Technology White Paper

on

Ocean Current Energy Potential on the U.S. Outer Continental Shelf

Minerals Management Service
Renewable Energy and Alternate Use Program
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OCEAN CURRENT ENERGY POTENTIAL ON THE U.S. OUTER CONTINENTAL SHELF

INTRODUCTION

With the passage of the Energy Policy Act of 2005 (EPAct), Public Law 109-58 (H.R. 6), the Minerals Management Service (MMS), a bureau of the U.S. Department of the Interior, was given jurisdiction over Renewable Energy and Alternate Use Program projects, such as wind, wave, ocean current, solar energy, hydrogen generation, and projects that make alternative use of existing oil and natural gas platforms in Federal waters. A new program within MMS has been established to oversee these operations on the U.S. Outer Continental Shelf (OCS). MMS is developing rules to guide the application and permitting process for development of Renewable Energy and Alternate Use Program projects on the OCS. To apply the requirements of the National Environmental Policy Act (NEPA) in the establishment of national offshore alternate energy development policy and a national alternate-energy-related use program and rules, MMS plans to prepare a programmatic environmental impact statement (Programmatic EIS). The Programmatic EIS process will (1) provide for public input concerning the scope of national issues associated with offshore alternate-energy-related use activities; (2) identify, define, and assess generic environmental, sociocultural, and economic impacts associated with offshore alternate-energy-related use activities; (3) evaluate and establish effective mitigation measures and best management practices to avoid, minimize, or compensate for potential impacts; and (4) facilitate future preparation of site-specific NEPA documents—subsequent NEPA documents prepared for site-specific Renewable Energy and Alternate Use Program projects will tier off of the Programmatic EIS and Record of Decision. The Programmatic EIS will evaluate the issues associated with development, including all foreseeable potential monitoring, testing, commercial development, operations, and decommissioning activities in Federal waters on the OCS. Information defining the issues and current technology will be obtained primarily from Federal research organizations, MMS, industry, and other valid sources.

In preparation for the Programmatic EIS, MMS has developed a series of White Papers on topics of interest to the Renewable Energy and Alternate Use Program. The overall objective of the White Papers is to provide sufficient information on the prospective alternative technologies to support assessments of the potential environmental impacts of the technologies and of the viable impact mitigation strategies in the Programmatic EIS. The White Papers also will serve as sources of information for stakeholder outreach.

This White Paper discusses the generation of energy from ocean currents on the U.S. OCS. Resource potential and technologies for capturing ocean current energy are discussed.[1] Major potential environmental and economic impacts associated with the technologies discussed herein have been identified from available literature.

[1] Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not represent its endorsement, recommendation, or favoring by MMS, the United States government, or any agency thereof.

RESOURCE POTENTIAL

Ocean currents are driven by wind and solar heating of the waters near the equator, although some ocean currents result instead from variations in water density and salinity. These currents are relatively constant and flow in one direction only, in contrast to the tidal currents closer to shore where the varying gravitational pulls of the sun and moon result in diurnal high tides. Some examples of ocean currents are the Gulf Stream, Florida Straits Current, and California Current (Figure 1). The Florida Straits Current starts only 8 km offshore in the southern part of Florida, close to Miami, and sustains relatively large speeds over significant distances in relatively unchanging patterns. In contrast, the California Current has relatively slow speeds and shifts periodically. Ocean currents tend to be concentrated at the surface, although significant current continues at depths below ships' drafts. The Aleutian passages have also been identified as an area for potential development of ocean current energy extraction.

Ocean current speeds are generally lower than wind speeds. This is important because the kinetic energy contained in flowing bodies is proportional to the cube of their velocity. However, another more important factor in the power available for extraction from a flowing body is the

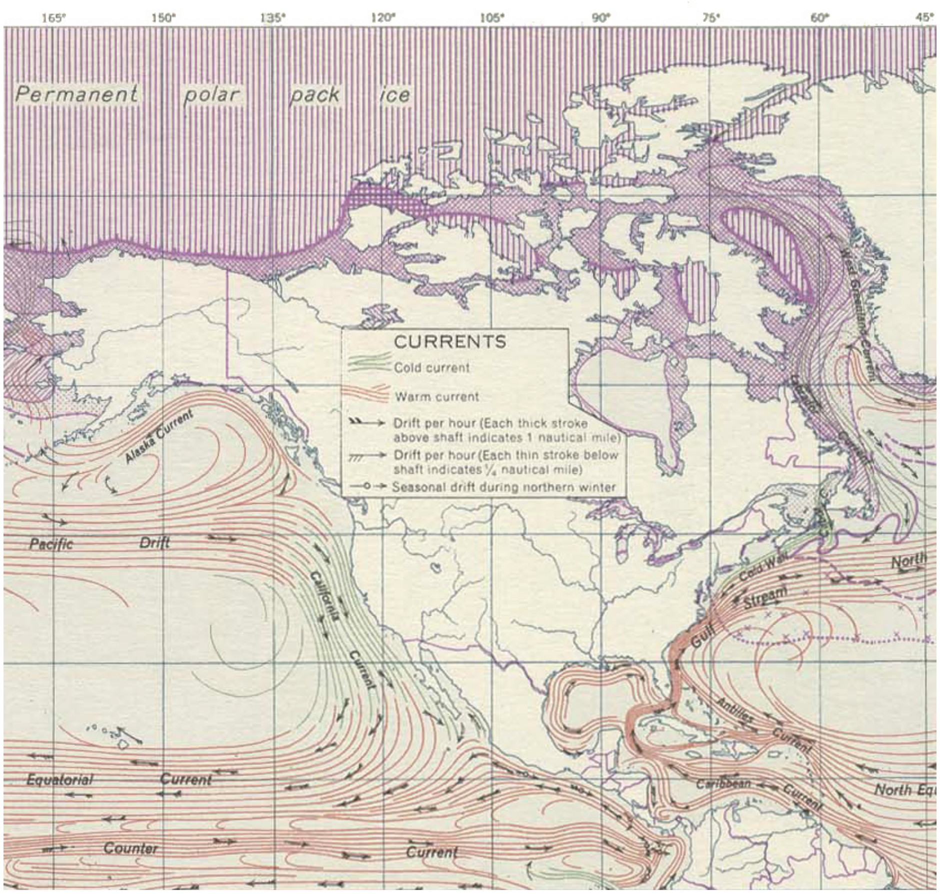

FIGURE 1 Ocean Currents in the Vicinity of the United States (Source: University of Texas Libraries 2006)

density of the material. Water is about 835 times denser than wind, so for the same area of flow being intercepted, the energy contained in a 12-mph water flow is equivalent to that contained in an air mass moving at about 110 mph. Thus, ocean currents represent a potentially significant, currently untapped, reservoir of energy.

The total worldwide power in ocean currents has been estimated to be about 5,000 GW, with power densities of up to 15 kW/m^2. The relatively constant extractable energy density near the surface of the Florida Straits Current is about 1 kW/m^2 of flow area. It has been estimated that capturing just 1/1,000th of the available energy from the Gulf Stream, which has 21,000 times more energy than Niagara Falls in a flow of water that is 50 times the total flow of all the world's freshwater rivers, would supply Florida with 35% of its electrical needs. Countries that are interested in and pursuing the application of ocean current energy technologies include the European Union, Japan, and China.

RESOURCE UTILIZATION TECHNOLOGIES

Ocean current energy is at an early stage of development, with only a small number of prototypes and demonstration units having been tested to date. One such technology involves submerged turbines. Energy can be extracted from the ocean currents using submerged turbines that are similar in function to wind turbines, capturing energy through the processes of hydrodynamic, rather than aerodynamic, lift or drag. These turbines would have rotor blades, a generator for converting the rotational energy into electricity, and a means for transporting the electrical current to shore for incorporation into the electrical grid.

Turbines can have either horizontal or vertical axes of rotation (Figure 2). Mechanisms such as posts, cables, or anchors are required to keep the turbines stationary relative to the currents with which they interact. Prototype horizontal axis turbines, similar to wind turbines, have been built and tested. Vertical axis turbines are either drag or lift designs. The lift devices seem to offer more potential (e.g., the Darrieus-design turbine design with three or four thin blades of aerofoil cross-section has been tested in the Kurushima Straits off Japan) (WEC 2001).

Turbines may be anchored to the ocean floor in a variety of ways. They may be tethered with cables, with the relatively constant current interacting with the turbine used to maintain location and stability. Such a configuration would be analogous to underwater kite-flying where the kite would be a turbine designed to keep upright and the kite flyer would be the anchor. Additional components may include concentrators (or shrouds) around the blades to increase the flow and power output from the turbine. Various alternative designs have been proposed, including the use of a barge moored in the current stream with a large cable loop to which water-filled parachutes are fastened. The parachutes would be pushed by the current, and then closed on their way back, forming a loop similar to a large horizontal waterwheel.

In large areas with powerful currents, it would be possible to install water turbines in groups or clusters to create a "marine current facility," similar in design approach to wind turbine facilities. Turbine spacing would be determined based on wake interactions and maintenance

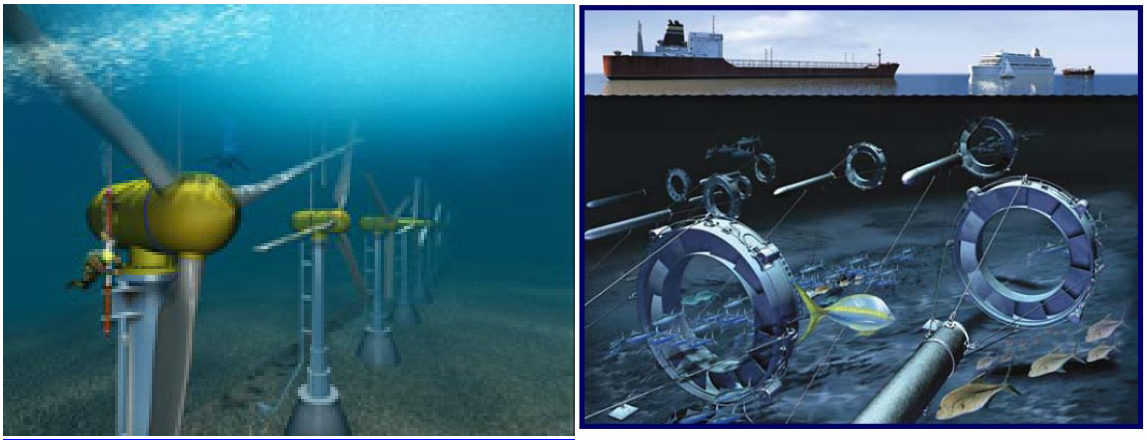

FIGURE 2 Visualization of Two Possible Turbine and Anchor Technologies (Sources: Hammerfest Strøm AS 2006; Gulfstream Energy Incorporated 2006)

needs. A 30-MW demonstration array of vertical turbines in a tidal fence is being investigated in the Philippines (WEC 2001).

For marine current energy to be utilized, a number of potential problems would need to be addressed, including avoidance of drag from cavitations (air bubble formation that creates turbulence and substantially decreases the efficiency of current-energy harvest), prevention of marine growth buildup, corrosion control, and overall system reliability. Because the logistics of maintenance are likely to be complex and the costs potentially high, system reliability is of particular importance.

No currently operating commercial turbines are connected to an electric-power transmission or distribution grid; however, a number of configurations are being tested on a small scale. For example, in 2000, three companies received small business innovation research (SBIR) awards from the U.S. Department of Energy to explore ocean-current power generators. An earlier study of ocean-current energy extraction from the Florida Straits Current, performed in the 1980s, used modeling to explore possible configurations and environmental effects (NTTC 2000).

ENVIRONMENTAL CONSIDERATIONS

Potential environmental impacts that would need to be considered with the development and utilization of ocean current energy on the OCS include impacts on marine ecology and conflicts with other potential uses of the same area of the ocean. Resource requirements associated with the construction and operation of these technologies would also need to be addressed. Regardless of the size and nature of the anticipated environmental impacts, project planning would need to consider the protection of species, particularly fish and marine mammals. The slow blade velocities should allow water and fish to flow freely and safely through the structure. Protective fences and sonar-activated brakes could prevent larger marine mammals from harm. In the siting of the turbines, consideration of impacts on shipping routes, and present as well as anticipated uses such as commercial and recreational fishing and recreational diving, would be required. Additional considerations include the need to introduce possible mitigating factors, such as the establishment of fishery exclusion zones.

Concerns have been raised about risks from slowing the current flow by extracting energy. Local effects, such as temperature and salinity changes in estuaries caused by changes in the mixing of salt and fresh waters, would need to be considered for their potential impact on estuary ecosystems (Charlier and Justus 1993).

ECONOMIC CONSIDERATIONS

Because no commercial turbines are currently in operation, it is difficult to assess the costs of current-generated energy and its competitiveness with other energy sources. Initial studies suggest that for economic exploitation, velocities of at least 2 m/s (4 knots) would be required (a 5-knot current has the kinetic energy equivalent of wind at more than 100 mph), although it is possible to generate energy from velocities as low as 1 m/s. Major costs of these systems would be the cables to transport the electricity to the onshore grid.

Although tidal-current energy extraction is not within the scope of this paper, there are many similarities and common problems. Tidal-energy extraction is being explored in many areas of the world. In 2003, the world's first commercial grid-connected tidal-current plant opened in Hammerfest, Norway, as a 300-kW plant generating 700 MW hours of power annually. Other locations pursuing tidal-generated power include San Francisco; Devon, England; and British Columbia.

SUMMARY

Ocean-current–generated energy technologies have many favorable characteristics, including the following:

- Water currents have a relatively high energy density.
- Some ocean currents are relatively constant in location and velocity, leading to a large capacity factor (fraction of time actively generating energy) for the turbines.
- Because they are installed beneath the water's surface, water turbines have minimal visual impact.
- The largest current energy resource on the U.S. OCS, the Florida Straits Current, is relatively close to heavily populated areas of Miami that have high power demands.

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