

# PO4 - SHADOW FLICKER ASSESSMENT

## Forest Wind

August 2019



## Forest Wind



CleanSight Pty Ltd  
[www.cleansight.com.au](http://www.cleansight.com.au)

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## 1. Introduction

Forest Wind Holdings Pty Ltd (**FWH**) proposes to develop and construct a wind farm called Forest Wind (**Forest Wind**) (the **Project**) located within an actively managed and operational exotic pine plantation in Queensland Government (the **State**) owned Toolara, Tuan and Neerdie State Forests (**State Forests**), situated between Gympie and Maryborough in the Wide Bay Region of Queensland. Specifically, the Project comprises a wind farm with up to 226 wind turbines and ancillary infrastructure (herein referred to as the Wind Turbine Area).

The Wind Turbine Area is characterised by flat to undulating terrain with elevations of 10m to 135m AHD (Australian Height Datum) and is used for the primary purpose of growing and extracting exotic pine from Australia’s largest pine forestry plantation.

FWH proposes that the Wind Turbine Area will accommodate up to 226 turbines, each with a capacity to generate up to 6MW (+/- 3MW), with a maximum height to blade tip of 295m above ground level (agl).

CleanSight Pty Ltd (**CleanSight**) has carried out an assessment of the impact of shadow flicker for the areas surrounding the Project and presents details and results in the following report which demonstrates planning compliance.

## 2. Planning Guidelines

The Queensland State Development Assessment Provisions (SDAP) for wind farm developments, State Code 23 (the **Code**) [1] for wind farm developments includes performance outcomes and corresponding acceptable outcomes relating to PO4 - Shadow Flicker as outlined in Table 1.

Table 1: State Code 23 PO4 - Shadow Flicker

Performance outcome	Acceptable outcomes
<i><b>PO4</b> Development avoids or minimises shadow flicker impacts on existing or approved sensitive land uses</i>	<p><i><b>AO4.1</b> The modelled blade shadow flicker impact on any existing or approved sensitive land use(s) does not exceed 30 hours per annum and 30 minutes per day</i></p> <p><i>AND</i></p> <p><i><b>AO4.2</b> Wind turbine blades have a low reflectivity finish/treatment.</i></p>

Supporting actions for Acceptable outcome AO4.1 and AO4.2 are provided in the State Code 23: Wind Farm development Planning Guidelines (the **Guidelines**) [2] as follows:

### Acceptable Outcome AO4.1:

*“Undertake a shadow flicker assessment that identifies the potential impacts and how these may be mitigated or managed. This assessment should consider the potential impacts on existing or approved sensitive land uses, and ensure that any modelled blade shadow flicker impacts affecting a sensitive land use do not exceed 30 hours per annum and 30 minutes per day. “*

**Acceptable Outcome AO4.2:**

*“Provide information which demonstrates that the wind turbine blades have a low reflectivity surface treatment/finish.”*

Appendix 2 of the Guidelines outlines a methodology for carrying out the assessment for potential shadow flicker impacts.

This involves in the first instance determining the extent of the area around the wind turbines to include in the assessment. This is specified as 265m x maximum blade chord and no assessment is required outside of this distance.

All existing and approved sensitive land uses including a 50m buffer, within the extent of the shadows from the proposed turbine positions must be identified and input for assessment. Recommended modelling parameter settings along with those used in the assessment for the Project are provided in Table 2. Guidelines for mitigating the potential impact on sensitive uses through assessment of cloud cover, vegetation blocking and turbine scheduling are included in the Guidelines.

Sensitive land uses mean any of the following as defined in the code:

- (1) caretaker’s accommodation*
- (2) child care centre*
- (3) community care centre*
- (4) community residence*
- (5) detention facility*
- (6) dual occupancy*
- (7) dwelling house*
- (8) dwelling unit*
- (9) educational establishment*
- (10) health care services*
- (11) hospital*
- (12) hotel*
- (13) multiple dwelling*
- (14) non-resident workforce accommodation*
- (15) relocatable home park*
- (16) residential care facility*
- (17) resort complex*
- (18) retirement facility*
- (19) rooming accommodation*
- (20) rural workers’ accommodation*
- (21) short-term accommodation*
- (22) tourist park.*

*A sensitive land use receptor does not include a temporary or mobile habitable building structure sited on the land (i.e. a caravan on private property).”*

### 3. Shadow Flicker Assessment

#### 3.1 Shadow Flicker Overview

Shadow Flicker can be described as intermittent shadows cast due to the rotating blades of wind turbines which appear to flicker to an observer at a fixed ground position.

The occurrence and duration of shadow flicker depends on many factors which combine to produce a ‘strobing’ shadow effect as the sun passes behind the rotating blades of a wind turbine, including:

- Position of the sensitive receptor in relation to the turbine
- Viewer’s distance from turbine: the further the observer from the turbine, the less pronounced the effect
- Weather patterns, number of cloudy days per year: cloud cover may significantly reduce hours of shadow flicker
- Wind direction: the shadow shape will be determined by the position of the sun relative to the rotor blade orientation, the rotor will be oriented to face the wind
- Wind speed: shadow flicker will only occur when wind turbine blades are rotating, the blades will be static during periods of low wind, high wind or during scheduled downtime for operational/maintenance purposes
- Position of the sun in relation to the turbine
- Time of year (season) and time of day
- Turbine height and rotor diameter
- Topography of the area: hills may reduce the occurrence of shadow flicker
- Vegetation cover: shadow flicker may be reduced by extensive vegetation/ forestry
- Visibility: reduced visibility due to haze, fog, smoke and other airborne particles reduces occurrence of shadow flicker

#### 3.2 Shadow Flicker Model

The number of annual hours of shadow flicker at a given location can be calculated using geometrical models incorporating the sun path, the topographic variation and wind turbine rotor diameter and hub height. In such models, the wind turbine rotor is modelled as a disk or sphere i.e. assuming worst case path of the sun always intersects the rotor and is always directly facing the sun.

CleanSight created a shadow flicker model for the Project using the Openwind Enterprise version 01.08.00.2886i software. The parameter settings used in the CleanSight Model are in line or more conservative than those specified in the Guidelines as described in Table 2.

Table 2: Shadow flicker model settings

Model Parameter	Guidelines Recommended Setting	CleanSight Model
Zone of influence of shadows	265m x maximum blade chord	<p>Typical blade chords 3-5m, currently intended model is 4.5m (1192.5m)</p> <p>CleanSight’s has elected to assess a conservative assumption, being evaluation of a zone of influence of shadows for a blade chord of up to 5m (1325m)</p>

Minimum angle to the sun	3°	3°
Shape of the sun	Disk	<p>Point – more conservative</p> <p>Where the sun-turbine vector intersects any part of the turbine blade/sphere it is considered to cause shadow flicker. Where the sun is modelled as a disk, it can happen that light rays from different portions of the sun disk superimpose around a shadow resulting in light intensity variations less than human perception.</p> <p>Where the sun is positioned directly behind the wind turbine hub, there is no variation in the light intensity at the receiver location and therefore no shadow flicker. Where a point source is used shadow flicker still arises in this case.</p>
Time and duration of modelling	One full year representing a non-leap year 12 to 15 years after date of DA submission	2031
Orientation of the rotor	Sphere or disk facing the sun	Sphere
Offset between rotor and tower	Not required	NA
Time Step	Ten (10) minutes of less	1 minute
Effects of topography	Include	Included
Receptor height	1.5m -2m and window / balcony height where dwellings have more than one storey	1.75m (single storey building)
Receptor Location	Map should be provided showing highest level of annual shadow flicker within 50m of centre of dwelling	Receptor with 50m buffer mapped
Grid size for mapping and assessment	Not more than 25m	25m

It is noted that a number of the model parameters result in a worst-case scenario. There are mitigating factors which can be calculated and applied in a Shadow Flicker Assessment as mentioned in Section 2. CleanSight has not investigated any mitigations for the worst-case scenario as based on the results it is not considered necessary for the Project. Considerations and assumptions in the CleanSight model for the Project which provide for a worst-case conservative scenario are outlined below.

1. Cloud cover has not been assessed.
2. The model assumes that the WTGs (spheres) will always be facing directly into or away from the sun. Figure 1 below shows the expected wind rose or wind direction frequency distribution for the Project showing this will be the case for only a small proportion of the time. A typical shadow flicker impact area is superimposed on the wind rose assuming a WTG position at the centre of the rose, with the extremities of the protruding lobes to the north resulting from summer solstice and to the south resulting from winter solstice. The western area is a result of morning sun and the eastern area is a result of evening sun.

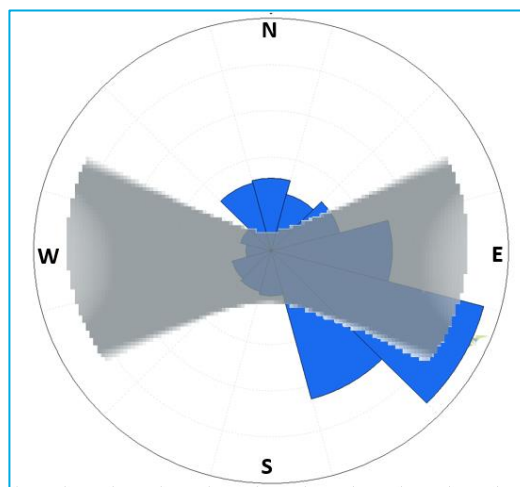


Figure 1: Wind rose and typical shadow flicker impact area

3. The diffusion of the direct sunlight due to airborne particulates and therefore intensity of light to cause shadows is not considered.
4. The WTGs are assumed to be always operating/ rotating, no consideration of wind speed or potential scheduling - operation/maintenance downtime.
5. Vegetation blocking has not been assessed.
6. The modelling of the wind turbine blades as spheres to determine shadow path overestimates the shadow flicker effect. The blades are of non-uniform width with the thickest viewable blade width (maximum chord) occurring closer to the hub and the thinnest being located at the tip of the blade. As outlined in point 3 above, the direct sunlight is diffused resulting in a maximum distance from the wind turbine that a shadow can be cast. This maximum distance is dependent on the human threshold of perception of variation in light intensity. When the blade tip causes shadow, the diffusion of direct sunlight means that the light variation threshold occurs closer to the wind turbine than when a shadow is caused by the maximum chord. That is, the maximum shadow length cast by the blade tip is less than by the maximum chord.
7. The model does not consider that no shadow flicker occurs when the sun is positioned directly behind a WTG hub.



### 3.1 Proposed Layout

The proposed wind turbine layout for the Project consists of 226 wind turbine generator (WTG) generator locations (nominal coordinates provided in Table 4, Appendix B). In addition, there are proposed alternative locations, as shown in Figure 2, Appendix A. The combination of all these proposed locations has been used in determining the zone of influence of shadows for this assessment. A distance of 1325m from the proposed WTG locations was used as a conservative case and to demonstrate that a maximum chord length well beyond the currently proposed WTG model (4.5m) will be possible. In reality, as based on code requirement, there will be no perceptible impact from shadow flicker beyond the 265m x maximum blade chord, currently 1192.5m.

CleanSight considered conservative case hypothetical turbine configurations to assess the potential extent of the shadow flicker impact in the vicinity of relevant sensitive receptors. These included dimensions as follows:

- Rotor diameter up to 190m
- Upper blade tip height up to 295m
- Lower blade tip height down to 85m

It was observed that a turbine configuration of 295m tip height and 190m rotor diameter produced the worst-case and so this scenario was used to produce a shadow flicker map for the whole Project. The results of this assessment can therefore be considered conservative for any WTG model with dimensions within this envelope.

### 3.2 Sensitive Receptors

Sensitive receptors were selected based on being the closest sensitive uses to the zone of influence of shadows boundary. Coordinates of sensitive receptors are shown in Figure 2, Appendix A, and provided in Table 5, Appendix B. Regardless of the conservative approach taken for the determination of the zone of influence of shadows, there is only one sensitive receptor within the zone. This is a caretakers accommodation on a host lot, labelled as SR09 in Figure 2.

## 4. Results

The worst-case shadow flicker was modelled as described in Section 3.2. It was found that only one sensitive receptor lies within the zone of influence of shadows. This sensitive receptor, SR09, is located to the south of the WTG locations and so there is no impact from shadow flicker.

Appendix A, shows SR09 with a 50m buffer and the shadow flicker impact from nearest WTGs. There is more than 400m separation between the 50m buffer around SR09 and the area of potential worst-case shadow flicker impact.

## 5. Blade Finish

Any reflection of the sun off the blades is not expected to be an issue for the Project. The blades will be coated with non-reflective paint complying with AO4.2.

## 6. Conclusion

The shadow flicker assessment as conducted by CleanSight in accordance with recommendations set out in the Guidelines shows that only one sensitive receptor is within the zone of influence and there is no impact from shadow flicker. Compliance for the Project with PO4 of the code is outlined in Table 3 below.

Table 3: Project Compliance with PO4 Shadow Flicker

Performance outcome	Acceptable outcomes	Compliance
<b>PO4</b> Development avoids or minimises shadow flicker impacts on existing or approved sensitive land uses	<p><b>AO4.1</b> The modelled blade shadow flicker impact on any existing or approved sensitive land use(s) does not exceed 30 hours per annum and 30 minutes per day</p> <p>AND</p> <p><b>AO4.2</b> Wind turbine blades have a low reflectivity finish/treatment.</p>	<p><b>Complies with AO4.1:</b> No impact on any existing or approved sensitive land uses</p> <p><b>Complies with AO4.2:</b> Blades will be coated with non-reflective paint</p>


## 7. References

- [1] State Development Assessment Provisions v2.5, State of Queensland Department of State Development, Manufacturing, Infrastructure and Planning, July 2019
- [2] State Code 23: Wind Farm Development Planning Guidelines, State of Queensland Department of State Development, Manufacturing, Infrastructure and Planning, June 2018


## Appendix A: Figures

*[refer to next page]*



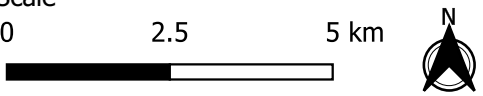


**Forest Wind**



Scale

0 2.5 5 km








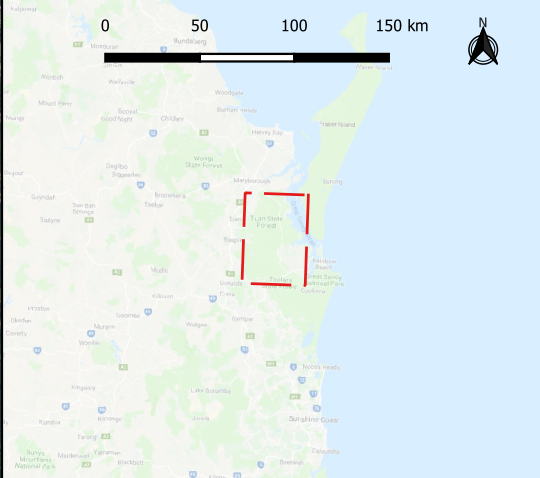
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 Created by: CleanSight Pty Ltd  
 Last modified: 6 September, 2019  
 Version: DWG036\_v02.6\_Zone of Influence of Shadows

**PO-04**

**Figure 2:  
Zone of Influence of Shadows**

**Legend**

-  Nominal Wind Turbine Locations
-  Alternative Wind Turbine Locations
-  Sensitive Receptor Host Lot
-  Sensitive Receptor Non-Host Lot
-  Zone of Influence of Shadows



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Forest Wind



Scale

0 100 200 300 m



1:26,000 on A3  
Created by: CleanSight Pty Ltd  
Last modified: 06 September, 2019  
Version: DWG036\_v03.3\_Shadow  
Flicker map SR09 Vicinity

PO-04

**Figure 3:**  
**Shadow Flicker Map SR09 Vicinity**

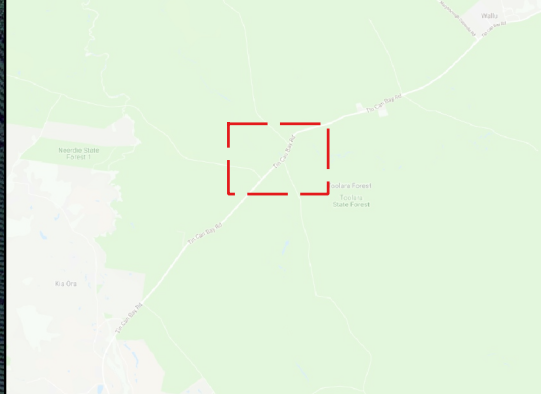
**Legend**

- Nominal Wind Turbine Locations
- Alternative Wind Turbine Locations
- Sensitive Receptor Host Lot
- Sensitive Receptor Non-Host Lot
- Zone of Influence of Shadows
- SR09 50m Buffer

**Worst Case Annual Flicker Hours**

- 0
- 3
- 6
- 9
- 12
- 15
- 18
- 21
- 24
- 27
- >30

0 5 10 km



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484000

SR09

## Appendix B: Tables

Table 4: WTG Coordinates - 226 WTG Nominal Layout

WTG ID	Easting	Northing
UTM z56 South (WGS84)		
1A_1	483768	7165491
1A_2	483625	7164998
1A_3	483479	7164519
1A_4	483264	7164073
1A_5	484180	7163791
1A_6	484076	7162498
1A_7	484189	7161711
1A_8	483696	7161487
1A_9	483070	7161120
1A_10	482780	7160765
1A_11	482346	7160250
1A_12	482146	7159940
1A_13	481935	7159547
1B_1	486211	7128427
1B_2	485233	7128009
1B_3	486343	7127867
1B_4	486706	7127070
1B_5	485088	7127056
1B_6	484246	7126399
1B_7	483489	7125687
2_1	481047	7167641
2_2	482202	7166893
2_3	481047	7166949
2_4	482101	7166324
2_5	480925	7166211
2_6	479998	7166065
2_7	482013	7165844
2_8	479920	7165465
2_9	481920	7165319
2_10	480051	7164748
2_11	481584	7164011
2_12	480278	7163998
2_13	481432	7163590
2_14	481763	7164518
2_15	482776	7163269
2_16	481440	7162932
2_17	483116	7162460
2_18	481448	7162280
2_19	483050	7161835

2_20	480844	7159474
2_21	481931	7158983
2_22	481560	7158681
2_23	481294	7158116
2_24	480960	7157328
2_25	482223	7157149
2_26	480265	7156658
2_27	482364	7156654
2_28	482428	7156134
2_29	482475	7155462
2_30	482242	7154987
2_31	481409	7154650
2_32	484542	7154702
2_33	483484	7152750
2_34	480958	7154090
2_35	484847	7153773
2_36	484411	7153527
2_37	480451	7153415
2_38	484120	7153140
2_39	484400	7150722
2_40	480172	7152397
2_41	482769	7152027
2_42	479298	7150947
2_43	481162	7152302
2_44	481839	7152228
2_45	479787	7151295
2_46	485524	7151223
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2_49	483735	7150813
2_50	478816	7150677
2_51	484838	7136386
2_52	483127	7150461
2_53	482080	7141517
2_54	482152	7150163
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2_63	484345	7137273

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<b>3_14</b>	477514	7147649
<b>3_15</b>	482087	7147596
<b>3_16</b>	476164	7146997
<b>3_17</b>	482494	7146717
<b>3_18</b>	481577	7146740
<b>3_19</b>	475047	7146156
<b>3_20</b>	475573	7146431
<b>3_21</b>	474475	7145973
<b>3_22</b>	479465	7144982
<b>3_23</b>	478592	7144744
<b>3_24</b>	477733	7144082
<b>3_25</b>	477000	7143716
<b>3_26</b>	475458	7143434
<b>3_27</b>	476351	7143327
<b>3_28</b>	478892	7142255
<b>3_29</b>	476914	7141688
<b>3_30</b>	478221	7141559
<b>3_31</b>	478300	7140344
<b>3_32</b>	476960	7138982
<b>3_33</b>	477002	7137876
<b>3_34</b>	475559	7137275
<b>3_35</b>	482026	7136529
<b>3_36</b>	481235	7136412
<b>3_37</b>	480074	7136141
<b>3_38</b>	480889	7135922
<b>3_39</b>	479426	7136050
<b>3_40</b>	478939	7135633
<b>3_41</b>	478374	7135365
<b>4_1</b>	478792	7162926
<b>4_2</b>	478542	7162577
<b>4_3</b>	481454	7161680
<b>4_4</b>	478198	7162213
<b>4_5</b>	481232	7161245
<b>4_6</b>	478376	7161439
<b>4_7</b>	478050	7161032
<b>4_8</b>	480653	7161339
<b>4_9</b>	480551	7160720
<b>4_10</b>	477743	7160608
<b>4_11</b>	480172	7160431
<b>4_12</b>	477685	7159749
<b>4_13</b>	476775	7159378
<b>4_14</b>	475996	7159348
<b>4_15</b>	477438	7159316
<b>4_16</b>	478581	7159245

<b>4_17</b>	475607	7158969
<b>4_18</b>	478626	7158597
<b>4_19</b>	475320	7158475
<b>4_20</b>	474494	7157923
<b>4_21</b>	478804	7157794
<b>4_22</b>	474101	7157613
<b>4_23</b>	473684	7157187
<b>4_24</b>	473379	7156791
<b>4_25</b>	472902	7156161
<b>4_26</b>	472479	7155608
<b>4_27</b>	472240	7154371

Table 5: Sensitive receptor coordinates

Sensitive receptor	Classification	Environment	Easting	Northing	Height (m AHD)
<b>Host lots</b>					
<b>SR09</b>	Caretaker accom.	Forestry yard	483374	7124827	50
<b>Non-host lots</b>					
<b>SR01</b>	Caretaker accom	Demolition yard	478534	7169811	16
<b>SR02</b>	Dwelling house	Rural	470298	7160786	40
<b>SR03</b>	Dwelling house	Rural	468335	7159198	21
<b>SR04</b>	Dwelling house	Rural	466763	7155600	40
<b>SR05</b>	Dwelling house	Rural	469848	7149608	35
<b>SR06</b>	Dwelling house	Rural	470800	7148861	30
<b>SR07</b>	Dwelling house	Rural	470612	7139963	56
<b>SR08</b>	Dwelling house	Rural	477704	7123913	65
<b>SR10</b>	Dwelling house	Rural	489701	7129760	88
<b>SR11</b>	Dwelling house	Rural	484902	7158499	7
<b>SR12</b>	Dwelling house	Residential	490293	7155589	8
<b>SR13</b>	Dwelling house	Residential	487291	7160004	5
<b>SR14</b>	Dwelling house	Residential	487646	7161478	5
<b>SR15</b>	Dwelling house	Residential	486989	7167139	8