VAWT Ventures Final Presentation

Design of a Vertical Axis Wind Turbine for Rooftop Applications

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April 24th, 2026

Honda Research Institute

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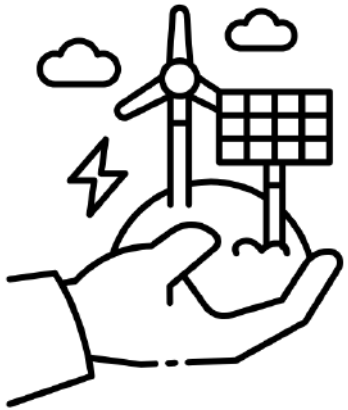
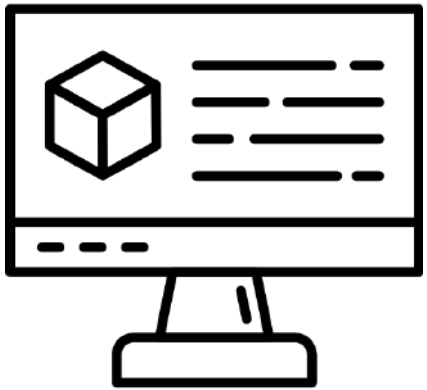
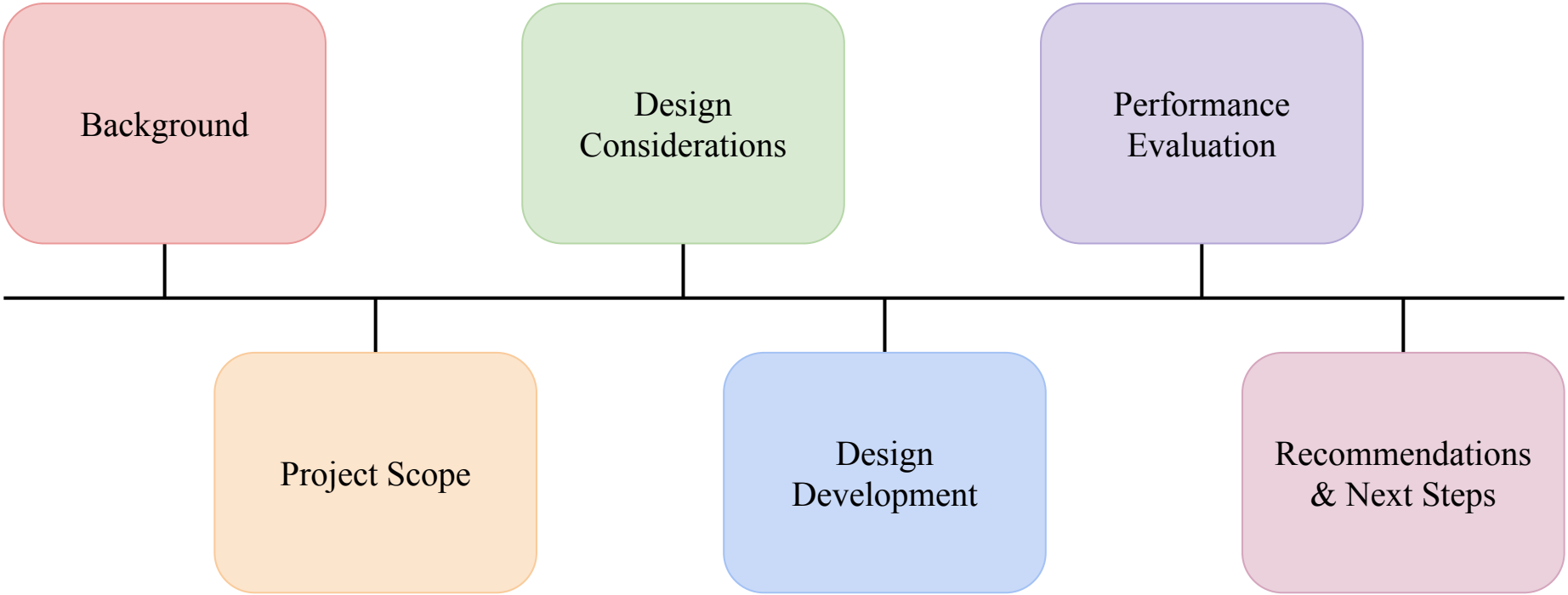


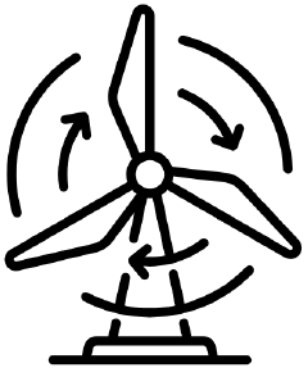


Presentation Overview



Background

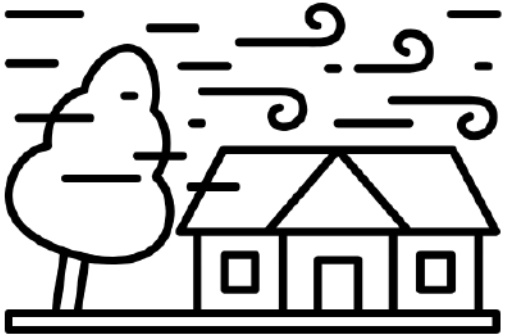
Horizontal Axis Wind Turbines (HAWTs)



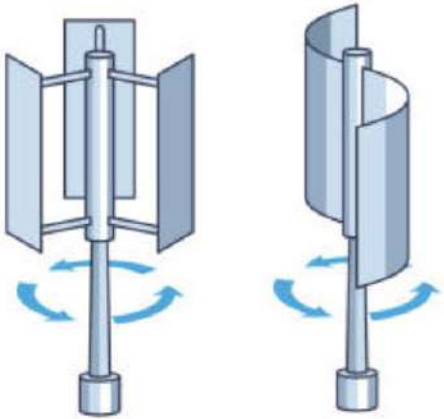
- Steady wind conditions
- Large wind farms

Urban Airflow

- High turbulence
- Changes in direction
- Lower wind speeds



Vertical Axis Wind Turbines (VAWTs)

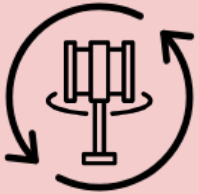


- Omnidirectional
- Lower cut-in speed

Technical Parameters

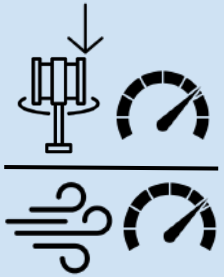
Cut-in Speed

The speed at which a turbine starts rotating



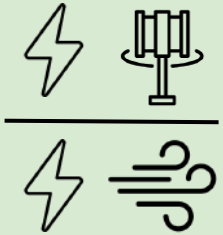
Tip Speed Ratio (TSR)

Ratio between the blade tip speed and the wind speed



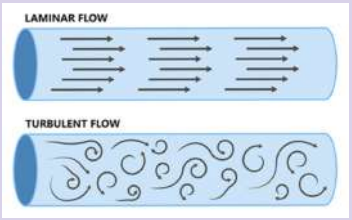
Coefficient of Power (C_P)

Ratio between turbine output power and power available in the wind



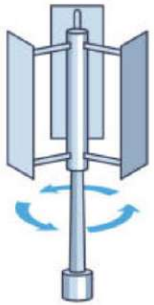
Reynolds Number (Re)

Ratio between inertial and viscous forces in fluid flow

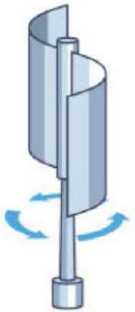


VAWT Geometry

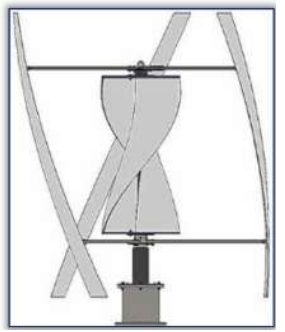
Darrieus
(Lift Based)



Savonius
(Drag Based)



Hybrid
(Combination)



- \+ Higher C_P in high wind speeds
- − Often cannot self start
- \+ Low cut-in speed
- − Low C_P

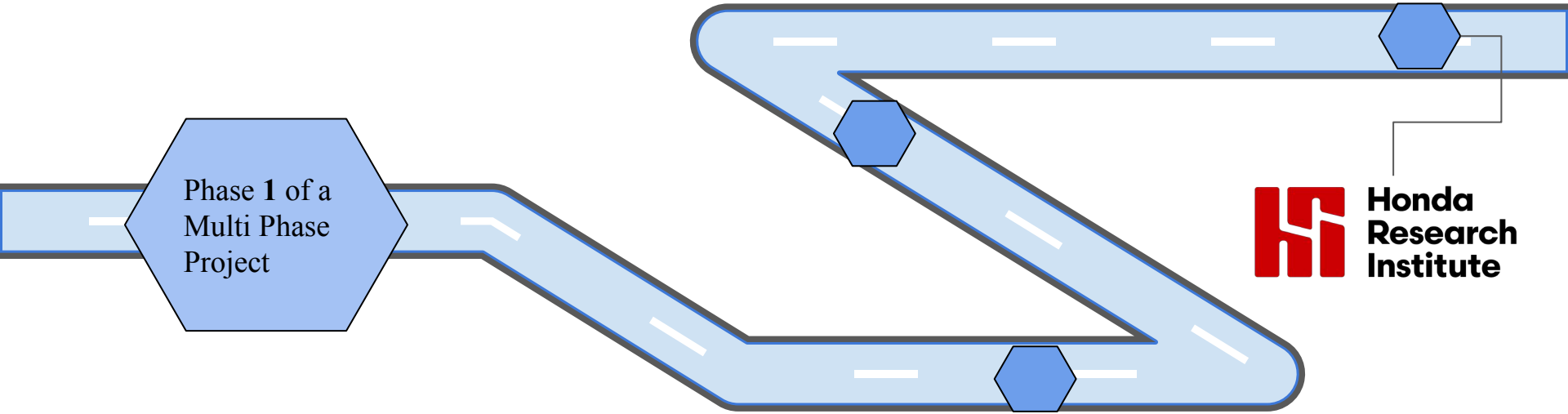
Combination of both rotors

Scope of Current Phase

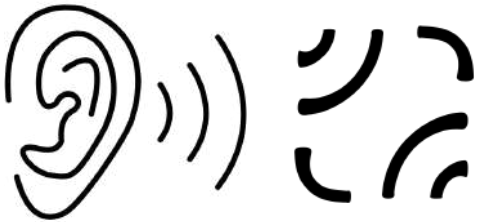
Phase 1: Conceptual Design and Simulation:

- Exploration of an Emerging Technology
- Design and Modeling
- Physical Prototype Testing & Refinement
- Computational Fluid Dynamic Analysis

→ Next Phase Project



Design Considerations



Noise and vibration levels

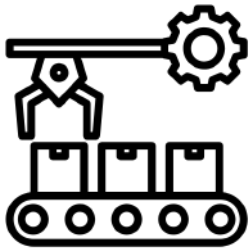
Durability

Structural stability

Maintenance costs

Power generation

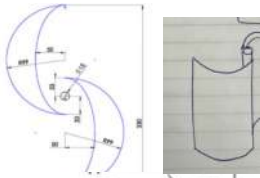
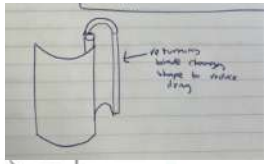
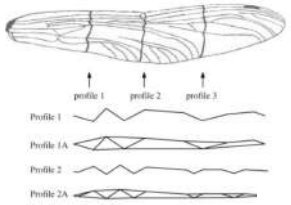
Compatibility with campus architecture

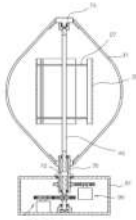
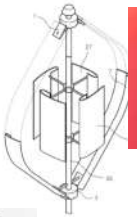


Manufacturability

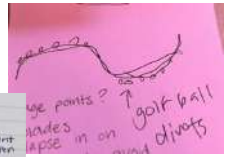
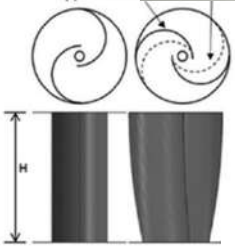
Concept Generation & Compilation

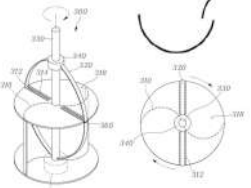
Design Development

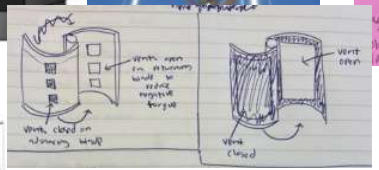
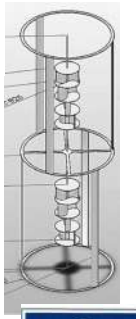
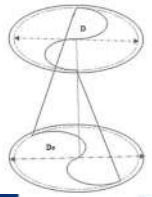
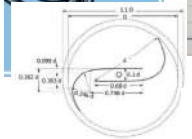
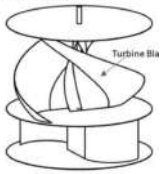
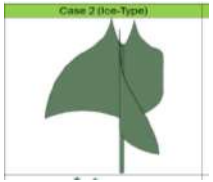




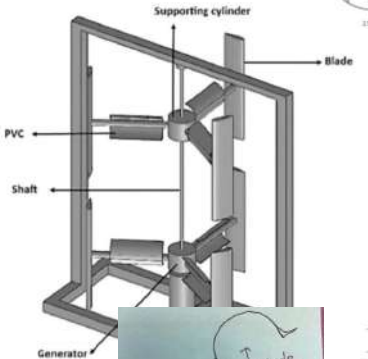



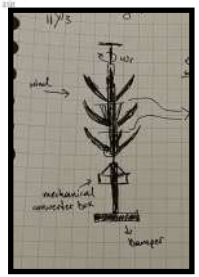


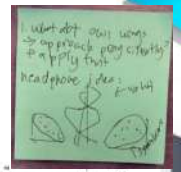
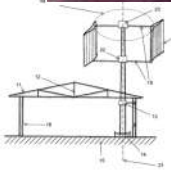



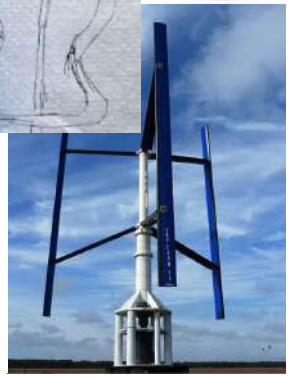
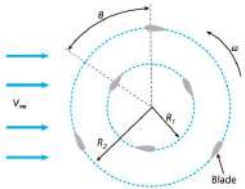


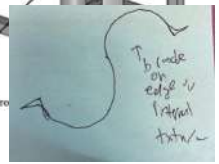
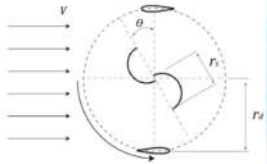












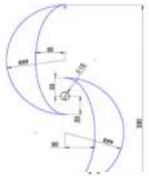
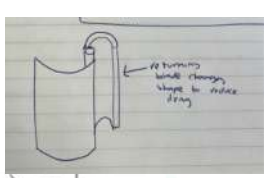
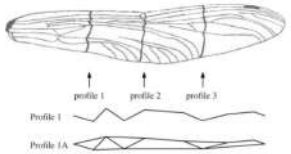
Concept Generation & Compilation

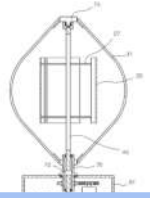
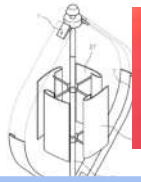
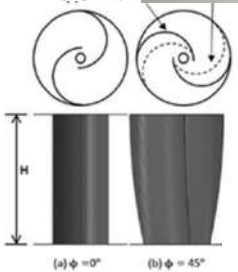
Design Development

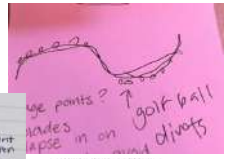
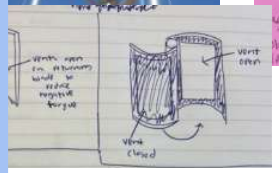
224 → 30 → 4

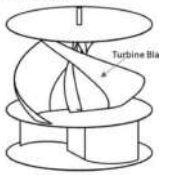


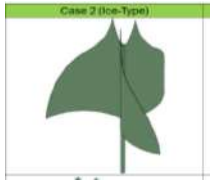


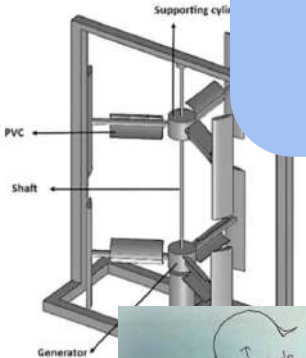





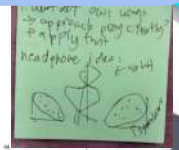
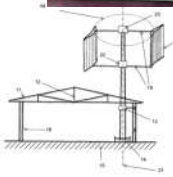




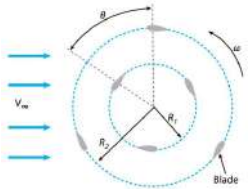



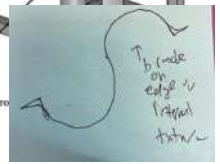
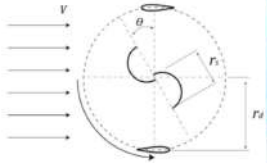






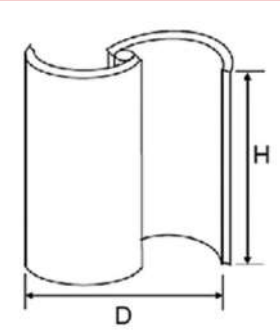




Selected Concepts

Classical Savonius

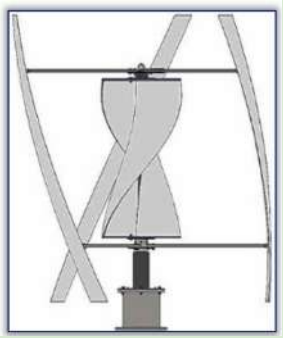


- Simple
- Well researched
- Low cut-in speeds

EN0005: Self-Start Darrieus

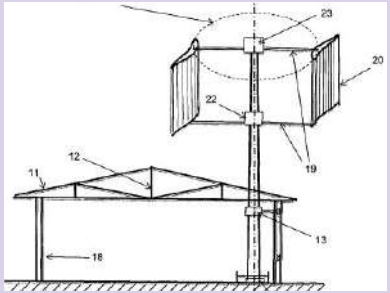
- Different geometry
- Low cut-in speed

Helical Hybrid



- Internal helical Savonius
- External helical Darrieus

H-Type with Savonius Compartments



- Unique Hybrid
- H-type Darrieus

Initial Prototyping

Classical Savonius

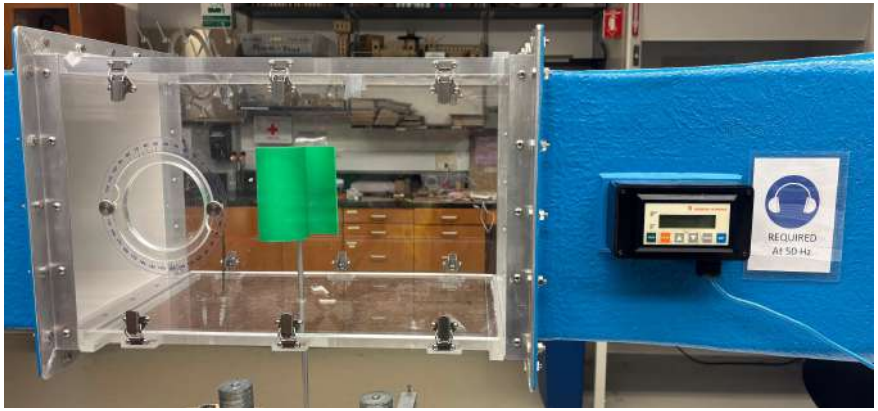
EN0005

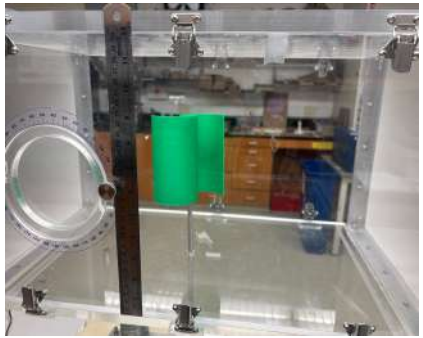
Helical Hybrid

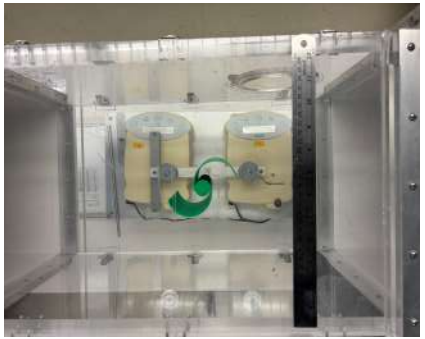
H-Type with Savonius Compartments

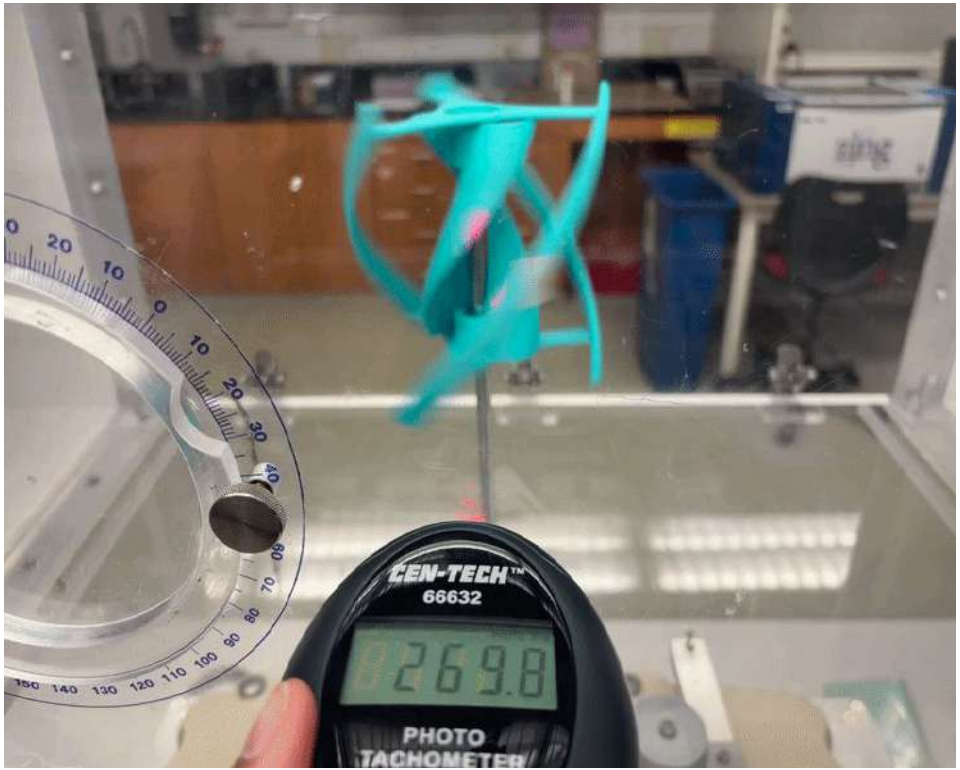
Design Development

Wind Tunnel Testing & Optimization









Initial Prototyping

Classical Savonius

EN0005

Helical Hybrid

H-Type with Savonius Compartments

Initial Prototyping

Classical Savonius

EN0005

Helical Hybrid

Prototyping & Optimization Part 1

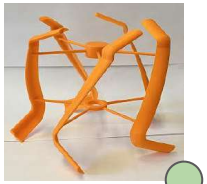
Savonius

End Caps

Optimized OR

Elliptical

EN0005



Altered Diameter

Smoothed

Helical Hybrid

Airfoil Shaped Blades

Flipped Airfoil

Asymmetric Airfoil Shape

Cut-in Speed Comparison

- Unable to cut-in
- High
- Medium high
- Medium low
- Low

Helical Hybrid Optimization

Design Development

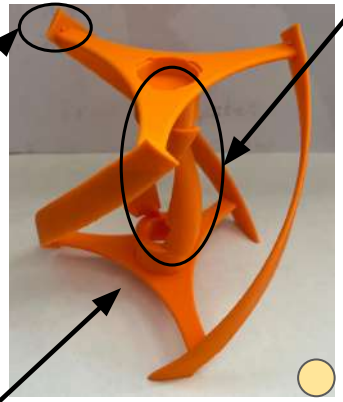
Parameters

- Connection mechanism
- Darrieus pitch
- Savonius width
- Savonius height
- Darrieus airfoil shape
- Combination variations

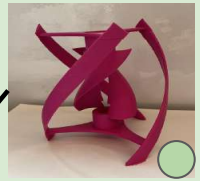
Curved Airfoil Shape

Altered Strut

Asymmetric Airfoil Shape



Wider Savonius



Taller Savonius

20° Pitch

Curved, Wider, and Taller

Cut-in Speed Comparison

- Unable to cut-in
- High
- Medium high
- Medium low
- Low

Evaluation

Cut-in Speed

Angular Velocity

Moment of Inertia

Researcher Sentiment

Team Contributions

Improvement Potential

Manufacturing Cost

Savonius

Helical Hybrid

EN0005

Evaluation

Cut-in Speed

Angular Velocity

Moment of Inertia

Researcher Sentiment

Team Contributions

Improvement Potential

Manufacturing Cost

Helical Hybrid

Performance Evaluation

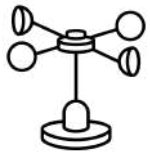
Physical Testing

- Compare cut-in
- Compare angular velocity

Computational Fluid Dynamics (CFD)

- Cp and power output for selected concept
- Flow visualization

Inlet velocity: 2 m/s



Wind speeds from McConnell Roof

Performance Evaluation

Computational Fluid Dynamics (CFD) SIMSCALE

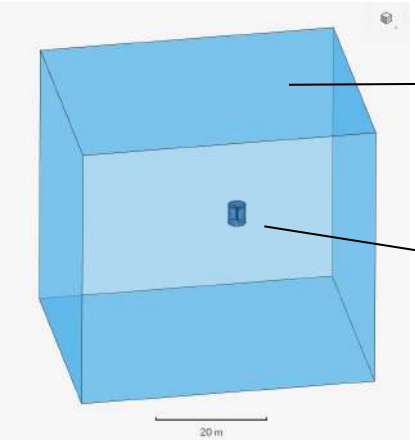
Purpose: determine C_P and estimate power generated of selected concept

CFD Set-Up

Meshing

Classical Savonius Studies

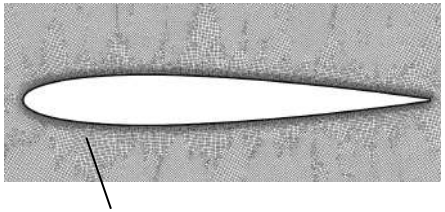
Goal: Set up an accurate workflow



Stationary External Domain

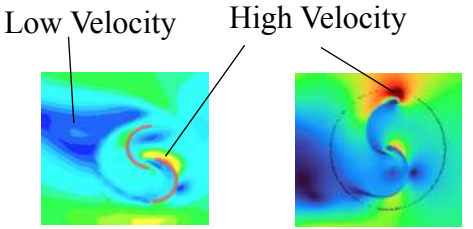
Rotating Inner Domain

Goal: Need appropriate meshing to get most accurate results



Boundary Layer Meshing

Goal: Validate velocity profile and C_P against literature



Our model

Literature

[1]

Computational Fluid Dynamics (CFD)

SIMSCALE

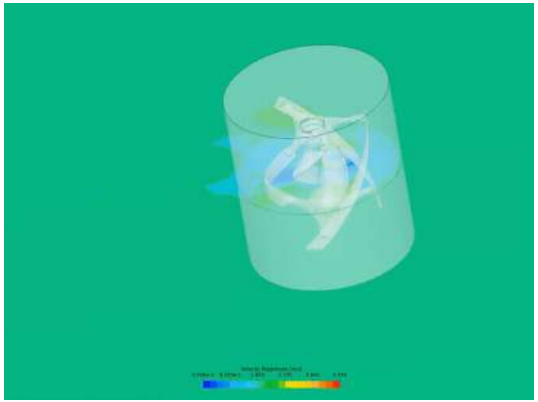
Purpose: determine C_P and estimate power generated of selected concept

Helical Hybrid Studies

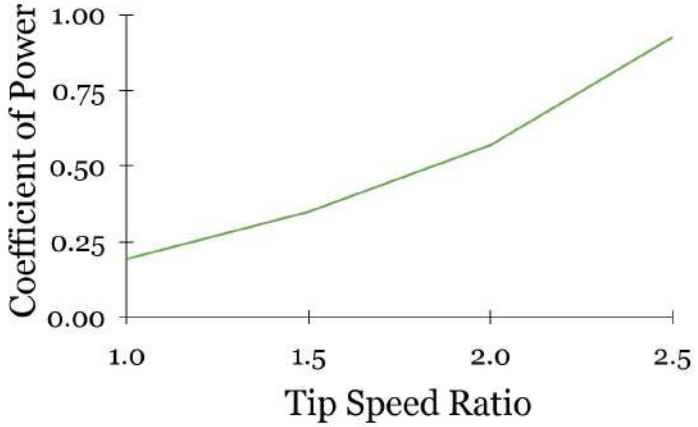
TSR Analysis

Initial Conclusions

Goal: Determine C_P for selected concept



Goal: Determine an optimal TSR range



C_P of 0.19

Limitations:

- Boundary Layer Meshing
- TSR Analysis

Performance Evaluation

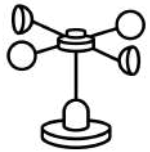
Physical Testing

- Compare cut-in
- Compare angular velocity

Computational Fluid Dynamics (CFD)

- Cp and power output for selected concept
- Flow visualization

Inlet velocity: 2 m/s



Scaling

Wind speeds from McConnell Roof

Initial Economic Analysis

CFD

Wind data

Estimated power production 10 kWh/yr

Estimated cost for full-scale prototype $12,000

Breakeven time is not realistic

Future Work & Recommendations

Honda Research Institute LABS

Continue to Target Urban Wind Conditions

- Impact of unsteady wind conditions + scaling
- Rooftop testing
- Continued optimization
- No CFD (not useful)

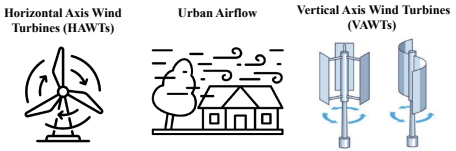
Shift to Application with Higher Wind Speeds

- Larger wind turbine
- Focus on getting current tech to market
- Redesign could help

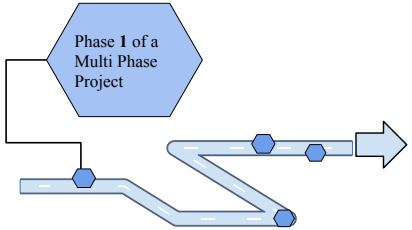
Focus on Digital Twin

- Higher fidelity CFD
- Meshing
- Comparison to wind tunnel testing with steady wind

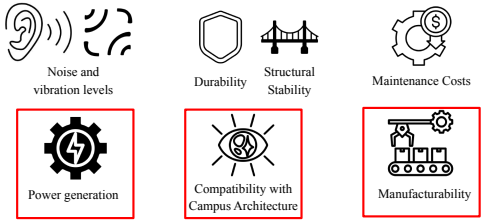
Recap



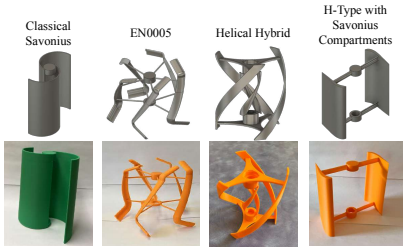
Background



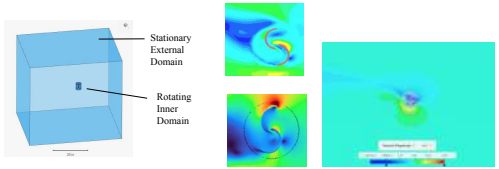
Project Scope



Design Considerations



Design Development



Performance Evaluation

Recommendations & Next Steps

Thank You!

Acknowledgements

- HRI Liaisons: Duane Detwiler, Ryan Lingo, Rajeev Chhajer
- Susannah Howe
- Honda: Zhenyu Wang
- HALO Wind Tunnel: Tom Ramsay
- 99P Labs/HRI: Phillip Acquino and team
- Katy Kaproth-Gerecht
- R Koh
- Wind Data: Nat Fortune, James Lowenthal
- Facilities Team: Beth Hooker, Charles Dougherty, Kevin Ulrick, Corey Lynch

Honda Research Institute

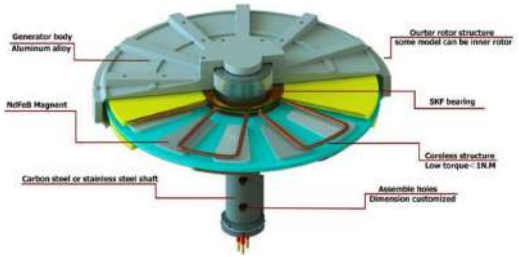
99P LABS

SMITH COLLEGE

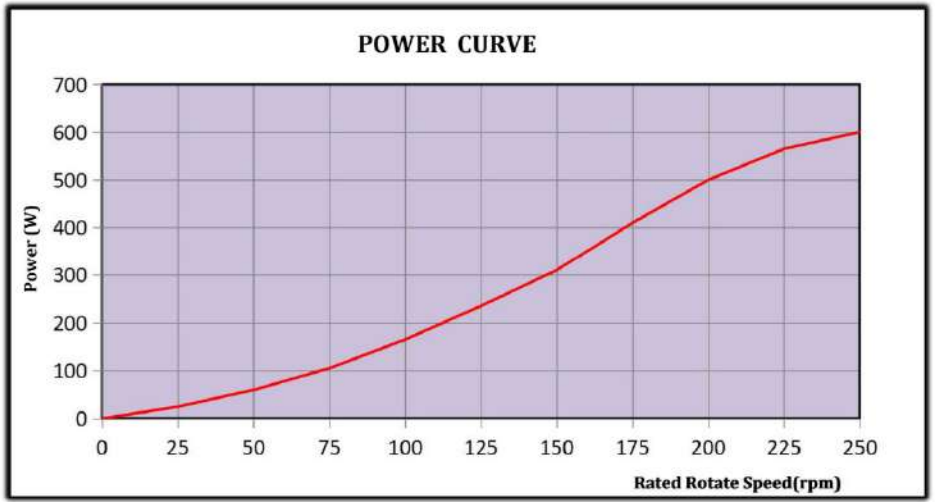
Supplemental Slides

Power Electronics

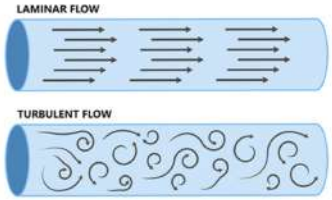
- Off the shelf generator
- 0.5 kW, Low Torque Permanent Magnet Generator (PMG)
- Well equipped for low, variable wind speed turbines and are highly efficient in energy production



Greef
Power the World with Green Energy



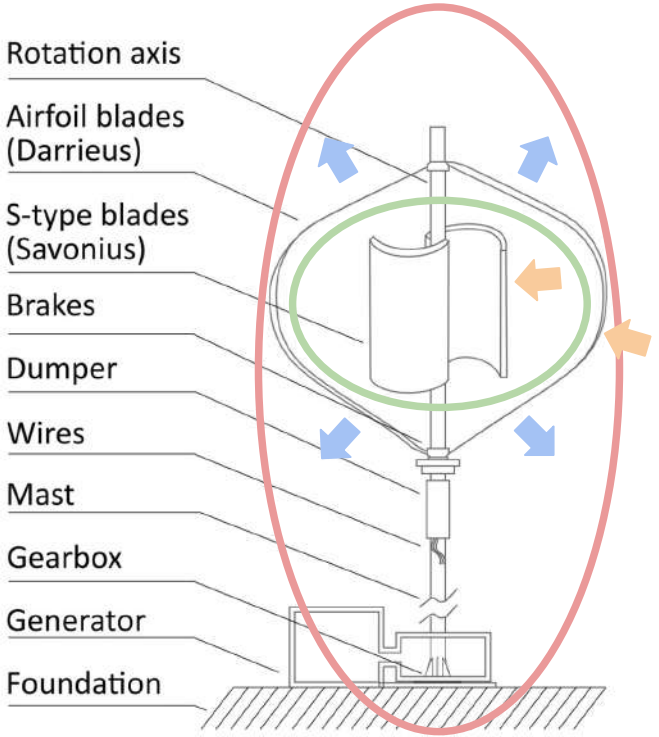
Scaling



Test	Result	Initial Conclusion
Can cut-in speed be scaled with Reynolds number?	Similar experimental and theoretical cut-in	Possible to scale cut-in with Reynolds number
Can aerodynamic behavior be scaled with Reynolds number?	Different experimental and theoretic TSRs	Not possible to scale aerodynamic behavior with Reynolds number alone

Concept Categories & Winnowing

- Skeleton of VAWT
- Blade Shape
- Interior Augmentation
- Exterior Augmentation
- Other Optimization

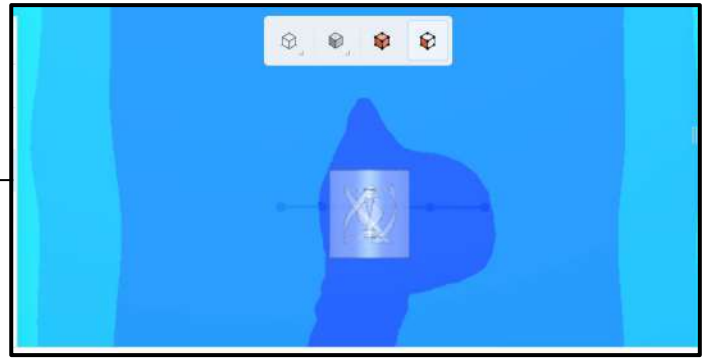


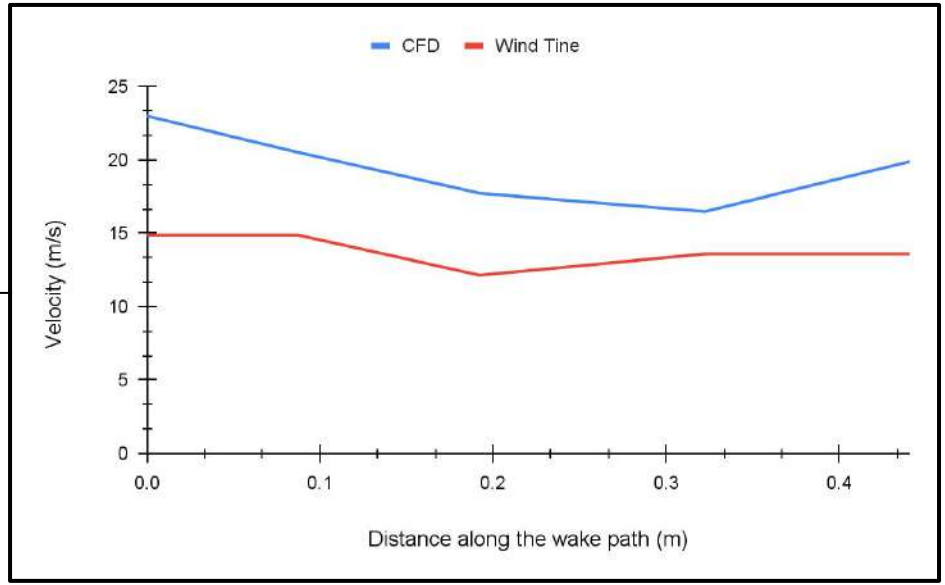
224 — Skeletons Only — 30

Wake Validation

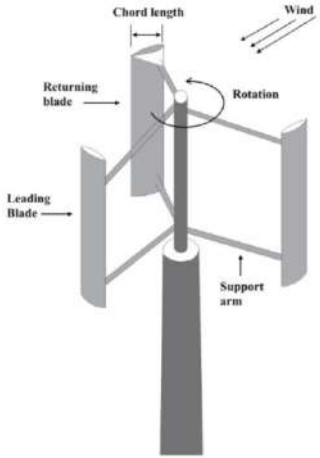
Goal: Validating CFD with a wake rake analysis

- Set up a wake rake in the wind tunnel
- Measured the velocity in the wake of the turbine
- Compared to CFD results

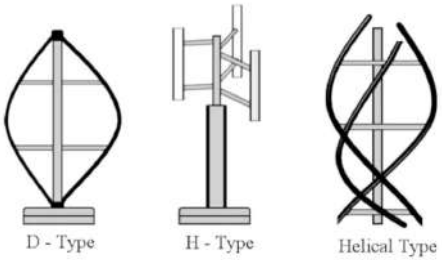




Darrieus Turbines

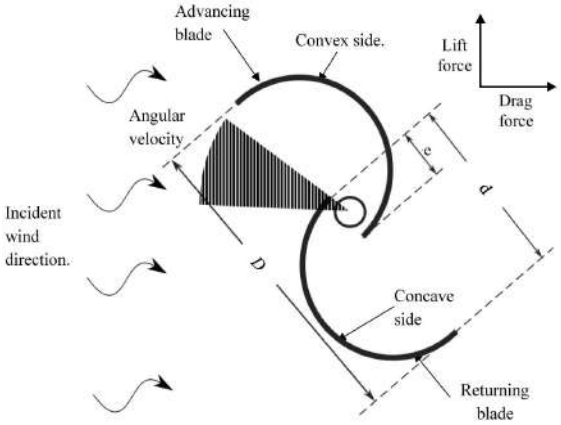


[1]



[2]

Savonius Turbines



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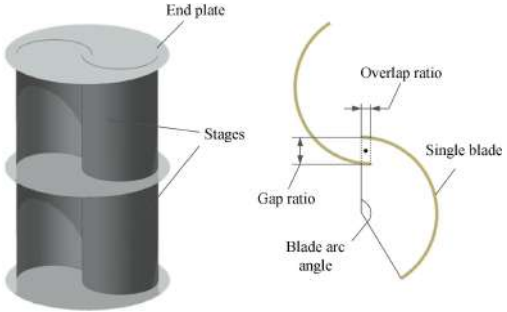
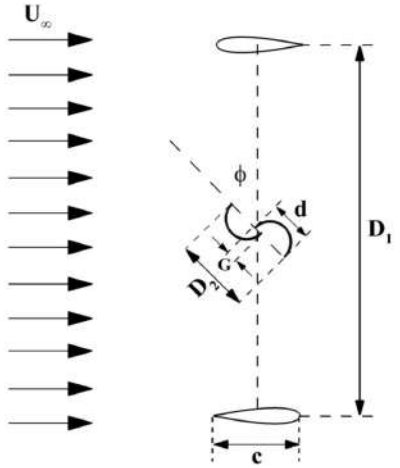


[4]

Hybrid Configurations



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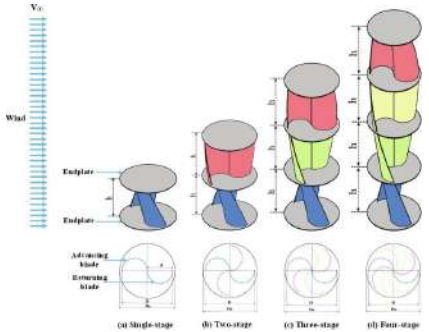
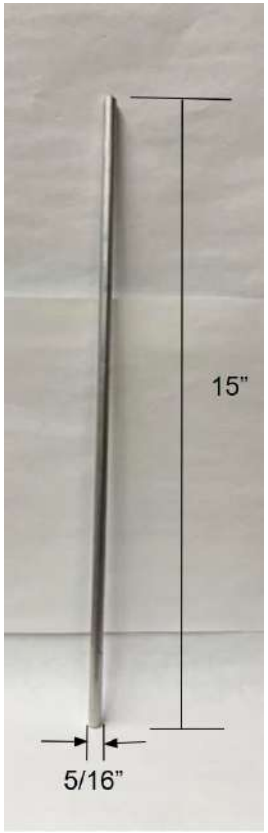
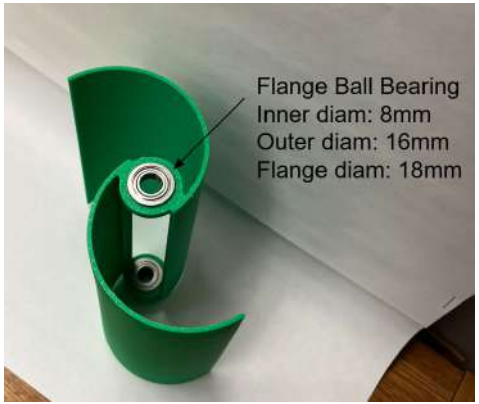
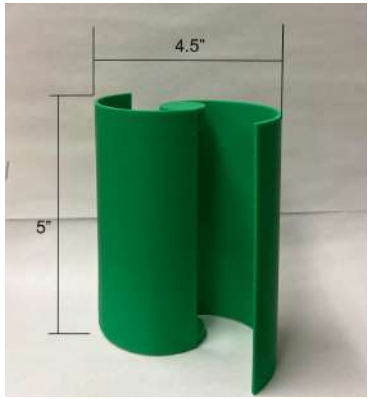


[6]

Progress in Prototyping







Technical Parameters

- Cut in Speed
  - ➢ The minimum wind velocity for a turbine to begin rotating

- Tip Speed Ratio (λ)

$$TSR = \frac{\omega \cdot R}{V}$$

- Moment/Torque Coefficient (Ct or Cm)
  - ➢ A non dimensional measure of the torque produced by a turbine

$$C_t = \frac{T}{0.5\rho ARU^2}$$

- Coefficient of Power (Cp)

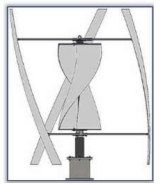
  Cp = Ct * TSR

$$C_P = \frac{P_T}{P_A} = \frac{T\Omega}{\frac{1}{2}\rho SU^3}$$

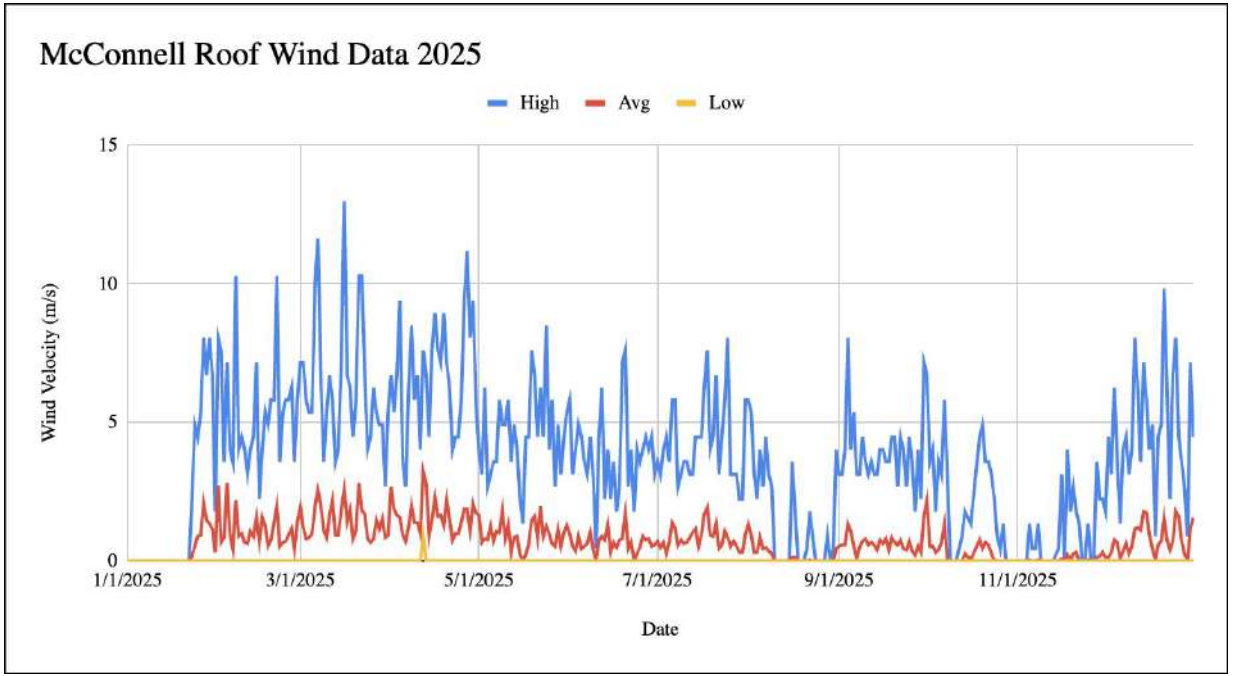
Darrieus - Lift Based

Savonius - Drag Based

Hybrid - Combination



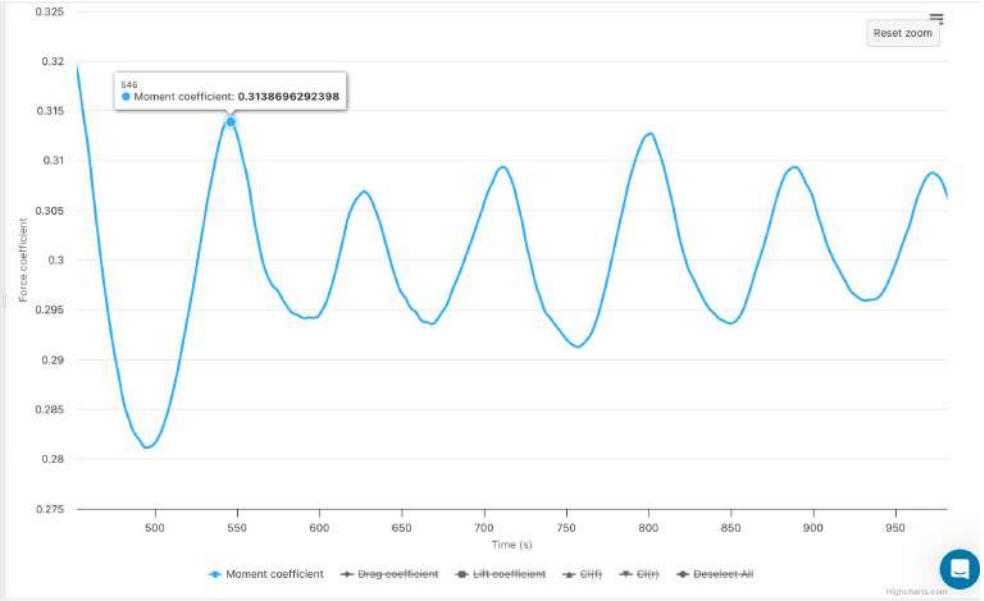
Wind Data on McConnell Roof

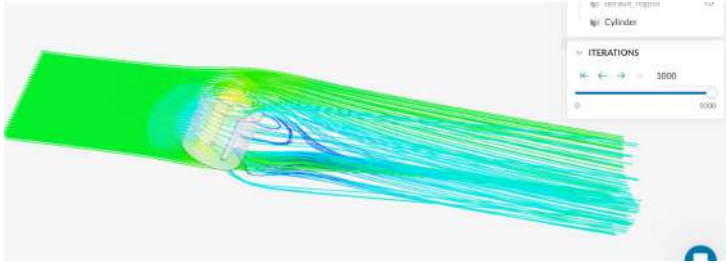


Median High	Median Low	Median Avg
4.02 m/s	0 m/s	0.67 m/s

High	Target	Low
8 m/s	4 m/s	2 m/s

Classical Savonius Validation





Target Based on Existing Studies:

- At optimal TSR = 0.8 → should expect a Cp ~ 0.2-0.25

Results:

- Ct ~ 0.3
- T ~ 3.57 N*m
- Ct (by hand to check) ~ 0.3 ✓
- Cp = Ct * TSR = 0.3 * 0.8 = 0.24 (within expected range) ✓

References

[1] The European Energy Atlas 2018, Facts and figures about renewables in Europe, Heinrich-Böll-Stiftung, 2018. [Online]. Available: https://www.boell.de/sites/default/files/energyatlas2018_facts-and-figures-renewables-europe.pdf (accessed Dec. 5, 2025).

[2] VectorMine, “Horizontal vs vertical axis wind turbine principle, structure outline diagram,” online vector illustration, available: https://vectormine.com/item/horizontal-vs-vertical-axis-wind-turbine-principle-structure-outline-diagram/. (accessed Dec. 5, 2025).

[3] R. Neumann, J. Peinke, and G. M. H. Krauter, “Short-term power prediction of wind turbines based on stochastic analysis of wind measurements,” *J. Wind Eng. Ind. Aerodyn.*, vol. 175, pp. 61–68, 2018. doi: 10.1016/j.jweia.2018.01.003.

[4] Renewable Energy Research Laboratory, University of Massachusetts at Amherst, “Wind power: Capacity factor & intermittency,” RERL-MTC Community Wind Fact Sheet Series, https://ljfo.vermont.gov/assets/docs/envy/2d50be63c1/Wind-Power-Fact-Sheet.pdf (accessed Oct. 18, 2025).

[5] S. Shubham, K. Naik, S. Sachar, and A. Ianakiev, “Performance analysis of low Reynolds number vertical axis wind turbines using low-fidelity and mid-fidelity methods and wind conditions in the city of Nottingham,” *Energy*, vol. 279, p. 127904, 2023. doi: 10.1016/j.energy.2023.127904.