Final Progress Report: Harnessing Wind Energy with Kites

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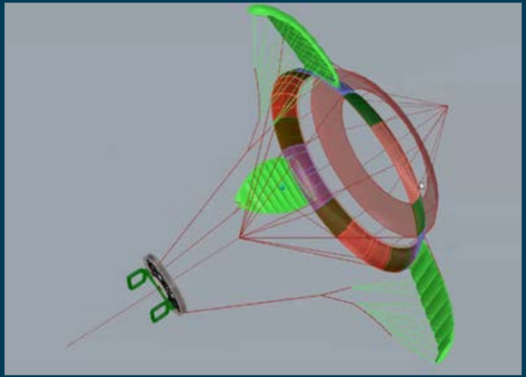
Motivations

- Renewable resource
- Coastal disaster relief
- Energy access
- Affordability



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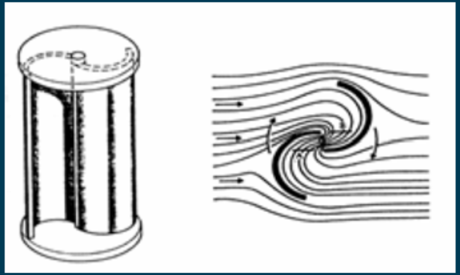

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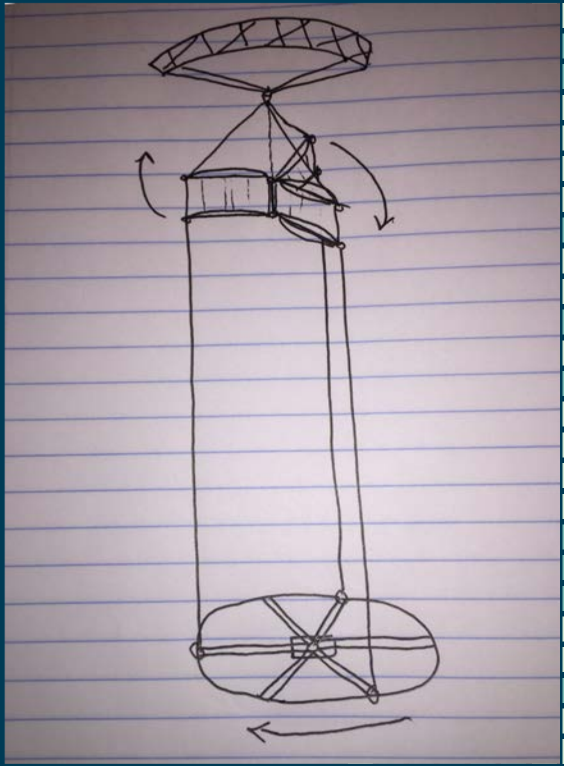
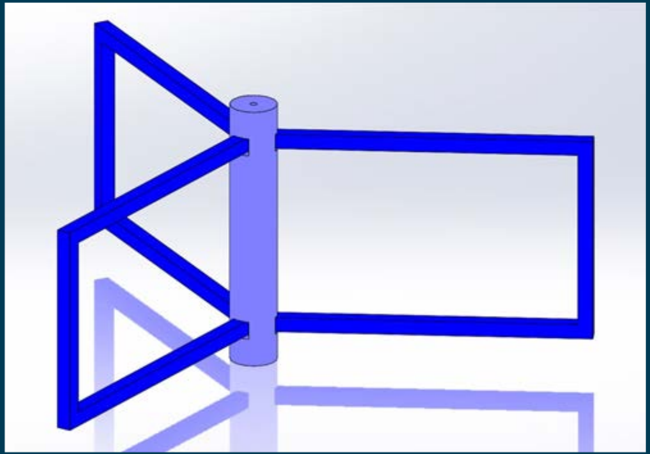
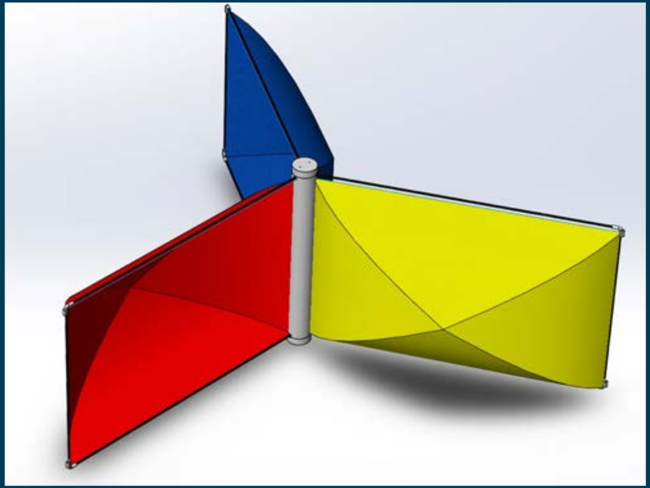


BIG CONCEPT





Sample Calculation: Energy

- Wind is perpendicular to the plane of the kite arm
- Kite area is roughly 1.5 m wide by 1 m tall
- Coefficient of drag: 1.28 (from NASA)
- Around a storm event, wind speed can be ~ 10 m/s
- Tip-Speed Ratio is 1

$$P_{Gen} = T\omega$$
$$= F_D * R_{Arm} * \omega$$
$$= F_D * R_{Arm} * \frac{V_{wind}}{R_{rotor}}$$
$$= (\tfrac{1}{2}\rho_{air} V^2_{wind} A_{rotor} * C_D) * R_{Arm} * \frac{V_{wind}}{R_{rotor}}$$
$$= \boxed{586.32 \text{ Watts}}$$

Sample Calculation: Energy

- Sanity Check: Use Betz's Limit
- Kite is roughly 54% efficient!

$$P_{Max} = \frac{16}{27}\rho r_{rotor} h v^3$$
$$= \frac{16}{27}(1.213\ kg/m^3 * (10\ m/s)^3 * 2 * 1)$$
$$= \boxed{1085.78 \text{ Watts}}$$

Prototype Analysis: Fan and Pump Laws

$$\frac{P_1}{\rho\omega_1^3 D_1^5} = \frac{P_2}{\rho\omega_2^3 D_2^5}$$

$$\frac{P}{\rho\omega^3 D^5} = g\left(\frac{Q}{\omega D^3}, \frac{\rho D^2 \omega}{\mu}\right)$$

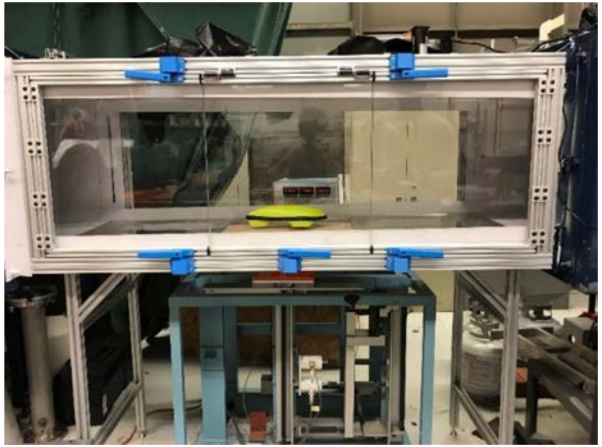
Wind tunnel analysis with 3D printed models

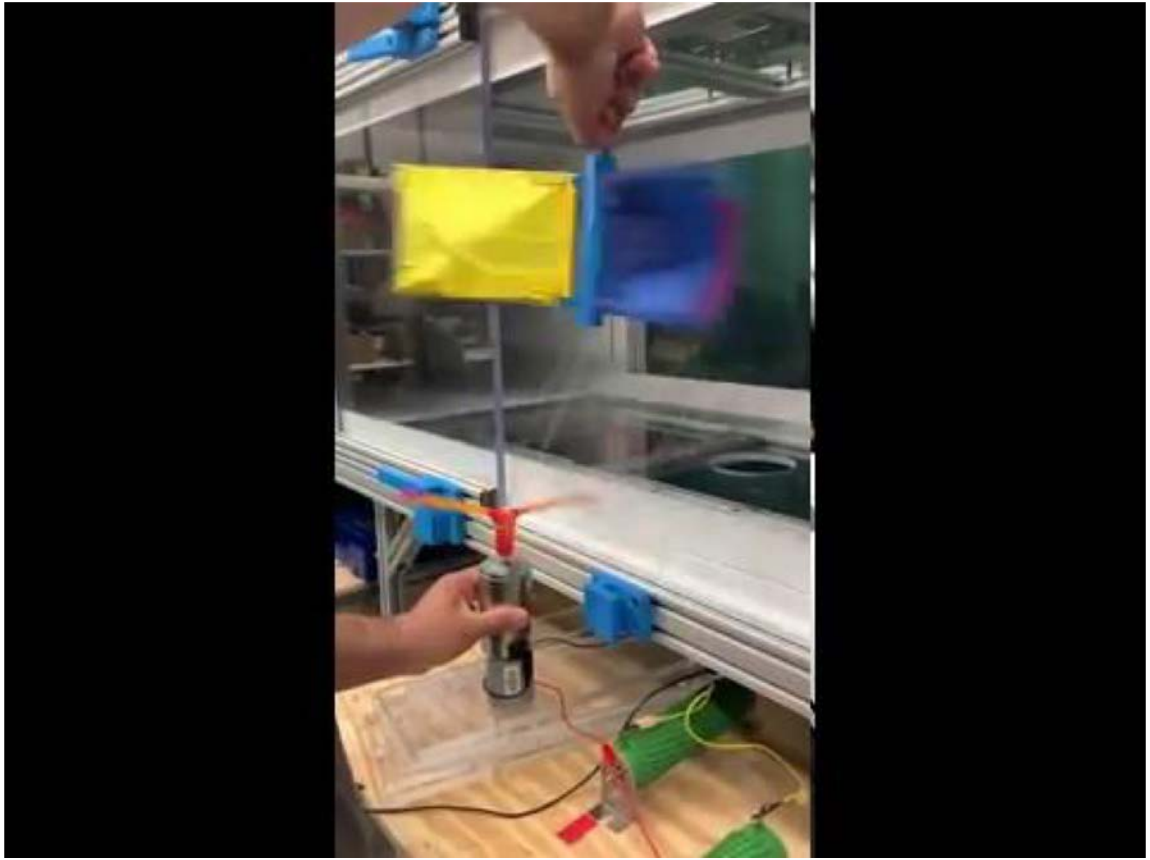
Power laws and scaling factors for comparison

Models must have an equal flow coefficient

Test Procedure

Change wind speed and resistance values
Diameter (by model)
Angular velocity (from laser tachometer)
Power (by extrapolating motor data)





Test Results

Assumption of Tip-Speed Ratio being 1 is correct (data shows 0.95-1.00 for several tests)

Efficiency at varying wind speeds is on average 50-60%.

Voltage values change on a smaller scale

Future Considerations

- Stronger wire frame, different shape
  - Pockets collapsed and stalled the turbine
- Two-Vane system
  - Could more effectively prevent stalling
- Easier way to connect tethers
  - More concrete base plan

Environmental Benefit Analysis

- Carbon offset
- Operating area

Carbon Offset: Replacing Generators

assuming model produces average power of 586 W

143

g CO_2 saved per hour compared to burning gasoline (without ethanol)

146

g CO_2 saved per hour compared to burning diesel

Carbon Offset: Broader Electricity

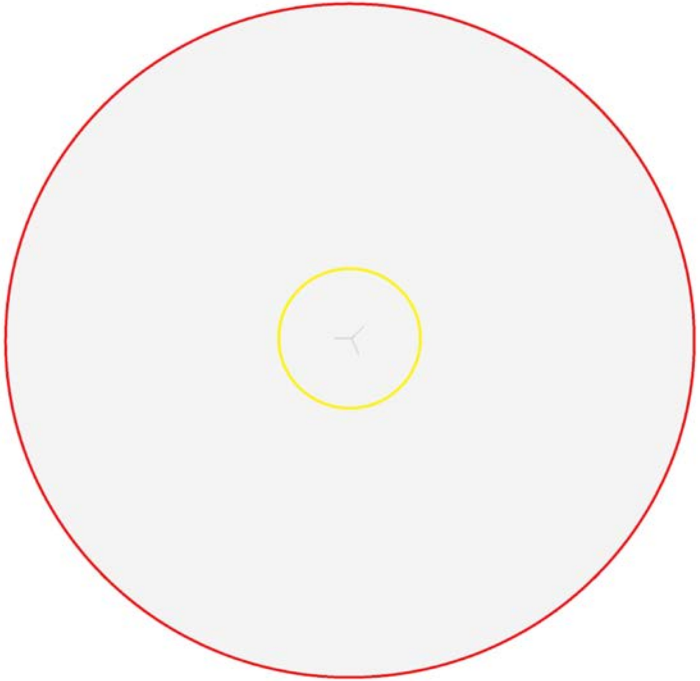
assuming model produces average power of 586 W

106

g CO_2 saved per hour compared to burning natural gas

195

g CO_2 saved per hour compared to burning coal (lignite)



88 to 98 percent less operating area per model than an industrial wind turbine

compared to GE 1.5sle, depending on terrain

Social Benefits

Health

Safety

Empowerment

One kW of wind energy replaces:

Small room heater

Mini-fridge or ice-maker

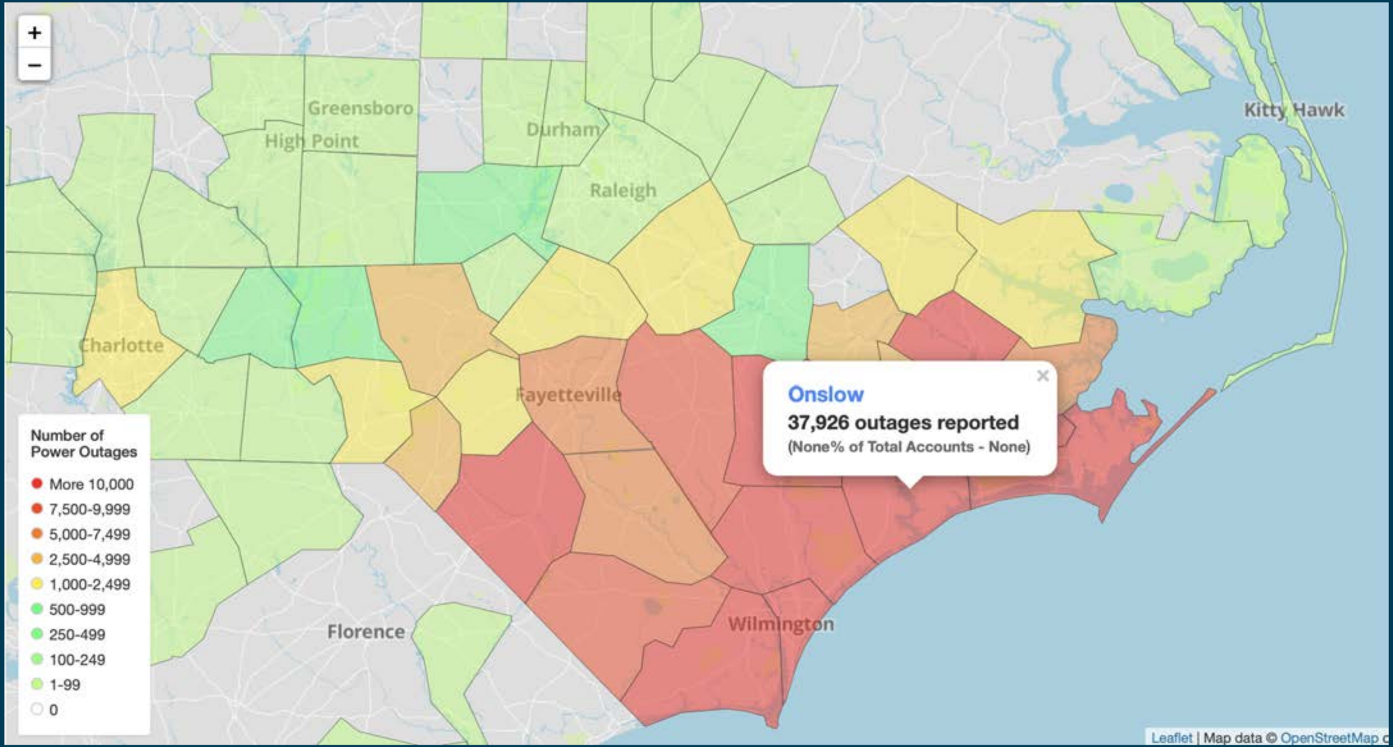
Electric stovetop

What will our target market look like?

Wind

Wind, waves and weather for kitesurfers, windsurfers, surfers and sailors
Petersburg
Norfolk
Greensboro
Durham
Raleigh
Kitty Hawk
Fayetteville
Florence
302
mph
61
59
54
49
45
40
36
31
26
22
17
13
8
3
0
CLOSE ✕
LAT: 34.8138 LON: -76.5417
DIRECTION
354° (N)
SPEED
13mph
Model: GFS
Last update: 5:50 AM
Next update: 11:50 AM local time
7AM
10AM
1PM
4PM
7PM
10PM
+3h
Tue, 3/5
3/6
3/7
3/8
3/9
3/10
3/11
3/12

Demand



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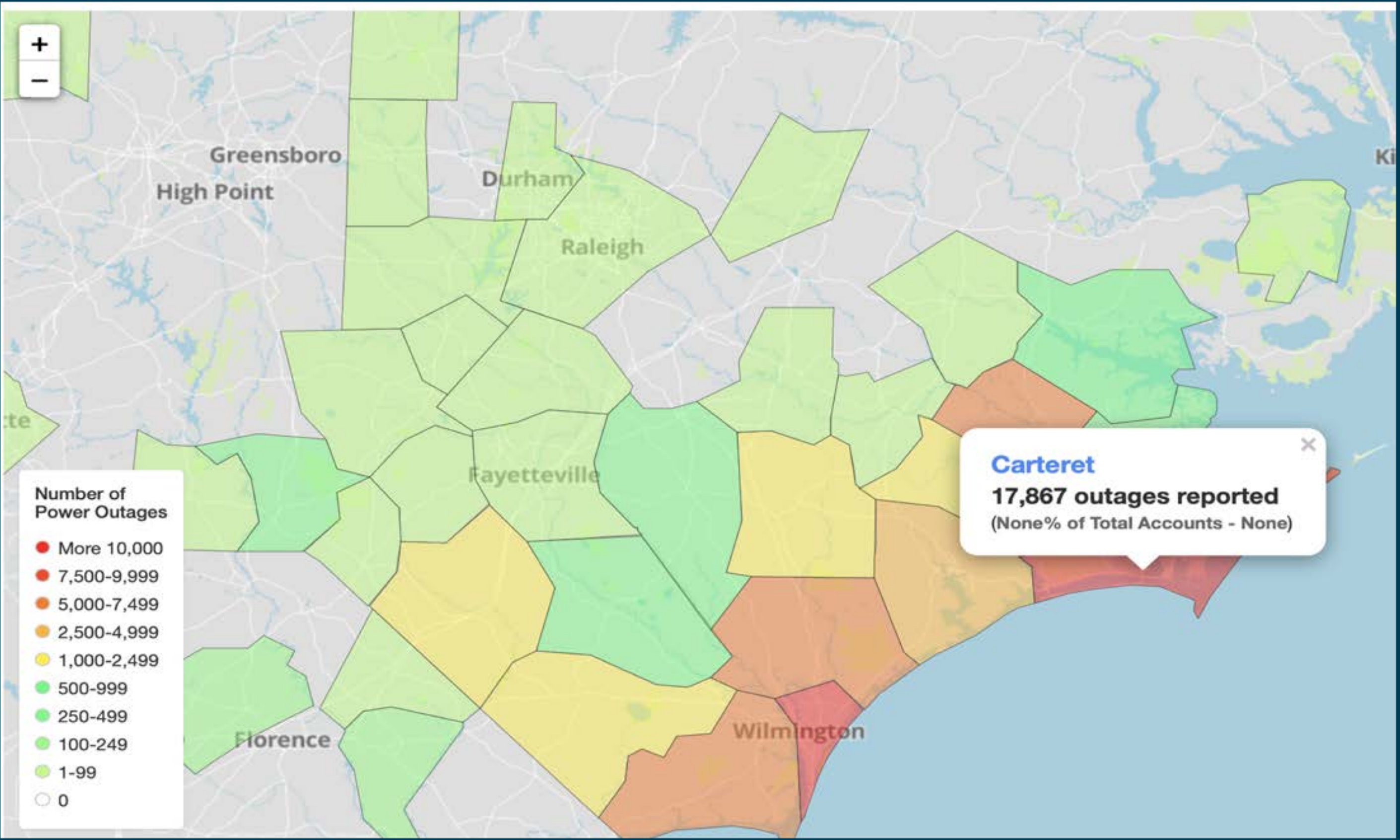
Greensboro
High Point
Durham
Raleigh
Kitty Hawk
Charlotte
Fayetteville
Onslow
37,926 outages reported
(None% of Total Accounts - None)
Number of Power Outages
More 10,000
7,500-9,999
5,000-7,499
2,500-4,999
1,000-2,499
500-999
250-499
100-249
1-99
0
Florence
Wilmington
Leaflet | Map data © OpenStreetMap

Demand



Greensboro
High Point
Durham
Raleigh
Fayetteville
Florence
Wilmington
Carteret
17,867 outages reported
(None% of Total Accounts - None)
Number of Power Outages
More 10,000
7,500-9,999
5,000-7,499
2,500-4,999
1,000-2,499
500-999
250-499
100-249
1-99
0

Storm Statistics

- Climate change amplifying storms: need for disaster-mitigation strategies
- Hurricane Florence caused an estimated $28.1 million in residential damages
- Duke Energy sent 20,000 employees across the state to restore power
- 670,000 people remained without power 4 days later
- Most vulnerable: ***hard-hit, coastal areas***

Target Market Analysis

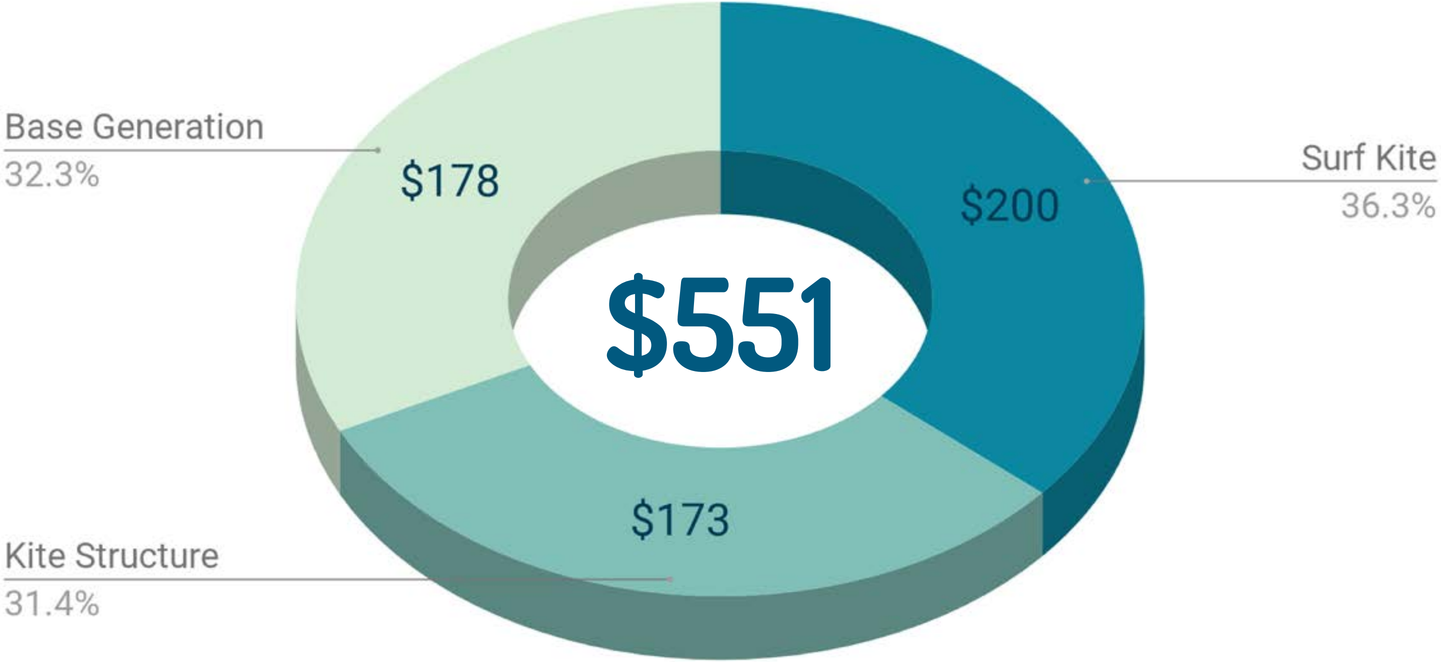
- *Demand*: Blackouts caused by hurricane damage
- *Solution*: Temporary power supply via wind kite

Business Plan

Basic Business Plan

- Cost of materials and manufacturing
- 20 regulations in North Carolina
- 18 financial incentives in North Carolina
- Revenue from advertising space on kites
- Cutting costs

Project Budget



Feasibility

- Cost of materials
- Replacement of kites and materials
- Land use
- Generator

Summary and Final Remarks

Low-cost energy system
Natural disaster relief
75% prototype in the making
Feasible design, but not perfect (yet)

Questions?