

POTENTIAL TOURISM IMPACTS OF AN OFFSHORE WIND FARM NEAR MONHEGAN ISLAND Technical Report



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Introduction

Visitors flock to Monhegan Island¹ every year as it is a prime example of the raw natural beauty Maine has to offer. However, several challenges threaten the sustainability of the Monhegan community, such as high energy costs and limited employment options. One potential solution to reducing energy costs is to generate electricity using an offshore wind farm (WF). When considering the siting of this alternative energy solution, the impact on Monhegan's tourism should be taken into account as tourism is a major industry on the island.

This report provides the results from a survey of visitors on Monhegan Island to determine their reactions to the proposed WF. These findings should help policy makers, business owners & residents better evaluate the WF's benefits (lower cost electricity²) and costs (potential tourism losses).

Background

This research project was encouraged by another active project at The University of Maine (UMaine). This latter project, headed by the UMaine-led DeepCWind Consortium (<http://composites.umaine.edu/our-research/offshore-wind/deepcwind-consortium/>), was created to establish the State of Maine as a national leader in deepwater offshore wind technology. Maine Public Law 2009, Chapter 270 (LD 1465) allows for the siting of a deepwater offshore WF near Monhegan Island for testing, an area selected by the state.

Background and Literature

Several authors (Firestone et al. 2012; Firestone, Kempton & Krueger 2009; Haggett 2011) highlight the lack of scientific research focused on understanding people's reactions to offshore WFs; even fewer focus on tourists & tourism (e.g., Ladenburg 2010; Landry et al. 2012; Lilly et al. 2010; Westerberg et al. 2013). Most of the tourist studies are in the "grey literature"; i.e., manuscripts not published in peer-reviewed academic journals (e.g., Braunová 2013; Business LF 2013; Fáilte Ireland 2012; Haughton et al. 2003; Albrecht et al. 2013; Tourism Research Centre 2008).

The small empirical literature examining tourist reactions use one of two approaches – (1) examine stated- (e.g., Bishop & Miller 2007) or actual- (Kuehn 2005; BWEA 2006; Jimeno 2007) reactions to an existing WF, or (2) examine stated-reactions to a proposed WF. For the latter, the surveys may (or may not) include static photo representations³ of what the WF would look like (e.g., see Landry et al. 2012; Westerberg et al. 2013).⁴ Results from these studies generally show that tourists are quite mixed in their reactions to WF (Riddington et al. 2008; Landry et al. 2012; Lilly et al. 2010). This may not be surprising given the differences in the projects' contexts (e.g., different populations studied).

¹ Monhegan is an island in Maine, about 12 nautical miles off the mainland. The population was 69 at the 2010 census. The island is accessible by ferry from Boothbay Harbor, New Harbor and Port Clyde.

² Currently residents pay \$0.70/kWh - the highest in the continental U.S.

³ Although use of viewsheds is increasingly critical for impact analyses & meeting regulatory guidelines.

⁴ Further, we have not found any research on people's reactions to the sound of WF.

Methods

Our project was motivated in direct response to interactions with the Monhegan Energy Task Force (METF). This group represents the Monhegan community: tourist-based business owners (e.g., M. Chioffi, Managing Owner, Trailing Yew⁵; T. Hire, Health Coach, Monhegan Island Wellness Retreats), assessors, power district representatives, commercial fisherman & residents; the Island Institute (H. Deese), the University of Maine (D. Brady, SMS; J. Ward, Vice President for Innovation & Economic Development), & Maine Sea Grant (P. Anderson). We worked with METF through weekly conference calls & several face-to-face meetings throughout the project. This group reached out to us to gather information to help them make an informed decision regarding the potential WF; importantly, they helped define the applied research questions & suggested a survey approach. METF had input into the survey design & survey administration protocols; they were also involved in drafting & delivering results to the wider Monhegan community.

Survey Data Collection

Data collection consisted of two undergraduate research assistants traveling to Monhegan Island on a weekly basis to perform intercept surveys with island visitors. Survey sampling began on May 29th 2014 and continued until August 24th 2014. These dates allowed for sampling of Summer tourist and visitors who may have been visiting for spring migration of birds, but unfortunately these dates do not encompass traditional fall bird migration season (mid-September). As tourists rely on private boat services to reach the island (e.g., Monhegan Boat Line), these sampling dates are consistent with the start of multiple boat trips available per day (prior to Memorial Day weekend, only one boat a day is available) with the multiple-boat per day availability ending in mid-October.

There were two survey versions, both deployed to participants via iPad. One version showed visitors a traditional two-dimensional picture of the WF from a location at the south end of the island (Appendix A) while the other version presented a 3-dimensional virtual landscape allowing them to view a dynamic WF (with blades spinning) and a 360 degree view of the landscape from the same location (Appendix B provides a complete description of the development of the virtual simulation). The photo and virtual landscape were based on 2014 WF data and both were rendered from an on-shore location at Lobster Cove, a prominent vantage point at the southeast of the island (see map in Appendix C). The WF consisted of two turbines located 2.96 (4.76) and 2.81 (4.52) miles (kilometers) away from the vantage point; atmospheric conditions were clear.

UMaine student surveyors intercepted people at various locations on the Island (Table 1) but most data was collected either in the center of the village, or at the ferry landing (both located in Region A on the map in Appendix C). These locations were optimal for surveying as the atmosphere is more open and visitors are more relaxed than on a walking trail. Further, visitors were more amenable to being surveyed while they were waiting for the ferry to arrive.

Given the main objective of the survey, we screened out individuals who stated they were a seasonal resident, or were visiting family or friends. This sampling strategy allowed us to focus

⁵ The Trailing Yew provides tourist lodging, dining, & wellness/art workshops.

our attention on collecting data from those visitors who would be most likely to change their visitation behavior in response to a WF constructed near the island. Over the course of the summer, 181 surveys were collected; however, we limited our analysis to those who stated they were on vacation/holiday (i.e., we dropped three individuals who stated they were on business travel).

Note we only surveyed visitors on the island and did not survey tourists on the mainland who had never been to Monhegan before (i.e., inexperienced tourists). As a result, we cannot make definitive statements about how a WF would impact the likelihood of these inexperienced tourists to visit Monhegan. That said, about 15 percent of our surveyed Monhegan visitors (27 visitors) were on their first trip to the island.

Table 1. Location on island where survey was administered^a

	Percent
Region A – Monhegan village and boat landing	89
Region B – Monhegan’s north shore	2
Region C – Monhegan’s east shore	3
Region D – Monhegan’s south shore	6

a Refer to map in Appendix C

The survey (see Appendix D) contained three sections. Section one consisted of questions aimed at understanding the visitation patterns of visitors who come to Monhegan. Section two was focused on asking opinions about the use of wind energy on Monhegan Island and how this would affect subsequent visitation to Monhegan. The last section asked about the demographics of the surveyed visitors. Outside of presenting visual representations of the WF, we did not provide respondents any other information about: the WF, current electricity prices, how electricity is currently produced on Monhegan (large diesel generator) and/or details of the WF contract.

Analysis

We analyzed the data using a combination of inferential statistics (analysis of variance [ANOVA] and cross-tabular analysis). To share the results from our interactions with island residents, two more trips were made to Mohegan Island, one in August and one in September. During these visits, it was discovered that the citizens of Monhegan Island also wanted us to compare results based on whether the visitor was a single- or multi-day visitor as multi-day visitors⁶ have a higher impact on Monhegan’s tourist economy. To simplify the tables, differences across visitor type (i.e., single- versus multi-day visits) are indicated by **BOLD**; full statistical results are presented in Appendix E.

Results

Who visits the Island?

There was an even number of male and female respondents with the average age being about 50 years old (Table 2). About a quarter of respondents are Maine residents. Respondents are

⁶ Preliminary analysis comparing results across the two visualizations find few differences; more detailed analyses would require more sophisticated statistical approaches and are beyond the scope of this paper.

generally well educated (80 percent had a bachelor's degree or higher), and many (40 percent) knew about the Monhegan windfarm plan. Given their level of education, it is not surprising that their average household income was \$126,000 per year. Although results differ across groups, only the respondent's level of education and their knowledge of the proposed WF showed statistically significant differences between single- and multi-day visitors.

Table 2. Characteristics of the surveyed visitors, overall and by visitor type^a

	Overall	Single-day visitor	Multi-day visitor
Gender (percent male)	51	58	47
Average age (years)	48.5	48	49
Percent stating they are a Maine resident	24	24	24
Education (percent stating) ^b			
12th grade or less	2	0	3
Graduated high school or equivalent	6	3	8
1-3 years of college, no degree	13	19	7
Graduated college (Bachelor's degree or equivalent)	39	42	36
Post-graduate degree (Master's, Doctorate, Law or other degree)	41	36	46
Percent knowing about Monhegan windfarm plans	41	28	50
Income	\$126,000	\$132,800	\$122,500

a **BOLD** indicates a significant difference across visitor type, at the five percent level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

Trip characteristics

Most visitors to the Island were on a multi-day trip (Table 3); consistent with a previous study (FutureMetrics 2005). Multi-day trips lasted, on average, about 5 nights; most of these overnight visitors rented a house, apartment or cottage. On average, visitors who were on a single- or multi-day trip were similar in the number of single-day trips taken annually; while those on a multi-day trip took slightly more multi-day trips than their single-day counterparts. Single- and multi-day visitors were similar in that the vast majority traveled with other adults and children (similar to the results found in FutureMetrics 2005). Not surprisingly, multi-day travelers were more likely to visit more areas of the island, especially those outside of the village area (Region A). In general, the south end of the island (where the WF would be most obvious) receive relatively lower numbers of visitors.

Table 3. Characteristics of visitors' trips, overall and by visitor type^a

	Overall	Single-day visitor	Multi-day visitor
Percent taking a single-day trip	43	NA ^b	NA
Percent taking a multi-day trip	57	NA	NA
Average number of nights on this trip	5.3	0	5.3
Percent staying in a bed and breakfast	44	0	44
Percent staying in a rented house/apartment/cottage	56	0	56
Average number of single-day trips taken annually	0.6	0.6	0.7
Average number of multi-day trips taken annually	0.8	0.6	1.0
Percent traveling with others	92	93	92
Average number of adults accompanying visitor	2.6	2.4	2.7
Average number of children accompanying visitor	0.5	0.5	0.6
How many areas of the island are you visiting during your trip? (Percent stating) ^c			
One area	15	23	9
Two areas	23	39	11
Three areas	16	21	11
Four areas	47	16	70
Average number of areas visited	2.9	2.3	3.4
What areas of the island are you visiting during your trip? (Percent stating) ^d			
Region A – Monhegan village and boat landing ^e	92	91	92
Region B – Monhegan's north shore	59	32	79
Region C – Monhegan's east shore	75	62	84
Region D – Monhegan's south shore	69	45	86

a **BOLD** indicates a significant difference across visitor type, at the five percent significance level; full statistical results are presented in Appendix E

b NA = Not applicable

c Percents may not sum to 100 due to rounding

d Percents may not sum to 100 since multiple categories could be chosen

e Refer to map in Appendix C

Visitors to Monhegan spend money both to get to the island and once they are on the island (Table 4). On average, a visitor on a single-day trip to the island will spend about \$120, of which the largest expense is for the ferry ride to and from the island. Those taking multi-day trips spend about \$300 per day, with the largest expenses being lodging (\$167/day) and food (\$59/day). If we subtract the amount spent on the boat ferry, then multi-day visitors spend almost five-times more (\$254/day) per day than single-day visitors (\$52/day).

Table 4. Average amount visitors spent per day, overall and by visitor type^a

	Overall	Single-day visitor	Multi-day visitor
Accommodations	\$97.02	\$0.00	\$167.67
Food/Dining	\$48.82	\$34.81	\$58.65
Gifts/Souvenirs	\$19.59	\$16.27	\$22.31
Boat Ferry	\$55.08	\$65.17	\$46.97
Recreation	\$2.26	\$0.68	\$3.22
Other	\$1.77	\$1.06	\$2.36
Total ^b	\$223.56	\$117.99	\$301.18

a **BOLD** indicates a significant difference across visitor type, at the five percent significance level; full statistical results are presented in Appendix E

b Totals may not sum to 100 due to rounding

Visiting the Island

There are many reasons why someone would visit Monhegan Island (Table 5). Visitors were almost unanimous in stating that beautiful scenery and pristine ocean views are ‘very important’ in their decision to visit the island. Almost as important is the relaxing, peaceful and quiet nature of the island. That views and noise levels⁷ are important to visitors suggests that a WF near Monhegan may lead visitors to reduce their visits to the island. Being a ‘good place to relax’ and ‘good for outdoor activities’ is more important for multi-day visitors; whereas, being ‘good for families’ is more important for single-day visitors. On average, viewing birds and wildlife were least important.

Reactions to Wind Energy

We asked visitors about their opinions on where wind turbines, in general, should be located (Table 6). In response to this question, people were generally supportive of wind energy (e.g., only 11% of respondents agreed with placing wind turbines “nowhere at all”). However, most visitors’ answers indicated preferences that wind turbines be located far away from people and scenic areas; multi-day travelers were more likely to have stronger preferences regarding protecting special locations while also being a stronger supporter for wind energy.

After respondents were shown a visual of the WF, they were asked another set of questions about the impact WFs would have on the Monhegan community, their visitor experience and their visitation patterns. Almost half of the visitors stated they did not have enough information or were uncertain about the impacts of the WF on Monhegan (Table 7). This would suggest that negative reactions to WFs may be overstated due to the uncertainty about the WF’s impacts; increased negative reactions seem to diminish after WFs are established (e.g., see Devine-Wright 2005, Wolsink 2007, Firestone et al. 2012). Many to most respondents disagreed with most of the other concerns, and over 80 percent disagreed that the WF would cause them to avoid visiting Monhegan. The only difference between single- and multi-day visitors is with respect to their evaluation that WFs will spoil the look of Monhegan; multi-day visitors provided more extreme responses (Agree/Disagree) compared to single-day responses (Neutral).

⁷ We did not provide visitors with wind turbine noise because the sounds from the WF (estimated at 20-29 dB(A); “equivalent to a whisper” pg. 4) would be masked by the sounds of waves and ambient noise on the island (Whiting et al. 2013)

Table 5. Importance of various reasons for visiting Monhegan (percent stating), overall and by visitor type^{a, b}

	Overall			Single-day visitor			Multi-day visitor		
	Not Important	Somewhat Important	Very Important	Not Important	Somewhat Important	Very Important	Not Important	Somewhat Important	Very Important
Beautiful scenery	1	4	96	1	7	91	0	1	99
Pristine ocean views	1	7	92	1	4	94	1	10	89
Good place to relax and get away from it all	1	11	88	1	24	75	0	2	98
Unspoiled environment	1	14	86	1	16	83	0	12	88
Peace and Quiet	1	19	80	3	24	73	0	15	85
Good for outdoor activities	5	19	76	11	26	64	1	14	85
Authentic Maine experience	4	27	69	1	31	68	5	24	70
Quaint village/lighthouse	6	30	64	3	32	65	8	28	64
Recreation	18	27	55	22	28	50	15	26	59
Good for families	21	28	51	26	16	57	17	37	47
Abundant wildlife	15	40	44	22	36	42	10	44	46
Bird/wildlife watching	18	44	38	20	38	42	17	49	34

a **BOLD** indicates a significant difference across visitor type, at the five percent level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

Table 6. Visitors agreement with statements of where wind turbines should be located (percent stating), overall and by visitor type^{a, b}

	Overall			Single-day visitor			Multi-day visitor		
	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Agree	Neutral	Disagree
Away from special scenic areas	78	15	7	68	26	5	85	7	7
Far out at sea	67	20	14	60	26	14	73	13	13
In remote, rural areas	64	17	19	69	19	11	61	14	25
Away from people and wildlife	62	25	13	58	24	18	64	26	9
Near town/Developed areas	39	23	38	34	25	41	43	22	35
Near the coast	36	29	34	40	30	30	33	29	38
Nowhere at all	11	16	73	14	23	63	8	11	80

a **BOLD** indicates a significant difference across visitor type, at the five percent level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

Table 7. Visitor agreement with possible reactions to the wind farm (percent stating), overall and by visitor type^{a, b}

	Overall			Single-day visitor			Multi-day visitor		
	Agree	Neutral	Disagree	Agree	Neutral	Disagree	Agree	Neutral	Disagree
I don't have enough information to evaluate the impact on Monhegan from the turbines	49	23	28	44	24	32	52	22	26
I feel a lot of uncertainty about the impact of the turbines on Monhegan	47	22	31	38	25	37	53	19	28
I am concerned about the impact on peace and quiet	38	18	44	40	18	42	37	18	45
Wind turbines spoil the look of Monhegan	31	22	46	23	37	41	38	12	50
I am concerned about the impact of the turbines on recreation	26	19	55	29	14	57	23	23	53
Fewer visitors will come to Monhegan because of the turbines	22	23	55	24	25	51	21	21	57
Wind turbines near Monhegan would appeal to visitors	18	23	59	18	25	57	18	21	60
Seeing wind turbines would add to my enjoyment of Monhegan	15	26	59	21	25	54	11	26	63
I will avoid Monhegan if wind turbines are nearby	8	10	82	7	11	82	8	9	82

a **BOLD** indicates a significant difference across visitor type, at the five percent level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

Visitors were also asked about how WFs would affect their overall experience to Monhegan Island. A majority of people are indifferent to a WF near Monhegan Island (Table 8); of those who are not indifferent, three times more people felt that the WF would detract from their experience compared to those feeling it would enhance their experience. When the detractors are asked to justify their opinions the most popular responses were that they perceived the turbines were too close and noisy.⁸ Single-day visitors had stronger reactions than multi-day visitors but only significantly so with respect to their perceptions that the turbines would be too noisy. We do not report justification results for people who stated the turbines would enhance their experience because of the small sample size (see survey instrument in Appendix C for a list of the justification options).

Table 8. Visitor evaluation of how a wind farm will affect their Monhegan experience (percent stating), overall and by visitor type^a

	Overall	Single-day visitor	Multi-day visitor
How Will Wind Turbines Affect your Visiting Experience? ^b			
Enhances the experience (n = 11)	7	12	3
Neither enhances nor detracts from the experience	69	65	72
Detracts from the experience	24	23	25
How would it detract from the experience? ^c			
It is too noisy	85	100	75
It is too close	80	94	71
It spoils the ocean views	65	75	58
It looks out of place/unnatural	62	69	58
It just looks better without it	55	69	45

a **BOLD** indicates a significant difference across visitor type, at the five percent level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

c Percents may not sum to 100 since multiple categories could be chosen

⁸ We did not provide any information about noise levels to any of the respondents

When asked what effect, if any, the construction of the WF would have on frequency of visits to the island, almost 90% of people said no change (Table 9). Only 1% of people said they would no longer visit Monhegan. When asked if the WF would affect where on Monhegan visitors would go, 69% of people said they would not change where they traveled. Ten percent of visitors stated they would avoid the trails on the south end of the island; however, it is noteworthy that 56 percent of these respondents did not visit the south end of the island during their current trip.

Table 9. Visitor evaluation of how offshore wind turbines would affect their visitation to Monhegan (percent stating), overall and by visitor type^a

	Overall	Single-day visitor	Multi-day visitor
Would they affect your frequency of visits to the island? ^b			
No change in number of visits per year	88	86	89
I would come less often	8	7	8
I would come more often	4	6	2
I would no longer visit Monhegan	1	1	1
Would they affect where you go on the island? ^c			
They would not change where I traveled	72	NR ^d	NR
I would avoid the trails on the South of the island	10	NR	NR
I would avoid the trails on the East of the island	4	NR	NR
I would stop hiking on Monhegan	4	NR	NR
I would use the trails on the North of the island	4	NR	NR
I would avoid the trails on the North of the island	2	NR	NR
I would use the trails on the South of the island	2	NR	NR
I would use the trails on the East of the island	1	NR	NR

a **BOLD** indicates a significant difference across visitor type, at the five percent significance level; full statistical results are presented in Appendix E

b Percents may not sum to 100 due to rounding

c Percents may not sum to 100 since multiple categories could be chosen

d NR = not reported due to small sample size

Conclusions

Our results showed that the proposed wind turbine would have little negative impact on visitation patterns to Monhegan Island. Over 90% of those surveyed would continue visiting the island at current or increased levels if offshore wind turbines are established; only one percent stated they would no longer visit the island. Most respondents were indifferent, people felt that wind power would not affect their visit at all, with almost three-quarters of visitors saying they would not change the locations of the island they visited, even if the proposed wind turbines were established.

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APPENDIX A: VISUALIZATION SEEN BY RESPONDENTS



APPENDIX B: METHOD USED TO DEVELOP THE SURVEY VISUALS

VEMI 3D Environment Project for SSI (iPad)

Aqua Ventus Panoramic Environment App: Data Collection, Processing, and Scene Compilation

To demonstrate the visual impact of the Aqua Ventus I project on Monhegan Island, the VEMI Lab created an augmented panorama with an interactive viewer designed for mobile devices. The WF dimensions and information provided in the panoramic environment app are accurate to the specified data we received as of Q1 2014 to model for this project. In order to account for / demonstrate the highly accurate nature of the panorama and accompanying viewer application, the entire modeling process is outlined below. The process can be separated into three phases: initial data collection, data processing, and construction of the virtual 3D and panoramic environments.

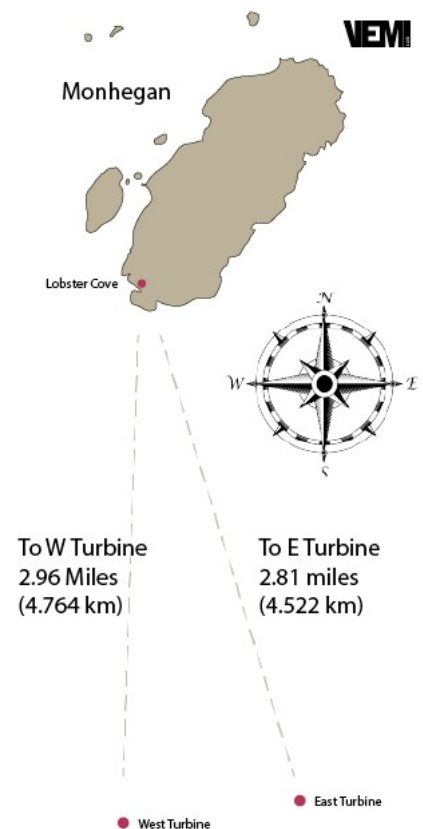
Initial Data Collection

VEMI staff traveled to Monhegan Island on April 12, 2014 to take the panoramic pictures and gather ancillary field data. The panoramic image itself was constructed from a series of high-definition digital photographs taken from a fixed standing location at Lobster Cove. This point was chosen due to high visibility of natural landmarks and coastline. This location was logged with an AGPS (Assisted GPS) receiver which is nominally accurate to less than 5m. In actuality, the horizontal resolution of the GPS location was likely much finer due to the clear skies on the day the measurements were obtained and the lack of signal interference on Monhegan¹. Being conservative, this report accepts the 5m error radius for robustness of proof of precision in the ensuing models we constructed. This accuracy translates to +/- 0.10495% of the total distance (4.764 km) from the location to the western turbine location. This high level of geographic accuracy is important when dealing with the calculation of angular diameter (perceived size) of distant objects.

Data Processing

After the individual images were stitched into a single cylinder-projection panorama, the orientation data was processed to assign a Northern heading to the projection cylinder; thus allowing the panorama to be matched to real-world directions. A distant landmark was used to rotate the projection cylinder to match real-world North with the virtual environment z axis. The landmark chosen was a house which is clearly visible in the panorama. GPS coordinates of this location were obtained and compared to the coordinates of the photographing location to obtain a bearing of 26.095 degrees West of North. This azimuth was used as a reference point on the projection cylinder and used to align the panorama.

Determining the exact distance from the viewing location to each turbine required special consideration; due to the scale involved any distance formula would need to account for the curvature of the Earth and return the spherical distance between locations. VEMI used the haversine formula; an equation derived from spherical geometry and specialized for navigation which returns the great-circle distance between two points on the surface of a sphere. The Great-circle distance between two points is the arc length between the given points along a circle that share a center point and diameter with the sphere. This calculation requires use of special trigonometric relations that have been massaged for use with spherical geometry and navigational calculus, the haversine formula takes into consideration the latitude and longitude of each point as well as the specific radius of the Earth at each point but ignores altitude. The haversine formula was chosen over other spherical distance formulae because it ignores altitude differences. By calculating only the distance between the viewing location and the footprint of each turbine, the perspective projections used in the 3D environment match exactly with the cylindrical projection used in the panoramic environment. By matching projection scales, VEMI ensured the scaling and angular diameter of the modeled turbines is as accurate as the location and size data made available to them and is unaffected by viewing angle. In determining the heading of each turbine relative to the viewing location, similar consideration for the curvature of the earth was required. Formulae outlined by Ed Williams in “Aviation Formulary V1.46”² allowed for the calculation of initial course heading between two points as determined by aircraft. Since the turbines and viewing location are all stationary, the initial course heading is all that is required. As these formulae were constructed for use in aviation, they leave altitude out of the heading calculations, relying exclusively on the latitude and longitude of both points; the desired altitude of an aircraft is generally determined by airspace regulation, not by navigation. For the purposes of placing the wind turbines in the panoramic scene, altitude is discounted in order to obtain more accurate values for heading. As with the haversine formula, the exclusion of altitude from the calculations proved advantageous by maintaining consistency of scale across projections.



Using the specified GPS coordinates at the photographing location (Latitude: 43.75727, Longitude: -69.32204) and the specified coordinates of the east turbine (43.716189, -69.305228), it was determined that the initial heading is 163.521944 degrees clockwise from North. The distance between these coordinates is 4.764 km. Similarly, using the specified coordinates of the west turbine (43.716625, -69.323858), the initial heading was determined as 181.851667 degrees clockwise from north. The distance to the west turbine is 4.522 km. GPS coordinates were specified by the site map document provided to the VEMI Lab.

Construction of the Virtual Environments

The first virtual environment we constructed was the panorama. The cylindrical projection surface was created by extruding a solid capsule to create a hollow 3D form. The panorama was applied as a texture on the inner cylindrical surface and a photo of the sky from the viewing location was applied on the inside of the top hemisphere. Using the known azimuth of the sun in the panorama, a compass rose was applied to the inside of the bottom hemisphere and aligned with true North. Construction of the 3D environment began with the assertion that the x- and z-axes are coplanar with the horizon-line in the panorama and that the origin - coordinates (0,0,0) were located at the center point of where the horizon line intersected the panorama's projection surface. The Unity 3D engine was used to accurately model the panoramic scene. Unity 3D is an engine widely used by the virtual reality industry for accurate simulations. The constructed model uses the engine's default scale of 1 unit = 1 meter, thus eliminating any conversion errors. A reference cube was scaled to the specified 164.5 m (539.7 feet) of the turbine and used to properly adjust the scale of the turbine models. The models were then placed at the before mentioned GPS locations using the relative distance and headings between the turbines and the viewing location calculated above. To perform error correction, the radial coordinates of the positioned turbines were then used in the same formula, but in reverse to determine the GPS coordinates.



Importantly, we found the result exactly matched the given coordinates. Perspective scaling of the turbines (e.g., where distant objects are perceived as looking smaller than the same-sized near objects) was handled by the Unity engine's built-in perspective projection "camera". This virtual camera takes the 3D environment and projects it with true-to-life perspective onto the two-dimensional screen of the device running the viewer application using a camera matrix built around the screen dimensions of the device. This functionality is based on industry standard calculations and is modeled directly on the behavior and functionality of physical optics. Any perceived error in the angular diameter of 3D rendered objects projected in this manner would be the result of underlying data structures, not the produced panoramic environment.

Using the angular size equation³, the accepted 5m accuracy of the AGPS readings at the viewing location gave an angular size of 0.0364 radians with 0.1106% error for the east turbine. This equates to an error of +/- 18.2 cm of height to the turbine, which would be perceived as an added height of 0.028 mm at arm's length from the viewing location. The previous calculations performed for the west turbine gave an angular size of 0.0345 radians with 0.105% error. This equates to an error of +/- 17.27 cm of height to the turbine, which would be perceived as an added height of 0.025 mm at arm's length from the viewing location. The perceived difference in height for both east and west turbines is less than a third of a pixel on the iPads used to view the panoramic environment and is thus sub-threshold for visual perception given the resolution of the viewing device.

References:

¹ Regarding GPS accuracy -

<http://blogs.esri.com/esri/arcgis/2013/07/15/smartphones-tablets-and-gps-accuracy/>

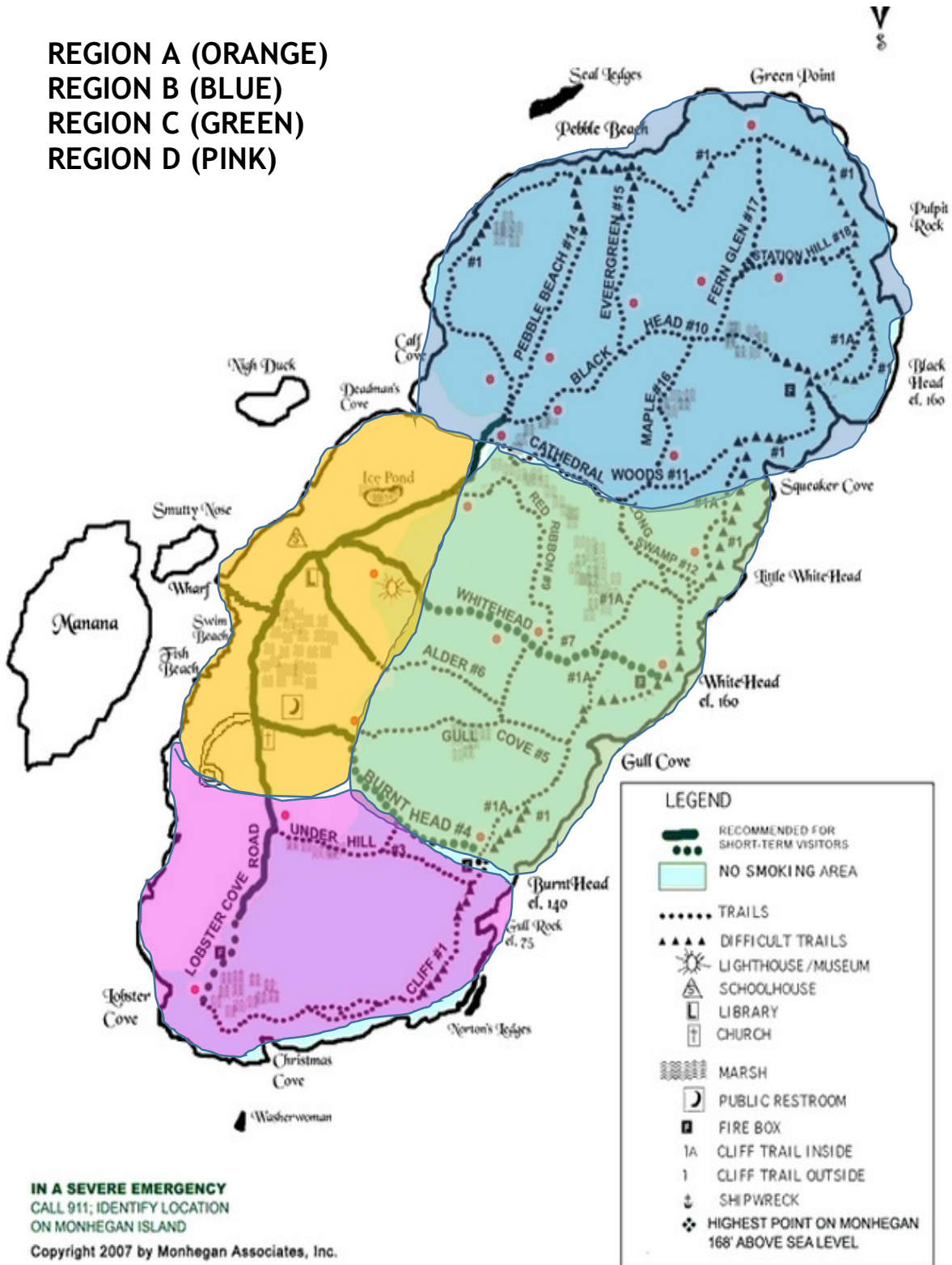
² Ed Williams in "Aviation Formulary V1.46" <http://williams.best.vwh.net/avform.htm>

³ Regarding angle and angular size from forced perspective –

http://en.wikipedia.org/wiki/Forced_perspective#Calculating_angular_size

APPENDIX C: MONHEGAN ISLAND MAP

REGION A (ORANGE)
 REGION B (BLUE)
 REGION C (GREEN)
 REGION D (PINK)



APPENDIX D: MONHEGAN ISLAND SURVEY

Are you over 18 years old? *

YES

NO

What is the purpose of today's trip to Monhegan? *

VACATION/HOLIDAY

VISITING FRIENDS OR FAMILY

BUSINESS SEASONAL RESIDENT

Section I: Visiting the Island

How many days are you spending on this trip to Monhegan?

JUST TODAY/DAY

TRIP MULTI-DAY

TRIP

On this trip, how many nights will you stay on Monhegan?

Please fill in the blank

On this trip where will/did you stay on Monhegan?

WITH FRIENDS OR RELATIVES

IN A BED & BREAKFAST/INN

IN A RENTED HOUSE/APARTMENT/COTTAGE

OTHER:

Are you traveling with others?

YES

NO

What areas of the island are you visiting during this trip?

REGION A (ORANGE)

REGION B (BLUE)

REGION C (GREEN)

REGION D (PINK)

On average, how many day trips do you take to Monhegan per year?

THIS IS MY FIRST DAY TRIP

LESS THAN 1 DAY TRIP PER YEAR

1-2 DAY TRIPS PER YEAR

3-5 DAY TRIPS PER YEAR

6-15 DAY TRIPS PER YEAR

MORE THAN 15 DAY TRIPS PER YEAR

On average, how many multi-day trips do you take to Monhegan per year?

THIS IS MY FIRST MULTI-DAY TRIP

LESS THAN 1 MULTI-DAY TRIP PER YEAR

1-2 MULTI-DAY TRIPS PER YEAR

3-5 MULTI-DAY TRIP PER YEAR

6-15 MULTI-DAY TRIPS PER YEAR

MORE THAN 15 MULTI-DAY TRIPS PER YEAR

Please indicate how important each of the following reasons is to you for visiting Monhegan.

	Not Important	Somewhat Important	Very Important
Abundant wildlife			
Pristine ocean views			
Authentic Maine experience			
Good place to relax and get away from it all			
Bird/wildlife watching			
Good for families			
Quaint village/lighthouse			
Recreation			
Peace and Quiet			
Beautiful scenery			
Unspoiled environment			
Good for outdoor activities			

Section II: Wind Energy

Where should wind turbines be located?

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Near town/Developed areas					
Far out at sea					
Near the coast					
Away from special scenic scenes					
In remote, rural areas					
Nowhere at all					
Away from people and wildlife					

Did you know there are plans to site two offshore wind turbines approximately two and a half miles south of Monhegan Island?

YES

NO

Now that you have seen the wind turbines, please express your level of agreement with the following questions:

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I am concerned about the impact of the turbines on recreation					
I feel a lot of uncertainty about the impact of the turbines on Monhegan					
Wind turbines near Monhegan would appeal to visitors					
Seeing wind turbines would add to my enjoyment of Monhegan					
I will avoid Monhegan if wind turbines are nearby					
Wind turbines spoil the look of Monhegan					
Fewer visitors will come to Monhegan because of the turbines					
I am concerned about the impact on peace and quiet					
I don't have enough information to evaluate the impact on Monhegan from the turbines					

How will the wind turbines affect your visiting experience?

ENHANCES THE
 EXPERIENCE DETRACTS
 FROM THE EXPERIENCE
 NEITHER

If you chose, "enhances the experience", how so?

IT IS GOOD FOR ENVIRONMENT

IT REDUCES OIL IMPORTS

IT LOOKS GOOD/OK/ACCEPTABLE

IT COULD REDUCE THE COST OF LIVING ON MONHEGAN

IT COULD REDUCE THE COST OF VISITING MONHEGAN

IT ADDS SOMETHING INTERESTING

Other:

If you chose "detracts from the experience", how so?

IT IS TOO CLOSE

IT IS TOO NOISY

IT SPOILS THE OCEAN VIEWS

IT JUST LOOKS BETTER WITHOUT IT

IT LOOKS OUT OF PLACE/UNNATURAL

What effect, if any, would the construction of offshore wind turbines, similar to the pictures you saw above, have on your frequency of visits to the island?

I WOULD NO LONGER VISIT MONHEGAN

I WOULD COME MORE OFTEN

I WOULD COME LESS OFTEN

NO CHANGE IN NUMBER OF VISITS PER YEAR

If you answered, "I WOULD COME MORE OFTEN", how many more days per year would you visit?

If you answered, "I WOULD COME LESS OFTEN", how many fewer days per year would you visit?

Would the wind turbines affect where you go on Monhegan?

I WOULD AVOID THE TRAILS ON THE SOUTH PART OF THE ISLAND (pink on the map)

I WOULD AVOID THE TRAILS ON THE EAST PART OF THE ISLAND (green on the map)

I WOULD AVOID TRAILS ON THE NORTH PART OF THE ISLAND (blue on the map)

I WOULD STOP HIKING ON MONHEGAN

Section III: Demographics

What is your gender?

MALE

FEMALE

Into which of the following ranges does your age fall?

UNDER 29

30-39

40-49

50-59

60-69

70 OR OLDER

REFUSE TO ANSWER

What is the highest level of education you have completed?

0-11 YEARS

12 YEARS (HIGH SCHOOL GRADUATE OR GED)

1-3 YEARS COLLEGE (SOME COLLEGE)

COLLEGE GRADUATE (BACHELOR'S DEGREE OR
EQUIVALENT) POSTGRADUATE (MASTER'S, DOCTORATE,
LAW, OR OTHER DEGREE)

About how much was your household income (before taxes) in 2013?

UNDER 20,000

20,000-29,999

30,000-39,999

40,000-49,999

50,000-59,999

60,000-69,999

70,000-79,999

80,000-89,999

90,000-99,999

100,000-124,999

125,000-149,999

150,000-174,999

175,000-199,999

200,000-499,999

500,000 OR MORE

APPENDIX E: STATISTICAL TESTS

Table 2. . Characteristics of the surveyed visitors

	Test statistics	p-value
Gender	$\chi^2 = 1.8803$	0.1703
Average age	$t = -0.67$	0.5025
Percent stating they are a Maine resident	$\chi^2 = 0.0024$	0.9612
Education	$\chi^2 = 10.5320$	0.0324
Percent knowing about Monhegan windfarm plans	$\chi^2 = 8.4999$	0.0036
Income	$t = 0.63$	0.5303

Table 3. Characteristics of visitors' trips

	Test statistics	p-value
Average number of single-day trips taken annually	$t = -0.38$	0.7049
Average number of multi-day trips taken annually	$t = -1.61$	0.1085
Percent traveling with others	$\chi^2 = 0.1194$	0.7297
Average number of adults accompanying visitor	$t = -0.90$	0.3674
Average number of children accompanying visitor	$t = -0.48$	0.6309
How many areas of the island are you visiting during your trip?	$\chi^2 = 46.5960$	<.0001
Average number of areas visited	$t = -6.96$	<.0001
What areas of the island are you visiting during your trip?		
Region A	$\chi^2 = 0.0628$	0.8022
Region B	$\chi^2 = 36.7214$	<.0001
Region C	$\chi^2 = 9.4926$	0.0021
Region D	$\chi^2 = 30.5379$	<.0001

Region and colors refer to the map in Appendix C

Table 4. Average amount visitors spent per day

	Test statistics	p-value
Accommodations	$t = -6.98$	<.0001
Food/Dining	$t = -3.07$	0.0025
Gifts/Souvenirs	$t = -1.39$	0.1669
Boat Ferry	$t = 2.35$	0.0198
Recreation	$t = -3.02$	0.0029
Other	$t = -0.92$	0.3599
Total	$t = -5.91$	<.0001

Table 5. Importance of various reasons for visiting Monhegan

	Test statistics	p-value
Beautiful scenery	$\chi^2 = 5.5859$	0.0612
Pristine ocean views	$\chi^2 = 1.7617$	0.4144
Good place to relax and get away from it all	$\chi^2 = \mathbf{19.2796}$	<.0001
Unspoiled environment	$\chi^2 = 1.9275$	0.3815
Peace and Quiet	$\chi^2 = 4.7656$	0.0923
Good for outdoor activities	$\chi^2 = \mathbf{12.0102}$	0.0025
Authentic Maine experience	$\chi^2 = 2.3577$	0.3076
Quaint village/lighthouse	$\chi^2 = 1.8637$	0.3938
Recreation	$\chi^2 = 1.5313$	0.4650
Good for families	$\chi^2 = \mathbf{8.4851}$	0.0144
Abundant wildlife	$\chi^2 = 4.3205$	0.1153
Bird/wildlife watching	$\chi^2 = 1.9909$	0.3696

Table 6. Visitors agreement with statements of where wind turbines should be located

	Test statistics	p-value
Away from special scenic areas	$\chi^2 = \mathbf{11.1913}$	0.0037
Far out at sea	$\chi^2 = 4.8003$	0.0907
In remote, rural areas	$\chi^2 = 5.1578$	0.0759
Away from people and wildlife	$\chi^2 = 2.4099$	0.2997
Near town/Developed areas	$\chi^2 = 1.4346$	0.4881
Near the coast	$\chi^2 = 1.3192$	0.5171
Nowhere at all	$\chi^2 = \mathbf{6.5075}$	0.0386

Table 7. Visitor agreement with possible reactions to the wind farm

	Test statistics	p-value
I don't have enough information to evaluate the impact on Monhegan from the turbines	$\chi^2 = 1.0484$	0.5920
I feel a lot of uncertainty about the impact of the turbines on Monhegan	$\chi^2 = 3.6501$	0.1612
I am concerned about the impact on peace and quiet	$\chi^2 = 0.2380$	0.8878
Wind turbines spoil the look of Monhegan	$\chi^2 = \mathbf{14.6676}$	0.0007
I am concerned about the impact of the turbines on recreation	$\chi^2 = 2.5975$	0.2729
Fewer visitors will come to Monhegan because of the turbines	$\chi^2 = 0.5704$	0.7519
Wind turbines near Monhegan would appeal to visitors	$\chi^2 = 0.3080$	0.8573
Seeing wind turbines would add to my enjoyment of Monhegan	$\chi^2 = 3.0883$	0.2135
I will avoid Monhegan if wind turbines are nearby	$\chi^2 = 0.2227$	0.8946

Table 8. Visitor evaluation of how a wind farm will affect their Monhegan experience

	Test statistics	p-value
How Will Wind Turbines Affect your Visiting Experience?	$\chi^2 = 4.7189$	0.0945
How would it detract from the experience?		
It is too noisy	$\chi^2 = \mathbf{4.7059}$	0.0301
It is too close	$\chi^2 = 3.1510$	0.0759
It spoils the ocean views	$\chi^2 = 1.1722$	0.2790
It looks out of place/unnatural	$\chi^2 = 0.4444$	0.5050
It just looks better without it	$\chi^2 = 2.0370$	0.1535

Table 9. Visitor evaluation of how offshore wind turbines would affect their visitation to Monhegan

	Test statistics	p-value
Would they affect your frequency of visits to the island?	$\chi^2 = 1.5874$	0.6623