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Sandia National Laboratories

FLOATING OFFSHORE VERTICAL AXIS WIND TURBINE PROJECT

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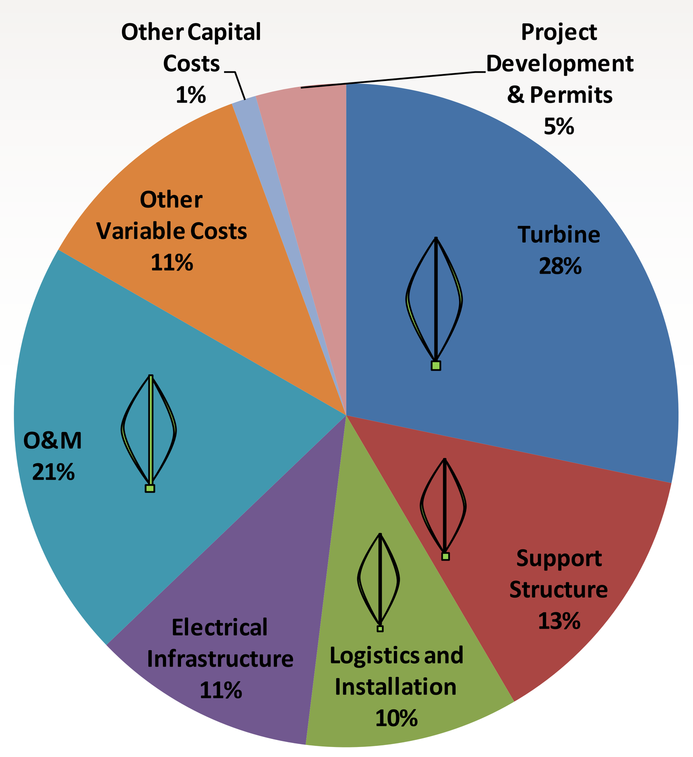
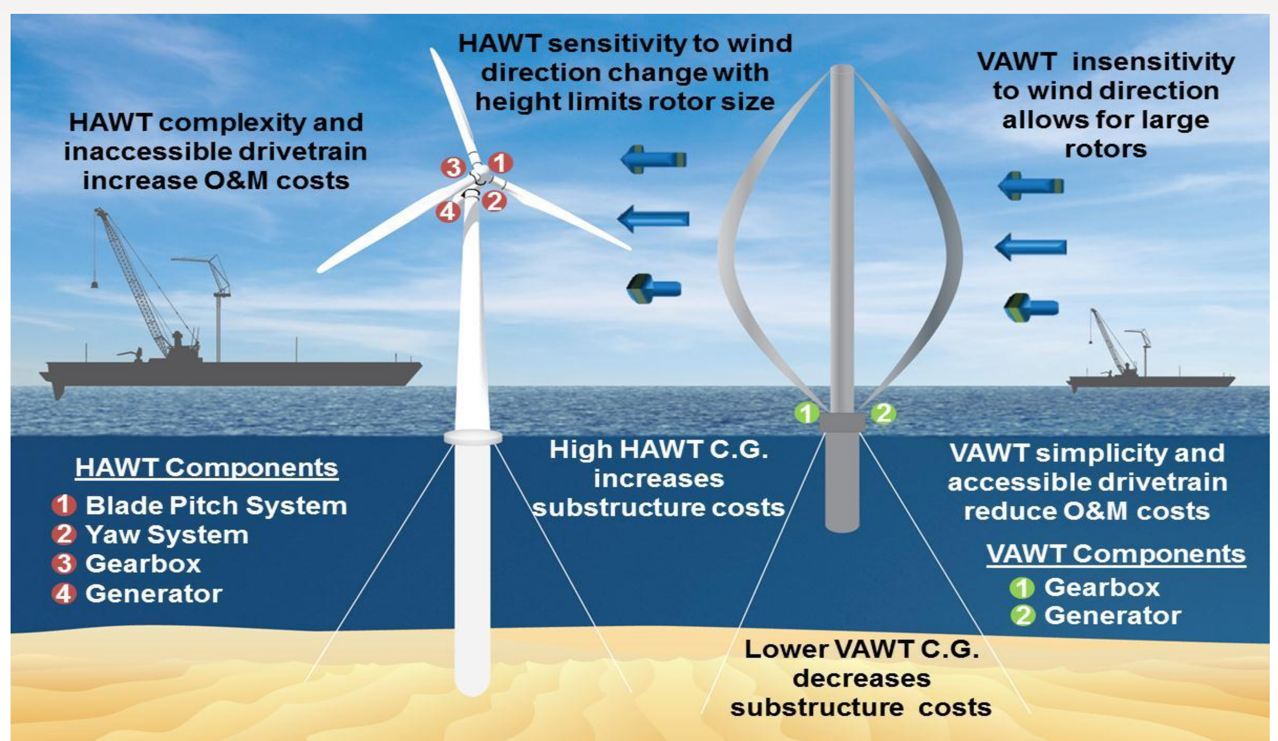
INTRODUCTION & MOTIVATION

Strong offshore wind resources available in US coastal regions with large population (and load) centers make offshore wind energy attractive. Estimates suggest that over 2000 GW is available in US offshore water depths of 60 meters and more. However, high costs must be addressed to realize the potential benefits of the offshore resource. Sandia is developing and evaluating technology to access this deep-water offshore wind resource where floating systems are required.

Offshore Wind Cost Breakdown (*left*); Advantages of Vertical-Axis over Horizontal-Axis Wind Turbines (*below*)





Vertical axis wind turbines (VAWTs) represent a deep-water solution with inherent advantages over horizontal axis wind turbines (HAWTs). For example, placement of the drivetrain at the base of the tower lowers the vertical center of gravity and improves accessibility of drivetrain components for installation and O&M, major cost drivers positively impacted by VAWTs.

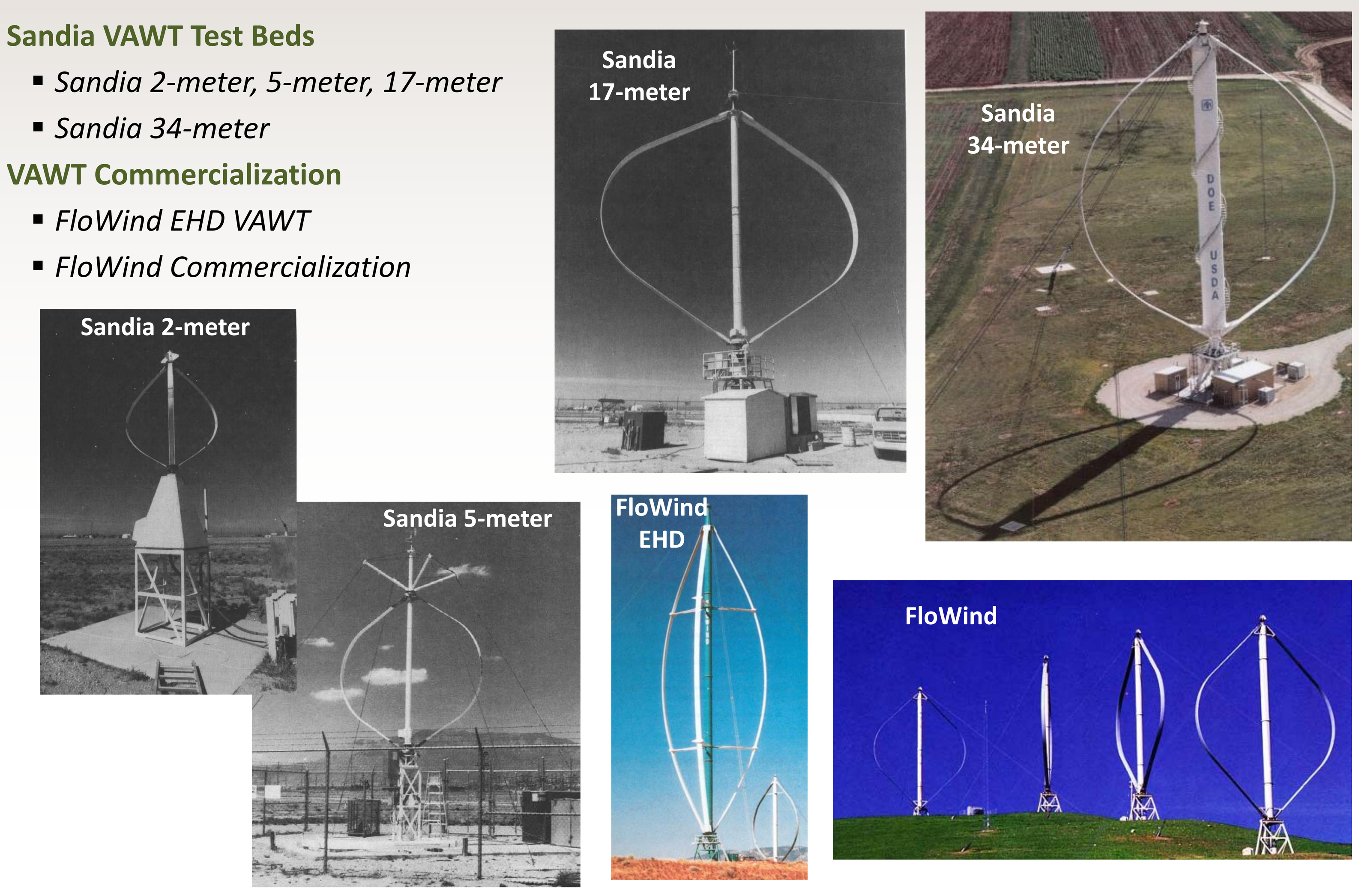
SANDIA LEGACY VAWT TEST BEDS

Sandia VAWT Test Beds

- *Sandia 2-meter, 5-meter, 17-meter*
- *Sandia 34-meter*

VAWT Commercialization

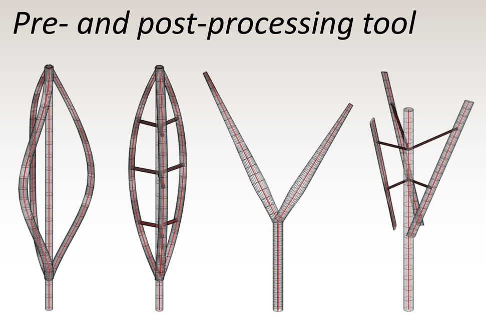
- *FloWind EHD VAWT*
- *FloWind Commercialization*



SANDIA VAWT DESIGN & ANALYSIS TOOLS

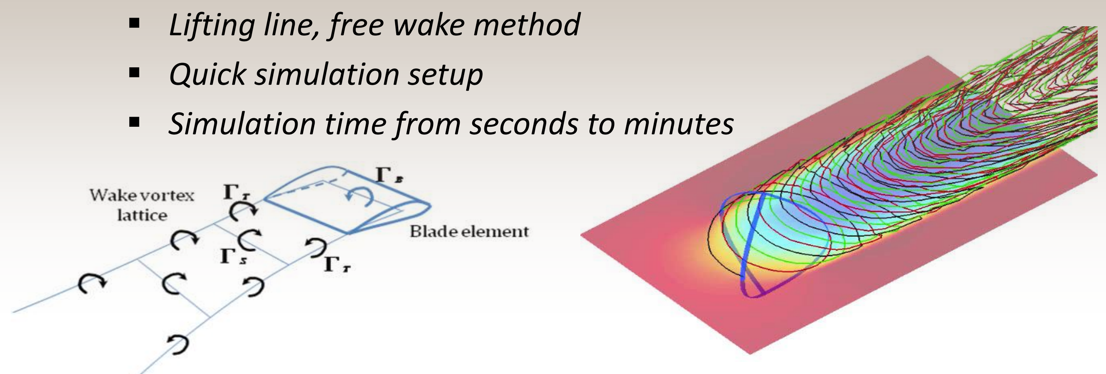
VAWT Geometry Generation (VAWTGen)

- *Arbitrary VAWT geometries*
- *Pre- and post-processing tool*



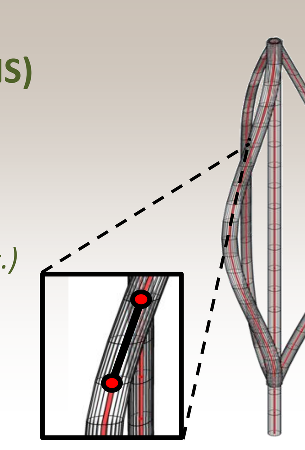
Code for Axial and Cross-flow TUrbine Simulation (CACTUS)

- *Lifting line, free wake method*
- *Quick simulation setup*
- *Simulation time from seconds to minutes*



Offshore Wind ENergy Simulation Toolkit (OWENS)

- *Finite element structural dynamics formulation*
  - *3D Timoshenko beam element*
  - *Rotational effects and geometric nonlinearities*
  - *Structural couplings (bend-twist, sweep-twist, etc.)*
- *Static, transient, and modal analysis*



WavEC2Wire Hydrodynamics & Platform Dynamics Code

- *Developed by Sandia National Labs, University of Maine, and Wave Energy Center in Lisbon, Portugal*
- *Superposition of hydrodynamic, hydrostatic, viscous, mooring, and applied (topside) forces.*

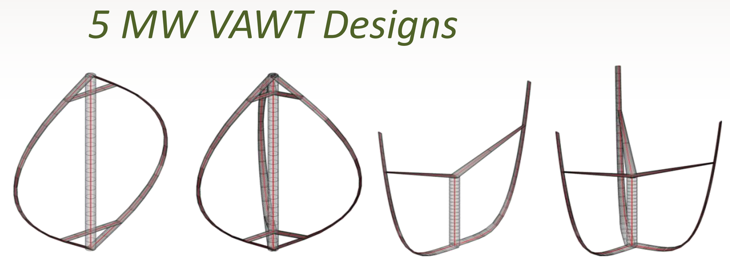
WavEC THE UNIVERSITY OF MAINE

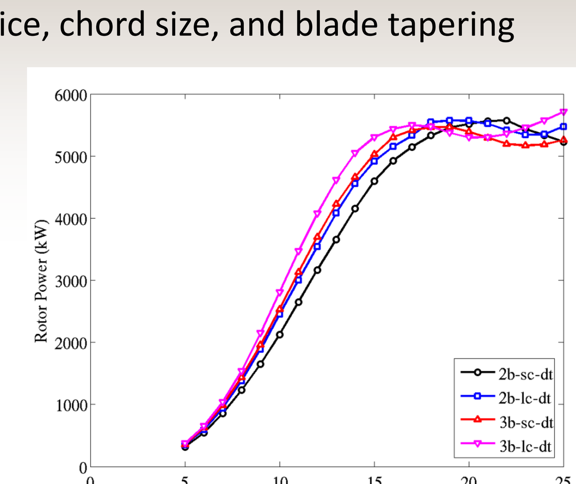
FLOATING VAWT DESIGN STUDIES

ROTOR DESIGN STUDIES

Sandia's rotor design studies include aerodynamic and structural design of a series of 5 MW VAWT rotors through an investigation of the following rotor design parameters: rotor configuration, number of blades, material choice, chord size, and blade tapering scheme.

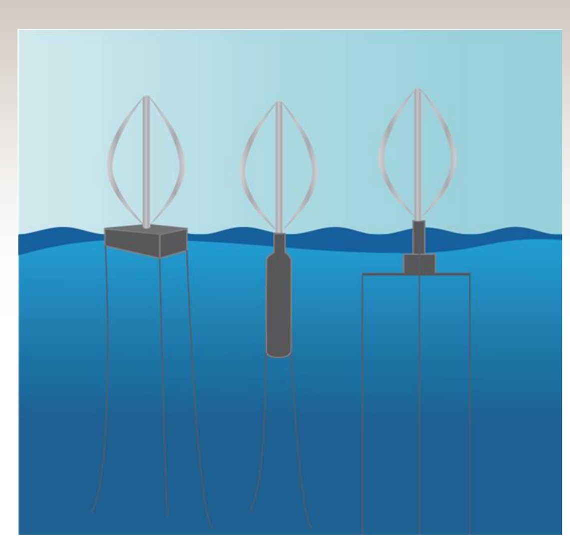
5 MW VAWT Designs





FLOATING PLATFORM DESIGN STUDIES

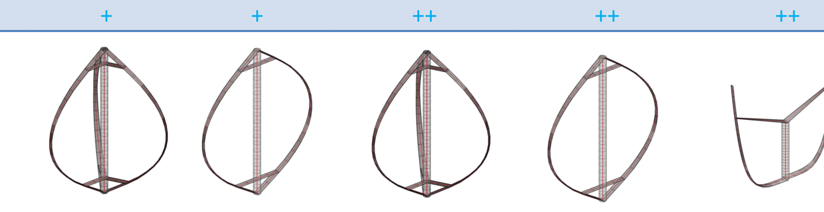
Current work focuses on platform and mooring design specific to VAWTs. Sandia is considering a range of platform options that use different stability mechanisms.



SYSTEM-LEVEL DESIGN & LCOE ANALYSIS

Design performance and cost trade-offs for the major VAWT components have been analyzed for a range of rotor configurations.

VAWT ROTOR CONFIGURATION DESCRIPTION	Carbon 3 blades Large chord	Carbon 2 blades Large chord	Glass 3 blades Small chord	Glass 2 blades Small chord	Carbon 2 blades Large chord
Normalized Turbine AEP (MW-hr)	1.0	0.92	0.94	0.85	0.95
Rotor Speed (RPM)	6.30	7.20	7.20	8.25	7.40
Drive-train Cost	+	+	+	+	+
Rotor Cost	++	++	+	+	++++
Platform & Mooring Cost	+	+	++	++	++



VAWT DESIGN GUIDELINES & CONCLUSIONS

TOWER RESONANCE IN VAWT DESIGN

Tower resonance has historically been an issue for VAWTs. Sandia developed and verified an analytical expression for critical tower modes of an N-bladed VAWT resulting in guidelines for VAWT designers to understand critical per-rev frequencies that drive tower resonance.

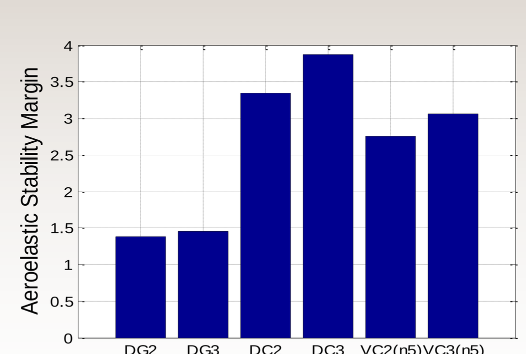
Critical Per-Rev Tower Excitation "Look-Up Table":

# of Blades	Per-Rev Sensitivity	Example Configuration
1	1,2,3,4	
2	1,3,5,7	SNL 17-m , SNL 34-m , DeepWind
3	2,4,5,7	VAWTPower VP60
4	3,5,7,9	
5	4,6,9,11	
6	5,7,11,13	Lux
7	6,8,13,15	
8	7,9,15,17	
9	8,10,17,19	
10	9,11,19,21	

AEROELASTIC STABILITY INVESTIGATION

Using aeroelastic theory as implemented in Sandia's BLade Aeroelastic Stability Tool (BLAST), VAWT flutter speeds were estimated for aeroelastic stability investigations of large, multi-MW VAWT designs.

Aeroelastic stability margins (>1 desired)



CONCLUSIONS

In deep water where floating platforms are required, VAWTs could potentially lower the cost of energy. Sandia continues to investigate the technical and economic feasibility of floating offshore VAWT systems.

Key activities and accomplishments of this project include:

- **Rotor design studies for large-scale VAWTs, including aerodynamic and structural design**
- **Platform design studies to address VAWT specific conditions** (in progress)
- **System-level design studies and VAWT LCOE model development** (in progress)
- **VAWT design tool development**
- **Design guidelines for VAWTs** (in progress)

Despite technical challenges associated with floating VAWTs, the systems have significant inherent advantages over floating HAWTs for reducing capital costs and reducing life-cycle O&M costs.

U.S. DEPARTMENT OF ENERGY NNSA National Nuclear Security Administration

For more information, contact: D. Todd Griffith, dgriffi@sandia.gov
Project Website: http://energy.sandia.gov/energy/renewable-energy/wind-power/offshore-wind/innovative-offshore-vertical-axis-wind-turbine-rotors/
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