



# United States Energy Association

Water-Energy Nexus: From New York to Victoria Falls



New York – East River



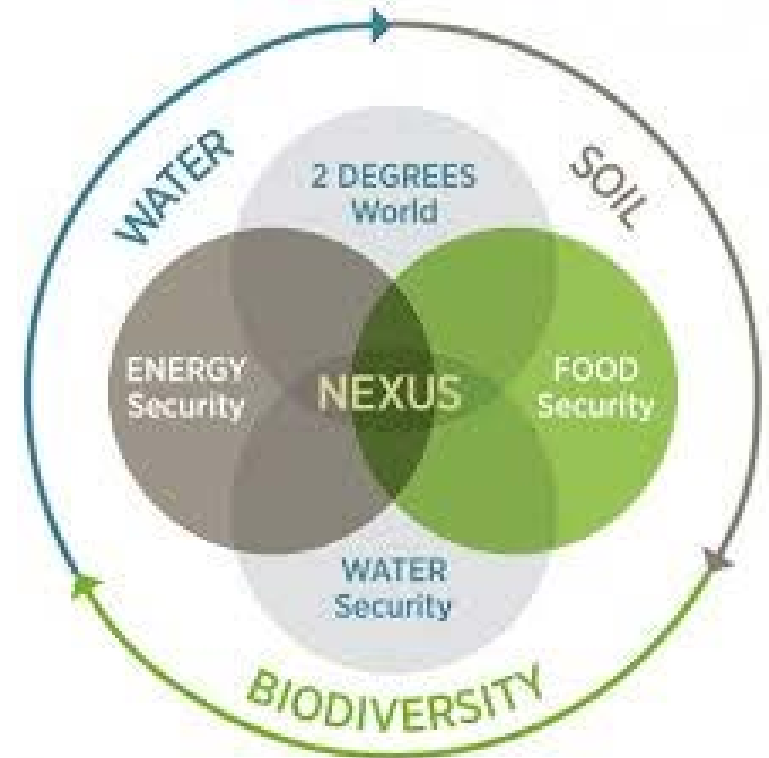
Marine Renewable Energy (MRE)



Victoria Falls – Zambezi River

15 August 2017

- Several trends are increasing urgency to address the water-energy nexus in an integrated and proactive way:
  - Climate change is affecting precipitation and temperature patterns throughout the world
  - Population growth and regional migration trends are likely to increase, complicating management of energy and water systems
  - New technologies in energy and water domains shift water-energy demands
  - Developments in policies are introducing additional incentives and challenges for decision making
- An integrated, strategic approach can guide technology research and development (R&D) to address regional water-energy issues and also have impact at the national and global scale
- Verdant Power's mission is to help build sustainable communities through integrated energy and hybrid power systems, microgrids, and water management



\*Source: U.S. Department of Energy The Water Energy Nexus: Challenges and Opportunities - JUNE 2014

- Founded in 2000, Verdant Power, a New York-based company, has developed proprietary, proven technology that converts hydrokinetic energy from underwater currents into clean power - Kinetic Hydropower System (KHPS) or Free Flow System (FFS)
- To date, \$37 million of funding for Milestones 1 and 2 has been raised from management, private investors, New York State Energy Research & Development Authority (NYSERDA) and U.S. Department of Energy (up to an additional \$3 million pending with equal match)
- The Company currently is undertaking a \$15 million Series B financing to complete Milestone 3 at its NYC demo site, the Roosevelt Island Tidal Energy (RITE) Project, leading to a global market launch in late 2019



Free Flow System  
NYC's East River - Roosevelt Island

**Milestone 1** (2002-05): FFS Prototype Test in New York's East River

**Milestone 2** (2006-16): Design & Innovation - New York Project (Demo)

- World's first grid-connected array of tidal energy turbines (RITE Project)
- First-ever Federal Energy Regulatory Commission (FERC) issued commercial license and first-ever Trade & Development Agency support
- Government and institution support: Cornell University, U.S. DOE & Department of Commerce, U.S. Navy, NYSERDA, NYCEDC, and Sustainable Development Technology Canada (SDTC)

**Milestone 3** (2017-19): Development & Implementation

- Third-party verification 5<sup>th</sup> generation (Gen5) FFS turbine & TriFrame™
- Implement IP plan
- Technology advancement to commercialization
- Complete resource assessments and feasibility analysis (RAFA)
- Transition RITE Project to world-class test and demonstration facility

**Milestone 4** (2019-27): Launch of Commercial Projects

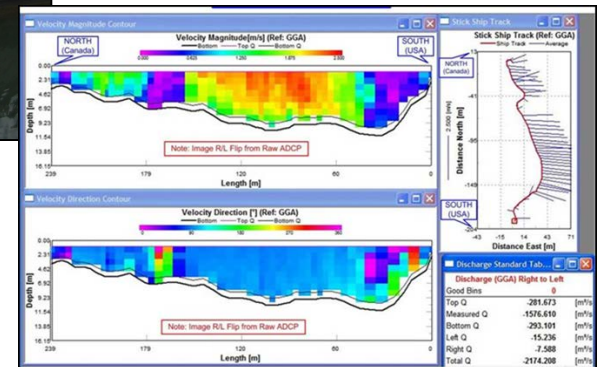
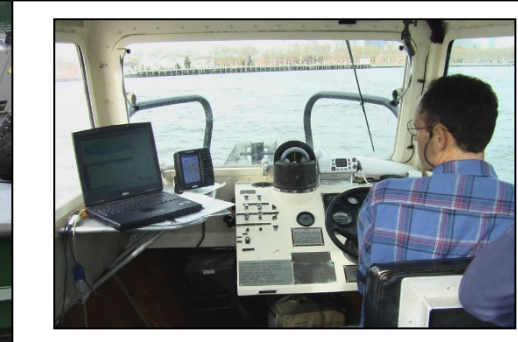
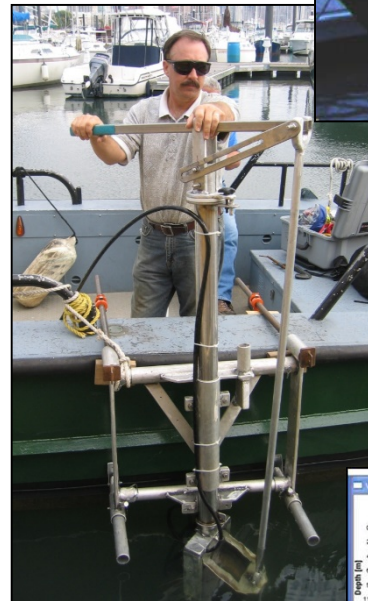
- New York projects build-out and commercial operation
- UK, Ireland, USA, and other tidal energy projects
- Canada, Africa, and other river energy projects

## Partners & Supporters





- First step - conduct resource assessment and feasibility analysis (RAFA) services to determine economic viability of a site
- Verdant Power has unique expertise to:
  - ✓ Evaluate sites using Geographic Information System (GIS) modeling techniques to analyze a site's topography, velocity, depth, and current; and
  - ✓ Tailor its Gen5 FFS to optimize array performance at that site
- First U.S. Trade & Development Agency (USTDA) supported RAFA project, downriver from Turkish dams, during 2014-16
- Preliminary assessments and RAFA services completed / underway in more than 10 countries
- Preparing RAFAs for additional domestic and international commercial projects



# MRE Market Increasing Sevenfold

## Total Addressable Market (TAM) - 250 GW

- River - 140 GW (World Energy Council)
- Tidal - 60 GW (Ocean Energy Council)
- Canal - 50 GW (Federal Energy Regulatory Commission)

## Serviceable Available Market (SAM) - 23 GW

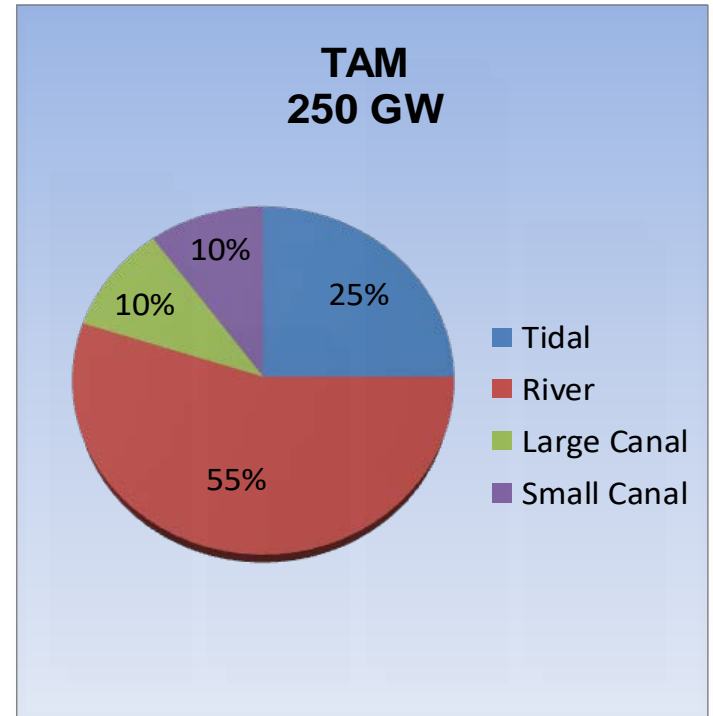
- Capacity to reach 23 GW by 2027 (\$80 billion) - Electric Power Research Institute (EPRI)
- Installed capacity to increase 7X by 2020 - PIKE Research Report (2012)

## Share of Market (SOM) - 2 GW

- Projected financials and pipeline by 2027
- Developing countries - 1.2 GW
- Developed countries - 0.8 GW

## New York State Market - 1 GW (NYSERDA); each GW benefits:

- Energy: offsets 6.7 million tons of coal per year
- Environmental: eliminates 5.7 million tons of CO<sub>2</sub> per year
- Economic: creates potentially 1,500 full-time jobs based on domestic use and exported goods and services



## Roosevelt Island Tidal Energy (RITE) Project - East River, New York City







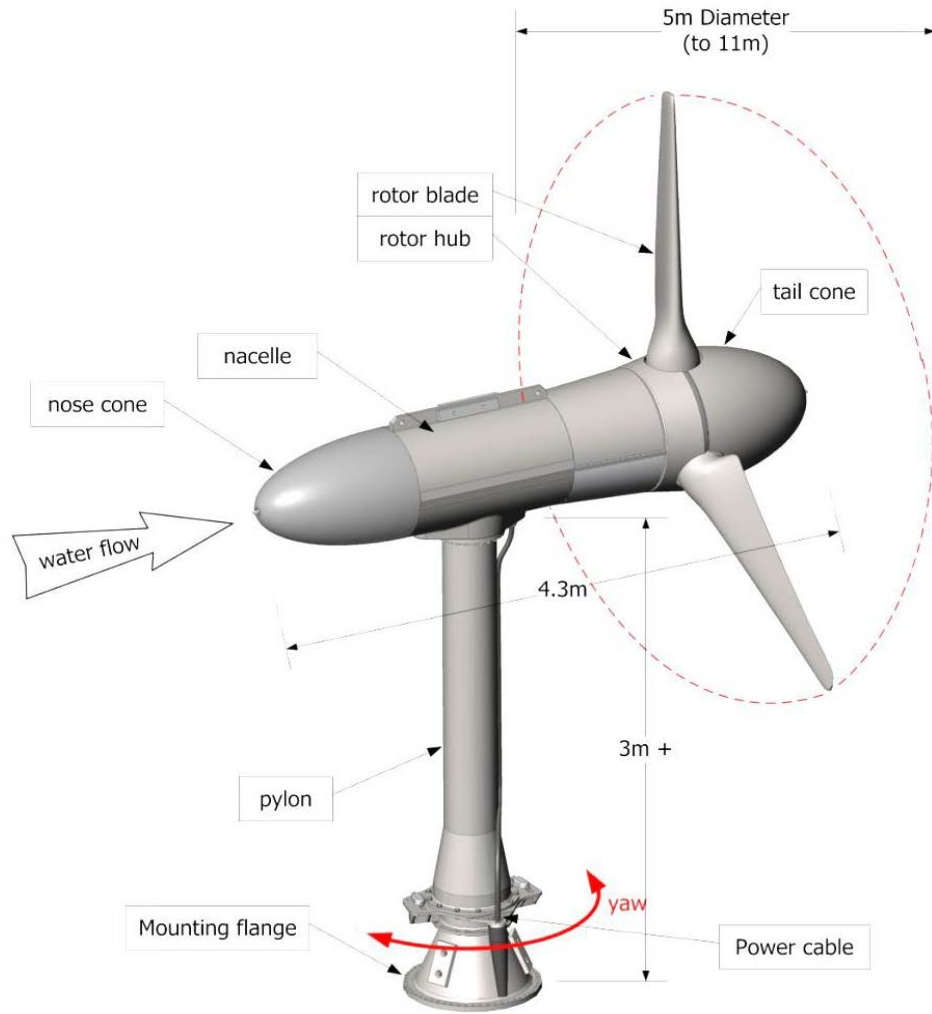


## Gen4 FFS Technology Accomplishments - RITE Project, New York City

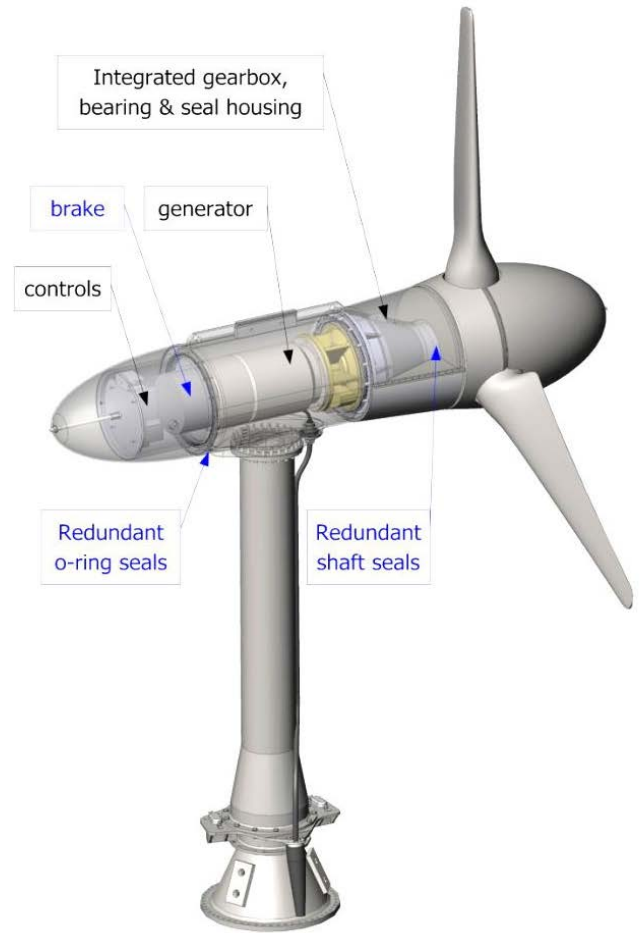
- 5m-diameter rotor in 10m water depth
- Five generator turbines rated 35kW @ 2.2m/s
- One rotor dynamometer turbine
- Multi-turbine array (2006-08) NASA-based TRL 7/8
- Grid interconnect
- 9,000 turbine-hours
- 70 MWh to grid generated
- Efficiency: water-to-wire 30-40%, inc. all losses
- Control: automatic and effective
- Yaw: passive, bidirectional performance
- Survivability: no debris fouling
- Full range of environmental studies; fish, avian, noise
- Lack of impacts shown
- Environmental monitoring technology development
- Expanding use of "adaptive management" - lowering future compliance costs



# Gen5 KHPS - AKA, Gen5 FFS



Verdant Power Gen 5 KHPS Turbine

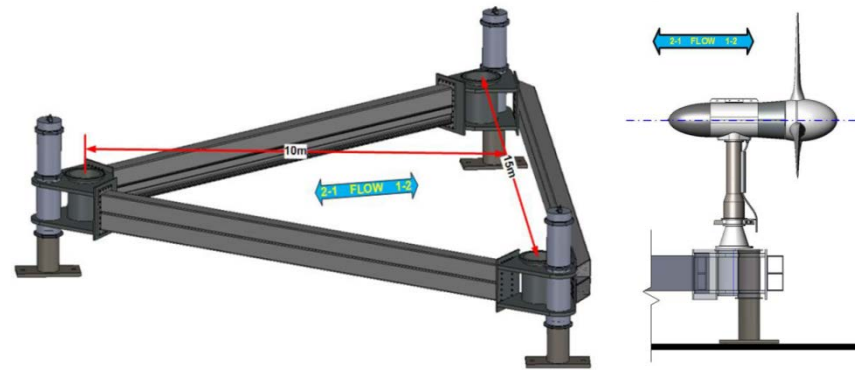


Verdant Power Gen 5 KHPS Turbine - Internal

## Competitive Advantage - Tailored to Sites

- Gen5 FFS with state of the art rotor sizes being scaled and extended for higher velocity currents and deeper waters (Gen5, 10m FFS)
- TriFrame™ mounting system supports three Gen5 FFS at once onto seabed cost-effectively
- Benefits of the new mounting system:
  - Provides for utility-scale systems ranging from 100 kW to 1.5 MW or more on each TriFrame™
  - Allows greater adaptation for utility and village-scale systems in more common water conditions than those found off the coast of Scotland or in the Bay of Fundy
  - Lowers O&M costs due to faster deployment and retrieval

Gen5 FFS TriFrame™ Mounting System



Power (kW) Generated by Gen5 FFS with Various Rotor Sizes (m) and Velocity Currents (m/s)

FFS Turbine	Rotor size (m)	2 m/s (kW)	3 m/s (kW)	4 m/s (kW)
Gen5, 5m	5	28	95	224
	7	55	190	450
Gen5, 10m	10	115	385	920
	11	138	470	1,110

The Gen5 Free Flow System was designed for simplicity in order to make it robust and reliable, as well as to minimize assembly and maintenance costs



# RITE Project - Commercial Pilot (1 MW)

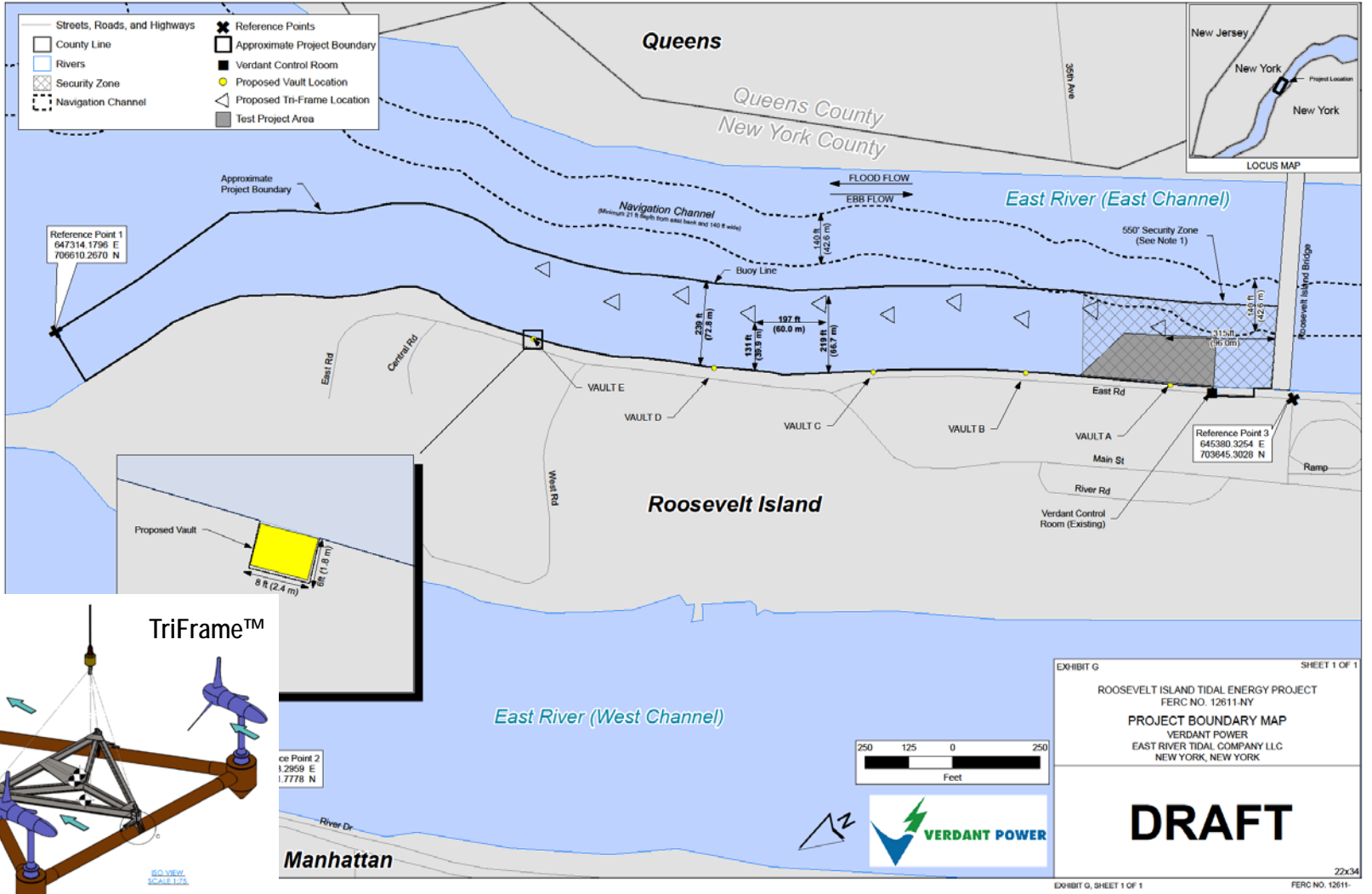


EXHIBIT G SHEET 1 OF 1

ROOSEVELT ISLAND TIDAL ENERGY PROJECT  
 FERC NO. 12611-NY  
**PROJECT BOUNDARY MAP**  
 VERDANT POWER  
 EAST RIVER TIDAL COMPANY LLC  
 NEW YORK, NEW YORK

DRAFT

22x34  
 EXHIBIT G, SHEET 1 OF 1      FERC NO. 12611-

- Established in 2003, EMEC is the first centre of its kind in the world to provide developers of both wave and tidal energy converters
- EMEC operates to relevant test laboratory standards enabling it to provide independently-verified performance assessments
- To date, around £34 million of public funding has been invested in EMEC by the Scottish Government, Highlands Islands Enterprise, The Carbon Trust, UK Government, Scottish Enterprise, the European Union, and Orkney Islands Council
- EMEC's grid-connected tidal site has depths up to 50m and velocity currents reaching 4 m/s, where a variety of 1 MW single device units have been tested
- At MeyGen, in Scotland's Pentland Firth with velocity currents reaching 5 m/s, Atlantis Resources is installing four 1.5 MW turbines with 16m rotor diameter turbines - a design that was tested at EMEC



# Competitor's Turbines: Complex & Costly



## Competitor Disadvantages (Euro-based)

- Require depths of 40m or more
- Highly capital intensive technology development
- Complex and heavy designs - uncertain reliability

## Verdant Power Advantages (USA-based)

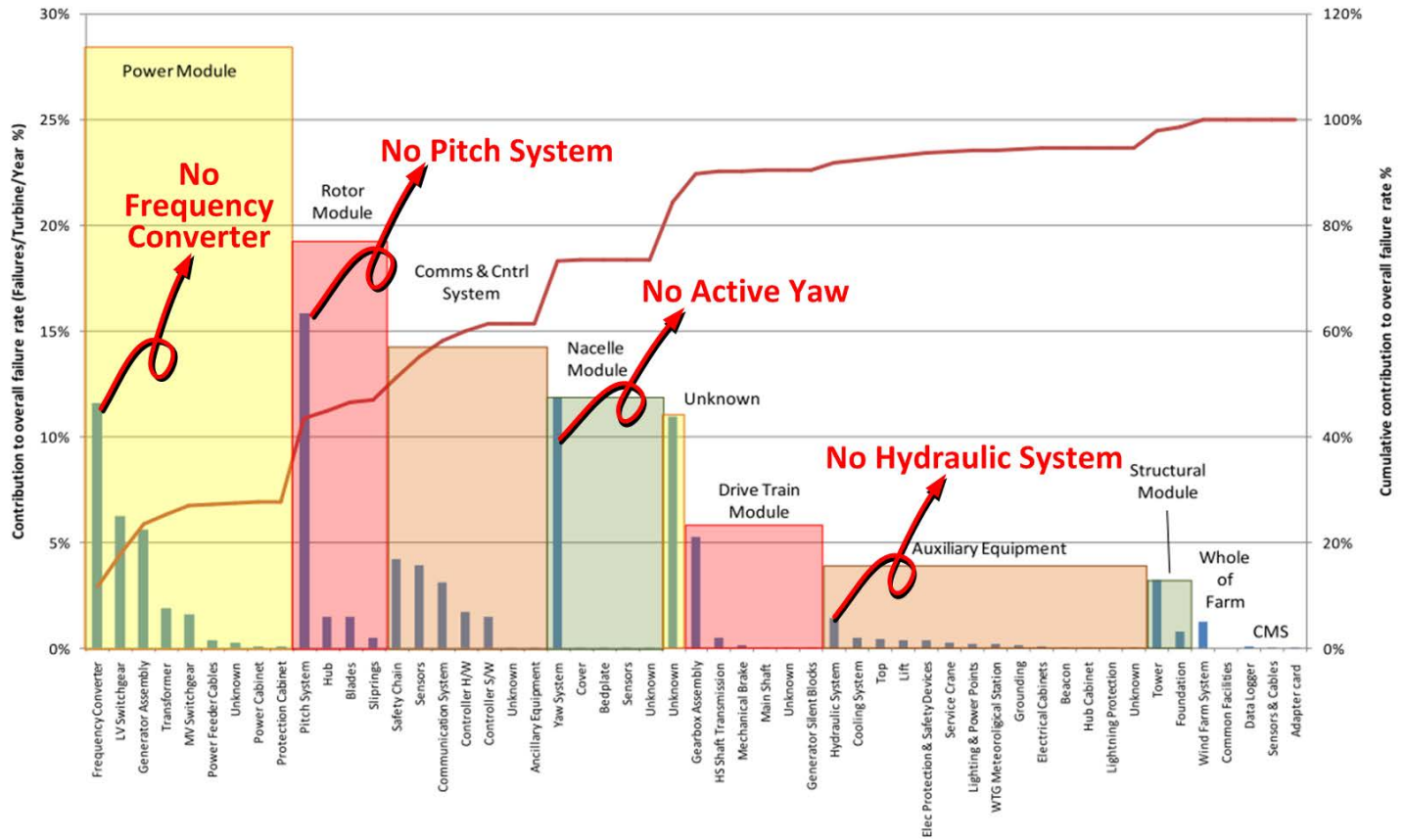
- Depths ranging from 10m to 60m
- Sited nearer power needs, less transmission costs, and lower O&M
- Market leader - proven technology, validated by industry
- More advanced than competitors - NASA / DOE-based TRL 7/8
- Simple and lighter design - readily scaled for greater application





# Verdant's Turbine: Simple & Reliable

Long-term Competitive Advantage is Keeping it Simple - the Key to Reliability



Wind Turbine Sub-System Failure Rates (ReliaWind database)

# RITE Project - Site Area



## Build a World-class Test & Demo Facility with Cornell University - a “Living Classroom”

- Ongoing, design, test, and demonstration - marine renewable energy (MRE) systems and underwater mounting system TriFrame™
- Convert RITE Project into world-class test and demo facility for distributed generation (DG) and integrated energy systems before the UN
- Lays foundation for hybrid power systems of distributed energy resources (DER) for microgrid in support of NYC’s grid resiliency
- Creates an industry cluster of DER solutions
- Provides foundation for commercial domestic projects and for global exportation creating full-time jobs in NYS and internationally
- Establishes a scientific R&D and education and training project of The Ocean Foundation, a 501(c)3 organization - Anchor Coalition

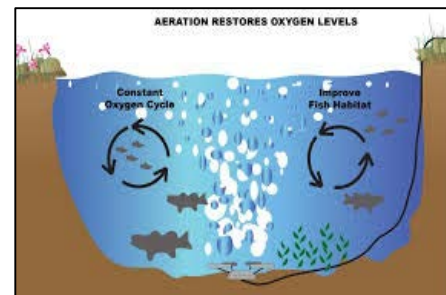
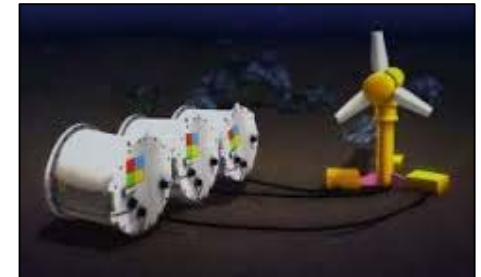


Roosevelt Island Tidal Energy (RITE) Project  
East River, New York



## MRE-based Integrated Energy Systems

- Utility and village-scale grid power, distributed generation (DG), rural electrification, and off-grid (e.g., replace diesel gensets)
- Large-scale energy storage (e.g., grid-oriented battery technologies, flow batteries, electric vehicles - recharged by dependable tidal power)
- Clean water systems (reverse osmosis and pumped water to filtration tanks and towers)
- Pumping systems for irrigation or aeration and electrolysis systems for hydrogen production
- Underwater data centers (cooling water & power)
- Hybrid Power Systems (integration of clean distributed energy resources [DER] with storage and combined heat and power [CHP] to create baseload power connected to microgrids and smart grids)



## MRE-based Hybrid Power Systems

- Baseload power provided to a grid or microgrid with integration of energy storage, CHP, and DER e.g., MRE, solar PV, urban wind, biogas, and waste-to-energy (e.g., anaerobic digestion)
- A microgrid is a small-scale power grid that can operate independently or in conjunction with the area's main electrical distribution grid, which can enhance grid resiliency
- "Islanding" operation maintains power quality even when disconnected from the distribution grid
- Energy storage smooths DER power generation making the above functions possible



## Address the UN's 17 Sustainable Development Goals by ...

### Empowering Community Self-sustainability:

#### Understanding

Start by understanding the issues that matter to communities, such as NYC and Victoria Falls - **define the problems before trying to solve them.**

#### Assessing

Take inventory of existing work (e.g., energy and water use audits) to draw synergies and collaboration, and survey existing local resources - **do more with less.**

#### Planning

Devise an **integrated plan** - adapt local planning to big-picture and long-term contexts.

#### Implementing

Implement **clean energy and water management strategies** - start with pilot-scale, manageable within a year to fine tune, before scaling up.

### Support for an Integrated Approach to Sustainable Communities



**GREEN  
CLIMATE  
FUND**



**ZINWA**



**Empire State  
Development**



## Anchoring Victoria Falls

Securing water and energy for the community of Victoria Falls, Zimbabwe

- This project will implement sustainable water supply and management through renewable technologies, and build on the work of private firms and local NGOs' community education programs
- The project seamlessly addresses Water-Energy-Food nexus through local and international efforts:
  - Household income increase by more than 80% through farming;
  - Higher rate of clean electrification;
  - Cleaner waterbody, not running dry;
  - Elephant conservation and human-elephant conflict mitigation



## Present: New York City - Demo Facility & Microgrid Showcase

- Verification and certification - MRE turbines/TriFrame™
- Advancing MRE technology - Cornell University
- Cornell's Atkinson Center for a Sustainable Future
- Demo facility & showcase - hybrid / integrated systems
- Industry cluster and shipping / exportation areas

## Near-term Future: Victoria Falls - Global Showcase

- Microgrids powered by DER and energy storage
- In-country regional assembly plants / maintenance depots
- Benefits for every GW produced: creates potentially 1,500 full-time jobs; offsets 6.7 million tons of coal per year; and eliminates 5.7 million tons of CO<sub>2</sub> per year





## For Example, Conservation by Design ...

### New York - Anchoring Roosevelt Island

- Investment in Verdant Power
- Support for world-class demo facility and global microgrid / self-sustainable showcase before the UN
- NY industry cluster for exportation of hybrid power systems and water management programs

### Zimbabwe - Anchoring Victory Falls

- Donation and/or support for Anchor Coalition
- Securing food crops; fighting human-elephant conflict
- Green Climate Fund - RPS programme with DBSA

### Vietnam - Anchoring Dak Bul Sor

- Donation and/or support for Anchor Coalition
- Empowering women and pumping irrigation water for coffee farms
- Green Climate Fund - RPS programme with ADB



Free Flow System  
NYC's East River - Roosevelt Island



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Anchor Coalition is a Project of  
The Ocean Foundation, a 501(c)3 organization



Cornell Tech campus – Roosevelt Island