

Stockyard Hill Wind Farm Pty Ltd
Level 12, 321 Exhibition Street
Melbourne
Victoria 3000

DNV GL - Energy
Renewables Advisory
Suite 25, Level 8
401 Docklands Drive
Docklands
Victoria 2008
Tel : 03 9600-1993
Fax: 03 9602-1714
ABN: 19 094 520 760

Our reference:
170809-AUME-L-01-B

Your reference:

Date:
29 August 2016

**Re: Shadow flicker assessment for the proposed Stockyard Hill Wind Farm
– effect of increasing turbine rotor diameter from 140 m to 142 m**


Dear Peter Marriott,

Garrad Hassan Pacific Pty Ltd, now trading as DNV GL, has been commissioned by Stockyard Hill Wind Farm Pty Ltd ("SHWFPL") (a subsidiary of Origin Energy) to independently assess the expected annual shadow flicker duration in the vicinity of the Stockyard Hill Wind Farm Wind Energy Facility ("SHWF WEF"), with the purpose of accompanying an application to amend Planning Permit No. PL-SP/05/0548 (Pyrenees Planning Scheme) ("the Permit"). The results of this assessment, based on a wind turbine model with a hub height of 110 m and rotor diameter of 140 m, are reported in document 170809-AUME-R-01 issue G. Further details of the assessment methodologies employed by DNV GL, together with the proposed amended turbine layout for the SHWF WEF, are also available in that document.

SHWFPL now intends to alter the application to amend the Permit to increase the wind turbine rotor diameter to 142 m, while maintaining a maximum overall blade tip height of 180 m. At the request of SHWFPL, DNV GL has reconsidered the findings of the shadow flicker assessment for a wind turbine model with a hub height of 109 m and rotor diameter of 142 m, in order to determine the effect of this change on the expected shadow flicker duration in the vicinity of the SHWF WEF. The results of this work are presented here.

A shadow flicker assessment using the revised turbine dimensions was carried out at all dwelling locations within 1.5 km of the proposed SHWF WEF. The theoretical and predicted actual annual shadow flicker durations at all dwellings identified to be affected by shadow flicker, and the maximum theoretical and predicted actual shadow flicker durations within 50 m of these dwellings, are presented in Table 2. A comparison between the number of dwellings affected by shadow flicker based on the revised turbine dimensions and the number of dwellings affected by shadow flicker based on the turbine dimensions considered in document 170809-AUME-R-01 issue G is presented in Table 1.

The results indicate that the number of dwellings in the vicinity of the SHWF WEF that are predicted to experience some shadow flicker within 50 m of the dwelling location, based on the methodology recommended in the *EPHC Draft National Wind Farm Development Guidelines* (July 2010), is unchanged



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by the increase in turbine rotor diameter from 140 m to 142 m and the reduction in hub height from 110 m to 109 m.

The number of dwellings at which the theoretical shadow flicker within 50 m is predicted to be greater than the limit of 30 hours per year specified by Condition 17 of the Permit and recommended in the *EPHC Draft National Wind Farm Development Guidelines* and *Victorian Planning Guidelines* (January 2016) is also unaffected by the change in turbine dimensions. When landowner agreements to accept shadow flicker durations above the limit specified in the Permit are taken into account, the change in turbine dimensions increases the number of dwellings predicted to experience theoretical shadow flicker durations above the applicable limits by one. However, it is noted that this dwelling (dwelling B120) is a participant dwelling with respect to shadow flicker and that the agreed shadow flicker limit is only exceeded at this dwelling by 2 hours per year, and only at a height of 6 m (representing second storey windows).

The change in turbine dimensions does not affect the number of dwellings in the vicinity of the SHWF WEF that are predicted to experience actual shadow flicker durations above the applicable limits (either the 10 hour per year limit recommended by the *EPHC Draft National Wind Farm Development Guidelines* or one-third of agreed theoretical shadow flicker limit, whichever is greater).

As discussed in document 170809-AUME-R-01 issue G, a number of mitigation measures are available to reduce the effects of shadow flicker, if required, including the installation of screening structures or planting of trees, the use of turbine control strategies, or micrositing of selected turbines.

Sincerely
for Garrad Hassan Pacific Pty Ltd

Naomi Brammer
Engineer

Trenton Gilbert
Principal Engineer

Direct: +61 3 9600 1993
trenton.gilbert@dnvgl.com

Table 1: Comparison of shadow flicker assessment results for the proposed SHWF WEF

Predicted shadow flicker within 50 m of dwelling	Number of dwellings affected				Anticipated change
	Amended layout with 140 m rotor diameter and 110 m hub height		Amended layout with 142 m rotor diameter and 109 m hub height		
	Total	Dwellings with agreed limit > 30 hours/year	Total	Dwellings with agreed limit > 30 hours/year	
Any shadow flicker (> 0 hours/year)	21	18	21	18	No change
<i>Predicted theoretical shadow flicker (recommended/specified limit: 30 hours/year)</i>					
Above recommended limit	8	8	8	8	No change
Above agreed or recommended limit, whichever is greater	1	1	2	2	Increased by one dwelling (B120)
<i>Predicted actual shadow flicker (recommended limit: 10 hours/year)</i>					
Above recommended limit	2	2	2	2	No change
Above one-third of agreed limit or recommended limit, whichever is greater	0	0	0	0	No change

Table 2: Theoretical and predicted actual annual shadow flicker durations for dwellings affected by shadow flicker with the amended layout configuration, a rotor diameter of 142 m, and a hub height of 109 m

House ID ¹	Easting ² [m]	Northing ² [m]	Applicable shadow flicker limit (theoretical) [hr/yr]	Contributing turbines	Theoretical annual				Predicted actual annual ⁴			
					At dwelling ³ [hr/yr]		Max within 50 m of dwelling ³ [hr/yr]		At dwelling ³ [hr/yr]		Max within 50 m of dwelling ³ [hr/yr]	
					SF at 2 m	SF at 6 m	SF at 2 m	SF at 6 m	SF at 2 m	SF at 6 m	SF at 2m	SF at 6 m
<u>B058</u>	<u>709623</u>	<u>5846924</u>	<u>60</u>	<u>L2</u>	<u>16.4</u>	<u>16.1</u>	<u>21.2</u>	<u>20.9</u>	<u>2.7</u>	<u>2.7</u>	<u>3.4</u>	<u>3.3</u>
<u>B064</u>	<u>710107</u>	<u>5842201</u>	<u>60</u>	<u>O6</u>	<u>45.7</u>	<u>45.1</u>	<u>52.3</u>	<u>51.5</u>	<u>7.3</u>	<u>7.3</u>	<u>9.1</u>	<u>9.0</u>
<u>B097</u>	<u>708404</u>	<u>5839745</u>	<u>60</u>	<u>N5</u>	<u>9.6</u>	<u>9.1</u>	<u>10.8</u>	<u>10.3</u>	<u>2.1</u>	<u>2.0</u>	<u>2.4</u>	<u>2.4</u>
<u>B104</u>	<u>710991</u>	<u>5832179</u>	<u>60</u>	<u>R1, T1</u>	<u>24.9</u>	<u>24.5</u>	<u>27.2</u>	<u>26.9</u>	<u>4.8</u>	<u>4.7</u>	<u>5.2</u>	<u>5.1</u>
B110	705895	5851752	30	A7	10.5	10.2	11.3	11.0	2.2	2.1	2.4	2.3
<u>B119</u>	<u>698409</u>	<u>5850995</u>	<u>60</u>	<u>A9</u>	<u>30.3</u>	<u>31.1</u>	<u>42.1</u>	<u>42.2</u>	<u>5.1</u>	<u>5.2</u>	<u>7.2</u>	<u>7.3</u>
<u>B120</u>	<u>699102</u>	<u>5852320</u>	<u>60</u>	<u>A8, A10</u>	<u>14.9</u>	<u>15.1</u>	<u>60.0</u>	<u>62.0</u>	<u>3.1</u>	<u>3.1</u>	<u>13.0</u>	<u>13.6</u>
<u>B124</u>	<u>695961</u>	<u>5853202</u>	<u>60</u>	<u>A12, A13</u>	<u>24.0</u>	<u>24.3</u>	<u>38.0</u>	<u>37.6</u>	<u>4.6</u>	<u>4.7</u>	<u>8.2</u>	<u>8.2</u>
B125	695651	5853628	30	A13	13.4	13.0	14.8	14.4	3.2	3.1	3.6	3.5
<u>B127</u>	<u>696999</u>	<u>5851953</u>	<u>60</u>	<u>A10</u>	<u>19.7</u>	<u>19.1</u>	<u>23.0</u>	<u>22.3</u>	<u>3.6</u>	<u>3.5</u>	<u>4.1</u>	<u>4.0</u>
<u>B140</u>	<u>706705</u>	<u>5846346</u>	<u>60</u>	<u>M6, M7</u>	<u>61.9</u>	<u>60.7</u>	<u>68.8</u>	<u>67.9</u>	<u>11.1</u>	<u>10.9</u>	<u>12.2</u>	<u>11.9</u>
<u>B143</u>	<u>703669</u>	<u>5844423</u>	<u>60</u>	<u>B7</u>	<u>20.4</u>	<u>19.9</u>	<u>29.0</u>	<u>28.6</u>	<u>4.9</u>	<u>4.7</u>	<u>7.2</u>	<u>7.0</u>
<u>B145</u>	<u>705091</u>	<u>5843052</u>	<u>60</u>	<u>B4, B6, C4</u>	<u>27.8</u>	<u>26.8</u>	<u>32.8</u>	<u>32.1</u>	<u>5.6</u>	<u>5.4</u>	<u>6.3</u>	<u>6.1</u>
<u>B146</u>	<u>705384</u>	<u>5841864</u>	<u>60</u>	<u>B5</u>	<u>25.5</u>	<u>25.0</u>	<u>35.2</u>	<u>34.4</u>	<u>4.3</u>	<u>4.2</u>	<u>5.5</u>	<u>5.4</u>
<u>B149</u>	<u>701380</u>	<u>5842799</u>	<u>60</u>	<u>C6</u>	<u>11.8</u>	<u>11.3</u>	<u>12.9</u>	<u>12.5</u>	<u>2.4</u>	<u>2.3</u>	<u>2.7</u>	<u>2.6</u>
<u>B168</u>	<u>701154</u>	<u>5837552</u>	<u>60</u>	<u>H6</u>	<u>20.7</u>	<u>20.0</u>	<u>28.0</u>	<u>27.2</u>	<u>5.9</u>	<u>5.8</u>	<u>7.4</u>	<u>7.1</u>
<u>B170</u>	<u>699004</u>	<u>5837890</u>	<u>60</u>	<u>G6</u>	<u>17.1</u>	<u>16.7</u>	<u>21.1</u>	<u>20.7</u>	<u>3.0</u>	<u>2.9</u>	<u>3.5</u>	<u>3.4</u>

¹ Participant dwellings are indicated by underlined italic text.

² Coordinate system: MGA Zone 54, GDA94 datum.

³ Dwellings with no shadow flicker limit have been omitted from this table. Dwellings predicted to experience zero hours of shadow flicker have also been omitted. Shadow flicker durations above the stated limits (for theoretical shadow flicker durations) or one-third of the stated limits (for predicted actual shadow flicker durations) are highlighted in red. See document 170809-AUME-R-01 issue G for further details.

⁴ Considering likely reductions in shadow flicker duration due to cloud cover and turbine orientation.

Table 2: Theoretical and predicted actual annual shadow flicker durations for dwellings affected by shadow flicker with the amended layout configuration, a rotor diameter of 142 m, and a hub height of 109 m - concluded

House ID ¹	Easting ² [m]	Northing ² [m]	Applicable shadow flicker limit (theoretical) [hr/yr]	Contributing Turbines	Theoretical Annual				Predicted Actual Annual ⁴			
					At Dwelling ³ [hr/yr]		Max Within 50 m of Dwelling ³ [hr/yr]		At Dwelling ³ [hr/yr]		Max Within 50 m of Dwelling ³ [hr/yr]	
					SF at 2 m	SF at 6 m	SF at 2 m	SF at 6 m	SF at 2 m	SF at 6 m	SF at 2m	SF at 6 m
<u>B203</u>	<u>701684</u>	<u>5836682</u>	<u>60</u>	<u>HZ</u>	<u>24.4</u>	<u>23.8</u>	<u>27.7</u>	<u>27.2</u>	<u>5.2</u>	<u>5.1</u>	<u>6.0</u>	<u>5.8</u>
<u>B245</u>	<u>701784</u>	<u>5837154</u>	<u>60</u>	<u>HZ</u>	<u>13.2</u>	<u>13.0</u>	<u>25.2</u>	<u>24.9</u>	<u>2.7</u>	<u>2.7</u>	<u>7.0</u>	<u>6.9</u>
<u>B345</u>	<u>705393</u>	<u>5841802</u>	<u>60</u>	<u>B5</u>	<u>31.5</u>	<u>30.7</u>	<u>37.8</u>	<u>36.7</u>	<u>4.9</u>	<u>4.8</u>	<u>6.4</u>	<u>6.2</u>
B366	705718	5852253	30	A7	16.8	15.8	23.9	22.2	4.1	3.8	5.6	5.2

¹ Participant dwellings are indicated by underlined italic text.

² Coordinate system: MGA Zone 54, GDA94 datum.

³ Dwellings with no shadow flicker limit have been omitted from this table. Dwellings predicted to experience zero hours of shadow flicker have also been omitted. Shadow flicker durations above the stated limits (for theoretical shadow flicker durations) or one-third of the stated limits (for predicted actual shadow flicker durations) are highlighted in red. See document 170809-AUME-R-01 issue G for further details.

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