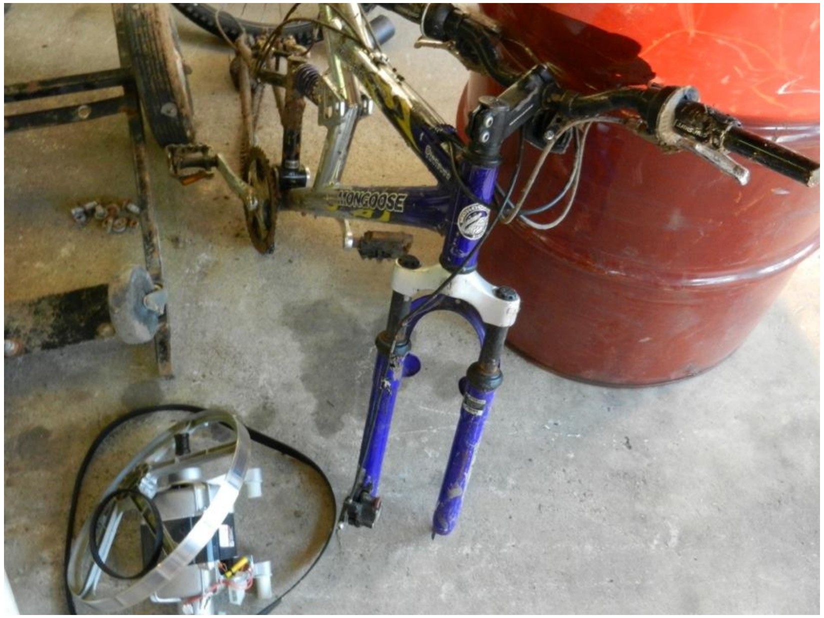
HAWT CAD MODEL



FINAL CONSTRUCTED HAWT

HAWT - Materials

- **Marpan Recycling**
  - Metals
    - Bicycles
    - Conduit Piping
    - AC Fans
    - Electric Exercise Bicycles
    - Washing Machines
    - Dynamos
    - Sheet Steel
    - 55 – Gallon Drum
  - Plastics
    - PVC Piping
- **Bicycle House**
  - Dynamos
  - Bicycle Wheels
  - Tires



HAWT – Energy Capture (Rotational Component)

- **Turbine Construction**
  - 8 in diameter PVC
  - Diameter to length ratio
    - 1:5
  - 42 in length PVC
- **Turbine Hub**
  - Angle of attack adjustment on blades
- **Connected via bicycle pedal axis**
  - Machined steel rod

HAWT – Energy Transfer (Gearing Assembly)

- **Eliminated Bicycle Chain and Sprocket**
  - Startup torque issue
- **Wheel Attached to Pedal Axis**
  - Machined steel rod
- **Wheel Diameters**
  - Tire = 27 in.
  - Dynamo = 0.75 in.

HAWT – Energy Conversion

- **Dynamo**
  - Spins on rubber tire
- **Reclaimed Bicycle Tensioner**
  - Spring loaded
  - Keeps pressure on dynamo
- **Dynamo Outputs AC**
  - Full wave rectification required

HAWT – Energy Storage (Battery)

- **Voltage Multiplier Circuit**
  - Provides full-wave rectification
  - Voltage doubler
  - Two zener diodes (AC to DC conversion)
    - One additional diode to prevent battery discharge into dynamo
  - Two capacitors
- **Voltage Production**
  - Must exceed 12.54V DC to charge automotive battery

HAWT – Severe Weather

- **Disengaging Wind Vane**
  - Manual high wind break-away system
  - Turns turbine out of wind direction
  - Extension spring and hinge combination

MHET – Theoretical Design Parameters

MHET POWER CAPABILITY

Power Coefficient Cp=0.35		
Velocity (mph)	**Velocity (m/s)**	**Mechanical Power (watts)**
1	0.45	0.37
2	0.89	2.86
3	1.34	9.75
4	1.79	23.24
5	2.24	45.55
6	2.68	78.01

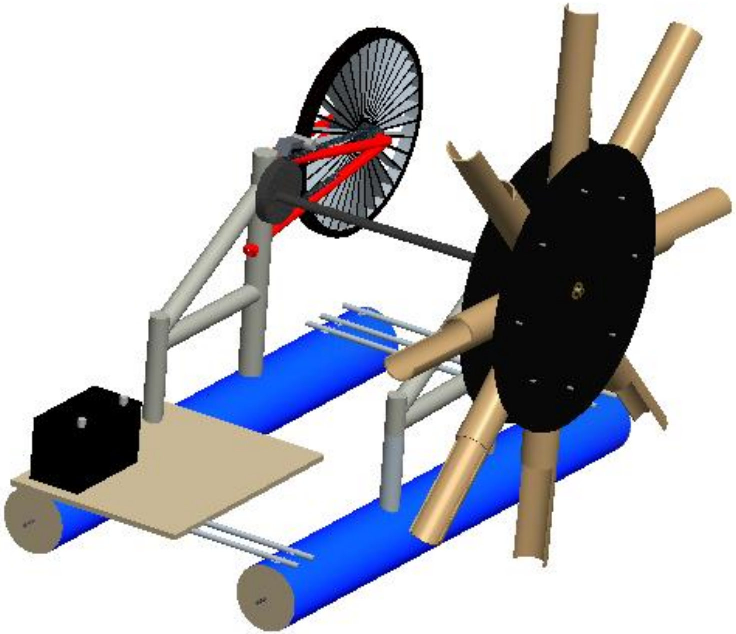
$$Mechanical\ Power = 0.5 * \rho * A * V^3 * Cp$$

MHET: THEORETICAL DESIGN

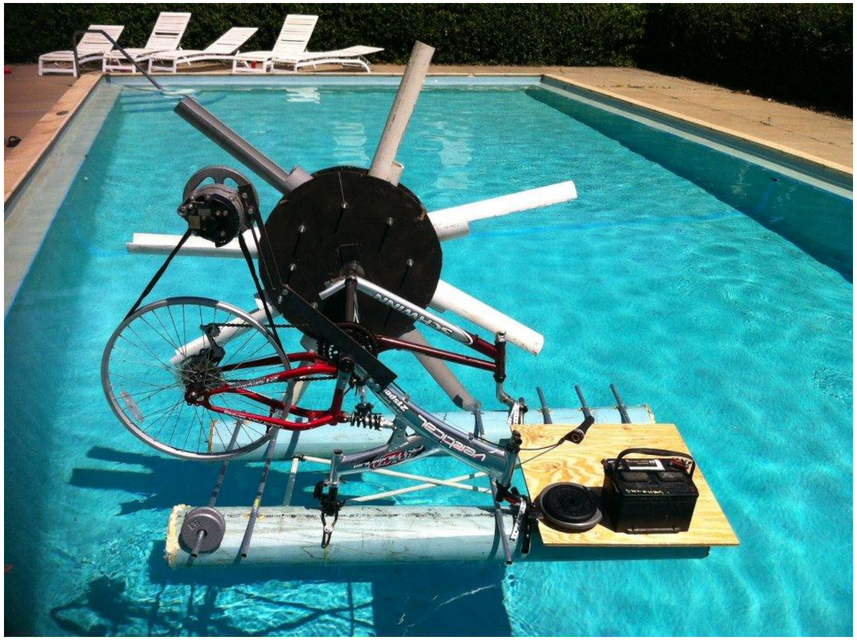
- **Paddle Wheel Dimensions**
  - 8 – blade design
  - Ensure two in contact with water at all times
- **Paddle Wheel Area**
  - Area = $0.0232 m^2$
  - Diameter = 1.33 m
- **Power Generated**
  - Gearing/pulley efficiency ~ 85%
  - Refurbished alternator efficiency ~ 80%
  - ~ 10 W
  - Flow velocity of 3 mph is adequate to produce 100 W•h/day

MHET – Final Design and Construction

MHET CAD MODEL



FINAL MHET CONSTRUCTION

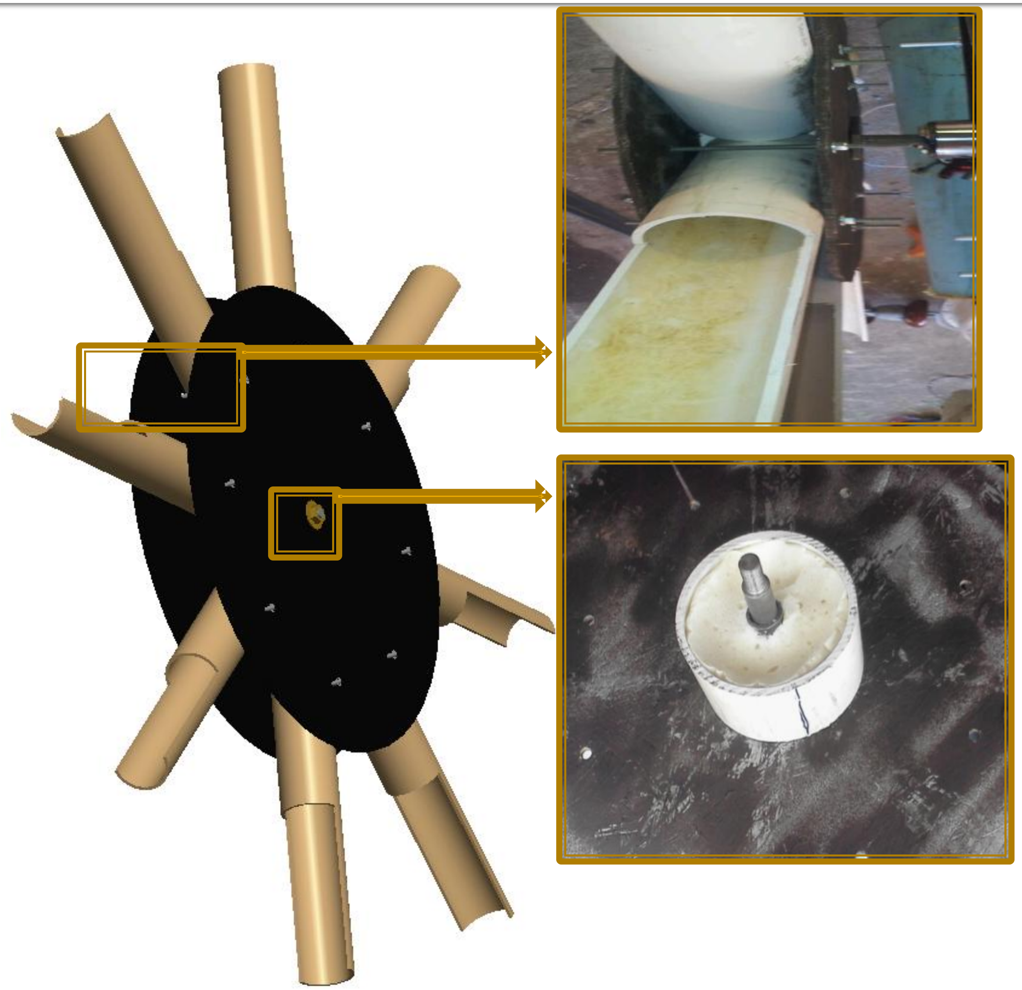


Materials

- **Marpan Recycling**
  - Metals
    - Bicycles
    - Conduit Piping
    - Electric Exercise Bicycles
    - Dynamos
    - Heavy Metal Equipment
  - Plastics
    - PVC Piping
  - Wood
    - Particle Board
    - Plywood
- **Home Depot**
  - Expanding Foam
- **Pick-n-Pull**
  - Automotive Battery

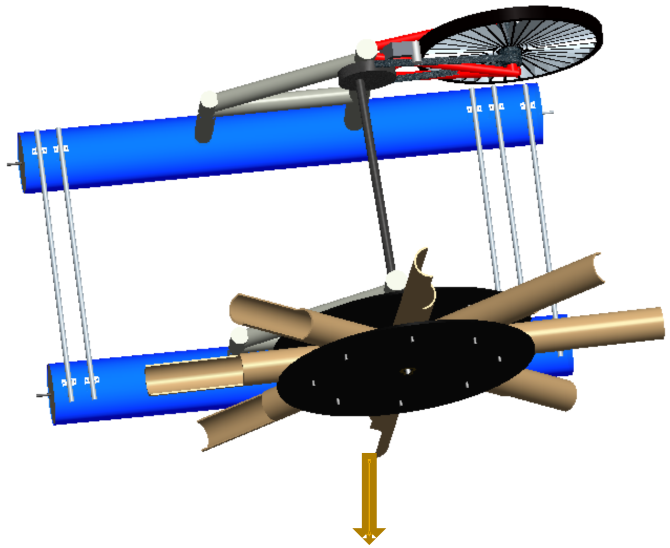
MHET – Energy Capture (Rotational Component)

- **Paddle Wheel Blades**
  - 8 blades of 4” PVC
    - *Substitute Timber Bamboo*
- **Particle Board**
  - Water sealant paint
- **Eight Pieces of All-thread**
  - Tighten individually to insure adequate pressure to hold paddles in place
- **Home-made Bushing**
  - Metal pipe surrounded by expanding foam in 6” PVC segment



MHET – Energy Transfer (Gearing Assembly)

- **Frame to Frame Energy Transfer**
  - Machined steel shaft
- **Center Sprocket to Rear Sprocket**
  - 3:1 gearing ratio
- **Wheel Diameter**
  - Tire = 24 in.
  - Dynamo = 0.75 in.



MHET – Energy Conversion

- **Dynamo**
  - Spins on rubber tire
  - Eliminated alternator
- **Dynamo Output in AC**
  - Rated for 12 V 6 W
- **Mounts on Bicycle Frame**

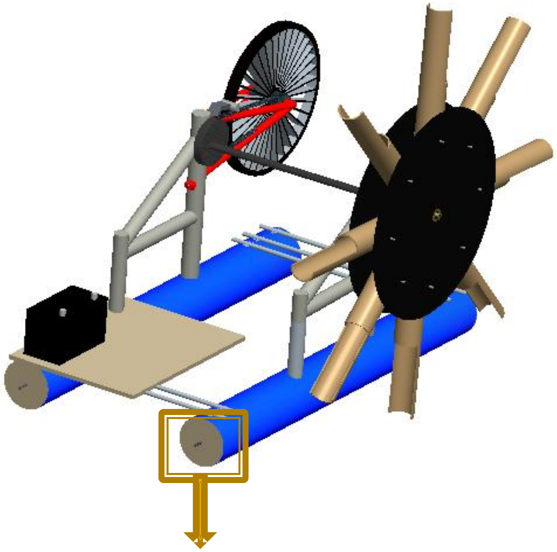
MHET – Energy Storage (Battery)

- **Voltage Multiplier Circuit**
  - Provides full-wave rectification
  - Voltage doubler
  - Two zener diodes (AC to DC conversion)
    - One additional diode to prevent battery discharge into dynamo
  - Capacitors (limit voltage ripple)
- **Voltage Production**
  - Must exceed 12.54V DC to charge automotive battery
- **Standard Automotive Battery**
  - Useful for balancing system

Zener Diode

MHET – Flotation Capability

- **Pontoons**
  - 9 in OD
  - Schedule 40 PVC
  - Cut two 64 in lengths
- **Sealing End Caps**
  - Particle board insert
  - Expanding foam
  - Plywood cap
    - Kept secure with all-thread
- **Gorilla Glue Sealing**



MHET – Stability and Strength

- **Steel Conduit Supports**
  - Across lengths
- **Bicycle Seats**
  - Attachment for frames to pontoons
- **Anchor**

Engineering Economics

HAWT		MHET	
Part	Cost (US $)	Part	Cost (US $)
Blades	0.27	Metal (Bicycle Assemblies/Steel Rods/etc.)	12.75
Hub	0.30	Wood	0.00
Bicylce assembly (Wind Vane)	3.15	U straps	2.00
Fasteners	3.50	PVC	1.50
Mount	1.65	Foam	4.00
Dynamo	15.00	Wires/diodes/capacitors	5.50
Wires/diodes/capacitors	5.50	Fasteners	6.00
Battery	19.97	Gorilla Glue	1.00
		Dynamo	15.00
		Battery	19.97
Total	49.34	Total	67.72

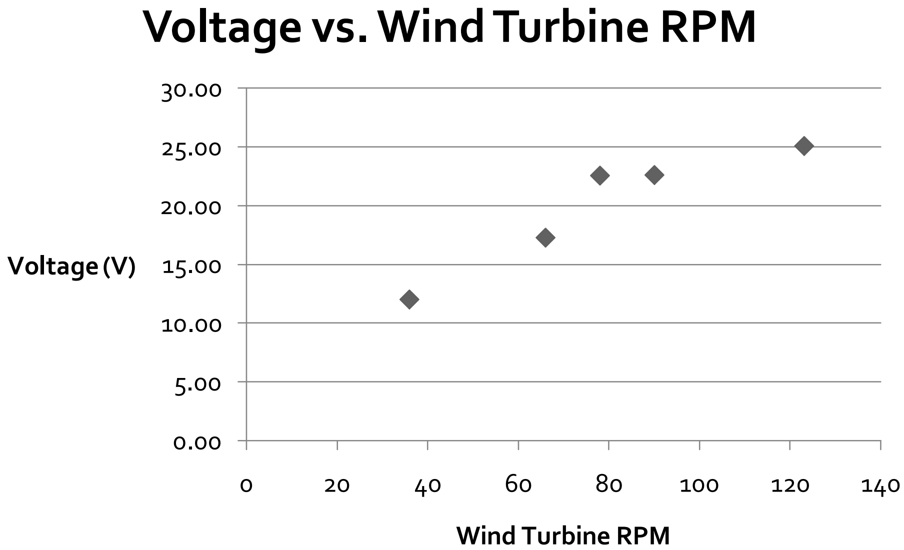
Results and Discussions (HAWT)

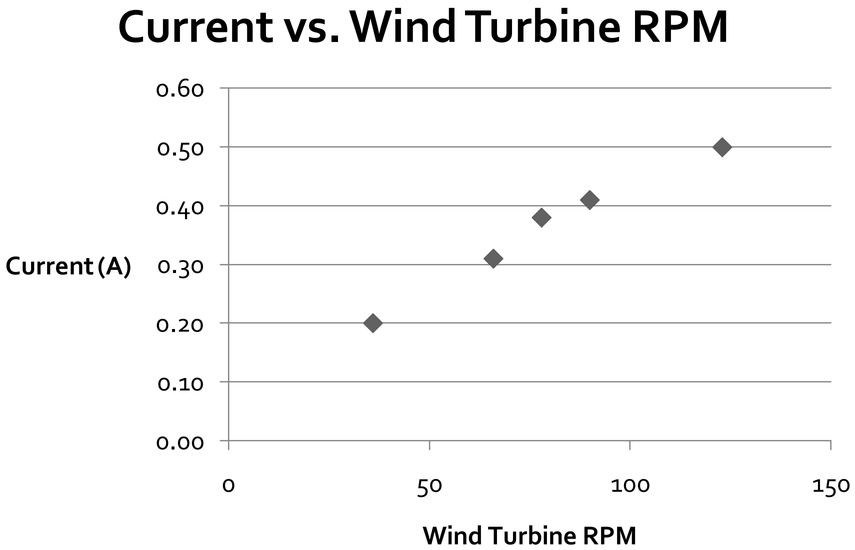
- **Dynamo Signal Output**
  - Bicycle wheel rotation at controlled RPM
    - Metronome
    - Two multi-meters (DC Voltage, DC Current)
- **Wind Speed Test**
  - Assembled HAWT in truck
    - Recorded turbine RPM at various wind speeds

Wind Speed (m/s)	Wind turbine Rotational Speed (RPM)	Dynamo Rotational Speed (RPM)	Power Output (W)	Voltage (V)	Current (A)
2.20	36	1296	2.41	12.04	0.20
4.00	66	2376	5.35	17.30	0.31
5.00	78	2808	8.62	22.58	0.38
6.00	90	3240	9.23	22.63	0.41
8.00	123	4428	12.55	25.10	0.50

Results and Discussions (HAWT)

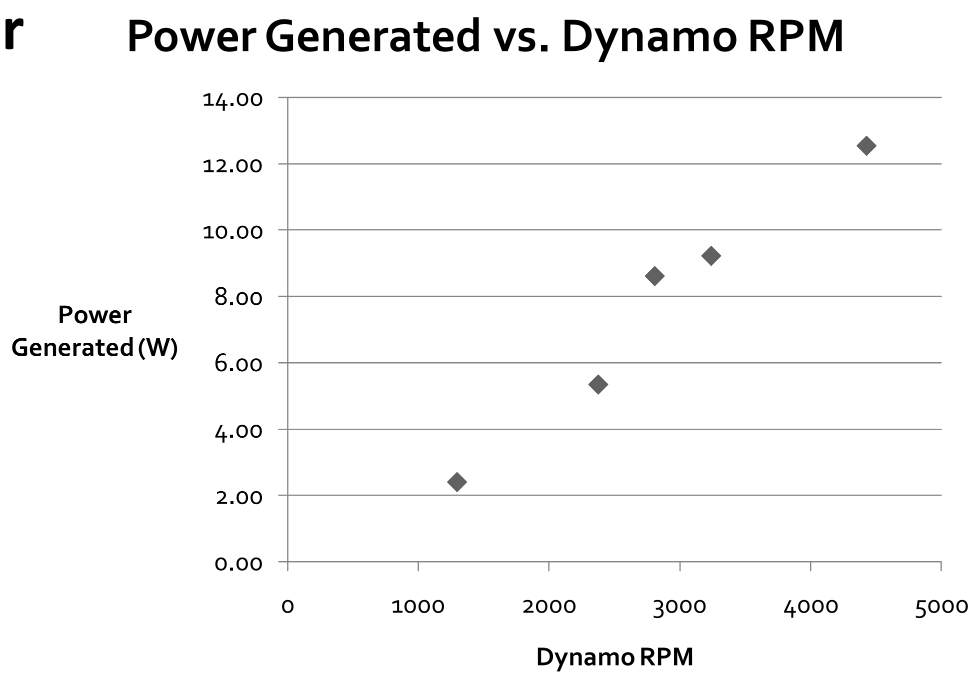
Wind Speed (m/s)	Power Generated (W)	Time Required for 100 W•h (hours)
2.20	2.41	41.53
4.00	5.35	18.69
5.00	8.62	11.60
6.00	9.23	10.83
8.00	12.55	7.97





Results and Discussions (MHET)

- **Minimum Required Water Speed**
  - 24-hour constant output
  - 4.17 W required
    - 1.56 m/s
    - 3.48 mph
- **Turbine Efficiency**
  - 0.80



Conclusions

- **HAWT**
  - Meets power requirements
    - Capable of generating more power than required
  - Meets cost requirement
    - May be reduced through mass production and volume cost of materials
  - Sustains severe weather
  - Lightweight and robust
- **MHET**
  - Meets power requirements
  - Uncertainty in cost
    - May be reduced through mass production and volume cost of materials
  - Sustains severe weather
    - May require additional attachment to land
    - Additional ballast

Questions?