Riding the Tide: Tidal Power Development in Puget Sound

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• Overview

• Devices

• Admiralty Inlet Studies
Tidal Hydrokinetic Turbines

- Superficial resemblance to wind turbines

- Key operational differences
  - Higher fluid density
  - Lower speed
  - Higher torque
Other Forms of Marine Energy

- Tidal Barrage
- Wave Hydrokinetic

- Ocean Current
- Ocean Thermal
- Salinity Gradient
- Offshore Wind
Tidal Energy Overview

**Benefits**
- No CO\(_2\) emissions during operation
- Power generation is predictable
- Very high resource intensity
- No visual expression during operation
- Short transmission distances

**Challenges**
- Deep, fast moving water
- High cost for first-generation technology
- Limited data on environmental risks
- Existing stresses in marine environment
- Long permitting pathway with high cost
Tidal Energy Sites in Puget Sound

**Siting Criteria**

- Resource
- Water depth and seabed type
- Electrical interconnection
- Environmental concerns
- Existing uses

**NNMREC-UW**

Depth-averaged velocity
SUNTANS model
Puget Sound Demonstration Projects

- Technology
- Economics
- Environmental risks

Clean Current

US Navy/Verdant

Snohomish PUD/Open Hydro
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Hydrokinetic Turbines

- **Verdant Power**
  - New York, East River
  - ~35 kW

- **Clean Current**
  - Race Rocks, BC
  - ~65 kW

- **Open Hydro**
  - EMEC, UK
  - ~150 kW

- **TGL**
  - EMEC, UK
  - ~500 kW

- **MCT**
  - Strangford, UK
  - ~1200 kW
Device Size to Generate 1 MW

1.5 m/s (2.9 knots)  
40m (131 ft) diameter

2.0 m/s (3.9 knots)  
26 m

2.5 m/s (4.9 knots)  
19 m

3.0 m/s (5.8 knots)  
14 m

\[ P = \frac{1}{2} \rho U^3 A \eta \]
Clean Current

Race Rocks demonstration project

- Offsets diesel load at lighthouse and marine science facility

- Bi-directional diffuser
- Permanent magnet generator
- 3 m diameter rotor
- Drilled pile foundation
Clean Current - Biofouling

Before

After

6 months deployment
Open Hydro

**European Marine Energy Center**
- First device tested at EMEC

- Surface piercing pile
- Permanent magnet generator
- Lift
- Drilled pile
- 6 m diameter rotor
Verdant Power

Roosevelt Island Tidal Energy project

- Only US demonstration to date
- Only array demonstration in the world

- 5 m diameter rotor (33 kW rating)
- Gearbox/Generator
- Passive yaw
- Drilled pile foundation
Marine Current Turbines

Strangford Lough demonstration

- First grid connected, utility-scale device

- 3m diameter

- Rotor (2 x 16m diameter, 1.2 MW rating)

- Gearbox/Generator

- Support pile

- Support "wing"

- Service platform and electronics
Marine Current Turbines

- Inspection/maintenance boarding around slack water

- Inspection boat running against current as support wing is raised
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NNMREC Overview

- Department of Energy funded partnership between Oregon State University (wave) and the University of Washington (tidal)

- Objectives
  - Facilitate responsible device commercialization
  - Inform regulatory and policy decisions
  - Close key gaps in understanding

- Partners on Tidal Energy
  - Snohomish Public Utility District
  - BioSonics
  - Pacific Northwest National Lab
  - Sound and Sea Technology
Device Selection

- Gravity base
- Permanent magnet rim generator
- Shrouded, high solidity blades
- Open center

10 m
20 m
Device Siting

- Camp Casey
- Fort Casey
- Point Wilson

5 km
Device Siting

- Admiralty Head
- Keystone Harbor
- Fort Casey
- Marine Reserve
- Weaker Currents
- Eddy Field
- Commercial Shipping Lanes
- Ferry Route
- 1 km
- 1.5 km
Environmental Considerations

- Effects on aquatic species
  - Avoidance
  - Aggregation
  - Strike

- Near-field environment
  - Noise (device, vessels)
  - Wake (sediment transport)
  - Hard substrate (artificial reef)
  - EMF
  - Toxicity (coatings, lubricants)

- Far-field environment
  - Circulation
  - Nearshore environment
  - Water quality
Far-field Effects at Pilot Scale (0.5 MW)

Northwest National Marine Renewable Energy Center

- Strait of Juan de Fuca
- Whidbey Basin
- Northern Admiralty Inlet
- Southern Admiralty Inlet
- Hood Canal
- Main Basin
- Tacoma Narrows
- South Sound
- Tacoma Narrows
- South Sound
- Hood Canal
- Main Basin
- Admiralty Inlet
- Whidbey Basin

Mean Range Change (mm)
Physical and Biological Site Characterization

- Velocity
- Background noise
- Seabed characteristics
- Water quality
- Aquatic species presence and use

Site Developer (SnoPUD)

Device Mfg. (OpenHydro)

Resource Agencies
Instrumentation Package

- **Acoustic release** (redundant recovery)
- **ADCP** (Acoustic Doppler current profiler)
- **Hydrophone** (background noise)
- **CTDO** (conductivity, temperature, depth, dissolved oxygen – partnership with WA Dept of Ecology)
- **VEMCO recorder** (tagged fish species – partnership with NMFS)
- **T-POD recorder** (porpoise clicks)
- **Lead Weight** (600 lbs)

Programmed for 3 month deployments
Findings: Current Velocity

Velocity > 1 m/s generally required to produce power
Findings: Velocity

- Velocity Magnitude (m/s)
- Velocity Direction (deg)
- Vertical Velocity (m/s)
Findings: Water Quality

**In-situ** measurements show slight halocline and thermocline *(for this cast)*

Lab results indicate low turbidity *(for this season)* *(WHO drinking water guidelines: < 1 NTU)*
Findings: Noise

- **Passenger and Car Ferry**
  - Chart showing pressure spectral density (dB 1 µPa²/Hz) vs. frequency (Hz)
  - Lines represent:
    - Quiet
    - Rain
    - Ship (Near site)
    - Ship (Distant)

- **Container Ships**
  - Images of container ships

Northwest National Marine Renewable Energy Center
Findings: Noise

Commercial shipping

Strong currents

Ferry

Strong currents

Frequency (Hz)

00:00 04:00 08:00 12:00 16:00 20:00 24:00

dB re 1\mu Pa^2/Hz

Northwest National Marine Renewable Energy Center
Questions?

http://depts.washington.edu/nnmrec

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