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**STUDY TITLE:** Roadmap: Technologies for Cost Effective, Spatial Resource Assessments for Offshore Renewable Energy

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**BACKGROUND:**

The future of offshore renewable energy is at a crossroads. Energy extraction devices utilizing wind, waves and currents are being rapidly developed in the US and abroad, yet very few examples of offshore renewable power use exist. In an apocryphal statement made several years ago, a US developer estimated 75% of the cost to market was site characterization, monitoring and permitting. In order for offshore renewable energy to be a viable alternative to traditional power systems, cost effective measurement technologies capable of operating in the harsh marine environment need to be available and their performance characteristics need to be assessed relative to needs of the renewable energy sector. This report assesses the available technology for renewable energy site characterization, describes new and innovative ways to enhance the usefulness of current technology, and in some cases creating new technology. A combination of the three approaches provides a roadmap for the cost effective, spatial resource assessments for offshore renewable energy for the near future.

This project uniquely involved a consortium of five major academic institutions, four leading technology companies and the government of the Commonwealth of Massachusetts under the program management of the New England Marine Renewable Energy Center all devoted to the use and manufacture of instruments used to characterize and monitor marine energy resources. In some cases the performance of monitoring technologies were assessed in the role of overall site characterization and monitoring, while in others the manufacturers explored the limits of existing technologies for addressing concerns specific to offshore renewable energy. This broad based program examined measurements from the sediment surface to the top of the marine atmospheric surface boundary layer with an emphasis on technologies providing spatial-temporal measurements. Thus, the program included technologies used to assess offshore wind potential, wave energy conversion, tidal turbine performance and efficiency, as well as the potential environmental impact of commercial installations on sensitive marine resources.

**OBJECTIVES:** The project objectives were to identify various technologies that may be used to evaluate the environment in a cost effective manner in support of offshore renewable energy development.

**DESCRIPTION:** The winds, waves and currents in the coastal oceans of the United States offer tremendous resources for renewable energy if that energy can be extracted in a cost effective manner. For sustainability, the potential environmental impacts must be surveyed from over a hundred meters in the air, through the water column, and into the bottom sediment. To ensure economic viability, the resources (winds, waves and currents/tides) must be surveyed over the size of the offshore facility to estimate its generating potential. Further, these surveys must span significant time periods to capture seasonal variability, requiring information across four dimensions, the volume of sea and air, and time. The development of an offshore power generation facility passes through a number of stages, extending from the initial site and resource characterization, through construction, to operation and maintenance. All of these phases require spatially-extended environmental measurements.

We illustrate these points with the specific example of wind power (similar considerations apply to wave and current power generation). Initial resource assessments and site decisions require

maps of the annual wind speed and direction over the spatial extent of the proposed wind facility. Once a site has been selected, an assessment of the likely environmental impact of the facility requires observations of birds, bats, fish, turtles, marine mammals, and benthic vegetation and organisms. Bottom surveys of sediment type and thickness are required to evaluate the effect of the installation on sediment transport, as well as determining optimal routes for buried power cables, and (in the case of floating turbines) the design of anchors. Additionally, sub-bottom surveys are required for piling-anchored towers. All of these are spatially-distributed measurements and hence require remote-sensing techniques. Once a site has been selected, construction activities require good forecasts of weather conditions and sea state, which are greatly improved if observations are assimilated into models, For example, real-time observations of waves can provide both a medium-time predict-ahead capability that can be helpful in deciding whether to undertake at-sea activities, and time resolved wave estimates that can facilitate the transfer of personnel and cargo from a ship moving in the waves to and from a fixed platform. Once operational, the wind facility can benefit from real-time observations of winds on several scales. For example, long-range mapping of the upstream wind field on scales of the order of 10 km will allow advance prediction of the expected power output of the facility, which can facilitate optimizing grid performance. Higher resolution measurements (both spatially and temporally) of the winds just upstream of the turbines are useful for real-time control to maximize their power output, and smooth out the mechanical loading on the blades. Lastly, as a research tool, mapping the vertical profile of the wind velocity within a facility will lead to a better understanding of wake interactions between the turbines in an array.

**SIGNIFICANT CONCLUSIONS:** Several technologies were evaluated to determine optimal and cost effective solutions for offshore renewable energy data collection. Of the technologies tested, the use of LIDAR was clearly superior to SODAR for offshore purposes, but additional development is necessary for use of LIDAR on floating platforms. HF Radar from shore has potential for measuring waves to evaluate their resource potential. The use of AUVs for seafloor mapping works for sonar but needs additional testing for subbottom profiling. Advancements were made on several areas to provide information for instrument design and use.

**STUDY RESULTS:** Spatial resource assessment for offshore renewable energy is technology intensive. In order for offshore renewable energy to be competitive both the technology and its use must be cost effective. Throughout this report technologies used to monitor and assess wind, wave, current, and environmental resources have been examined to determine the best directions technology should pursue to provide cost effective tools for offshore renewable energy.

Available technologies for assessing offshore wind resources were evaluated and compared. While two dominant technologies exist, LIDAR and SODAR, the investigators found that LIDAR holds the greatest promise for spatial assessment of offshore renewable energy resources. A great impediment for development of this resource is the cost of deployment which requires either a stable platform or ways to compensate for the movement of floating platforms. The latter is the preferred pathway for the future as it provides the greatest flexibility from site prospecting through to post installation monitoring.

Traditional methods for assessing offshore wave resources rely on buoys with high deployment and maintenance costs or radar arrays which lack flexibility and often are at odds with the aesthetic ideals of coastal and beach communities. Smaller inconspicuous arrays were developed which can operate at multiple frequencies providing greater information in many varied conditions. In addition, traditional marine radars were modified and repurposed to provide similar information from ships farther out to sea. Both of these studies provide a path towards economical spatial assessment of offshore wave resources. Furthermore, these studies provide an example of how incentives for collaboration between industry and manufacturers can pave the way for technology development specific to the needs of offshore renewable energy.

Development of new technology is not the only way to increase cost effectiveness. Doppler current data produced by existing technology was reexamined with reference to the specific needs of offshore wave and tidal current renewable energy. By reinterpreting data from horizontal acoustic Doppler current profilers it was found that invaluable near real time wave prediction was possible. Not only could these insights provide cost effective wave resource assessment, but if developed further, these insights could provide early warning of incoming damaging waves allowing time to protect wave energy converters. In addition, the same information could be used to optimize the efficiency of wave energy conversion to a constantly changing wave regime.

Tidal current and environmental resources were assessed with available technology deployed from an AUV instead of using traditional ship mounted or towed arrays. It was shown that AUV technology has advanced to the point that they can provide data comparable to the best traditional methods. Furthermore, in the difficult, energetic environments characteristic of offshore renewable energy sites, AUV's were able to maneuver in critical regions safely, unobtainable by surface vessels. The initial capital cost of AUV's has also decreased significantly allowing rapid cost recovery as a result of being able to use less personnel and smaller vessels to perform simultaneous surveys of multiple parameters. AUV's point towards a future in which current velocity prospecting as well as critical baseline environmental surveying may be performed better, in less time and at lower expense than today.

These studies have mapped out promising pathways to cost effective spatial resource assessment for offshore renewable energy ranging from wind to the benthos. The common thread throughout has been close collaboration between the manufacturers of required technology and the scientists and developers that use that technology. Fostering this collaboration provides incentive for manufacturers to focus limited resources towards finding solutions to problems specific to the needs of the maturing offshore renewable energy industry.

**STUDY PRODUCTS:**

Terray, E., B. Howes, W. Stein, J. McGowan, J. Manwell, P. Flament, W. Plant, P. Dragos, D. Triza, R. Anderson, and J. Mullison. 2014. Roadmap: Technologies for Cost Effective, Spatial Resource Assessments for Offshore Renewable Energy. US Dept. of the Interior, Bureau of Ocean Energy Management, Office of Renewable Energy Programs, Herndon. OCS Study BOEM 2014-604. 169 pp.