To: Susannah Howe and HRI Liaisons

From: VAWT Ventures

Date: November 5, 2025

Subject: Concepts from commercial technologies, research studies, patents, and emergent ideas from VAWT Ventures.

Introduction

The purpose of this memo is to provide a broad overview of VAWT concepts, defining the design space from which we will ultimately select and develop a concept to pursue. The memo contains tables of concepts from commercial technologies, research studies, patents, as well as original ideas developed by the team. The tables are organized by the three main categories of VAWTs: Darrieus, Savonius, and hybrid configurations. Each table lists the concept number, level of development, relevant images, and reference numbers. Furthermore, it provides an overview of emergent ideation strategies and processes used by team members.

Level of Development Methodology

As we sorted the concepts into their respective tables, we assigned each one a numerical value representing its level of development. Concepts that were marked with a 1 or 2 require more research and testing, which may include CAD modeling and simulation, before the team can evaluate, while concepts given a 3 are ones that we can immediately proceed with in evaluation. The scale is further provided below:

3 - ready to evaluate now

2 - minimal development

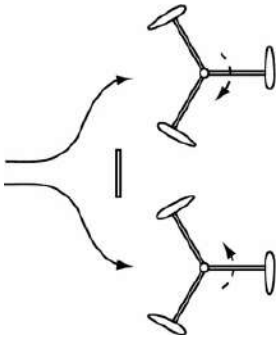
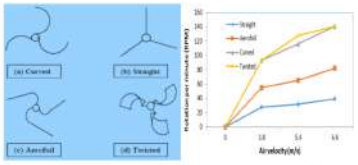
1 - needs significant development

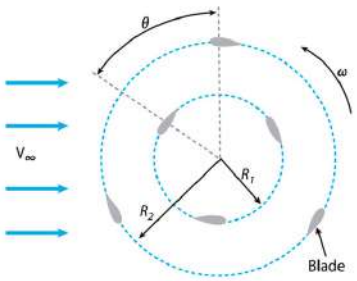
Darrieus

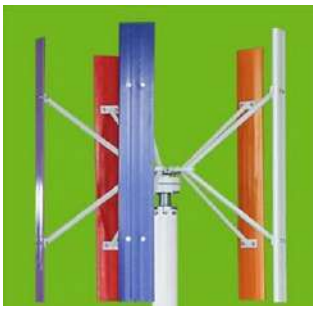
Darieus VAWTs are lift-based turbines that use airfoil-shaped blades to generate torque as wind flows across their surfaces. They can be subcategorized as D-type (eggbeater), H-type, or Helical. While Darrieus VAWTs tend to be more efficient than drag-based VAWTs, they are unable to self-start and experience high fluctuating torque during rotation. Table 1 contains VAWT concepts sourced from research papers, patents, and commercial technologies meant to address issues specifically related to Darrieus VAWTs.

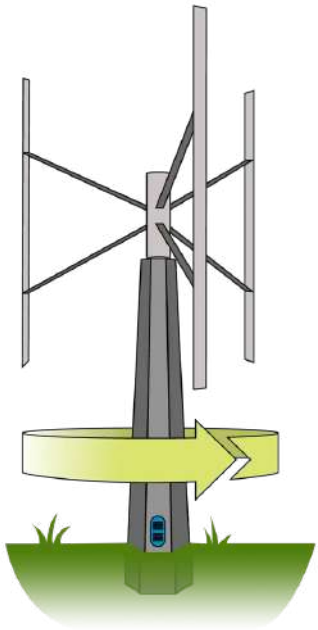
Table 1. Darrieus Vertical-Axis Wind Turbine (VAWT) Concepts

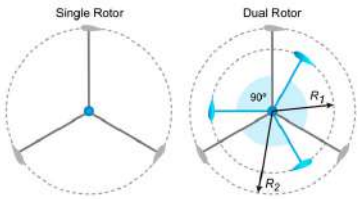
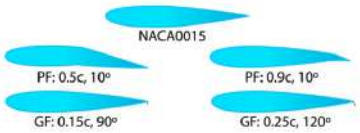
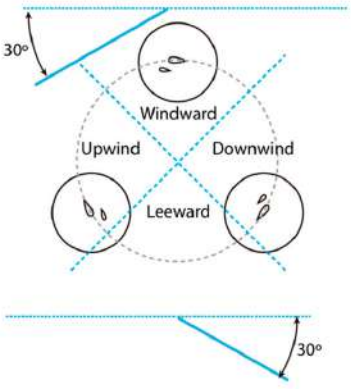
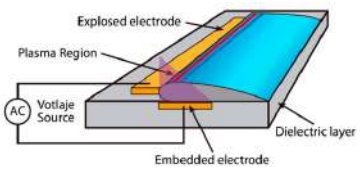
Concept	Description	Level of Development (1-3)	Image	Reference number
1	Adding a dimple to the airfoil profile of a Darrieus turbine	1		[1]
2	Intelligent blade pitch control for Darrieus - improved power output by 25% compared to a fixed pitch angle	1		[1]
3	Darrieus with auxiliary internal blades with fixed chord ratio, better for low wind speed	1		[1]
4	NACA0018 airfoil shape for Darrieus	1		[1]
5	S-1046 non-symmetric airfoil for Darrieus	1		[1]
6	Wind-gathering device (WGD)	1		[1]

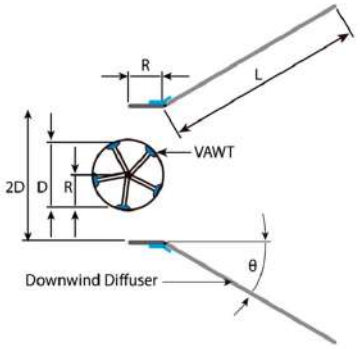
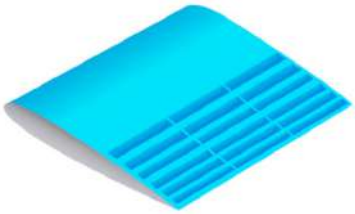
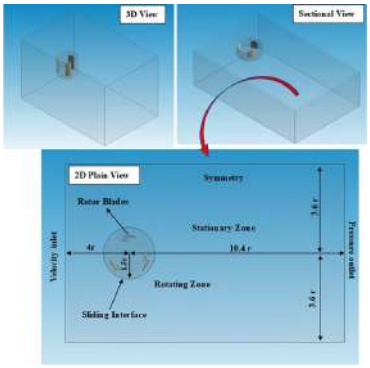
Concept	Description	Level of Development (1-3)	Image	Reference number
7	Adding a deflector to redirect airflow (effectiveness depends on deflector position)	2		[1][2]
8	Addition of small Savonius rotor(s) for startup assistance	2		[3][4]
9	Curved airfoil blades arranged vertically on a rotary framework	1		[3]
10	Channel beam reinforcement	1		[5]
11	Lateral restraint supports	1		[5]
12	Variable-pitch blade configuration for straight-bladed VAWTs	1		[6]
13	Winglet addition at blade tip	1		[6]
14	Helical Darrieus	3		[7]
15	4 types of helical darrieus blades (comparison)	2		[8]

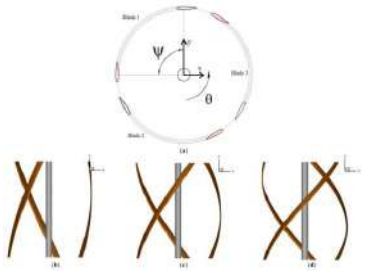
Concept	Description	Level of Development (1-3)	Image	Reference number
16	3-blade helical darrieus	3		[9]
17	Doubling the number of blades used (3 blades to 6 blades)	2		[10][11]
18	Using a horizontal Savonius profile combined with a vertical Darrieus one	2		[10]
19	Anodizing the blades	2		[12]

Concept	Description	Level of Development (1-3)	Image	Reference number
20	Zinc plating the blades	2		[12]
21	Using C%+M paint coating for the blades	2		[12]
22	Electro-magnetic brakes	2		[12]
23	Eliminating friction from disk generator	3		[13]
24	Quiet Revolution Qr 6	3		[14]

Concept	Description	Level of Development (1-3)	Image	Reference number
25	Wind Harvester Model 4.0	3		[15]
26	Eastern Wind Power's Sky Farm™ 50 kW Vertical Axis Wind Turbine	3		[16]
27	Using cambered airfoils instead of symmetric ones	1		[11]
28	J-type airfoil profiles	2		[11]
29	Hybrid blade sections	2		[11]
30	Adjusting solidity	2		[11]

Concept	Description	Level of Development (1-3)	Image	Reference number
31	Optimizing number of blades	2		[11]
32	Variable or dual-radius blades	2		[11]
33	Dual-row or hybrid rotor configurations			[11]
34	Variable geometry rotors			[11]
35	Passive devices (Gurney flaps, edge modifications, vortex generators)	2		[11]
36	Surface texturing of blades	2		[11]
37	Guide vanes or deflectors	2		[11]
38	Active pitch control or adaptive blade geometry	2		[11]
39	Active boundary-layer control (synthetic jets, plasma actuators)	2		[11]

Concept	Description	Level of Development (1-3)	Image	Reference number
40	Dynamic rotor geometry adjustment	2		[11]
41	Diffusers, shrouds, or concentrators around rotor	2		[11]
42	Flow-guiding structures	2		[11]
43	Incorporation of auxiliary airfoils with varying aspect ratios onto the H-type Darrieus rotor	3		[17]
44	Variation of rotor aspect ratio (AR) for different auxiliary configurations	3		[17]
45	Integration of deflectors on airfoil blades	2		[18]

Concept	Description	Level of Development (1-3)	Image	Reference number
46	Airfoil geometry modification (thickness increase)	2		[18]
47	60 degree angle/angle optimization for helical turbine blades	2		[19]
48	Carbon fiber blades for a helical darrieus	3		[20]

Savonius

Savonius VAWTs are drag-based turbines that typically consist of two curved blades, one convex and one concave. The working concept for Savonius VAWTs is a difference in drag between the convex and concave blades which causes the turbine to rotate. Savonius VAWTs face challenges related to low power generation and efficiency because certain portions of the rotation produce negative torque. A wide range of these concepts aim to address this challenge, found in research papers and commercial technology, are listed in Table 2. These primarily include changes to blade design and external augmentation to direct windflow.

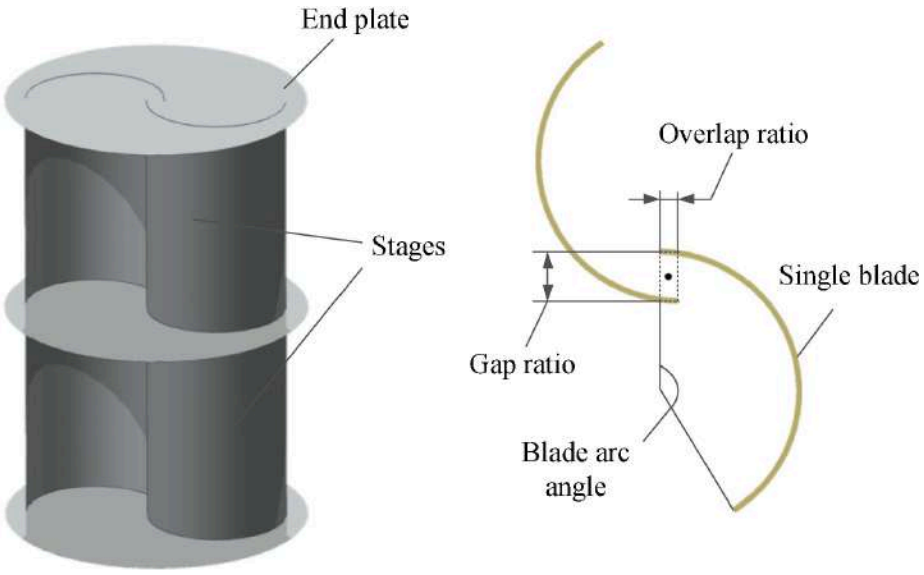
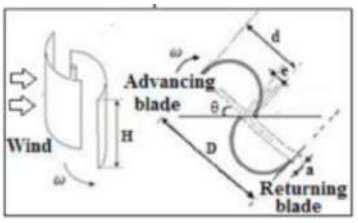
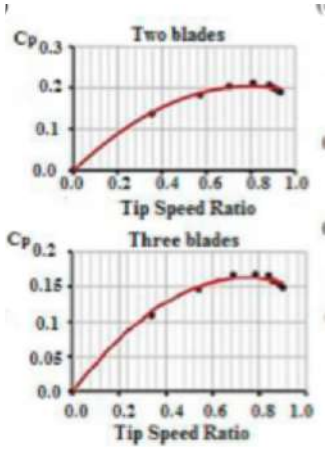
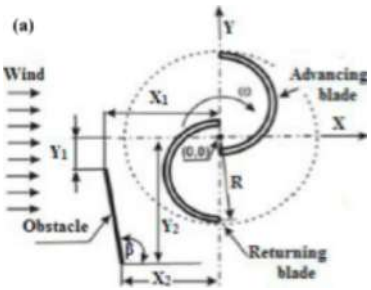
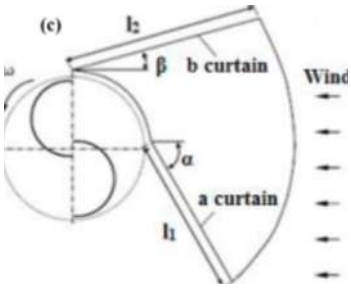
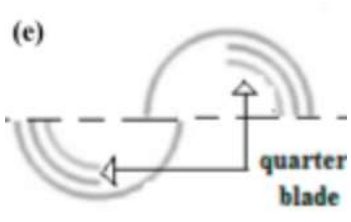
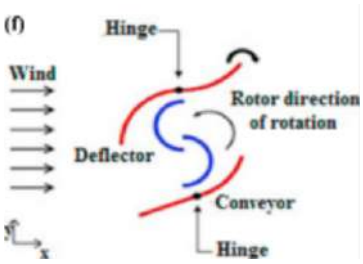
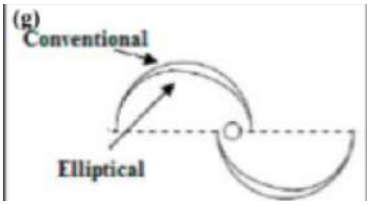
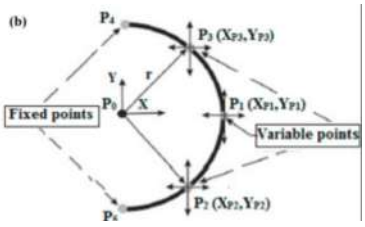
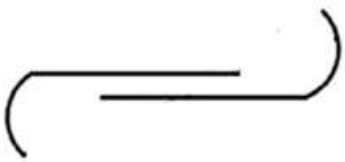
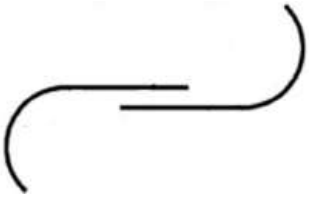


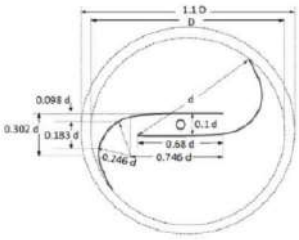
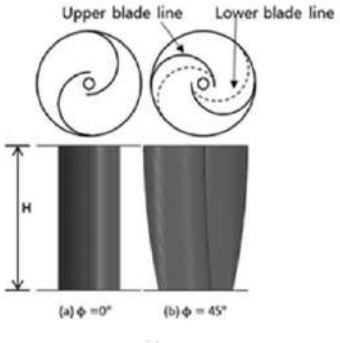
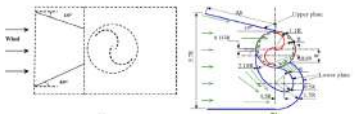
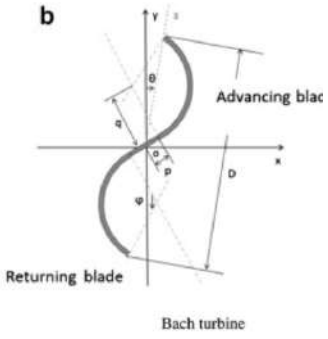
Figure 1. Parameters optimized in Classical Savonius for various studies [28]

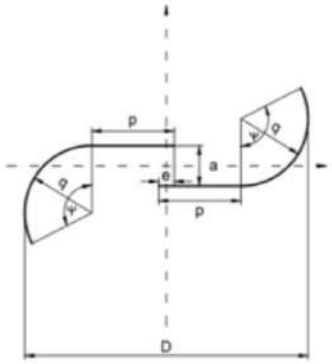
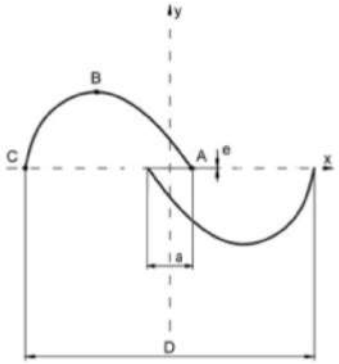
Table 2. Savonius Vertical-Axis Wind Turbine (VAWT) Concepts

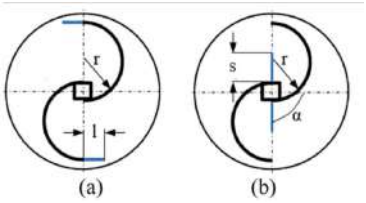
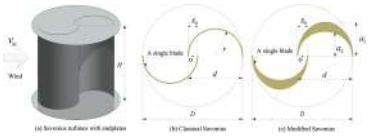
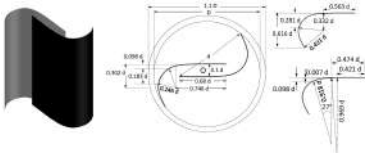
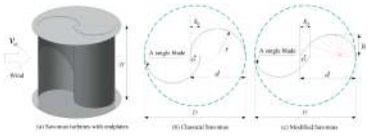
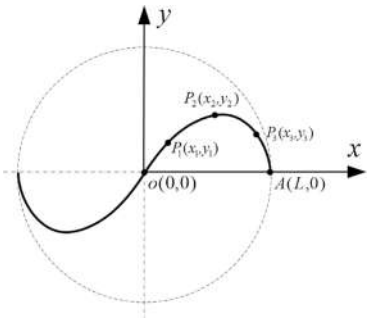
Concept	Description	Level of Development (1-3)	Image	Reference number
1	Optimization of diameter, thickness, and attachment angle of semi-circle blade.	3		[1]
2	Optimization of Aspect Ratio, getting larger increases the power coefficient, but decreases the structural stability.	2		[8]

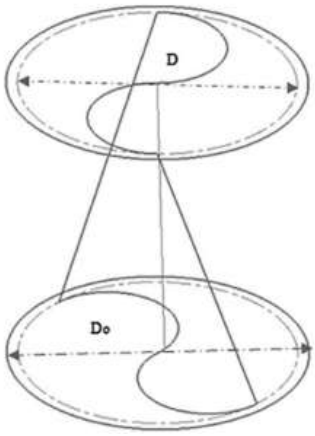
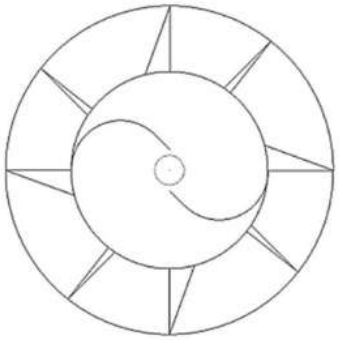
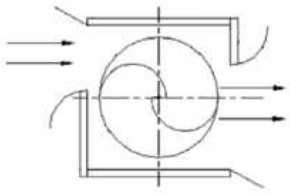
Concept	Description	Level of Development (1-3)	Image	Reference number
3	2-bladed classical Savonius shows higher power coefficient compared to 3-bladed of the same blade design.	2		[8]
4	Overlap ratio optimization within 0.1 and 0.3.	3		[8]
5	Obstacle shielding with diagonal plate	3		[8]
6	Curtain shielding	3		[8]
7	Quarter blade shielding	3		[8]

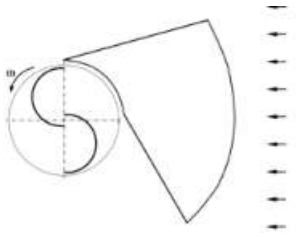
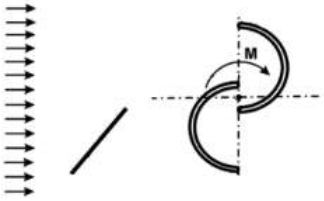
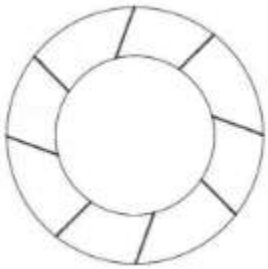
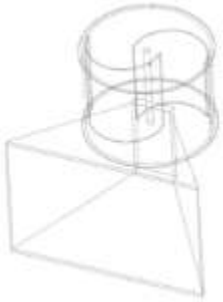
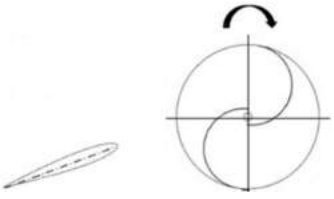
Concept	Description	Level of Development (1-3)	Image	Reference number
8	Hinged Deflector	3		[8]
9	Elliptical blade shape	3		[8]
10	Optimized positioning for obstacle shielding	3		[8]
11	Semicircular Savonius blade shape	2		[21]
12	Benesh Savonius Blade Shape	2		[21]
13	Elliptical Savonius Blade Shape	2		[21]
14	Modified Bach Savonius Blade Shape	2		[21]

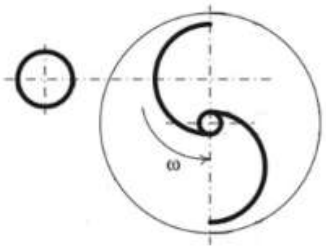
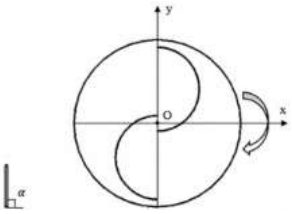
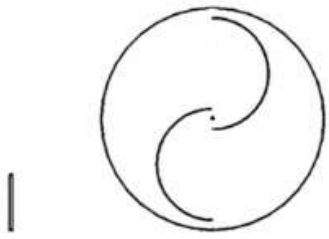
Concept	Description	Level of Development (1-3)	Image	Reference number
15	Newly developed blade, flat internal segment with length between bach and benesh and more elliptical blade shape for blade edges	2		[22]
16	Optimization of Twist Angle of Blade (45 degrees)	3		[21]
17	Conveyor deflector curtain system	3		[21][23]
18	Optimized Bach-type	2		[24]

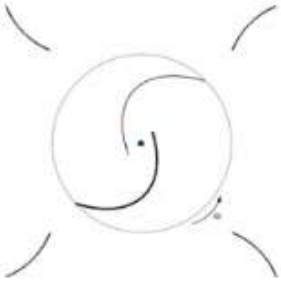
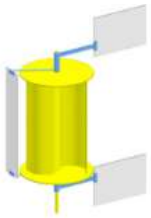
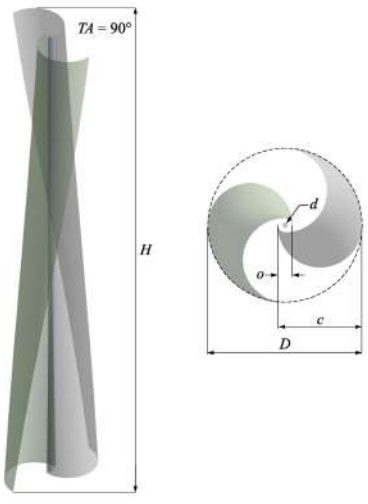
Concept	Description	Level of Development (1-3)	Image	Reference number
19	Another Optimized Bach-type	3		[25]
20	Elliptical Blade Design	3		[25]
21	Optimized Blade Arc Angle, 160 degree angle generated the most power for 2- bladed classical Savonius	2		[26]
22	Vented elliptical blade	2		[23]
23	Non-vented elliptical blade	2		[23]
24	S-Shaped Optimum Blade Design	2		[23]
25	Twisted Modified Design	2		[23]
26	Helical Bach Design	2		[23]
27	Bezier Curved Blade	2		[23]
28	Three-Fourth Modified Blade	2		[23]
29	Multiple Quarter Blades	2		[23]

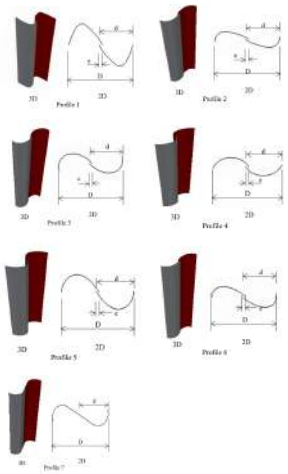
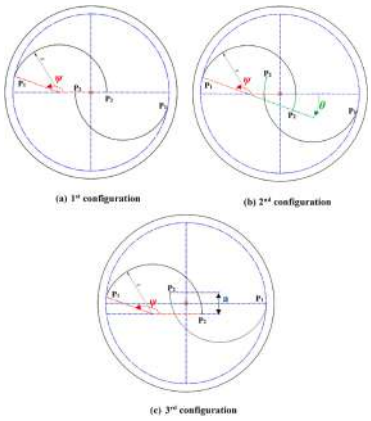
Concept	Description	Level of Development (1-3)	Image	Reference number
30	Additional Design: Increased blade length and addition of internal straight blades to optimized classical savonius	2		[27]
31	Multiple Miniature Blades	2		[23]
32	Optimal Design: Thickened blades for 2-bladed classical savonius	2		[28]
33	Two-quarters conventional blade	2		[23]
34	Additional inner blade	2		[23]
35	Multi-blade geometry	2		[23]
36	Zigzag surface blade	2		[23]
37	Newly developed blade: Bach with extended internal flat blade and more obtuse blade ends.	2		[29]
38	Fullness of blade	2		[23]
39	New Blade design with moment arms	2		[23]
40	Optimal Design: Use of parametric curve to alter shape of classical savonius blade	2		[30]
41	Optimized Blade shape alteration based on genetic algorithm	2		[31]

Concept	Description	Level of Development (1-3)	Image	Reference number
42	Flexible-blade	2		[23]
43	Deformable blade	2		[23]
44	Novel delta-bladed	2		[23]
45	Airfoil-shaped blade	2		[23]
46	Circular End Plate	3		[21]
47	Guide Vanes	3		[21]
48	Miniature and quarter blades (co-centrically within rotor blades)	2		[21]
49	Guide Box Tunnel	3		[23]

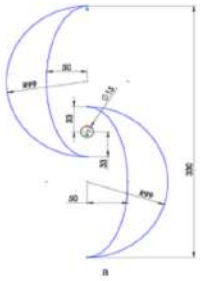
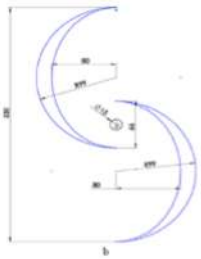
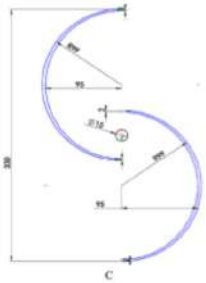
Concept	Description	Level of Development (1-3)	Image	Reference number
50	Curtain Arrangement	3		[23]
51	Shielding Obstacle	3		[23]
52	Guide Blade Arrangement	3		[23]
53	Nozzle Design	3		[23]
54	Airfoil-shaped deflector	3		[23]

Concept	Description	Level of Development (1-3)	Image	Reference number
55	Circular cylinder	3		[23]
56	Porous deflector	3		[23]
57	Guide vane	3		[23]
58	Wind-lens	3		[23]
59	Wind-lens with a dual turbine	3		[23]
60	Nanofiber-based deflector	3		[23]

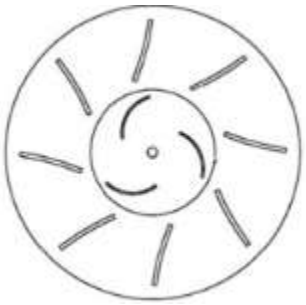
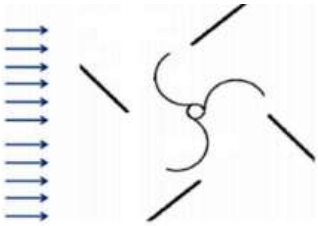
Concept	Description	Level of Development (1-3)	Image	Reference number
61	Deflector Blade	3		[23]
62	Passive deflector	3		[23]
63	Ice Type	3		[32]
64	Inward and outward overlaps	2		[33]
65	A novel SWT design method	2		[34]

Concept	Description	Level of Development (1-3)	Image	Reference number
66	Aerodynamic performance Investigation: 7 different 2-bladed twin-rotor Savonius turbine blade designs suggested, tested, and compared	2		[35]
67	Twisted blade profile	2		[33]
68	V-shaped rotor	2		[33]
69	Blade arc: changing blade arc angle on classical savonius to optimize power generation	2		[36]
70	Tiered zig-zag shaped surface	2		[33]
71	Enhanced aerofoil shaped blade	2		[33]
72	Modified batch Savonius	2		[33]
73	Optimized blade plane	2		[33]
74	Modified blade	2		[33]
75	eliptical-semi circle design	2		[33]
76	Redesigned blade profile	2		[33]
77	Scooplet-based design	2		[33]

Concept	Description	Level of Development (1-3)	Image	Reference number
78	triangular plate blocked the air	2		[33]
79	a rotating cylinder for vortical shedding	2		[33]
80	wake-controlling splinters	2		[33]
81	a structured surface roughness approach to managing the wake on the deflector	2		[33]
82	Single-, two- and three-stage (max. two-stage) Semicircular and twisted blade (max. twisted blade) Two and three bladed (max. two-bladed)	2		[37]
83	Elliptical-bladed multistage (one, two, three-stage) (max. two-stage)	2		[37]
84	Multi-stage turbines with twisted blades (a) single-stage, (b) two-stage, (c) three-stage, (d) four-stage (max. four-stage)	2		[37]
85	2 blade simple rotor, semicircular	2		[22]
86	2 blade simple rotor, twisted (12.5)	2		[22]
87	3 blade simple rotor, semicircular	2		[22]
88	3 blade simple rotor, twisted (12.5)	2		[22]
89	2 blade double rotor, semicircular	2		[22]

Concept	Description	Level of Development (1-3)	Image	Reference number
90	2 blade double rotor, twisted	2		[22]
91	3 blade double rotor, semicircular	2		[22]
92	3 blade double rotor, twisted	2		[22]
93	2 blade triple rotor, semicircular	2		[22]
94	2 blade triple rotor, twisted	2		[22]
95	3 blade triple rotor, semicircular	2		[22]
96	3 blade triple rotor, twisted	2		[22]
97	ice wind rotor (3 & 4 blades)	2		[22]
98	deformable blade	2		[22]
99	Savonius 2-blade classical thickness (highest)	3		[38]
100	Savonius 2-blade classical blade thickness (med)	3		[38]
101	Savonius 2-blade classical blade thickness (low)	3		[38]

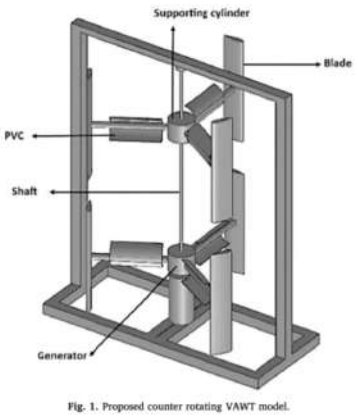
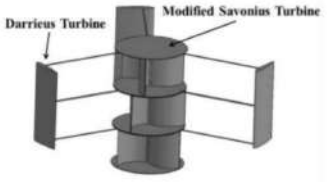
Concept	Description	Level of Development (1-3)	Image	Reference number
102	Persion original VAWT	3		[9]
103	2 blade helical Savonius	3		[9]
104	2 layered classical Savonius	3		[9]
105	ODGV Turbine	3		[9]
106	diffuser system that stabilizes turbulent airflow.	3		[39]
107	remote wifi-monitoring system	3		[39]
108	waterproof enclosure for the electronics	3		[39]
109	Curved "tulip" type blade design	3		[40]
110	aircraft wing design	3		[40]
111	coreless generator	3		[40]
112	smaller rotor radius	3		[40]
113	FLTXNY 1000W Vertical Wind Turbine Permanent Magnet Generator 3 Phase 12V 24V Vertical Axis Coreless Wind Generator	3		[41]
114	FT 2M-Lite Turbine : 2 Bladed Vertical Axis Wind Turbine	3		[42]
115	Using High efficiency permanent magnetic generators	3		[42]
116	using fiberglass for the blades	3		[42]
117	using multiple VAWTs in tandem	3		[42]
118	Helix Wind Corp S594 wind	3		[43]

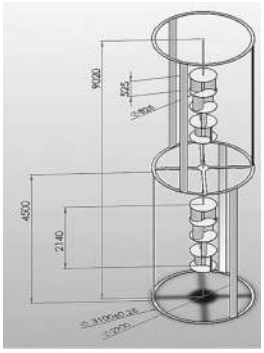
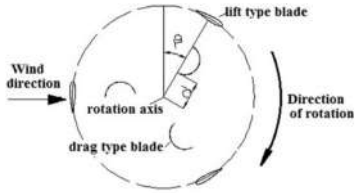
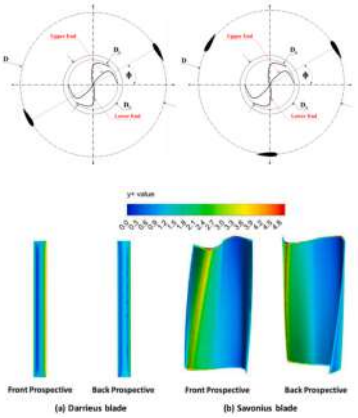
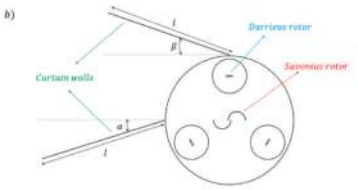
Concept	Description	Level of Development (1-3)	Image	Reference number
	turbine			
119	single stage helical bach	3		[44]
120	add valve to rotor	3		[22]
121	tower cowling	3		[23]
122	rotor house	3		[23]

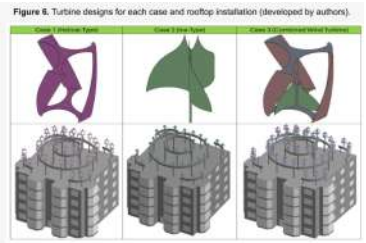
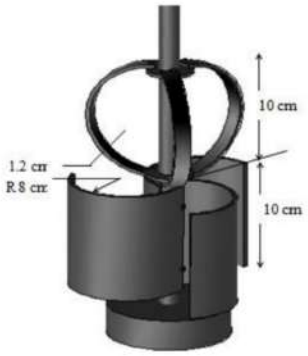
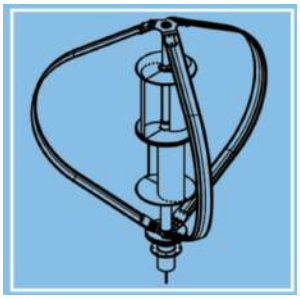
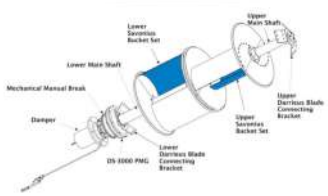
Hybrid

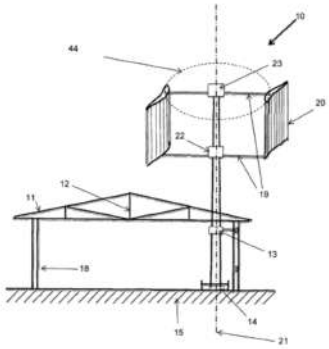
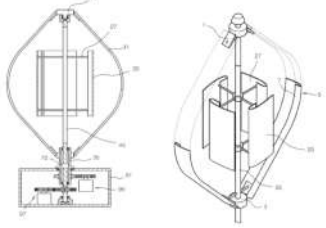
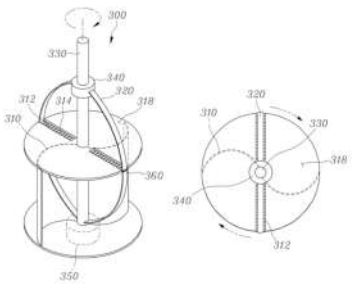
Hybrid VAWTs combine aspects of Darrieus and Savonius turbines. They often include one or more Savonius rotors within a larger Darrieus rotor. Table 3 lists hybrid VAWT concepts. It includes both single stage and multi-stage designs with varying types of Darrieus and Savonius rotors. In addition, some concepts combine multiple Savonius or Darrieus rotors into a single turbine.

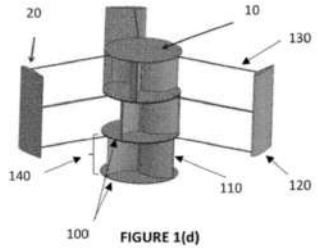
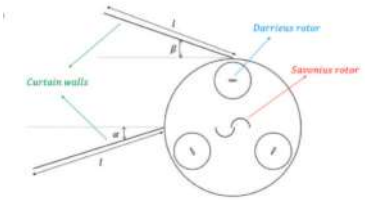
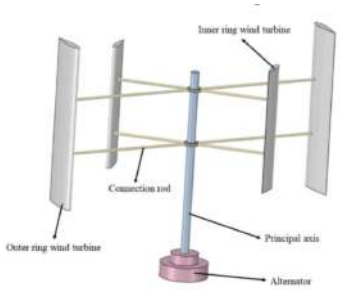
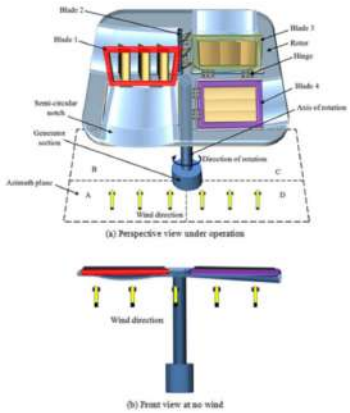
Table 3. Hybrid Vertical-Axis Wind Turbine (VAWT) Concepts

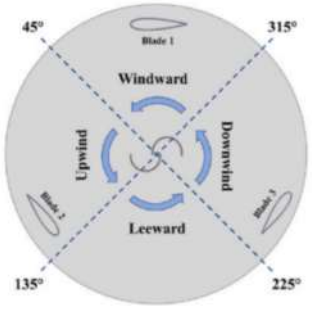
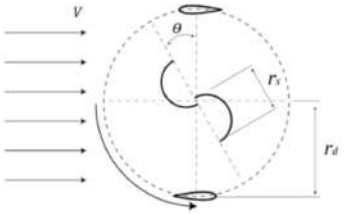
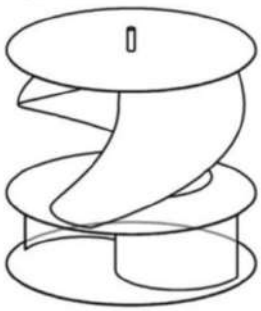
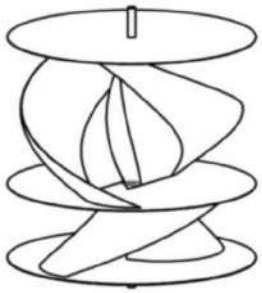
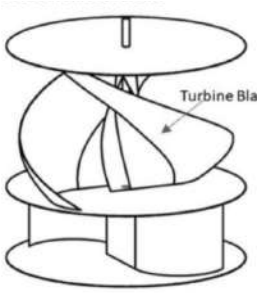
Concept	Description	Level of Development (1-3)	Image	Reference number
1	Hybrid with three internal Savonius blades and three external Darrieus blades There are two stacked rotors spinning along the same axis, but in opposite directions	2	 Fig. 1. Proposed counter rotating VAWT model.	[45]
2	Hybrid with three modified internal Savonius blades and three external Darrieus blades	2		[46]

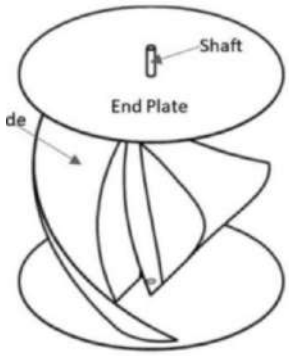
Concept	Description	Level of Development (1-3)	Image	Reference number
3	Two tiers - each with four two blade bach Savonius turbines and one three blade H-rotor Darrieus	2		[47]
4	Electro-magnetic switch mechanism for dis-/engagement mechanism to run Darrieus and Savonius together or separately	1		[48]
5	Combined 3 blade Savonius-type Bach turbine and a 3-bladed H-Darrieus turbine	3		[48]
6	Hybrid wind rotor has twisted Savonius blades with a modified blade profile combined with 2 or 3 Darrieus blades	2		[49]
7	Two blade Savonius, three blade darrieus hybrid with curtain	2		[4]

Concept	Description	Level of Development (1-3)	Image	Reference number
8	Combined helical + IceWind	1		[32]
9	Hybrid 3 blade Eggbeater + 3 blade classical Savonius ● Darrieus stacked above Savonius	2		[50]
10	Two stacked two-blade Savonius within a 3-blade eggbeater Darrieus	3	 	[51][52]
11	Stacked Savonius of different sizes within a Darrieus	2		[52]

Concept	Description	Level of Development (1-3)	Image	Reference number
12	Using ASTM A283 grade D steel for the VAWT axis pole	3		[52]
13	Adding a damper	3		[52]
14	Stacked DS-3000W VAWT, 3 blade darrieus, 2 blade Savonius	3		[53]
15	Darrieus with two horizontal channel beams with compartments that support each blade. The channels act similarly to Savonius type VAWT generate torque	1		[54]
16	Double Darrieus hybrid - H-rotor inside an eggbeater	2		[55]
17	Darrieus Savonius hybrid where the Darrieus can be moved closer or further from the center - starting far out and moving closer	2		[56][57]

Concept	Description	Level of Development (1-3)	Image	Reference number
18	3 layer 3 blade classical Savonius + 3 blade H-rotor Darrieus	2	 FIGURE 1(d)	[58][59]
19	Classical 2-blade Savonius + 3 blade H-rotor Darrieus with curtain	2		[4]
20	Double H-rotor Darrieus (4 blades, 2 lower radius interior and 2 larger radius exterior)	2	 Fig. 1. Schematic diagram of the DD-VAWT model.	[60]
21	New "eccentric" VAWT with characteristics of both Darrieus and Savonius, seems complicated	1		[61]

Concept	Description	Level of Development (1-3)	Image	Reference number
22	2-bladed Savonius and 3 bladed H-rotor Darrieus	2		[62]
23	2-bladed Savonius and 2 bladed H-rotor darrieus	2		[63]
24	Double Savonius hybrid - stacked helical and standard	2		[44]
25	Double Savonius hybrid - stacked simple helical and helical bach	2		[44]
26	Double Savonius hybrid - stacked simple bach and helical bach	2		[44]

Concept	Description	Level of Development (1-3)	Image	Reference number
27	Single stage helical bach turbine	2		[44]
28	Crossflex turbine - building integrated	2		[9]

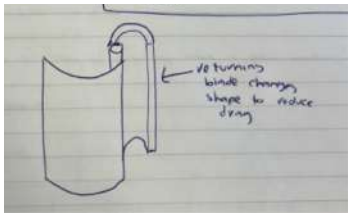
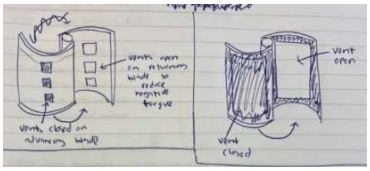
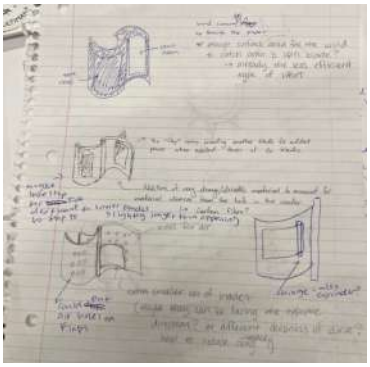
Emergent Ideation by VAWT Ventures

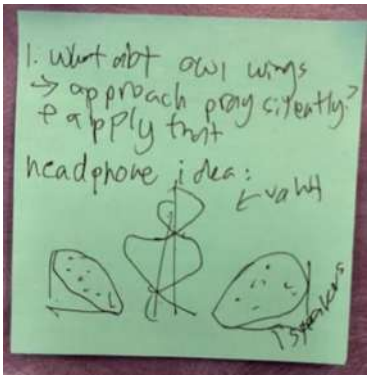
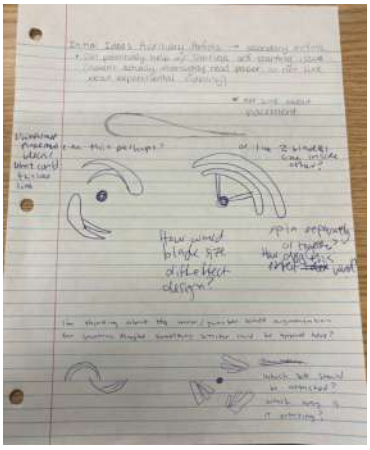
The Emergent Ideation Table compiles concept ideation done by members of the group, including full VAWTs, specific adjustments, and augmentation ideas. The processes used for this were SCAMPER, Biomimicry, Brain Writing, Brute Think, and Concept Tables. The SCAMPER method is a structured approach consisting of asking multiple questions about a specific design problem. The acronym SCAMPER stands for Substitute, Combine, Adapt, Modify, Put to another use, Eliminate, and Reverse. SCAMPER is a useful method because it helps overcome conventional thinking patterns and also helps facilitate innovative solutions. Biomimicry is the process of researching and applying the ways in which nature has provided solutions to current problems. Brain Writing is the process of stating a design problem and working as a team to generate ideas through collaboration and idea circulation. This method was used the most during team meetings; an initial concept/design problem with emergent ideas was listed, and then the

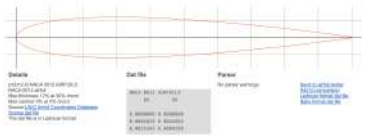
concepts/ideas would be passed around the group multiple times. Each member would add their own concepts and ideas, and the final result was a compilation of ideas generated by the team, which are provided in Table 4. Another method used in individual concept generation was Brute Think which consists of selecting a random word, thinking about things associated with that word, and then forcing connections between the word and the problem. Finally, when using Concept Tables for individual concept generation, we identified parameters in the solution, listed options for each parameter, and then experimented with different combinations.

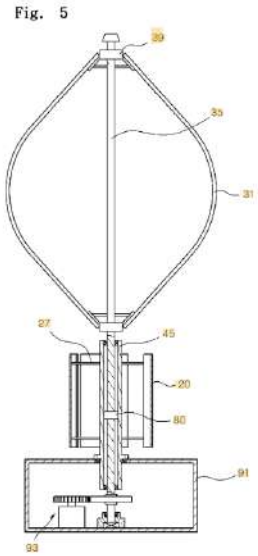
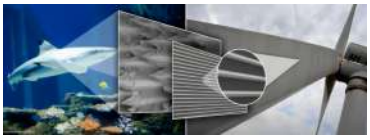
Table 4. Emergent Ideation

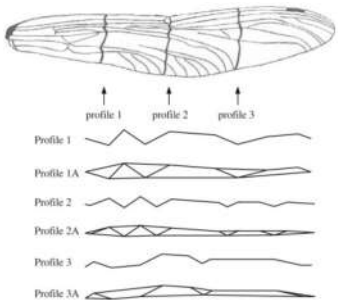
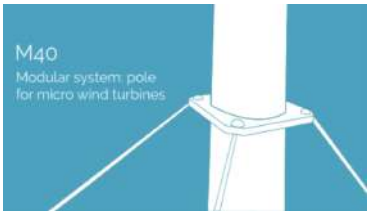
Concept	Description	Level of Development (1-3)	Image	Reference number
1	Savonius blade design based on the fibonacci spiral	2		[63][64]
2	Helical blade shape based on seed pods of two trees: Mimosa and Bauhinia Variegata	2		[65]
3	Serrated edge inspired by owl feathers to reduce turbulence behind the blade, allowing the rotor to spin faster	1		[66]
4	Improve efficiency of turbine blades by adding bumps inspired by the tubercles on the leading edge of humpback whale flippers	1		[67]

Concept	Description	Level of Development (1-3)	Image	Reference number
5	Flexible blades that change shape as they return to decrease drag	1		
6	Coating or texture on blades - maybe different on either side	1	For example, the textured NACA0015 	[11]
7	Introduce vents or holes in the returning blade to allow some air to pass through to decrease difference in pressure and negative torque (Brain Writing)	1	 	
8	Soundproofing the mechanical gearbox to reduce mechanical noise	3		[67]
9	Altering airfoil profile to reduce noise	2		

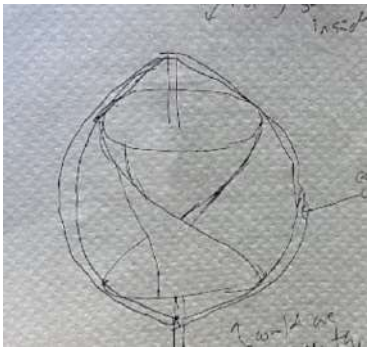
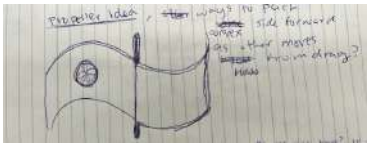
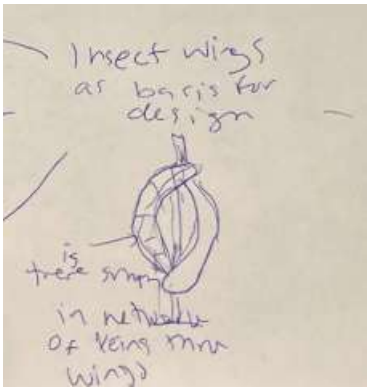
Concept	Description	Level of Development (1-3)	Image	Reference number
10	System that produces equal opposite phase frequency waves to cancel out the hum of the VAWT (like noise cancelling headphones)	1		[68]
11	Using sound absorbing materials, such as insulation placed around the base of the VAWT	2		
12	A setup around the VAWT to dampen noise without blocking wind	2		
13	Pole made of sound absorbent material	2		
14	Secondary/auxiliary airfoils (Brain Writing)	2		
15	Add elements of Savonius without passing the hybrid threshold	2		

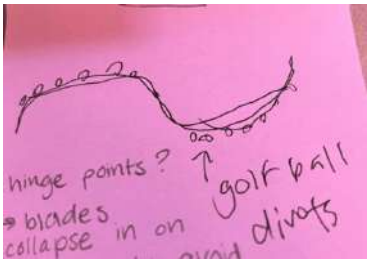
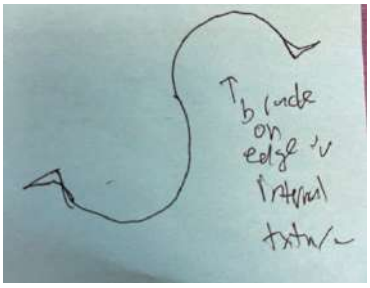
Concept	Description	Level of Development (1-3)	Image	Reference number
16	Using more blades for maximized power output	3		[69]
17	Runs on lift and drag	3		
18	Stacked Darrieus and Savonius → Savonius helps to start Darrieus	3		[53]
19	Switches from Savonius to Darrieus	1		
20	Expandable blades	1		
21	Use of more aerodynamic blades For example using NACA 0012 airfoil blades, known for their symmetry and aerodynamic properties	2		[70]

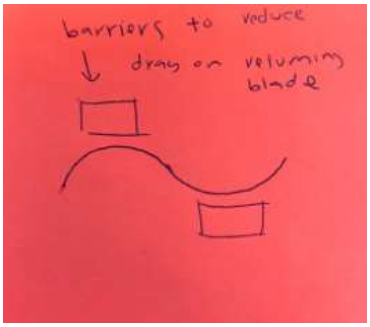
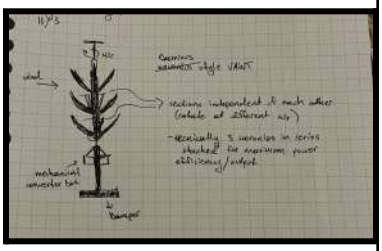
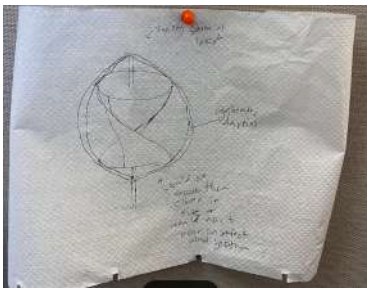
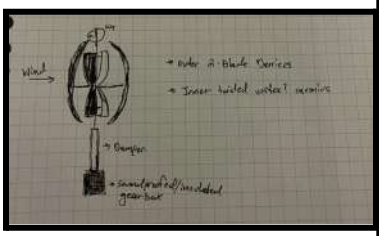
Concept	Description	Level of Development (1-3)	Image	Reference number
22	Using lift-based blades	3	 Like a Vertical shaft type darius windmill	[71]
23	Using double airfoil blades	2		[72]
24	Dampening system at base of VAWT	2		[52]
25	Gearbox insulation	2		
26	VAWT modified for lower TSR	1		[67]
27	Elimination of extra friction and vibrations in all parts	1		
28	Designing the blades with implemented Riblet coating which is a surface coating that mimics shark denticles	2		[73]

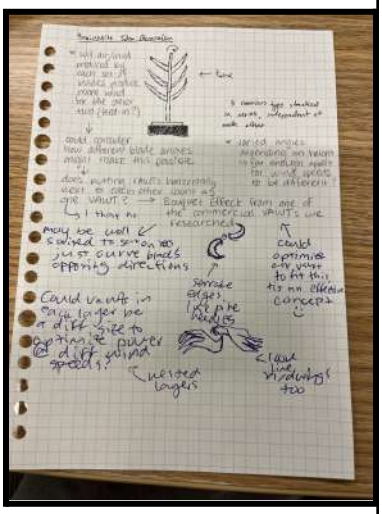
Concept	Description	Level of Development (1-3)	Image	Reference number
29	Corrugated blade design based on the corrugated winds of dragonflies	2		[74]
30	Implementing materials like cotton, wood, or bamboo to minimize noise	2		
31	Using carbon fiber for the blades	2		[20]
32	Strengthening the base structure	1		
33	Implementing a braking system	2		[12]
34	Shut off mechanism	1		
35	Coating/material to protect from hot/cold weather	2		[12]
36	Collapsable pole component (changeable height)	1		[69]

Concept	Description	Level of Development (1-3)	Image	Reference number
37	Triangular base	2		[12]
38	Columns built into the building to act as a foundation for the VAWT.	1		
39	Triple Twisted Helical Savonius. Typically	1		
40	Snack-cup inspired Deformable Helical Savonius	1		
41	Tightly Twisted Helical Blade for Darrieus	1		

Concept	Description	Level of Development (1-3)	Image	Reference number
42	Helical and Eggbeater Combined Darrieus Blade	1		
43	Combined Helical and Eggbeater Darrieus and Internal Savonius	1		
44	Hybrid with large internal Helical Savonius	1		
45	Propeller to help push blades with the direction of the drag.	1		
46	Insect wing inspired helical darrieus - in blade shape, material, and veining	1		

Concept	Description	Level of Development (1-3)	Image	Reference number
47	Application of Savonius Augmentation on Ice Savonius Type (slits in blades, end plates, shielding plateS)	1		
48	Further twist to Ice Savonius Type	1		
49	Two Bladed Ice Savonius Type	1		
50	Golf ball divots on concave side of Savonius blades (note: may belong on other side)	1		
51	Collapsing blades to reduce or increase drag depending on type.	1		
52	Additional material on blades to increase drag.	1		
53	tails on blades to increase drag.	1		

Concept	Description	Level of Development (1-3)	Image	Reference number
54	Barriers to reduce drag on returning blade.	1		
55	Stacked Darrieus in series VAWT	1		
56	Considering size differences in hybrids and what combinations have not been attempted.	1		
57	Outer 2-bladed Darrieus, inner twisted Savonius	1		
58	Rubber or ductile polymer for deformable blades	1		

Concept	Description	Level of Development (1-3)	Image	Reference number
59	3D Printed blade for speed of production and cost efficiency	1		
60	Stacked Darrieus in series VAWT with further contributions (Brain Writing)	1		

Conclusion

This memo aimed to compile concept generation ideas from research studies, patents, and commercial technologies, and then provide a section for emergent ideation by group members. The memo gave a brief description of each concept, its level of development, and relevant images. There is also potential to apply concepts within the Savonius, Darrieus and hybrid sections to other categories and to create new combined concepts of multiple designs. Building on documented concepts, the team should prioritize hybridization studies that combine aspects of lift-based and drag-based turbines, specifically mixed configurations.

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