Renewable Energy in Future Bayside Projects?

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Save Barnegat Bay Student Grant Program 2019

Abstract

During the seven-week sampling period that took place from 6/15/19-7/26/19, wind and solar measurements were considered in order to understand the feasibility of running bayside projects on renewable energy. An example of such projects is the raised bed shellfish growing operations (upweller systems) carried out by ReClam the Bay. Upweller operations were used as the focus in this study as a clear example of grid-tied energy being used at several locations along Barnegat Bay. Through weekly visits of three sites including Sedge Island boat dock off of Island Beach State Park, Holiday Harbor Marina in Waretown, NJ and the Waretown OCVTS school site, it was noted that the sites closer to the shore had consistently higher average wind speeds, further supporting existing coastal wind energy initiatives. When comparing the Helix and Standard three-blade turbines in the wind tunnel located in Waretown, NJ, the Standard turbine exhibited a higher voltage output to the battery and began charging the battery at a lower wind speed; however, this turbine was a 400 W system, whereas the helix turbine was a 300W system. Solar availability did not differ among the sites as was expected. With average weekly wind speeds maxing out at 10.9 and 4.1 mph for Sedge Island and Holiday Harbor respectively, it is concluded that grid tie-ins or sufficient battery storage would still be necessary to safely and consistently run upweller operations.

Introduction

In seeking methods to alleviate environmental strain and lessen grid dependency, the use of alternative energy has gained traction in recent years. According to a study done on upwelling currents by Snyder et al., ocean temperatures, land temperatures and coastal wind stress affect the upwelling events, causing them to occur later in the year. These changes are linked to increased atmospheric CO_2 associated with climate change (2003). The more intense storm action and storm frequency generally associated with climate change can play a part in this. Wind energy is generally an unpopular alternative energy method. Negative assumptions about wind and wind turbines include the thought that nuisance noise or shadows will come from turbines, turbines make areas look more developed and lower property value, or that turbines block valuable or desirable views (Carter, 2011). Another challenge with the use of wind energy is that the turbines generally must be very tall in order to be successful in power generation. Figure 1 below shows the predicted average annual wind speeds in New Jersey at a height of 80 meters.

Wind development is generally considered suitable at speeds of 6.5 m/s (20 ft/s) or greater (WIND Exchange). New Jersey's coasts do meet this minimum requirement, but the height requirement of 80m makes gaining permits and funds for building difficult and often discourages the use of wind. Orsted, a Danish wind developer recently landed a contract for a 1.1 gigawatt wind farm project that is expected to power over half a million homes (Stromsta, 2019). This is New Jersey's first offshore wind project, paving the way for future coastal projects. Smaller, more isolated systems used to sustain smaller projects are a feasible option in the meantime of larger grid-wide projects, and they can still make an impact on lessening grid dependency.

Solar has become one of the cheapest sources of new energy (O'Boyle & Blumenthal, 2018). The positive incentives surrounding solar technologies including job opportunities and money savings opportunities for customers create momentum for renewable projects. The most recent target outlined for New Jersey is to reach 650 megawatts of energy produced with renewables. Additionally, New Jersey also has a "requirement of supplying 5.1% of retail sales with distributed solar energy by 2021, while empowering renters and low-income customers to access clean energy" (O'Boyle & Blumenthal, 2018). The use of solar energy as an alternative energy source is widely more popular than wind; however, it is generally less efficient than wind energy. Current monocrystalline commercial solar panels on the market maintain between 15 and 20% efficiency at full capacity (Energy Informative). Figure 2 below lays out the average solar potential for the state of New Jersey based on panels tilted at the appropriate angle according to latitude. Coastal areas, including the sites included in this study, have an average yearly solar potential of about 4.4 kWh/m2/Day.

Sedge Island maintains a solar panel array paired with lead-acid battery storage in its main boathouse (Figure 3). Major complications found with the system include degradation of the panels over time due to seagulls dropping shells on the unit, saltwater corrosion, and battery degradation over time. Batteries like those utilized in the Sedge Island system range from $100-$400 per battery according to the wholesale market depending on the storage capacity. Battery storage technology remains one of the largest obstacles and most important components in the reliability and consistency of energy powered by renewables. With units like the ones utilized in this study, battery connection is essential in the operation of the turbines. The charge controller included with solar arrays and turbines will not allow for the overcharging of batteries or the burnout of equipment such as pumps like those in coastal clam bed operations. Including the battery storage in the circuit allows for the excess energy to be stored, the charge controller to withhold stopping mechanisms, and the turbines or panels to run at full capacity.

Currently, most bayside projects are run primarily on the grid, including the ReClam the bay lifted clam- bed operations. In the summer of 2018, a project was conducted through the Rutgers Cooperative Extension and ReClam the Bay to observe the effect of different water quality parameters on the growth of clams and oysters in three upwellers in Barnegat Bay. ReClam the Bay is a local non-profit organization that manages the growth of juvenile clams and oysters (seeds) to be released throughout the Barnegat Bay Watershed (http://reclamthebay.org/what-we-do/). At marinas throughout the Barnegat Bay system, ReClam volunteers maintain nine upweller boxes that flush growing seeds with aerated water directly from the bay using electrical pumps. Research done by the Rutgers Cooperative Research & Extension program supports that larger seeds have better survival rates, making the upwellers essential in clam and oyster conservation initiatives (Flimlin & Kraeuter 2003). The volunteers run educational programs where they speak about the importance of conservation and the details of the upwellers' function. These clam nurseries are tied to the main electrical grids of the marina and run 24 hours a day.

Working closely with the upwellers sparked the question of whether bayside projects, such as upwellers, could be run on renewable energy or not. Through the Save Barnegat Bay Student Grant Program, the feasibility of running bayside project operations on renewable energy was able to be tested. This study focused primarily on the capability of two differing wind turbine types, although solar was considered in sampling for comparison with the Sedge Island array.

It is hypothesized that a combination of solar and wind will account for at least half of the energy necessary to run estimated upweller operations. The approximate costs for the alternative energy components and model upweller components can be found in Table 1 below.

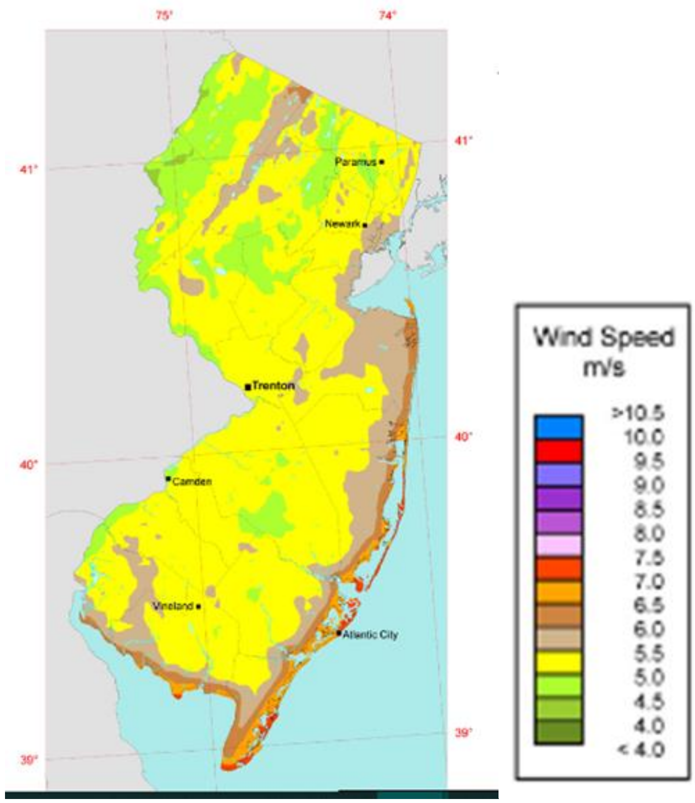


Figure 1: Wind resource map from the National Renewable Energy Laboratory with predicted mean annual wind speeds at a height of 80m (WINDExchange).

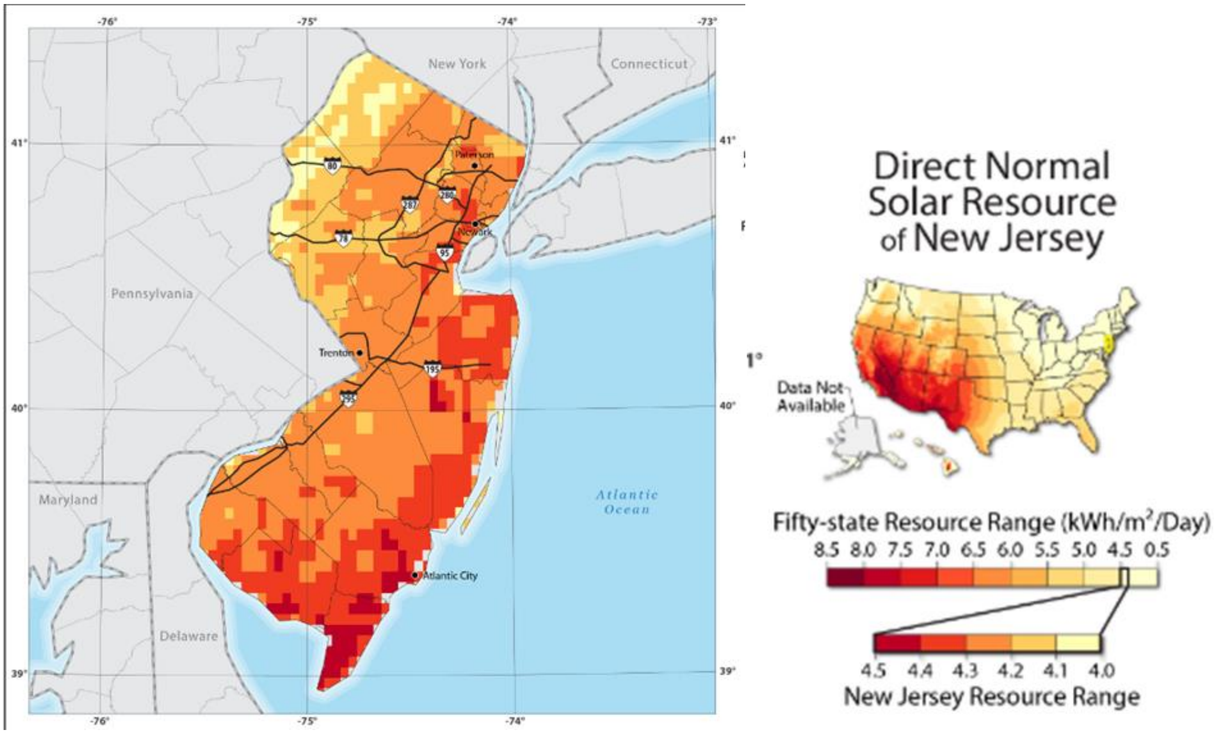


Figure 2: Annual average solar resource potential for New Jersey in kWh/m2/Day (NREL 2017).

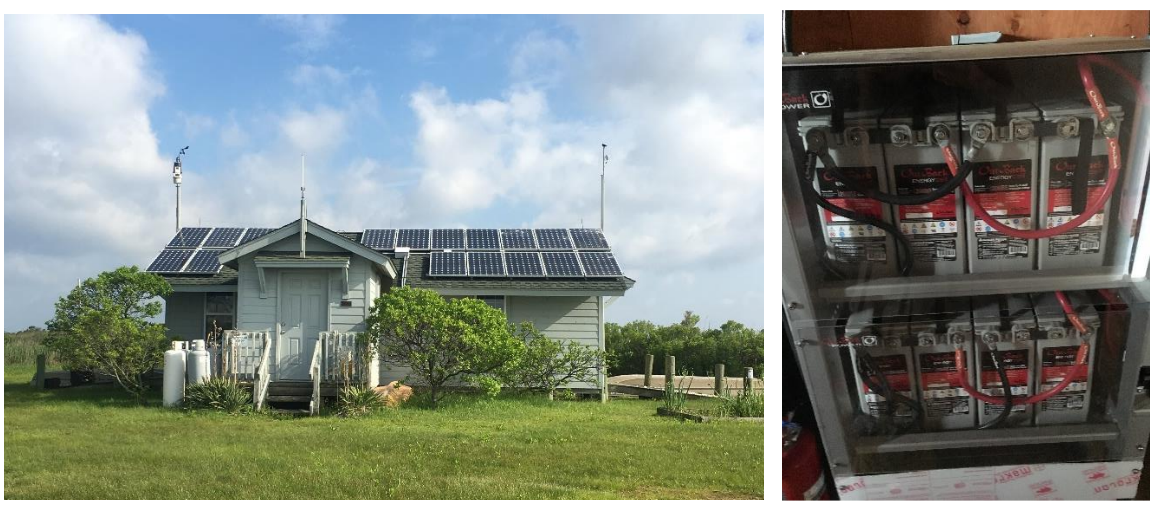


Figure 3: Solar array located at Sedge Island including battery storage found within the boat house.

Table 1: Approximate prices for alternative energy components. All pricing based on Amazon.com

Component	**Approximate Cost**
Helix wind turbine (Taishi 300 W)	$320
Standard 3-blade (MarsRock 400W)	$285
Solar Panel Array (Renogy 1KW)	$300
Deep Cell lead acid battery (Renogy 12 V 100Amphours)	$235
Submersible water pump (SEAFLO 12V)	$80

Methods

<u>Study Sites:</u>

The three sites utilized for sampling during this study were the Sedge Island boat dock at Island Beach State Park (A-21), Holiday Harbor Marina in Waretown, NJ and the Ocean County Vocational Technical site in Waretown, NJ. Figures 4-6 below shows map images of the three sites. Two of the sites were considered coastal sites and the OCVTS site was utilized as an inland control. Weather station data from Weather Underground ® was matched with the Sedge Island (KNJWARET3) and the Holiday Harbor (KNJWARET5) sites.

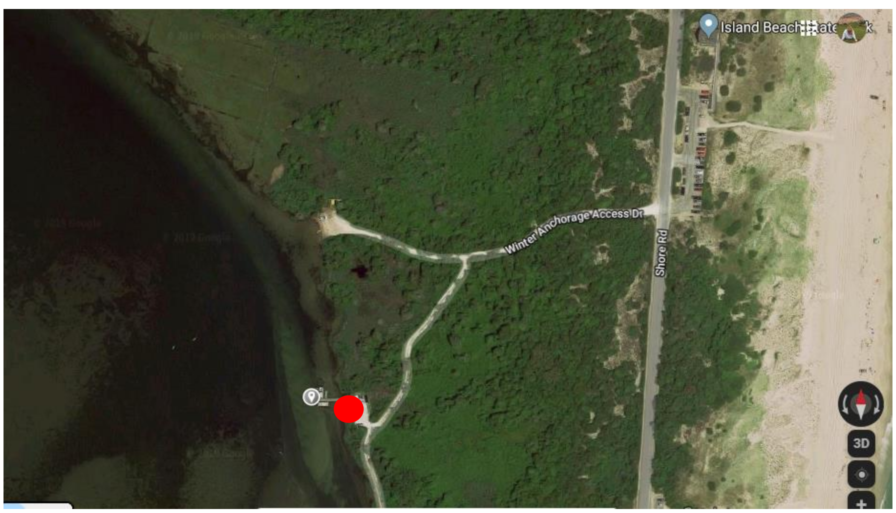


Figure 4: Satellite map image of Sedge Island dock. The Red dot indicates where wind, solar, and air temperature samples were taken.

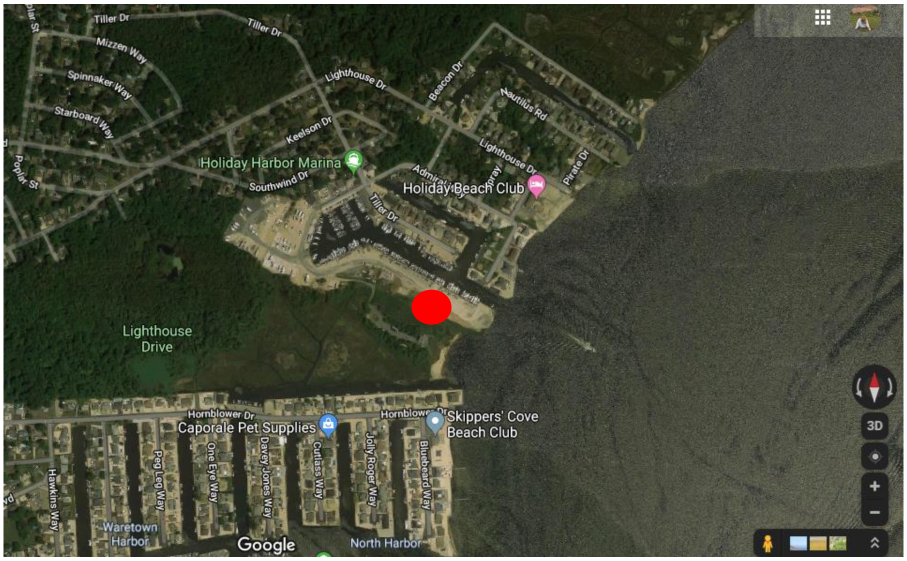


Figure 5: Satellite map image of Holiday Harbor Marina site. The Red dot indicates where wind, solar, and air temperature samples were taken.

Figure 6: Satellite map image of the Waretown OCVTS site. The Red dot indicates where wind, solar, and air temperature samples were taken.

<u>Weekly Sampling/Data Collection</u>:

Between June 15 and July 26, 2019, measurements were taken each week. Wind speed (mph), air temperature (°F), and solar light intensity(lux) were taken at each of the three sites except for the week of June 15 when the OCVTS Waretown inland location was not sampled. Each parameter was measured three times in a ten-minute period. For wind speed, the Kestrel anemometer was used on the avg wind setting, and each of the three measurements was taken over a one-minute time span. Air temperatures were taken using a thermocouple meter. Solar light intensity was measured using a Milwaukee lux meter at location unobstructed by trees or buildings at each site. Wind data was collected from the weather stations at Sedge Island and near Holiday Harbor, and a solar radiometer was installed on Sedge Island's weather station to allow for solar intensity to be compared to the sampled measurements.

Construction:

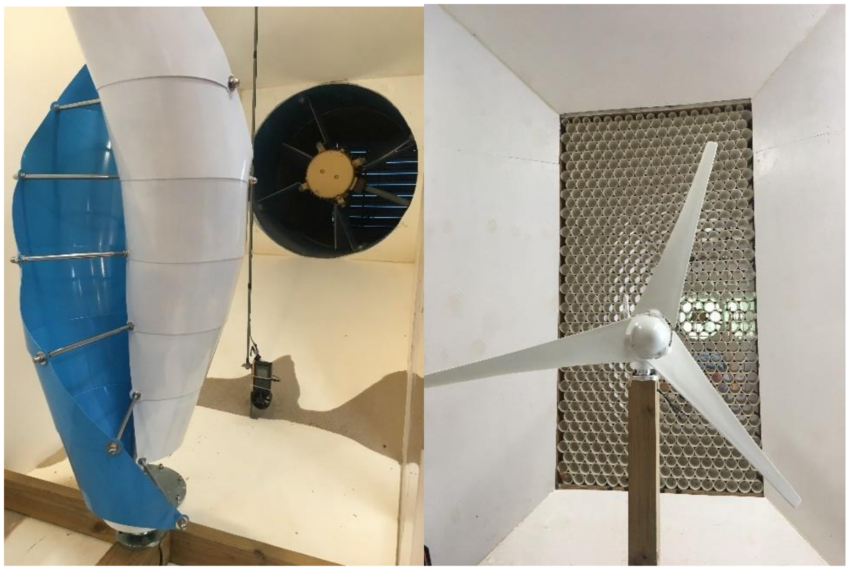
Prior to wind tunnel testing, a model upweller, as well as the two wind turbines were constructed. The model upweller (Figure 7) was constructed with a sturdy plastic storage container. A hole was drilled near the top of the container for the water outflow, and a hose spicket was attached using screws and a water sealant glue. Three 2-gallon buckets were used to simulate the drums where clams are kept in on-site upwellers. Holes were drilled near the bottoms of each bucket, and clear tubing was used to connect the buckets and container to the 12/24 V submersible pump (Figure 8). The pump was submerged in a bucket outside of the main container which would represent the bay or main source of water being pumped into the upweller.

The Taishi 300 W, 24 V helix turbine (Figure 9) was constructed, and the three-phase output was wired directly to the charge controller provided. The charge controller's positive and negative wires were prepared to be wired to the submersible pump. The turbine was mounted onto a wood stanchion to support it during wind tunnel testing.

The MarsRock 400 W, 12 V standard 3-blade turbine (Figure 10) was constructed, and similarly to the helix turbine, the three-phase output was wired to the charge controller. The charge controller was also prepared for connection to the submersible pump. This turbine was larger than the allowed space within the wind tunnel; therefore, the wood stanchion was prepared outside of the tunnel where wind exits the facility.

Figure 7: Model upweller with three 2-gallon white buckets representing the drums where clams would be held in a functioning upweller.

Figure 8: Submersible pump utilized in model upweller during wind turbine testing. The pump is rated for 12 or 24 V and can handle a maximum amperage of 8 amps at 12V operation. Cost for pump was $80.



Figures 9 &10: Taishi 300 W 24 V helix turbine utilized for this study (left). Cost for this turbine was approx. $320. MarsRock 3-blade 12 or 24V turbine (right). Cost for this turbine was approx. $285.

<u>Wind Tunnel Testing</u>:

On Monday August 5 and Tuesday August 6, 2019, the wind tunnel was utilized for testing the power output capabilities of the two different wind turbines. The wind tunnel was set in intervals between <0.1 and 60 Hz allowing for measurable wind speeds between <0.1 and approximately 35 mph. Wind speeds within the tunnel were measured by a stationary anemometer, and wind speeds at the outflow of the tunnel were taken using a Kestrel handheld anemometer. The helix turbine was positioned within the main chamber of the wind tunnel, and the standard turbine was positioned at the outflow of the tunnel because its width prevented it from being in the main chamber.

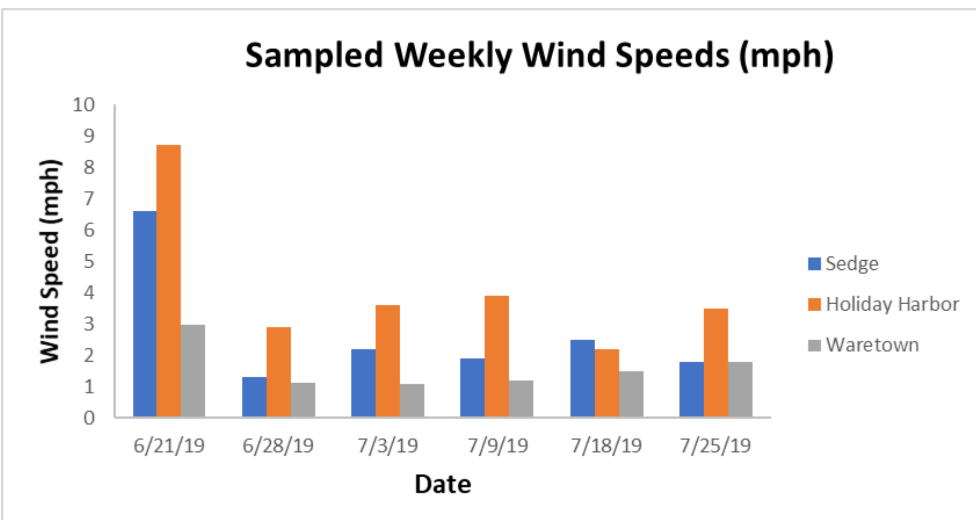
<u>Data Analysis</u>:

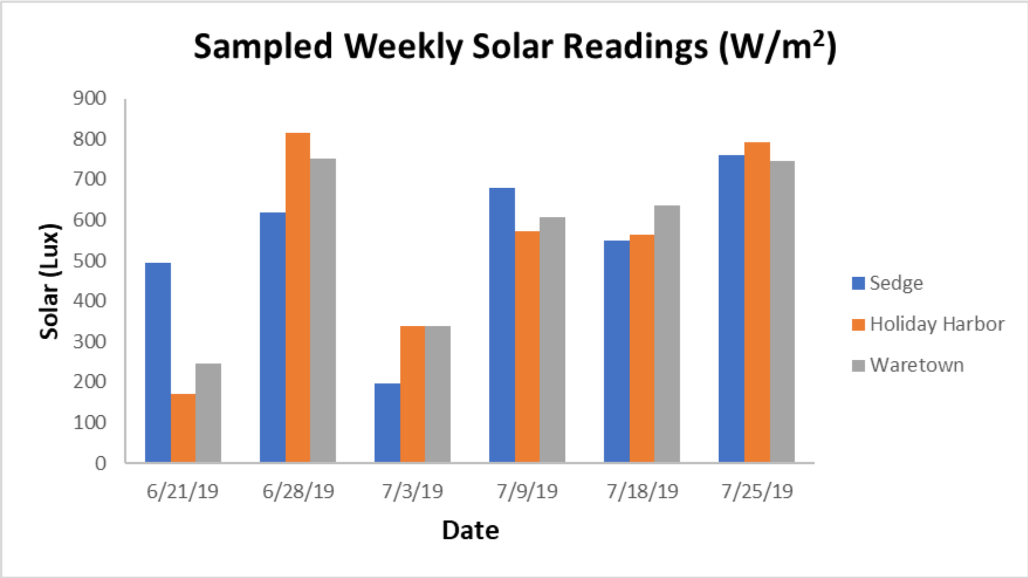
The weekly sampled wind speeds, air temp, and solar intensity were compared across the three sites using an ANOVA. For ANOVA testing, only the last 6 weeks (6/21/19-7/26/19) were used because Waretown OCVTS was not sampled in week one. All sample data in each of the categories was averaged for this 6-week period. Additionally, the solar intensity was converted from lux to Watt/m^2 using the formula lux* 0.0079=W/m^2. The voltage output for each of the turbines was plotted against the corresponding wind speed of the wind tunnel. The speeds at which the battery began charging were noted, and these speeds were compared to the wind speeds seen in field sampling.

Results

Weather Data:

Over the course of the primary 6-week sampling period, it was found that the average wind speed measured for each of the three sites were 2.7 mph for Sedge Island, 4.1 for Holiday Harbor, and 1.6 for Waretown OCVTS. The p-value for the ANOVA that included all measured data was 0.0822 meaning that there was no statistical difference among the data sets. The average solar intensity in W/m2 for Sedge, Holiday Harbor, and Waretown OCVTS were 550.1, 545.42, and 554.14 respectively. A p-value of 0.99 from the ANOVA analysis reflects that the difference between the means for the three sites was not significantly different, and there was no difference in solar intensity for inland versus coastal sites. The average weekly air temperatures were 82.0, 83.6, and 85.2 for Sedge, Holiday Harbor, and Waretown respectively. The inland Waretown site consistently had the highest air temperatures. The weekly numerical data can be seen in Figure 11 a-c below. According to the data collected from the weather stations, the average wind speeds for the sampling period were 10.9 mph for Sedge Island with average wind gusts between 12.3 and 17.7 mph, and 4.1 mph for Holiday Harbor with average gusts between 5.3 and 6 mph. For the weeks that the weather stations at Sedge Island and Holiday Harbor both collected wind data, a t-test was done. The t-stat was 9.39, and there was a significant difference in the wind speeds. Considering the weeks that the solar radiometer collected data consistently on Sedge Island, the average solar intensity was 871.2 W/m^2.





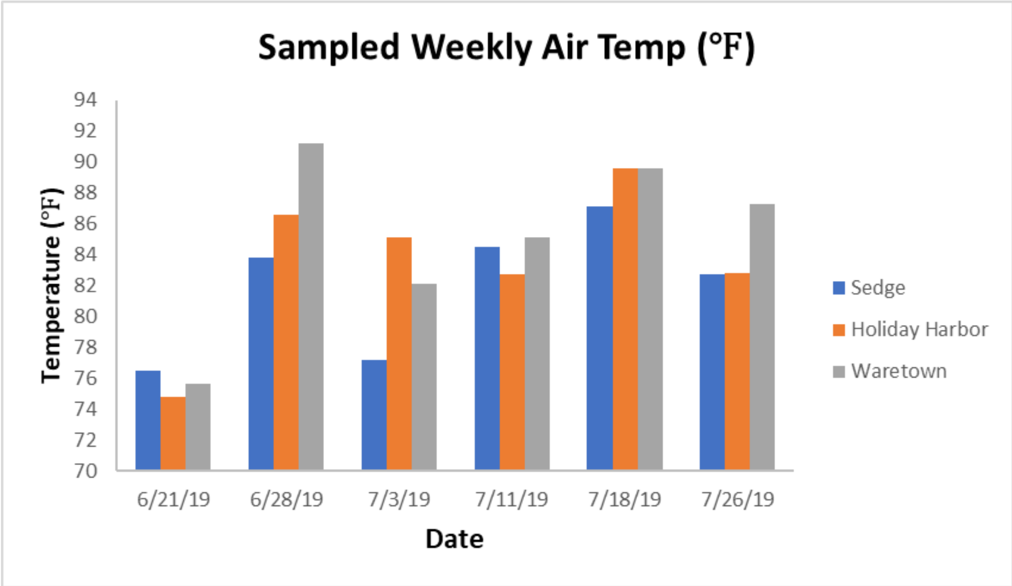


Figure 11 a-c: (top-bottom) Bar graphs with weekly sampling data. Mean wind speeds were 2.7, 4.1, and 1.6 for Sedge, HH, and Waretown respectively. Mean solar intensities were 550.1, 542.4, and 554.1. Mean air temperatures were 82.0, 83.6, and 85.2.

Wind Tunnel Testing:

During the wind tunnel testing of the helix turbine, the turbine began movement at only 3 mph. The battery connected to the system was able to maintain charge and the pump was able to run starting at 3mph; however, the battery did not start charging due to power provided by the turbine until the wind speed reached 23 mph within the tunnel. With the tunnel at peak wind speed of approximately 35 mph and the battery attached, the helix remained in full operation without the charge controller needing to limit the amperage flowing to the battery and pump. When the battery was disconnected at this speed, the charge controller activated, lowering the turns per second of the turbine and preventing too much amperage from reaching the pump. When the turbine was providing 12V to the battery, the 300 W turbine was providing an amperage of 25 amps. When voltage output for the helix turbine was plotted against wind tunnel speed, an R-square value of 0.49 was found. The plot of wind tunnel speed vs. voltage output from the helix turbine can be seen in Figure 12 below.

During testing of the 3-blade turbine, the turbine did not begin rotating until wind speeds reached >7 mph; however, once this turbine began rotating, significantly more amperage was received by the battery and pump. When the tunnel reached 14 mph, the battery was fully charged, and at 26.2 mph, the charge controller kicked in, slowing the rotation speed of the turbine to prevent overcharging of the battery, as more power was being sent to the battery than was being utilized by the pump, and to prevent burning out of the pump motor. When the turbine was providing the base 12 V to the battery, this 400 W turbine was providing an amperage of approximately 33 amps. When voltage output for the standard turbine was plotted against wind tunnel speed, an R-square value of 0.97 was found. The plot of wind tunnel speed vs. voltage output from the standard turbine can be seen in Figure 13 below.

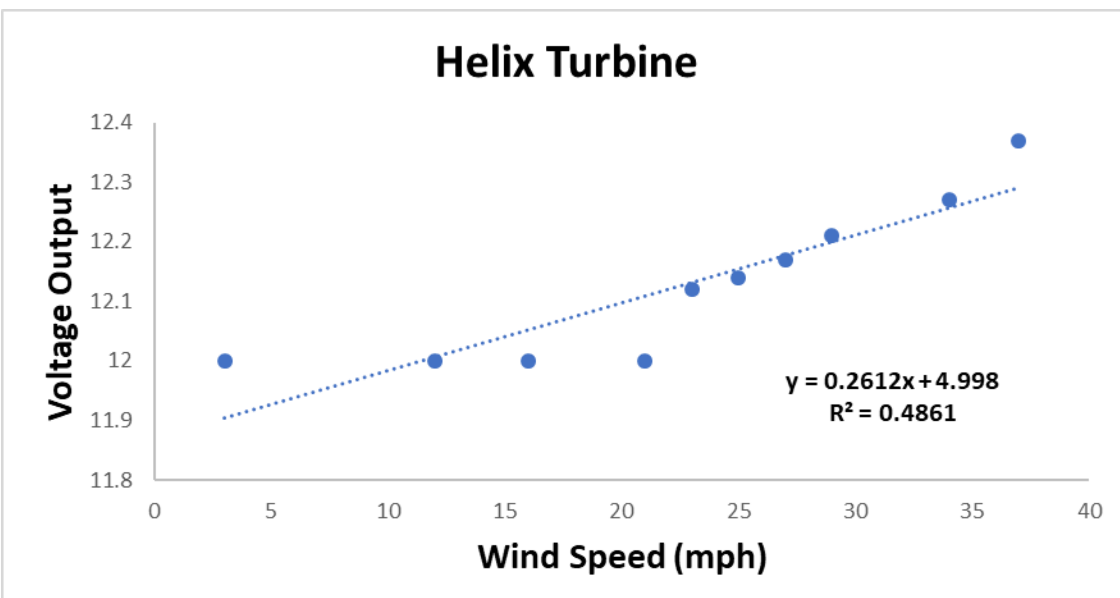


Figure 12: Scatter plot on wind speed of the wind tunnel (mph) versus the voltage output from the helix turbine to the battery.

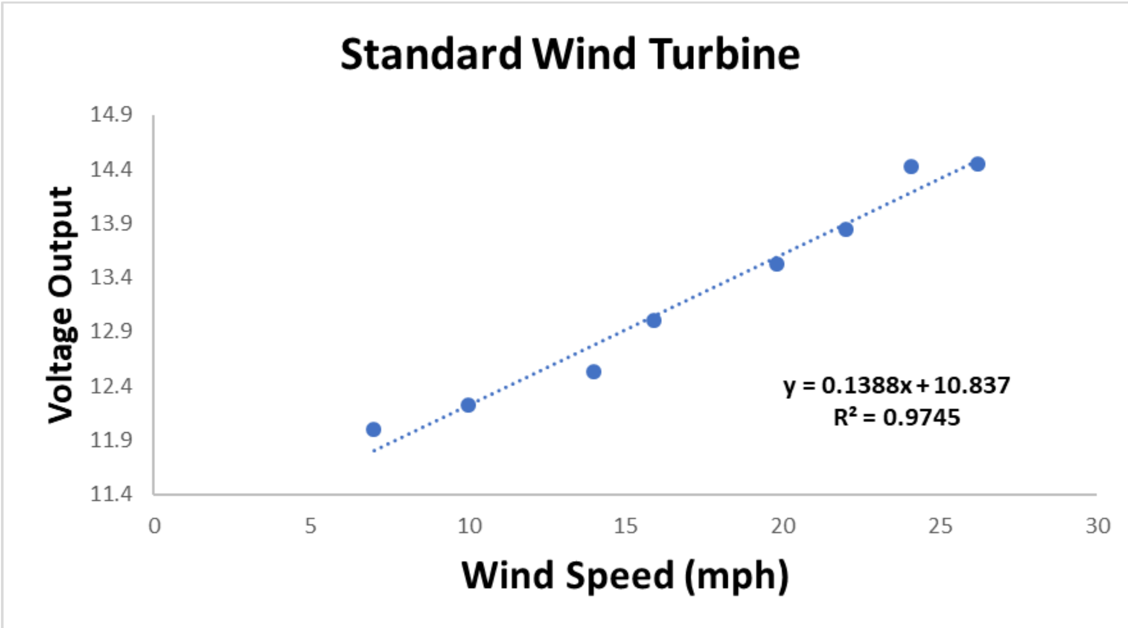


Figure 13: Scatter plot on wind speed of the wind tunnel (mph) versus the voltage output from the standard 3-blade turbine to the battery.

Discussion and Conclusions

The measured wind speeds were consistently higher at the two coastal sites than at the inland site, further justifying coastal wind energy initiatives versus the use of wind harnessing technology inland; however, the measured data were not significantly different across all three sites. However, according to the weather station data, Sedge Island consistently had higher wind speeds than Holiday Harbor (Figure 14), and the t-test revealed that the wind data sets collected from the weather stations were significantly different. This significance may be attributed to the wind averages having been measured at a greater height than the weekly measured data (>15 ft.), and the wind speeds being measured and averaged consistently at times that were not sampled during weekly sampling.

The solar measurements were not significantly different among the three sites meaning that if maximum possible efficiency is achieved, utilizing solar is just as beneficial inland as it is at coastal locations. However, this does not consider the degradation to solar panels over time when they are placed on coastal sites due to salt corrosion and animal interference. With wind turbines generally being 10-20% more efficient in design that solar panels, it is assumed that if carried out in a future coastal project, wind harnessing technology would take precedence.

In wind tunnel testing, the standard 3-blade turbine out-performed the helix turbine; however, the 3-blade had an advantage being a 400 W unit allowing it to charge the connected battery at a lower wind speed than the helix turbine was able to. It is speculated that if both units were capable of the same power performance, they would have had more comparable measurements during wind tunnel testing. The single connected 12 V battery was able to sustain the function of the pump at wind speeds too low for the turbines to produce power; however, the time taken to drain the battery was not measured. The battery was necessary in the circuit for both turbines to perform at full capacity. When the battery was disconnected, the voltage meter dropped back to 12 V. When the battery was disconnected, the charge controller hindered the performance of the turbines in order to protect the pump from excessive amperage (> 8 amps) and burnout. Therefore, the performance of the turbine is as dependent on the battery being connected as the battery charging and performance of the pump are dependent on the performance and speed of the turbine. Greater battery storage capacity would prevent the breaking that occurred by the charge controller in the testing of the standard turbine.

A single standard turbine would be able to operate a single upweller's operation without use of a battery backup at consistent wind speed of approximately 10 mph. The weather station wind data is valuable in that it includes wind speeds measured at the height that would most likely be achieved by an efficient and safely constructed turbine. During the course of this study, Sedge Island's weather station measured average wind speeds of 10.9 and gusts up to 17.7 mph, allowing this location to be most likely to run upweller or similar operations on a singular standard 3-blade turbine with battery backup to guarantee operation. A setup like this would cost approximately $520 not including upweller costs. Based on turbine testing, the 300W helix turbine would be less suited for this location. Holiday Harbor's nearest weather station only exhibited average wind speeds of 4.1 mph with gusts up to 6 mph making this site a possible contender for a multiple-unit system of helix turbines that can harness energy at lower wind speeds or a combination system with wind and solar technology. It is approximated that >2 helix turbines and battery backup would be necessary to guarantee operation at this location. A system consisting of these components would cost approximately >/= $875 not including the upweller costs.

For a non-profit organization like ReClam the Bay, it would be feasible to utilize renewable technology, as long as the cost of equipment could be covered by grants or participating entities like the marinas and yacht clubs that house upweller operations. Alternative energy technology including wind and solar are valuable to projects related to the Barnegat Bay, because it creates an avenue for outreach education about the topic. Considering the outreach programs like those already run by the ReClam the Bay organization, including alternative energy in upweller operations would allow volunteers to educate people about a more carbon neutral approach on energy and how this benefits the bay ecosystem in the long run.

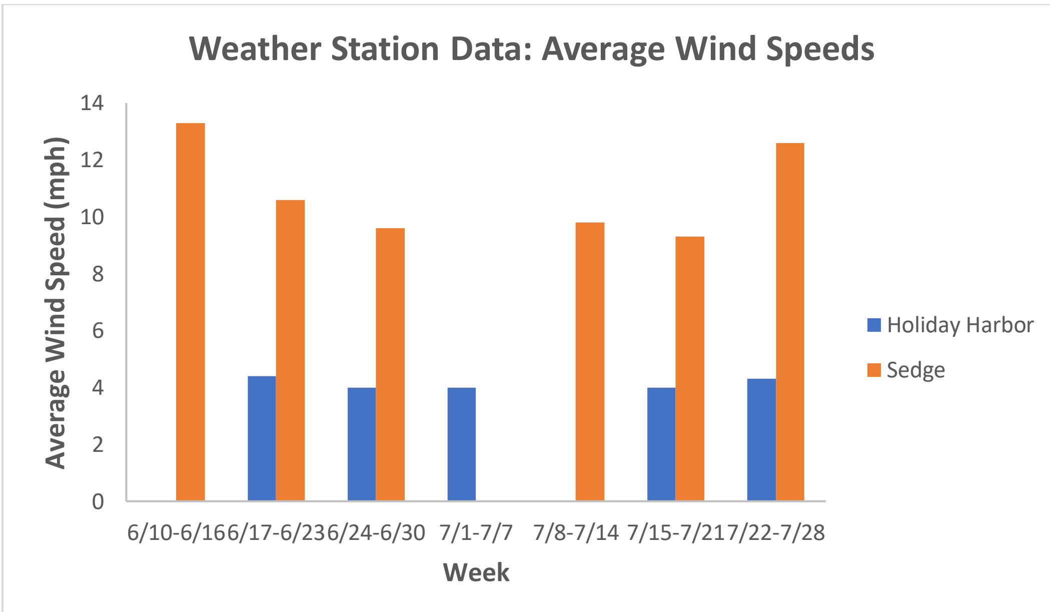


Figure 14: Weekly average wind speeds measured by the weather stations at Sedge Island (KNJWARET3) and near Holiday Harbor (KNJWARET5). Weeks where no data is displayed represent weeks in which the weather stations' data did not display on the Weather Underground ® website. For Sedge Island, the average wind speed over the sampling period was 10.9 mph, and for Holiday Harbor the average speed was 4.1 mph.

Future Considerations

All wind field measurements were taken at the ground level. In future studies to guarantee the conditions necessary to power coastal projects, a true-wind site assessment could be done, measuring conditions at the height that turbines would be installed to eliminate interference from nearby trees, buildings and other obstructions. Additionally, for a future project, gaining permissions to run a true upweller and test clam growth would make for a worthwhile comparison between the renewable and non-renewable operation.

Acknowledgements

I would like to thank the Save Barnegat Bay Student Grant Program for the opportunity to carry out this project with the support of the other teams and advisors. Thank you to Dr. John Wnek for being my mentor for this project and for helping me to obtain the wind turbines, pump, and other special equipment needed to carry out this project. Thank you, Tyler and Maya, for your help with sampling. Finally, thank you, Dad, for your mental and technical support, on-the-fly building skills, and truck towing capabilities.

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