Small-Scale Wind for Rooftop Applications

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Introduction:

This project has a focus on optimizing small-scale wind turbines (2.2m diameter with <1 kW capacity) for rooftop applications to provide disaster relief and local power generation for commercial, industrial, and agricultural buildings. Performed in partnership with Aerovec, a start-up company based out of Buffalo, NY, the team investigated 3 assumptions for rooftop implementation and several design considerations supplemented by experimental testing.

Investigation of the Assumptions:

Question 1: Is it feasible to install a small-scale wind turbine on a rooftop while mitigating the effects of any noise and vibration?

Method: Noise estimations were obtained from subject matter experts at Carrier. Vibration was modeled as a rotating mass asymmetry, using a method published by the DoD (AHRI, ANSI, ASHRAE, AST Standards).

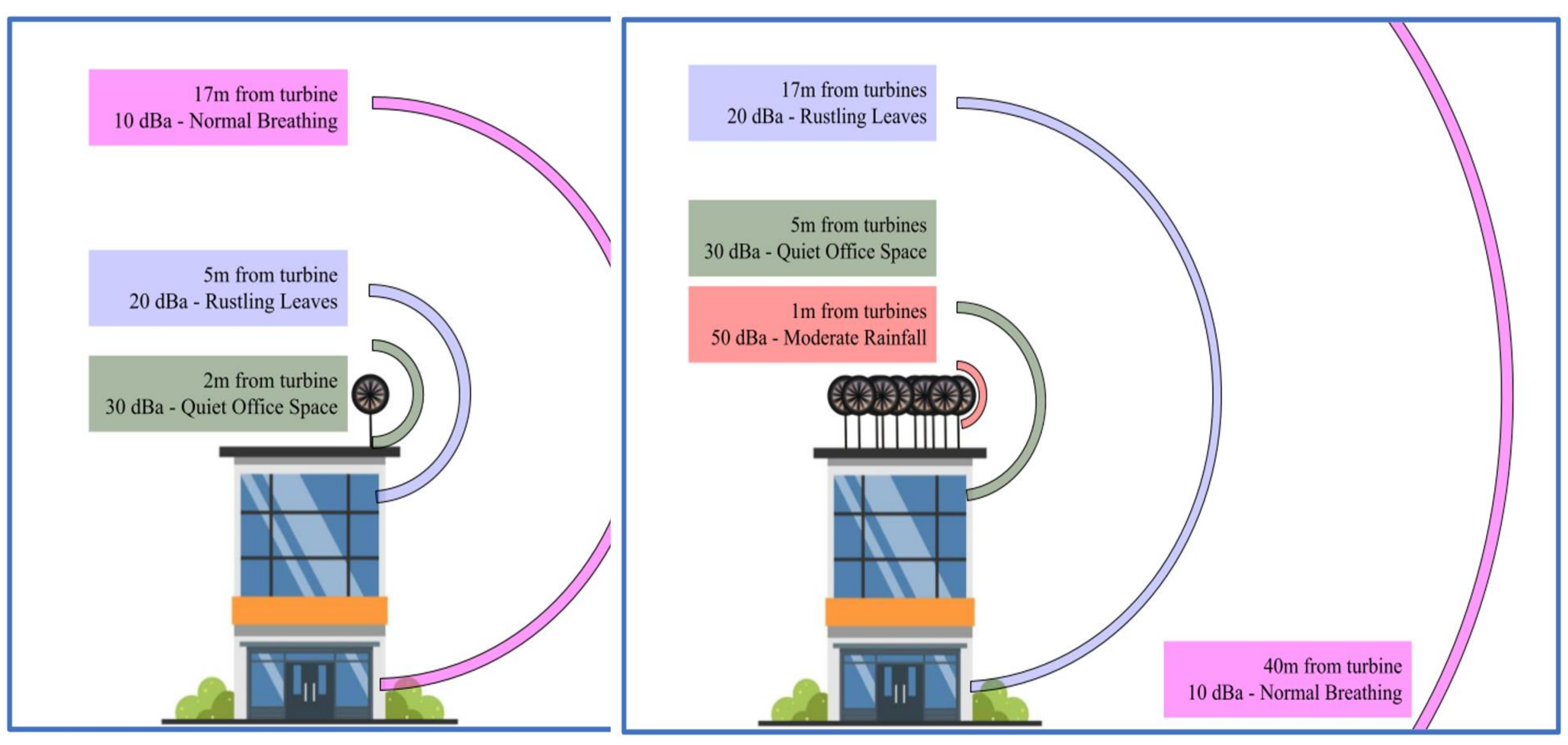


Figure (1): Theoretical noise production of 1 and 10 turbines on a 20-meter-high rooftop.

Outcome: Noise is well below acceptable limits for any number of small-scale wind turbines near a 2-meter diameter. Vibration is classified as imperceptible by published DoD standards.

Question 2: Would eliminating active yaw motion of the turbine still capture >75% of the total possible power?

Method: Available power by degree of misalignment was experimentally found during wind tunnel testing (Figure 3). This was compared to historical wind direction data in Syracuse, NY (Figure 4).

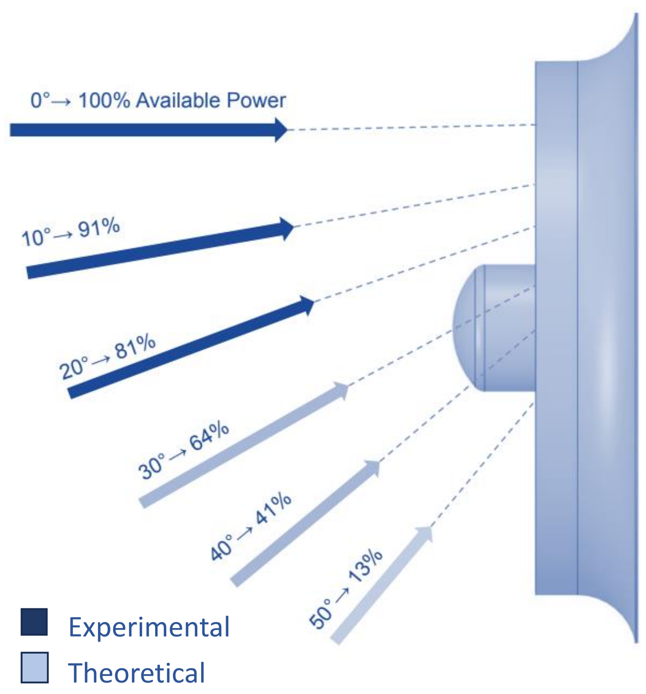


Figure (3): Degree of misalignment effects on available power for a no-yaw turbine.

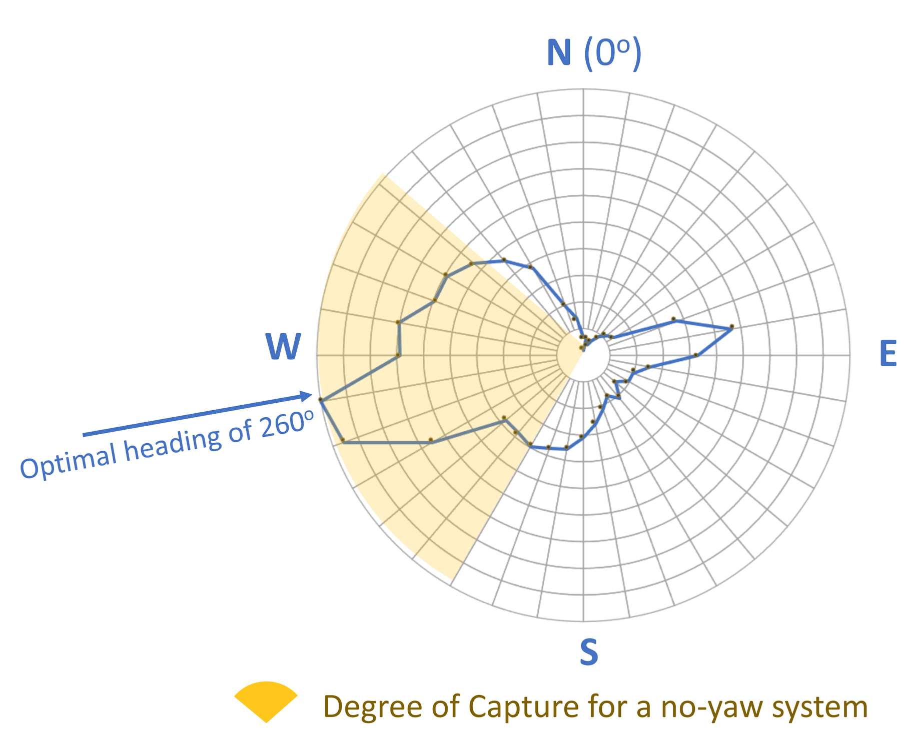


Figure (4): Wind magnitude by direction in Syracuse, NY.

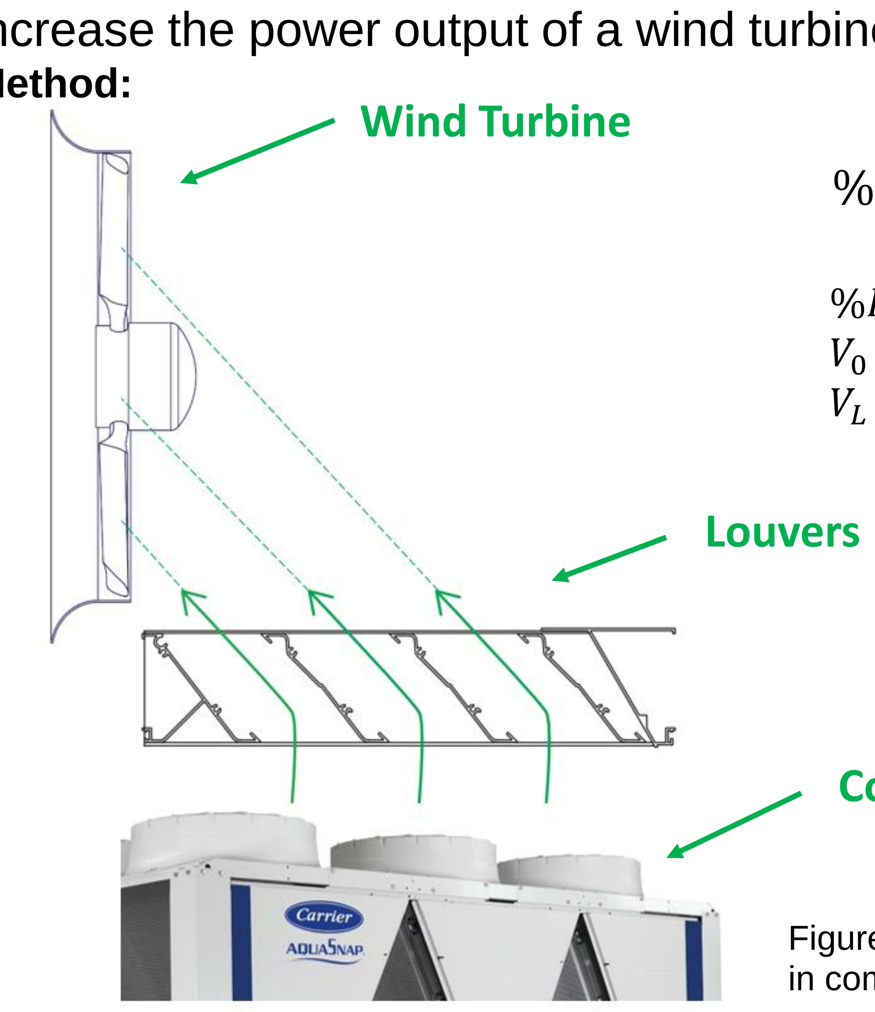
Outcome: Eliminating yaw motion is estimated to capture 48% of total possible power (< 75%).

Question 3: Would redirecting the outlet airflow from a rooftop HVAC unit increase the power output of a wind turbine by >20%?

Method:

$$\%P = 100\% \times \left[1 - \left(\frac{V_0}{V_0 + V_L}\right)^3\right]$$

$\%P$ = Percent power increase
V_0 = Average wind velocity in Syracuse, NY
V_L = Wind speed added by louver system



Figure(7): Schematic of a rooftop air-cooled chiller in combination with a louver system.

Outcome: After redirecting the flow from an HVAC unit, the airflow will increase power output of a wind turbine by a theoretical maximum of 4.4% (< 20%).

Evaluating Additional Design Parameters:

Task 1: Determine the optimal blade design.

Method: Testing on a 1/5 scale, 3-D printed model was performed in a subsonic wind tunnel. Aerovec has considered two blade prototypes. The team assessed the prototypes' performances against a third design, a "baseline" wind turbine from Cornell University.

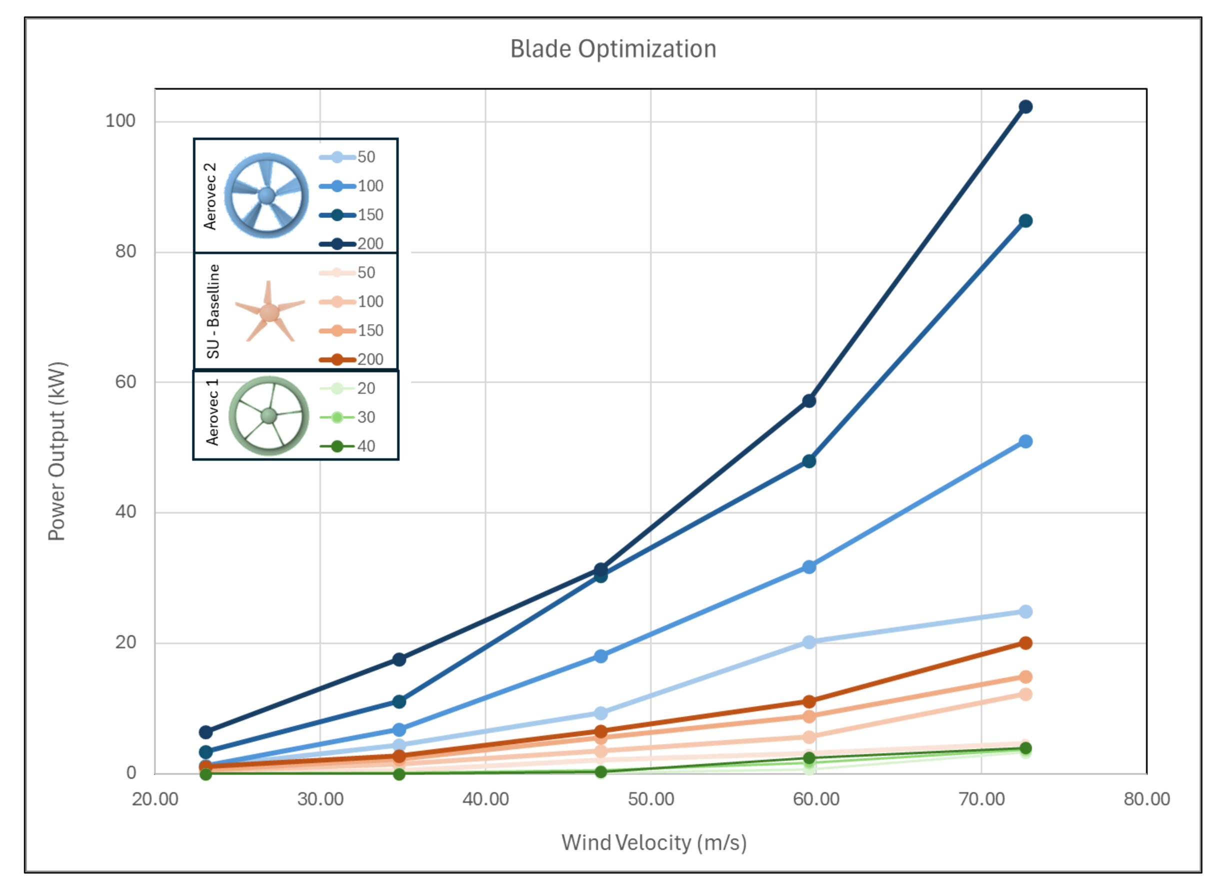


Figure (2): Performance of various blade designs in experimental testing at 5 wind speeds and 5 rpms.

* Large wind speeds due to fan scaling laws

Conclusion: The Aerovec prototype #2 has the highest power output. Note the addition of the outer cowling on Aerovec 1 and 2, as labeled in Figure (2).

Task 2: Determine the effectiveness of the rotating cowling diffuser.

Method: Experimental testing. The diffuser provides a theoretical increase in velocity at the blade due to an induced pressure differential and reduction of radial losses. Testing was performed on the "Baseline" blade design.

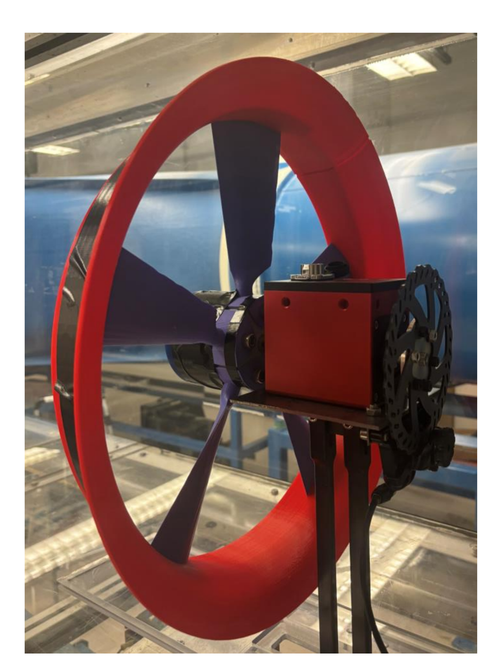


Figure (5): Testing setup including torque meter and friction brake.

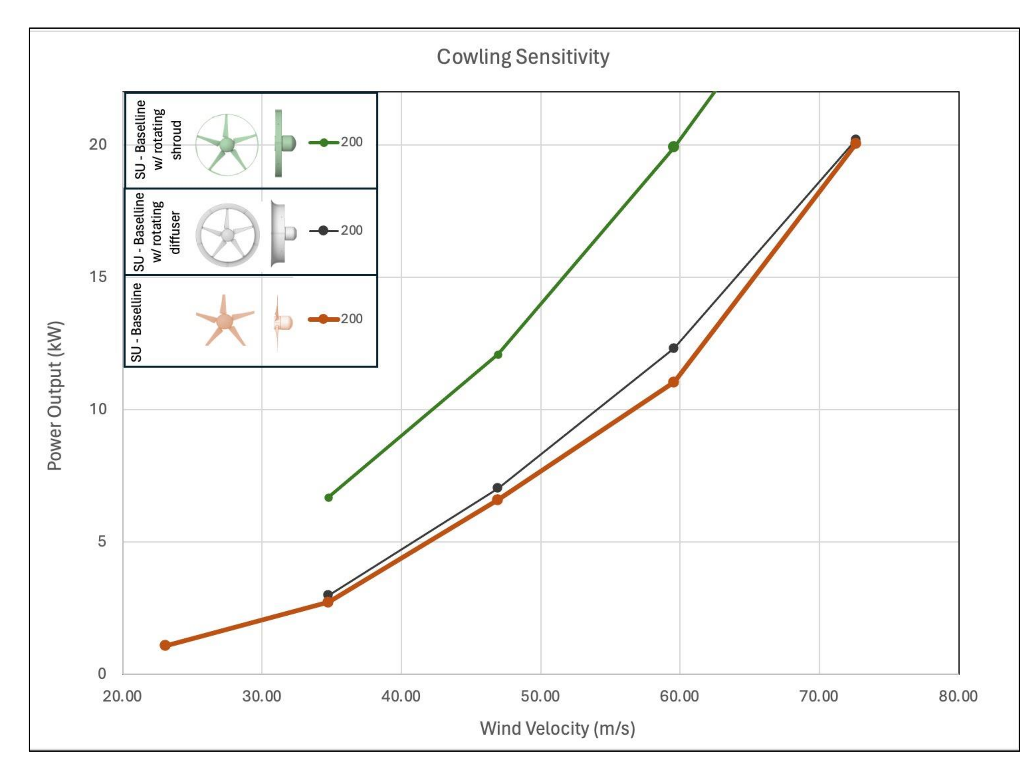


Figure (6): Assessing the effects of multiple cowling configurations.

Conclusion: The cylindrical shroud, seen in green, had the best performance. It provides capture of radial flow loss without the additional mass but loses the velocity gained by pressure differential.

Task 3: Isolated investigation of the diffuser.

Method: Experimental testing. Aerovec's cowling diffuser rotates with the blades. This experiment compares the rotating diffuser, the rotating shroud, and a configuration with a rotating shroud paired with a stationary diffuser.

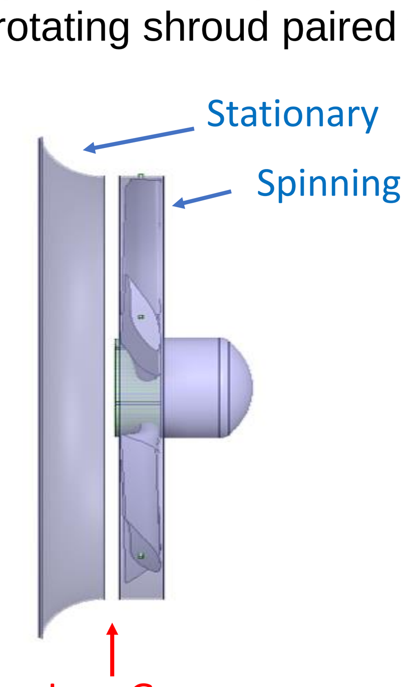


Figure (8): Diagram of the rotating shroud paired with a stationary diffuser.

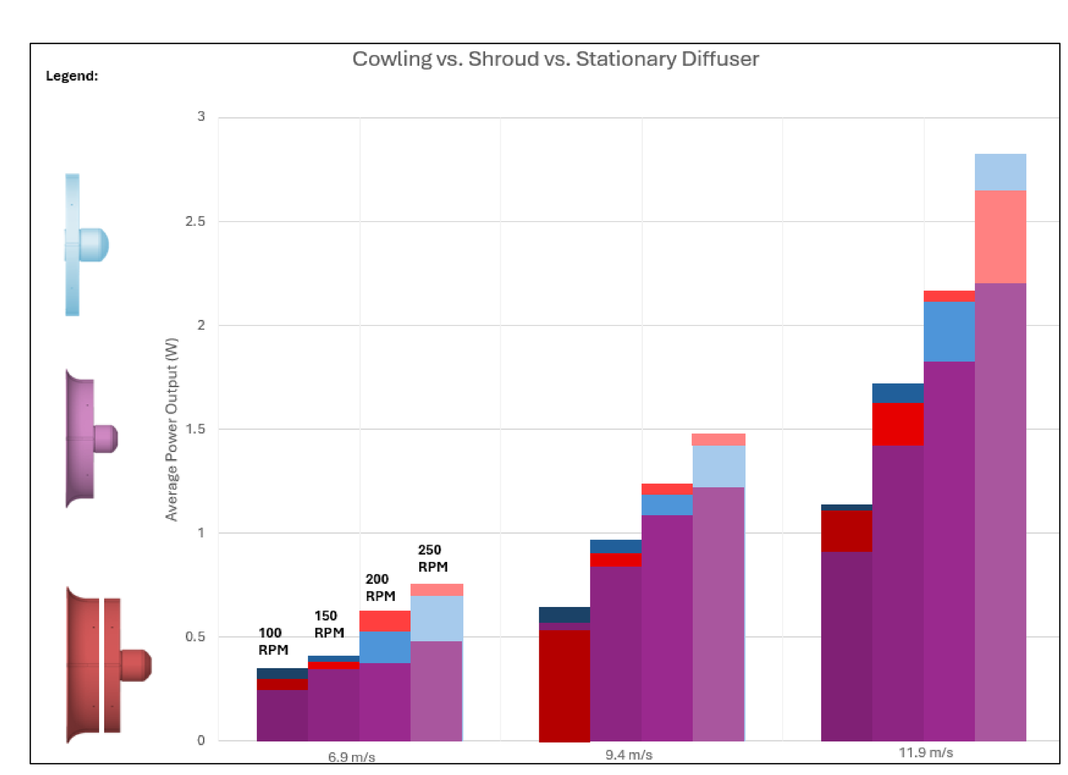


Figure (9): The 3 stated configurations compared at 3 wind speeds and 4 rpms.

Conclusion: As expected, the full rotating cowling (purple) shows the worst performance. When comparing the rotating shroud with and without diffuser function, the addition of the diffuser generally shows an improvement at higher rpms, but a decrease in power at lower rpms. Future work includes reduction of losses by utilizing a vertical gap rather than horizontal.

Literature Cited:

- AHRI, ANSI, ASHRAE, and ASTM Standards
- White, F. M. (2006). *Viscous Fluid Flow*. McGraw-Hill Higher Education.
- Burton, T. (2011). *Wind energy handbook*. John Wiley & Sons, Ltd.

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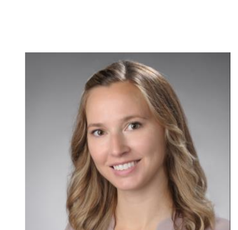


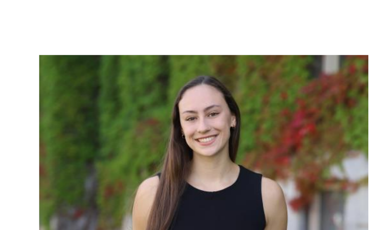

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