# Utility Scale Wind Turbines on a Grid Connected Island

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## Abstract

This paper analyzes the technical and economic feasibility of installing utility scale wind turbines on Fox Islands, located 12 miles from the coast of Maine in the United States. The nearly 1600 year round residents on the islands receive their electricity from the mainland via undersea cables. Due to the high cable cost, transmission charges to customers are nearly twice the cost of electricity itself. Three locations are analyzed in detail as potential sites for wind turbine installations. Annual hourly load and wind speed data was available for the island. As discussed here, the logistic problems of transporting and installing wind turbines on the island will require innovative solutions. These include locally available amphibious vessels, which can land turbine components at suitable shallow spots on the island, self-erecting towers, which allow use of a smaller crane for installation and a special turbine foundation suitable for the local ground conditions. For the economic analysis, the market for Massachusetts Renewable Energy Credits (REC) was considered. This work concludes that the installation of sub-megawatt wind turbines on the island is logistically possible and will lead to a reduction in the cost of electricity to the customers.

## Description of Fox Islands

The Fox Islands are located 12 miles from the coast of Maine off Rockland. Vinalhaven and North Haven are the two main islands that make up the Fox Islands. Vinalhaven, with approximately 1200 year round residents has the largest population of the 14 year round inhabited islands in Maine. Lobster fishing is the main component of its economy. The island is approximately 9 miles long and 6 miles wide. North Haven, the second largest island of the group has a year round population of 350. Since the island has mostly summer homes, the island population increases many folds in the summer.

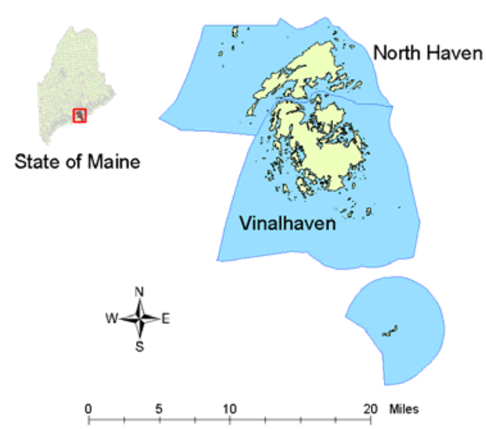


**Figure 1:** Fox Islands Political Boundary

## Electricity Supply

Fox Island Electric Cooperative (FIEC) has been providing electricity for Vinalhaven and North Haven since 1975. In 1977 the cooperative installed submarine cables between Vinalhaven and the mainland. Figure 2 shows the average monthly load from September 2002 to August 2003. The curve shows two peaks, one during August, due to tourists, and the other in January, attributed to the winter load.

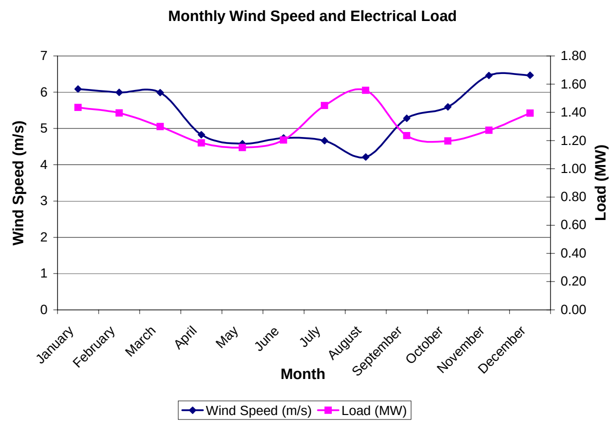


**Figure 2:** Average monthly wind speeds and electric loads

## Proposed Power System

The customers of FIEC are paying a high charge for electricity (about 15¢/kWh) due to high transmission charges of 10¢/kWh. FIEC is considering electricity generation from wind turbines (sub-megawatt sized) on the island to offset these charges. At the present time, only Vestas supplies a suitable sub-megawatt turbine in the form of the V47-660 kW machine. The wind turbines will be connected to the distribution grid on the island. Electricity generated will offset the electricity purchased from the mainland. If electricity in excess of the local demand is generated, it will be fed into the mainland grid via undersea cables. The feasibility of the proposed power system is evaluated from the resource, logistic and economic point of view. Detailed evaluation has been carried out for installation of 1, 2 or 3 wind turbines at the proposed sites.

## Wind Resource

Figure 3 shows the wind map for the Fox Islands. Onshore wind speed varies from 6.5 m/s to 7.5 m/s. Higher wind speeds are found offshore. RERL has been monitoring the wind speed on Vinalhaven since August 2002. Wind speeds are observed to be lowest in summer and highest in winter (Figure 2). SSW is the most frequent wind direction. For siting wind turbines on Vinalhaven, different sites are being considered. Wind speeds at the monitoring site cannot be directly used for these different sites. Thus, for this study, average wind speed at hub height was found using the New England Wind Map [1]. The hourly monitored wind speed was then scaled to the new average to get representative hourly wind speed time series at the selected sites.

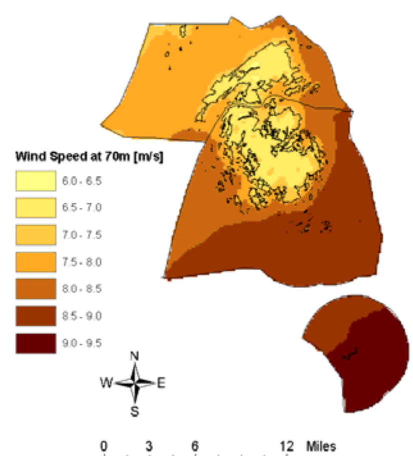


**Figure 3:** Wind Map at 70m height

Source: New England Wind Map by True Wind

## Transportation and Installation

Since the site is located on an island with limited infrastructure there are unique transportation and installation challenges. There is a regular ferry service between Vinalhaven and Rockland. Vinalhaven has a pier with a load bearing capacity of 80,000 lbs. This capacity is suitable for landing the wind turbine components on the pier. However, the pier is located in the most densely populated part of the island. Therefore, for equipment to be transported from the pier to the site, it needs to pass through narrow roads and sharp turns. While the nacelle, turbine rotor and tower sections can be transported using the pier, alternate transportation arrangements are required for transporting the blades due to the large turning radius of the transportation truck.

One such alternative is using an amphibious vessel. A local company in Rockland undertakes transportation to the island using such a vessel. Figure 4 shows a photograph of the vessel. The vessel with a length of 95 ft and width of 28 ft can carry up to 100 tons of gross weight. The vessel can be landed at a suitable shallow landing point near the potential site for the turbine installation. The blades can then be transported to the site using the existing roads or new roads may need to be constructed.

**Figure 4:** Amphibious vessel

Source: Island Transporters, Rockland, ME

To allow for installation of the V47 on the island, with tower sections supplied by Vestas, a crane is required for lifting the nacelle (20.4 Tons weight) to a hub height of around 60m. Transportation of such a crane to the island is not feasible. Valmont's Wind Energy Structure [2] addresses this problem by allowing use of smaller cranes for wind turbine installation. Presently the company supplies "self erecting" towers only for the V47. For installation on site a 70-ton Linkbelt hydraulic truck crane with extended boom package or a standard 90-ton hydraulic crane is required. The 70-ton Linkbelt hydraulic crane in available in Rockland and has been transported to the island using the amphibious vessel.

Conventional wind turbine foundations require large quantities of concrete and water. Vinalhaven is a rocky island and use of conventional foundations will require a large quantity of rock to be removed by blasting. For turbine installation on a rocky site rock anchor foundations can be used.

## Economic Analysis

Three sites were selected for detailed analysis – Isle au Haut, Round Neck and Leadbetter Island with average wind speeds at 70m of 6.9m/s, 7.5m/s and 7.8m/s respectively. A detailed costing was done for each of the sites considering the cost of wind turbine, tower, foundation, electrical interconnection, road construction, site preparation, transportation, installation and dismantling. A brief description of the economic analysis follows.

In April 2002, Massachusetts implemented a Renewable Portfolio Standard (RPS), requiring retail electricity sold in the state to include a minimum percentage of electricity with renewable attributes. With RPS the environmental attributes of electricity are unbundled from the electricity itself. This is done using Renewable Energy Credits (REC). Maine also has an RPS, but the inclusion of hydropower in the definition of renewable energy precludes the development of wind energy in the state. Both Maine and Massachusetts are part of the New England Power Pool (NEPOOL) which is a voluntary association of entities engaged in electric power business in New England. NEPOOL has a single regional electric transmission network. Massachusetts allows electric suppliers to achieve compliance using certificates from generation sourced anywhere in NEPOOL or an adjacent power pool, provided that the power flows onto the NEPOOL grid. Therefore REC from electricity generated in Maine can be sold to a utility in Massachusetts. REC are currently trading at $38/MWh [3].

For the Fox Islands there are two alternatives for selling the excess electricity generated. The electricity can either be sold to a ‘brown utility’ (Utility not using renewable energy) while the attributes can be sold as REC in Massachusetts. The other alternative is to sell electricity through a local non-profit organization as ‘green electricity’. REC cannot be claimed for this electricity since it is being sold as green electricity. We assumed that market forces would ensure that both alternatives yield the same economics. The analysis is therefore carried out for the first alternative with 3.5¢/KWh as the selling price of electricity.

The economic analysis was carried out using a 20% down payment, 20-year loan and system lifetime, 4% loan interest rate, 2% inflation rate and 3% discount rate. The levelized cost of electricity purchased was calculated for the present case (no wind energy) and with wind energy included. With inclusion of wind energy, capital cost and yearly costs are included in the calculation for the net present value of savings compared to the present case. Table 1 lists the results for the analysis which includes the income from REC but does not include the Renewable Energy Production Incentive (REPI) that expired in September 30, 2003.

**Table 1:** Savings over 20 years from Wind Turbine Installation

| | NPV of savings ($ million) | | |
|---|---|---|---|
| No. of wind turbines | **1** | **2** | **3** |
| Isle Au Haut | 1.04 | 2.19 | 3.25 |
| Round Neck | 1.28 | 2.65 | 4.02 |
| Leadbetter Island | 1.63 | 3.55 | 5.48 |

**Offshore wind energy**

FIEC also expressed interest in offshore wind energy for the future. An analysis was carried out using Geographic Information Systems (GIS) to determine the most favorable locations for offshore installations (a raster analysis with a cell size of 200x200m was used). The cost of electricity generation was evaluated for each cell assuming that cell to be the center of a wind farm (consisting of 10, GE1.5 MW wind turbines) and conditions (water depth [4], wind speed [1], and distance of cable travel) for the whole farm being the same as the selected cell. Only areas with water depth less than 30m are considered for the analysis. The cable length to the interconnection point on the island was calculated using a cost function of 1 for travel over land and 5 for travel undersea to account for the differential cost of transmission. A simple cost model was used for evaluating the levelized cost of energy over a 20-year period using the same interest, discount and inflation rate as the earlier onshore analysis. Costs were included for wind turbines, support structure material, wind turbine installation, cable to landing point on the island, balance of station and operation and maintenance. Figure 5 shows the levelized cost of energy for the offshore installation. The best potential is on the south east of Vinalhaven with a cost of energy around 6.5¢/kWh excluding REC. This is a very economic price for offshore wind energy. The reason for the low cost of energy is the combination of low water depth (less than 20m), high wind speed (8.5 – 9.0 m/s) and less distance to the island (~1 mile).

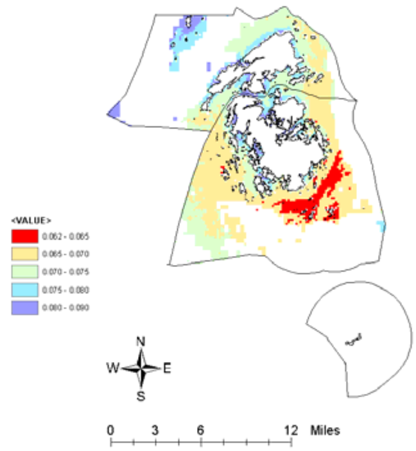


**Figure 5:** Cost of energy for offshore installation

## Conclusions

Fox Islands have a viable potential for wind energy. Out of the three selected sites, Leadbetter Islands shows the highest potential. Public acceptance and permitting may finally be the deciding factors in selecting the final site. With 14 year round inhabited islands in Maine, this project could serve as a model for wind energy development in the State.


## Acknowledgement

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## References


[1] New England Wind Map by True Wind Solutions (http://truewind.teamcamelot.com/ne/)

[2] Valmont Industries (http://www.valmont.com)

[3] Evolution Markets LLC (http://www.evomarkets.com)

[4] Gulf of Maine Coastal Program (http://gulfofmaine.fws.gov)