The State of Renewable Ocean Energy

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Executive Summary

The State of Renewable Ocean Energy in Maine 2010 is the fourth chapter in *The State of Maine's Environment 2010*, a report produced by the Environmental Policy Group in the Environmental Studies Program at Colby College in Waterville, Maine. This is the sixth State of Maine's Environment report published since 2004.

This report seeks to synthesize current published and original research on tidal turbines, wave generators and wind turbines and their application to development in Maine's oceans. Maine's renewable ocean energy potential has shown promise in initial research. Offshore wind has the greatest development potential, estimated at 149 gigawatts. Tidal projects are shown to have great potential when sited in compatible locations, such as Cobscook Bay which has an estimated 7.1 megawatts. Wave projects have limited potential in Maine until technology is improved.

Our spatial analysis highlights the importance of state and federal boundaries in the siting of potential test sites and the implications for the future of commercial research and development in Maine. Continued exploration of renewable ocean energy's environmental, economic, and social impacts, along with the existing state and federal permitting structure, and the investment environment must be completed before proposed projects move forward. Strategic investment in Maine's renewable ocean resource has the potential to dramatically transform the way the state generates its electricity in the coming decades.

Introduction

> *"The ocean energy industry in Maine shows great promise. Maine needs to continue its efforts to decrease our dependence on fossil fuels by harnessing our natural resources. This will create valuable jobs here at home, and preserve our environment and quality of life."*
>
> *Governor John Baldacci, 2010*

Maine's oceans have functioned for centuries as highways of maritime commerce and fishing grounds (Firestone et al. 2005). Today, Maine's ocean resources continue to play a vital, albeit evolving, role in the state's economy as a dominant commercial fishing industry is being replaced by tourism and recreation. Moreover, homes once owned by fishing families are now purchased by vacationing, second-home buyers. Maine's coastal communities, spread across more than 5,000 miles of shoreline, accounted for 70% of the state's gross domestic product and provided jobs for 55% of the state's population in 2007 (Abbett and Englert 2009).

Approximately 60 percent of Maine's (and New England's) electricity generation capacity is derived from non-indigenous sources including natural gas, oil, and coal. When home heating and transportation are added to the calculation of Maine's dependence on non-indigenous sources, the number rises to 90 percent (OETF 2009). When crude oil prices soared to $147 a barrel in 2008, the shock to Maine's economy was substantial given the extent to which Maine residents use their vehicles, and home-heating's rising share of homeowner's budgets: from approximately 5% in 1998 to 20% in 2008 (Erario and Groghan 2009). Although these price shocks have stabilized, they highlight the magnitude of Maine's dependence on non-indigenous sources for electricity generation.

In an attempt to secure greater state energy independence, Governor John Baldacci formed the Ocean Energy Task Force by Executive Order in 2008. As the state more seriously considers its oceans for their electricity generation potential, specifically from wave, tidal and offshore wind energy, renewable ocean energy development for indigenous electricity generation has become a priority for the state of Maine (OETF 2009).

Development of Maine's vast ocean energy resources is a central feature of the Maine Ocean Energy Task Force's proposal for an energy-focused economy. The task force's report, published in 2009, recommended an ambitious goal to develop 3 gigawatts of wind generation capacity annually by 2020 while continuing to develop tidal turbines and wave generators to produce additional capacity. Such generation capability would make Maine the largest renewable ocean energy producer in New England (OETF 2009).

Despite optimism from developers, residents, and the Ocean Energy Task Force over offshore tidal turbines, wave generators, and wind turbines, Maine still have substantial obstacles to overcome. The environmental, economic, and social impacts, along with the existing state and federal permitting structure and the investment environment, must be further evaluated to best understand how the development and installation of ocean electricity generation technologies will affect the state of Maine's oceans and the state's energy generation strategy for the foreseeable future.

In this report we synthesize current published and original research on tidal turbines, wave generators, and wind turbines and their application to development in Maine's oceans. Our spatial analysis highlights the importance of state and federal boundaries in the siting of potential test sites and the implications for future of commercial research and development in Maine. We introduce laws and regulations applicable to renewable ocean energy siting and development, and discuss relevant stakeholders. We then introduce examples of renewable ocean energy technologies and weigh their relative benefits and concerns for the state of Maine. We offer conclusions and recommendations for Maine's best prospects for sustainable energy economy supported by indigenous, renewable energy technologies sited in Maine's oceans.

Methods

We gathered our data through a literature review using Academic Search Premier, Web of Science, Google Scholar, and additional resources available in the Colby College Library. Our primary sources of data were government reports and documents, with journal articles, books, and agency websites providing supplemental material. We used documents published by public and private stakeholders including the Maine State Planning Office (SPO), the Energy Information Agency (EIA), National Renewable Energy Laboratory (NREL), and Electric Power Research Institute (EPRI). We visited Stonington, Maine to meet with Ted Ames of the Penobscot East Resource Center and to tour the Stonington fishery in Penobscot Bay aboard his lobster boat, the Mary Elizabeth. This trip helped us to understand existing economic uses of Maine's ocean resources. We also attended the National Ocean Policy Symposium at Bowdoin College, where we heard from former Congressmen Tom Allen and many other opinion leaders about the future of Maine's offshore renewable energy resources and the impact of the Obama Administration's Interagency Ocean Task Force on Maine's plans for coastal and marine spatial planning.

We used Geographic Information System (GIS) to visually represent and analyze spatial data obtained from the Maine Office of GIS, including state boundaries and bathymetry, the measurement of the varying depths of the ocean. We used ArcGIS software (ESRI 2009) to visually represent the location of testing sites for tidal, wave, and wind technologies.

Laws and Regulations

There are 11 federal and 7 state laws and regulations that are most relevant to the siting of offshore energy development projects in Maine. This section is divided into three sub-sections: International Agreements, Federal Laws, and State Laws. Table 4.1 and Table 4.2 summarize the key points of these laws and agreements. These laws directly affect the stakeholders discussed in the next section.

Table 4.1 State laws and regulations for offshore renewable energy

Law	**Year**	**Description**	**Location**
Mandatory Shoreline Zoning Act	1971	Requires all municipalities to create zoning ordinances for areas within 250 feet of the high water line of any body of water, river, wetland, and coastline. The state holds the right to develop a zoning plan for municipalities not in compliance.	MRS Title 38 Chapter 3 § 439-449
Maine Wind Energy Act	2003	Established policy that finds wind energy to be in the best interest of the state thereby making it a priority for state agencies to encourage wind development.	MRS Title 35-A, Chapter 34 § 3404(2)(B)
Public Trust Doctrine		The State of Maine holds state-owned submerged lands (lands below mean low-tide line out to 3-mile limit) in trust for the benefit of the people of Maine (Abbett and Englert 2009). In accordance with this common law, the State manages these lands and the natural resources in the public interest.	(Sax 1970)

Table 4.2 Federal laws and regulations for offshore energy

Law	**Year**	**Description**	**Location**
Rivers and Harbors Act	1899	Require permission to construct any causeway in or over any navigable water or to cause any diversion or obstruction to the navigable capacity of any water in the United States.	USC Title 33 § 401-403
Migratory Bird Treaty Act (MBTA)	1918	Makes it unlawful to pursue, hunt, take, capture, kill, offer for sale, to purchase, or to offer for shipment any bird, egg, or nest protected under several migratory bird treaties.	USC Title 16 § 703 et seq.
Submerged Lands Act	1953	Requires a Granted states title to the natural resources (oil, gas, and all other minerals) located within three miles of their coastline.	USC Title 43 § 1301-1315
National Environmental Policy Act (NEPA)	1970	Establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment.	USC Title 42 § 4321 et seq.
Coastal Zone Management Act	1972	Provided states with federal assistance for those who develop and maintain a comprehensive management plan for their coastal jurisdiction or a Coastal Zone Management Plan as reviewed by the National Oceanic and Atmospheric Administration.	USC Title 16 § 1451-1456
Noise Control Act	1972	National policy to promote an environment for all Americans free from noise that jeopardizes their health and welfare.	UCS Title 42 § 4901-4918
Marine Mammal Protection Act (MMPA)	1972	Makes it unlawful to harass, hunt, capture kill, or collect marine mammals in U.S. waters. Also has a provision for Incidental Take Authorization (ITA) which applies to certain activities including energy development projects.	USC Title 16 § 1361-1407
Pollution Prevention Act (PPA)	1990	Establishes standards for reducing the amount of pollution generated through cost-effective changes in production, operation, and raw materials use.	USC Title 42 § 13101 et seq.

Energy Policy Act	2005	Sets forth an energy research and development program covering: (1) energy efficiency; (2) renewable energy; (3) oil and gas; (4) coal; (5) Indian energy; (6) nuclear matters and security; (7) vehicles and motor fuels, including ethanol; (8) hydrogen; (9) electricity; (10) energy tax incentives; (11) hydropower and geothermal energy; and (12) climate change technology.	USC Title 42 § 8251 et seq.
American Clean Energy Leadership Act	2009	Promotes clean energy technology development, enhanced energy efficiency, improved energy security, and energy innovation and workforce development, and for other purposes.	S. 1462
Executive Order 13547: Stewardship of the Ocean, Our Coasts, and the Great Lakes	2009	Adopts many of the recommendations of the Interagency Ocean Policy Task Force. Strengthens ocean governance and emphasizes the importance of a flexible, interagency approach for coastal and marine development and planning	Executive Order 13547

Stakeholders

A diverse group of stakeholders has vested interests in Maine's pursuit of offshore alternative energy development and its possible economic, environmental, and social impacts. Key stakeholders include national and state government agencies, regional governmental committees, and NGOs as well as energy developers, researchers, and Maine citizens.

Federal Government Agencies

National Oceanic and Atmospheric Administration

The National Oceanic and Atmospheric Administration (NOAA) is a scientific agency that conducts research on the state of the oceans and atmosphere in order to effectively manage coastal and ocean resources. There are several offices within the agency that deal with the research, development, and management of offshore energy in marine ecosystems. NOAA also deals with the permitting process of offshore energy siting by assisting in the review process for the National Environmental Policy Act, Endangered Species Act, and Coastal Zone Management Act.

Environmental Protection Agency

The Environmental Protection Agency (EPA) is in charge of safeguarding human health and the environment though the enforcement of federal laws and regulations.   Legislation important to the permitting process such as the Water Quality Act, Clean Water Act, Endangered Species Act, and the National Environmental Policy Act all fall under the jurisdiction of the EPA. This agency is also responsible for reviewing projects' Environmental Impact Statements, which are necessary for offshore energy development proposals (EPA 2010).

United States Fish and Wildlife Services

The US Fish and Wildlife Service (FWS) is charged with identifying, protecting, and restoring threatened and endangered species (FWS 2010). This agency is responsible for assessing the impact of offshore energy development on threatened and endangered species. This analysis is an important aspect of the Environmental Impact Statement which is considered for development proposals.

United States Geological Survey

The US Geological Survey (USGS) is a scientific government agency that provides scientific data about natural resource conditions, issues, and problems (USGS 2010). This agency also provides data, such as topography, of the ocean floor landscape, which is important for siting processes especially for tidal development, which requires certain sediments for construction.

Army Corps of Engineers

The US Army Corps of Engineers (USACE) is a federal agency dealing with public engineering, design, and construction management largely within the waterway systems. This agency is responsible for all structures and work on, under, or over navigable US waters. Therefore all wind, tidal, and wave energy projects are subject to permitting requirements of the Army Corps as part of Section 404 of the Clean Water Act and section 10 of the Rivers and Harbors Act (USACE 2010).

Department of Energy

The Department of Energy (DOE) aims to promote national, economic, and energy security through scientific and technological innovation. The DOE is especially focused in improving the technologies for renewable energies including those offshore in order to reach their goals. The Department of the Office of Energy Efficiency and Renewable Energy (EERE) works to promote clean energy technologies to strengthen the national economy, reduce impacts on the environment, and increase national energy independence (DEP 2010).

Federal Energy Regulatory Commission

The Federal Energy Regulatory Commission (FERC) regulates the transmission of electricity in the United States. FERC is also responsible for licensing permits for hydrokinetic projects within state boundaries. Due to the increase in permit requests for hydrokinetic energy development, FERC has established a streamline permitting process for testing demonstration projects off the coast of Maine (FERC 2010).

Bureau of Ocean Energy Management, Regulation and Enforcement

The Bureau of Ocean Energy Management, Regulation, and Enforcement (BOEMRE), previously Mineral Management Service (MMS), is responsible for leasing permits for energy development on the outer continental shelf, which is relevant for deep offshore wind and wave technologies (BOEMRE 2010).

Regional Government Agencies

Gulf of Maine Council on the Marine Environment

The Gulf of Maine Council on the Marine Environment is a partnership between the US and Canada that promotes ocean ecosystem quality as well as sustainable resource use (Council 2010). This network of New England states and Canadian provinces works to further the research and management of the Gulf of Maine. A current project called the Gulf of Maine Mapping Initiate (GOMMI) will provide data for seafloor mapping and biological data, which will be important for offshore energy development. This organization also fosters information sharing, coastal/marine education, and grant funding for sustainable industries.

State Government Agencies

State Planning Office

The Maine State Planning Office (SPO) works to sustainably develop Maine’s economy through effective planning, management, and policy development. This office advises the Governor on strategies to balance the growth of the state’s economy with resource conservation. A major program within this office is the Maine Coastal Program, which works to ensure the proper management of coastal areas. Major objectives of this program include fostering clean coastal industries, promoting more effective municipal planning, and reducing coastal pollution (SPO 2010). The State Planning Office also runs an Energy Program that facilitates discussion and collaboration for energy developers and state/federal agencies.

Public Utilities Commission

The Maine Public Utilities Commission (MPUC) regulates the rates and services of electric, natural gas, telecommunications and water utilities within the state. These stakeholders work with energy developers to connect generated power to the grid. Developers would need to work with this agency to facilitate new transmission cables to connect offshore devices to the main land as well as to the nearest grid.

Department of Marine Resources

The Department of Marine Resources (DMR) oversees the conservation and development of marine resources. The DMR conducts scientific research and work to promote local development of fishing and coastal communities through the enforcement of relative laws and regulations. This department monitors oceanic weather conditions, including data for the Gulf of Maine Ocean Observing System (GoMOOS), which provides hourly data on the conditions of winds, waves, tides, and ocean currents. These data are extremely useful in measuring the potential for offshore energy (DMR 2010).

Department of Environmental Protection

The Maine Department of Environmental Protection (DEP) works to protect and restore the state’s natural resources primarily through the reduction and control of pollution. The DEP also regulates the permitting process for all hydropower technologies including wave and tidal projects under the Maine Waterway Development and Conservation Act (MWDCA) (DEP 2010). This act requires extensive social and Environmental Impact Statements for the proposed sites, which are discussed in greater detail in the discussion section of this report.

Department of Conservation

The Maine Department of Conservation (MDOC) manages and protects state and public lands. The MDOC is working with the State Planning Office in the selection and management of “Ocean Energy Testing Areas” for potential offshore wind. They are also involved in the permitting process for offshore wind technologies (MDOC 2010).

Local Agencies

Coastal Municipalities

Coastal municipalities are affected by local energy development on various levels. Communities serve to benefit economically and socially from growth in renewable power but may witness negative environmental and social externatlities from this development as well. This will be further elaborated on in the discussion section of this report.

Energy Developers

Offshore wind, tidal, and wave developers and entrepreneurs are the leading advocates for new energy technology development in these fields. The main obstacle for these stakeholders is the complicated and restrictive permitting process regulated by state and national agencies. These businesses also face funding challenges to conduct research feasibility studies for their technologies. While many developers have sought development rights for potential for off-shore energy, at this point in time only a limited number of companies have acquired the required permits and funding to develop on the coast of Maine. Ocean Renewable Energy Company (ORPC) is the major tidal developer in Maine. Currently there are no developers focused on wave technology in Maine. The DeepCwind consortium in concert with the University of Maine is spearheading offshore wind development in Maine.

Energy Researchers

New energy technologies require extensive research and analysis in order to become viable for development and implementation. Academic and scientific data analysis are required to assess the efficiency, longevity, and implications of new offshore energy technologies. As a result, many major academic institutions, including the University of Maine and Maine Maritime Academy, have become heavily involved in the development and research for wind, tidal, and wave technologies.

Fishing Industries

Local fishing communities are also affected by the development of offshore energy, as these projects pose potential threats for competing ocean resource use. The installation of new technologies may interfere with fishermen’s historical claims to ocean fishing territories, and may also disrupt fish migrations. These changes may also compromise local peoples’ livelihoods which are heavily dependent on the fishing industry.

State of Topic

Tidal Energy

Tidal power is a form of hydropower that harnesses the power of a tide’s ebb and flow. While tidal power technologies date back to the early 19th century, only recently has the technology advanced to a stage that is both economically feasible and environmentally benign. Whereas past tidal technologies dammed tidal passages, which adversely affected ecological systems, new technologies, called tidal in-stream energy conversion (TISEC) are considered more non-polluting, safe, and projected to be cost effective with other renewable energies in the near future (Ferland 2008). While traditional damming techniques are employed around the world, TISEC technologies are only being utilized in a few international locations and have yet to be implemented for commercial use in the United States. However, this does not mean that new tidal technologies are not feasible on a large scale. Studies have already shown that TISEC plants have the potential for massive energy production with relatively few drawbacks (Claffey 2010). A major obstacle at this point for tidal development is the high cost of initial construction because the technology is still relatively new to the United States. These costs are projected to decreased, however, and eventually place tidal energy at a cost competitive rate compared to other alternative fuel sources.

TISEC technologies will be the focus of the analysis of this report as they are the most effective system being researched and tested in the United States and Maine. Tidal in-stream energy conversion devices are large turbines, similar to those utilized by wind technologies, which are submerged underwater to capture the kinetic energy of the tides as they move back and forth. These systems are commonly referred to as hydrokinetic technologies and can employ either horizontal axis turbines or vertical axis turbines. They function best at sites where coastal currents run between 3.6-4.9 knots, water depth measures between 20 and 30 meters, and the tidal range exceeds more than 5 meters. As depicted in figure 4.1 tidal power potential increases with a higher tidal range. Given these requirements, tidal power is very limited in its operation as only approximately 40 sites globally reflect these conditions (DEP 2010).

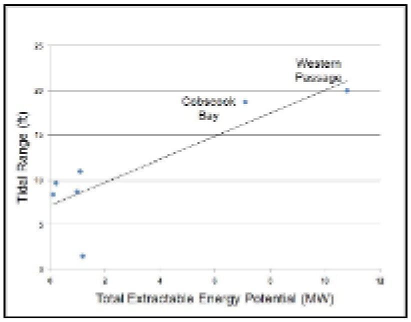

Figure 4.1 Energy potential versus tidal range from potential tidal development sites

Benefits of Tidal Energy

Tidal energy has certain advantages compared to other renewable energy sources. Since moving water has a high energy density, 800 times that of air, tidal technology can generate significantly more power than wind turbines at relatively low water speeds (ORPC 2008). Globally, it is estimated that tidal power potential exceeds 800 TWh/yr of power (Hagerman and Bedard 2006). Additionally, though past devices were known to negatively impact marine fisheries and wildlife, current technology poses relatively few environmental concerns. Tidal systems also pose no visual or aesthetic impairments since the structures are submerged completely underwater.

Drawbacks of Tidal Energy

While tidal energy has great potential, it is limited to areas with high tidal ranges and flows, which only exist in a handful of sites around the world. Additionally, the current technology only allows for an approximate 15% extraction rate, meaning that only a small percentage of the potential power can be utilized for commercial use. While it does not cost much to manage and operate tidal devices, initial construction costs are very high, which makes for a lengthy payback period. Consequently, the cost of electricity per kilowatt-hour is currently estimated at 18-23 c/kWh, which is not competitive with other energy sources, renewable or non-renewable. In fact, tidal power is estimated to be more than three times more expensive than natural gas or coal (Jacobson 2010). Another drawback of tidal power is that it is still in the early stages of development so that its political and public infrastructure has yet to be developed for efficient permitting processes, funding requests, or citizen support. While these drawbacks pose concerns as to whether tidal power will be a viable energy source for Maine or the US, it is important to note that all new energy technologies face these initial setbacks.

Case Study: Cobscook Bay

Despite its drawbacks, the benefits of tidal power indicate that this energy has huge potential for specific sites that exhibit key tidal and ocean characteristics. Within the US only a few states show tidal power potential including Alaska, Washington, California, Massachusetts, and Maine. Additionally, within these states there are relatively few sites compatible for TISEC technology; Maine is unique in that it features some of the highest tidal ranges in the world. Specifically, in the Bay of Fundy, on the Maine/Canada border near Eastport, tidal rages average approximately 20 feet. Comparatively, Maine exhibits the most potential for tidal energy production in New England especially over its regional neighbor, Massachusetts, as depicted by Figure 4.2. According to a 2006 study by the Electric Power Research Institute (EPRI) Maine has a combined total potential generating capacity of 100-150 megawatts (Sorenson 2010). Sites in Passamaquoddy and Cobscook Bays present the highest energy potential for the state, which has led to the development of various test sites to study the efficiency and compatibility of tidal technologies in these ecosystems (Baldacci 2009).

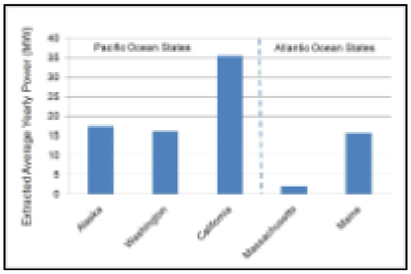

Figure 4.2 Extracted average yearly tidal energy (EPRI 2006)

Cobscook Bay has recently drawn substantial attention from tidal developers due to its high-energy potential as confirmed by the 2006 study conducted by EPRI. This research identified ten sites off the coast of Maine that depicted high potential for energy extraction, and highlighted the area surrounding the Bay of Fundy as a site of tremendous tidal potential. One developer, Ocean Renewable Power Company (ORPC), has been working to construct and test prototypes of the new tidal models since 2008. As of October 2010, ORPC secured funding from various government and private sources, including a $10 million grant awarded by the federal Department of Energy, to begin construction of turbines in Cobscook Bay, which will be connected to the Bangor Hydro-Electric grid. This will be the first major in-steam tidal energy conversion project in the United States (Du Houx 2010). This company has patented their tidal in-steam technology as the TidGen™ Power System and is in the early stages of their first phase that will last thirteen months and establish the foundation for the first TidGen™ unit. After this stage, ORPC will expand its development to include four additional units that will connect to a main underwater power consolidation box which will transport energy to a grid connection onshore. This five-unit power system is projected to be the first tidal in-stream energy technology connected to the grid for commercial use (Du Houx 2010). Eventually ORPC hopes to generate enough electricity to power all of Downeast Maine (ORPC 2010).

As of November 2010, many new permits have been requested to develop tidal technologies in Maine, especially within the Downeast region, largely due to the increasing amount of public and private support of renewable offshore energy. However, in order to move forward with these requests, each development must undergo extensive environmental impact assessments and coordinate with the local community and municipalities to ensure a collaborative and sustainable process. ORPC's work in Cobscook Bay has served as an ideal model for tidal projects as the company has worked closely with environmental organizations, government agencies, and the local community of Cobsook to ensure a successful development (Johnson 2010).

Wave Energy

Wave energy converters (WECs) harness energy directly from surface waves or from pressure fluctuations below the ocean surface (DOE 2010). Currently, the industry remains in the research and development stage, but over 70 WEC companies are competing to emerge as the technological leader (DOE 2008). Yet, there is a diversity in design as there are four common strategies to extract electricity through wave power. These include the use of an *attenuator*, *oscillating water column*, *point-absorber*, or an *overtopping* device (NNMREC 2010).

The reason for competition within the industry is the potential value of wave energy. On the same magnitude as current global electricity consumption, the estimated power of the resource is approximately two terawatts. Of these two terawatts, a conservative extraction rate ranges between 10-25%, which would be a major contribution to the global energy portfolio (Cruz 2008). However, the wave energy resource is not distributed evenly. Factors including prevailing wind patterns and fetch (the distance wind travels over water) determine the optimal siting locations for wave energy parks. One of these locations is the Pacific Northwest US.

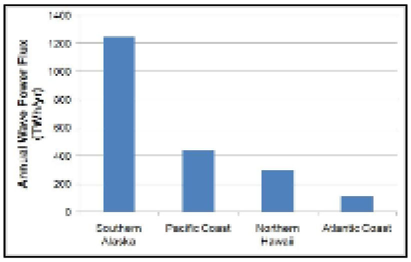

Figure 4.3 Wave power in the United States by region (EPRI 2005)

The Pacific Northwest, specifically the coast of Oregon and Washington, along with Alaska and Hawaii, possesses the best wave climate in the United States (EPRI 2004). As a result, the most exciting research and development occurs at these locations. Funded by the US Department of Energy (DOE), the Northwest National Marine Renewable Energy Center (NNMREC) is a partnership between the University of Washington (UW) and Oregon State University (OSU). OSU focuses on wave energy while UW focuses on tidal energy research. The Hawaii National Marine Renewable Energy Center (HINMREC) is another institution funded by the DOE that works with universities in order to facilitate the development and commercialization of wave energy technology.

The pursuit of a successful WEC system is not limited to the US. Companies abroad have yet to firmly establish this industry. For example, the Scotland-based Pelamis Wave Power system launched the first commercially viable wave park in Aguçadoura, Portugal in 2008. However, the devices failed later that year (Wang 2010).

Funding deficiencies also threaten the industry. In early 2010, Pacific Gas and Electric Company (PG&E) filed an application for a 5 megawatt pilot project that would simultaneously test three to four different WECs in the waters off Humboldt County in Northern California three miles from shore. The utility's project would have boosted WEC companies in search of capital and technological development, but PG&E decided to suspend the project in October due to the unproven nature of the technologies and high costs (Wang 2010).

Benefits of Wave Energy Conversion

Although the wave energy industry remains in the research and development stage, wave power maintains several advantages when compared to other renewable energy resources. A 2005 Electric Power Research Institute report cites three critical factors for the generation of electricity from ocean waves: power density, intermittency, and predictability (Bedard 2005). When compared to solar, wind, and tidal, wave energy ranks the highest in energy density. This means that in the same amount of space, waves are the most productive resource. Another benefit of choosing this technology is the quality of forecasting. Wave behavior can be accurately predicted days in advance despite being highly variable hour-by-hour. Alternatively, wind patterns can only be effectively forecasted hours in advance (Bedard 2005).

Wave energy maintains another distinct advantage due to its minimal environmental impact. In the fall of 2010, New Jersey based Ocean Power Technologies became the first US WEC company to successfully connect to the electricity grid with the installation of a 40 KWh point-absorber buoy. Deployed in Kaneohe Bay, Hawaii, the buoy also set a benchmark standard for its environmental impact statement in a NEPA mandated review when the device received a Finding of No Significant Impact (FONSI) rating (OPT 2010). However, according to Paul Jacobson, ocean energy leader of EPRI, environmental impact is dependent upon the wave energy system, the siting location, and the scale of the project (Jacobson 2010). As a result, an environmental impact statement is always necessary for a new project.

Additionally, WECs have a minimal visual impact. Both Ocean Power Technologies and Pelamis Wave Power advertise this quality of their systems. Ocean Power Technologies cites visual impact as “one of the reasons that many communities have opposed plans to develop offshore power projects” and explains that only a small portion of its PowerBuoy is visible up close and the device is usually not visible from shore (OPT 2010). Pelamis Wave Power notes that its devices are ballasted to be 50% submerged so only approximately two meters is visible above the water (PWP 2010). As expressed above, a decreased visual impact of WECs decreases the likelihood of community opposition.

Drawbacks of Wave Energy Conversion

There are also drawbacks for the implementation of wave energy technology, mainly related to high costs. Not only are WEC devices expensive, but there is also a lack of existing infrastructure for underwater ocean electricity cables. Additionally, operational costs contribute to the investment needed for a project. PG&E estimated $50 million for power transmission infrastructure as well as monitoring for its Humboldt County project. Operation and maintenance expenditures reached $5 million annually. This estimate excludes the cost of WEC devices (Wang 2010).

Cost of electricity is also a stumbling block for development. The estimate for cost of electricity per kilowatt-hour ranges between 34 and 39 cents (Jacobson 2010). This cost is high even compared to tidal energy at 18-24 cents and offshore wind at 6.5 c/kWh (Musial and Butterfield 2004).

Lastly, WECs are still in the research and development stage so technology remains unproven on the commercial scale. Technical challenges include the pursuit of a higher energy extraction rate as well as a more durable wave energy device.

Case Study: Old Orchard Beach

The East Coast of the United States, including Maine, has a poor wave energy climate compared to the Pacific Coast (EPRI 2004). There have not been any WEC installations in Maine to date. However, the EPRI conducted a wave power feasibility study to evaluate the economics of wave power in six US locations. The study includes a site at Old Orchard Beach in Cumberland, Maine.

Table 4.3 Wave power flux at six US locations (EPRI 2005)

State	**County**	**Harbor**	**Grid Interconnection**	**Average Annual Power Flux (kW/meter of wave crest length)**
California	San Francisco	San Francisco	Ocean Beach Water Treatment Plant	20.0
Oregon	Douglas	Coos Bay	Gardiner Substation	21.2
Hawaii	Oahu	Honolulu	Makai Pier, Waimanalo Beach	15.2
Massachusetts	Boston	Boston	Wellfleet Distribution Line	13.8
Maine	Cumberland	Portland	Old Orchard Beach Substation	4.9

Based on Pelamis Wave Power’s device, the EPRI used National Data Buoy Center information to model the cost-effectiveness of potential WEC development sites in Maine, Massachusetts, California, Oregon, Washington, and Hawaii. The results showed that the Maine and Massachusetts sites demonstrated a wave energy power flux (kW/m wave crest height) of 4.9 and 13.8 respectively. The mean wave power flux for the four western states is over 20 kW/m, which illustrates a wave power comparative advantage for the Pacific Ocean (Bedard 2005).

The EPRI study did not eliminate the possibility of WEC development in Maine, but it did recommend that the state wait until further development of the industry before seriously considering the option. Maine’s Ocean Energy Task Force adopted this recommendation in its December 2009 final report to Governor Baldacci.

Wind Energy

> *"Wind power isn't the silver bullet that will solve all our energy challenges---there isn't one. But* it is *a key part of a comprehensive strategy to move us from an economy that runs on fossil fuels to one that relies on more homegrown fuels and clean energy"*
>
> *President Barack Obama, April 2010*

Together onshore and offshore wind power is the fastest growing source of energy in the world (Firestone et al. 2005). Worldwide, wind power contributes positively to nations' diversified, renewable energy portfolios. Wind is an inexhaustible resource and when captured by turbines sited on or offshore, it mitigates greenhouse gas emissions and climate change, increases a nation's domestic energy security, and stimulates national and international economies through opportunities for investment, research and development, and job creation.

The United States leads the world in installed, land-based wind energy, but has no installed offshore wind energy generation capacity to date. Offshore winds blow harder and more uniformly than on land (Musial and Ram 2010); the development of the United States' offshore resource on the East and West Coast and in the Great Lakes would provide the potential for increased generation capacity that is smoother and steadier than the resource captured by the existing stock of onshore wind turbines (Schwartz et al. 2010).

Although European nations have installed the majority of the world's offshore wind generation capacity to date, the National Renewable Energy Laboratory ("NREL") estimates that the US's absence is not a reflection of an anemic resource. The estimated gross offshore wind generation capacity for the US is four times greater than the nation's current electric capacity (Schwartz et al. 2010). Twenty offshore projects representing more than 2,000 megawatts (MW) of capacity are in the planning and permitting process; although the United States will not overtake Europe's offshore electricity generation capacity in the near future, it can learn a lot from Europe's example (Musial and Ram 2010).

The strength of the wind resource increases as the distance from the shoreline increases; however, the majority of Europe's offshore wind farms, beginning with development in Denmark in 1991, were sited in shallow water (Musial and Ram 2010). Defined as depths less than 30 meters, shallow water, bottom-anchored wind turbines, generally sited close to shore, were developed based on decades of research and development for land-based turbines. Turbines suitable for siting in transitional and deep depths, generally farther away from the shoreline, do not benefit from such a long development history and are purely theoretical today. Depths between 30 and 60 meters are defined as transitional water and depths greater than 60 meters are defined as deep water (Schwartz et al. 2010). Due to its bathymetry, the measurement of the varying depths of the ocean, much of the East Coast's transitional and deep-water zones are located in federal waters beyond the three nautical-miles controlled by state governments requiring the involvement of state and federal government in all stages of proposed development.

Benefits of Deep Offshore Wind

In addition to capturing a greater wind resource, at a sufficient distance from land, deep water offshore turbines mitigate visual intrusion and noise concerns raised by onshore turbine opponents (Musial and Butterfield 2004). While the technology suitable for citing in transitional and deep water zones is currently in the early stage of testing or theoretical, respectively, unlike proven onshore wind turbine technologies, deep offshore wind technology has the potential to profoundly impact how electricity is generated in the state of Maine as is discussed further in the subsequent discussion section.

Drawbacks of Deep Offshore Wind

Since turbines sited further offshore can be larger and better equipped to capture the resource, they can potentially capture the strongest wind currents. However, more severe weather conditions and deep water anchoring and transmission cabling needs challenge current turbine design and development (Musial and Butterfield 2004). Today, no deep offshore wind turbine projects are installed and all resource capacity assessments are modeled on assumptions that could prove to be unrealistic. The uncertainty inherent in this nascent stage of research, development, and testing is reflected, for example, by the lack of consensus on the best strategy to anchor deepwater wind turbines: numerous truss tower and anchoring technologies have been developed at the National Renewable Energy Laboratory and by private enterprises alongside floating turbine solutions, but remain untested in the United States (Dagher 2010).

Case Study: Monhegan Island

Since 2006, developers have permitted, financed, and constructed five land-based wind farms in the state of Maine. Five additional projects are either under construction or in an advanced stage of the proposal process. Although these projects have helped to stimulate Maine's economy and mitigate its greenhouse gas emissions, like all land-based turbines, their size is constrained by the capacity limitations of available transportation and installation equipment (Firestone et al. 2005). Regulations relating to visual and acoustic impacts also limit onshore and near-shore, typically shallow water based, wind projects. These limits don't necessarily apply to offshore turbines depending on how far they are sited from the shoreline.

To begin the required testing and development to capture its offshore wind resource, Maine Public Law, Chapter 270 (L.D. 1465), passed in 2009, authorized the construction of the state's first offshore wind energy test site near Monhegan Island. Deemed the most suitable site within the state's ocean boundary, the construction of the floating, 100 foot-to-hub, 1/3-scale model began this year and will continue through 2012. The design and testing of the turbine will be facilitated by the DeepCwind consortium as the first phase of its Maine Offshore Wind Plan (Dagher 2009). Supported by approximately $12 million from the United States Department of Energy and an additional $11 million bond approved by Maine voters in June 2010, the DeepCwind Consortium is a collaborative effort led by the University of Maine that includes additional universities, nonprofits, utilities and developers whose collective goal is to establish Maine as the nation's leader in offshore wind technologies (Musial and Ram 2010 and Dagher 2010).

The results of the Monhegan Island test and the further development of deep offshore technologies at the University of Maine's Advanced Structure and Composites Center will determine whether the DeepCwind Consortium will carry out the second phase of its development strategy, the construction and testing of a 3 to 5 megawatt (MW) full-size, 300 foot-to-hub, floating turbine prototype planned for 2011 to 2015 (Dagher 2009).

Discussion

Tidal Power

Benefits to Maine

Maine's tidal power potential exceeds that of any other New England state due to the state's extensive coastline and extremely high tidal range (EPRI 2006). However, even within Maine there are only a handful of sites that can be successfully developed for tidal power generation. An ideal location must have a high tidal range, fast moving water, and bathymetry and seabed properties compatible with the technology, minimal environmental and social conflicts, and accessible connection to the grid. A feasibility study conducted by the Electric Power Research Institute in 2006 highlights nine sites for possible tidal development in Maine. As depicted in table 4.4 and figure 4.4, sites are ranked according to their total extractable energy potential revealing the Eastport region as the leader in tidal power potential for the State.

Table 4.4 Sites of possible tidal development in Maine (EPRI 2006)

Site Name	**Region**	**Tidal Range (ft)**	**Total Annual In-Stream Energy Base (MWh)**	**Total Extractable Energy Potential (MW)**	**Rank[1]**
Western Passage	Eastport	20.0	314,000	10.8	1
Outer Cobscook Bay	Eastport	18.7	23,8000	7.1	2
Lubec Narrows	Eastport	1.5	36,000	1.2	3
Penobscot River	Bucksport	11.0	3,650	1.1	4
Piscataque River	Kittery	8.7	3,360	1.0	5
BagaduceaNarrows	Castine	9.7	780	0.23	6
Kennebec River Entrance	Bath	8.4	440	0.13	7

Figure 4.4 Sites of tidal potential in Maine with relative energy potential in megawatts (EPRI 2006)

Within the Eastport region, two sites including Western Passage and Cobscook Bay show tidal power potential significantly higher than other sites in Maine. As of October 2010, a Portland-based tidal energy developer, Ocean Renewable Power Company, has secured funding to begin construction of turbines in Cobscook Bay with plans to connect a five unit system to the grid within a few years (ORPC 2010).

The groundbreaking development in Cobscook Bay situated in the Bay of Fundy has the potential to benefit Maine at various levels through the effective collaboration of multiple stakeholders. Since this is the first installation of its kind, Maine has the advantage of being a world leader in new tidal technologies and serves as an example of how to best implement and maintain these devices. By investing in this renewable technology, Maine is supporting green energy, businesses, and jobs, which in turn support a healthy and growing economy and social well-being. Not only does this technology provide clean, renewable energy, it also directly aids local communities where the development takes place.

The Cobscook Bay site is projected to produce approximately 7.1 MW given the 15% extraction rate, which measures out to be 1.639 kW/sq.m. It is forecasted that by 2016 the Cobscook site will be approved for commercial use and potentially power an area proportional to all of Downeast Maine (Marquis 2010).

Tidal power will also benefit local communities. Washington County, where Cobscook Bay is located, has the highest unemployment rate in the state of Maine as well as the lowest per capital income average. This business endeavor has already led to the proposed development of the Maine Marine Energy Center, which would serve as a manufacturing center for ocean energy system components and create approximately 80 jobs for local residents. Eventually, business leaders hope that this center will service off-shore wind components as well (Farwell 2010). With one of the highest unemployment rates in the state, tidal energy development could help bolster this region's economic and social standings.

Tidal energy development will also encourage scholarly and scientific research, which will provide vast opportunities for Maine's colleges and universities. The University of Maine is currently conducting research on the economic, social, and environmental impacts tidal technologies will have on local Maine communities. This institution is also a partner in the development process, as several top researchers are supervising the project in Cobscook Bay especially with concern to environmental impact assessments (UMaine 2010).

The Maine Maritime Academy is also heavily involved in the development and research of tidal energy due to the recently constructed Tidal Energy Demonstration and Evaluation Center (TEDEC). This research center is the second station of its kind and the first in the United States. Not only does this center provide a stage for important research, but it also trains and prepares students and researchers for jobs in the upcoming tidal industry.

Concerns in Maine

Despite the various benefits from tidal power production, tidal power energy production in Maine faces the same global tidal problems outlined above in relation to economic and technological obstacles. High initial construction costs and yearly operation and maintenance costs are estimated to be $20-25 million dollars in the case of the Cobscook Bay site (Previsic et al. 2006). This initial investment requires multiple funding sources and grants, which are slowly becoming more available for tidal technologies. While the cost of electricity per kilowatt-hour is currently in the range of 18-23 c/kWh, this is expected to decrease as more investment in tidal technologies takes place (Jacobson 2010).

Certain concerns have also arisen as to the compatibility of this technology with current marine ecosystems and resource use. Cobscook Bay is an active fishing area, both recreationally and commercially, for lobster, scallops, and sea urchins. There are also salmon farms in the area that could be negatively affected by the tidal power technology. Since the Downeast region is largely dependent on the fisheries industry, tidal power developers could be seen as a threat to marine resources. As a result, local communities are concerned for the wellbeing of their fishing industries. These environmental and social concerns are important to address in order to proceed with development plans. ORPC is working closely with the Cobscook community to ensure civic engagement and participation at all levels of research and development. The company has held community forums to address community concerns and has even moved their project location so as to not interfere with historical fishing grounds (Johnson 2010). ORPC's particular attention to questions regarding social and environmental implications where development is taking place should serve as an example for future tidal developers and their projects.

Another issue in tidal power development is the complex permitting processes required by federal and state agencies. This is discussed in detail in a subsequent section.

Wave Energy

Benefits to Maine

Although Maine's Ocean Energy Task Force decided that the state should lower the priority of wave power, there are several reasons for further development of the industry. First, there is room for growth in the technology for electricity generation. With over 100 different methods for harnessing wave energy currently in development (OETF December 2009), extraction rates are likely to improve. Also, production increases will introduce economies of scale, driving down the cost of electricity from this renewable source.

Benefits also extend to research opportunities for universities and colleges. The University of Maine, especially, can play a major role in wave energy research and testing. The institution is already collaborating with the DeepCwind Consortium (further discussed in the wind energy section) in order to develop and monitor wind energy generation at a test site near Monhegan Island in Maine (DeepCwind 2010). This familiarity with offshore energy development could facilitate the study of innovative hybrid technologies.

As documented by Stanford University doctoral candidate, Eric Stoutenburg, co-located wind and wave energy farms can reduce power output variability (Stoutenburg 2010). Hybrid systems are also under development. For example, the Danish company, Floating Power Plant, has developed single-structure combination of offshore wind and wave energy called the Poseidon (FPP 2010). This pioneering design presents yet another research opportunity for Maine academic institutions to conduct a power feasibility test.

Concerns in Maine

The largest concern for wave energy in Maine is that the wave climate is too poor to make a project feasible. However, this statement is not yet confirmed. Research conducted by the EPRI and the University of Maine can inform policy makers and direct Maine's path towards accomplishing its renewable energy goals.

Another concern is that offshore wind and tidal development outcompete the wave energy industry in terms of cost of electricity. Even if economies of scale and industrial streamlining reduces WEC systems costs, the technology will be obsolete if wind and tidal technologies achieve lower prices.

Finally, a complex and expensive permitting process can deter WEC development in Maine. This topic will be discussed in a subsequent section of the report.

Wind Energy

Benefits to Maine

Maine's offshore wind resource is substantial. Approximately 82% of Maine's coastal waters have Class 5 or stronger winds, and federal waters adjacent Maine's territorial waters have measured capacity of Class 5 or better winds (OETF 2009), where Class 5 winds are defined by wind speeds of 7.5 – 8 meters per second (m/s) at 50 meters (Musial and Butterfield 2004). Successfully capturing this resource will allow the state to minimize its greenhouse gas emissions, lessen its reliance on non-indigenous energy sources, while simultaneously stimulating its economy with the creation of the jobs necessary to construct, maintain and eventually decommission proposed offshore wind projects (OETF 2009).

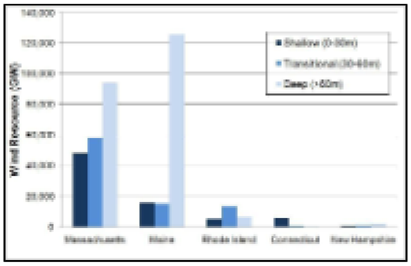

Figure 4.5 New England offshore wind resource (gigawatts) by water depth category estimated by the Natural Renewable Energy Laboratory. Resource areas limited to >7.0 m/s at 90-m height and within 50 nm of shore (Schwartz et al. 2010).

Maine's offshore wind resource is especially noteworthy when compared with the rest of New England (Schwartz et al. 2010). Of the five coastal New England states, Maine, Massachusetts, New Hampshire, Rhode Island and Connecticut, Massachusetts has the greatest offshore wind potential, approximately 200 gigawatts (GW), located in its shallow, transitional and deep territorial and adjacent federal waters (see Figure 4.5). Maine, with approximately 156 GW of offshore wind energy potential, does not have such an equally distributed resource. Eighty percent of Maine's estimated electricity generation capacity from offshore wind measured at wind speeds greater than 7.0 m/s is located in its deep water, areas with depths greater than 60 meters. By way of comparison, 47% of the Massachusetts resource is located in deep water; only 0.1% of Connecticut's offshore wind resource is located in its deep water (Schwartz et al. 2010).

Maine's substantial deep offshore wind energy resource potential, due in part to its unique bathymetry, the measurement of the varying depths of the ocean, explains why the majority of its proposed development focuses in the deep water, both within and beyond its 3 nautical miles of state-controlled territory. And while developers of land-based and shallow water offshore wind farms have encountered substantial opposition, those deep off shore projects sited in federal waters, greater than 3 nautical miles from shore mitigate many, if not all, of wind turbine's human impacts. Construction in deep water areas minimizes visual impact and noise pollution concerns created by land-based and near-shore, shallow water wind farms (DECC 2009; Pelc and Fujita 2002).

The DeepCwind Consortium estimates that the first two phases of its Offshore Wind Plan, the construction of the floating 100-foot to hub, 1/3-scale model that began this year and will continue through 2012 and the construction and testing of a 3 to 5 megawatt (MW) full-size, 300 foot to hub, floating turbine prototype planned for 2011 to 2015, will together create 125 addition jobs annually for Maine's economy. If these two phases were successful, the construction of a "stepping-stone," 25 MW floating wind farm 10 to 50 miles offshore from 2013 to 2016 would bring an estimated 320 jobs additional annually. If development and investment, of which DeepCwind estimates $20 billion will come from outside the state, keeps pace with the consortium's additional two phases of development, commercial, floating offshore wind farms could create between 7,000 and 15,000 jobs annually between 2020 and 2030. Although incredibly speculative in nature, DeepCwind's estimation of 5,000 MW of total annual installed indigenous electricity generation capacity by 2030 (Dagher 2009) would markedly transition Maine's energy economy away from its existing dependence on non-indigenous fossil fuels.

Concerns in Maine

Deep water turbine projects, despite their similarities to previously installed and proven onshore wind turbine projects and shallow water projects, must be much larger in terms of project scale and turbine size to pay for the necessary seabed support structures and transmission cabling costs required to transmit power onshore (Musial and Butterfield June 2004). Beyond the uncertainties inherent in developing efficient wind turbines capable of operating in deep water environments, transmission cost allocation is a considerable variable in the per kilowatt hour (kWh) cost of delivered wind-generated electricity (O'Connell and Pletka 2007).

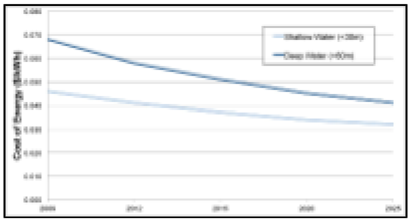

Figure 4.6 Cost of Energy estimates ($ per kilowatt hour) for offshore wind for Class 6 winds from Natural Renewable Energy Laboratory. Class 6 wind speed is 8-8.8 m/s at 50M, shallow water assumed <30 m depth, deep water assumed >60m depth (Musial and Butterfield 2004).

Although the development in deep water areas, with a depth greater than 60 meters, is an especially attractive option for Maine due to its bathymetry and measurements of its estimated resource made by the Natural Resource Energy Laboratory (NREL), the cost of generating and transmitting deep water wind generated electricity is estimated to be notably more expensive than electricity generated by turbines sited in shallow water, where shallow water is water depth less than 30 meters (see Figure 4.6). This difference can be attributed to the additional estimated cost, especially in initial development stages, of currently untested truss tower, anchoring and floating turbine technologies required to securely site wind turbines in deep offshore zones and transmission lines required to bring electricity generated offshore onto the grid (Dagher 2010 and Wright et al. 2002).

Unlike Europe's developed offshore wind industry, the United States does not yet possess the expertise or manufacturing capability to manufacture all the necessary components to construct the turbines for its proposed projects or their accompanying transmission lines at substantial volumes (Wright et al. 2002). Notably, the University of Maine's Advanced Structures and Composites Center will be the only facility in the US that includes complete wind turbine development capabilities from design to performance testing of turbine components when it completes the construction of additional laboratory space in the coming years (Dagher 2010).

In addition to high capital investment costs required to build and site turbines, transmission cables require substantial capital expenditure. Based on past European projects, total transmission costs. cost of the cable itself, laying costs and infrastructure costs, can be as much as 20% of the total cost of a wind farm (Wright et al. 2002). Cabling costs are affected by the project's distance from shore; as the projects distance from shore increases to capture the stronger wind resource, the importance of the choice of transmission voltage and technology, alternating current (AC) or direct current (DC) also becomes increasingly important (Musial and Ram 2010 and Wright et al. 2002). Like proposed anchoring and floating turbine technologies, offshore transmission line technologies remain essentially untested in the United States and substantially more development is required before a consensus over the most appropriate transmission technology for the Gulf of Maine is reached (Musial and Ram 2010).

Offshore wind farms and their transmission cables also have a minimal, but nevertheless non-trivial, environmental impact. According to a study conducted by the U.K.'s Department of Energy and Climate Change (DECC), the environmental impact of offshore wind turbines includes the acoustic and physical disturbance of seabed habitats and the physical disturbance caused by the presence of offshore infrastructure and support activities. Above water wind farms likely pose potential impacts to bird populations and bird migrations and, if not properly sited, may interfere with existing marine shipping and commercial fishing uses (DECC 2009; Pelc and Fujita 2002). Although European findings may provide a solid basis for understanding offshore wind's environmental impacts, additional multi-year testing and analysis must be done in the United States before environmental impact statements can be drafted and approved by state and federal regulators (Musial and Ram 2010).

One such study was completed by the New Jersey Department of Environmental Protection (NJ DEP) in July 2010. After two years of analysis of 1,360 nautical miles of state and federal waters along the New Jersey coastline, NJ DEP found that the highest density of bird populations was found closest to shore, and that approximately 7.6 miles from shore the number of birds declined substantially (NWF 2010). The DeepCwind consortium's plan for Maine proposes that wind farms be sited between 10 and 50 miles from shore. Moreover, NJ DEP noted that fewer marine animals like dolphins, whales, seals and sea turtles were observed than expected during the study, but that seasonal variability, winter's effect on avian movements and summer's effect on sea turtle migration, played a larger role than expected in fluctuations in the ecosystem (NWF 2010). At the conclusion of its study, NJ DEP suggested that brief turbine shut-downs during peak migration seasons for birds and marine species would be a suitable technique for mitigating negative environmental impacts in the marine ecosystem (NWF 2010).

Another issue in wind power development is the complex permitting processes required by both state and federal agencies; this is especially important given that the DeepCwind Consortium's Offshore Wind Plan includes the development of majority of Maine's commercial offshore wind generation capacity 10 to 50 nautical miles offshore, beyond Maine's three nautical mile territorial boundary (Dagher 2009). The current state of federal and state permitting requirements is discussed in detail in the following sub-section.

Permitting Process for Offshore Technologies

One of the commonalities of these three renewable energy resources is a historically complex and inefficient permitting process. Regulatory overlap and interagency misunderstandings over jurisdiction have created a tense atmosphere surrounding new offshore energy development projects. When the permit approval process is unclear, businesses face risks due to cost uncertainties and cannot even be certain to receive a permit. Hence, complex permitting has been a major obstacle to the progression of the tidal, wave, and wind industries in the United States. Wave and tidal permitting can be classified into the same category because both are considered to be "hydropower development" according to the definition provided in Maine's Water Development and Conservation Act (38 M.R.S. §341 - §358). Offshore wind power, while not officially categorized as "hydropower" is subject to a similar permitting process.

For wave and tidal energy, the greatest disruption to the permitting process has been the disagreement between the Federal Energy Regulatory Commission (FERC) and the Bureau of Ocean Energy Management, Regulation and Enforcement (BOEMRE), formerly the Minerals and Management Service (MMS). Certain details are necessary to understand their dispute. First, the baseline is defined as the mean low tide mark. Second, the area between the baseline and three nautical miles offshore contains state waters. Last, the area from this boundary extending to the U.S. Exclusive Economic Zone (EEZ) at 200 nautical miles is called the Outer Continental Shelf (OCS).

FERC is principally recognized for its oversight of hydropower projects, which has been limited to electricity generating damns on streams and rivers. However, with the advent of offshore wind, wave, and tidal power technology, FERC decided to assert regulatory control in oceans. Since the legislative definition of its jurisdiction did not restrict FERC from ocean hydropower projects, they pushed their case whenever possible.

Concurrently, the MMS, which administered mineral exploration and the development of the OCS following an amendment to the Outer Continental Shelf Lands Act, attempted to gain regulatory control of ocean energy development in that region. To complicate matters, optimal locations for WECs are typically located between 2.9 and 3.2 miles from shore, a region which straddles the boundary of state and federal waters (Sherman 2009). However, in 1988, President Reagan issued an executive proclamation to extend state waters to 12 nautical miles, further confusing the delineation between the jurisdictions of the two agencies (Sherman 2009).

Despite a muddled past, FERC and MMS entered into a Memorandum of Understanding (MOU) signed in April of 2009 that promises collaboration between the two agencies in order to “clarify jurisdictional understandings [in the OCS]” and “to develop a cohesive, streamlined process that would help accelerate the development of wind, solar, and hydrokinetic [i.e. wind and wave] energy projects” (FERC 2009). As a result of this agreement, FERC was granted authority issue licenses for all hydrokinetic projects on the OCS while the MMS will oversee the leasing and easement process (Sherman 2009).   Another important facet of the agreement is FERC’s concession to stop issuing permits on the OCS.   While this MOU represents progress towards a simpler permitting process, the inclusion of multiple agencies in the process still presents unnecessary steps from the perspective of an energy developer.

In Maine’s oceans, the status of the permitting process has shown signs of progress, especially with regards to a recent August 2009 of a MOU between FERC and state agencies as well as the Final Report of the Ocean Energy Task Force to Governor John E. Baldacci in August 2009. The MOU’s principal goal is to expedite the permitting process of tidal energy projects (including but not limited to tidal) through the creation of a timely, well-coordinated application review process. Once again, this MOU does not create any binding commitment, but, if followed, will drastically improve the state of Maine’s offshore permitting process. The Ocean Energy Task Force document provides a thorough discussion of current problems surrounding permitting, but one suggestion stands out as the most logical and influential change that would reduce barriers to testing and development of projects.   Simply, the task force suggests that environmental permitting requirements be “commensurate with the scope and size of the pilot projects currently proposed and less demanding than those for a full-scale, commercial project” (Final Report OETF).

In order to streamline the permit and leasing process, the OETF suggests a “one-stop-shop” approach in both federal and state waters. For Maine, this would mean that the DEP would take charge of all ocean renewable energy projects. Instead coordinating with several agencies in order to comply with the National Environmental Policy Act, the Clean Water Act, the Coastal Zone Management Act, etc., an ocean energy company would deal directly with DEP. A successful model exists for this “one-stop-shop” approach in the Danish offshore wind industry, and Denmark produces 35% of 2 GW of global production (OCD 2010). In US legislation, the 1980 Ocean Thermal Energy Conversion Act (OTECA) tasks the *National Oceanic and Atmospheric Administration* (NOAA) with the licensing for construction and operation of commercial Ocean Thermal Energy Conversion (OTEC) plants (_HNMREC 2010). While OTEC has not been established in the US, the structure allows for “the majority, if not all federal, state, and local requirements [to be] handled through the NOAA licensing process” (HNMREC 2010).

Testing in Maine

Current testing sites for tidal turbines, wave generators and wind turbines span Maine’s 5,000 miles of coastline. Test site determination is based on the strength of the resource, historical usage, proximity to the grid, and other factors specific to each technology.

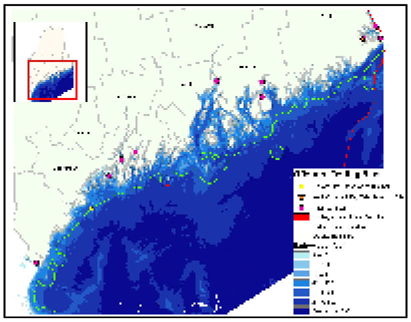

Figure 4.7 Location of Maine’s tidal, wave and wind testing sites (Maine GIS Catalogue, DeepCwind Consortium, Electric Power Research Institute)

Our spatial analysis highlights the importance of state and federal boundaries in the siting of potential test sites and the implications for future commercial research and development in Maine (see Figure 4.7). Due to the additional layer of complexity involved in permitting in federal waters outside of Maine’s territorial waters, as discussed previously, all testing has been sited within the state’s waterways.

Tidal turbines sited closer to shore fall within Maine’s territorial waters and will not be impacted by federal requirements (see Figure 4.8). Tidal projects will have to consider local and regional legislation in order to appease social and environmental concerns due to proximity to coastal communities. Tidal projects located on the US-Canada border will also have to take international agreements into account (EPRI 2006).

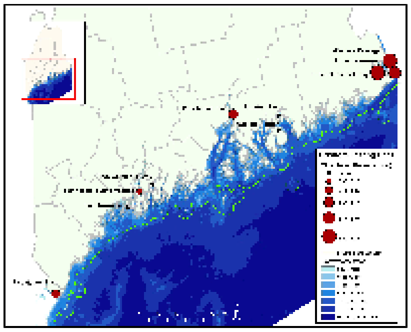

Figure 4.8 Location of Maine's tidal testing sites and relative energy potential (Maine GIS Catalogue, Electric Power Research Institute)

Wave generators, traditionally sited closer to shore, may not fall into federal jurisdiction if their development continues within Maine’s territorial boundary. Future research and development of wave generators co-located in deep waters with wind turbines or comprising wind-wave hybrid systems will invoke federal permitting requirements (EPRI 2006).

Future commercial wind farm research and development must overcome federal permitting requirements so that wind farms can be sited in deeper, federal waters adjacent to Maine’s territorial waters where a stronger, more reliable wind resource is available. Due to the disproportionate allocation of Maine’s offshore wind resource in deep water zones, it is unlikely that developers would consider large-scale commercial projects within Maine’s territorial waters (Dagher 2009).

Future testing and commercial development should be sited in locations that continue to fully consider the multiple uses for Maine’s oceans, which include commercial fishing, recreation and tourism, and a complex marine ecosystem. To equitably allocate Maine’s ocean resource, policymakers and developers should utilize marine spatial planning (MSP), a technique that effectively identifies areas most suitable for various types of activities in order to reduce conflicts among uses and reduce environmental and social impacts to meet multiple usage objectives (Abbett and Englert 2009). MSP was recommended by “The State of Coastal and Marine Management in Maine 2009,” the first chapter in *The State of Maine’s Environment 2009*, and the final recommendations of the Obama Administration’s Interagency Ocean Task Force published in 2010.

Scenarios

Based on the discussion of the benefits and concerns of Maine’s offshore energy development, we propose three scenarios for the future of offshore renewable energy in Maine.

"Poseidon’s Paradise": Wide Adoption of Renewables in Maine

Sufficient investment from public and private sources necessary for technological development coupled with community outreach and a streamlined permitting process sparks progress in Maine Ocean Energy Task Force’s goal of producing 300 gigawatts of offshore wind, along with further research and development of tidal and wave technologies by 2020 (OETF 2009).

"Siren’s Song": Reliance on Traditional Energy Sources

Concerns over high economic costs and potential environmental impacts minimize research and development of tidal, wave and wind technologies. Instead Maine further invests in its reliance on non-renewable resources and wood reserves to the point of collapse, resulting in massive economic, environmental, and social consequences.

"Ursula’s Ultimatum": Poor Investment Environment

Contrary to the assumption that fuel oil costs will continue to rise, making investments into initially more costly renewable technologies more attractive, global fossil fuel energy prices decline. As a result, Maine halts all existing research and development indicatives for offshore renewable energy.

Conclusions

Maine’s oceans play a vital role in the state’s economic and social well-being. The use of this resource has expanded to include potential energy extraction for tidal turbines, wave generators, and wind turbines. The opportunity for Maine to make strategic investments in these technologies, facilitating a move toward state energy independence, would help Maine to continue moving toward a sustainable future.

Despite early indications of offshore energy's potential, especially for wind and tidal development, there are no current commercial projects in Maine. It is estimated that offshore wind has the greatest potential for Maine with 149 GW followed by high tidal power potential in compatible locations such as Cobscook Bay. Wave projects have limited potential until technology is further improved.

In order to fully harness this renewable ocean energy potential continued exploration of its environmental, economic, and social impacts must be completed. Additionally, a comprehensive and effective permitting process must be developed since existing permitting regulations at the state and federal level are complicated and difficult to navigate. This can best be implemented through collaboration throughout the process to ensure transparency and effective communication between all stakeholders especially with regard to the use of a Marine Spatial Planning mechanism.

Recommendations

1. The LePage Administration should acknowledge the findings and recommendations of the Baldacci Administration's Ocean Energy Task Force and pave the way for a favorable climate for continued research and development
2. Investment and development
    a. Focus on the offshore wind industry due to the state's substantial wind energy resource
    b. Tidal energy should receive equal support in those specialized sites appropriate for its application such as the Bay of Fundy
    c. Wave energy should receive limited funding
3. Research for wave energy should include the study of co-location with offshore wind turbines as well as hybrid wind-wave systems
4. Create a "one stop shop" for permitting applications
5. Continue to research environmental impacts specific to Maine

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