Florida Atlantic University

Southeast National Marine Renewable Energy Center

Marine Renewable Energy (MRE) is the resource embodied in ocean currents, waves, tides, and thermal gradients. Tapping MRE resources will reduce our reliance on fossil fuels and help Florida along the road to energy self-sufficiency. Research areas of focus include improving understanding of ocean current and thermal-gradient resources, implementing testing capabilities to expedite commercial development of these resources, and understanding potential environmental impacts and how to mitigate them.

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Description: The SNMREC mission is to catalyze ocean-based solutions to the Florida's energy challenge. A primary focus is on determining the potential of Florida's ocean-current resource and on ocean thermal energy conversion in waters offshore. Part of this involves the regulatory process at State and Federal levels for ocean energy infrastructure and operation in the offshore continental shelf, which is neither clearly defined nor have the roles and interdependencies of the individual agencies been clearly articulated. In addition, knowledge to make these decisions is more on a macro- rather than the micro-level necessary to assess individual devices. SNMREC's role is to bridge the gap between concept and commercial deployment of ocean energy technologies by providing at-sea testing facilities for both ocean current and thermal energy research and for technology development. Research cuts across environmental, ecological, resource, and technology areas.

Universities: Florida Atlantic University, with UCF, FSU, USF, ERAU, University of Miami, Oregon State University, University of Washington, Pennsylvania State University, University of New Hampshire, University of Hawaii, University of Edinburgh, Heriot-Watt University, Nova Southeastern University, Virginia Polytechnic Institute and State University, and Florida Institute of Technology

External Collaborators: Numerous industry and State and federal government as well as FFRDCs, such as the National Renewable Energy Laboratory, Oak Ridge National Laboratory, Pacific Northwest National Laboratory, Woods Hole Oceanographic Institution, U.S. Department of Energy (Office of Energy Efficiency and Renewable Energy, U.S. Department of Interior (Bureau of Ocean Energy Management, Regulation, and Enforcement), U.S. Department of Commerce (National Oceanic and Atmospheric Administration), Florida Department of Environmental Protection, and others as well as numerous industry partners.

Progress Summary

The Southeast National Marine Renewable Energy Center at Florida Atlantic University (FAU) was established by an award from the US Department of Energy in 2010 out of the FAU Center for Ocean Energy Technology, which was originally founded in 2007 as part of the 2006 Florida State University System Center of Excellence Program. Over the past several years, the regulatory environment associated with MRE development on the continental shelf has evolved considerably, and the Center's initial strategy has expanded as well to accommodate the regulatory requirements. In particular, the Center has continued to move forward in strategic research, in pursuing key technology, and in defining standards criteria; it has also become more and more deeply engaged in regulatory process formation, which will influence the development of MRE in Florida, while continuing to educate and engage the public.

Research and development for an ocean energy industry is being addressed with a system-level, phased approach. Joint research is ongoing at FAU, with FESC partners, and other industrial, government, and academic partners. Initial research in areas such as ocean resource analysis and modeling, prognostics and health monitoring systems, materials and anti-fouling, mooring and anchor systems, and environmental/benthic baseline assessment have been funded.

SNMREC's technology and industry support efforts are underway in three distinct but inter-related tracks. First, the Center is actively engaged in sensor and instrument acquisition, deployment, and analysis to more fully characterize offshore energy resources, as well as the benthic and pelagic environment. Second, in support of ongoing research and to further an operational and technical understanding of offshore energy systems and challenges, the Center has designed, partially fabricated, and will begin testing a small-scale hydrokinetic turbine system. Testing will be completed for components, sub-systems, and major systems of the turbine, eventually evolving to full system testing in a phased, risk-reduction process. Finally, the Center is working to begin early development of system-level test operations and data collection infrastructure. This effort is intended to support and promote a phased approach for early-stage testing to minimize risk and further scaled development for the growing industry, as well as to help establish standards criteria and practice for the future sector.

Notable accomplishments during the past year include completed milestones in resource assessment, research, regulatory process activity, partner relationships, infrastructure development, and outreach. Stand-alone instruments deployed offshore in 2009 were recovered, and the data obtained reveals new and important features of the Florida Current that will influence design of offshore MRE systems. An application to lease deployment sites has been submitted to and is being reviewed by the US Bureau of Ocean Energy Management, Regulation, and Enforcement. An onshore 20 kW dynamometer system, for testing MRE system components, is installed and is currently undergoing operational testing. In March, SNMREC hosted an industry / government / academe workshop on issues associated with MRE development that produced a clear consensus about the importance of negotiating the maze of regulatory issues if the endeavor is to succeed. And the Center developed a curriculum for upper-division high-school students to introduce the topic within secondary education.

2010 Annual Report

Introduction

The Summary in Section 2 provides an overview of SNMREC, which was first founded as the Center for Ocean Energy Technology. COET programs segued into SNMREC with the national center designation in July, 2010 by the U.S. Department of Energy.

Areas of Significant Progress

Resource Assessment

Although most of the emphasis at SNMREC has been on understanding the marine hydrokinetic (MHK) resource of the Florida Current, there have also been ongoing efforts aimed at assessing the thermal resource for possible ocean thermal energy conversion (OTEC) development. Conductivity, temperature, and depth (CTD) surveys have mapped the temperature structure offshore of SE Florida. Assessments include more than 48 weekly data sets of ocean thermal structure offshore of Fort Lauderdale and more than 6 monthly data sets of ocean thermal structure in three other locations stretching from Miami northward to Stuart. The measurements are taken from nearshore Florida's SE coast to more than 30 nm offshore into the Florida Straits.

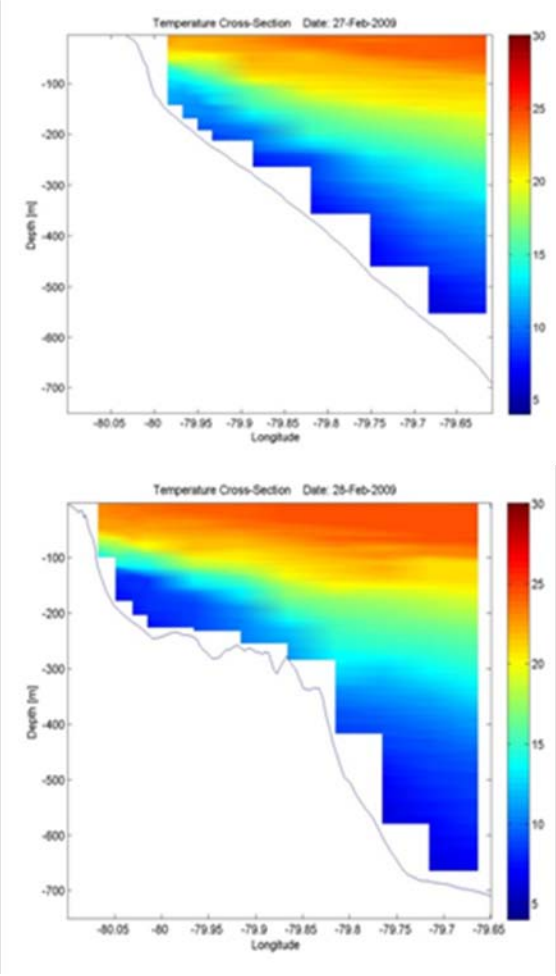
Figure 1 depicts winter-time results offshore of Stuart (top) and Fort Lauderdale (bottom). Of considerable interest to developers is the pool of cold water just offshore in the Fort Lauderdale section at depths of 200-250 m, on the bathymetric feature known as the Miami Terrace. Not only is this cold water

far more accessible than it is in many OTEC-rich locations, such as Hawaii, it is also continually renewed by the northward flow in the Florida Straits.

Typically, OTEC implementation requires temperature differences of 20°C or more. Because surface temperatures are at or near their lowest in February, it appears that the potential for OTEC development in the Florida Straits is high.

To complement this localized observational study of OTEC resources, SNMREC has undertaken a global analysis of OTEC potential in partnership with Lockheed-Martin, Inc., in a project funded by the US Department of Energy. This effort will utilize a global model-assimilation dataset produced by the Naval Research Laboratory to map global temperature differences relevant to OTEC. Initial work has involved acquiring the 6 terabytes of data to be analyzed.

Work on assessing the MHK resource of the Florida Current has also produced noteworthy results despite some disappointments. In March, 2009, four Acoustic Doppler Current Profilers (ADCPs) were deployed in an east-west section off Fort Lauderdale. One of these was recovered after only a month (its communications system seemed to be faulty; but its data acquisition system was, in retrospect, quite healthy); the others remained *in situ* until April, 2010. One of these three produced a remarkable and unique time series of the behavior of the Florida Current near its core region (Fig. 2).



Florida, obtained at SNMREC using CTDs.

Full analysis of this rich dataset is underway, but even at this early stage several interesting results are apparent. First, it is clear that significant variations of current speed occur on a variety of time scales. The daily spikes in current speed shown in the bottom panel are especially important for system developers to consider. Second, the rather abrupt decrease of the current speed with depth has implications for deployment strategies. Given that the power that can be generated by an underwater turbine system is proportional to the cube of the current speed, near-surface deployments will be attractive. However, other considerations (weather and ship traffic, in particular) must be balanced against this option.

Regulatory Environment

Continual evolution of (both state and federal) agency requirements has made obtaining permits for open-ocean deployment of even experimental test systems a challenge. After more than a year of joint discussions concerning a draft application to the Bureau of Ocean Energy Management, Regulation, and Enforcement (formerly the Minerals Management Service of the US Department of the Interior), SNMREC submitted in May its formal application for leases of offshore sites in the Florida Straits. Pursuing both research and development in renewable energy on the Outer Continental Shelf (OCS) must comply with the federal Outer Continental Shelf Lands Act. With respect to the SNMREC deployments of prototype devices/systems the major permits, approvals, and authorized actions necessary to construct, operate, maintain, and decommission project facilities while falling outside of State of Florida waters (i.e., the deployment and operations will be more than 3 miles offshore), will involve interaction with the Florida Fish and Wildlife Commission due to its agreements with the U.S. Fish and Wildlife Service. In addition, shore-side activities in support of the offshore deployment will be conducted within State

waters, at a commercial marina under the purview of the Florida Department of Environmental Protection. These activities will also engage agencies such as the U.S. Army Corps of Engineers, the National Oceanic and Atmospheric Administration's Marine and Fisheries Service, the U.S. Coast Guard, the U.S. Navy, etc.

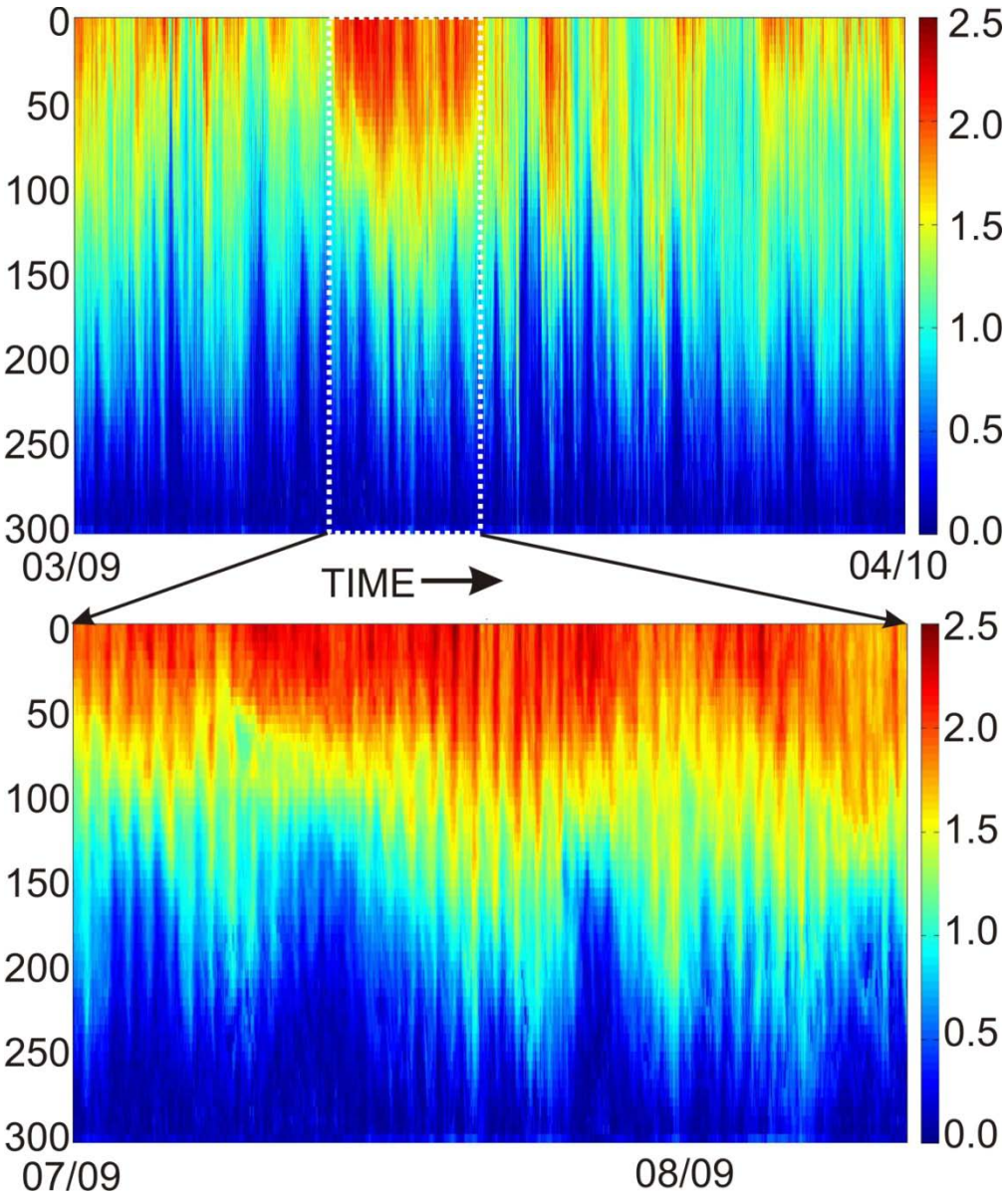


Figure 2. ADCP time series showing current speed as a function of depth, about 25 km offshore of Port Everglades. Bottom panel shows magnified section of particularly robust current.

The discussions of the drafts have proven to be worthwhile, as the relationship developed during that phase (which resulted in some SNMREC language being adopted in the regulations) led to opportunities to further refine the application as rules continued to change. As a result, an amendment is in the development process at this writing.

In addition, recent research results, some of which were supported by SNMREC, have provided additional information about a newly discovered genus of corals that inhabit the outer parts of the Miami Terrace and other bathymetric features in the Florida Straits. The vulnerability of these corals to deep-trawl commercial fishing has led the National Oceanic and Atmospheric Administration to designate a large part of the sea-bed offshore of Florida and Georgia as a Habitat Area of Particular Concern. While this designation will have relatively little impact on SNMREC operations – the Center's two or three anchor systems can easily be deployed on the large, sandy patches that exist between coral beds – there will likely be significant challenges for commercial-scale deployments in the future.

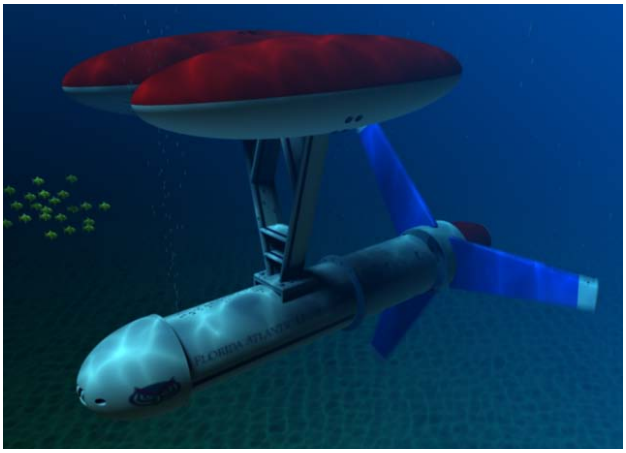


Figure 3. Artist's rendering of the SNMREC OCT.

Infrastructure

Design and fabrication of equipment for SNMREC testing activities moved ahead in the 2009-2010 time frame.

Fabrication began on the prototype ocean-current turbine (OCT) system under development at SNMREC (Fig. 3). Originally intended to be used to test operational testing protocols and strategies, the system is now also envisioned to act as a platform for component testing. For example, developers who require rotor testing can mount their designs on this system (replacing the original rotor) instead of building an entirely new OCT for this purpose.

One of the biggest unknowns in the operations of OCT systems concerns the behavior of the generator sub-system as it experiences both variable loads and the torque differentials associated with changing currents acting on the rotor. In order to provide a capability to test generators under conditions as realistic as possible without actually having to go to sea, SNMREC has developed a computer-controlled dynamometer system, located at the FAU SeaTech facility in Dania Beach.

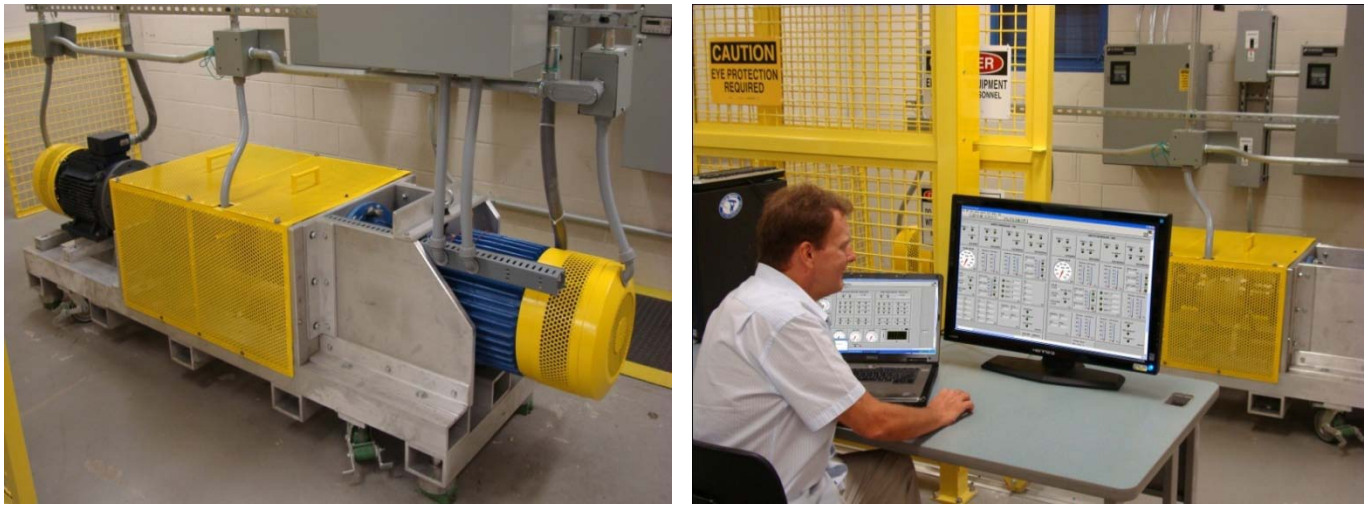


Figure 4: SNMREC dynamometer for generator testing. Unit on left (much of which in hidden by the computer display in the right-hand photograph) is ~3 m long.

The system, which uses an electric motor to drive generators of up to 20 kW capacity, is shown in Figures 4. It is currently undergoing final testing.

Education and Outreach

Professional Community

In March 2010, SNMREC hosted the first Offshore Ocean Energy Dialogue in Boca Raton. This event brought together 55 industry, university, and federal and state agency participants to begin an ongoing conversation about a coordinated approach to meeting the research and development challenges of recovering energy from surface waves, tidal flows, open-ocean currents and the potential of the thermocline. The group approved seven consensus recommendations that will be helpful in addressing some of the challenges facing development of these important resources:

- For ocean energy development to succeed, all stakeholders should focus on affordable demonstration test facilities to accelerate the development and implementation process.
- For field test facilities to succeed, academia, industry, and government must:
  - plan to accommodate long-term test needs,
  - organize and provide the needed input environmental data,
  - resolve scaling and evaluation requirements and definitions,
  - develop a shared liability model, and
  - manage different expectations and processes by regulatory agencies.
- Development risk should be mitigated by:
  - Additional public sector funding
  - Independent assessment of development readiness and progress; standards and measurement expectation(s) availability
  - Addressing missing capabilities and assets for prototype deployment
  - Addressing early in the development process various longer-term challenges such as public outreach and grid integration
- Standards must be developed for prototype or early device testing.
- System monitoring and prognostic efforts for prototype systems need to be expanded to include data to account for environmental interaction that will be useful for environmental impact analysis.
- Florida needs a state task force that collaborates with the US Department of the Interior Bureau of Ocean Energy Management, Regulation, and Enforcement
- All parties should:
  - Conduct outreach at the governmental level
  - Develop and deliver a unified understanding of adaptive management.
  - Collaborate to consolidate all relevant data

Education

SNMREC has developed an Educational Curriculum to enhance interest in science, mathematics, engineering, and technology and to support improvements in education for students from K-12 with original curricula and teacher workshops. *Energy from Ocean Currents: the New Renewable* is an ocean-energy curriculum developed for 11th and 12th grade students with funding from an award by the US Department of Energy's Office of Energy Efficiency and Renewable Energy. The curriculum is based on the "5 E's", an innovative instructional-based model used for teaching that fosters inquiry-based

thinking by *engagement, exploration, explanation, elaboration,* and *evaluation.*

There are six comprehensive lessons built around the scientific basis of SNMREC research, each aligned with the Florida Sunshine State Standards benchmarks, with hands on activities reinforcing each lesson. One such activity is building an electric generator from a soda can to demonstrate an induction coil alternating current generator. The lessons also include "Meet the Scientist" segments that feature a SNMREC engineer or scientist.

The curriculum was introduced to 40 teachers from three counties in South Florida in three workshops. Teachers who participated in the pilot workshop implemented the curriculum with their classes and gave valuable feedback. They also participated in the second and third workshops as facilitators, and they received in-service credits from their school districts. Pre- and post-lesson tests at the workshop and an online survey after utilizing the lessons in their classrooms provided the teachers with the opportunity for assessing the program, and the feedback was very positive. The second year of the program will reach additional teachers and incorporate enhancements to the original curriculum.