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Ocean Energy: Challenges and Opportunities

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Ocean Energy –
Challenges and Opportunities

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Ocean Energy

Kinetic sources:
- tides
- waves
- currents

Thermal sources:
- thermocline $\Delta T$

FAU/COET Focus
World-wide...

...interest, and R&D, is governed largely by available (oceanic) resources, not all of which have been fully assessed. The tides and waves of the North Sea, for example, have stimulated considerable effort in the nearby EU countries.

Operational deployments will also be governed by the locally available resource.
Early Estimates of Potential Marine & Hydrokinetic Resource Penetration (GW)

Potential MHK Resource

More detailed resource assessments and validation for wave, current, tidal and OTEC to be completed by 2012
Major Challenges to Renewable Ocean Energy Development

- Regulatory and Institutional
- Technology Readiness
- Testing Capability
- Global Standards
- Renewable Energy Policy and Legislation
- Cost-competitive systems
The Ocean as a System
Ownership – No one; Everyone!

- Interdependencies between: environment, ecology, resource, and power extraction systems
  AND
- Owners / Users (Stakeholders): Public, Government, Private Industry

Meeting this challenge will require engaging the large stakeholder community in the public policy debate
Challenges - Jurisdictional

**Ocean Jurisdictions**
- Many projects will span both state and federal waters via
  - Location of machinery
  - Transmission Cable
  - Connection to Land-based Grid
  - Staging Area for Construction

- Siting of Projects includes, but is not limited to:
  - Marine Spatial Planning
  - Public Attitudes/Engagement
  - Optimal Resources

Source: US Ocean Commission
Federal-State-Local Compliance

Permitting Process Complex

• **At Federal Level**-
  • Compliance with multiple federal statutes including NEPA
  • MMS lead permitting agency for OCS
  • USACOE likely lead permitting agency for Great Lakes

• **At State Level**-
  • Environmental Quality Review Boards
  • Coastal Zone Management Programs
  • Siting Boards for Energy Facilities and Transmission Lines

• **At Local Level**-
  • Town Planning and zoning Boards
  • By-laws (e.g., setbacks)
Maturing Research – Advancing Technology

Building upon a framework from NASA and DOD:

Technology Readiness Levels

Basic Research → Applied Development → Operational Deployment

Feasibility → Demonstration

TRL 1 → TRL 2 → TRL 3 → TRL 4 → TRL 5 → TRL 6 → TRL 7 → TRL 8 → TRL 9
Devices convert wave displacement into another form of energy (e.g., hydraulic);

Production depends on wave height and frequency.

Continental west coasts are best locations.
Work like wind turbines underwater; apply to both tidal and open-ocean currents

Tidal channels: shallow, but flows change direction;
Open-ocean: unidirectional, but water is deep.
Global Research Focus

Not Inclusive:

- Resource assessment and flow characterization
- Prognostics and health monitoring
- Turbine performance and fluid/rotor interaction
- System dynamics and stability
- Ecosystem interactions
- Materials, Corrosion, and Bio-fouling
- Data management, analysis and visualization
- Integrated modeling and simulation
- Energy transmission & grid integration
- Alternative uses for energy generated
- Standards development
Open Water Test Centers – Marine Hydrokinetic Devices

- UK / EU: Pre-permitted, open-water facility
  - EMEC, Wavehub and Galway Bay

  - But

- No existing facility in US to test Marine HydroKinetic devices at advanced TRLs
  - All projects must be deployed on public lands (waters)
  - Existing licensing process based on large-scale hydro and fossil fuel projects

Tested at EMEC

OPT

Tested at EMEC

OpenHydro (Snohomish PUD)
In the US...

...the Department of Energy’s Wind and Hydropower Technologies Program is attempting to stimulate R&D leading toward commercialization here. Two official centers have been established:

• Northwest National Marine Renewable Energy Center (waves/tides: nnmrec.oregonstate.edu)
• Hawaii National Marine Renewable Energy Center (waves/OTEC: hinmrec.hnei.hawaii.edu)

FAU’s COET is the only center working open-ocean currents.
Potential Effects

Quantifying environmental baselines and risks on an industry-wide basis is critical to securing permits for demonstration projects in the short term and ultimately reducing licensing costs across project types:

- Wakes and their influences (alteration of currents and waves)
- Alteration of bottom substrates, sediment transport and deposition
- Alteration of benthic habitats
- Interference with animal movements and migrations
- Strikes and entanglement
- Inadvertent FADs issues
- User conflicts (shipping; fisheries)
- Noise & Electromagnetic fields
- Chemical toxicity
TC 114 was created in 2007 – Marine Energy: Wave, tidal and other water current converters

Secretariat held by the British Standards Institute (BSI), United Kingdom

15 Member Countries with participating status (P-member), 4 Countries as observers (O-member)

Two plenary meetings held
- Inaugural meeting in Ottawa, Canada, May 2008
- 2nd plenary meeting in Seoul, South Korea, May 2009

Formal Liaisons established
- TC 4 – Hydraulic Turbines
- TC 88 – Wind Turbines
- IEA – OES
- EquiMAR
To prepare international standards for marine energy conversion systems.

The primary focus will be on conversion of wave, tidal and other water current energy into electrical energy, although other conversion methods, systems and products are included.

Tidal barrage and dam installations, as covered by TC 4, are excluded.
Standards will Address

- System definition
- Performance measurement of wave, tidal and water current energy converters
- Resource assessment requirements
- Design and safety requirements
- Power quality
- Manufacturing and factory testing
- Evaluation and mitigation of environmental impacts
• **Actions Needed:**
  - Develop a Research and Development agenda to advance components and systems to demonstration phase
  - Identify, assess and minimize key environmental impacts to facilitate demonstration permits
  - Establish comprehensive testing strategy at progressive technology stages
    - Evaluate performance drivers
    - Quantify costs
  - Develop tools, models, and materials to ensure system survivability
  - Integrate resource assessments, technology cost and performance data
  - Establish advanced cost/performance models to identify critical drivers in overall cost reduction
...the waves are tame;
...the tides are weak;

In Florida -

...but we've sure got current.

Moreover, we have a significant thermal potential as well.
Ocean Thermal Energy Conversion

- Ocean thermal energy has the greatest potential
- A pilot plant is being developed in Hawaii
- Florida is also a prime location (water is renewed by Gulf Stream flow)

Temperature Cross-Section Between Ft. Lauderdale and the Bahamas
FAU’s Center for Ocean Energy Technology, embedded in the College of Engineering and Computer Science, was founded with an award from the Florida Center of Excellence Program in 2007.

Additional funding from the State of Florida and from the US Department of Energy is underwriting our efforts to advance the science and technology of oceanic energy extraction.

We’re starting with the Florida Current and progressing toward OTEC implementation.
Regulatory Framework

- U.S. Army Corps of Engineers
- U.S. Coast Guard
- U.S. Navy
- Federal Communication Commission
- U.S. Environmental Protection Agency
- Federal Energy Regulatory Commission
- U.S. Department of Interior – Minerals Management Service
- National Oceanic and Atmospheric Administration, NOAA Fisheries
- U.S. Fish and Wildlife Service
- Florida Dept. of Environmental Protection
- Florida Fish and Wildlife Commission
4 bottom mounted ADCP buoys measuring the water profiles every 30 minutes with bin sizes from 2–8 meters

- These buoys are located approximately 5, 10, 15, and 20 miles off shore
- 2 buoys have both upward and downward looking ADCPs
- 2 buoys have only upward looking ADCPs
- Two additional buoys are scheduled to be deployed this year
- Ship mounted ADCPs will allow us to make transects across the Gulf Stream
Two surface current radar stations have been installed.
These measure an approximately 40 x 40 mile area off our coast.
Measurements are made every 30 minutes.
Resolution is approximately 2 miles.
Two more stations may be added.
Water property profiles are made from near the surface to 10 meters from the bottom.

Measurements are made along four 25-30 mile long transect lines along a constant latitude separated by 33 miles with 9-11 profiles made along each transect.

Conductivity, temperature, pressure, salinity, PH, and dissolved oxygen are simultaneously measured at 24 Hz.

48 transects have been made off our coast (See Table) and 8 at the other locations.

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Ocean Current Prototypes and Testing

- Demonstrate feasibility of extracting ocean current energy
- Investigate technology gaps and hurdles
- Study environmental and ecological interactions
- Develop a platform to support ocean energy technology development
- Initial turbine has a 3 m diameter rotor, 20 kW generator, and 1500 kg dry weight
- Prognostics and health monitoring systems to ensure assessment, avoidance, and risk mitigation
Summary

- Renewable energy – in all cases some form of solar power that has been processed by various components of the Earth System – represents an alternative to the “ancient” sunlight locked up in fossil fuels.
- The oceans, an important component of the Earth System, are finally being tapped for their renewable potential.
- Like the atmosphere’s winds, the oceans’ large-scale current systems offer significant potential for electrical power generation be it hydrokinetic or ocean thermal.
- The challenges are significant, but not insurmountable.
- We must work together on global renewable energy solutions.