

Section 5 – Shadow Flicker Assessment

In order to address comments made by the Planning Inspector in the Appeal decision for the Baydon Meadow proposal in relation to potential shadow flicker at 2-3 properties to the east of the proposal, the following independent shadow flicker assessment has been completed. The report has been produced by The Energy Workshop Limited, reference TEWL368.

REPORT TEWL368
BAYDON MEADOW
SHADOW FLICKER ASSESSMENT

By Dr P.L. Surman MA, MSc, PhD, C.Sci, C.Chem, C.Eng

The Energy Workshop Ltd

25 Queen's Square Business Park
Huddersfield Road
Honley
HD9 6QZ

May 12th, 2006

1. INTRODUCTION

Tall structures such as wind turbines cast shadows, which vary in length according to the sun's altitude, and position according to the sun's azimuth (bearing). Rotating turbine blades cast moving shadows, which could under certain conditions cause flickering. A useful assessment of Shadow Flicker is by Clarke (A.D Clarke, "A case of shadow flicker/flashng: assessment and solution", Techno Policy group, Open University, Walton Hall, Milton Keynes).

Planning Guidance on Shadow Flicker is contained within Planning Policy Statement 22 (PPS 22). The relevant paragraph states:-

Under certain combinations of geographical position and time of day, the sun may pass behind the rotors of a wind turbine and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as 'shadow flicker'. It only occurs inside buildings where the flicker appears through a narrow window opening. The seasonal duration of this effect can be calculated from the geometry of the machine and the latitude of the site. Although problems caused by shadow flicker are rare, for sites where existing development may be subject to this problem, applicants for planning permission for wind turbine installations should provide an analysis to quantify the effect. A single window in a single building is likely to be affected for a few minutes at certain times of the day during short periods of the year. The likelihood of this occurring and the duration of such an effect depends upon:

- *the direction of the residence relative to the turbine(s);*
- *the distance from the turbine(s);*
- *the turbine hub-height and rotor diameter;*
- *the time of year;*
- *the proportion of day-light hours in which the turbines operate;*
- *the frequency of bright sunshine and cloudless skies (particularly at low elevations above the horizon); and,*
- *the prevailing wind direction.*

Only properties within 130 degrees either side of north, relative to the turbines can be affected at these latitudes in the UK - turbines do not cast long shadows on their southern side.

The further the observer is from the turbine the less pronounced the effect will be. There are several reasons for this:

- *there are fewer times when the sun is low enough to cast a long shadow;*
- *when the sun is low it is more likely to be obscured by either cloud on the horizon or intervening buildings and vegetation; and,*
- *the centre of the rotor's shadow passes more quickly over the land reducing the duration of the effect.*

At distance, the blades do not cover the sun but only partly mask it, substantially weakening the shadow. This effect occurs first with the shadow from the blade tip, the tips being thinner in section than the rest of the blade. The shadows from the tips extend the furthest and so only a very weak effect is observed at distance from the turbines.

Shadow flicker can be mitigated by siting wind turbines at sufficient distance from residences likely to be affected. Flicker effects have been proven to occur only within ten rotor diameters of a turbine. Therefore if the turbine has 80m diameter blades, the potential shadow flicker effect could be felt up to 800m from a turbine.

1.1 Shadow Flicker and Epilepsy

According to PPS22: "Around 0.5 % of the population is epileptic and of these around 5 % are photo-sensitive. Of photosensitive epileptics less than 5 % are sensitive to lowest frequencies of 2.5-3 Hz, the remainder are sensitive only to higher frequencies. The flicker caused by wind turbines is equal to the blade passing frequency. A fast-moving three-bladed machine will give rise to the highest levels of flicker frequency. These levels are well below 2 Hz. The new generation of wind turbines is known to operate at levels below 1 Hz."

Should it occur, the effect of shadow flicker is most noted from dwellings at distances, according to Clarke, within ten rotor diameters of a turbine in directions from southwest through north, to southeast. Clarke concludes that the frequency of flicker of turbine blades (<1 Hz) is outside of the range (2.5 to 20 Hz), which affects epileptics. Further information on Shadow Flicker can be obtained from the web site of the Danish Wind Industry Association (www.windpower.org/en/tour/env/shadow/index.htm).

2. THE PROPERTIES OF SHADOWS

A structure casts a sharp well-defined dense shadow when it completely obscures the sun. This is termed the umbra. If the structure only partially obscures the sun, then a fainter shadow is cast – the penumbra.

The turbine proposed for Baydon Meadow is up to 50 metres to the hub with a rotor diameter of up to 62 metres. The blades have a maximum average width of 1.8 metres, and a maximum tip width of 0.75 metres.

The sun subtends an angle to the observer on earth of 0.5° . Thus for a 1.8m blade to just obscure the sun it will need to be at a distance of $0.9 / \tan 0.25$ which is about 200 metres. Thus the umbra extends to about 200 metres from the turbine (if the sun is sufficiently low in the sky) and beyond that distance the shadow becomes progressively weaker as the blade obscures

less of the sun. The PPS 22 distance of 620 metres corresponds to a maximum obscuration of the sun of about 30% (this will reduce with the relative angle of the blade to the observer as the turbine yaws to face the wind). The above refers to bright cloudless conditions. No noticeable penumbras will be cast on cloudy or misty days. No flicker will occur if the turbine is stationary.

For a shadow to reach 620 metres from a turbine the sun must be low in the sky (ie near dawn or dusk or in midwinter). For a structure 81 metres tall, to cast a 620 metre penumbra the sun will need to be at an altitude of 7.4° above the horizon assuming that the ground is flat. Longer penumbras will need the sun to be lower in the sky.

At Baydon Meadow the sun rises at an azimuth of about 50° and sets at 310° on midsummer's day. Thus no shadows at all can be cast from the sector between 310 and 50 degrees.

Near the horizon the sun's rays tend to be diffracted and the light becomes more diffuse. Thus near dawn and sunset, shadows are weaker than at other times of day. To the east and west of a turbine, long shadows are only cast within about an hour of dawn and sunset and so the duration of penumbras, at a particular location, will normally be limited to perhaps half an hour.

3. RELATION OF THE BAYDON MEADOW TURBINE TO DWELLINGS

The positions of nearby dwellings and turbine positions are shown in Figure 1. The green line represents an area within 620 metres (ten rotor diameters) of the turbine; the green hatched zone excludes the southern and northern shadow-less quadrants. This assessment is focused on the properties that may be affected by shadow flicker. Whilst a number of additional dwellings lie within 620m of the proposed wind turbine, these are believed to be visually screening by vegetation or have no windows facing towards the proposal. The choice of dwellings for which this assessment has been completed also reflects comments in the Inspector's Report pertaining to the planning appeal for the Baydon Meadow Wind Turbine (APP/W0340/A/04/1150153): "*This may, in my judgement, be particularly disturbing before dusk when the setting sun may at times be perceived to flicker between the blades [at Woodlands Lodge and Brickmakers Cottage]*". (paragraph 20). Two dwellings (House 1 and House 2) lie within this zone.

4. SHADOW FLICKER CALCULATIONS

The WindFarm software produced by ReSoft Ltd was used to calculate the time and extent of shadows at the 3 dwellings. This software takes account of the latitude and longitude of the proposed site and uses a model of the sun's position in the sky throughout the year to calculate shadow lengths, positions

and times. The software does not consider any effect of shading by trees etc. Bearing in mind that all dwellings are beyond the distance at which shadow flicker is thought to be a significant problem (the umbra), it was not considered necessary to conduct a full site survey of representative dwellings (including size and orientation of windows, position of shading trees etc). Instead, for each of the 3 dwellings, the worst case was assumed; a single window, directly facing the proposed turbine and having dimensions of 1 metre by 1 metre, without any intervening shade.

Analysis provided by the Danish Wind Industry Association, has estimated the proportion of days when shadows will not be cast due to no bright sunshine, the turbine not turning and the turbine facing at about right angle to the receptor.

Using this analysis, the following assumptions have been applied:

- Percentage time when turbines are not running - 20%
- Days when the sun is not shining brightly - 50%
- Days when the turbine discs are turned at right angles to a dwelling - 25%

Overall the likely incidence of shadow flicker will be about 30% of the maximum potential, and this factor is used to estimate the number of days on which the phenomenon is likely to occur in practice.

5. ASSESSMENT CRITERIA

In carrying out our assessments of the significance of shadow flicker, we have developed the criteria set out in the table overleaf. The significance of the impact of shadow flicker at the nearest properties has been assessed against these criteria.

Total Hours Predicted	Obscuration of sun %	Significance of Impact
0	0	None
<30	<50 >50	Low Low/Medium
30-70	<30 30-70 >70	Low Medium High
>70	<30 30-70 >70	Low/Medium Medium/High High

6. RESULTS

Graphical representations of shadows on affected properties are given in Figures 2 and 3. The thickness of the red line represents the potential duration of the phenomenon.

6.1 - Dwellings within 200 metres of a turbine – (The umbra)

This criterion corresponds to a fully dense shadow (the umbra) and corresponds to blades obscuring 100% of the sun's disc. It is within this zone that shadow flicker is particularly noticeable. No dwellings lie within this zone.

6.2 - Dwellings within 10 rotor diameters of a turbine – (PPS 22 Assessment Zone)

This criterion corresponds to blades obscuring about 30% or more of the sun's disc as they pass.

6.2.1 House 1

House 1 lies within the assessment zone, at a distance of about 570 metres (9 rotor diameters) of the turbine. House 1 could experience shadow flicker from

penumbras cast by the turbine on 12 days (38 maximum theoretical) in the year. The mean duration of each episode is calculated to be about 22 minutes, occurring in April and August/September at around 1800 to 1820 gmt. The average obscuration of the sun at this distance is calculated to be 32% for the average blade width and 16% for the blade tip. The impact of these weak shadows is considered to be of low significance.

6.2.2 House 2

House 2 lies at a distance of about 600 metres of the turbine (9.6 rotor diameters). House 2 could experience shadow flicker from penumbras cast by the turbine on 12 days (38 maximum theoretical) in the year. The mean duration of each episode is calculated to be about 20 minutes, occurring in April and August at around 1820 to 1840 gmt. The obscuration of the sun at this distance is calculated to be 30% for the average blade width and 15% for the blade tip. The impact of these weak shadows is considered to be of low significance.

Table of Results

Dwelling	Distance From Turbine	Days in the Year	Mean Episode Duration	Average Obscuration of the Sun	Approx. Time of Day GMT	Total Hours of Episodes per Annum	Significance of Impact
House 1	570m	12	22 mins	32%	1800	4.4	Low
House 2	600m	12	20 mins	30%	1830	4	Low

7. MITIGATION

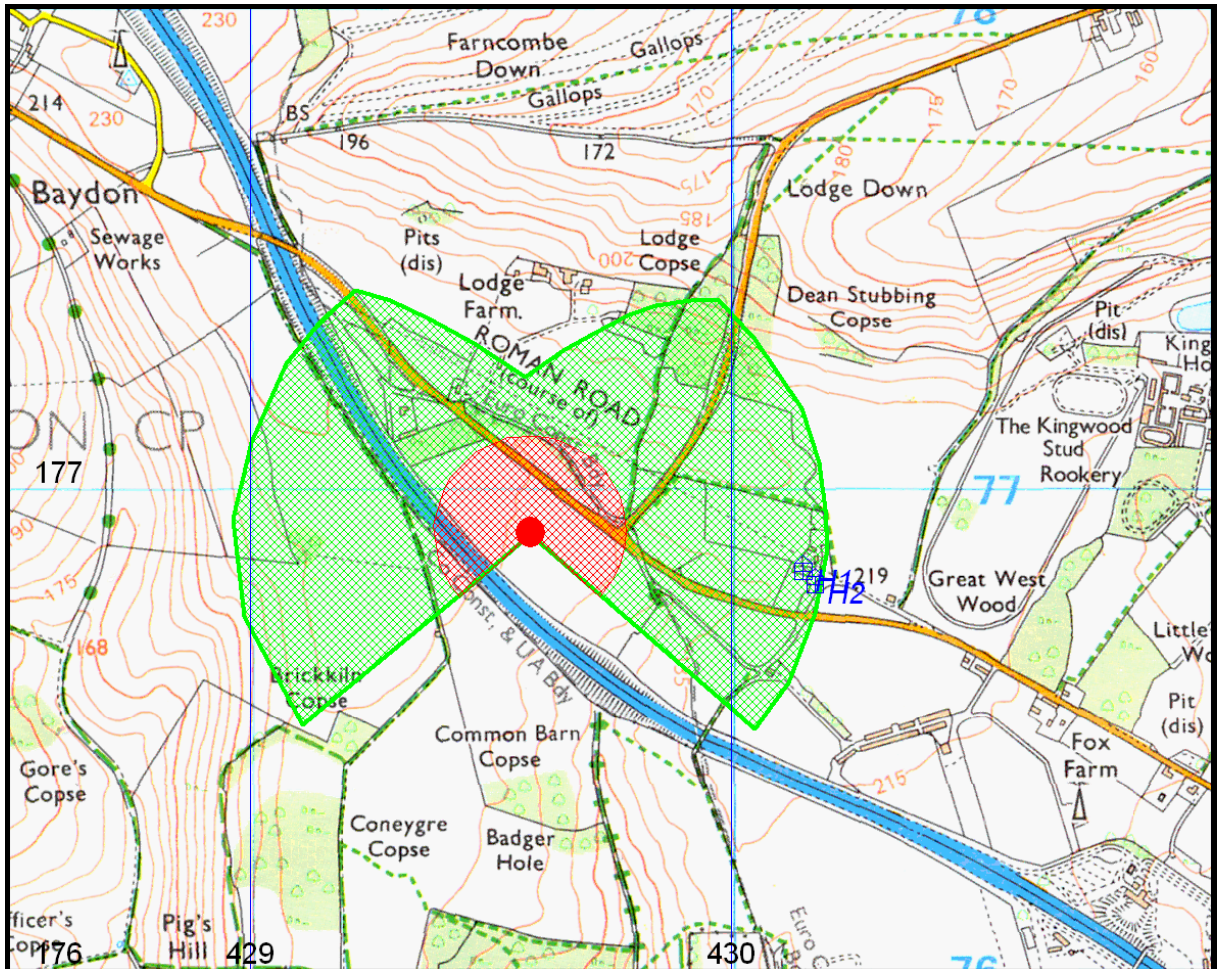
Where shadow flicker has been assessed to potentially affect dwellings in the vicinity of wind turbines, a number of mitigation measures have been employed, often controlled by way of planning conditions. In respect of the Baydon Meadow proposal, there are a number of options that may well be sufficient to mitigate the weak shadow flicker calculated, including:

- The drawing of the dwellings curtains or window blinds, which also prevents the sun's disturbance.
- The planting of shading vegetation.
- Controlling the wind turbine's operation. When turbines are not rotating, flicker does not occur. The technology exists for the turbine's operation to be inhibited when the sun is shining brightly and during the highly predictable dates and times when shadow flicker could occur.

8. CONCLUSIONS

1. House 1 and House 2 lie within the PPS 22 assessment limit and are predicted to be exposed to weak shadow flicker on some spring and autumn evenings. The impact of which is considered to be of low significance.
2. The calculated duration of any shadow flicker event is sufficiently short to have only a temporary effect.
3. The frequency of any shadow flicker from the proposed turbine is outside of the range, which is thought to affect epileptics.
4. Available mitigation measures include fitting of window blinds, and tree planting. If such measures prove to be insufficient then the technology exists for the operator to inhibit the rotation of the turbine at times when shadow flicker is found to be causing a nuisance (although this needs to be balanced with the inevitable reduction in green energy production).

Figure 1 Shadow Zone



Dwellings – blue symbol

Turbine – red solid circle

Scale 1km grid

Penumbra shadow zone – green hatch

Umbra shadow zone – red hatch

620 metres from turbine - green circle

Based on Ordnance Survey Map
with permission of HMSO

Crown Copyright

OS Licence 100002185

The Energy Workshop Ltd

HD9 6QZ

Figure 2, House 1

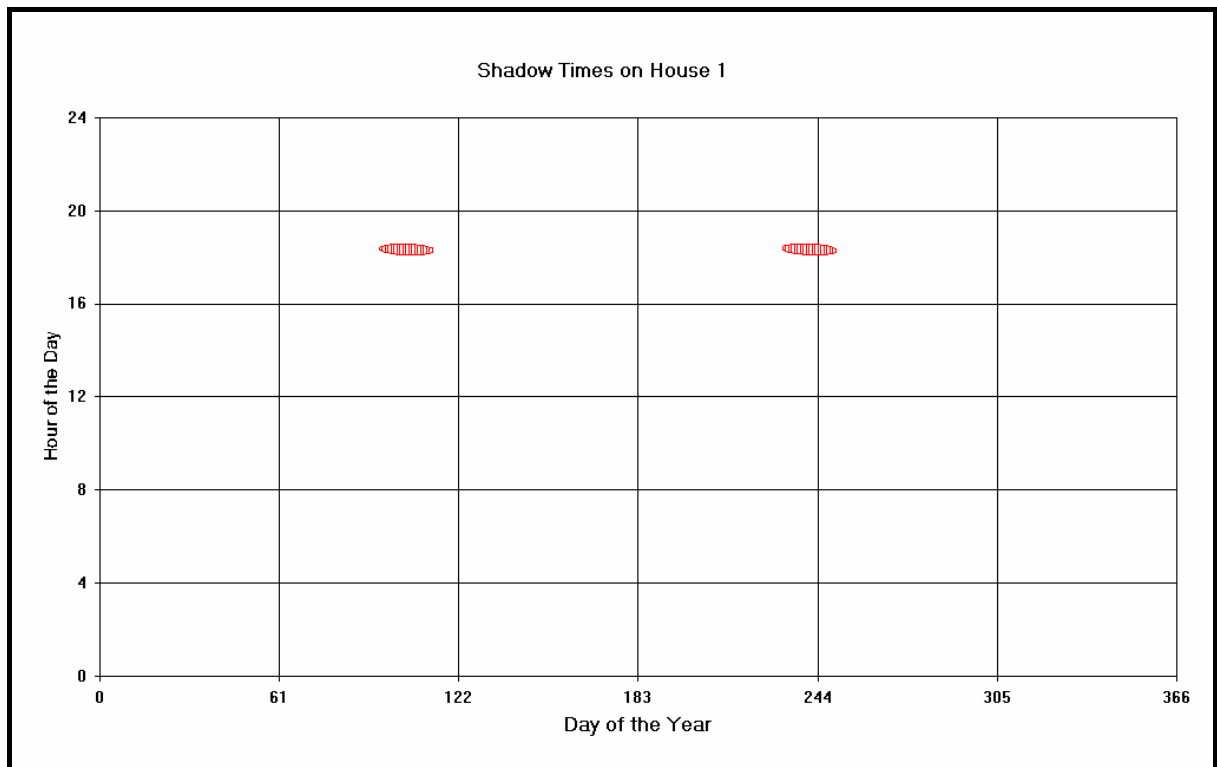


Figure 3, House 2

