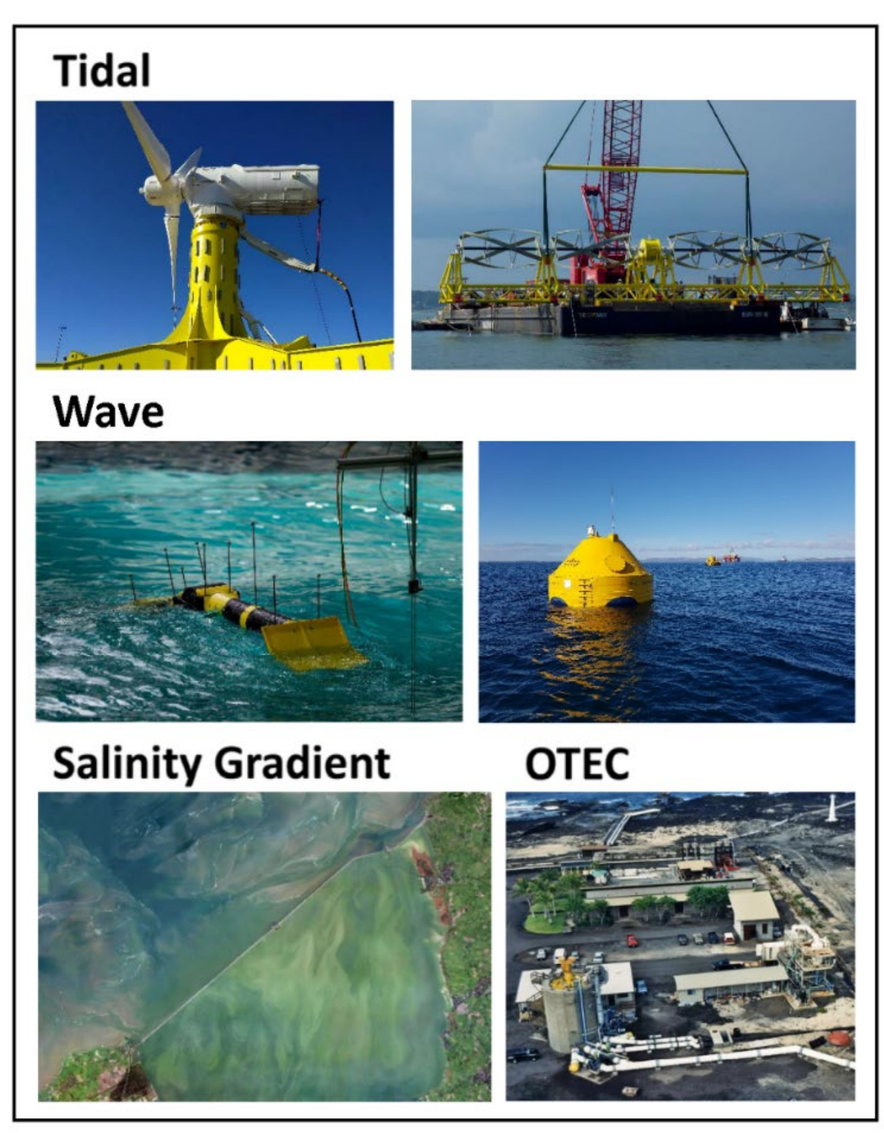
Innovation in Marine Energy

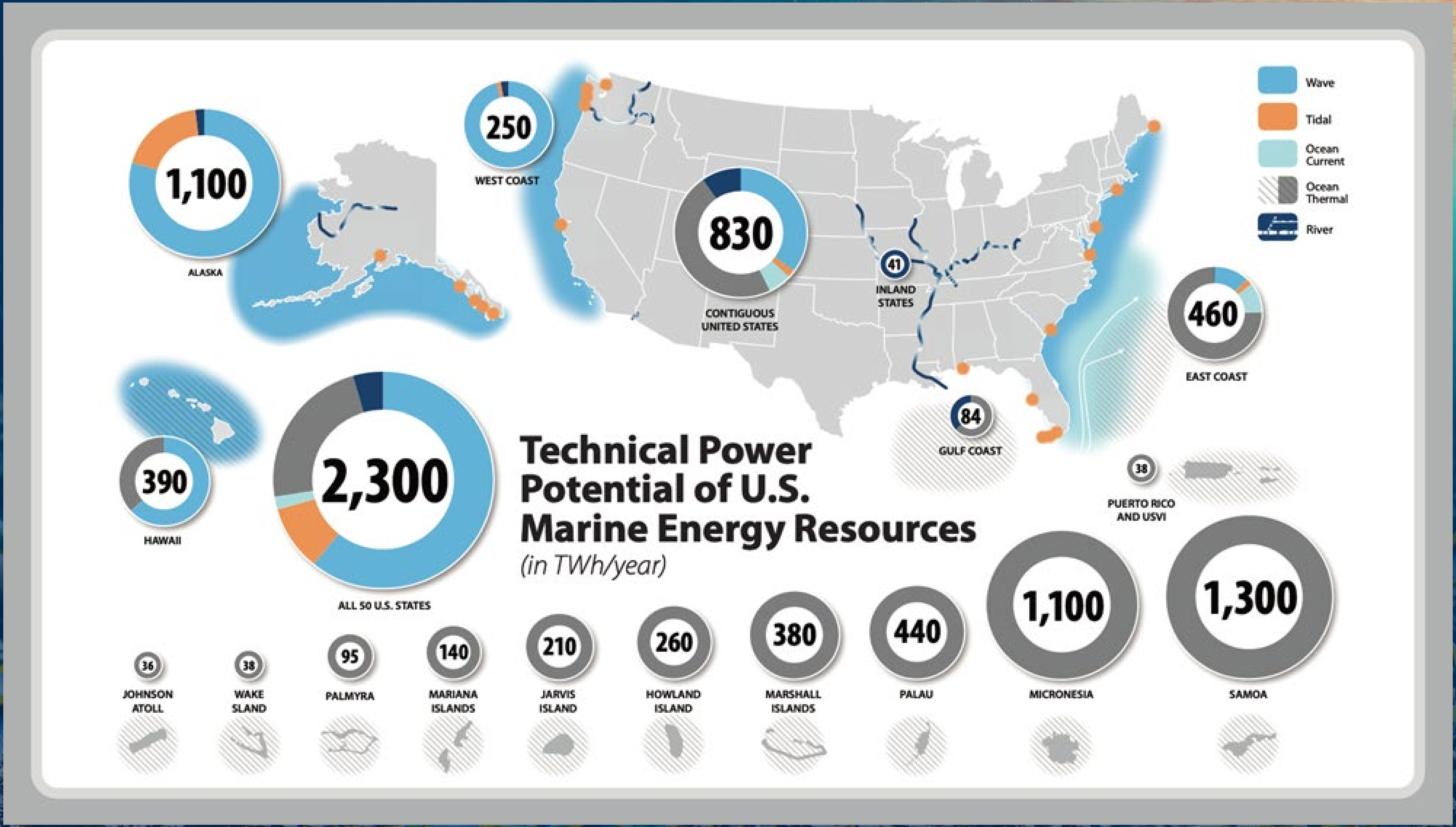
Ruth Branch, Andrea Copping, Rob Cavagnaro
Pacific Northwest National Laboratory (PNNL), Seattle, WA

Background: Marine Renewable Energy

- **Tides, Waves, Ocean Currents**
- **Salinity and Temperature gradients including ocean thermal energy conversion (OTEC)**
- **Devices cover a range of sizes and applications**
  - Pictured examples courtesy of: (1) ANDRITZ Hydrotidal turbine, (2) ORPC TidGen Power System, (3) Mocean Energy Blue Horizon attenuator, (4) CorPower Ocean C3 point absorber, (5) REDstack salinity gradient plant at Afsluitdijk (photo courtesy of Van Oord), (6) Natural Energy Laboratory of Hawaii Authority OTEC plant at Kona (photo courtesy of DOE).

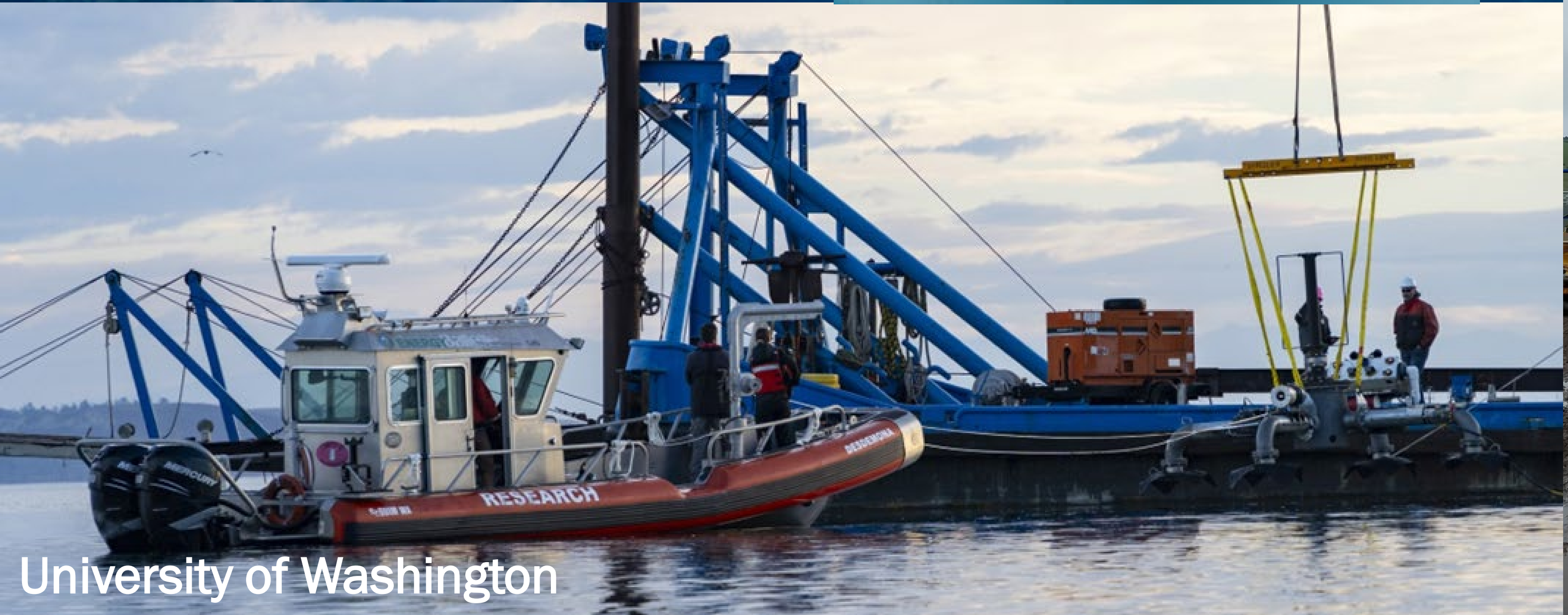


Marine Energy Resources in U.S. Waters



Tidal and riverine: kilowatts to megawatts

Bladerunner Energy



University of Washington

Andritz Hydro

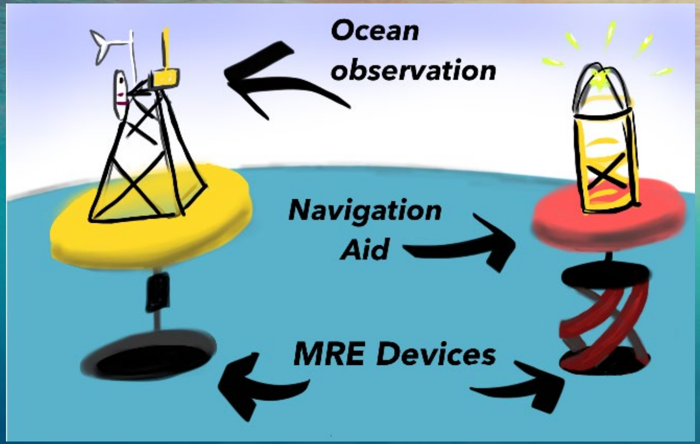
Waves: milliwatts, kilowatts, megawatts

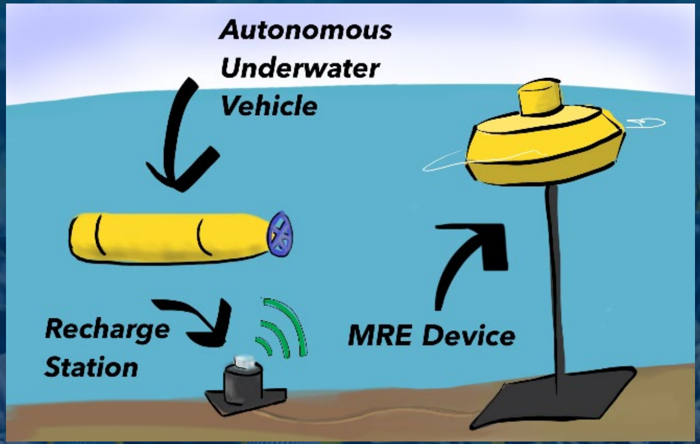
Pacific Northwest National Laboratory

CorPower Ocean

Methods: Marine Energy for Powering Ocean Observations

- **Provide power in off-grid and offshore locations to support a variety of ocean-based activities, including ocean observations and navigation.**
- **Present focus on how marine energy can provide power to extend ocean observing missions for both fixed and mobile platforms, including operations of AUVs.**





What are the Main Limitations to Ocean Observations Now?

- **Power availability and batteries**
- **Data transmission and communications and survivability**
- **Other limitations for ocean observations:**
  - Device reliability
  - Cost of ship time
  - Cost of cables for observatories
  - Biofouling
  - Hazards associated with lithium-ion batteries
  - Onboard processing
  - Winter ice conditions

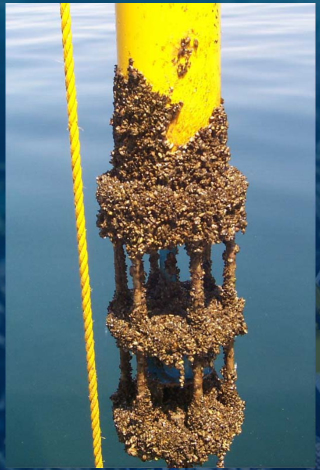
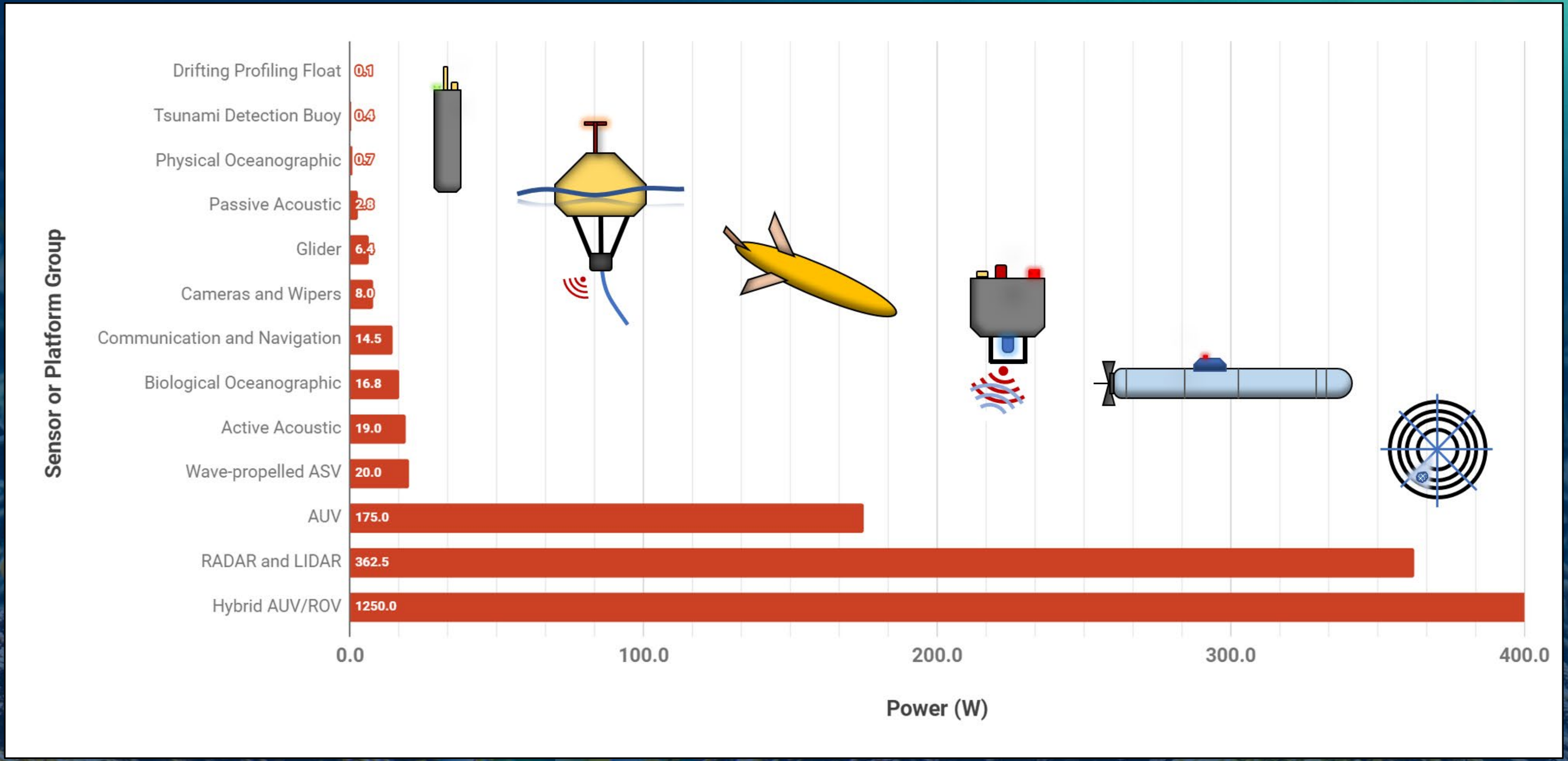


Photo Credits: *USCG; NOAA GLERL*

Power Used by Ocean Observation Technologies

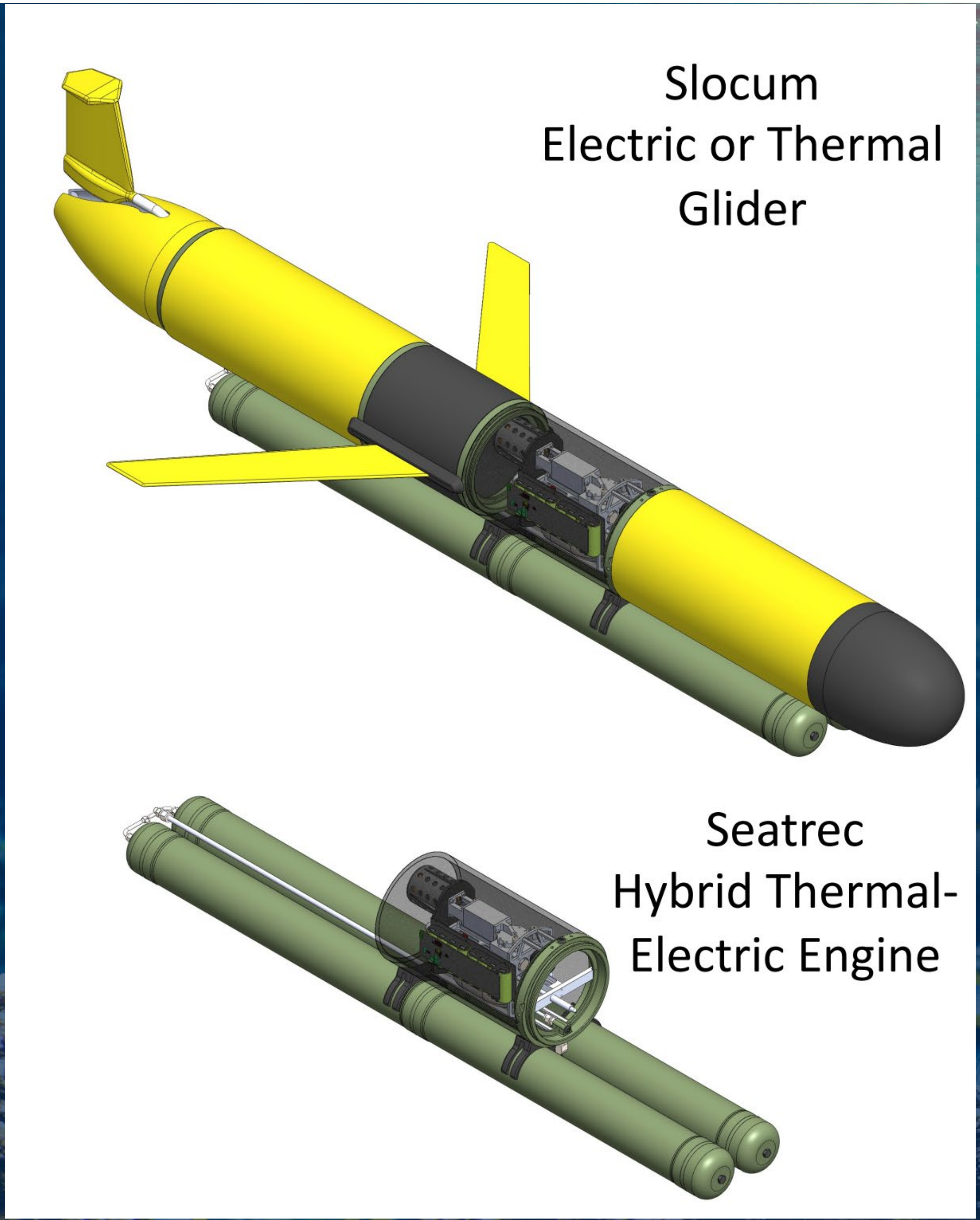
Survey results: About a quarter (26%) of sensors run on less than 1 W, nearly half (48%) run on 1-10 W, 19% require 10-100 W, and the remaining (7%) use >100 W.



SEATREC: thermal gradient power

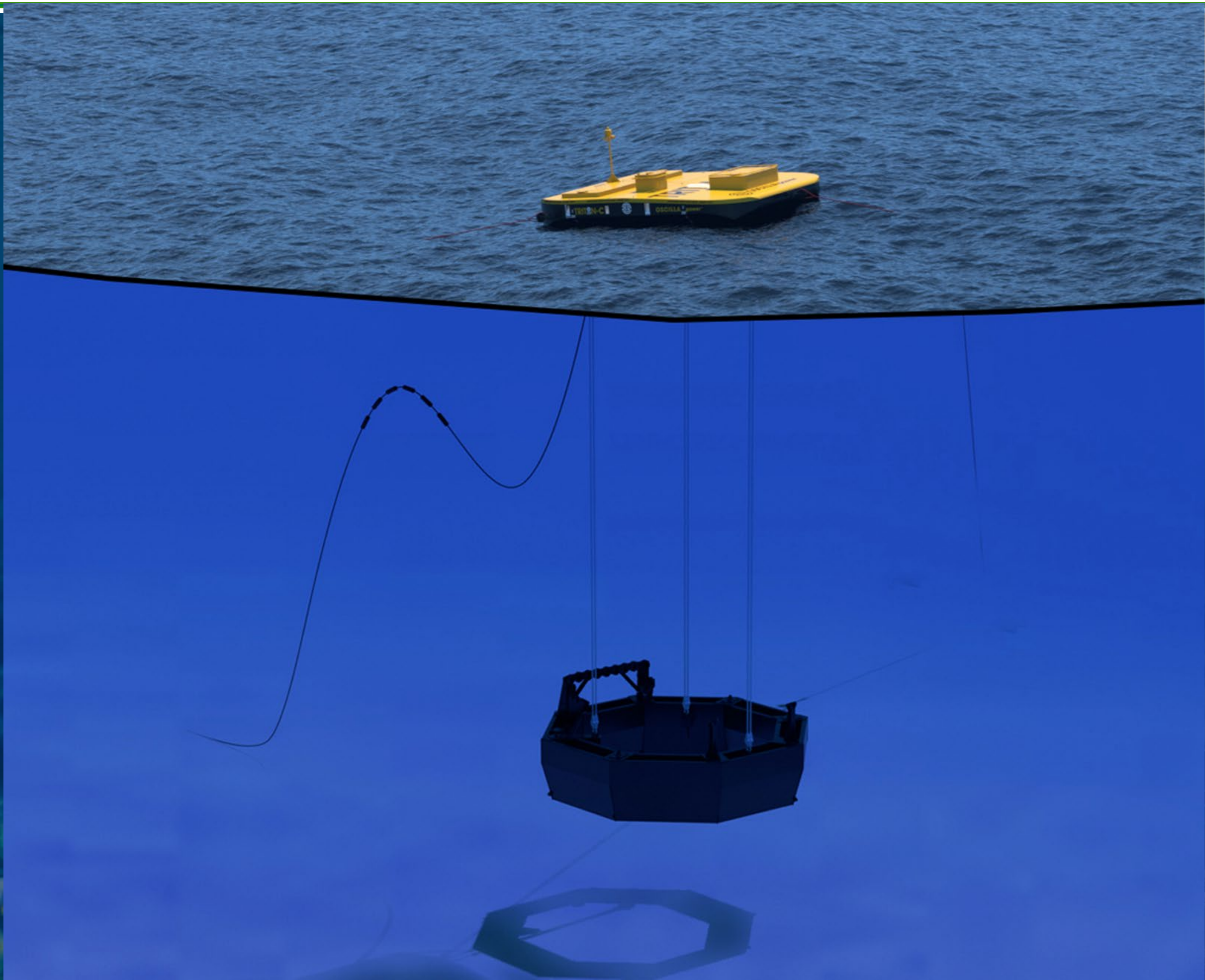
Yi Chao (Yi.Chao@seatrec.com)

- **Profiling floats**
- **Gliders**



Oscilla Power: Triton-C

Tim Mundon (Mundon@oscillapower.com)



Marcus Lehmann (marcus@calwave.energy)

Pioneer WEC

Ryan Coe (rcoe@sandia.gov)
Sandia National Laboratories

Concept design report


SANDIA REPORT

Pioneer WEC concept design report

- 10-100W
- 3.3 m diameter
- Team: Sandia, Woods Hole Oceanographic Inst., National Renewable Energy Lab, Monterey Bay Aquarium, Johns Hopkins University, East Carolina University, Evergreen Innovations

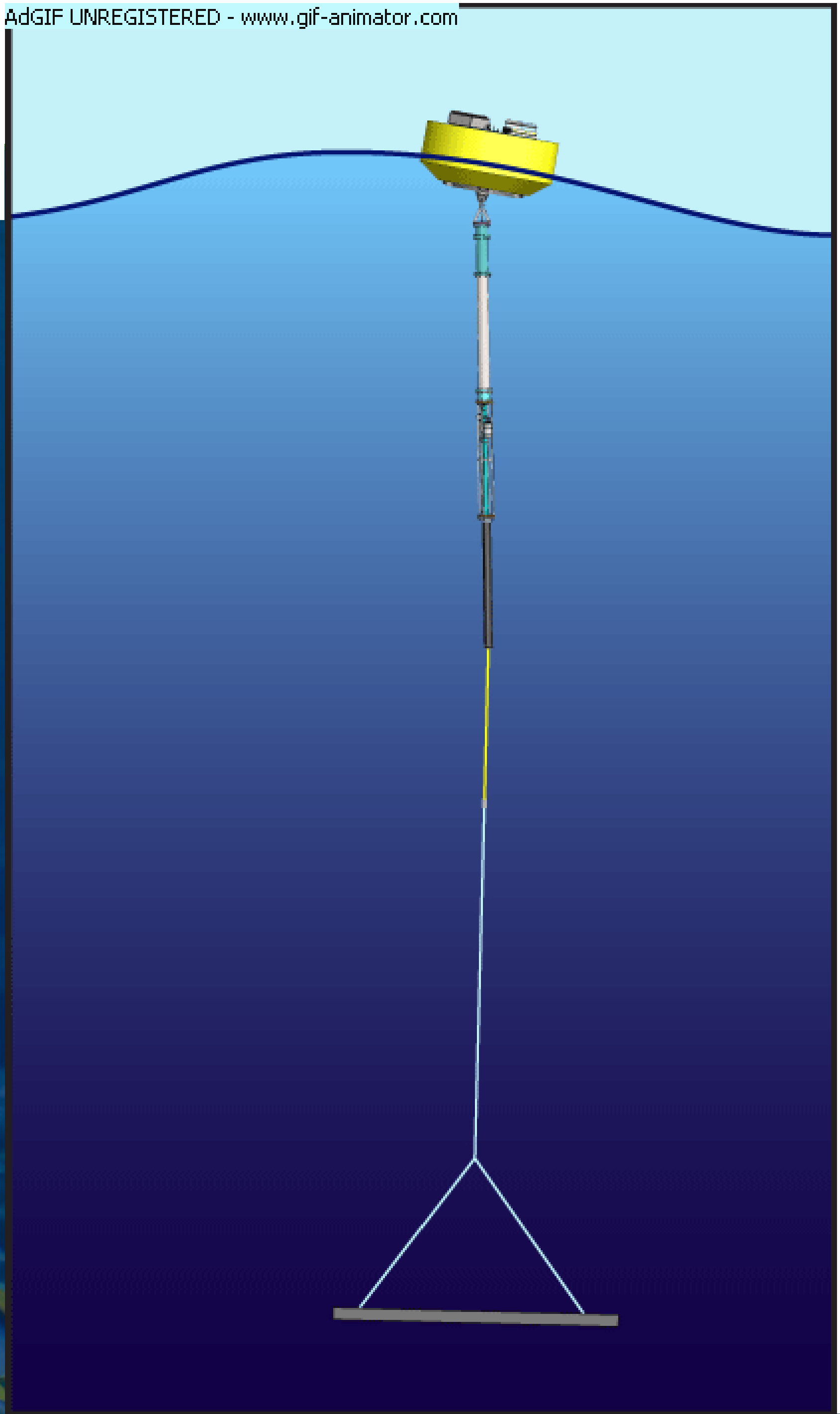
This work was supported by the Department of Energy (DOE), Office of Energy Efficiency and Renewable Energy (EERE), Wind and Water Power Technologies Office (WWPTO). Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

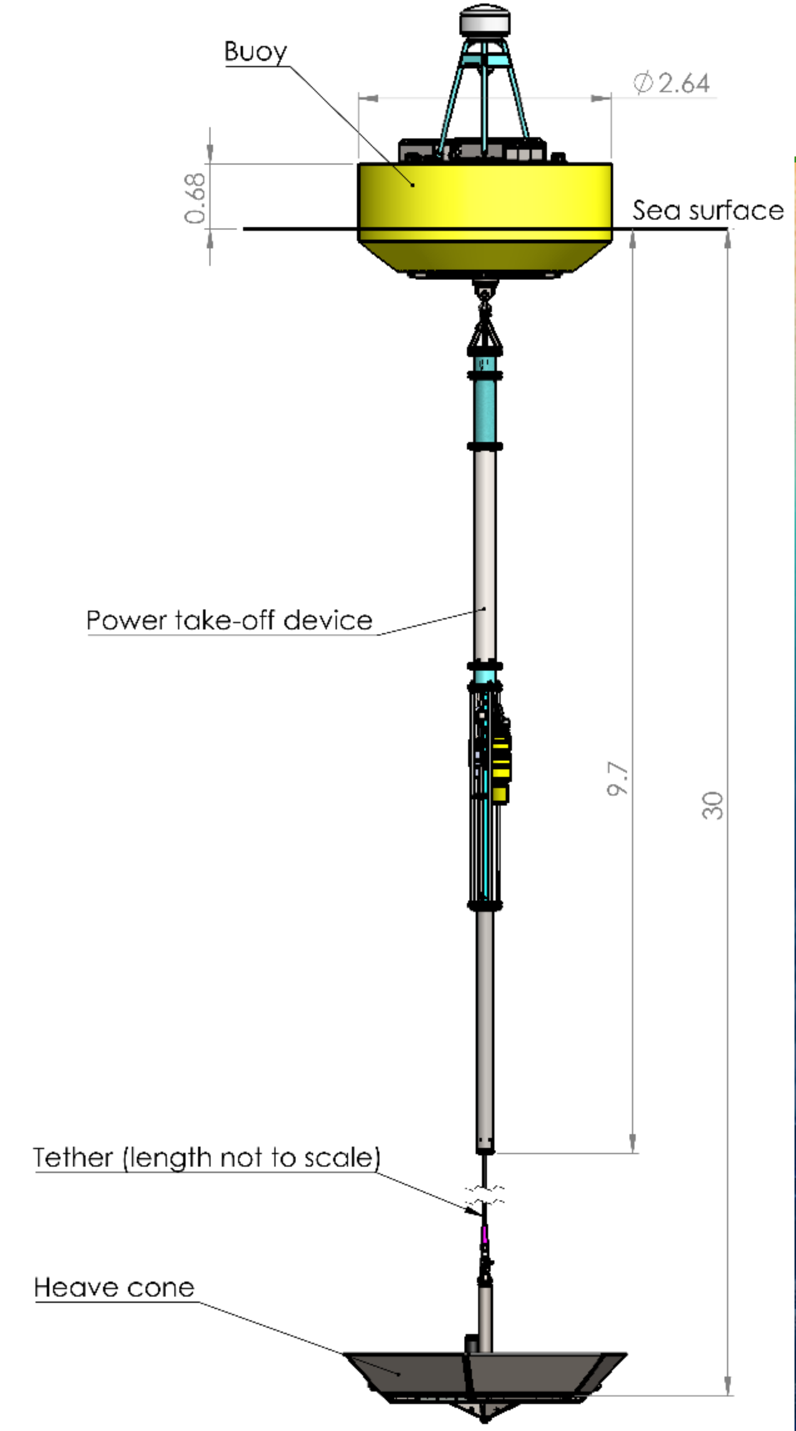
MBARI

Andrew Hamilton (hamilton@mbari.org)

Waves = 200W-300W

Wind and Solar = 50W





NREL HERO WEC - Hydraulic and Electric Reverse Osmosis Wave Energy Converter

Modular Design

- **Hydraulic configuration** – pumps water directly to reverse osmosis desalination system (no electrons necessary)
- **Electric configuration** – onboard generator produces electricity that powers pump for desalination system

Two laboratory test programs

- 86 processed data files with visualization script available from 2023 test program available on MHKDR
- Tested on NREL's 6 DOF motion platform

Three ocean deployments

- 2024 deployment data will be made public this summer

Quick Facts:

- Produces 25-250 gallons of drinking water per day
- Has produced water in sub-0.25m waves
- Entire design is publicly available
  - CAD files, bill of materials, laboratory and ocean test data are all available on HERO WEC website
  - Scan the QR code below for publicly available data.

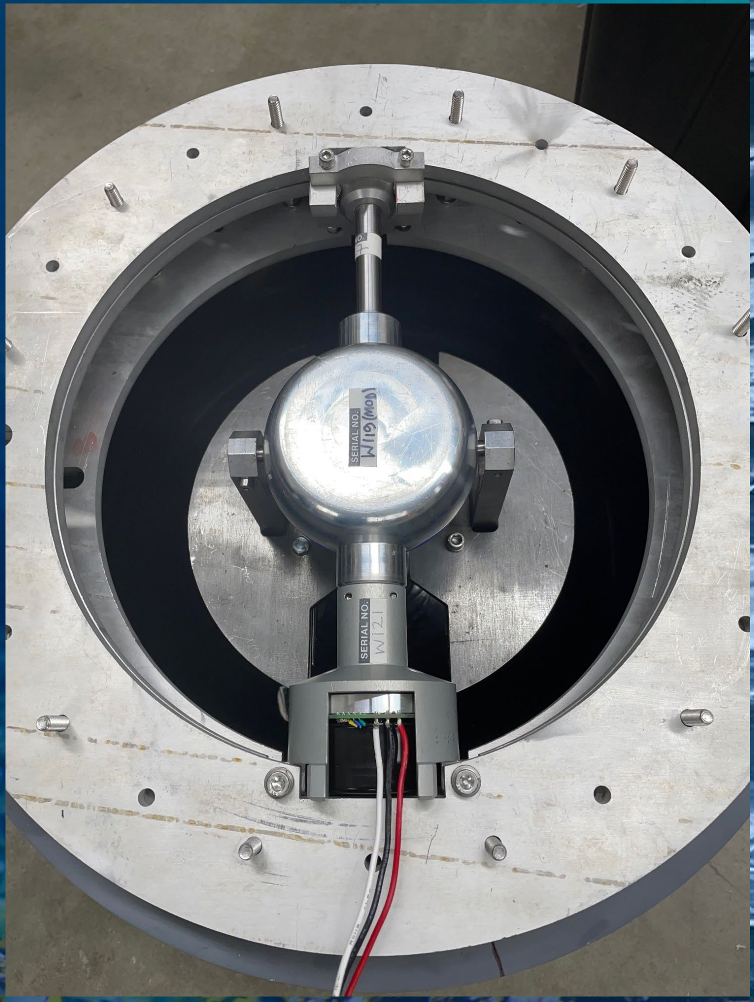
Questions?

Contact Scott Jenne
dale.jenne@nrel.gov

Image Credit: Scott Jenne / NREL

PNNL: drifting WEC buoy

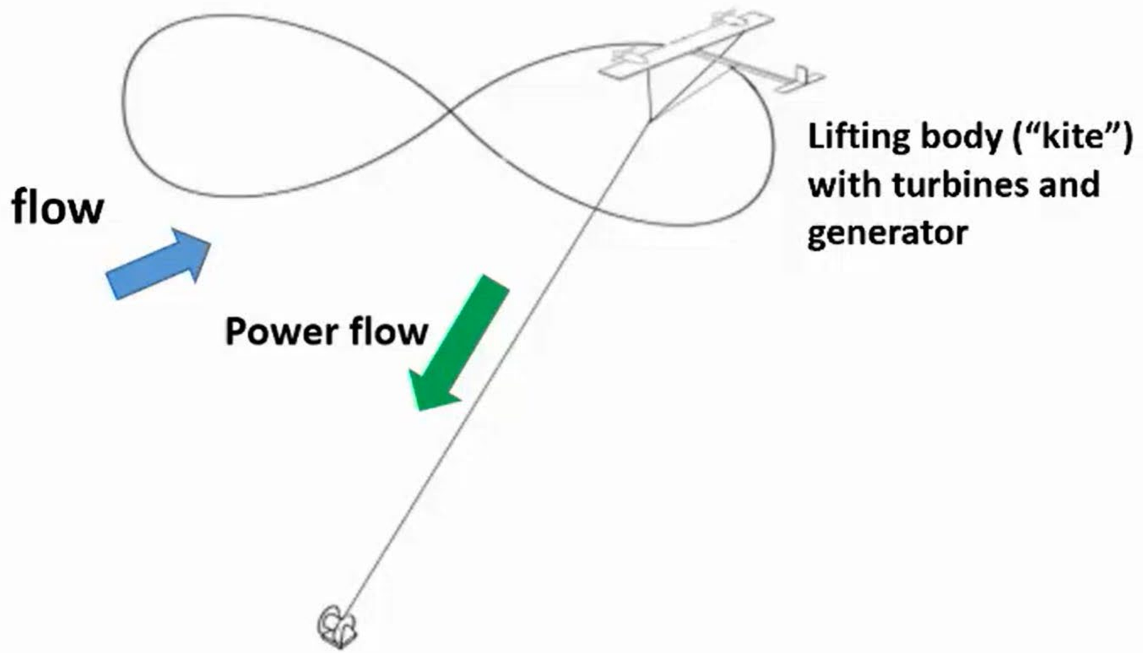
- 6 dof WITT Energy pendulum system
- Max power > 5 watts in 0.5 m waves
- Designed for temperature measurements in the Arctic



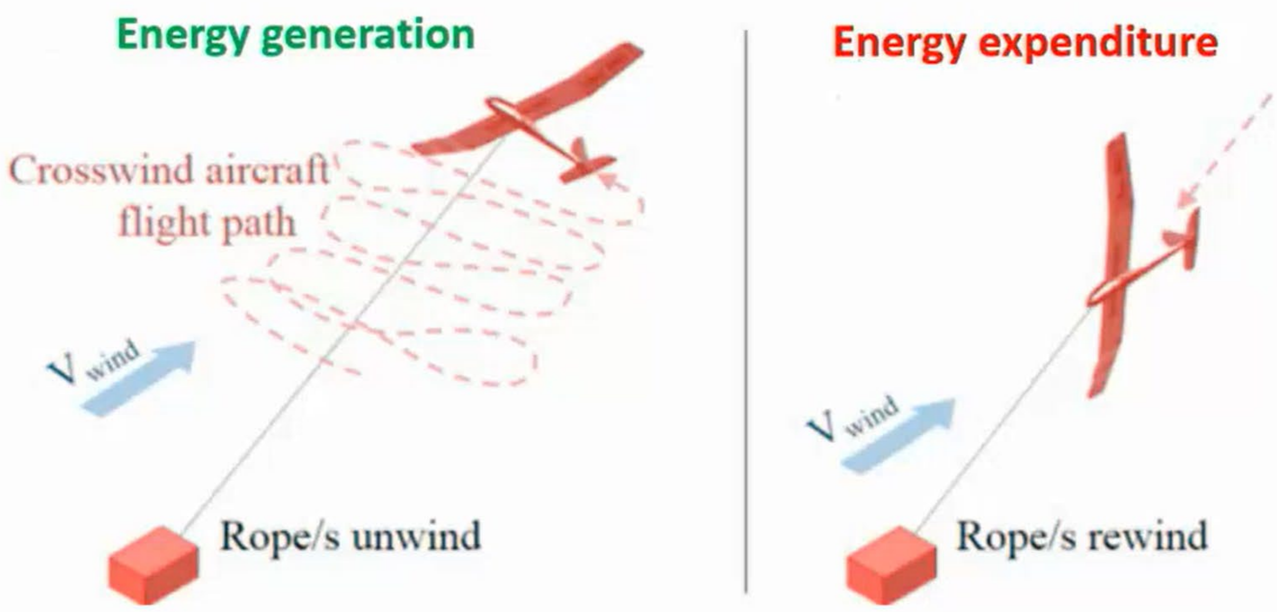
Kites as Current Energy Converters

Christopher Vermillion cvermill@umich.edu

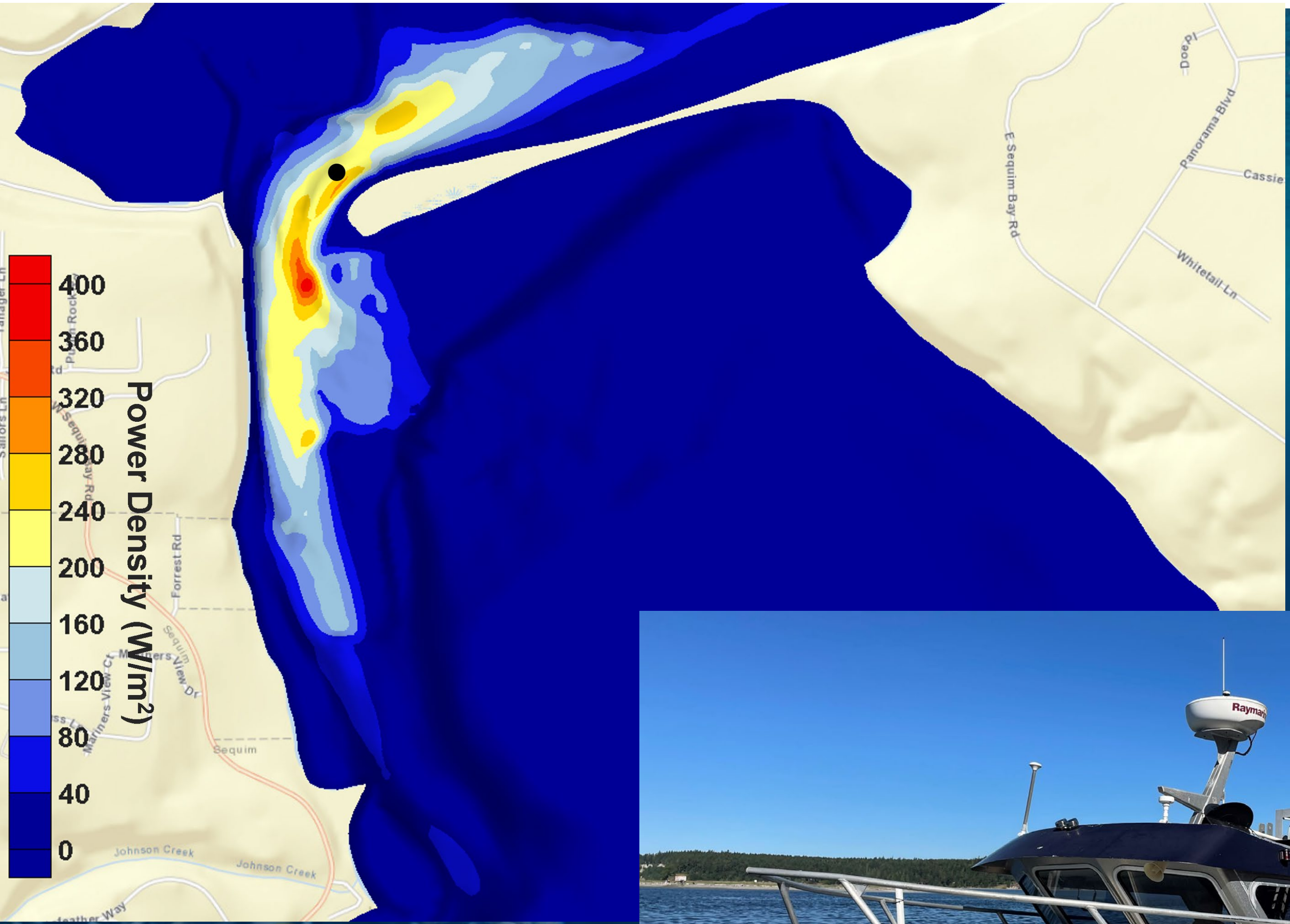
On-board generation:

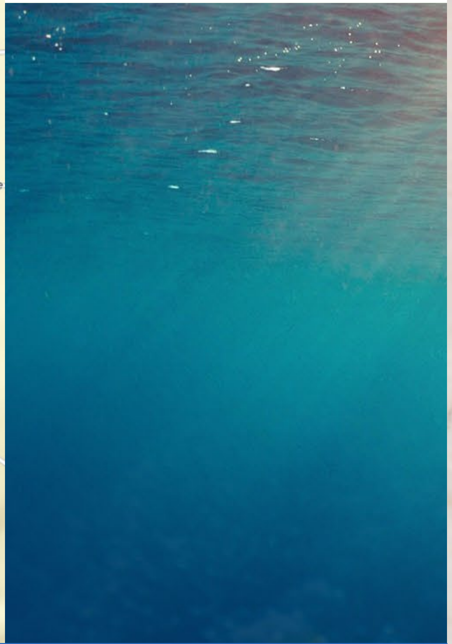


Ground-based generation:



PNNL: Vortex Induced Vibration Testing



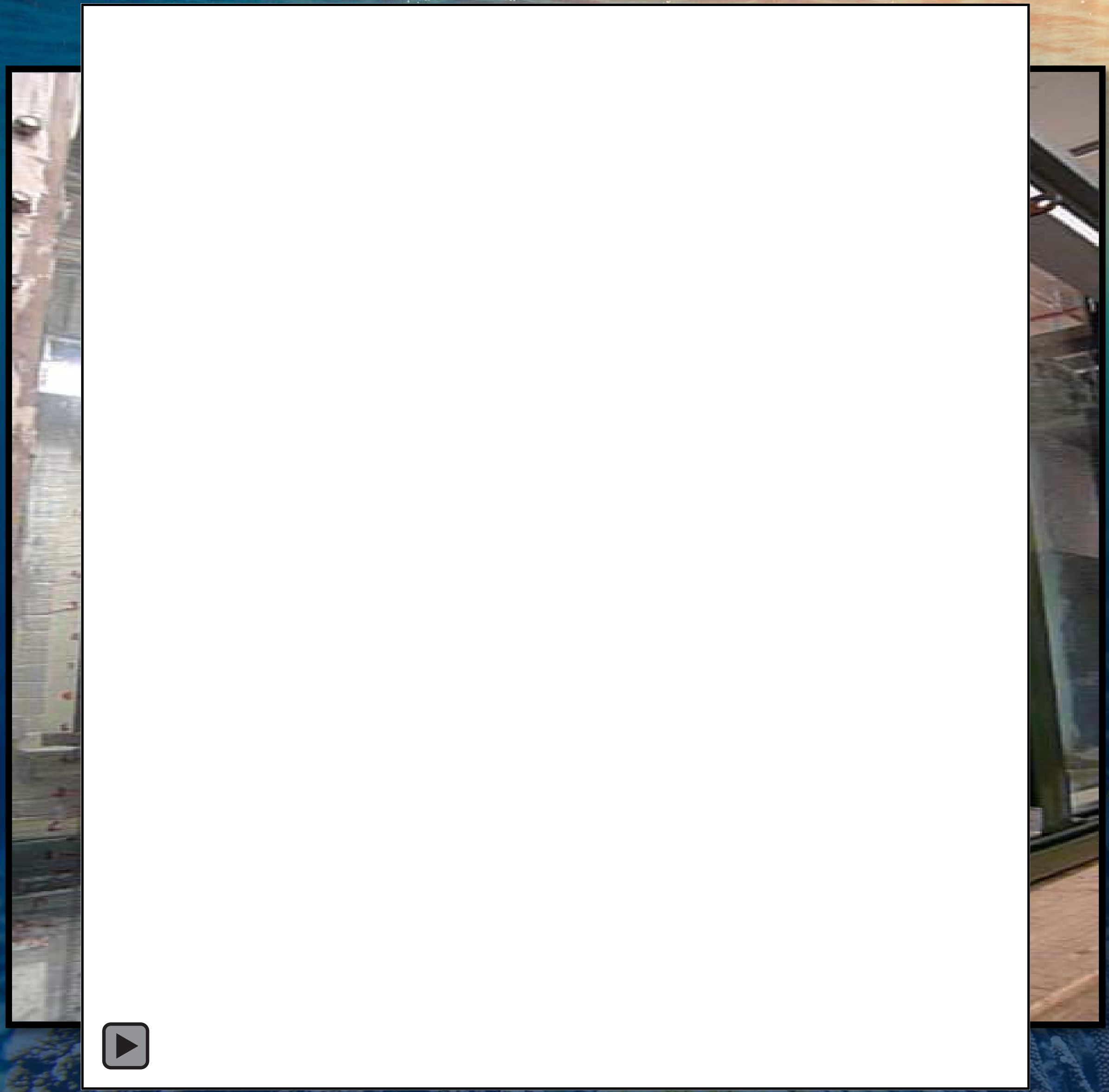


PNNL: Vortex Induced Vibration Testing

Vortex Hydro: VIVACE

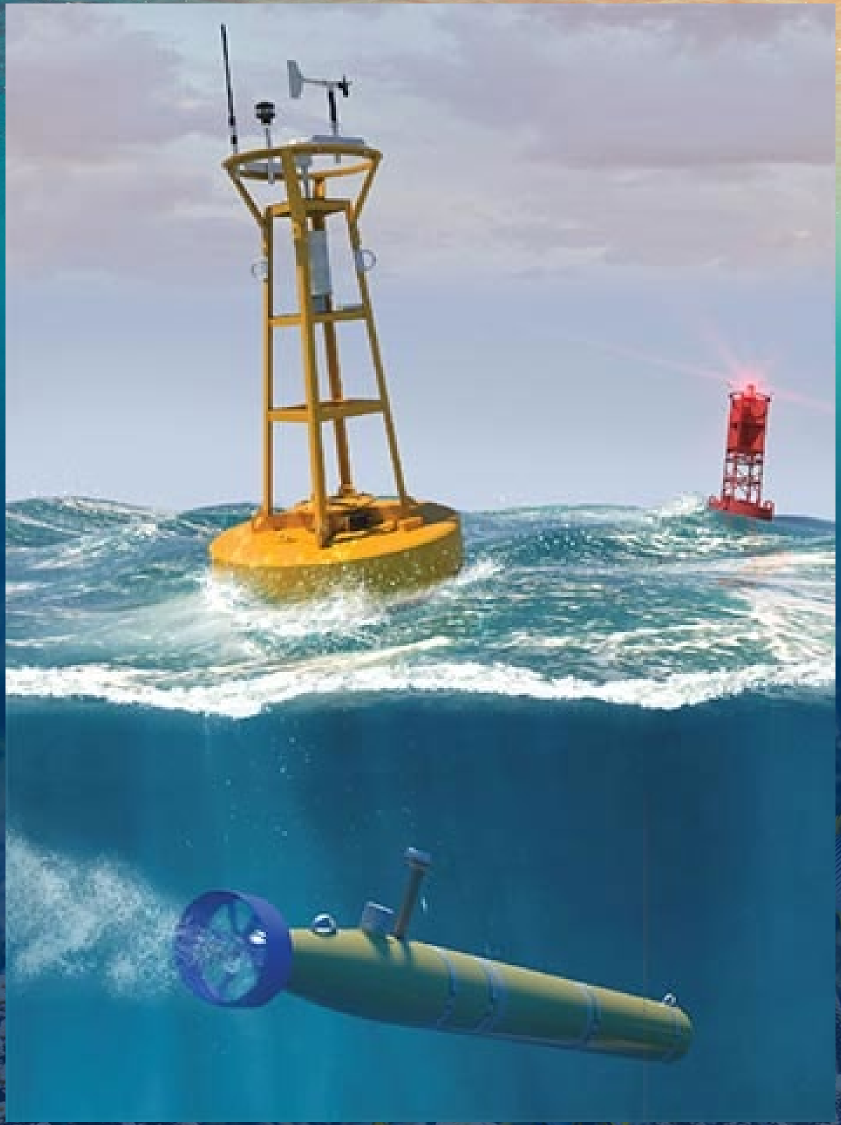
PNNL: Vortex Induced Vibration Testing

Vortex Hydro: VIVACE



The Future of Marine Renewable Energy

- Tidal power for remote communities
- WEC powered moored observation buoys
- WEC powered drifting buoys
- WEC powered drones
- WEC powered AUV charging stations
- Thermal gradient powered profiling floats
- Current powered AUV charging stations



Acknowledgements

- Funding provided by the U.S. Department of Energy Office of Energy Efficiency and Renewable Energy Water Power Technologies Office.
- The authors are grateful to our colleagues at the National Renewable Energy Laboratory and Sandia National Laboratory.

THANK YOU!

Ruth.Branch@pnnl.gov