Ealing Urban Wind Study

Final Version

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Executive Summary

This report presents the results of a feasibility study undertaken by the Centre for Sustainable Energy (CSE) on incorporating wind power within a proposed development at Northala Fields, near Northolt, in the London Borough of Ealing. The development will provide new ecological, educational and recreational facilities for the public, and will incorporate new landforms in the form of four large conical mounds directly alongside the A40. The report considers the issues that may arise in planning for, installing and operating a small-scale wind turbine on top of one of these mounds. In doing so, it aims to also provide a basis for developing a general methodology on maximising the potential of urban wind power within the borough.

A methodological approach was used in assessing the site for wind power. Initially, a desk-based assessment was undertaken on wind speeds at the site and drew upon a number of sources. These comprised the DTI's 'NOABL' UK wind speed database, historical data from a nearby meteorological station and modelled wind speed using 'WAsP' software. The results produced estimates for annual average wind speed and a wind 'rose' indicating the historical wind profile in terms of magnitude and direction.

The wind directional profile was found to be predominantly south-west. This is advantageous for the proposed turbine location, as the approach or wind 'fetch' from this direction will be relatively unhindered. Wind speeds were considered at a height-above-ground of 35m, which represents the height of a 20m mound plus a 15m turbine mast. At this elevation, average annual wind speed was estimated to be in the range 4.4 m/s, as modeled by WAsP, to 5.6 m/s, as modelled by NOABL. The difference in values highlights the uncertainty in predicting wind speeds, the method of which requires general assumptions for nature of terrain or 'surface roughness'. It is reasonable to assume that the lower estimate is of greater accuracy as, with this method, more localised factors are taken into account. However, the report concludes that the values are still only estimates, and a suitable range should be considered in predicting energy yield. Where possible, actual on-site wind speed measurements will provide the most reliable data.

A technical options appraisal was conducted for the proposed mound-top installation. Issues such as turbine and mast type, size, method of erection, electrical connection and maintenance were considered and a shortlist of turbines, up to 20 kW, compiled for assessment. A particular issue of concern was the method of erection needed for a mound-top installation and subsequent access for maintenance. A crane-erect or winch-erect turbine could be installed subject to certain design modifications to the mound, particularly to the flat plateau area. In selecting the turbine size, annual energy outputs were predicted for comparison with estimates of site load. In part, emphasis was placed on visual impact as the ‘awareness-raising’ potential of the renewable energy installation would be a key benefit. Issues with grid connection and battery storage were also discussed.

The study includes an economic appraisal that considers capital costs, operation and maintenance costs, and revenue generation. Net Present Values of each cost element were used to calculate payback periods for different scenarios.

The report identifies two turbines, rated at 10 kW and 20 kW, from those considered for further appraisal and lists comparisons between both. Predicted savings in CO_2, based on all generated electricity from the larger of these turbines displacing that which would otherwise be imported, range from around 6 to 10 tonnes per year, for an annual average wind speed of 4m/s & 5 m/s respectively.

A summary of the report's other main conclusions is as follows:

- As is typical of urban areas, average wind speed at the proposed site is significantly lower than that normally encountered in rural, less built-up areas, where turbines are usually sited. Energy production and turbine load factor will therefore also be low. However, it is thought that other benefits, such as the 'awareness-raising' value of the installation, will justify this.

- In light of the above, a key factor in choice of turbine is the 'start-up' wind speed, i.e. the wind speed at which the turbine rotor begins to turn. If this value is too high, the low average wind speeds will result in a stationary turbine for significant periods of the year. For an annual average wind speed of 4.5 m/s, the two turbines selected are likely to be stationary for a period equivalent to around 21% of the year.

- A 10 or 20 kW turbine mounted on a 15m or 18m mast is likely to provide adequate visual impact whilst allowing for a feasible mound-top installation. In most cases, annual maintenance can be undertaken by an existing site technician following training.

- Estimates of annual energy production should be regarded with caution. Power curves, on which these estimates are based, are rarely independently certified for small-scale turbines.

- Annual 'revenue' could be sourced from a combination of Renewable Obligation Certificates (ROCs), Levy Exemption Certificates (LECs), electricity exports, and avoided electricity imports. The combined value, which may be greater than the price paid for electricity imports, will depend on the amount generated, site load patterns and the deal negotiated with the supplier.

- Economic viability is sensitive to annual average wind speed, and net annual revenue. Assuming electricity generated is given a value approximately equal to that imported, 'discounted' payback periods for the turbines considered were long (>50 years) for annual average wind speeds of 4 and 5 m/s, and 50% grants levels on capital costs.

- The turbine installation is unlikely to have any adverse environmental impacts. Nearby dwellings are of sufficient distance away to be unaffected by turbine noise relative to that from background sources. Initial feedback from key players in the wind power planning process (Defence Estates, CAA) indicate that the installation is unlikely to cause a problem.

- There is potential for the project to offer educational opportunities to the park's visitors and local schools, and to create an iconic landmark to assist in publicising the park.

The report also discusses the opportunities for wind power elsewhere in the borough and recommends that Building-Augmented Wind Power be considered as an option for the future.

Table of Contents

1 INTRODUCTION

1.1 Scope and objectives of study

This report presents the results of a feasibility study undertaken by the Centre for Sustainable Energy (CSE) on incorporating wind power within a proposed development at Northala Fields, near Northolt, in the London Borough of Ealing. The study aims to highlight the issues that may arise in planning, installing and operating a small-scale wind power system at this site, and, in doing so, provide the basis in developing a general methodology on maximising the potential of urban wind power.

The London Borough of Ealing commissioned CSE to conduct the study, which commenced in June 2002, as a result of being awarded funding from the National Grid Community 21 Awards. The feasibility study focuses principally on the Northala Fields site, but also considers the potential of the Borough as a whole to utilise its wind resource.

The Northala Fields site covers some 18.5 ha in the Northolt area of the borough and is located alongside the A40, one of the busiest roads in London. The Northolt & Greenford Countryside Park Society are currently working in partnership with the London Borough of Ealing's Parks and Countryside Service and the local community to develop a new public ecological and recreation facility at this site. This development will provide new ecological, educational and recreational facilities currently unavailable elsewhere in West London and will incorporate new landforms in the form of four conical mounds directly alongside the A40. A guiding principle for the park's design is to minimise resource use.

The mounds will serve as a gateway marker and icon for the park, as well as forming part of a visual, noise and pollution barrier between the park and the A40. It is also proposed to mount a wind turbine on one of the mounds as part of the scheme. Although it is recognised that urban wind power is unlikely to ever generate a substantial proportion of energy requirements, a key concept behind this project is that people's awareness of renewable energy issues is likely to be most quickly raised if they can see renewable energy in action. Wind power is the most easily visible of all the renewable energy technologies.

1.2 Context

Large-scale wind power is now recognised as a commercially viable form of renewable energy and is hoped to be a major contributor to the Government's target of sourcing 10% of the UK's electricity suppy from renewables by 2010. The Government's recent energy White Paper[1] also stated an 'aspiration' to increase this figure to 20% by 2020. Considering it has the largest wind resource in Europe, the UK is well placed to achieve this by the development of wind farms. These will tend to be located in off-shore or rural areas where wind speeds are higher. Research into the suitability of urban areas for wind power is comparatively rare and the low wind speeds commonly inherent in built-up areas are seen to justify this. However, there is a case for small-scale urban wind power in influencing public perceptions and raising awareness of renewable energy. Following an appropriate methodology

[1] www.dti.gov.uk/energy/whitepaper/index.shtml

to maximise the potential of urban wind power will not only achieve this, but will also identify the most economically viable sites to consider.

2 METHODOLOGY

The study was initiated by first conducting a literature and internet search on all aspects relating to urban wind power, including any relevant case studies. A summary of information sources identified throughout the study is listed in Appendix F. Relatively little was found regarding case studies and on urban wind power applications in general.

2.1 Sites for investigation

At the onset of the study, Ealing Borough Council had identified two sites as having potential for siting a wind turbine. One is Northala Fields, as described earlier, and the other is a playing field near Coston School. The playing field is located approx. 1-2 km from the school and there are no buildings currently present hence no specific load exists, although a toilet block is planned at some stage in the future. A preliminary site visit to the site identified a potential problem in the form of a bank of nearby trees, which may present an obstacle to wind flows at the site. For these reasons, the site was not selected for further study. However, although the following sections of this report refer specifically to Northala Fields, the general methodology used could be applied to other sites such as these.

2.2 Technological and economic appraisal

Site wind profiles were investigated using data obtained from the Met Office and the NOABL database. WAsP software was also used to model wind speed at the Northala Fields site (see Section 3.2).

Due to the nature and location of the proposed site at Northala Fields, it was thought appropriate to select turbines below 20kW for detailed evaluation. A selection of potential installers were contacted and technical options, specifications and quotes were obtained for assessment. Economic forecasts were undertaken using standard discounting methods (see Sections 4 & 5).

3 SITE SELECTION

3.1 Initial considerations

Small-scale wind projects in urban areas have been few to date due to low wind speeds and potential difficulties in obtaining planning permission. Those that do exist have tended to come about for reasons other than economic viability. Incentives to consider small-scale wind power in urban areas have usually stemmed from the desire to demonstrate sustainable energy in practice and to promote wind power to those unfamiliar with the technology. If opportunities for urban wind power arise, however, it is good practice to methodically consider all options, including economic viability, and to examine as far as possible all factors that could influence development of the project.

The main aims and objectives of the project will clearly influence the order of priority that each factor will be given. The question may be asked, for example, whether the proposed location of a wind turbine is to take advantage of higher localised wind speeds or to be visually prominent. There may be situations where both are satisfied, or where visual prominence is not desired. The factors that should initially be considered can be listed as follows:

- Aims and objectives of project
- Wind resource
- Budget
- Potential planning restrictions

Assessing wind resource is clearly of high importance. Even if economically viable wind speeds are not present, there must still be a certain level of reasonably uninterrupted wind in order for the turbine to generate. This is dealt with in the following section.

3.2 Wind resource

As budget and time considerations can be limited, most small-scale wind power projects rely on estimates of annual average wind speed in order to calculate predicted energy yields. Small increases in wind speed result in large increases in energy production hence this value is crucial in assessing economic viability. The power contained in the wind can be represented by the following equation:

$$\text{Power} = \tfrac{1}{2}\rho A V^3$$

where ρ = air density, A = area intercepting the wind and V = instantaneous wind speed.

Thus, if the wind speed doubles, the available power will increase by a factor of 8. Predictions as to increases in annual energy production resulting from specific increases in annual average wind speed is not an exact science and will depend on the turbine rating, performance and the wind speed distribution assumed (e.g. Rayleigh). Table 6 (Section 4.1) shows annual energy production estimates for a range of annual average wind speeds.

All potential data sources should therefore be investigated to increase accuracy of estimates. The preferred option, if time and financial constraints allow, is to undertake on-site wind monitoring. However, this would need to start at least 6 months in advance of turbine installation.

3.2.1 Existing data

As will be explained, budget, time constraints and on-site practicalities will dictate the sources of wind speed data available for a particular site. An initial desk-based appraisal can produce estimates of wind speed by sourcing existing data, which may consist of modelled wind speed databases or measured data from local meteorological stations. Additional data, based on real measurements, may also be available from universities or other organisations with an interest in met data. Two sources of existing data were obtained for the Northala Fields locality, these being the NOABL database and data from the Meteorological Office.

NOABL database

The NOABL database is offered as a free download from the British Wind Energy Association (BWEA) website[1]. It contains estimates of the annual average wind speed throughout the UK at $1km^2$ resolutions for heights of 10m, 25m and 45m above ground level. The data is the result of an air flow model that estimates the effect of topography on wind speed, but does not take into account local thermally driven winds such as sea breezes or mountain/valley breezes. Variations in local surface roughness caused by buildings, trees, etc are also ignored. For these reasons, the data should be used as a rough indication only.

Table 1 presents results for the Northala Field site.

Northala Fields (Grid Ref: TQ128836)			
Height above ground (m)	10	25	45
Annual average wind speed (m/s)	4.7	5.4	5.9

Table 1: NOABL predicted wind speeds at Northala Fields

Wind speeds from the NOABL database for the entire Borough of Ealing are considered in Section 3.2.2.

Meteorological data

Enquiries to the customer centre at the London Met Office revealed that the nearest 'met' station to Northala Fields is Northolt Aerodrome, approximately 2 km to the North West. Other nearby sites include the London Weather Centre at Holborn and Heathrow Airport. Wind speed data is available at various costs depending on the period and frequency requested. A 'standard' wind frequency analysis was obtained for around £300 comprising data of hourly average wind speed bands and direction, logged on a monthly basis, over a ten year period.

The wind speeds are measured to the nearest knot and wind direction to the nearest 10 degrees, with no intermediate values. Each hourly-averaged wind speed reading results in a 'count' which is then sorted into a wind speed band (e.g. 11 to 16 knots), according to each 20 degree wind directional sector. Calculation of annual average wind speed from this data format may be misleading due to the large wind speed ranges used. A value for annual average wind speed would require specific analysis by the Met Office and be chargeable at a cost beyond the resources of this study.

Figure 1 presents the wind speed data supplied as a frequency distribution.

[1] http://www.britishwindenergy.co.uk/noabl/index.html

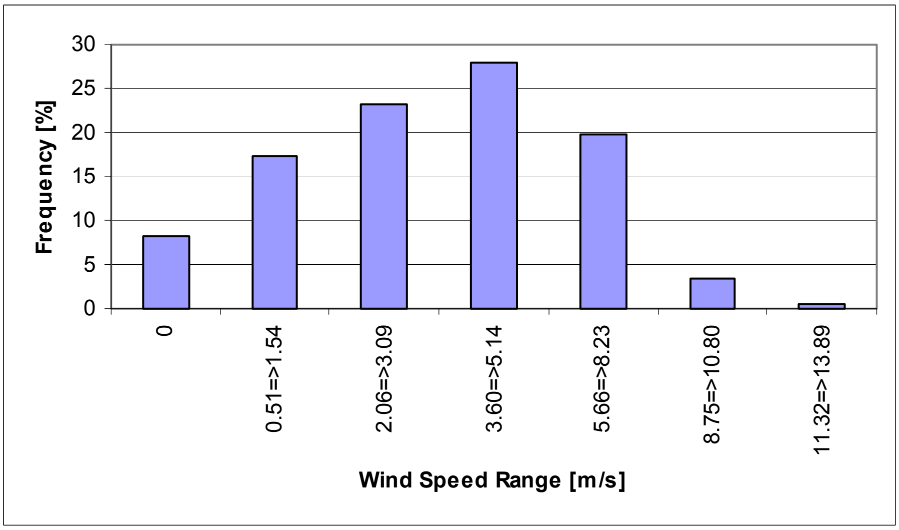


Figure 1: Wind frequency distribution at Northolt Aerodrome 1992-2001 NGR 5092E 1850N Alt 40m AMSL (Source: London Met Office) Windspeed range originally in Knots

The data was used to obtain a 'wind rose' shown in Figure 2. This indicates both wind speed and direction, and clearly indicates a prevailing wind direction from the south-west.

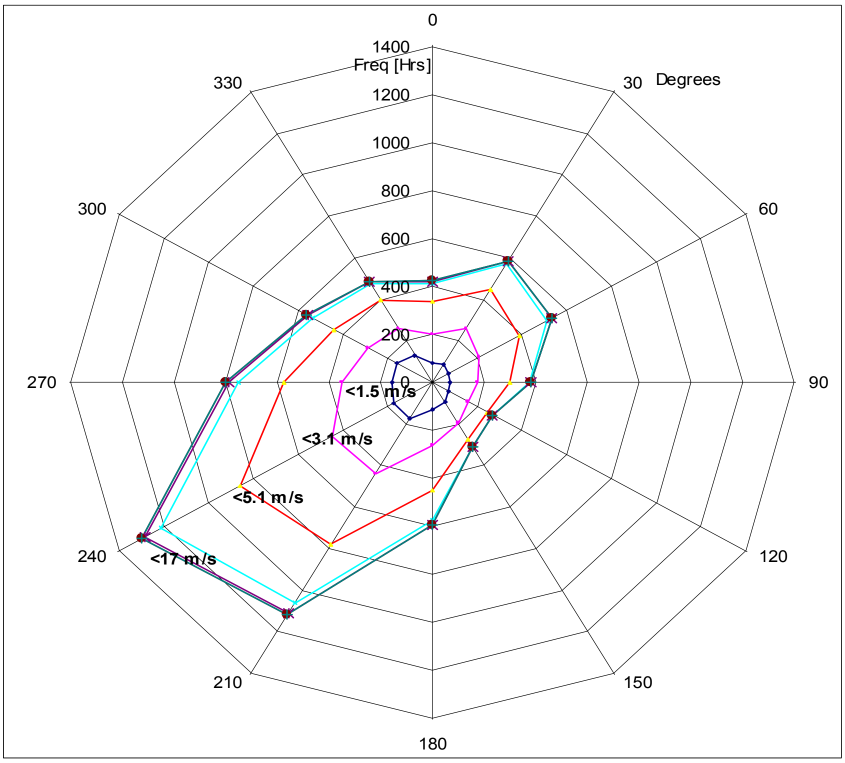


Figure 2: Annual Wind Rose at Northolt Aerodrome based on data for 1992-2001 supplied by London Met Office

3.2.2 Modelling and mapping wind speed

Local obstacles and topography

Nearby obstacles can significantly affect wind speeds at a particular site. They contribute to surface 'roughness' which causes turbulent wind flows. Not only does this slow the wind down, but it can also have a long-term detrimental effect on a turbine. Wind turbines are designed for laminar flow (evenly-layered) winds and constant exposure to turbulent wind flows may increase wear and tear.

The general rule of thumb is to site a turbine at a distance from the obstacle of at least ten times the obstacle's height. Alternatively, the turbine height should be increased to compensate. Potential obstacles upwind of the prevailing wind direction should be avoided as a priority. The local topography of the site can also exert an effect on the wind flows. Elevated positions with smooth approaches are preferable to those near sharp ridges or cliffs. More information regarding siting can be found on the BWEA's website mentioned in Section 3.2.1.

The proposed turbine location at the Northala Fields site is benefited by its elevated position on top of a mound, which lends a slight increase to the wind speed by virtue of the height above ground level. Smooth mounds or hills also tend to promote a speeding-up effect at the top, although it is unclear as to the magnitude of this effect for the size of mound proposed. The fairly smooth and unobstructed wind ‘fetch’ to the south-west is also advantageous, as this is the prevalent wind direction. (See Appendix A)

WAsP analysis

In order to gain further estimations of wind speed for the Northala Fields site, a software package was used to attempt to model data for the area. The Wind Atlas Analysis and Application Program[1] (WAsP) was developed by the Wind Energy Department at the Risø National Laboratory in Denmark. The software is used to predict the wind climate at a certain location and estimate subsequent wind turbine energy yields for the same site.

The WAsP programme is based on the ‘wind atlas’ method which uses empirical wind data from meteorological stations. The programme then normalises this data by considering the local terrain effects around the site and ‘subtracting’ these from the measured data. The resulting wind atlas refers to homogenous, flat terrain with uniform surface roughness. WAsP then attempts to predict wind climate statistics at potential sites for wind turbines within 50 km of any met station used in the wind atlas. The local terrain effects for the site under consideration are applied to the data set to derive wind speed/direction statistics, average wind speed and power density, and power production for a specified wind turbine type. The ‘local terrain effects’ modelled by the programme include contour height data, terrain classification (roughness) and the effects of local sheltering obstacles.

[1] www.wasp.dk

For the site under study, Heathrow Airport (approx. 16 km south-west from Northala Fields) is the nearest data source within the programme's available wind atlas. A 'roughness' map indicating the terrain classification of the area as used in the analysis is shown in Figure 3, where Roughness A = 0.3 and B = 0.5, indicating how the roughness changes as one moves westwards out of the highly built up area. The 'roughness length' as used in the programme is scaled from 0 (open sea) to 1 (city) and is illustrated in Table 2. Appendix A presents a plan of the Northala Fields site indicating two possible locations for the turbine and existing nearby sheltering obstacles.

Results of the analysis for annual average wind speed are presented in Table 3. Predicted annual energy yields for specific turbines are presented in Section 4.1.

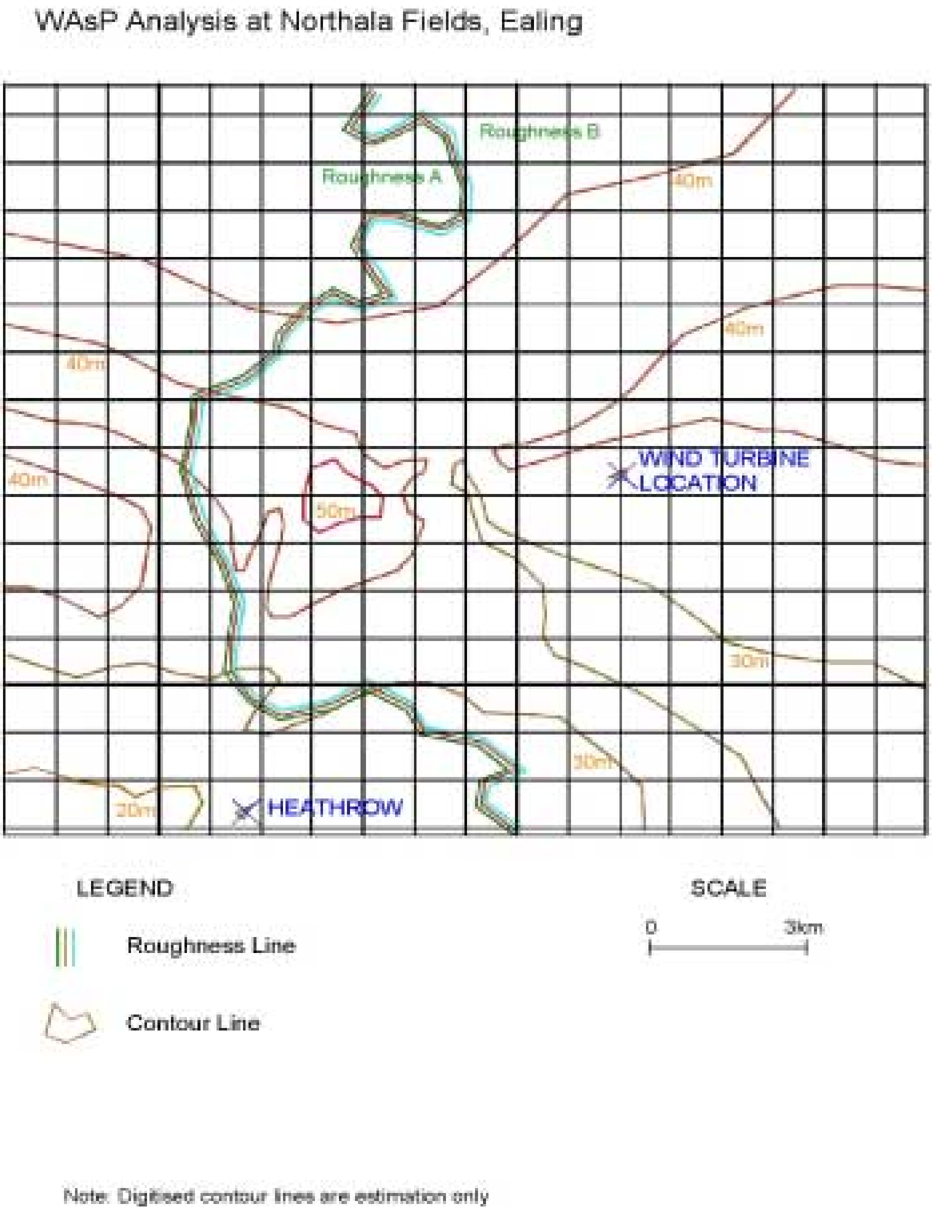


Figure 3: Map showing areas of different roughness. Values of 0.3 and 0.5 were assumed for A & B respectively, in the analysis.

Roughness Length, z_0 [m]	**Terrain Surface Characteristics**	**Roughness Class**
1.00	City	3
0.50	Suburbs	
0.30	Shelter belts	
0.20	Many trees and/or bushes	
0.10	Farmland with closed appearance	2
0.05	Farmland with open appearance	
0.03	Farmland with very few buildings, trees, etc. Airport areas with buildings and trees	1
0.01	Airport runway areas	
	Mown grass	
5×10^{-3}	Bare soil (smooth)	0
1×10^{-3}	Snow surfaces (smooth)	
3×10^{-4}	Sand surfaces (smooth)	
1×10^{-4}	Water areas (lakes, fjords, open sea)	

Table 2: Roughness length, surface characteristics and roughness class. Source: WAsP literature

Height Above Ground [m]	Predicted Annual average Wind Speed [m/s]
29	4.2
35	4.4

Table 3: Annual average wind speeds as predicted by WAsP for the Northala Fields site. Elevations are based on a 9m and 15m hub height (options for the Proven WT6000) on a 20m mound.

Although these values appear to be low when compared to NOABL results, it is reasonable to assume that they are more accurate as they consider local terrain factors in more detail. Actual wind speeds may be marginally higher due to effects not fully considered in the WAsP analysis, i.e. the smooth shape of the mound and the clear wind 'fetch' in the immediate vicinity in the prevailing wind direction as discussed above.

Wind speed mapping

In order to examine wind speeds over the borough area, and to compare with the particular sites under study, a wind mapping exercise was undertaken using the NOABL database. This provides point wind speeds for each 1km^2 of the UK with a uniform distribution at heights of 10, 25 & 40m above ground level. MapInfo Professional GIS was used to generate an interpolation for the study area from which wind speed contour regions were deduced. Ealing GIS team (Ealing Council) supplied Ordnance Survey postcode, elevation and background mapping together with aerial photography. This was combined with the wind data to produce the maps presented in Appendix B. The application of GIS also allowed the generation of a postcode unit level database of wind speeds for the borough within an Excel spreadsheet.

3.2.3 Measuring wind speed

Clearly, the most accurate wind speed data for a particular site will be that measured at the same location over a sufficiently long period. Ideally, the wind speed and direction should be measured at the proposed hub height and position of the turbine. Typically this will involve erecting a temporary 'met' mast at the site with various sensors and datalogging equipment installed.

The decision of whether to monitor, and to what extent, depends on a number of factors which may include:

- Scale and nature of project
- Available budget
- Time constraints
- Availability/accuracy of existing data
- Site constraints
- Contractual requirements of project, e.g. energy generation forecast

A monitoring regime should ideally collect at least one year's worth of data. Alternatively, six months of data can be taken and extrapolated using correlation techniques applied to wind regime statistics from a nearby met station for the same period, if available. Full site monitoring for large scale projects may involve a range of instrumentation including wind speed, wind direction, temperature and barometric pressure sensors, and high specification data loggers with remote data download facilities.

Smaller scale projects will typically require a lower specification monitoring system. The most basic system will comprise a low-cost anemometer and a simple counter-based datalogging device. One particular package currently on the market ('Windlogger'[1]) incorporates a bicycle 'trip' computer to record instantaneous, average and maximum wind speeds over various periods and is available for around £110.

The low-cost wind monitoring package mentioned above was considered an option for the Northala Fields site. Monitoring at hub height and position of the proposed turbine would have involved erecting a 35m mast in order to account for the height of the mound. The cost of this was not considered viable for the feasibility study, so an alternative option was investigated where the anemometer would be mounted on the top of a nearby lamppost along the A40. The datalogger could then have been securely housed in an enclosure at the lamppost base, with manual data readings being taken on a regular basis. Corrections to the data for the difference in height can be easily applied using the 'Power Law' method as follows:

$$V = Va\ (h/ha)^x$$

Where:

V = hub height wind speed

Va = Measured wind speed

h = hub height

ha = Height of measured wind speed

X = wind shear or surface roughness exponent. [This is a measure of the rate at which wind speeds increase with height –depending on ground terrain. Typical values[2] are 0.1 for water or ice, or 0.25 for suburbs with woodlands.]

On-site monitoring for this site, however, was eventually ruled-out due to time constraints.

Low-cost monitoring such as that described above can be useful for smaller-scale projects and can give a good indication of average wind speeds. However, care must be taken in positioning the equipment to reduce turbulence effects from the structure on which the instrument is mounted. Urban locations in particular can give rise to highly localised turbulent wind flows due to the high number of nearby obstacles. Wind monitoring should therefore take place as close to the proposed turbine location as possible.

The degree of data post-processing will largely depend on the type and amount of data collected. An accurate 'historical' annual wind frequency distribution can be obtained from higher sample rates (10 minute averages based on 2 second samples are typically used with high spec equipment for wind farm evaluation). This can then

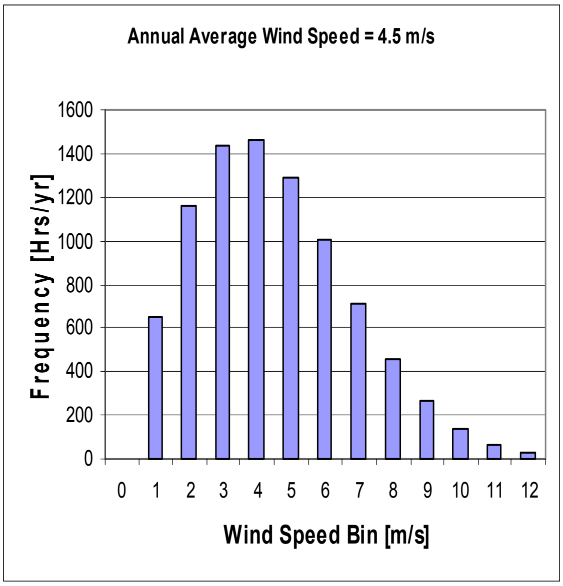
[1] www.provenenergy.com
[2] Source: *Wind Energy Basics*. Paul Gipe 1999

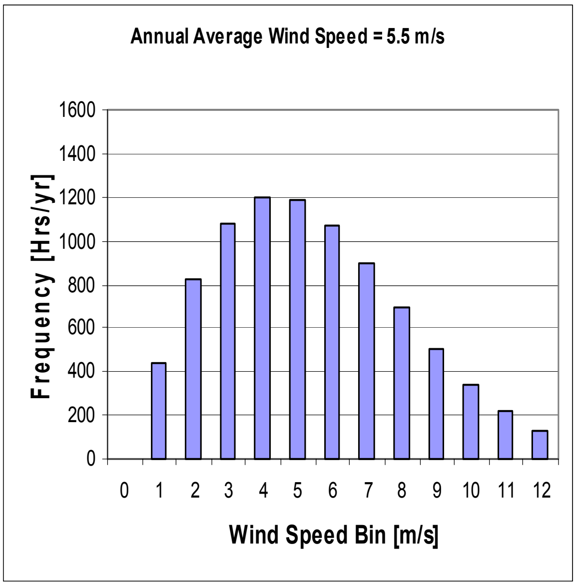
be directly applied to a wind turbine's power curve to obtain predicted annual energy yield.

3.2.4 Wind frequency distribution

Where estimates of annual average wind speed are available only, statistical methods, such as the Weibull distribution, can be used to model a frequency distribution. The form of this distribution is dependent on how 'peaked' the curve is (indicated by the Shape Factor, K) and on the overall levels of wind speed (indicated by the Scale Parameter, A). Turbine manufacturers generally use a distribution with a Shape Factor of 2, then called a Rayleigh distribution, when predicting annual energy output. Figures 4 & 5 show Rayleigh frequency distributions for annual average wind speeds of 4.5 m/s and 5.5 m/s respectively.

Wind turbines have specific start-up wind speeds, usually in the range 2.5-4.5 m/s, at which point the rotor begins to turn. It can be seen from Figure 4 that wind speeds below 2.5 m/s are likely to occur for around 1,818 hours (21%) of the year, for an annual average wind speed of 4.5 m/s. This implies that the turbine rotor will be stationary during these periods. This figure will decrease to around 1,263 hours (14%) for an annual average wind speed of 5.5 m/s.





Figures 4 & 5: Rayleigh Wind Speed Frequency Distributions

3.3 On-site energy demand and use

For reasons given in Section 3.4, it is sensible to design a small wind power installation to meet a particular on-site load. The option of selling electricity back to the grid may not always be an attractive option in economic terms (see Section 5.4). It is therefore good practice to obtain a good estimation of the site's electrical energy annual demand and load profile. In such cases, it is preferable to use as much generated energy as possible on site. Clearly, a wind turbine may be generating 24 hours per day, so it would be advantageous if the site incorporated a load pattern to match this as far as possible.

No specific details were available at time of writing on the load profile for the proposed development at Northala fields. However, the plans for the visitor centre currently include an office, café/restaurant, kitchen, public toilets and meeting room. In addition, a water pump and exterior lighting may be installed. Based on an estimated floor area of 255 m^2, the electrical load of the centre is estimated to be at least 8,000 kWh/year based on best practice benchmarks for naturally ventilated, office-type buildings. Added to this will be any water heating, exterior lighting, water pump and ground-source heat pump electrical requirements.

Table 4 shows estimated electrical demand of the site. The water pump, exterior lighting and possibly the ground-source heat pump are likely to require an electrical supply during the night which would help to create a more even load profile, better matched to the output of a wind turbine. It is likely that the opening hours of the centre would extend to 7 days a week, further ‘smoothing’ the load profile.

Load	Estimated Annual Electrical Demand [kWh]
Visitor Centre	8,415[1]
Exterior Lighting	2,000[2]
Water Pump	Unknown
Ground-Source Heat Pump	Unknown

Table 4: Estimated annual electrical demand of the Northala Fields site (does not include any water heating requirement)

3.4 Integration of renewable energy systems

Other types of renewable energy sources are also being considered for the Northala Fields development and may include solar thermal collectors, photovoltaics (PV) and a ground-source heat pump. Clearly, any on-site electricity generation in addition to that from a wind turbine should also be taken into account when matching generation capacity to load. A grid-connected PV system is relevant in this case and would provide electricity during daytime only. Typical annual energy yields[3] for PV systems in the UK are 800-900 kWh per installed kW_p. Assuming a south-facing 3 kW_p array (covering an area of approximately 24m^2 using monocrystalline panels), the annual energy yield is therefore estimated to be around 2,550 kWh. Both the wind and PV system can contribute to grid export, with a single export meter needed. In this case, connection costs charged by the DNO will be no different to that for a turbine only.

[1] Based on good practice benchmark for a naturally ventilated, cellular office (33 kWh/m^2/yr) www.projects.bre.co.uk/gpg286
[2] Based on 500W for 4000 hrs/year
[3] Source: Photovoltaics in the UK: An introductory guide for new consumers (Environmental Change Institute –University of Oxford)

A recent installation[1] at the Eden Project in Cornwall serves to illustrate a non-grid connected wind/solar hybrid system. The installation consists of a toilet block/bus shelter, without a mains electricity supply, powered by solar and wind. Power for lighting, cleaning appliances, a vending machine, display and solar hot water system pumps are provided by a 690 Ah battery bank. This is charged by a 1 kW wind turbine and a 480 W PV array. A solar thermal system provides heat for hand wash water and underfloor frost-protection heating, which is supplemented by the introduction of a 24Vdc 2kW dump immersion heater into the tank. This is powered by the wind/PV systems when the batteries are fully charged and via the batteries at set periods during the day. The equipment has been sized and installed in such a way to allow for expansion, should demand increase.

Certain combinations of renewable technologies will complement each other. A ground-source heat pump, for example, will typically transmit 3 to 4 kWh of heat energy for each kWh of electrical energy it consumes. A further step towards ‘carbon neutrality’ is then taken if this electricity supply is sourced from renewable generation, e.g. a PV system or from a ‘green’ utility tariff.

3.5 Grid-integration issues

There are two main options for connecting the power from the system. The first is grid-connection, where any surplus electricity that is not used immediately on-site is exported to the local grid. The second is stand-alone battery storage, where the energy generated is used to charge a battery bank, which, in turn, supplies power for the site. In cases where grid connection for export is prohibitively expensive, there may be an additional option of using a turbine to charge a battery storage system to supply the site, but that can be charged via mains electricity in times of high demand or low wind resource. This might typically be done overnight using cheap-rate electricity.

The choice of a stand-alone or grid-connect small-scale wind power system will depend on a number of factors, the most important usually being location and proximity to a connection point on the electricity network. For this reason, remote rural developments are more likely to be stand-alone and incorporate a battery storage facility. This will normally incur extra cost to that of a grid-connect system, depending, of course, on connection costs charged by the local District Network Operator (DNO). Depending on the battery bank capacity, the necessity of a back-up system will also need to be addressed, should there be times when demand exceeds supply. A battery bank will require additional maintenance and storage space. Health and safety risks would also need to be addressed by providing a secure, suitably ventilated enclosure. Unlike stand-alone systems, safety considerations mean that grid-connected turbines will shut down if loss of mains is detected.

Developments in urban areas will usually be located close to a suitable connection point thus favouring the grid-connect option. The advantages are the ability to sell excess electricity not used on site back to the utility, and the availability of a back-up supply at times of high demand. It may, however, add an extra cost element to the project in arranging a connection. This will partly depend on the turbine size and the

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[1] For further information contact Tony Thurgood Tel: 01364 72059 or tony@empecon.co.uk www.empecon.co.uk

connection standard required e.g. G83/G59 (See Section 4.3.1). Tariffs offered by utilities will vary and may not always be economically attractive. For projects with a level of commercial interest, it is important to undertake an economic analysis, projected over the expected life of the system, in order to compare capital and operational costs against predicted income. Although the negotiated tariff and site annual average wind speed will be critical in determining economic feasibility, the recent appearance of Renewable Obligation Certificates (ROCs) and Levy Exemption Certificates (LECS) may also play a part in this respect (see Section 5.4).

The electricity network in rural remote areas may require reinforcement in order to transmit wind-generated electricity, depending on size and type of turbine, which can increase costs. All installations, however, have the potential to cause electrical disturbances, such as voltage fluctuations and harmonics, to the local network. For this reason the local DNO will need to know details of the proposed development at an early stage in order to identify potential problems. If necessary, an initial survey may be undertaken, and will be chargeable. The subsequent connection costs will depend on the power rating of the turbine, the distance to the nearest connection point, the connection voltage and whether an export tariff is arranged.

Small-scale turbines such as those considered in this study will generally connect directly to the existing low-voltage network. The local DNO for the Northala Fields site, Scottish and Southern Ltd, were only able to provide an indication of costs as no specific details on connection points or site cabling were available at time of writing. Based on initial discussions with a Scottish & Southern representative[1], it is unlikely that an initial survey would be required. The nearest likely substation to the proposed location of the visitor centre is at Gulliver Close. Assuming a standard 3 phase supply is routed to the visitor centre, there should be no problems with direct connection for the size of turbine considered here. If electricity export is required, connection costs are estimated to be around £500-£600[2]. The turbine installers will typically include the installation of cabling and conditioning equipment within their scope of works, leaving additional export metering and the final inspection for the DNO, before switch-on. Depending on the connection standard, the connection costs will be lower if metered electricity export is not required.

An option exists to 'dump' turbine electrical output as useful heat (e.g. for water heating or storage heating) if there are periods of zero demand and the turbine is generating. This arrangement may be appropriate in off-grid installations, for example, when the battery storage facility is fully charged and there is no other demand. It may also be relevant where the economics involved with grid connection for export and/or the expected generation revenue do not warrant such an arrangement. It is always preferable in economic terms, however, to utilise the power as electricity rather than as heat.

[1] Phil Deacon <phil.deacon@scottish-southern.co.uk>
[2] Actual cost subject to finalised details of visitor centre and turbine installation

4 TECHNICAL OPTIONS APPRAISAL

4.1 Urban wind power: choice of turbine

Available budget, technical feasibility and planning constraints are the principal factors that will restrict the size of a wind power installation. The latter is especially true for urban applications and will depend on such issues as proximity to residential areas and flight paths, and other environmental impacts. Generally, smaller turbines are more likely to have less impact in this respect and hence turbines up to 20 kW only are considered in this study. Economies of scale will also apply in sizing a project and will directly affect economic viability. Larger scale turbines may also have potential as a visitor attraction and benefit economics e.g. Ecotech Wind Turbine at Swaffham[1].

Apart from small 'micro' turbines (<500W), the vast majority of free-standing wind turbines now on the market are of the horizontal axis 3-blade design. Two bladed rotors are available and tend to be cheaper, but are less balanced and are usually noisier due to higher rotational speeds which also promote increased wear. Vertical axis machines are now rarely available and are generally considered visually less attractive. However, a number of new designs are being developed in the field of 'Building-Augmented Wind Power' (BAWP) -see below.

Urban locations have lower wind speeds than rural areas and can give rise to areas of increased turbulence due to the high number of obstacles present. Excessively turbulent wind flows can exert increased stresses on turbine components which may lead to noisier operation and premature wear and tear. It is therefore important to examine the proposed site in this respect and attempt to assess the impact of surrounding obstacles.

When urban sites are considered, the low wind speeds should be assessed in relation to the 'start-up' and 'cut-in' wind speeds of the turbine i.e. the wind speeds at which the rotor will begin turning and the turbine begin generating. For most small turbines, the start-up wind speed is less than that of its cut-in wind speed. Other turbines, such as the Gazelle, will begin to rotate only when the cut-in wind speed is reached and sustained for a period of time. Using the wind speed frequency distribution for the site, an estimate can therefore be made as to the proportion of time a turbine will be generating, as well as the proportion of time the rotor will be moving (see Section 3.2.4). This will be particularly important for high-profile installations where raising public awareness is a key objective.

For the purpose of this study, a selection of small-scale turbines are considered and compared for suitability of installation at the selected sites. These machines range from 6 to 20 kW and their basic specifications are summarised in Table 5. The list is not exhaustive and other turbines may be available. Energy production for various annual average wind speeds are shown in Table 6. Illustrations are shown in Appendix C.

[1] www.ecotricity.co.uk/projects/op_ecotech.html

Model	Supplier	Rating [kW]	Rated Wind Speed [m/s]	Start-up Wind Speed [m/s]	Rotor Type	Mast Type & Hub-height
WT6000	Proven Engineering	6	12	2.5	3 blade 5.5m diam downwind	Free standing 9m or 15m
Montana	Fortis	5.8	14	2.5	3 blade 5m diam. upwind	Guyed or free-standing from 12 m
Alize	Fortis	10	12	2.5	3 blade 7m diam. upwind	Guyed or free-standing from 12 m
BWC EXCEL (Grid link)	Bergey	10	13.8	3.1	3 blade 7m diam. upwind	Guyed or free standing 18m to 37m
Westwind 10 kW	Westwind	10	14	Start-up -3 Cut-in 4	Upwind	Guyed as standard from 18m
Gazelle	Gazelle Wind Turbines Ltd.	20	12.5	4	3 blade 11m diam. downwind	Free standing 13m
Westwind 20 kW	Westwind	20	14	Start-up 2.5 Cut-in 3.0	3 blade 10m diam. upwind	30m guyed as standard

Table 5: Selection of small-scale turbines

Annual average wind speed [m/s]	Estimated annual energy production [kWh] for each turbine model						
	WT6000 [6 kW]	Montana [5.8 kW]	Alize [10 kW]	Excel [10 kW]	Westwind[1] [10 kW]	Westwind [20 kW]	Gazelle [20 kW]
4	6,765	3,664	7,723	5,951	7,300	14,000	No data
5	11,622	6,334	14,472	11,484	12,775	24,000	36,000
6	16,900	9,568	22,029	17,779	18,615	36.000	53,000
7	21,944	13,126	29,091	23,698	23,360	49,000	68,000

Table 6: Estimated energy production of selected turbines for annual average wind speeds.

Estimated energy yields are indeed estimates only and should be treated with a degree of caution[2]. They are normally derived from the turbine's power curve which, for small turbines, may not always be 'certified' by an independent body due to the costs incurred in doing so. In Table 6, values were taken directly from 'average annual wind speed vs annual energy output' curves, as supplied by manufacturers, where possible. Where these were not available, estimates were obtained from power curves using a Rayleigh wind probability distribution function, which most manufactures use in estimating energy yields.

[1] 'Light' as opposed to 'standard' model –claims to produce more energy at lower wind speeds.
[2] See Home Power Magazine #90 or www.homepower.com for downloadable article

Augmenting Wind Turbines

The concept of adding a structure, such as a shroud, to improve turbine performance has developed into a number of prototype designs. As well as improving performance, the idea is to increase acceptability of wind turbines in the built environment by making them quieter, less visually intrusive and able to act as part of a building structure. Designs where buildings also act as wind 'concentrators' are commonly known as Building-Augmented Wind Turbines (BAWTs).

4.2 Installation issues

Small-scale turbines are generally erected via crane or use of a 'tilt-up' winching system on to a concrete block foundation. An installation at ground level, i.e. not on top of a mound, or the site near Coston School, should pose no problem in this respect as access is good and the area in which a turbine could be located is relatively flat. However, installation on top of a mound as proposed at Northala Fields needs further investigation. The proposed mound shown in Appendix A will have a diameter of approximately 110m at base, with the summit levelled off to around 8m in diameter, leaving an overall height of around 20m. The slope, area and shape of plateau, and mound material will all affect the feasibility of a turbine installation. It is expected that the material for the mounds will be sourced from local building sites and consist of general excavation soil and clay.

Following discussions with installers, the installation issues are considered below:

Erection

Most small-scale turbines are winched into position via a tilt-up method with anchor points. This is the case for all the turbines listed in Table 5, apart from the Gazelle, which is currently a crane-erect machine. Mast types can be either free-standing or guyed. The Gazelle and WT6000 come supplied with free-standing tubular masts, whereas the Fortis, Bergey and Westwind machines come with guyed masts as standard, but with options for free-standing. Free-standing (or self-supported) masts tend to be more expensive than guyed, and may need to be custom specified.

Proven have stated that, for the WT6000, a plateau of at least 33m in length would normally be required to allow for the 15m turbine mast and winching equipment. Using a 9m turbine mast would reduce this length to 21m. The plateau area could be reduced if a non-standard lifting arrangement was employed which may incorporate a larger winch and/or a temporary support structure for the turbine. The option to use a crane is possible if vehicular access to the plateau is incorporated.

Galeforce have stated that installation of their turbines on the mound is feasible and would require a plateau of around 8-10 m diameter, depending on the type of mast used.

The Gazelle is currently a crane-erect machine and requires a standard 25 tonne crane for installation. The plateau would need to measure at least 8m by 8m in order to position the crane. The crane, however, would need a track in order to ascend the mound, which would probably take the form of a spiral to gain an acceptable gradient. The alternative to a track would be to use a crane with 'crawler' tracks, although the slope of the mound will be a limiting factor.

Considering the above, it would appear that the mound design would need some degree of modification to enable a turbine installation. A winch method erection would be facilitated by a larger plateau area and may be helped by a temporary scaffold or support. However, levelling-off the mound, whilst maintaining its plateau height of 20m, would increase the slope of the side and the overall shape would change. The absence of an access track to the top would require equipment to be winched up.

Further discussions between the site developers and turbine installers will be required to decide on the most compatible combination of mound design, mast type and installation method. Access for maintenance will also need to be addressed (see Section 4.4).

Foundations

Small-scale turbine foundations typically consist of a reinforced concrete block, with additional anchor point foundations for winch-erect machines. The turbine foundation would need to be 3m square x 1.2m deep for the WT6000 and around 4.5m square x 1m deep for the Gazelle, which would also need a minimum ground-bearing pressure of 85kN/m^2.

Cabling

Power and control cabling would require trenching from the turbine base to a suitable connection point in the mains distribution board for the visitor centre. The length of this run is expected to be no greater than 100m. A suitable location will be required for any electrical conditioning equipment, which typically consists of an enclosure housing a rectifier/inverter, along with a control panel.

4.3 Electrical connection

Note: some elements of electrical connection options are also covered in Section 3.5.

4.3.1 Grid connection

Costs of grid connection by the DNO will depend on a number of issues including size & voltage of turbine, distance to a suitable connection point and metering costs. Based on information currently available, Scottish & Southern have stated that connection costs may be in the order of £500-£600, although the actual cost may be higher depending on the final layout of the site, turbine rating and grid-connection equipment used. Their scope of work will cover inspection and approval of the installation, and provision of metering. The arrangement for purchase of any electricity exported from the turbine to the grid does not necessarily need to be with the local DNO. This is covered further in Section 5.4.

The type of turbine generator will determine the type of conditioning equipment required before connection to the mains supply. The Gazelle generates 3-phase 415V AC and can connect directly to 3-phase mains. The other turbines considered are similar in their requirements for electrical connection. The generators typically generate at 3-phase which is rectified to DC, before being converted to mains level voltage by an approved inverter.

A turbine control/data cable will terminate in an enclosure housing the basic controls. In order to avoid excessive voltage drop, there will be some limitation on the length of installer-recommended cables. As the actual length of the route between the proposed locations of the turbine and visitor centre is estimated to be between 80 and 100 m, an alternative method would be to locate the enclosure at the base of the turbine and run a suitable cable from there.

Currently, the installation will need to comply with the G59 standard, as the connection rating will be above 5 kW. However, a new G83 standard is expected to come into force in the near future. Depending on the finalised details of this, there may be a requirement for half-hourly metering above a certain threshold (possibly 10.8kW) which may add to grid-connection costs.

4.3.2 Battery storage

Stand-alone energy storage tends to be an expensive component of a wind energy system and needs to be sized with care, especially if integrating with other generation, such as PV, in order to match load patterns and keep costs down. Based on quotes obtained for 5.8 and 10 kW wind systems[1], a battery storage option will cost around 15 to 20% more than equivalent grid-tie systems. Additionally, the design of the visitor centre will need to incorporate a suitable room or enclosure for the battery bank. Lead-acid deep cycle batteries will have a typical life span of 5-8 years before replacement is required. This will add a significant future cost element to the project.

4.4 Operation and maintenance

Turbine servicing is typically undertaken annually and consists of visual and audible checks for blade erosion and signs of component fatigue. Lubrication may be necessary for certain components within the turbine nacelle, although most units use sealed bearings with little or no maintenance requirements. Access is made easier when a mast can be lowered to the ground using a winch, as is usually the case with all models considered here except the Gazelle. In this case, a ladder is incorporated on the mast for hub access. An alternatively to winching is to use a scaffold/ladder arrangement or a crane/cherry-picker, providing vehicular access is available.

Generally, persons responsible for site maintenance can carry out routine servicing on small turbines with guidance from the suppliers and reference to the instruction manual. It is suggested that the person responsible for site engineering maintenance is given instruction on turbine maintenance during or after installation. Galeforce, for example, offer a one-day tutorial in turbine maintenance. Alternatively, a maintenance contract can be arranged with the turbine supplier/installer if required, although this is likely to be more costly. The suppliers of the Gazelle recommend that their own contractors undertake servicing. A battery storage system would need additional maintenance requirements such as the

[1] Quotes from Galeforce Ltd.: 5.8kW system with 230 Ah battery bank; 10kW system with 460 Ah battery bank.

periodic checking of individual batteries, connections etc. and replacement where necessary.

Operation is fully automatic with automatic 'cut-in' and 'cut-out' at preset wind speeds. It is recommended that an employee based at the site is selected to undertake occasional rudimentary checks e.g. meter readings, and to report on any problems or issues noted.

5 ECONOMIC ANALYSIS

5.1 Capital and installation costs

Estimated costs have been obtained for supply, installation and commissioning for a selection of turbines. Breakdowns of these costs, where available, are presented in Table 7.

	Approx. Costs [£]		
Turbine Model	**Equipment**	**Installation**	**Total (inc. VAT)**
Montana 5.8kW	9,500	3,000	12,500
WT6000 6kW	15,390	3,000	20,700
Excel 10 kW	26,850	4,500	31,350
Alize 10 kW	24,850	4,500	30,800
Alize 10 kW + battery storage*	29,814	4,500	36,000
Westwind 10 kW	29,000	4,500	33,500
Westwind 20 kW	38,000	5,000	43,000
Gazelle 20 kW	-	-	80,000

*Table 7: Estimated capital and installation costs for selected turbines. Costs assume grid-connect systems apart from **

Costs are only estimates at this stage and may be higher due to the non-standard techniques required in erecting on a mound, and type of mast chosen. Further discussions with the turbine suppliers and site developers are required to agree the final mound design and most appropriate method of installation before more accurate quotes can be given. Installation costs may be minimised if timed to coincide with the construction of the mounds and existing on-site equipment is utilised as far as possible.

5.2 Operation and maintenance costs

The method of accessing the turbine for routine servicing and maintenance will largely define costs of labour and equipment required. As described in Section 4.2, winching, crane/cherry-picker or scaffold/ladder access could be required depending on the turbine and mast chosen. The figures shown in Table 7 assume one annual service and occasional maintenance, which may require a total of one day's work per year. A maintenance contract, for example, with the Gazelle suppliers can be arranged for a fee of around £750/yr.

5.3 Financing options

The main source of grant funding for small-scale community or household wind power is currently from the government's 'Clear Skies' programme. This offers part funding for feasibility studies and/or project implementation costs for certain renewable energy technologies. Funds are available to householders and non-profit organisations with strong links to the community. Further details on this and other funding sources is listed in Appendix E.

5.4 Revenue generation and payback

Appendix D presents the basic economic model spreadsheet. The results are summarised in Table 8. A battery storage option is also included for comparison.

Turbine model	Total capital cost [£] minus 50% grant	Estimated annual O & M costs [£]	Annual average wind speed [m/s]	Estimated annual energy production [kWh]	Discounted payback period [yrs] at 6% discount rate	Estimated annual CO2 saving [tonnes]
WT6000 [6kW] grid-connect	10,350	250	4	6,765	>50	2.9
			5	11,622	>50	5.0
			6	16,900	23	7.3
			7	21,944	13	9.4
Alize [10kW] grid-connect	15,400	250	4	7,723	>50	3.3
			5	14,427	>50	6.2
			6	22,029	26	9.5
			7	29,091	14	12.5
Westwind [20kW] grid-connect	21,500	250	4	14,000	>50	6.0
			5	24,000	>50	10.3
			6	36,000	17	15.5
			7	49,000	10	21.1
Gazelle [20kW] grid-connect	40,000	750	4	No data	>50	No data
			5	36,000	>50	15.5
			6	53,000	38	22.8
			7	68,000	18	29.2
Alize [10kW] battery storage	18,000	500	4	7,723	>50	3.3
			5	14,427	>50	6.2
			6	22,029	>50	9.5
			7	29,091	20	12.5

Table 8: Summary of economic analysis

Assumptions:

- 50% grant is that offered by the Clear Skies Programme (see Appendix E). There may be additional sources of funding in the form of sponsorship, advertising, utility funds, etc. which would further reduce capital costs and payback periods.

- Estimated capital costs are as quoted by installers based on standard installation. Actual costs may vary subject to final design of mound and turbine erection method. Cost of additional specialist equipment e.g. displays, not included.

- All generated electricity is valued at 6.5 p/kWh. Discounted payback period is the approximate period after which the cumulative cash flow becomes positive. Yearly cash flow is calculated using Net Present Values (NPV) for income and expenditure over the life of the project. See Appendix D for example spreadsheet.

- Operation and maintenance costs are estimates based on 1 day per year for turbine servicing but do not include specialist equipment hire. Apart from the Gazelle, it is assumed that maintenance will be undertaken by the site engineer. The figure for the battery storage option allows for additional battery maintenance work.

- CO_2 savings are based on emission factor 0.43 $kgCO_2/kWh$[1]

- CO_2 savings based on all generated electricity offsetting conventional sources.

It can be seen from the analysis that payback periods, even with 50% grant funding, are excessive for annual average wind speeds of 4 m/s and 5 m/s. The payback periods stated are based on the assumption that each unit of electricity generated on site is given a value equal to each unit imported (6.5p/kWh is assumed here). However, this will depend on the site load and usage profile, size of turbine and the deal negotiated with the utility. It is likely that some electricity will be exported during times of low demand, and the price obtained for this will affect payback periods. Net metering is not commonly available as yet in this country and revenue from exports is unlikely to equal that from avoided imports. It may be the case that an arrangement with the utility regarding ROCS[2], LECs and generated electricity together may be the preferred option. This will depend on the amount generated per year, the amount exported and the terms offered by the utility.

The payback periods stated for the battery storage option are again based on all generated electricity directly offsetting imports. In reality, there will be times when the batteries are fully charged and excess electricity will be dumped as heat or

[1] from Energy Efficiency Commitment 2002.
[2] For further details see: www.reic.co.uk/powerpurchaseagree.html or www.ofgem.gov.uk/ofgem/index.jsp contact Steve McBurney tel: 020 7901 7371

possibly exported. More accurate predictions can only be made once site load patterns are known.

It should also be noted that payback periods are sensitive to annual expenditure on operation and maintenance. A requirement to hire specialised equipment, e.g. crane or cherry-picker for access to turbine, may significantly increase payback periods.

To illustrate a fairly typical export tariff currently on offer, the utility service providers for the Northolt area, Scottish and Southern, are currently offering the following indicative terms for the purchase of energy from small scale wind generation sites for 2002/2003:

Between 00.30 hrs and 07.30 hrs each day: 1.49 p/kWh

At all other times: 2.11 p/kWh

The export units would be measured by the installation of a separate domestic meter wired in reverse. Billing would be done on a 6-monthly basis and would incorporate a £15 per bill surcharge to cover metering and administration costs. The energy generated may also qualify for an additional revenue stream in the form of Renewable Obligation Certificates (ROCs) and Levy Exemption Certificates (LECs). These are awarded for every MWh of renewable energy generated in each month, assuming a minimum of 500kWh/month is generated. The issue of ROCs and LECs is dependent on the renewable energy installation being accredited by Ofgem.

The minimum equivalent value of ROCs are 3p/kWh[1], but currently trade at up to 4.5p/kWh. It is thought that this applies to all electricity generated, not just that which is exported. LECs are currently fixed at 0.43p/kWh. Hence, by combining the above, the value of each kWh could approach that of imported electricity.

6 PLANNING, SOCIAL AND ENVIRONMENTAL CONSIDERATIONS

6.1 CO_2 savings

Electricity generated by the turbine will offset that generated from conventional sources and carbon dioxide emissions associated with conventional generation will be reduced as a result. Estimated annual savings of CO_2 are shown in Tables 8 & 9. There will also be savings in other emissions such as NOx and SOx.

6.2 Noise and visual impact

Wind power systems have, in recent years, come under increased scrutiny in regard to visual impact and, to a lesser extent, noise. Any planning application will therefore need to address these issues carefully. Noise will be particularly relevant in urban areas where dwellings are likely to be in close proximity and the dynamic nature of a turbine will add to the visual impact. This latter point can be an issue when, in bright conditions, the shadow cast by the rotor can cause disturbance to those in its path, known as 'shadow flicker'.

For the Northala Fields site, the noise level generated from the proposed turbine is expected to have a minimal impact on the surrounding residential area. For the

[1] See www.r-p-a.org.uk for further info

residents north of the A40, the turbine noise is unlikely to be noticeable above the existing traffic noise. The four mounds proposed on the site will, to some extent, shelter the area to the south-west from traffic noise and hence lower the background noise level, possibly increasing the relative noise from the turbine. This may be especially true at low traffic levels during the night. However, the nearest existing dwelling is around 200m from the turbine position, which is outside the 180m limit recommended for the Gazelle turbine. Proven have tested noise levels from the WT6000 and have concluded that they generally do not exceed background noise levels beyond a distance of 25m.

The turbine is likely to have a significant visual impact on the surrounding area due to its position on top of a 20m mound. Indeed, raising the public's awareness of sustainable energy issues is one of the project's main objectives and it is hoped that the turbine will serve as an iconic landmark along the busy A40. The issue of visual intrusion to local residents is one that should be carefully considered. It is thought unlikely that there will be many objections to a turbine of this scale, although it is highly advisable to inform residents of the proposals at an early stage. It is expected that some form of public consultation will be conducted in regard to the eco-park as a whole and the turbine proposal will form a part of this.

6.3 Other environmental impacts

The scale and nature of the proposed turbine is unlikely to significantly affect wildlife at the Northala Fields development. An ecological survey will normally be required for a development of this scale, as the proposed landscaping will involve major changes. Disturbance to birds has occasionally been cited as a negative environmental impact of a turbine although little evidence of this exists.

6.4 Other planning/social issues

To date, a relatively large number of wind farm planning applications have been refused due to objections from the Ministry of Defence. The main concern is that aircraft communications or radar may be disrupted by electromagnetic interference from the wind farm. As a result, details of all planned wind farms are required to be submitted to the MOD, the Civil Aviation Authority (CAA) and the National Air Traffic Service (NATS). Assessment is made against air safety and defence interests through evaluation of the possible effects on air traffic systems, defence systems and low flying needs[1].

Exactly what scale a project has to be before it warrants such an application is not clearly defined. However, having outlined the proposal at Northala Fields to an appropriate Defence Estates representative, it was recommended that the standard application form be submitted. The proximity of the site to Northolt Aerodrome, and to Heathrow Airport, also gave weight to this procedure. At time of writing, Defence Estates have confirmed that they hold no objection to the proposed ‘wind farm’ at Northala Fields. The Directorate of Airspace Policy have also responded with a recommendation to contact the BAA, as the site is within 30km of Heathrow Airport. No response has yet been received from BAA or NATS.

[1] Follow link http://www.britishwindenergy.co.uk/aviation/index.html for proforma application form

7 CONCLUSIONS AND RECOMMENDATIONS

7.1 Proposed installation

7.1.1 Site selection

The NOABL wind speeds across the borough area (Appendix B) would indicate that the Northala Fields site lies within the lower range, although the differences are relatively small. Any site-specific factors to enhance wind speed would therefore be preferable. The proposed turbine location at Northala Fields benefits from an elevated position on top of a mound and a reasonably clear fetch in the direction of the prevalent wind speed to the south-west. It is therefore a suitable location in terms of maximising wind speeds.

The wind data obtained has produced varying estimates of annual average wind speed. The above-ground hub height assumed at Northala Fields is 35m (20m mound height plus 15m mast) and results in predicted wind speeds of 4.4 m/s (WAsP) to around 5.5 m/s (NOABL). Based on these results, a hub height of 15m, i.e. if the turbine was erected at ground-level, would produce annual average wind speeds in the range 3.5m/s to 4.5 m/s. In this case, a taller mast may be considered to gain higher wind speeds.

It is reasonable to assume that WAsP provides a better estimate as more localised factors are taken into consideration. However, the method still depends on assumed values of surface roughness and, in this case, on the extrapolation of data from a site 16km distant. Uncertainties in both values therefore exist but are difficult to evaluate. In predicting annual energy outputs, annual average wind speeds of 4 m/s and 5 m/s, thought to represent high and low estimates, have been used for comparison. This exercise highlights the fact that on-site measurements are the preferable option and will provide the most accurate results, providing at least 6 months of data can be obtained and the equipment is appropriately located.

The proposed location on top of a mound raises certain issues as to installation method. This depends on the type of turbine and is hence considered in the following section.

7.1.2 Turbine selection

As described in Section 4, a number of turbines up to 20 kW were considered. All models normally employ a winch-erect installation method apart from the Gazelle, which uses a crane. In this latter case, a track would be required for the crane to gain access to the mound top. In order to install anchor points and use winching equipment, the other turbines require a ‘flat’ plateau, the area of which varies depending on the turbine and mast height. Free-standing masts, which are not designed to be lowered, can often be used in place of guyed masts, but this is a more expensive option and may require additional design work and crane access for installation.

Following discussions with installers, it would appear that a mound-top installation is feasible for all turbines considered, subject to certain alterations to the mound design and arrangements for maintenance access. This would require detailed discussions between the site developers and turbine installers. Installation is likely to be easier if arranged to coincide with construction of the mound.

As discussed earlier, values stated for energy produced by most small-scale turbines tend to be estimates only and largely depend on the provision of an accurate power curve, and the application of statistical wind data. Assuming an annual average wind speed of 5 m/s, a 6 kW turbine is likely to meet the basic electrical demand of the visitor centre, but not additional loads such as a ground source heat pump. The 10 kW and 20 kW machines will supply more energy and, with the larger rotors, are considered more visually impacting. Payback periods for all grid-connect options are long (>50 yrs) for annual average wind speeds of 4 and 5 m/s for the conditions considered with 50% funding. It is only when annual average wind speeds reach 7 m/s and above that payback periods decrease to <20 years.

Although the most visually striking of the choices, the Gazelle is not recommended owing to its higher start-up wind speed and limited options for installation. A battery storage option is also not thought appropriate due to the expected low cost of grid connection and the increased maintenance and cost requirements.

Considering the above, the two most appropriate choices appear to be the 10 kW Alize and the 20 kW Westwind. For an average annual wind speed of 4.5 m/s, the 2.5 m/s start-up speed of these turbines may typically result in the rotor being stationary for around 21% of the year. The final decision will depend on the relative importance given to the economics, ease of installation/access and visual impact. Table 10 summarises the main issues in this respect.

	Alize 10 kW	Westwind 20 kW
Appearance (See Appendix C)	3 blade 7m diam. with tail fin. Start-up wind speed = 2.5 m/s	3 blade 10m diam. with tail fin. Start-up wind speed = 2.5 m/s
Installation/access	Depends on choice of mast. 18m guyed tilt-up type supplied as standard, but other heights available.	Depends on choice of mast. 30m guyed tilt-up type supplied as standard, hence a shorter, non-standard mast will be required (likely to increase cost).
Cost	Lower capital cost. Long payback (>50 years) at expected annual average wind speeds on site.	Higher capital cost. Long payback (>50 years) at expected annual average wind speeds on site.
Performance	Less energy generated per year than 20kW Westwind.	More energy generated per year – approx. double that of the Alize at 4m/s.

Table 10: Comparison of the Alize 10 kW and Westwind 20 kW turbines

It should be emphasised that the relatively low wind speeds predicted on-site will result in very long payback periods making the project unviable in purely economic terms. These results have been produced using estimates for certain parameters within the analysis, namely, installation costs, annual operation and maintenance costs, and the assumed value of the electricity generated. Actual values for these parameters may vary significantly and payback periods will vary accordingly. It is recommended that further analysis is undertaken once better estimates are available.

The low annual average wind speeds will also result in the rotor of an installed turbine being stationary for a significant proportion of the time. Based on a Rayleigh distribution (See Section 3.2.4) of a 4.5 m/s annual average wind speed, it is estimated that this period could be around 21% of the time.

7.1.3 Connection options

The main advantage of battery storage is independence from the grid. Disadvantages include higher costs –both for capital outlay and replacement batteries over the project life span, and increased maintenance and space requirements. The option to grid-connect is therefore recommended as the visitor centre design is thought to include a mains electricity supply, and the estimated costs of connecting to this are relatively low. Although the local utility's purchasing rates are currently not economically attractive, other purchase agreements are now becoming available and could include net-metering arrangements. Further discussions with potential purchasers are required to negotiate rates and investigate the use of ROCs and LECs. The metered export of electricity may also play a part in the educational aspects of the project.

7.2 Potential for wind power in the Borough of Ealing

The wind map of the borough shown in Appendix B indicates estimated wind speeds. In planning for other wind power projects, this will be a useful resource in initially identifying 'hot-spots' i.e. potential sites with the highest wind speeds. The next steps, as conducted for Northala Fields, may involve the following:

- Site survey to identify feasibility in terms of general planning, local obstacles and other physical practicalities
- Consultation with local District Network Operator
- Identification of potential load profiles
- Further assessment of wind speeds –on-site measurements if possible
- Technical options appraisal & consultation with potential installers
- Economic analysis
- Consideration of specific planning, social & environmental issues

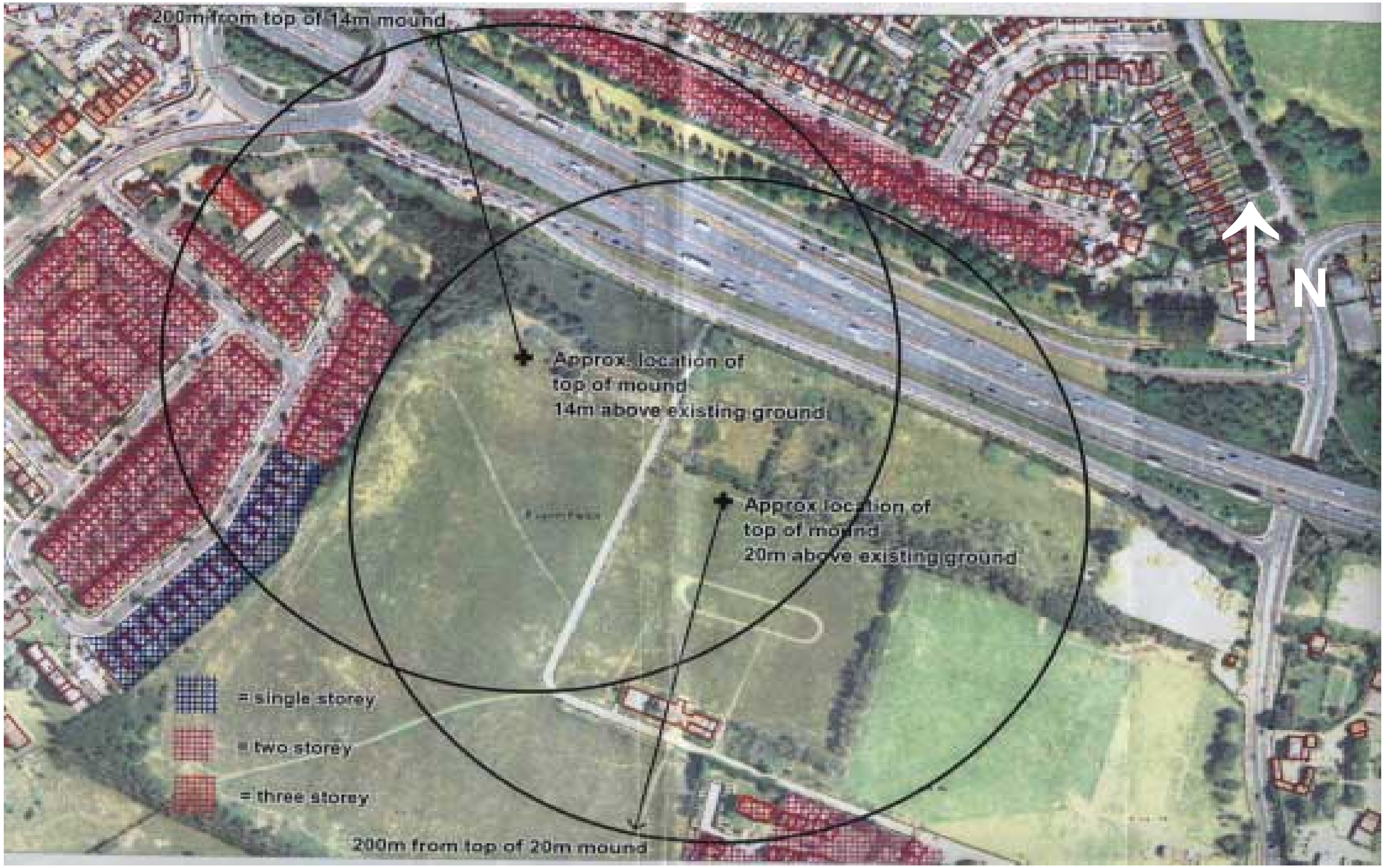
Projects such as Northala Fields will tend to be few in number due to the disadvantage of low urban wind speeds. For small turbines, urban 'hot-spots' with higher wind speeds may turn out to be marginally economically viable, but installations in these areas may not be feasible for a variety of reasons. Economic viability is more likely to be the case for larger turbines due to economies of scale, but planning difficulties may then be more of an issue. The range of average wind speeds indicated on the wind map across the borough is relatively small, around 0.5 m/s, with Northala Fields located at the lower end of this range. In comparison to the mound-top installation at Northala Fields, this increase in annual average wind speed may add around 25% to annual energy production. However, this is unlikely to significantly increase economic viability for the turbines considered in this study, as average wind speeds need to approach 7 m/s before payback periods under 15 years are encountered.

In planning for urban wind, options for Building-Augmented Wind Turbines should be given consideration (see Section 4.1). Although still at an early stage of development, they will potentially offer increased economic viability and be designed to blend in more with the urban environment, and hence be more acceptable to planners. Novel designs are currently being considered in certain developments – see Appendix F for contacts.

APPENDICES:

A: Site plan: Northala Fields
B: Wind speed map of borough
C: Turbine images
D: Economic model spreadsheet
E: Funding sources/economic incentives
F: List of information sources & contacts

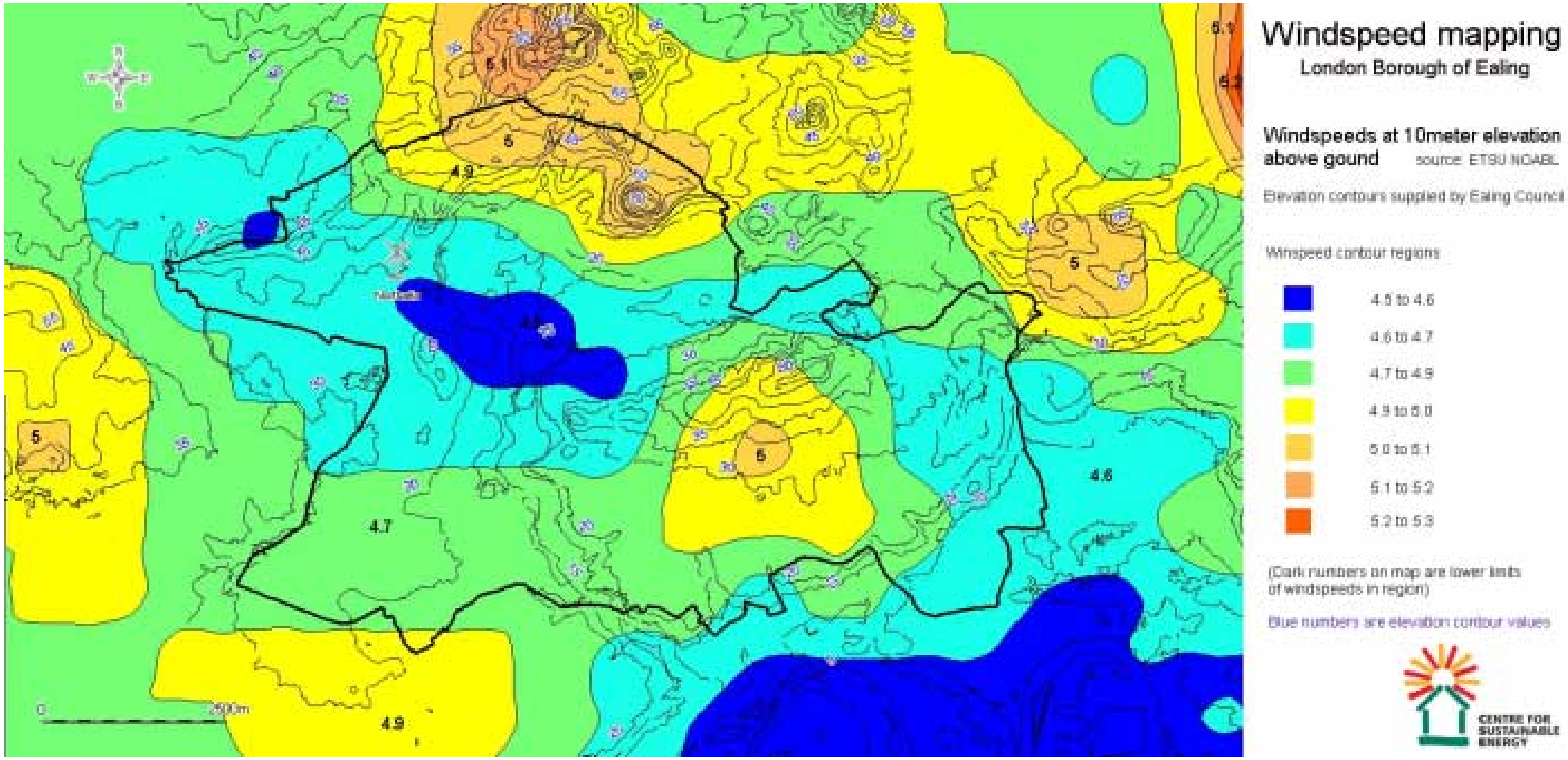
Appendix A: Site Plan: Northala Fields



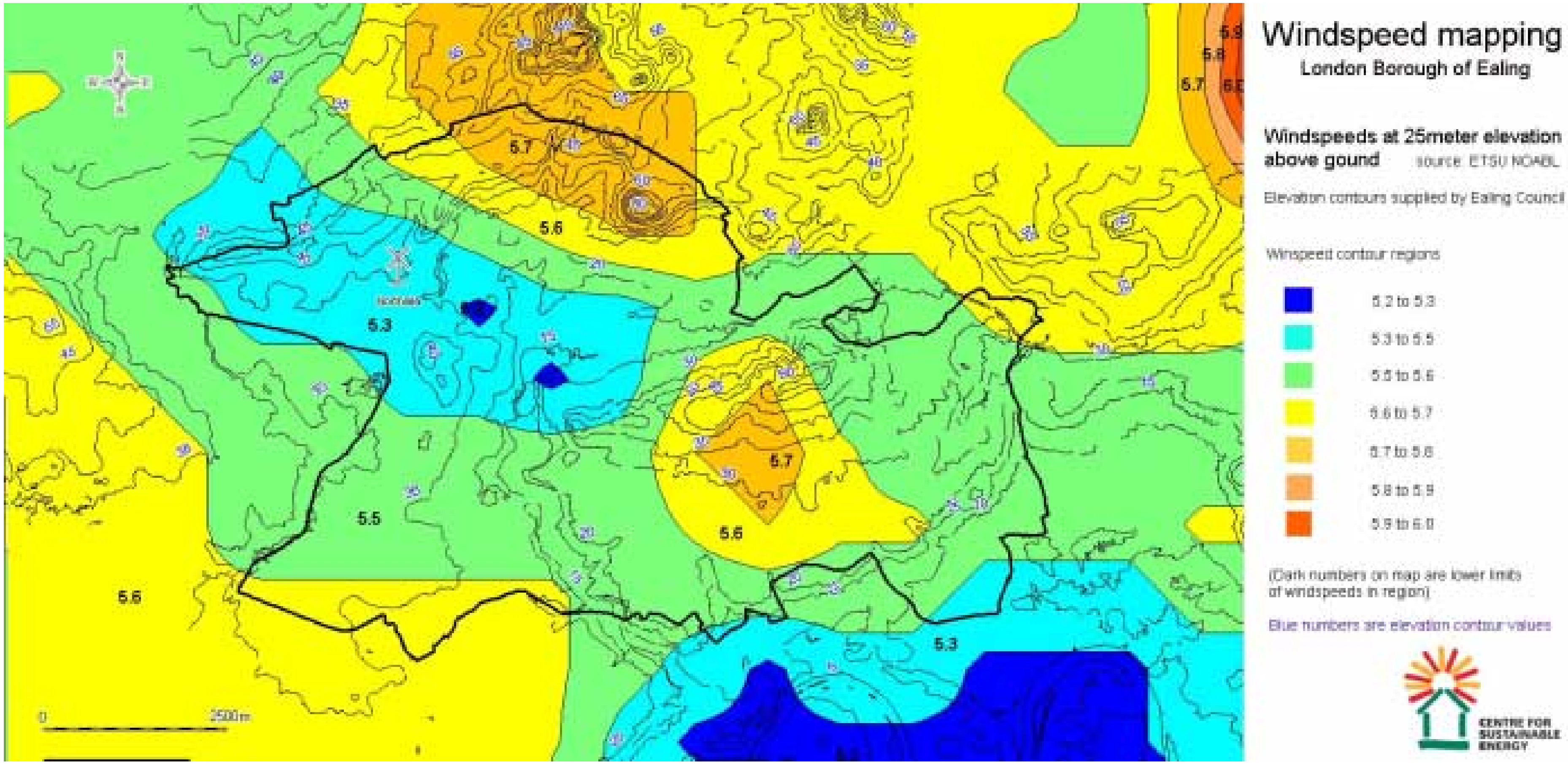
Note: Initial proposed locations of turbine shown. The 20m elevated position is considered more appropriate.

Appendix B: Wind map of Borough of Ealing

10m elevation above ground (borough boundary indicated)



25m elevation above ground (borough boundary indicated)



Appendix C: Turbine images

Fig A: Proven WT6000 (6kW) on 15m mast

Fig B: Alize 10kW

Fig C: Westwind 20kW on 30m mast

Fig D: Gazelle 20kW on 15m mast

Appendix D: Economic model spreadsheet

FINANCIAL MODEL WITH DISCOUNTED CASH FLOW

Site:	Northala Fields	
Turbine	Westwind 20kW	
Bid Price	0.065	£ per kWh
Discount rate	0.06	
Gross annual output	36,000	kWh
Turbine size	20	kW
Turbine number	1	
Array effic	1.00	
Elec effic	0.98	
Availability	0.98	
Site output	34,574	kWh
Site rating	20	kW
TOTAL CAPITAL COST	£21,500	
Cost /kW	£1,075	

WT6000
Alize 10kW
Westwind 20kW
Gazelle 20kW

	Year	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
REVENUE	Index	1.00	0.94	0.89	0.84	0.79	0.75	0.70	0.67	0.63	0.59	0.56	0.53	0.50	0.47	0.44	0.42	0.39
Expected Annual Output	kWh	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**	**34,574**
Electricity price £/kWh	£	**0.065**	**0.06**	**0.06**	**0.05**	**0.05**	**0.05**	**0.05**	**0.04**	**0.04**	**0.04**	**0.04**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**	**0.03**
Electricity sales	£	**2,247**	**2,120**	**2,000**	**1,887**	**1,780**	**1,679**	**1,584**	**1,495**	**1,410**	**1,330**	**1,255**	**1,184**	**1,117**	**1,054**	**994**	**938**	**885**
Other revenues	£	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
TOTAL CASH IN		**2,247**	**2,120**	**2,000**	**1,887**	**1,780**	**1,679**	**1,584**	**1,495**	**1,410**	**1,330**	**1,255**	**1,184**	**1,117**	**1,054**	**994**	**938**	**885**
CAPITAL COSTS -50% grant																		
TOTAL	£	**21,500**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**
OPERATING COSTS																		
a) Turbine Operation & Maintenance	£	**250**	**236**	**222**	**210**	**198**	**187**	**176**	**166**	**157**	**148**	**140**	**132**	**124**	**117**	**111**	**104**	**98**
c) Rates	£	**0**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**	**0.00**
TOTAL OPERATING COSTS	£	**250**	**236**	**222**	**210**	**198**	**187**	**176**	**166**	**157**	**148**	**140**	**132**	**124**	**117**	**111**	**104**	**98**
TOTAL CASH OUT	£	**21,750**	**236**	**222**	**210**	**198**	**187**	**176**	**166**	**157**	**148**	**140**	**132**	**124**	**117**	**111**	**104**	**98**
Cash Movement	£	**-19,503**	**1,884**	**1,778**	**1,677**	**1,582**	**1,493**	**1,408**	**1,328**	**1,253**	**1,182**	**1,115**	**1,052**	**993**	**936**	**883**	**833**	**786**
Cumulative cash		-19,503	-17,618	-15,841	-14,164	-12,582	-11,089	-9,681	-8,353	-7,100	-5,917	-4,802	-3,750	-2,757	-1,821	-937	-104	682

Note: Example shown is Westwind 20 kW at 6 m/s annual average wind speed and 6% discount factor.

Appendix E: Funding sources/economic incentives

Name	**Clear Skies**
Description and main criteria	Fixed grants are available on a range of renewable installations, with separate conditions for household and community applications. Technologies supported include solar water heating, micro-wind, micro-hydro, ground source heat pumps powered by renewable electricity, automated wood pellet fuel stoves and wood fuelled boiler systems. Community applications are invited from community/environmental groups, local authorities and public service organisations. SMEs are not eligible. Applicants must demonstrate evidence of real community involvement and engagement and must enhance public awareness/ understanding of renewable energy. Preference is shown for schemes that; are located in an area of social need; can demonstrate cross-community involvement; have evidence of match funding. The following conditions apply to both community and household applications: schemes must use components on the DTI's approved product list; all measures must be professionally installed; grant applications can not be retrospective.
Funder	DTI
FUNDING TYPE	Feasibility and Capital funding available
Amount of Funding per project & Leverage	Household - fixed grants vary from £500 to £5000 depending on the technology Community - Maximum of 50% of total capital and installation costs or £100,000, whichever is smaller. Development funding is available - 75% of feasibility study costs or £10,000, whichever is smaller
Date of next call	Household grant applications can be made at any time Community applications – Four competitive funding rounds will be held per year. Forthcoming deadlines: 2/5/03, 1/8/03. 31/10/03, 30/1/04. Application forms available from the Clear Skies website
Contact for more information	www.clear-skies.org

Name	**Regional Electricity Supplier Funds – e.g. Scottish Power's Green Energy Trust; SWEB Green Fund**
Description and main criteria	Green funds are set up by electricity suppliers which have fund-based green electricity tariffs. The premium paid by customers contributes to the fund to support the development of new renewable energy projects. Usually projects funded under the scheme must be located within the supplier's traditional supply area. Npower's renewable energy product 'Juice' is for green supply and currently has no fund attached to it for project work. **Scottish Power's Green Energy Trust**, does not restrict applications by geographical area. The fund aims to create new renewable energy sources; encourage R&D in renewable electricity; promote education in the community on renewable energy generation
Funder	Scottish Power (Green Energy Trust)
FUNDING TYPE	Development and Capital funds
Amount of Funding per project &	The Green Energy Trust will fund up to 50% of total project costs

Leverage	
Date of next call	Applications are considered at least 3 times a year
Contact for more information	http://www.scottishpower.com/pages/aboutus_ourcustomers?nav=ourcustomers

Name	**National Grid Community 21 Awards Scheme**
Description and main criteria	The scheme aims to improve the environmental, social and economic quality of life in local communities by providing support for innovative sustainable development community projects run by local authorities across England and Wales. Funding can be in support of new initiatives or development of an existing initiative.
Funder	National Grid UK
FUNDING TYPE	Development and capital funds
Amount of Funding per project & Leverage	A maximum of £5,000 available per project. £10,000 available to the most innovative community projects demonstrating best practice in "Community Leadership".
Date of next call	TBA – probably Summer 2003
Contact for more information	http://www.nationalgrid.com/uk/social&environment/sponsorship Nadia Farrell, Tel: 01727 850761

Name	**The Landfill Tax Credit Scheme**
Description and main criteria	The LTCS offers tax breaks to Landfill Operators to support environmental projects. Environmental organisations can receive landfill money either directly, by registering with ENTRUST as an Environmental Body, or indirectly, via a Distributive Environmental Body. The LTCS website gives lists of DEBs by geographical region. There are several local and national DEBs servicing the South Glos area. Each has different funding priorities and programmes. LTCS funds must be spent in compliance with landfill tax regulations – e.g. projects that encourage the development of projects from waste, land reclamation, pollution reduction, education on waste issues and other schemes promoting environmental improvement. Some projects must be within 10 miles of a landfill site
Funder	Individual LOs or DEBs (see LTCS website for a directory)
FUNDING TYPE	Capital and development
Amount of Funding per project & Leverage	Varies according to DEB and programme. Most expect a 10% third party contribution (which may be other grant funding). **Two-thirds of all landfill tax credits collected after 1/4/03 will be diverted to public spending on strategic waste projects. Thus funds available for recycling and waste projects will be severely curtailed**
Date of next call	Varies according to DEB and programme
Contact for info:	http://www.ltcs.org.uk ; http://www.entrust.org.uk

Name	**SEED**
Description and main criteria	Projects funded through the SEED programme aim to support local community development and support the development of community enterprise. They must focus on helping disadvantaged communities improve the quality of their environment and promote a more sustainable lifestyle. Community renewables projects, including biomass are supported via the energy efficiency stream. Other streams include waste minimisation, recycling and reuse; environmental education; consumption and lifestyles; sustainable transport; local food initiatives and biodiversity. Preference will be given to projects that address more than one programme theme.
Funder	The New Opportunities Fund (National Lottery
FUNDING TYPE	Major capital outlay cannot be funded.
Amount of Funding per project & Leverage	Grants will rarely exceed £50K. Those that do must achieve 50% match funding and submit a business plan. Applicants must attract at least 50% match funding, of which 30% must be cash. There is a fast track programme for projects between £500 and £4999.
Date of next call	SEED is a rolling programme that will cease at the end of 2004. Applications are considered in Feb 2003, May 2003, Aug 2003, Nov 2003, Feb 2004. Work must be completed by Dec 04.
Contact for more information	http://www.rsnc.org/seed/

Name	**Climate Change Levy**
Description and main criteria	The climate change levy was introduced in April 2001 as part of the government's commitment to reduce carbon dioxide emissions by 12.5% by the year 2010. It applies to all businesses using energy generated from fossil fuels. The levy is charged at a flat rate on each kWh of energy consumed at the rates specified below. Energy intensive industries are eligible for discounts of up to 80% in return for a legally binding commitment to an energy reduction target over a ten year time frame All business using energy generated from renewable sources are exempted from the levy.
FUNDING TYPE	Business Tax
Levy rates	Electricity 0.43p/kWh Natural gas 0.15p/kWh Coal/ignite 0.117p/kg (approx 0.15p/kWh) LPG 0.96p/kg (approx 0.07p/kWh) Oil products are exempt because they already carry excise duty.
Contact for more information	http://www.climate-change-levy.info

Appendix F: List of information sources & contacts

UK Trade Associations

British Wind Energy Association: http://www.bwea.com

International Trade Associations

American Wind Energy Association: http://www.awea.org
European Wind Energy Association: http://www.ewea.org
Danish Wind Industry Association: http://www.windpower.dk
IEA wind energy activities: http://www.afm.dtu.dk/wind/iea/

Other Websites

http://www.dti.gov.uk/renewable

http://www.bdsp.com/web (Wind energy for the built environment

http://www.windside.com (Vertical axis turbines)

Written Material

Wind Energy Basics –a Guide to Small and Micro Wind Systems. Paul Gipe 1999

Installers

Proven World Friendly Energy www.provenenergy.com
Gazelle Wind Turbines Ltd. www.mkw.co.uk
Galeforce Wind Turbines Ltd. www.galeforce.uk.com
EnergyTech Ltd. www.energytech.co.uk

List of UK suppliers: http://www.greenenergy.org.uk/suppliers/Trade%20Wind.pdf

Useful Contacts:

Met Office wind data: Alastair Dawson, Utilities Account Manager tel: 0161 932 7153 www.metoffice.com

Wind planning applications: MOD approval: Mark Pickett tel: 0121 311 3847 or Chris Evans, Safeguarding Team, Defence Estates, tel: 0121 311 2025. www.defence-estates.mod.uk

Civil Aviation Authority: D. Cutler, Directorate of Airspace Policy, tel. 020 7453 6545 www.caa.co.uk

BAA: Andrew Gibson or Lesley Duggan tel. 01293 507756, safeguarding@baa.com

Case Studies

Mile end turbine see: www.mileendpark.co.uk
Turbines on RIBA building -‘Earthed’ Feb 2003 edition see:
Vertical axis turbine example application: www.zedfactory.com/earth/earth.html
Proposal for large-scale wind turbines at Dagenham:
www.london.gov.uk/mayor/planning_decisions/strategic_dev/2003/jun0403/wind_turbines_report_havering.pdf