SECTION 26 SHADOW FLICKER

Tetra Tech conducted a shadow flicker analysis for the Project proposed turbine locations using the WindPro software package (Exhibit 26-1 [Shadow Flicker Report]). The WindPro analysis was conducted to predict the annual duration of shadow flicker at sensitive receptors in the vicinity of the Project under realistic impact conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors surrounding the Project wind turbines. The realistic impact condition scenario is based on the following:

- The elevation and position geometries of the wind turbines and surrounding receptors (potentially occupied residences). Elevations were determined using U.S. Geological Survey digital elevation model data. Positions geometries were determined using geographic information system and referenced to Universal Transverse Mercator Zone 19 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute-by-minute basis over the course of a year.
- Historical sunshine availability (percent of total hours available). Historical sunshine rates for the area (as summarized by the National Climatic Data Center[26] for Portland, Maine) used in this analysis are provided in Table 1 of Exhibit 26-1 (Shadow Flicker Report).
- Estimated wind turbine operations and orientation based on wind data (wind speed and direction) measured at meteorological towers located in the Project area.
- Receptor viewpoints (i.e., house windows) were assumed to be directly facing the turbine-to-sun line of sight (“greenhouse mode”).

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun’s path, with respect to each turbine location, is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon were excluded. Since shadow flicker is only an issue when at least 20% of the sun’s disc is covered by the blades, WindPro uses blade dimension data to calculate the maximum distance from the turbine where shadow flicker must be calculated. For the proposed 150-m rotor diameter, WindPro calculates a maximum distance of 1,905 m. Beyond this distance, the turbine would not contribute to the shadow flicker impact. It should be noted however, that WindPro provides a conservative estimate of shadow flicker since obstacles such as trees, haze, and visual obstructions (window facing, coverings) are not accounted for despite the likelihood of their reducing or eliminating shadow flicker impacts to receptors.

Shadow flicker is predicted to potentially occur at only one sensitive receptor (D34) (Exhibit 26-1 [Shadow Flicker Report], see Table 2 and Figure 1). All other sensitive receptors are located outside the shadow flicker impact zone. Sensitive receptor D34 has just 1 hour and 2 minutes of potential shadow flicker impact predicted. This level of shadow flicker is well below the 30-hour annual limit set forth in 06-096 CMR 382 (4)9B.

Exhibits

- Exhibit 26-1 Shadow Flicker Report

[26] National Oceanic and Atmospheric Administration. 2019. Comparative Climatic Data for the United States Through 2018.

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EXHIBIT 26-1 SHADOW FLICKER REPORT

Shadow Flicker Impact Analysis

Western Maine Renewables Energy Project
Somerset County, Maine

Prepared For:

Western Maine Renewables, LLC

P.O. Box 1000
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Prepared By:

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February 2021

EXECUTIVE SUMMARY

Tetra Tech, Inc. has completed a shadow flicker impact analysis for the proposed Western Maine Renewables Wind Energy Project (Project) under development in Somerset County, Maine. An analysis was completed to evaluate the expected shadow flicker impacts resulting from the Project wind turbines. The shadow flicker impact analysis evaluated 14 potential wind turbine locations represented in the February 2, 2020 Project site layout. The Project is considering the Vestas V150-4.2 wind turbine model to be installed.

The analysis was conducted using the WindPro 3.4 software package to determine shadow flicker impacts on sensitive receptors in and around the Project area. Impact conditions accounted for regional terrain, historical sunshine, and meteorological conditions, as well as a number of conservative assumptions. This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at sensitive receptors surrounding the Project wind turbines.

The analysis of potential shadow flicker impacts from the Project on nearby receptors shows that shadow flicker impacts within the area of study are expected to be minor and within acceptable ranges for avoiding nuisance and/or health hazards. Shadow flicker impacts are expected to be less than estimated in this conservative analysis, and shadow flicker is not expected to be a significant environmental impact.

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ATTACHMENTS

ACRONYMS/ABBREVIATIONS

Acronyms/Abbreviations	Definition
Hz	Hertz
Western Maine Renewables	Western Maine Renewables, LLC
Project	Western Maine Renewables Wind Energy Project
Tetra Tech	Tetra Tech, Inc.
UTM	Universal Transverse Mercator

1.0 OVERVIEW

Western Maine Renewables, LLC is proposing to construct and operate the Western Maine Renewables Wind Energy Project (the Project) located in in the Town of Moscow, Somerset County, Maine. The Project will be located, in part, on the former Moscow Air Force Base. The Project is expected to have an up to nominal 58.8 megawatt power output capacity after constructing up to 14 wind turbines. The shadow flicker assessment analyzed 14 wind turbine locations represented in the February 2, 2020 Project site layout. Western Maine Renewables has contracted Tetra Tech, Inc. (Tetra Tech) to conduct a shadow flicker impact assessment to evaluate the expected shadow flicker impacts resulting from the Project wind turbines.

2.0 PROJECT COMPONENTS

The Project is considering a layout consisting of 14 Vestas wind turbines. The turbine layout being considered for the Project has the following specifications:

- **Vestas V150-4.2 wind turbines:** Three-blade 150-meter rotor diameter, with a hub height of 105 meters and generating capacity of 4.2 megawatt. The Vestas V150-4.2 has a normal high rotor speed of 10.4 rotations per minute, which translates to a blade pass frequency of 0.52 hertz (Hz; 0.52 alternations per second).

3.0 SHADOW FLICKER BACKGROUND

A wind turbine's moving blades can cast a moving shadow on locations within a certain distance of a turbine. These moving shadows are called shadow flicker and can be a temporary phenomenon experienced at nearby residences or public gathering places. The impact area depends on the time of year and day (which determine the sun's azimuth and altitude angles) and the wind turbine's physical characteristics (height, rotor diameter, blade width, and orientation of the rotor blades). Shadow flicker impact to surrounding properties generally occurs during low angle sunlight conditions, typically during sunrise and sunset. However, when the sun angle is very low (less than three degrees), sunlight passes through more atmosphere and becomes too diffused to form a coherent shadow. Shadow flicker does not occur when the sun is obscured by clouds or fog, at night, or when the source turbine(s) are not operating. In addition, shadow flicker occurs only when at least 20 percent of the sun's disc is covered by the turbine blades.

Shadow flicker intensity is defined as the difference in brightness at a given location in the presence and absence of a shadow. Shadow flicker intensity diminishes with greater receptor-to-turbine separation distance. In general, increasing proximity to turbines may make shadow flicker more noticeable, with the largest number of shadow flicker hours, along with greatest shadow flicker intensity, occurring nearest the wind turbines.

Shadow flicker frequency is related to the wind turbine's rotor blade speed and the number of blades on the rotor. From a health perspective, the low flicker frequencies associated with wind turbines are harmless, and public concerns that flickering light from wind turbines can have negative health effects, such as triggering seizures in people with epilepsy, are unfounded. Epilepsy Action (the working name for the British Epilepsy Foundation) states that there is no evidence that wind turbines can cause seizures (Epilepsy Action 2018). However, they recommend that wind turbine flicker frequency be limited to 3 Hz. For comparison, strobe lights used in discos have frequencies that range from about 3 Hz to 10 Hz (1 Hz = one flash per second). Since the proposed Project's wind turbine blade pass frequency is approximately 0.52 Hz (less than one alternation per second), no negative health effects to individuals with photosensitive epilepsy are anticipated.

Shadow flicker is regulated by applicable state regulations. The Wind Energy Act Standards in Maine Department of Environmental Protection Chapter 382 require that an applicant must demonstrate that the generating facilities of a proposed wind energy development have been designed to avoid unreasonable adverse shadow flicker effects at any occupied building located on property not owned by the applicant, subject to a lease for a duration at least as long as the anticipated project life, or subject to an easement for shadow flicker in excess of 30 hours per year. The applicant must submit a shadow flicker analysis based on WindPRO, or other modeling software approved by the Department. The analysis must assume that all shadows cast by rotating turbine blades on occupied buildings are unobstructed, and shall not take into account any existing vegetative buffers. The shadow flicker analysis shall model impacts to any occupied building within one mile, measured horizontally, from a proposed turbine. A proposed development may not result in shadow flicker effect occurring at an occupied building for more than 30 hours per calendar year. An applicant may request that this general restriction be waived by showing that 30 hours or less of shadow flicker per year will occur during times when an affected public building is in use, or where an affected private building is used seasonally or intermittently such that occupants will experience 30 hours or less of shadow flicker per year. An applicant may also qualify for a waiver by submitting evidence of agreements or easements with affected property owners in which the property owners state that they do not object to the projected level of shadow flicker. If the shadow flicker analysis predicts that any occupied building will receive more than 30 hours of shadow flicker per calendar year, the applicant may propose mitigation measures to reduce this impact to 30 hours or less per calendar year.

4.0 WINDPRO SHADOW FLICKER ANALYSIS

An analysis of potential shadow flicker impacts from the Project was conducted using the WindPro software package. As described above, 14 wind turbine locations were evaluated.

The WindPro analysis was conducted to determine shadow flicker impacts under realistic impact conditions (actual expected shadow). This analysis calculated the total amount of time (hours and minutes per year) that shadow flicker could occur at receptors surrounding the Project wind turbines. The realistic impact condition scenario is based on the following:

- The elevation and position geometries of the wind turbines and surrounding receptors (potentially occupied residences). Elevations were determined using U.S. Geological Survey digital elevation model data. Positions geometries were determined using geographic information system and referenced to Universal Transverse Mercator (UTM) Zone 19 (NAD83).
- The position of the sun and the incident sunlight relative to the wind turbine and receptors on a minute-by-minute basis over the course of a year.
- Historical sunshine availability (percent of total hours available). Historical sunshine rates for the area (as summarized by the National Climatic Data Center [NOAA 2019] for Portland, Maine) used in this analysis are provided in Table 1.
- Estimated wind turbine operations and orientation based on wind data (wind speed and direction) measured at meteorological towers located on the Project area.
- Receptor viewpoints (i.e., house windows) were assumed to be directly facing the turbine-to-sun line of sight ("greenhouse mode").

Table 1. Historical Sunshine Availability

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
57%	58%	53%	55%	53%	55%	62%	63%	60%	58%	47%	49%

WindPro incorporates terrain elevation contour information and the analysis accounts for terrain elevation differences. The sun's path, with respect to each turbine location, is calculated by the software to determine the cast shadow paths every minute over a full year. Sun angles less than 3 degrees above the horizon were excluded for the reasons identified earlier in Section 3.0. Since shadow flicker is only an issue when at least 20 percent of the sun's disc is covered by the blades, WindPro uses blade dimension data to calculate the maximum distance from the turbine where shadow flicker must be calculated. For the proposed 150-meter rotor diameter, WindPro calculates a maximum distance of 1,905 meters. Beyond this distance, the turbine would not contribute to the shadow flicker impact. It should be noted however, that WindPro provides a conservative estimate of shadow flicker since obstacles such as trees, haze, and visual obstructions (window facing, coverings) are not accounted for despite the likelihood of their reducing or eliminating shadow flicker impacts to receptors.

A total of 37 residential structures were identified within and near the Project area as occupied or potentially occupied residences. These residences are considered potential shadow-flicker receptors for the purpose of this analysis and are shown on Figure 1 (Attachment A). A receptor in the model is defined as a 1-meter-squared area (approximate size of a typical window), 1 meter (3.28 feet) above ground level. Approximate eye level is set at 1.5 meters (4.94 feet). In addition to the identified residential structures, Figure 1 also shows the turbine locations considered.

5.0 SHADOW FLICKER ANALYSIS RESULTS

As expected, WindPro predicts that shadow flicker impacts would be greater at locations closer to the wind turbines. Figure 1 (Attachment A) illustrates the WindPro-predicted potential shadow flicker impact areas.

Table 2 presents the WindPro-predicted shadow flicker impacts for the top 10 worst-case impact receptors. The predicted shadow flicker impact for all 37 receptors is presented in Attachment B. Only one receptor (D34) has predicted shadow flicker impact. All other receptors are outside of the turbine shadow flicker impact zones. Receptor D34 has just 1 hour and 2 minutes of expected shadow flicker impact predicted. This level of shadow flicker impact is well below the Maine regulation threshold of 30 hours per year.

Table 2. WindPro Top 10 Expected Shadow Flicker Impacts

Receptor ID	Receptor Type	Maximum Shadow Flicker Hours per Year (Hours:Minutes/Year)
D34	Residential	1:02
D1	Residential	0:00
D2	Residential	0:00
D3	Residential	0:00
D4	Residential	0:00
D5	Residential	0:00
D6	Residential	0:00
D7	Residential	0:00
D8	Residential	0:00
D9	Residential	0:00

6.0 CONCLUSION

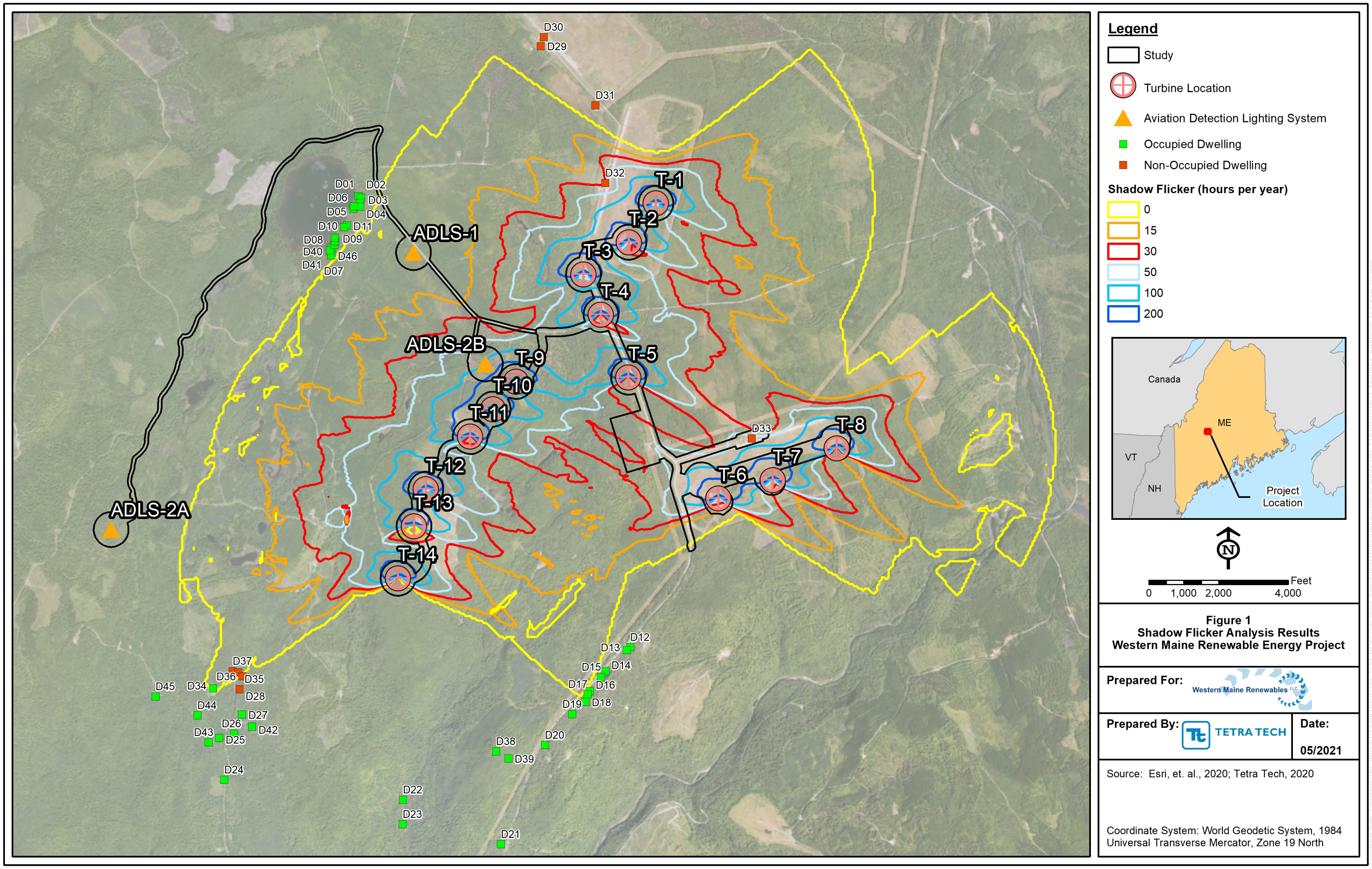
The analysis of potential shadow flicker impacts from the Project on nearby receptors shows that shadow flicker impacts within the area of study are expected to be minor and within acceptable ranges for avoiding nuisance and/or health hazards. The analysis assumes that the receptors all have a direct in-line view of the incoming shadow flicker sunlight and does not account for trees or other obstructions that may block sunlight. In reality, the windows of many houses will not face the sun directly for the key shadow flicker impact times, and vegetation is likely to provide a degree of mitigation. For these reasons, shadow flicker impacts are expected to be less than estimated in this conservative analysis, and shadow flicker is not expected to be a significant environmental impact.

7.0 REFERENCES

Epilepsy Action. 2018. Information Web Page on Photosensitive Epilepsy. British Epilepsy Association. https://www.epilepsy.org.uk/info/photosensitive-epilepsy/triggers. Accessed December 2020.

NOAA (National Oceanic and Atmospheric Administration). 2019. Comparative Climatic Data for the United States Through 2018.

ATTACHMENT A. FIGURES



Not for Construction

Figure 1. Shadow Flicker Analysis Results Map

ATTACHMENT B. DETAILED SUMMARY OF WINDPRO SHADOW FLICKER ANALYSIS RESULTS

Table B-1. Detailed Summary of WindPro Shadow Flicker Analysis Results

Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Expected Shadow Flicker (Hours:Minutes per Year)
D01	430640.9	5001060.4	0:00
D02	430665.3	5001048.7	0:00
D03	430654.2	5001002.0	0:00
D04	430657.3	5000970.0	0:00
D05	430594.6	5000951.7	0:00
D06	430602.7	5000972.2	0:00
D07	430402.8	5000546.2	0:00
D08	430437.7	5000668.7	0:00
D09	430436.0	5000698.5	0:00
D10	430516.2	5000792.2	0:00
D11	430540.3	5000806.9	0:00
D12	433020.1	4997127.0	0:00
D13	432989.6	4997100.0	0:00
D14	432805.7	4996916.1	0:00
D15	432764.8	4996865.6	0:00
D16	432666.5	4996742.3	0:00
D17	432647.6	4996715.0	0:00
D18	432628.9	4996649.0	0:00
D19	432512.8	4996542.3	0:00
D20	432274.1	4996272.5	0:00
D21	431888.7	4995406.1	0:00
D22	431031.2	4995795.7	0:00
D23	431029.0	4995580.6	0:00
D24	429467.7	4995970.4	0:00
D25	429424.9	4996334.2	0:00
D26	429553.1	4996373.0	0:00
D27	429623.8	4996538.0	0:00
D34	429371.0	4996766.6	1:02
D38	431846.6	4996217.0	0:00
D39	431954.5	4996154.6	0:00
D40	430429.9	5000636.3	0:00

Receptor ID	UTM-E (m)	UTM-N (m)	WindPro Expected Shadow Flicker (Hours:Minutes per Year)
D41	430408.3	5000612.2	0:00
D42	429711.5	4996433.6	0:00
D43	429329.7	4996294.9	0:00
D44	429232.1	4996531.7	0:00
D45	428865.6	4996696.2	0:00
D46	430394.0	5000591.4	0:00