Sonsight Long Blade 3.5kW Prototype Turbine

Sonsight Wind
Long-Blade Small Turbines

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Problem

- Due to economies of scale (in this case size, not number) generally the larger the turbine the lower the LCOE
  - Basically, no small turbines under ~12 kW with LCOE less than ~ $0.18/kWh
  - Many more potential customers for these than for larger turbines

Energy generated here at ~$0.03/kWh

Electricity costs $0.21/kWh here
(Wigton Wind Farm in Manchester, Jamaica)

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One solution is longer blades, but…

- Longer blades typically mean more massive and costly turbines
  - They need lower RPMs (to prevent increased TSR), and power delivery at lower RPMs require more massive and costly generators
- They typically require more massive and costly towers and foundations
  - Longer blades increase thrust unless rpm is kept low
  - more thrust means more tower and foundation costs
- They require more powerful and/or more sophisticated over-speed control
  - For generator induced stall control this typically also requires more massive and costly generators
- Hard to decrease LCOE via longer blades if there are significantly higher associated costs

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Our Path to Developing a Long Blade 3.5kW Turbine with Relatively Low LCOE

- Develop low RPM, low-mass, low-cost generator
  - Needed to generate rated power at the lower RPMs of the longer blades without significantly increasing turbine mass or cost
  - Needed to maintain low RPMs for low thrust to maintain low tower, foundation and installation costs
  - Need strong generator for over-speed control via generator induced stall
- Develop a 3.5kW turbine around the generator that has the swept area of a 5kW turbine but the mass and cost and thrust of a 3kW turbine
  - Develop a precise control system that maximizes energy output within the low RPM constraints and provides robust overspeed control
- Easier to first develop a grid-tie turbine (battery charging later)

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Prototype Generators (Presently using a 6kW)

- Segmented stator comprised of individual stator modules
  - allow cost-effective high-torque low-RPM ring layout (i.e. less copper, electrical steel & magnets)
  - easier coil fixturing
- Novel low-cog teeth design facilitates segmented stator (no stator skewing)
- Encapsulated stator for reliability and better thermal conductivity
- Light weight support structure
- Low RPM **&** Low Mass

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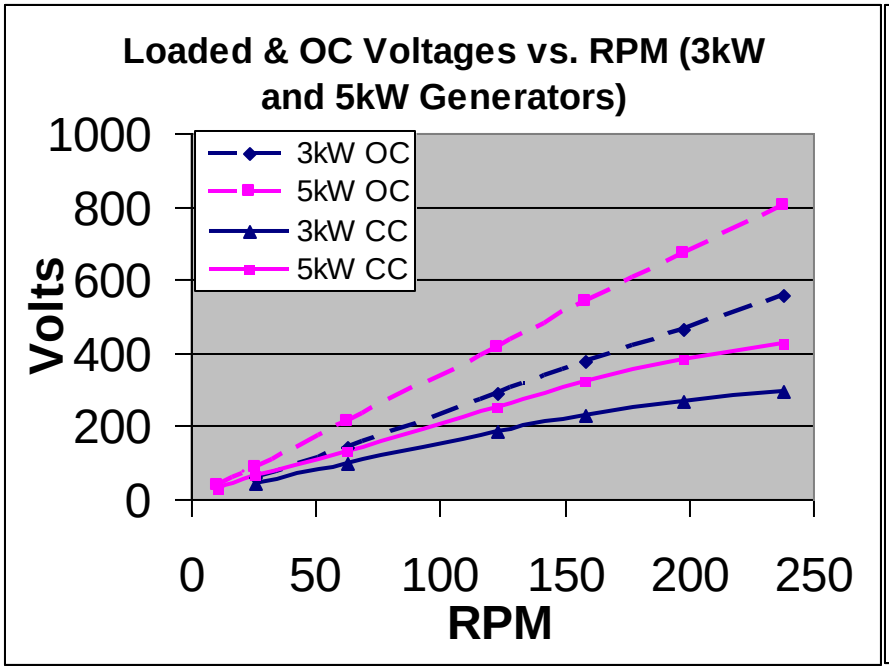
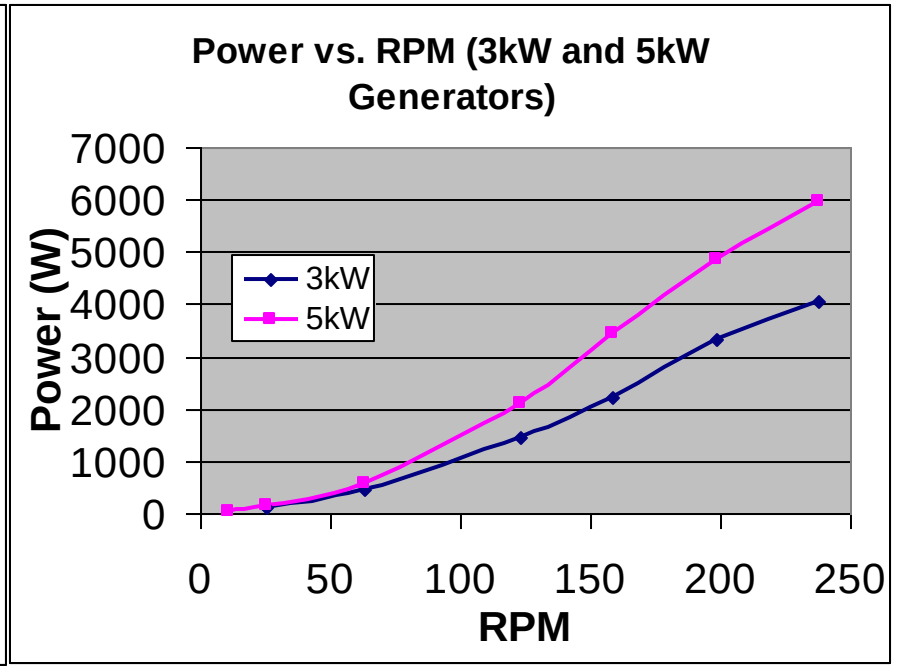
Prototype Generators (Currently using a 6kW)

	3kW			5kW		
	Sonsight	Others	% Diff	Sonsight	Others	% Diff
RPM	200	~250-300	38	200	~200-260	15
Weight (lbs)	146	~170-210	30	182	~310-350	81





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Initial Approach for 1st Prototype Turbines

- Aerodynamically efficient blades like the ARE110 designed for easy low-wind startup
- Tail furl like the ARE110
  - Simple low-cost overspeed control
- Simple turbine head structure like the ARE110
  - Exposed generator externally attached to yaw structure – low cost

- Commercial grid-tie wind inverter with MPPT and simple interface box-type controller with relay trigger for shorting generator to prevent over-voltage
- **The big improvement** - SS Gen allow using long blades for more energy in moderate winds for lower LCOE (i.e. longer blades require lower RPM)
- **The big idea** – low-cost ~3kW turbine with energy generation, thrust and mass like a 5kW

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Early Prototype Turbines

- Designed and built the 5m Dia blade rotor
- Paired with a SS 5kW generator
- Skystream Tower (all prototypes)
- Field tested in Frederick County MD
- But…
  - Overspeed control via furling very tricky and inconsistent
  - Somewhat noisy and expensive blades

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Early Prototype Turbines

- Switch to Imported blades
  - Lower cost for lower LCOE
  - Very quiet
- Improved frame and tail
- Control / Furling issues
- Simple Controller (no data processing)
- Carlos Fernandez-Bueno – provided site
- Funding via USDA

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Carlos Site (Frederick Co, MD)

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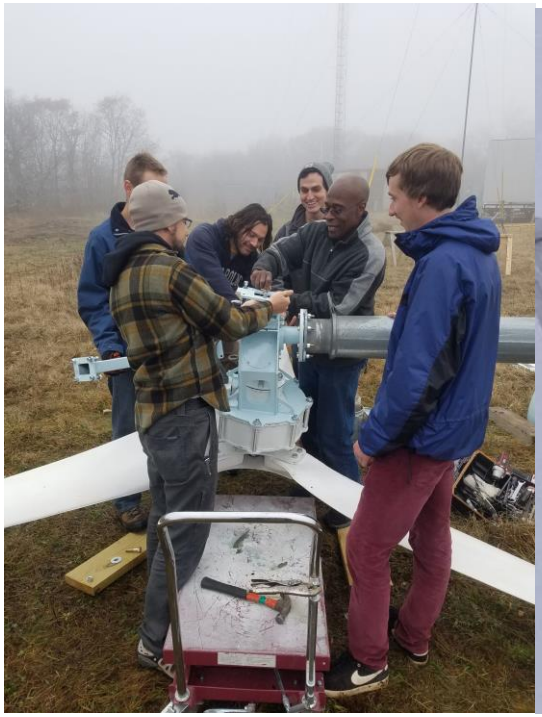
Prototype With Furl Sensor (Furl ➡ Stall)

- First field testing at Beech Mtn (with Brent Summerville and his grad students from ASU)
- Improved frame and tail
- Furl Sensor but still furl issues
- Saw need to transition to away from furling
- Saw need for adapting solar inverter & developing MPPT within controller
- Eventually migrated to microcontroller
- First of several CIP contracts via NREL



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Beech Mtn Site (Beech Mtn, NC)

- Previously administered by Apalachin State University
- Only the Sonsight turbine remains

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Present Prototype (Blade Stall)

- Continued testing at Beech Mtn
- Upgraded generator
- Updated, enclosed nacelle with electrical load and relays
- Software centered controller with MPPT and braking
- Adapted solar inverter

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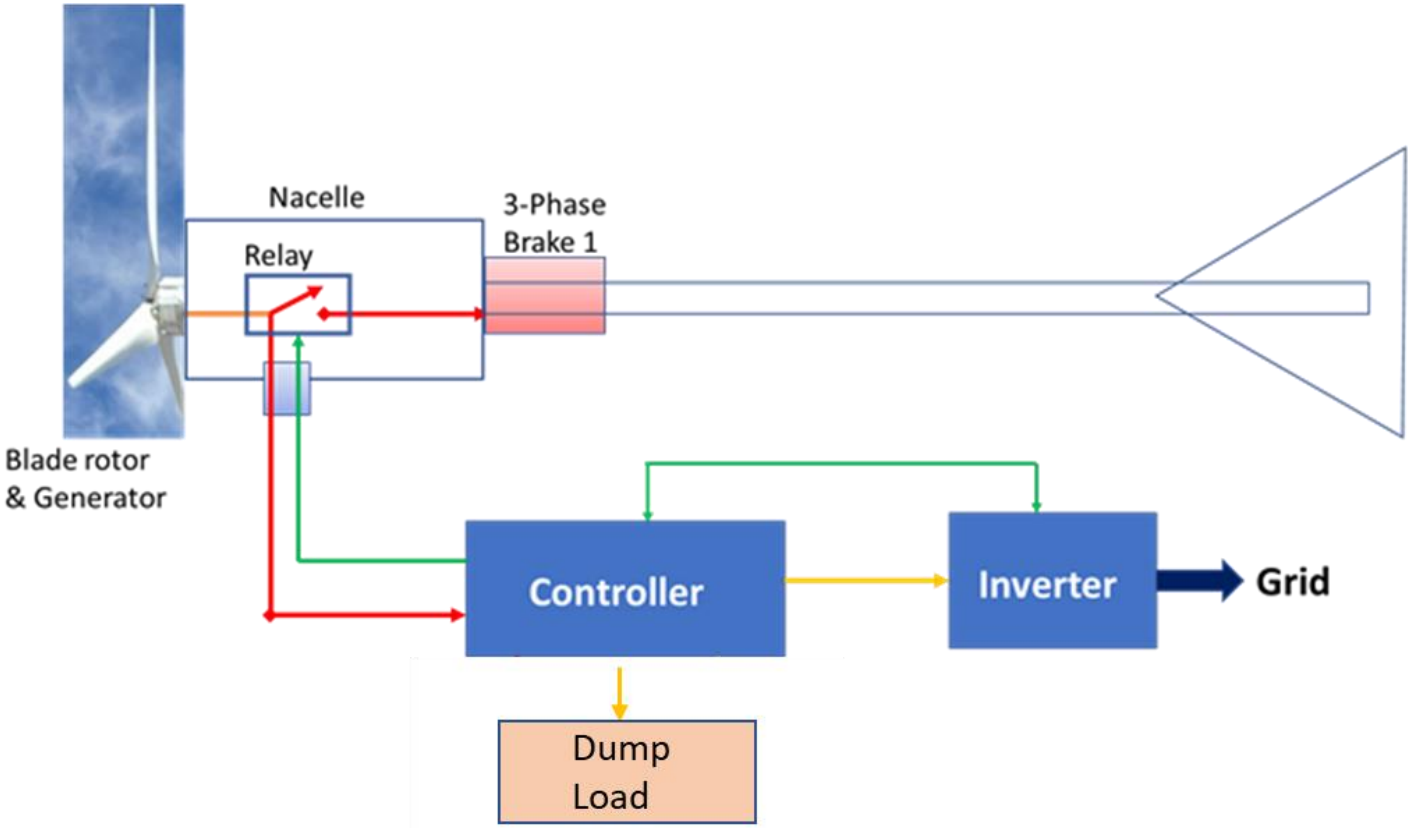
Present Prototype (Blade Stall)



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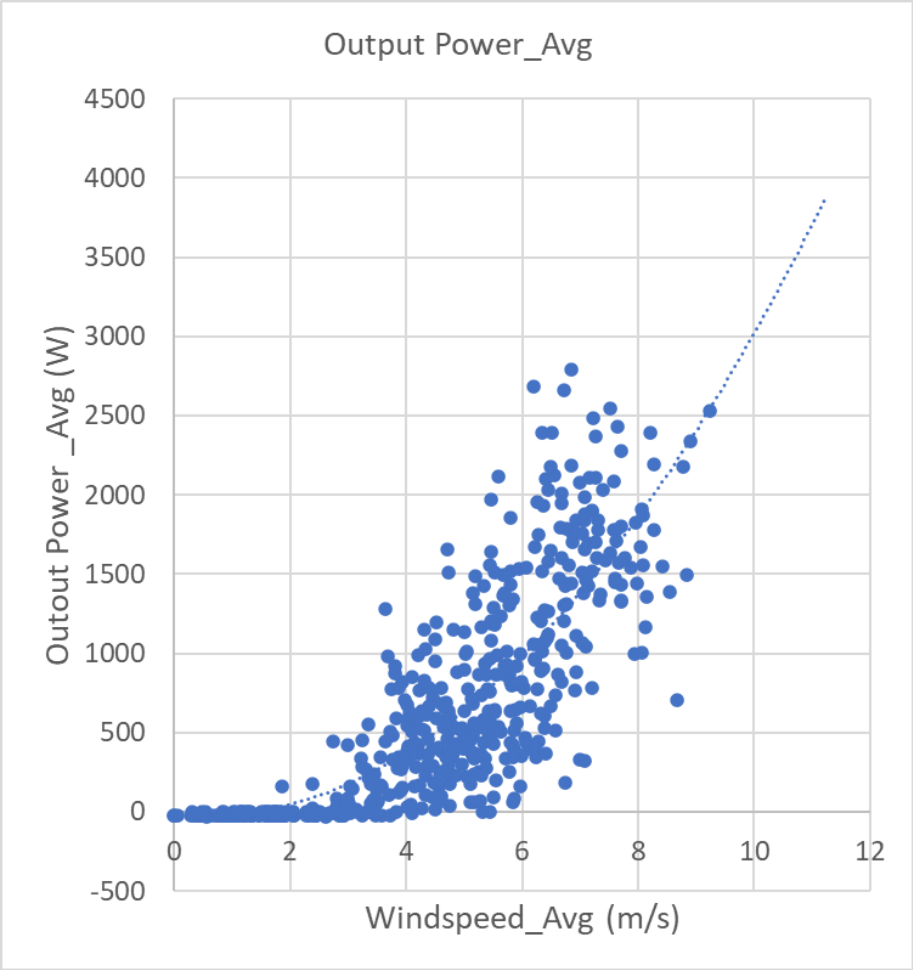
Present Prototype (Blade Stall)

- Results from early this year
- Here, roughly 3kW @ 10m/s
- But still improving power curve



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Present Prototype 2.0 (Blade Stall)

- Larger Tailfin
- Improved power curves

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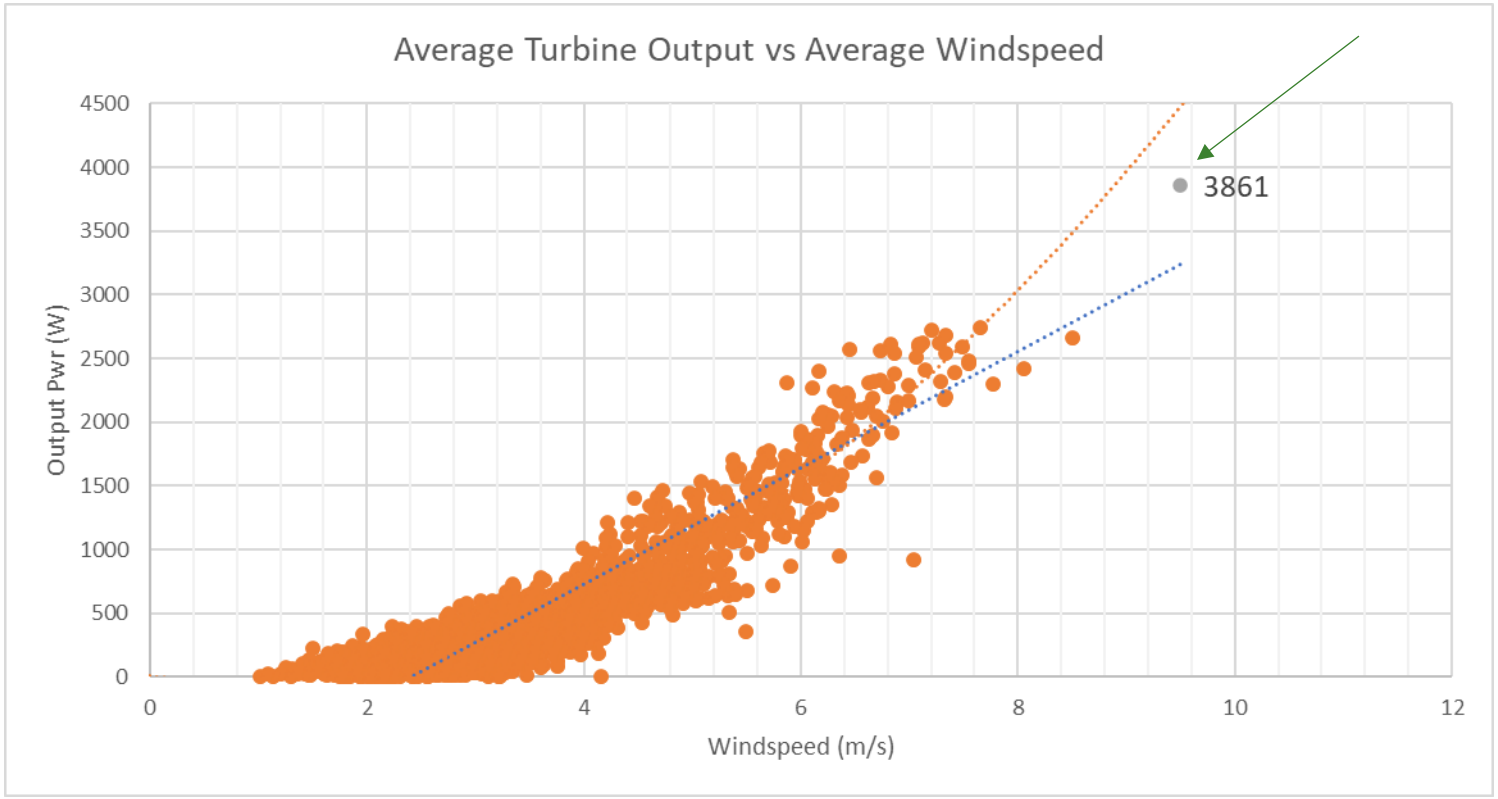
Present Prototype (Blade Stall)

- Results from earlier this month with adjusted power curves
- Only low winds available, but 3.5kW @ 9.5m/s looks promising

3.86kW @ 9.5m/s



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Present Prototype (Projected Specs)

Sonsight 3.5kW Turbine Specs	
Rotor Diameter (m)	5
Number of Blades	3
Rated Power (kW) *	3.5
Max Power (KW) *	4.2
Rated Windspeed (m/s) *	9.5
Max (Survival) Windspeed (m/s) *	53
Cut-in Windspeed (m/s) *	2.5
Cutout Windspeed (m/s) *	21
RPM at Rated Windspeed (1/min) *	168
Max Thrust Force (N)	670
Turbine Mass (kg)	180
Generator Mass (kg)	91
Gen Power @ 200 RPM (kW)	6.2
Generator type	PM, 3-Phase
Overspeed Regulation	Blade Stall via E-Brake
Blade Material	FRP

* Projected

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For a Site With 6m/s Avg Windspeed @ 30m (Standard NREL LCOE Calc Assumption)

Projected Values

	30m Hub Height	20m Hub Height	15m Hub Height
Windspeed (m/s)	6	5.4	5
Gross AEP (kWh/yr)	15,023	13,207	11,846
Turbine Cost (includes Controller & Inverter) ($)	11,305	11,305	11,305
Installed Cost ($)	24,638	20,138	18,138
LCOE (98% Availability) ($/kWh)	0.13	0.12	0.12

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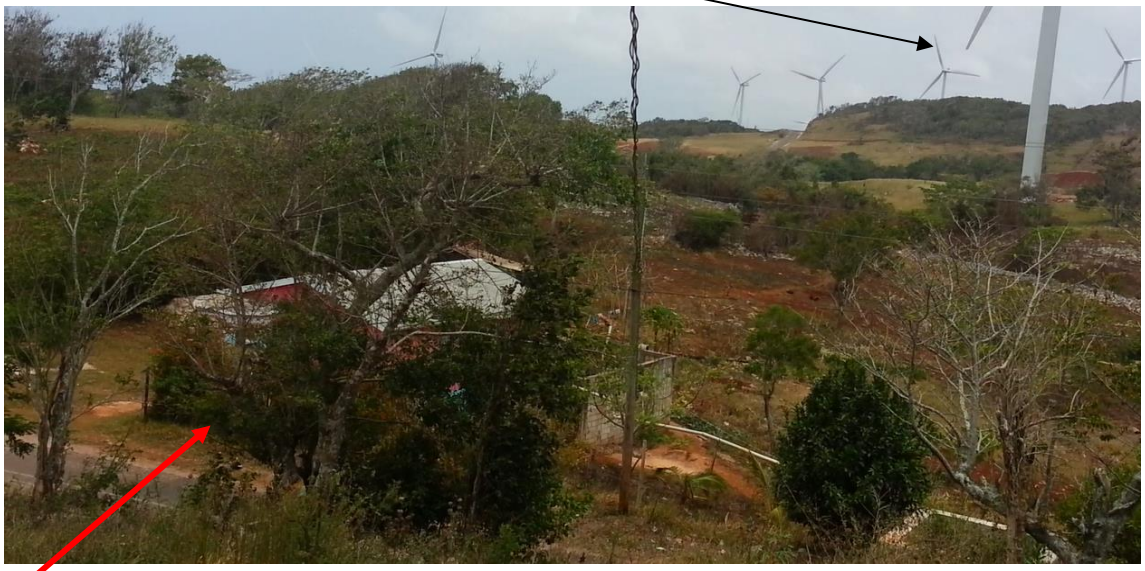
A New Option

- Sonsight 3.5kW Turbine: $0.12/kWh

Energy generated here at ~$0.03/kWh



Electricity costs $0.21/kWh here
(Wigton Wind Farm in Manchester, Jamaica)

- Rooftop Solar (Residential): $0.147 to $0.221 per kWh *
- Rooftop Solar (Commercial & Industrial): $0.067 to $0.180 per kWh *

* Statista (2021), Lazard (2021)

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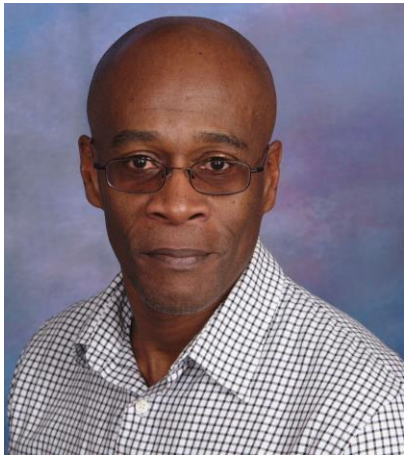
Commercialization

- Expect to begin certification testing and start commercially producing the SS3 by end of 4th Qtr next year
- Will be looking for partners to help market, distribute and install the turbines

Theresa James,
Operations Assist

Francisco Rivera,
Tech Assist



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