An Analysis of Wind Power Development in the Town of Hull, MA

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Hull Municipal Light Plant

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Contents

Over the past three decades the Town of Hull, MA has solidified its place in U.S. wind energy history through its leadership in community-based generation. This is illustrated by its commissioning of the first commercial-scale wind turbine on the Atlantic coastline, the first suburban-sited turbine in the continental United States, pursuit of community-based offshore wind, and its push toward creating an energy independent community.

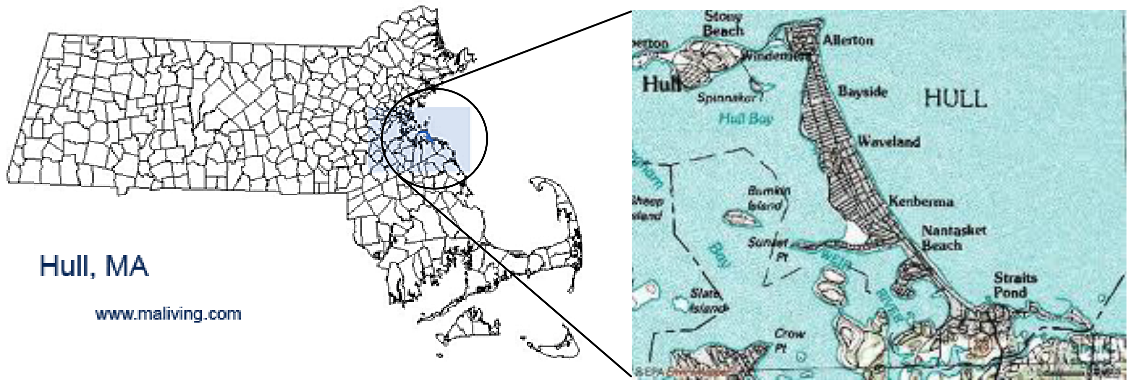


Figure 1. Town of Hull, MA. U.S.G.S. Topographic Map.

Background and Demographics

The Town of Hull is a seaside community of roughly 10,200 residents situated south of Boston in Plymouth County, Massachusetts. First settled in 1622, Hull is located on a Peninsula bordered to the west by Massachusetts Bay and Hingham Bay, and the Atlantic Ocean to the east.

Primarily a fishing and trading community in its earliest days, Hull evolved into a vacation resort during the mid and late 19th century attracting, vacationers to its fine sand beaches. Today, it retains its beach resort community status, while also offering an attractive option for Boston commuters who can travel into the city via ferry, and offers some lower priced housing options compared to other neighboring Boston Suburbs.

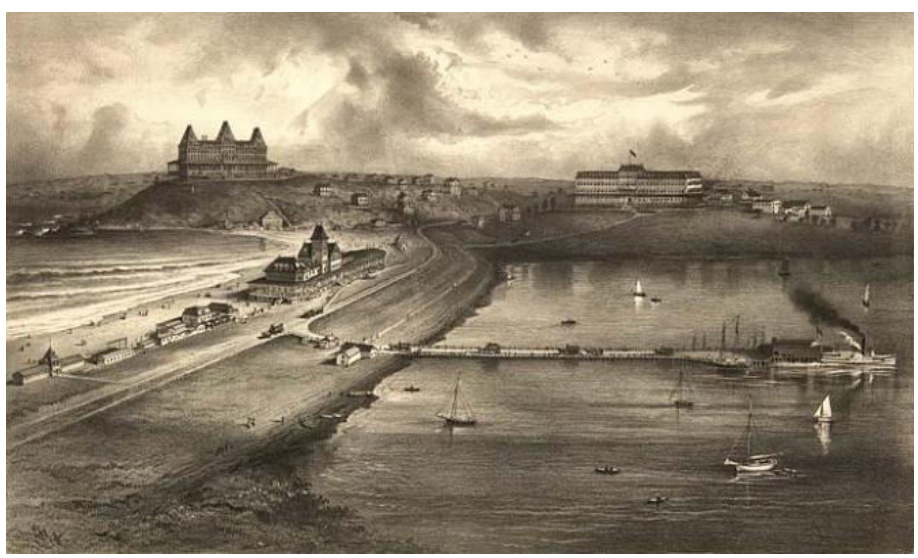


Figure 2. Southeastward view of Nantasket Beach, 1879. Lithograph of Nantasket Beach, by Richard Parrot Mallory (1813-1890).

Hull is one of the smallest towns in the state by land area (28 sq. miles), and is moderately population dense at 3,676 people per square mile. As of 2010, the median household income was $70,503 with a predominantly white middle aged population. The workforce is a blend of both white and blue-collar careers (2010 U.S. Census).

Hull Municipal Light Plant

Municipal Light plants have a long history of service in Massachusetts. Established in 1893, Hull Municipal Light Plant (HMLP) is one of forty-one municipally owned utilities in the state that provide electricity to a town-specific customer base. HMLP is a member of and purchases the bulk of its power from the Massachusetts Municipal Electric Company (MMWEC), a non-profit, public corporation and political subdivision of the Commonwealth of Massachusetts. In addition to domestic wind production, its energy portfolio includes nuclear power, combined cycle (oil & gas), and oil generation facilities. The Light Plant serves 6,164 customers with a peak annual service load of 12.5 MW by way of a single, two-circuit transmission line running through the Town of Weymouth from a National Grid substation. The light plant owns and maintains its own distributions system. HMLP is governed by the publicly elected, five member Hull Municipal Light Board of Commissioners. Daily operations are directed by the plant's Operations Manager.

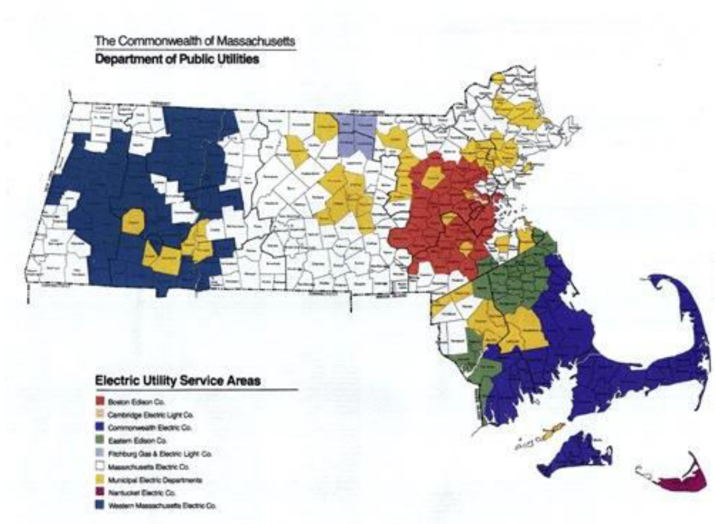


Figure 3. Massachusetts Utility Service Areas. Yellow shade denotes municipally owned utilities. Image from Massachusetts DPU.

Wind Power in Hull

Early History

The idea of harnessing wind power for industrial uses was brought to America by the early European colonists who were familiar with the technology. During the Revolutionary War, the British blockades made salt, which among other uses was a critical food preservative, difficult to obtain. To compensate for lack of availability, enterprising colonists turned to the sea. As salt works evolved, windmills were employed to more efficiently pump the large amounts of water needed from the ocean to the salt works, in order to produce adequate amount of product (Caldwerwood, 2008). One such windmill and perhaps others were erected in Hull during the late 18th and 19th centuries. In fact, the northernmost tip of Hull was named Windmill Point for that very reason.

Figure 4. This photo shows the use of wind power in the production of salt. Three wind structures can be seen: two "pump mills' on the left and a more significantly sized conventional windmill in the background right. Photo from Orleans Historical Society.

Modern Onshore Wind

Breaking Ground in Massachusetts

Hull's interest in home-grown power began in the mid 1980's with the erection of a 40kW Enertech turbine placed atop an 80 foot tower adjacent to the town's high school on Windmill Point. The commissioning of this wind turbine generator (WTG) in 1984 placed Hull in the history books as the first town in Massachusetts to supply power from a municipally-owned wind turbine. The $78,000 project expense was supported by grant funding from the Massachusetts Executive Office of Energy Resources or EOER (now the Executive Office of Energy and Environmental Affairs).

This, the first of Hull's wind turbines, produced power to offset electricity costs at the high school for over a decade until it was irreparably damaged by a winter storm in 1997. According to a report written at the time, over its lifetime the turbine had offset approximately $61,500 in electricity usage at the high school. However, over the lifespan of its operation, the turbine failed to produce the power anticipated, largely as a result of down time required for frequent repairs (Bolgen, 1996). When repairs and maintenance were factored in, the net savings were approximately $44,500.

Hull Wind I

In the early 1990's, state and town officials were examining the feasibility of replacing the original turbine with a larger unit. In 1993, a negative town meeting vote squashed a state funded plan to install a 500-600 kW turbine at Windmill Point. The idea stemmed from a belief that the wind resource was indeed adequate to support a larger machine, and was the state's response to a growing need for more renewable based generation. Marginal performance of the previous turbine and lack of a "local champion" were cited as reasons for the town meeting failure (Manwell, 2003).

However, in 1997, with a vision for greater wind energy in Hull and the potential to create a base of public support for local power generation, a group of citizens including Malcolm Brown and Anne Marcks- a high school science teacher, began a movement to repower the site with a larger, modern turbine. Ms. Marcks was able to incorporate the project into the curriculum of her physics class, thus involving local students in the process.

To formalize support and organization, Brown established the citizens group, Citizen Advocates for Renewable Energy in 1997 (hullwind.org). This resulted in a citizen's petition requesting the HMLP formally support this initiative, now known as Hull Wind I.

The idea also found support in the form of technical assistance from EOER, the Renewable Energy Research Laboratory at the University of Massachusetts, Amherst (now called the UMASS Wind Energy Center) under the leadership of Dr. James Manwell, and the National Renewable Energy Laboratory (NREL). Established in 1972, the Wind Energy Center is nationally recognized for its technical expertise in renewable energy systems.

Since the erection of commercial wind facilities was uncharted waters for the Commonwealth at this point in time, careful consideration went into the permitting and review process for this significantly larger sized turbine. All aspects of this project's feasibility and potential impacts were thoroughly scrutinized over a two year period including: siting analysis, wind resource quantification, environmental and regulatory reviews, and economic analysis. The resulting study (Ellis, Rogers, and Manwell, 1999) has been seen as the foundation for onshore wind permitting in the state.

Figure 5. Hull Wind I on Windmill Point.

Following what was described as a very positive public meeting in June of 2000, where broad support for the project was exhibited from town residents; HMLP issued a Request for Proposals in early 2001. By the end of the year, a new Vestas V47 – a 660KW turbine with a hub height of 50 meters and 47 diameter rotors was producing power. The total installed cost was $802,000. According to the Light Plant, in its first two years of operation the turbine had produced almost 3,000 MWh of energy, for a capacity factor of 27%. Wind I's success was evident in the long list of awards it garnered from federal and state agencies and other organizations.

The Hull Wind I project had proven a success in terms of power production and cost efficiency, and had won over the majority of Hull's residents. In fact, a survey conducted in 2002 found 95% felt positively about the Town's onshore wind project and supported the idea of erecting additional turbines in Hull.

Hull Wind II

Based on the overwhelming success of Wind I and sensing a desire among ratepayers to expand municipal renewable power production, Hull's wind champions, spearheaded by Malcolm Brown who had since become an elected Light Board Commissioner and its Vice Chair, began planning the next phase of wind energy expansion.

Simultaneously, the Town was considering the construction of a desalinization plant for water supply. Hull does not have domestic access to public water and imports it from neighboring towns through a private contractor. This consideration also played a role in discussing the potential expansion of wind power as a means to offset the increased electrical demands of such a plant. This thinking also led those involved to ponder the idea of a small offshore wind farm.

After consideration, the town chose to not move forward with the desalinization plant primarily due to economic factors. They did however select a site for a second turbine: atop the Town's capped landfill. The adaptive re-use of a closed landfill was a landmark move that required detailed engineering, analysis and regulatory approval. This site was selected in a large part due to its acceptability to residents, the greater height it offered, and a convenient connection to the power grid (Manwell, 2006).

Again Vestas was chosen as the turbine manufacturer of choice, but this time a larger V80 unit was selected. Rated at 1.8 MW, the V80 has a hub height of 67 meters, and a rotor diameter of 80 meters. Hull Wind II was commissioned in May, 2006. According to light plant records, Hull II produced over 4,000 MWh of power in its first year.

Together, the Town's two wind turbines produce approximately 11 percent of the ratepayer's electricity demand. Movement gained in the initial Hull I project including its public support and the presence of a local - municipal electric company which created a sense of "local ownership" of the project and the power it produced, were key components in the success of this second project according to Manwell in his report: "Hull Wind II: A Case Study of the Development of a Second Large Wind Turbine Installation in the Town of Hull, MA" (2006)

Figure 6. Hull Wind II sits atop the town's capped landfill.

Figure 7. Project Timeline - Hull Wind II

Date	Description
2002	HMLP pursues second turbine idea
2004	Final site selection
	FAA determination of no hazard issued
	Letter of approval – Hull Conservation Commission
2005	Landfill site ownership transferred to HMLP
	Post Closure permit from DEP
	DEP Final approval received
May 2006	Hull Wind II commissioned

Leading to Offshore Wind

Through their efforts with Hull Wind I and Wind II, the light plant and its partners had worked through many of the significant challenges associated with wind power installation in urban environments, a subject extensively written about by Dr. Manwell (UMASS, Amherst).

The strong community support created and nurtured by a dedicated group of local champions, and recognition of the public benefits associated with community based wind, had grown into the idea of creating an energy independent community. Unfortunately, in a population dense town with little buildable land, there proved a lack of adequate sites available to meet this goal of approximately 15 MW.

Discussions around the idea of offshore wind began, as mentioned, during the planning for Hull Wind II and consideration of a town-owned desalinization facility (Manwell, 2003). If successful, Hull would likely be the first municipally owned offshore wind facility in the nation.

The original stated purpose of the project was to “Provide the Town of Hull with an emission-free, renewable power source that will promote diversity and independence, provide resources through the production and sale of renewable energy credits, promote price stability, displace emission generated through fossil-fuel firing, and empower Hull to continue in its role as a municipal leader in the Commonwealth” (MTC proposal, 2006).

HMLP also considered other land-based locations in town. Through this evaluation process however, they concluded that there were no suitable land-based sites available for further wind facility development. As a result, they began examining options for locating turbines offshore.

Figure 8. Early graphic showing a possible siting schematic of offshore turbines north of Hull. Graphic from “Turbine Siting in an Urban Environment” (Manwell, 2003).

At this point (and currently) there were no installed domestic offshore wind facilities, although several were in the planning stages including the Cape Wind in Nantucket Sound and Deepwater Wind’s Block Island project.

In addition to the availability of space, other benefits of looking at offshore development included the potential for higher capacity factors resulting from larger turbines and better wind resources. According to research conducted by the NREL, the northeastern U.S. has some of the best wind resources in the nation, ranging between 9-10 meters per second (see figures 9-11).

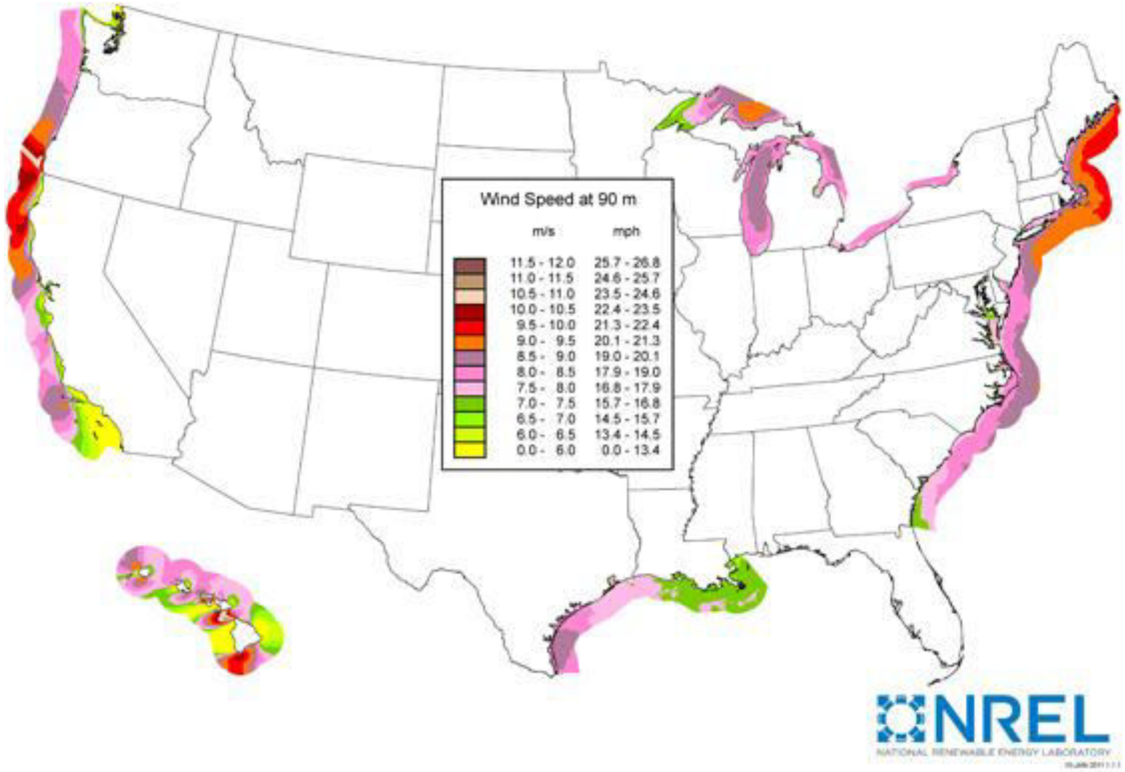


Figure 9. U.S. coastal wind resources map. From National Renewable Energy Laboratory.

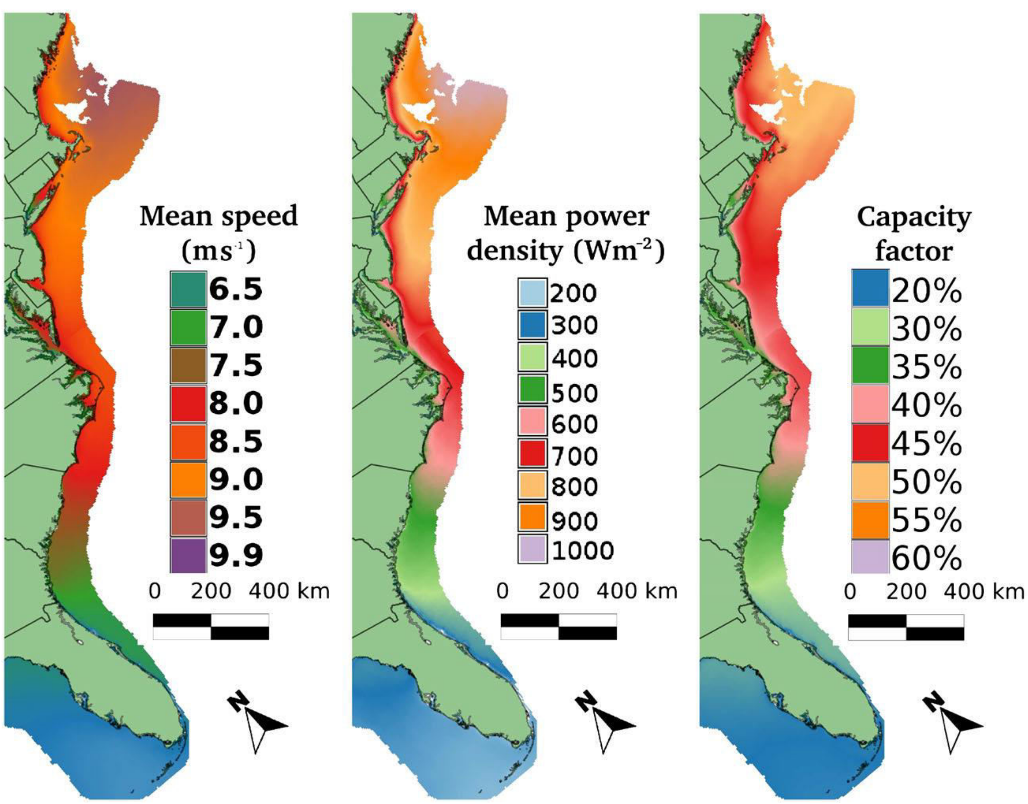


Figure 10. Annual, 24-hourly wind resource of the US EC at the 90 m hub height for the modeled years 2006–2010 (US East Coast OWE resources and their relationship to peak-time electricity demand M. J. Dvorak et al., 2012).

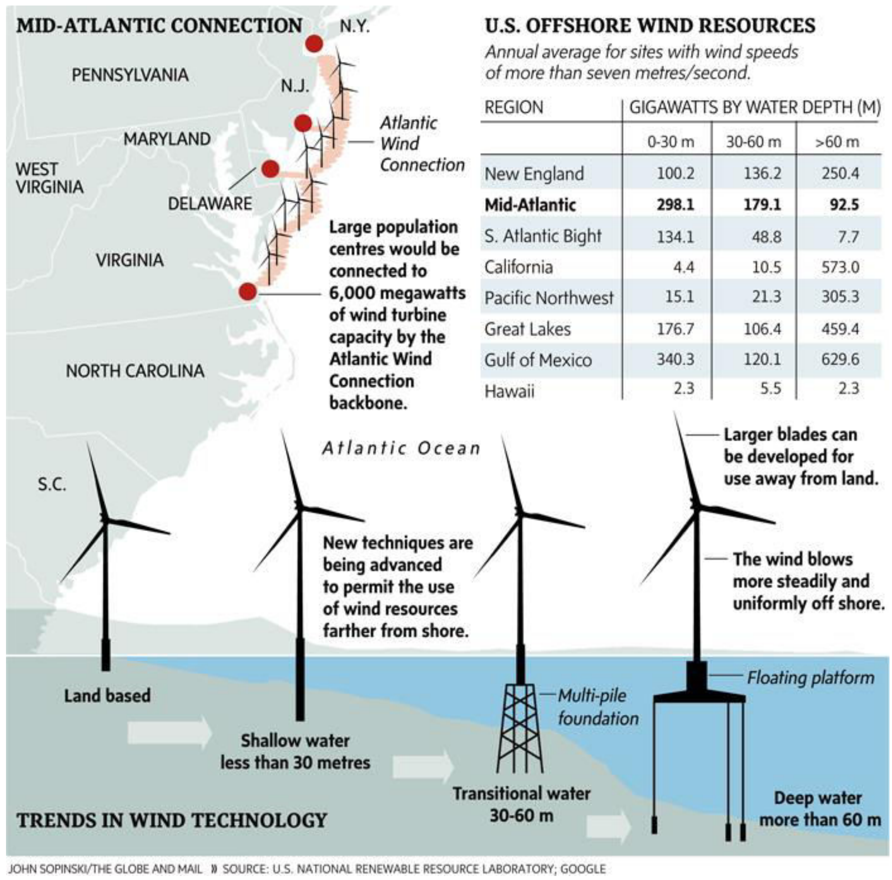


Figure 11. U.S. wind resources. Source: U.S. Renewable Energy Laboratory.

In the fall of 2003, the idea of installing a single offshore turbine gained traction, allowing for the ability to scale up with additional units over time. In 2005, the Massachusetts Technology Collaborative (MTC) agreed to consider funding technical studies for the project through collaboration with the Renewable Energy Research Laboratory (RERL) and the HMLP. An application entitled “Proposal by the University of Massachusetts, the Renewable Energy Research Laboratory and the Hull Municipal Lighting Plant to the Massachusetts Technology Collaborative for Support of HMLP’s Offshore Wind Turbine Project and Best Practices for Site Selection, Design and Installation of Offshore wind turbines” was submitted in March of 2006 (Manwell, 2007). A shift in thought at MTC resulted in an altered proposal to award a forgivable loan. This lead to submission of a new proposal, covering the many same components as the initial one, but was submitted directly by the HMLP. With minor revisions the proposal was accepted in the fall of 2006.

The proposed project evolved from a single unit into a small scale offshore wind energy facility, comprised of an array of up to four 3MW wind turbines that would collectively produce up to 15MW of electricity. The array was proposed for an area in the vicinity of Harding Ledge, approximately 1.5 miles east-northeast of Nantasket Beach. The hub height of the machines would have been approximately 80 meters above sea level, with a rotor diameter of approximately 100 meters. The turbines would have been interconnected at sea, and then subsequently tied into the onshore power grid operated through a single cable.

Preconstruction/Feasibility Efforts Begin

As with any similar sized projects, a comprehensive amount of feasibility work must be undertaken to determine fatal flaws, physical, environmental, and socioeconomic constraints and other factors that will shape the final scope, location and build design.

Factors considered in the fatal flaw analysis included:

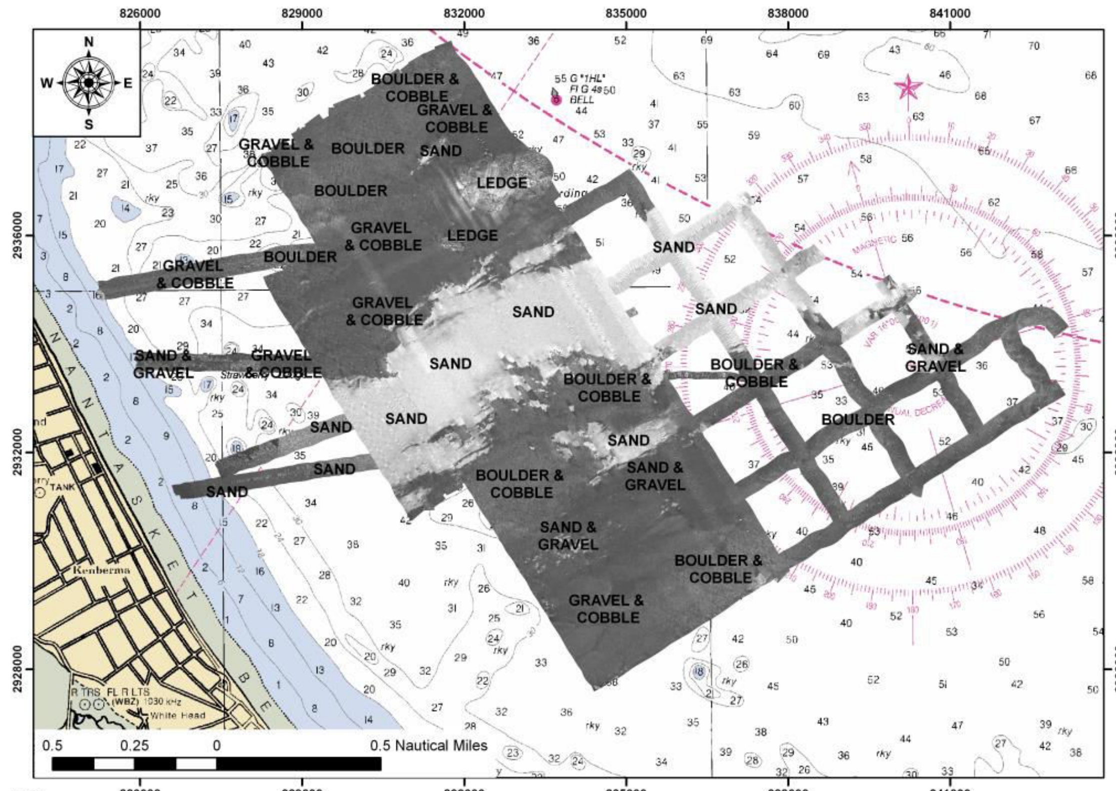
- FAA conflicts due to the flight line for Boston's Logan International Airport.
- Coast Guard navigation conflicts associated with shipping lanes into the Port of Boston including the Nantasket Roads channel just North of Point Allerton in Hull, and the approach for the Fore River in Quincy which passes just West of Windmill Point. Additionally, impacts on other maritime uses such as commercial fishing, and recreation.
- Municipal and state waters boundaries and permitting constraints.
- Grid interconnectivity.
- Available wind resources.
- Economic feasibility.
- Social acceptance.

Site Assessments and Studies

In order to define the best sites for turbine placement as well as possible cable routes, technical analyses were conducted over an approximate 3.35 square mile area including: geophysical and geotechnical assessments, benthic invertebrate sampling and a benthic habitat/lobster habitat assessment, wind resource analysis, meteorological/oceanographic investigations, sub-sea studies, site layout planning, and support structure preliminary design selection. Additionally, statutory analyses (federal, state and local) were undertaken to help determine an appropriate location for the project jurisdictionally (ESS, 2008 and Fathom, 2009).

Geotechnical and geophysical studies were conducted between 2007 and 2009. Single-beam bathymetry documented bottom elevations relative to Mean Lower Low Water (MLLW). Average elevation found was -39.3 feet MLLW and a "high energy" environment that fluctuates with storms. Side scan sonar (100-kHz and 500-kHz) identified a seafloor dominated by gravel, cobble and boulder substrates. Magnetometry identified broad-area anomalies associated with site geological processes or formations and scarce man-made anomalies. Low to mid-frequency sub-bottom profiling found the presence of an approximately 3 to 12 ft layer of mobile surficial sand in the central portion of the entire survey area with varying degrees of penetration in other areas ranging from 2-12 feet. Data from low frequency (0.5 - 2 kHz) Boomer "deep" sub-bottom found the estimated minimum acoustic basement at the proposed wind turbine generator locations was approximately 70 ft at WTG-1 and WTG-2, 20 feet at WTG-3, and nearly 100 feet below the sediment surface at WTG-4 (GZA, 2008).

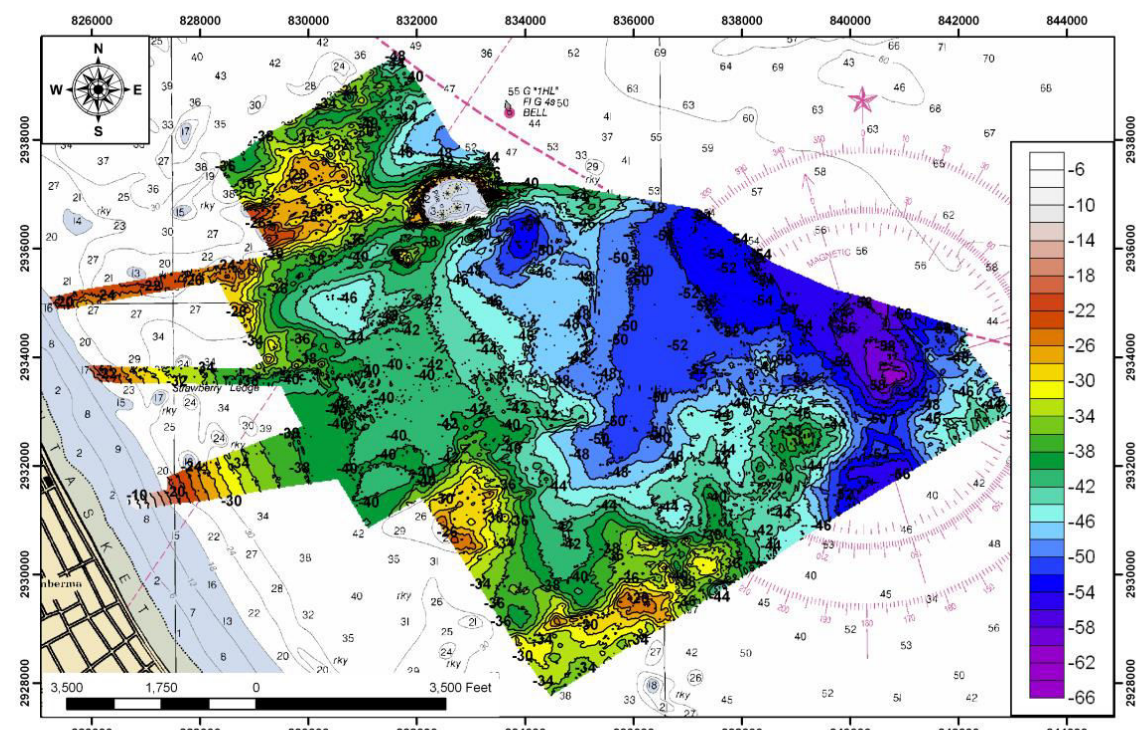
These results were used to identify appropriate locations for exploratory vibracore sampling and borings collected by CR and ESS Group, Inc., and two deep exploratory borings collected by GZA and Warren George, which supported the geophysical survey results (CR Environ., 2008). Vibracore and sub bottom sampling were conducted via jack-up barge.



Notes:

1. Side scan sonar survey conducted on August 21 - 23, 2007 and May 8, 2008 by CR Environmental, Inc.
2. Scale = 1:24,000. Grid: Massachusetts Mainland State Plane, NAD83, US Foot.
3. 100 & 500-kHz signals, ranges between 25 - 56 meters.
4. Not for Navigation.

Figure 13. Side scan sonar mosaic and preliminary bottom classifications. From CR Environmental



Notes:

1. Bathymetric survey conducted August 21-23, 2007 and May 8 , 2008 by CR Environmental, Inc.
2. Scale = 1:24,000. Grid: Massachusetts Mainland State Plane, NAD83, US Foot.
3. Transparency of bathymetric data layer added to allow correlation with USGS & CR acoustic backscatter.

Figure 12. Overview of Nantasket superficial geology (via side scan) and bathymetry. From CR Environmental.

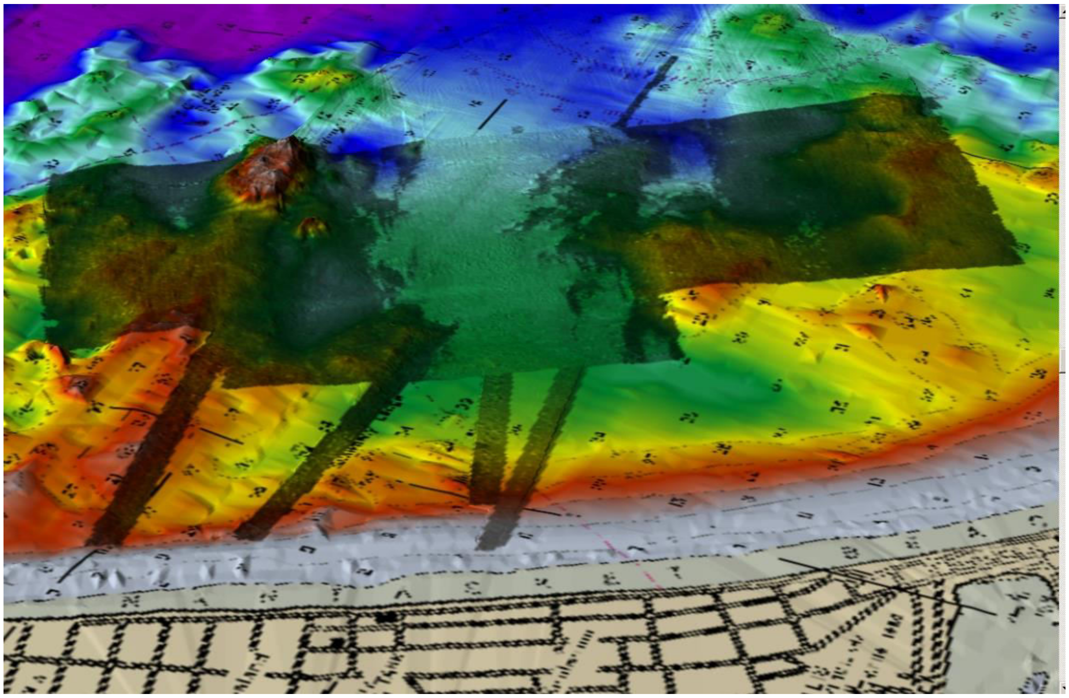


Figure 14. Bathymetric contours of the offshore wind study area and proposed cable routes (MLLW). From CR Environmental, Inc.

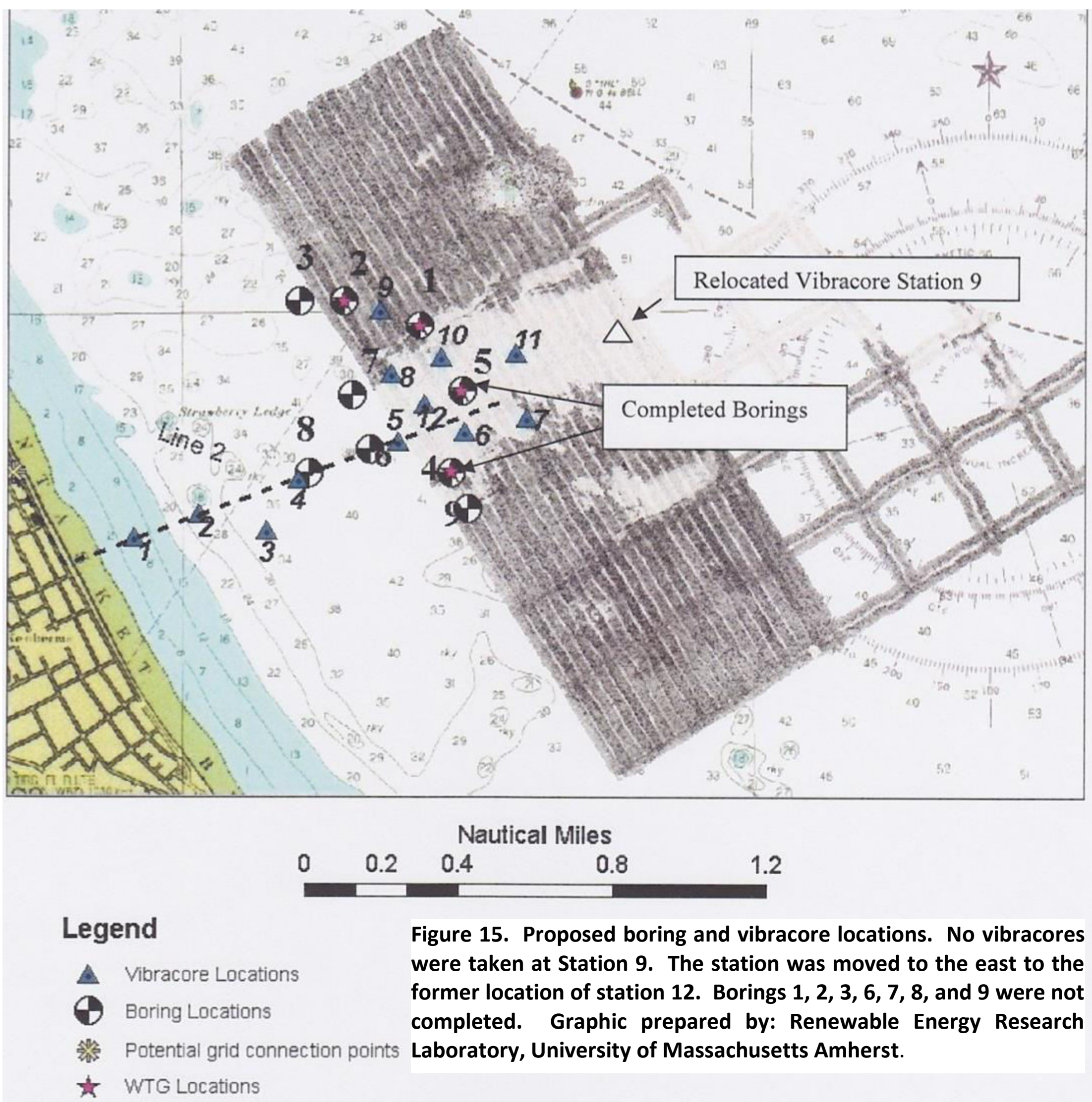


Figure 15. Proposed boring and vibracore locations. No vibracores were taken at Station 9. The station was moved to the east to the former location of station 12. Borings 1, 2, 3, 6, 7, 8, and 9 were not completed. Graphic prepared by: Renewable Energy Research Laboratory, University of Massachusetts Amherst.

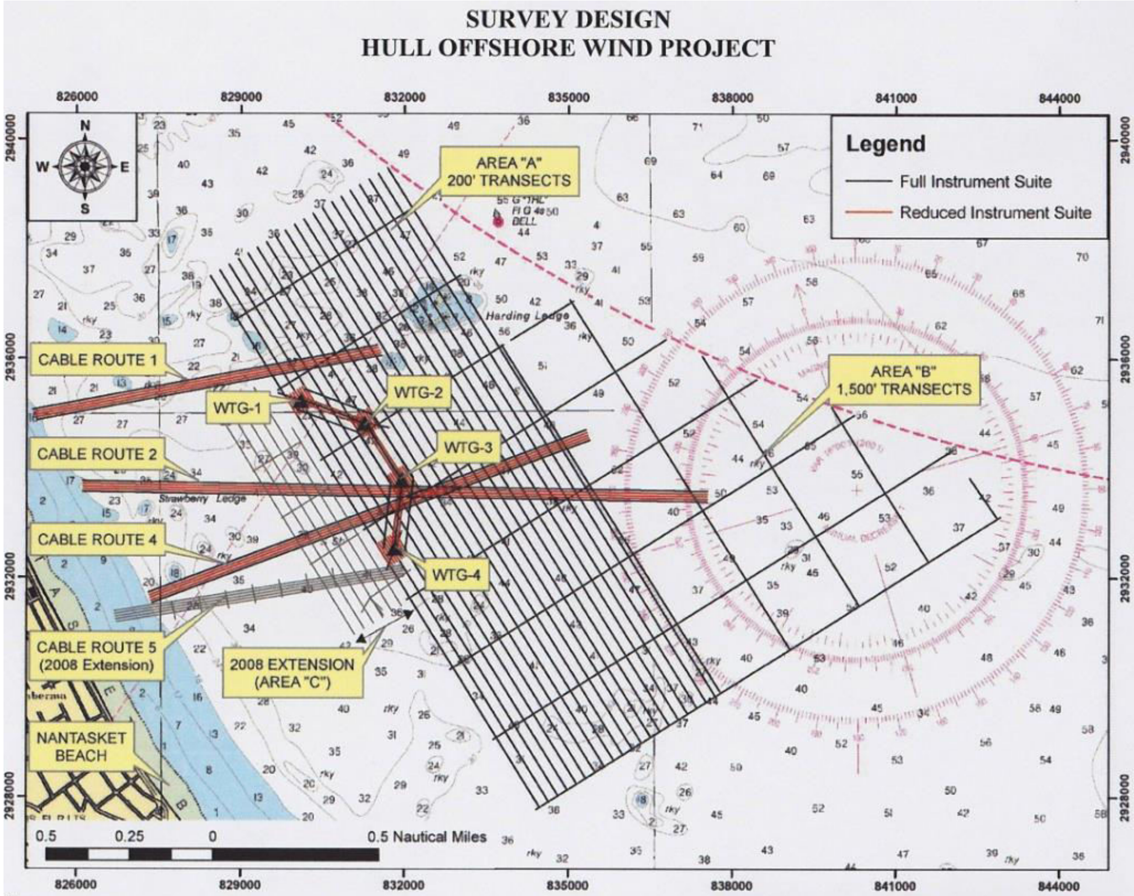


Figure 16. Survey design. From CR Environmental, Inc.

Figure 17. Photo simulation of arched array. Source: RERL

A Marine Archeological reconnaissance survey (Fathom, 2009) was conducted including archival research, field surveys and geotechnical data analysis to assess archeological sensitivity and determined the presence of submerged archaeological deposits within the proposed project area. The survey found that the study area:

- "Possesses a low archaeological sensitivity for containing submerged pre-contact archaeological deposits and a high archaeological sensitivity for containing submerged post-contact archaeological deposits, although contains no previously identified National Register-eligible or listed archaeological properties.
- Contains no evidence contextually intact paleosols with pre-contact archaeological sensitivity and contains no remote sensing evidence of post-contact period shipwrecks.
- No evidence of archeological significance on the site."

ESS Group, Inc. conducted an assessment of the benthic macro invertebrates encountered along the proposed cable routes as well as an underwater video survey to assess lobster population and bottom habitat type. The data collected during the field component of these studies as well as review of existing source data was intended to prepare an assessment of major habitat types and biological resources, including American Lobster, finfish, and shellfish, and to develop an alternative analysis as required in the MEPA Certificate (ESS, 2008).

According to the report, "Temporary physical disturbance of benthic habitat within the proposed submarine cable area and associated impacts on the existing benthic community from installation of the proposed submarine cable are likely to be minimal and temporary." "Due to the limited width of the direct impact anticipated during cable installation, mobile invertebrates living in adjacent, less-disturbed areas are expected to quickly recolonize the area disturbed by construction. Bivalves and other benthos with dispersive reproductive cycles will generally recolonize once their veligers or larvae settle into the area from nearby populations. For these reasons, the limited area of direct disturbance is unlikely to have more than a very localized and temporary impact on the benthic community."

Wind Resource and Sea Conditions

Data on available wind resources in the vicinity of Harding Ledge were collected from the following locations: a meteorological tower on Thompson Island (42.315035N, -71.010217W), the WBZ tower in Hull (42.2789 N/70.8762 W), Logan Airport (42.36297 N/71.00642 W) and a LIDAR unit placed on Little Brewster Island in Boston Harbor (42.328 N/70.89 W). LIDAR measurements were made at 10, 60, 100 and 120 meters above ground level. Based on data collected, it was determined that hub height wind resources of 8 meters per second could be anticipated. (Manwell, 2007).

Sea conditions (wave height, period, direction, and current speed and direction) were measured using the National Data Buoy Center (NDBC) buoy 44013, located outside of Boston Harbor, approximately 18km NNE of Harding Ledge (42.35389 N/70.69139 W). Wave data was also collected off Nantasket Beach with a Sontek acoustic Doppler profiler. NOAA nautical charts indicate water depths from 2 to 65 feet (MLLW) in the study area.

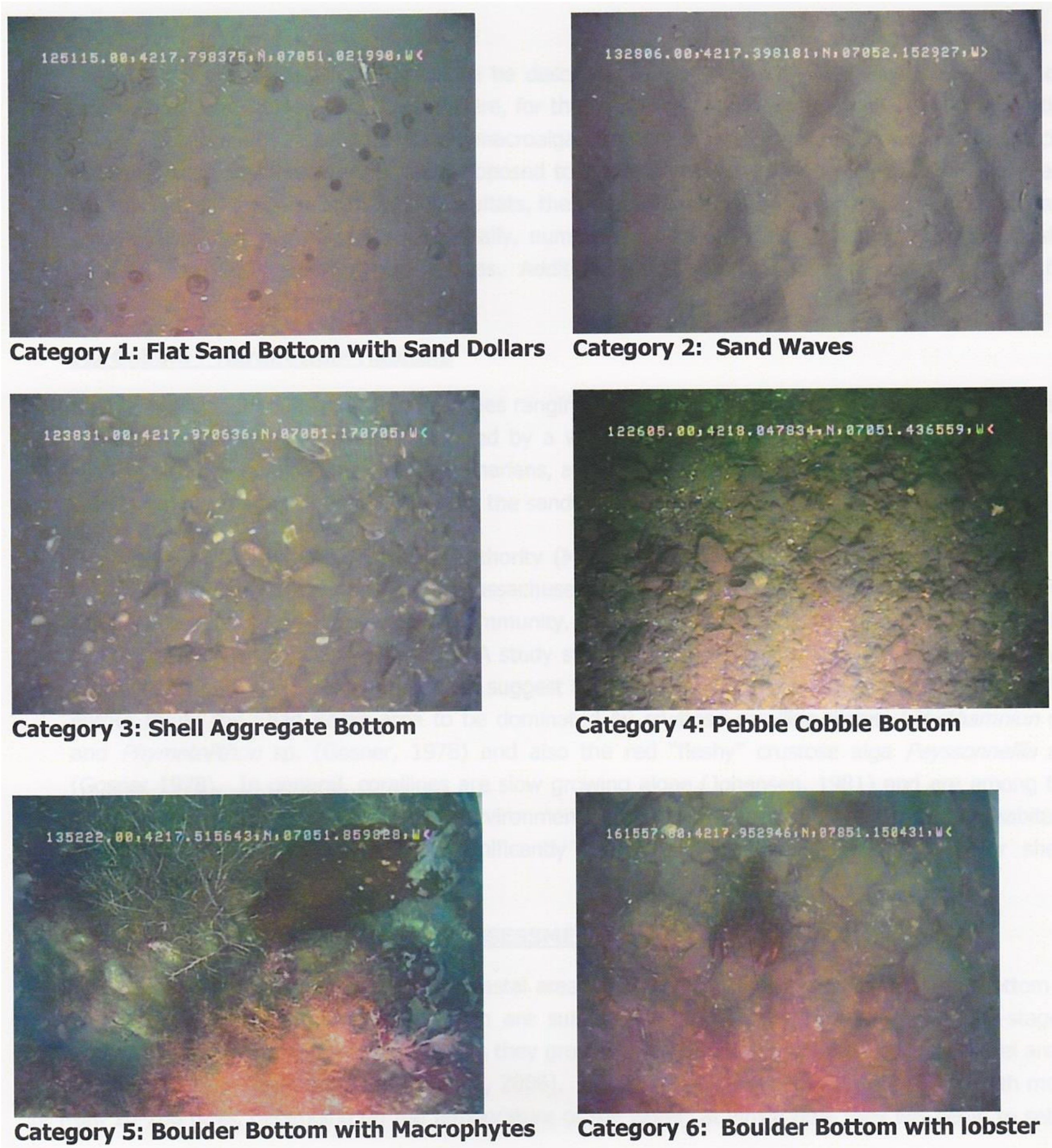


Figure 18. Screen captures from underwater video survey. From ESS Group,

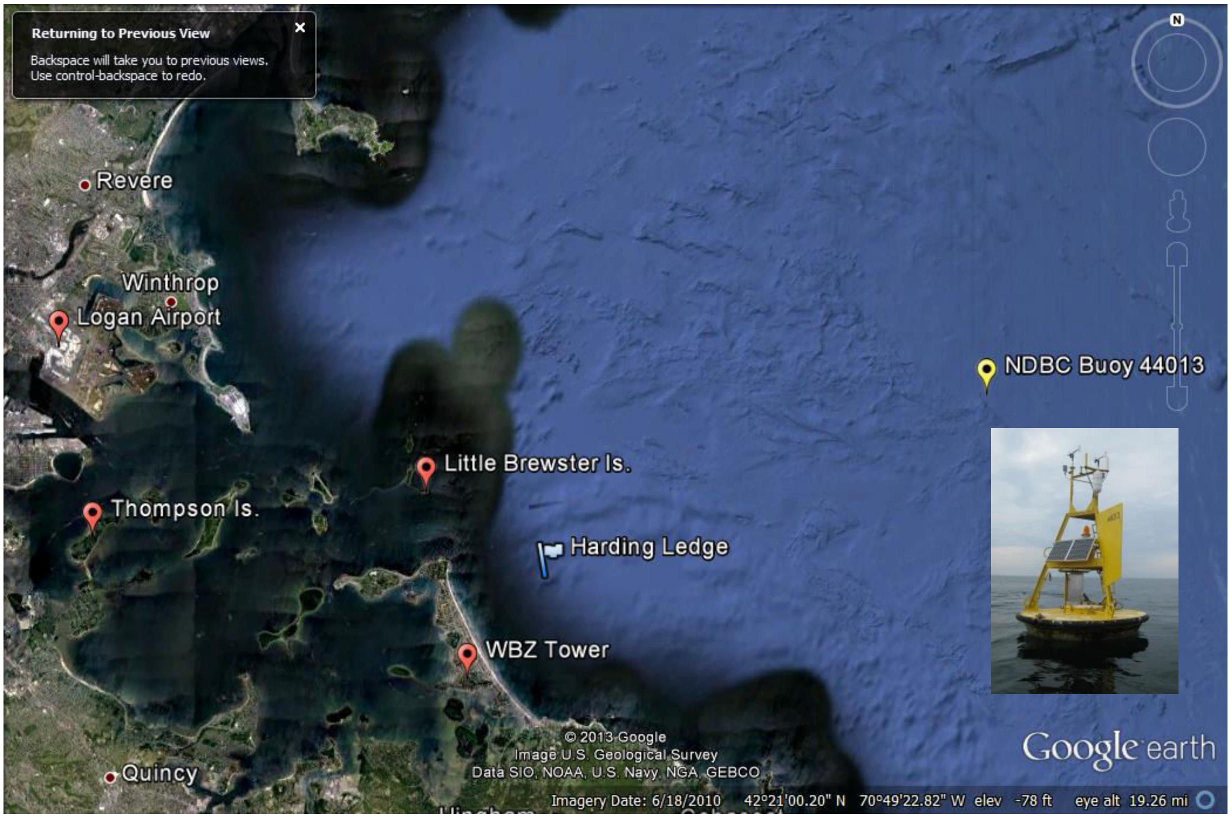


Figure 19. Wind and sea data collection sites. Source: Google Earth and National Buoy Data Center.

Foundations

Several support structures were considered including monopole, tripods or gravity foundations. A study conducted by Garrad Hassan evaluated soil and other geophysical survey results to assess the feasibility of different foundation types and to provide an initial cost estimate and determine if steel monopile foundations were appropriate. Site selection was based on geophysical acceptability for monopole foundations, primarily based on lower installation costs.

Siting Configuration

The initial visual simulations of the project show an arched configuration (see figures 16 & 17). However, at the conclusion of the aforementioned data collection an alternate arrangement was configured based on bottom suitability for foundation placement as shown in Figure 20.

Reconfigured Siting Following Technical Assessments

Figure 20. Photo Simulation of reconfigured turbines

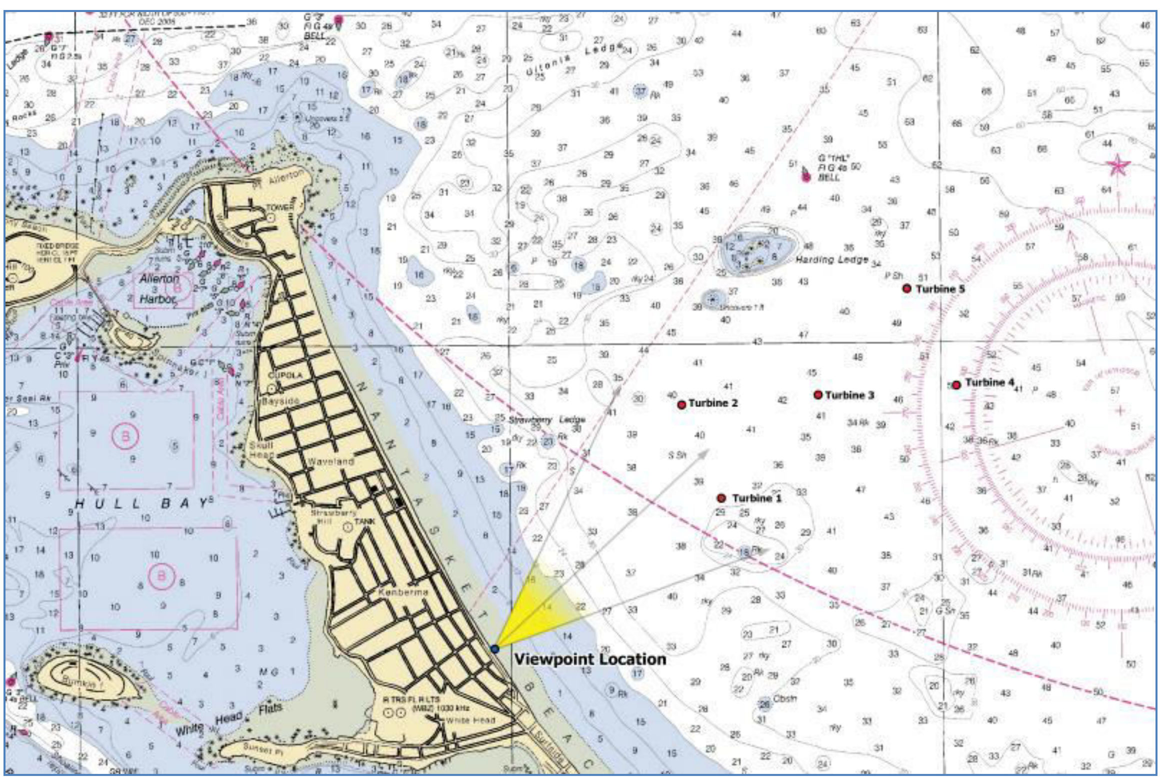


Figure 21. Plots on NOAA nautical chart showing viewpoint location for photo. From ESS Group, Inc.

ENF Filed

In December, 2007 HMLP filed an Environmental Notification Form (ENF) to comply with the Massachusetts Environmental Policy Act (MEPA). In turn, the Commonwealth issued a MEPA Certificate (February, 2008) requiring the formulation of an Environmental Impact Report (EIR), identified additional requirements, and established a Technical Working Group (TWG). Cost estimates to complete the work outlined in the EIR were upwards of $800,000. including: alternatives analysis, marine resource analysis, sediment transport processes, avian studies, visual impact analysis, historical and archeological studies and land alteration studies assessing cable route impacts, water quality impact assessment, electromagnetic field impacts analysis on fisheries and marine mammals, noise and vibrations, air quality, phased construction, maintenance and decommissioning plans, environmental management plan, navigation risk assessment, FAA hazard determination, and economic analysis.

Financial Assessment

In 2009, HMLP commissioned a preliminary financial feasibility study with the firm, LaCapra Associates. LaCapra's analysis assumed a maximum of four, 3MW wind turbines with an anticipated construction date of the fourth quarter of 2010. The evaluation used a capacity factor of 31% based on available wind data and turbine power curve information for a Siemens 3.6MW WTG, and 2010 capital expenses (CAPEX) estimated at $3810/kW. (LaCapra, 2009). Their analysis focused on three major capital cost categories: the wind turbine themselves, the foundations and substructures, and the grid interconnection. In terms of financing, LaCapra examined two scenarios: town-owned and financed, and privately owned and financed through a long-term PPA with HMLP. Four revenue streams were considered in the analysis including: energy market, renewable energy certificates (RECs), capacity market, and state and federal incentives.

	MUNICIPAL FINANCING		PRIVATE FINANCING	
	LOW COST	HIGH COST	LOW COST	HIGH COST
REVENUE REQUIREMENTS (LEVELIZED COST OF ENERGY)	$137.11	$177.12	$115.31	$135.63
TOTAL REVENUES	$129.86	$129.86	$125.86	$125.86
DIFFERENCE	$7.25	$47.26	($10.55)	$9.78
20 YEAR NPV ($000)	(3,314)	(21,588)	4,818	(4,465)

Figure 22. Financial model results from LaCapra assuming reference energy prices (levelized 2011 $/MWh).

LaCapra summarized their findings as such: "The financial analysis and summary results presented in this document represent a first cut at an economic assessment of the proposed Hull Offshore Wind Project. Since the time the project was first envisioned in 2003, interest in offshore wind has exploded as concerns with climate change have also increased. European countries have plans to greatly expand their installed capacity of offshore wind many fold, while offshore wind is increasingly seen as the only realistic option to provide large-scale renewable power to the load centers found in the Northeast U.S.

Unfortunately, along with this increased interest have come increased cost pressures. Wind turbine price increases have outpaced the materials and labor price pressures faced by non-renewable power plant developers due to increased demands on a limited pool of turbine manufacturers and offshore installation companies. Moreover, given the size of the proposed offshore facility, it may be difficult to contract with turbine manufacturers and/or foundation companies given the size and scope of competing worldwide demand. The results described in this report assume that such conditions will not significantly impact the prices that will have to be received from the output of the project; rather, the project size may require as a prerequisite that Hull be able to piggyback on other offshore efforts.

The financial estimates provided here necessarily feature a range due to uncertainty in a number of project assumptions as well as overall uncertainty in offshore wind costs. Nevertheless, taken together, the analysis provides a ballpark revenue requirement of approximately $157/MWh for the municipal financing option, with higher estimates possible assuming escalation in costs to levels higher than assumed here."

The results of the financial analysis report dealt a significant blow to project momentum. As a result, HMLP, its consultants and partners began to assess other possible scenarios where building an offshore facility may be economically feasible. The project's vision began to evolve from being strictly generation based, to the possibility of incorporating a testing and certification component for offshore wind developers that could also be used for training and educational opportunities. What followed was a shift to three possible project strategies: continuing with the idea of a wind generation facility, constructing a platform for research and development of offshore wind technologies, or erecting a wind testing tower that would allow components from various manufactures to be installed and tested.

DOE Funding Received

In 2009, with the support and sponsorship of U.S. Representative Bill Delahunt, HMLP received congressionally directed funding through two Department of Energy appropriations bills in the amount of $1,701,500. [Omnibus Appropriations Act of 2009, (HR 1105, PL 111-8, $951,500.), and the Energy and Water Development and Related Agencies Appropriations Act, 2010 (HR 3183, PL111-85, $750,000.)] to support their pursuit of an offshore wind farm project. This funding became an 80% federal, 20% non-federal matching grant from the Department of Energy (DE-EE-0000326).
The purpose of this grant was to determine the feasibility of constructing an offshore wind project and if so, to develop a project plan and begin regulatory permitting.

Wind Workshop

The first phase of the DOE grant consisted of organizing and hosting an offshore wind workshop. The purpose of the workshop was to summarize the work that had gone into the project to date, engage leaders in industry, government and academics to assess the possibilities mentioned above. Topics for the agenda were organized into four groups: construction, permitting, technology, and finance. Participants in the event included: Commonwealth of Massachusetts, U.S. Army Corps of Engineers, the Bureau of Ocean Energy Management, National Renewable Energy Laboratory, U.S. Department of

Energy, ESS Group, General Electric, Siemens, Nixon Peabody, Novogradac & Company, Bluefin Robotics, and Keystone Engineering.

Offshore Wind R&D Platform: The inspiration for an offshore R&D platform came from the similar work done in Europe. Examples of such a facility include FINO 1 and FINO 2 in the North Sea, and FINO 3 in the Baltic Sea (see figure 22). The purpose of the platform would be to allow oceanographic, meteorological, and technical research and environmental studies in an effort to help reduce risks for offshore turbine farms.

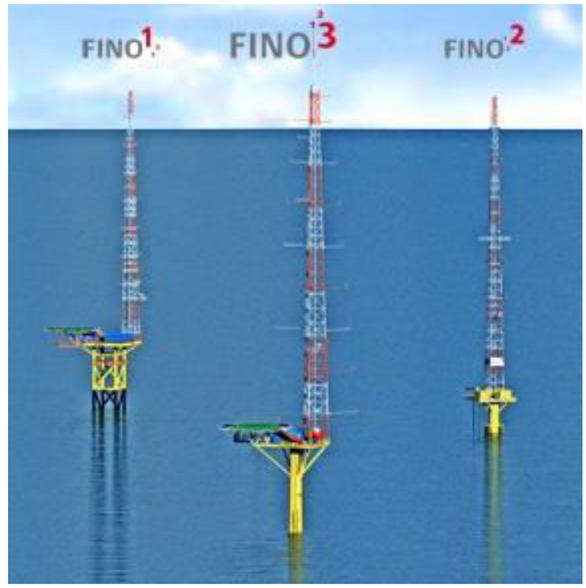


Figure 23. Graphic of FINO 1,2,3 (not locationally specific). From www.fino-offshore/de.

Offshore Wind platform and tower with interchangeable components: This designed would construct an offshore platform, likely on a gravity foundation, with a specially engineered tower that would allow turbine manufacturers to rent space and install various components for testing and/or certification. The benefit for Hull would come from a power cable to capture and use electricity generated from the platform.

At the Conclusion of the workshop, it was agreed that the physical site appears attractive for an offshore wind energy project and the proposal has no identified fatal flaws. Multiple studies and permits are required for any of the scenarios as well as detailed economic analysis and project plan development. Also, identification and availability of funding sources would be critical in determining which build scenario, if any, would be implemented.

Private-Partner Discussion

In 2011, with guidance from the EOEEA, the town entered into discussions with Spanish turbine manufacturer Gamesa, regarding the possibility of using the Hull project to establish a U.S. test site for its new G11X, 5MW turbine. Through these discussions it was learned that the turbine test stage typically involves testing a pair of turbines, one on land, and a twin offshore in the prototype phase. Once the prototype evaluation is complete, manufacturers seek installation of up to ten TWGs for testing in the offshore environment for a period of 2-5 years. While a site that accommodate all ten turbines was preferable, at least half (5) of the total would be required for serious consideration as a test site.

With the intent of enticing private development opportunities, HMLP requested and DOE granted changes to the project's scope to accommodate what would likely be a larger project than previously conceived. The scope was adjusted to reflect an array of up to five 5MW class WTGs that would collectively produce up to 25MW of power. The tower height of the WTGs would be approximately 85 meters above mean sea level, with a rotor diameter of approximately 128 meters and a length of 62 meters.

The scope change was approved in late summer, 2012 and HMLP began to address the following tasks: Fatal flaw analysis including updated FAA determinations, assessment of navigational conflicts with U.S. Coast Guard officials, gauging public support for a significantly larger project in terms of the number of turbines as well as their size. Pending outcome of public support analysis, a more detailed wind resource assessment was planned using a SODAR measurement device.

Talks with Gamesa proceeded for much of 2011 and early 2012. In the end, Gamesa chose to not move further with consideration of Hull for a test facility. Similarly, Gamesa backed out of plan to install what would have been the first offshore wind turbine in U.S. waters, a 5-MW prototype turbine three miles off Cape Charles in the lower Chesapeake Bay. Construction was expected to be completed by 2013.

In its announcement, Gamesa stated that: "an analysis of current conditions [that indicates] a viable commercial market in the United States is still farther out, as much as three or four years away, at the earliest." In the statement they described slow industry growth due to: regulatory issues, lack of an offshore grid, and the uncertain future of the Production Tax Credit. They went on to say, "Without a mature offshore wind market in the United States, it is extremely difficult to justify the enormous expenditure of capital and utilization of engineering and technical resources that would be needed to build and install a prototype in the U.S." In its announcement abandoning the project, the company also stated their intention to develop this prototype at a site off the coast of Spain's Canary Islands.

Concerns raised by HMLP officials over the projects viability without either significant governmental or private financial support prompted a requested update of the financial analysis performed by LaCapra, including comparison of the original smaller scale project with the larger proposal.

Updated Financial Assessment

In its updated analysis, LaCapra provided an objective, market based review of the financial assessment to build either a 15 or 25MW offshore wind farm. Again they examined two major cases: a town owned and financed, and privately owned and financed project. The study period was from 2016-2035 and assumed use of 3 or 5 5MW machines producing 15-25MW of power, placed close to shore, and able to support 30+% capacity factors.

LaCapra Associates

Energy Revenues (Comparison, 2009 and 2012)

	2009 Reference ($/MWh)	2012 Reference ($/MWh)
2012	62.65	n/a
2016	77.09	56.74
2020	107.23	66.22
2025	138.04	92.25
2035	176.09	140.81

[11]

Figure 24. Financial Analysis - Revenues

LaCapra Associates

Financial Model Results (assuming reference prices)

	2009		2012	
	Municipal Financing	Private Financing	Municipal Financing	Private Financing
Revenue Requirements (LCOE)	$157.12	$125.47	$219.48	$213.74
Total Revenues	$129.86	$125.86	$170.40	$170.40
Difference	($27.26)	$0.39	($49.08)	($43.34)
20 Year NPV ($000) 3 Turbine	($12,451)	$177	($25,931)	($22,898)
20 Year NPV ($000) 5 Turbine	n/a	n/a	($42,554)	($38,414)

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Figure 25. Financial Model Results. From LaCapra Assoc

LaCapra concluded the following:

- Increases in offshore wind costs coupled with reduced energy market revenues have led to challenging development environment.
- Massachusetts' RPS provides valuable revenue support but still not enough to support profitable investment.
- Capital cost assumptions are key.
- Lower capital costs coupled with higher wind resources are necessary to justify project development.
- Other barriers not considered: availability of financing and environmental impacts.

Project Concludes

In November 2012, the HMLP held a public project update meeting at Hull High School. At this meeting an update on the project status, the offshore industry as a whole, and the results of the updated financial analysis were presented to residents. This meeting was also videotaped and recast on public television.

After examining both the economic realities and existing market conditions and making an assessment of the offshore wind industry's position in the United States, the Light Board concluded that municipal funding was not a viable option and that with no significant external funding foreseen in the near future, it was impractical to proceed further and expend further funding on the project.

In order to fully examine what other opportunities may be available in renewable energy under the existing DOE grant funding, HMLP engaged in discussions with DOE to examine the possibility of exploring other renewable energy resources as either supplements or alternatives to offshore wind including: solar, wastewater geothermal and tidal/current sources.

However after further investigation, DOE informed HMLP that movement away from offshore wind, essentially reprogramming the grant, would require a physical language change in two federal statutes resulting from the original authorizing legislation. After consulting with elected officials and project partners it became clear that attempting such a change was unrealistic and not advised. Faced with this reality and a looming grant expiration date of March 31st, the HMLP Board of Commissioners voted unanimously to discontinue the project on March 28, 2013.

Market/Industry Factors

The offshore wind market as a whole played a role in determining the fate of Hull's initiative.
In late 2012, globally installed wind power capacity stood at 241,000MW. The United States ranked second at 49,802MW, or enough to power approximately 13 million homes (AWEA, 2012). In the offshore wind sector (OSW), there were roughly 4,000MW installed globally, none of which was in the U.S. The domestic offshore resource potential was estimated at 4,150,000MW.

Some of the commonly stated benefits to developing offshore wind include: greater wind resource potential, stronger and more consistent winds that blow at times of high energy demand (day and early evenings), high wind resource areas near major demand centers such as the northeast U.S., the ability to deploy larger turbines offering greater capacity and efficiency through increased rotor diameter and taller hub heights, as distance from shore increases impacts on viewshed, flicker, and noise disturbance are minimized.

Most of the challenges in developing wind power offshore surround its higher costs, at least twice the costs of its onshore counterparts. Several of the factors that influence the cost include: lengthy permitting and review process, absence of a developed supply chain including U.S. flagged construction vessels, port facility upgrades, and near-port manufacturing facilities; larger machines (taller, heavier, larger blades and nacelles); more expensive foundations; higher installation and O&M costs; lack of an offshore power grid requiring full interconnection build by farm developer; and high investor risk resulting in elevated financing costs.

Many analyses of the offshore wind market show bright prospects and expect it to play an enduring role in the nation's energy mix in the coming 20 years. But in order to do so, the industry needs to bring costs down to where OSW can compete in the energy mix with little or no subsidy. An analysis by Price Waterhouse Cooper identified several critical factors shaping offshore wind's future in the U.S. (PWC Offshore wind power survey, 2011):

1. Scale (larger turbines and larger wind farms)
2. Technological and engineering innovations (such as floating turbine technology)
3. Overcoming Supply chain constraints
4. Funding transmission infrastructure
5. Costs of fossil fuels
6. Consumer sentiment towards paying subsidies
7. Ability to minimize investor risk
8. Regulatory certainty and clear government goals
9. Whether technological breakthroughs in OSW will be overtaken by breakthroughs in other renewable energy technologies

U.S. Federal Offshore Wind Strategy

To address these challenges, the federal government has set a goal of developing 54 GW (54,000 MW) of OSW by 2030, at $0.07 per kWh and an interim goal: 10 GW (10,000MW) deployed by 2020, at $0.10 per kWh (Doe, 2011). The objectives of this strategy are to reduce the cost of offshore wind energy and reduce the deployment timeline through: Investment in technology development, Market barrier removal, and advanced technology demonstration.

Production Tax Credit

In late 2012 the Production Tax Credit (PTC), the primary incentive for the industry was set to expire. The PTC provides an income tax credit, currently at 2.2 cents/ KWh, for electricity produced by wind (and other qualifying renewables) and greatly reduces the overall cost of development. It was clear that with no certainty that the PTC would be renewed and dimmed hopes of a national clean energy standard or significant climate legislation on the horizon, offshore developers were not advancing projects and in several cases were shrinking U.S. workforces and plans. In 2013 the PTC was extended for one additional year.

Lessons Learned

Hull provides a near-shore opportunity for an offshore wind facility of moderate water depth, access to several deep water ports including Boston and New Bedford, and is proximal to the Wind Blade Test Center in Charlestown, MA for a developer who wishes to establish a testing facility for its turbines.

The Town is traditionally in favor of offshore wind power provided it is economically advantageous.

There were no fatal flaws found that would prohibit construction of such a project up to the 499’ ceiling (based on FAA determinations). Impacts to navigation appeared to be manageable based on discussions with Coast Guard officials. Preliminary assessment of grid interconnections found no major obstacles.

Offshore wind facilities involve an exhaustive amount of study, assessment and review compared to their onshore counterparts. The nature of working in the marine environment results in longer timeframes for permitting, and significantly higher costs.

Regulatory and general market uncertainty in the offshore wind space made finding private partners difficult. If identified, a private partner would need to make significant financial investment in the project in order to make it feasible.

Due to the high costs involved in construction, operations and maintenance, and cost of energy based on current market factors it is not financially feasible at the present time for a small community (just over 6,000 ratepayers) to shoulder the costs of such a project.

It is important to conduct initial financial assessments and modeling at the earliest possible point, to determine if further expenditures on site assessment and permitting are justified.

Community/stakeholder involvement - Throughout Hull’s history of wind power projects, community involvement has been a critical component to its success. Over the course of the offshore project’s development, it was discussed regularly at Light Board meetings, reported on in local and regional press, and included several public meetings where project update presentations were made and visual simulations were presented. Compared to the two earlier land-based initiatives, achieving public engagement proved to be more challenging in the offshore project. This may have been in part to the preliminary stage of development at which the project was in. Since this project is expected to create a certain amount of opposition, it was anticipated that a very active outreach campaign would be critical to the project gaining public acceptance. Due to its impacts on the neighboring communities, primarily in terms of visual appearance, critical partnerships would need to be fostered.

A comprehensive assessment of the projects impacts on tourism would need to be addressed. Hull relies economically on a robust summer tourism industry. How this project, sighted just offshore from Hull's popular beaches, would impact (positively or negatively) tourism would be a critical component of the project's assessment process. Finally, as seen in the success of Hull I and II, local leadership in the form of project champions is critical. Either re-engaging former wind champions or identifying new ones would be necessary and important for project success.

According to town officials, Hull's wind initiatives were promoted as projects that made good business sense, producing an economic benefit for its ratepayers including low to moderate electricity rates and rate stability. These benefits helped residents look beyond some of the adverse impacts of wind power installation. In the case of the offshore project, preliminary findings did not meet these criteria. As a result, officials concluded that the costs of moving forward with the project outweighed its benefits and that the positive public view of wind energy which had existed on Hull I and II would not be present under existing market conditions.

Timeline-Offshore Wind Project

2003	Idea emergence
2006	MTC forgivable loan
2006	Studies/assessments begin
2007	ENF filed
	Wind/desalinization study (Bureau of Reclamation)
	Wind Data Report, WBZ Tower
	Hydrographic/geophysical surveys
2008	MEPA Certificate issued
	Notification of EIR requirement
	Working group established
	Initial FAA approvals
	Vibracore sampling
	Benthic habitat assessment
2009	Financial feasibility assessment
	Archeological assessment
	DOE funding received
2011	Offshore Wind Workshop
	Public/private partnership discussions
2012	Scope change to increase size of project
	FAA determinations up to 499'
	Updated LaCapra economic feasibility study
	Public meeting
2013	Commissioners discontinue project
	DOE Grant period ends

Figure 26. Timeline – Offshore Wind Project

Required Studies/Assessments/Permits

STUDIES/ASSESSMENTS REQUIRED
Geophysical survey
Geotechnical analysis
Marine resource sampling and analysis
Sediment transport
Rare species and avian/bat impact assessments
Fisheries/lobster and marine resources assessment including essential fish habitat
Impact analysis on commercial and recreational fishing
Visual impact analysis combined with historical and archeological study
Air quality assessment (Greenhouse Gas Emissions Policy)
Archeological survey
Land alteration
Wetlands impact assessment
Water quality impacts assessment
Noise impact analysis
Alternatives Analysis
Construction/maintenance/decommissioning plans
Environmental monitoring plan
Environmental Impact Report
PERMITS/ APPROVALS REQUIRED
MEPA Review
Chapter 91 License
Chapter 91 Dredge Permit
401 Water Quality Cert.
National Heritage & Endangered Species Program Review
Mass Historical Commission Review
CZM Federal Consistency Review
Order of Conditions – Conservation
ACOE Section 52 Nationwide Permit
USCG Aid to Navigation Permit
EPA Non-Point Discharge Elimination Permit
FAA Determination of No Hazard

Figure 27. Required Studies/Assessments/Permits

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Appendix 2: LaCapra Financial Study

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Appendix 4: Geophysical/Geotechnical Studies