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Docket Number:	22-IEPR-05
Project Title:	Emerging Topics
TN #:	243812
Document Title:	Wind-to-Hydrogen Concept
Description:	Taylor Energy
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Organization:	Taylor Energy
Submitter Role:	Public
Submission Date:	6/30/2022 11:28:15 AM
Docketed Date:	6/30/2022

Wind-to-Hydrogen Concept

1.0 Wind-to-Hydrogen

1.1 Aeroderivative wind turbines, based on ever larger airplane propellers **(Figure-1**), are presently the dominant wind-to-power technology, which may be viewed as the 1st-modern-generation of commercially successful wind generators.

However, improvements that enable the use of low-velocity wind, on-set with 5-kilometers/hour wind, designed for the direct production of ultra-clean hydrogen -- which can be stored and used for Flexible Power generation -- will change the wind industry significantly.

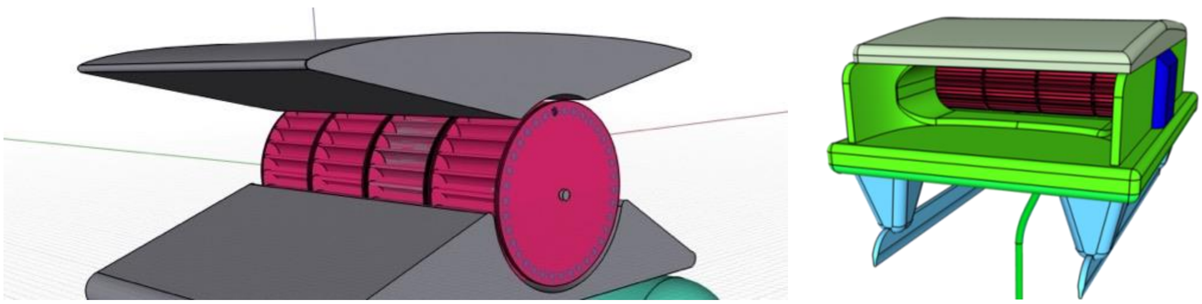
1.2 Floating wind systems should one of the next efforts funded by the Energy Commission, and ultimately funded by the federal government through NREL. These R&D activities would fit with CE-CERT's objectives at UC Riverside, working in collaboration with Taylor Energy.

1.3 Within the Energy Commission, the EPIC program will oversee R&D grants for the pilot-scale development of floating wind turbine technology. Taylor Energy has developed concepts that are attractive for California, considering the need for horizontal turbines that recover power from low-velocity wind, and on-demand electric power enabled by H_2 energy storage.

Figure-1. Existing Aeroderivative Turbines: Based on Airplane Propeller Technology

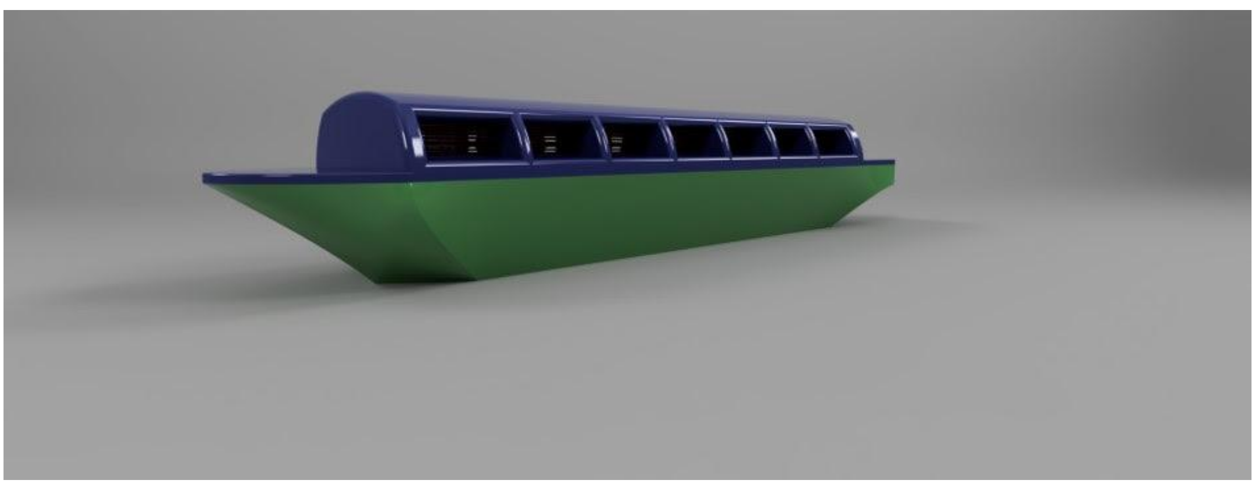
1.4 The novel wind turbine technology uses a horizontal rotor, with a converging/diverging nozzle arrangement to magnify the power of low-density wind streams. For example, shipboard cowlings would form a convergent/divergent nozzle to enable power recovery from low-velocity winds, as low as 5-kilometers/hour, according to the technical literature (**Figure-2**).

Figure-2. Horizontal Low-Velocity Wind Turbine with Converging/Diverging Nozzle



1.5 The federal government will be funding wind R&D through NREL. Floating wind-to-hydrogen technology will require a development-path that includes multiple trials a pilot-scale, and then scaling to large capacity, probably reaching the footprint of a container ship (**Figure-3**), but with a low-profile.

Figure-3. Scaled for deployment on board Container-Ship Size, 100' x 1000'



2.0 <u>Problem with Aeroderivative Wind Machines</u>:

Large propeller-driven wind-turbines have reached their maximum economic size (10-MWe). The bigger the rotor, the slower the shaft speed; consequently, the gear box becomes more expensive than the rotor because of the step-up speed required. Alternatively, wind-machines without a gear box are costly, and very heavy, recovering power at high-torque and low-rpm.

"The direct-drive generator becomes huge. Instead of the 100-ton gearbox, you have a 200-ton generator" (Polinder). Moreover, low-velocity wind power available in the Pacific region is not recovered by aeroderivative turbines (**Figure-4**), which do not recover wind-power below about 9-mph; whereas, the majority of wind-power is available down around 5-mph.

Figure-4. Aeroderivative Wind Turbines have reached their maximum scale.

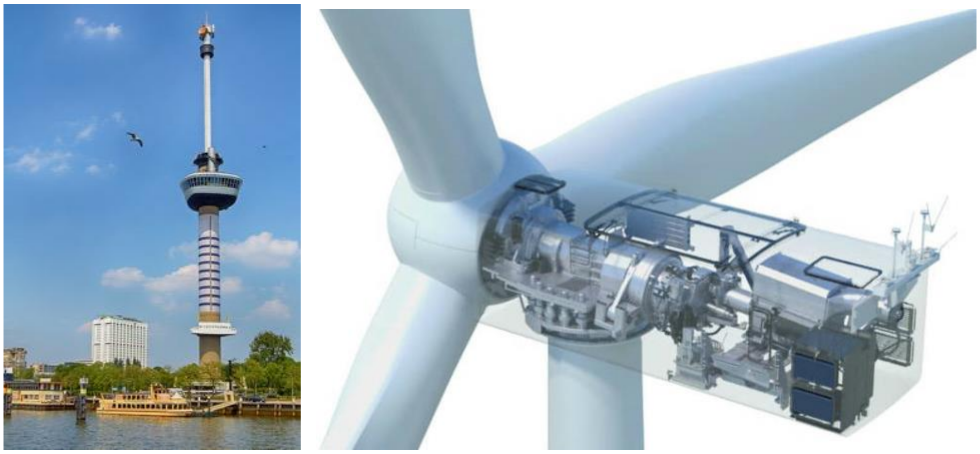
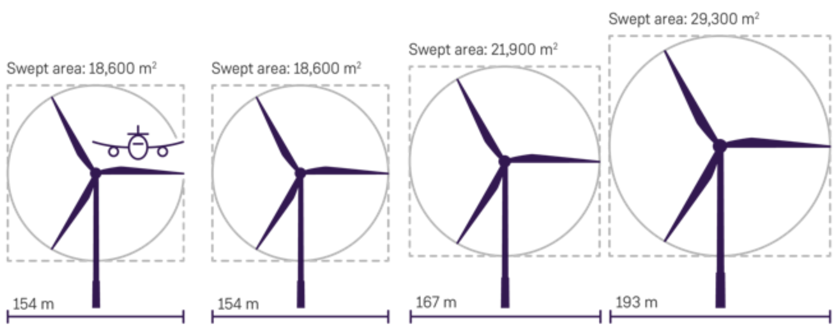
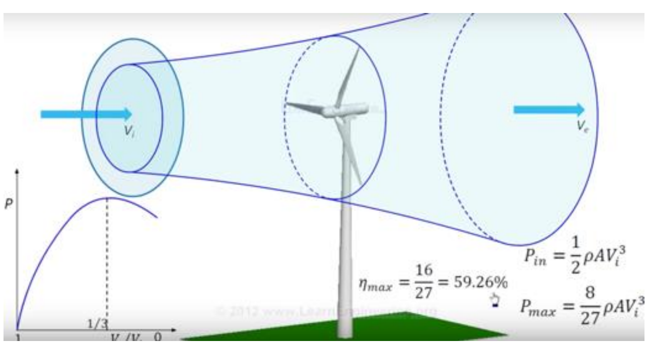


Figure-5. 10-MW Turbine has 94-meter diameter rotor



	SWT-6.0-154	SWT-7.0-154	SG 8.0-167 DD	SG 10.0-193 DD
IEC Class	IA	IB	S (1B)	S (1B)
Nominal Power	6,000 kW	7,000 kW	8,000 kW	10,000 kW
Blade length	75 m	75 m	81,4 m	94 m

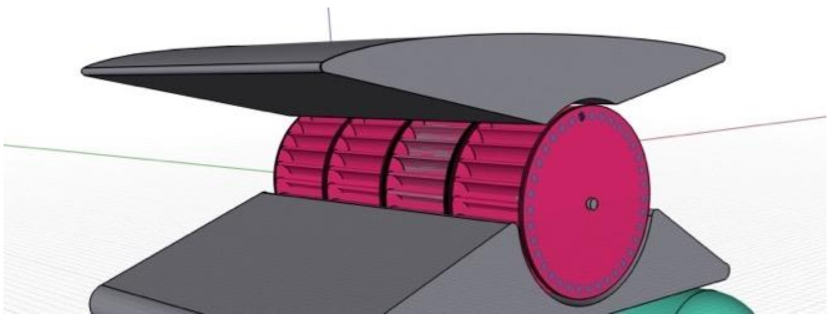
Figure-6. Swept Area Proportional to Power Recovery



2.1 Technical Approach Summary:

This type of project would design a proof-of-concept prototype for a novel wind-to-hydrogen system that significantly improves upon existing large-scale aeroderivative based wind-to-power technology. The design team would develop a prototype horizontal wind machine based on Russian technology (developed to prototype scale during the early 1990's) using a converging-diverging nozzle-type wind turbine that serves to increase the momentum of low-velocity wind (**Figure-8**).

Figure-7. Wind-to-Hydrogen Concept Employed to Generate Hydrogen



- The rotor design would employ neodymium-magnets on the outer circumference of turbine-wheels; therefore, the larger the diameter the turbine wheel, the greater the differential speed that drives electric current generation, which is the opposite of aeroderivative wind machines.

- The electric generator would be designed to produce direct-current at a low-voltage that is specifically selected for optimum electrolysis of seawater to produce hydrogen.

- Hydrogen (H_2) would be produced directly by the use of low-voltage current applied to the separation of hydrogen atoms from water molecules using an emerging fuel-cell concept, presently state-of-the-art for the use of low-purity water for electrolysis.

- The horizontal wind turbine/nozzle combination is mounted on a barge, anchored by two cables that enable the craft to turn into the wind or fall off the wind during storms.

- This wind-to-hydrogen technology would meet the growing need in California for transportation uses, and the immediate need for on-demand electric power that can be dispatched by the Independent System Operator (CA-ISO).

2.2 Pilot-scale Test & Development

Ultimately, the scale-up would require the development of a custom-designed permanent magnet DC-motor, with magnets mounted on the outer circumference of the turbine wheel. But that is another stage in the scale-up process when the rotors are intended for 100-foot diameter.

A pilot program would demonstration modification to an ocean-going platform (a Pacific barge) designed to support a series of proof-of-concept wind turbines. In the pilot-scale design shown below, the electric generators might be installed below deck, well below the wind turbines, one generator driven by one horizontal turbine: belt driven, adjustable for testing & development.

Figure-8. Floating Offshore Platform for Horizontal Wind Turbine Testing