Urban wind turbines: Development of the UK market

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Summary

This paper examines existing installations of small wind turbines in urban areas of the UK. The resultant data from a questionnaire shows the current market status and identifies problems and constraints which have affected installations to date. An economic analysis on real installations examines the factors which can most influence the cost of installations. Current planning guidelines, incentives and grid connection standards and regulations are examined to assess their effectiveness in encouraging small wind turbine installations; and recommendations are made to improve shortfalls in current legislation in order to best promote the technology. This work is part of the EC-funded WINEUR project (Wind Energy Integration in the Urban Environment, www.urbanwind.org).

The UK government has a target of 15% of electricity from renewables by 2015, and wants renewable micro-generation in urban surroundings to contribute. There are at least 15 companies manufacturing or developing prototypes of more than 20 different vertical axis and horizontal axis small wind turbines in the UK. 30% of existing urban small wind installations are located in villages or country parks with only 16% in denser areas near tall buildings. The primary motivation for installation is educational value, followed by environmental reasons. Accurately estimating energy yields in the urban environment remains a challenge and owners of urban turbines tend to be disappointed with their energy yield. The capacity factors for turbines studied ranged from 1.6 to 13.6% with the average being 6.4%. There is much variation in the cost of small systems. Costs decrease as the size of the turbine increases, with average cost per installed kW at 4780 Euro/kW. Site factors have a significant influence on the cost of smaller installations. The UK urban wind industry has much potential; its biggest asset is currently the overwhelming interest from both public and private sectors which have a positive attitude towards the technology.

1. Introduction

Traditionally wind turbines have been placed in rural areas where they can take advantage of strong continuous wind regimes high above the ground. As the realisation of the need for generating energy from sustainable sources expands, there is more interest in sighting smaller wind turbines in areas not conventionally considered as suitable, such as urban and peri-urban zones. Interest in small turbines for the urban environment is coming from many sectors e.g. educational and environmental establishments, and commercial developments.

Fuelling this interest are the newly introduced sustainable policies of a number of UK local authorities, such as Merton Borough Councils expectation of new developments to generate 10% of their own energy demand [1]. At the same time, a strong interest is being shown from domestic consumers of electricity. Significant numbers of household level enquiries have been reported by small wind turbine manufacturers such as Swift and Windsave for their 1kW and 1.5kW building mounted turbines respectively.

The sector has benefited from grant funding of up to 50% from the government over the last few years, which has no doubt contributed to its growth; however this grant funding will end in March 2006. It remains to be seen what kind of grant or other incentive will be available in the future, if any, and how much this change in subsidy regime may affect the demand for the technology. The UK government will be announcing the funding changes in its impending micro-generation strategy in April 2006. Despite this uncertainty, this is a time of rapid development and commercialisation for the small wind turbine sector in the UK.

However, the high general interest in the small wind sector hides a lack of experience in many aspects associated with its deployment. Local town planning departments dealing with planning applications have limited knowledge of the technology and the effect such devices may have on the electricity distribution system is unknown. Perhaps most importantly, it is unclear how much wind energy potential realistically exists in urban sites.

The aims of the WINEUR project are to put some of these questions into context and provide answers and advice to prospective wind turbine owners and professionals so that barriers facing the industry can be recognised and solutions developed. This paper will report on:

- Case studies and lessons learnt, where existing installations will be reviewed, including energy yield, obstacles met during implementation and perception of owners and local communities towards small wind turbines.
- Policy and planning issues, where national, regional and local planning guidelines and incentives for small wind turbines will be examined with identification of constrains and opportunities for improvement.
- Techno-economic analysis, where costs per installed kW for small wind turbines will be examined. The factors which most influence the cost of an installation are to be identified.

- Grid connection issues, where current standards and regulations and their effectiveness will be identified with a discussion of constraints regarding injection of energy from small wind turbines on the distribution network.

The information gathered, analysed and displayed in this paper has been compiled as part of the WINEUR project and is freely disseminated to interested parties through a dedicated website, www.urbanwind.org, the main purpose of which is to provide advice, information and encouragement to those interested in installing small wind turbines in the urban environment.

2. Methodology

To access the current state of the small wind turbine industry in the UK a Case Studies Questionnaire was sent out to known turbine owners. Turbine owners were located through an internet search and from manufacturers' and installers' references. The questionnaire was designed to build a database of key information about installations. The questionnaires had a 23% response rate and data was collected from 21 installations in total. Furthermore, in order to assess the costs of small wind turbines, information was collected from four main sources:

- Manufacturers' and installers' questionnaire: An 'economic questionnaire' was developed and sent to manufacturers and installers of small wind turbines.
- Interviews and questionnaires of wind turbine owners: phone interviews were carried out with and questionnaires were also sent to, wind turbine owners who agreed to answer questions about the economic aspects of their turbine.
- ClearSkies grants programme: information was also sought from the ClearSkies programme, which is the government grants programme for small-scale renewables, including wind. ClearSkies provided an anonymous database of technology used and total installation costs. Although there was no detailed breakdown of costs provided, this information provided a basis for comparison with results from the case study questionnaires.
- Literature review: lastly, a thorough literature review, including websearch, was carried out to find any previous analyses that had been done on the economics of small wind turbines.

The planning guidelines and incentives for renewables were researched and regional and local planning departments contacted to ask about their experiences, if any, with small wind turbine applications and their advice as to what would make a successful planning application.

The effect of increased renewable energy on the economic national distribution of electricity is a widely discussed topic. A questionnaire was designed for issue to Distribution Network Operators (DNOs) so an overall picture of the concerns and perceptions of industry professionals regarding micro-generation on the distribution network could be assessed and evaluated. Each DNO was contacted by telephone to find the most suitable recipient of the questionnaire. Upon finding the relevant person, the questionnaire topic generated much interest and discussion and in most cases a telephone interview was conducted. This approach lead to a 100% response rate. Information was also collected and compiled to form a summary of the standards and regulations currently in place for connection of small scale wind systems on the electricity network.

All statistical information regarding wind turbine installations are from the case studies questionnaire [2], unless otherwise stated.

3. Technologies

There are currently 9 UK companies manufacturing and selling more than 10 different small wind turbine models; all horizontal axis wind turbines (HAWT). In addition, some of these companies and a number of other organisations are designing and developing small wind turbines for urban applications. Of these prototypes at least 4 are vertical axis (VAWT). In total there are more than 15 companies either manufacturing or designing more than 20 different small wind turbines, all of which could theoretically be placed in the urban environment.

The more established products that can generate a substantial amount of electricity and are available now for the built environment are the 'larger' HAWTs made by Proven (6kW and 15kW), Iskra (5kW) and Gazelle (20kW). Traditionally these products are ground-based. However, Proven have recently started building-mounting their turbines. Products which have recently emerged onto the market which are specifically intended to be building-mounted on domestic properties (and other buildings) are the 'smaller' or HAWTs made by Ampair, Eclectic Energy, Renewable Devices Swift and Windsave. The products available from these companies are typically in the range of 0.6 to 1.5kW and all are HAWTs. There are also some 'micro' HAWTs technologies produced by LVM and Marlec that could be considered suitable for installation in an urban environment, although their primary market is the yacht industry. These turbines' electricity production is so small they are not considered further in this paper.

There are currently no UK manufactured VAWTs on the market but VAWTs are under development for the built environment (and that should be suitable for building-mounting) and the prototypes currently being tested should be available in 2007/2008. Tables 1 & 2 below summarise some of the turbines currently being directed at the urban environment, although this is not an exhaustive list.

Table 1. Turbines being manufactured for the urban environment

Manufacturer and model	Rated power, kW
Eclectic Energy D400	0.4
Ampair	0.6
Windsave	1
Swift (Renewable Devices)	1.5
Proven WT600	0.6
Proven WT2500	2.5
Iskra	5
Proven WT6000	6
Proven WT15000	15
Gazelle	20

Table 2 – Prototypes being developed for the urban environment

Model & designer/developer	Rated power, kW
Rugged Renewables (VAWT)	0.4
Eurowind (VAWT)	Many (1.3 to 30)
FreeGEN	Unknown
Posh Power	~ 2-2.5
Renewable Devices Swift	1
XCO2 (VAWT)	6
Wind Dam (VAWT)	2 + (stackable modular design)

4. Installation location and drivers

The survey showed that 30% of current small wind installations are located in villages or country parks, with the remainder evenly distributed in commercial, industrial, residential, sub urban and inner-city locations (Figure 1). Most of the turbines are located near open spaces with only 16% in denser areas near tall buildings. Building mounted turbines are a relatively new concept and none of the contacted current installations were willing to respond to the questionnaire. This could be due to the fact that they are installed at commercial properties promoting a green image, and the questionnaire seemed to get lost between layers of bureaucracy and third parties. Reasons why organisations installed turbines were 46% for educational purposes, 26% for environmental, 20% to improve the organisations image and just 4% deciding to install for financial reasons (Figure 2). 37% of wind turbine owners did not know the annual electricity production from their systems. This was due to the installation being very new or monitoring equipment either not installed or not operational. Owners were generally happy they were helping the environment by installing a turbine but not knowledgeable about the actual electricity production.

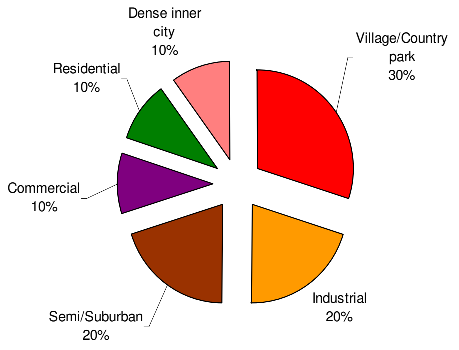

Figure 1. Location of urban turbines

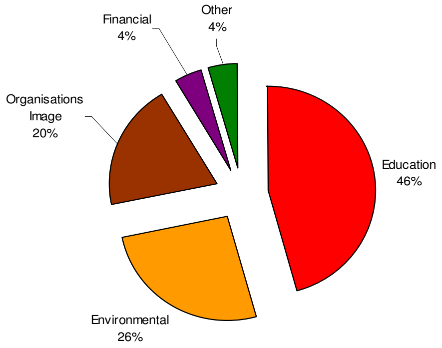

Figure 2. Motivation for installation

37% of installations had problems in the planning stage, mostly because additional evidence needed supplying to convince inexperienced planning departments and community members of the benign effects a small turbine would have in the local environment. As shown in Figure 3 there was a positive change in the opinion of local communities and neighbouring residents before and after installation, with approximately the same amount of people again who thought having a small wind turbine in their community did not have such a significant effect on their lives to warrant a strong opinion either way.

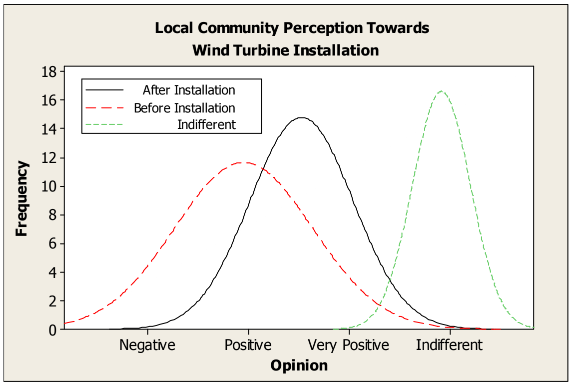

Figure 3. Distribution of attitudes towards small wind turbine installations

5. Energy yield

Owners of urban turbines tend to be disappointed with their energy yield. This is because installers estimate the energy capture based on the annual mean wind speed in the Noabl database, which is the result of a mass wind flow model across the UK with corrections made for land/sea interfaces [3]. The model does not take into account roughness changes such as in urban areas and it is likely that predictions of the wind speed in areas of complex terrain are inaccurate. Table 3 below shows the mean wind speed from three sites in the questionnaire calculated from their stated annual electricity production, compared to those from the Noabl database. These calculations assume a 85% availability and a 97% electrical efficiency of the system and a Rayleigh distribution of wind speeds. The results showed the calculated mean wind speed to be significantly lower, especially when the hub height of the turbine was comparatively low.

Table 3. Calculated wind speeds at urban sites

Site	Hub Height (m)	Calculated Wind Speed (m/s)	Noabl Wind Speed (m/s)
Sports-centre, Scotland	9	2.7	4.3
Primary School, Bucks.	9	3.8	6.3
Eco-Centre,Teesside	30	5.2	6.1

6. Capacity factors

Many owners commented that their installer's after market service was poor and their response to problems was slow. Therefore it was often the case that a simple fault would lead to a substantial down time. The impact of the lower wind regime and availability of the studied systems are reflected in their low capacity factors. The capacity factors for turbines in the study ranged from 1.6 to 13.6% with the average being 6.4%. Figure 4 shows that the capacity factor distribution is positively skewed. This may reflect the low urban wind regimes interacting with the cut in speed of the wind turbines, or could simply be a product of the low sample size.

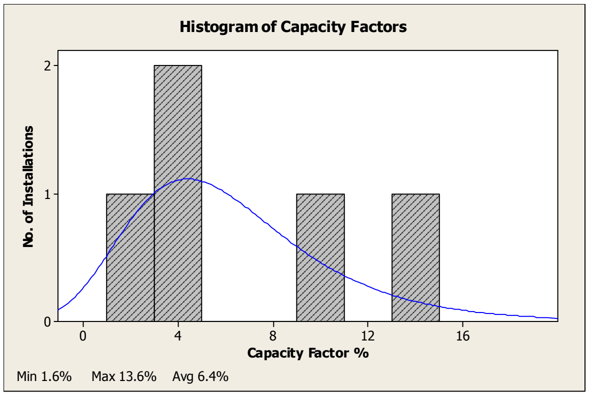

Figure 4. Distribution of capacity factors of turbines in urban areas

Despite the issues faced by the small wind sector, as stated above, 90% of owners are happy with their wind turbines and say that they would install again. There is a general understanding amongst owners that the small wind industry is relatively new and there is a learning process which needs completing. However, this understanding stance from customers cannot be relied upon indefinitely and addressing the availability and performance issues should be a priority in the sector in order to retain its customer base.

7. Costs per installed kW

The information collected allowed a techno-economic analysis for the following technologies:

Table 4. Wind turbines studied

Manufacturer	Model	Rated capacity, kW	Installation type
Eclectic Energy	D400	0,4	Building mounted
Proven	Proven	0,6	Ground installation
Windsave	Windsave	1	Building mounted
Renewable Devices	Swift	1,5	Building mounted
Proven	Proven	2,5	Building or ground
Iskra	Iskra	5	Ground installation
Proven	Proven	6	Building or ground
Proven	Proven	15	Ground installation
Gazelle	Gazelle	20	Ground installation

ClearSkies estimates that a typical system costs 3625 - 7250 EUR /kW [4]. In Figure 5 below the Clear Skies estimate is that furthest to the left, next to the y-axis. The figure shows the minimum and maximum estimated cost for each kind of installation. The range of cost tends to decrease as the capacity of the turbine increases. However, this data has some limitations in accuracy. For example, there is more data for some technologies, such as the Proven 2.5kW (ground-mounted), than others. More data means a greater chance of cost variation. This is because the installed cost of a turbine depends a great deal on individual site factors. Some of the other technologies might show the same range of cost if more data were available. Building-mounting Proven 2.5 and 6kW turbines does not seem to be significantly more expensive than ground-mounting them. However, there is still limited experience with building mounting these kind of turbines in the UK and therefore, there was limited data on costs. It should also be noted that some turbine costs were only available from manufacturers. For example, the Windsave 1 kW turbine is the cheapest turbine per installed kW, but this is the manufacturer's estimate of cost. Very few installations exist, so the price cannot be confirmed and may be subject to change.

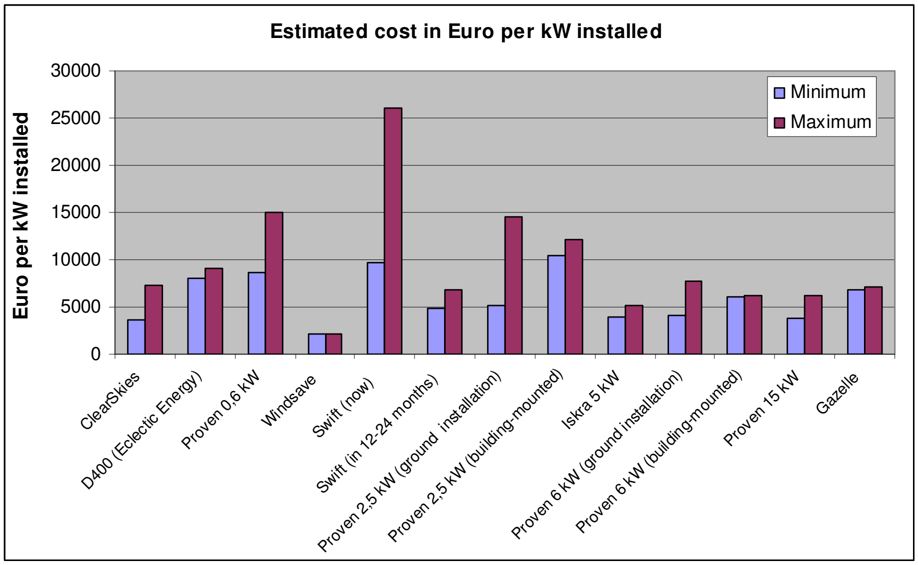

Figure 5. Estimated turbine installed costs for all technologies studied

The total installation cost per kW installed for the 21 systems for which case study questionnaires with cost data were received back is shown below in Figure 6. There is a significant variation in the cost of small systems, with both the variation and cost reducing as the installed capacity increases. The logarithmic function explains 56% of the variation in the costs, which statistically is a weak correlation; this signifies that the installations costs are greatly dependant on individual site factors. Site factors have a greater influence on the cost of smaller installations, since they account for a higher percentage of the overall cost. The average cost per installed kW for the systems analysed in the case studies questionnaire was 4870 EUR/kW.

Comparing the results from the case studies with the data from the ClearSkies programme (Figure 7), we can see that there is a good correlation. The ClearSkies data logarithmic function explains 42% of the variation in the costs, which again emphasises the importance of individual site factors. This trend line also shows that cost reduces significantly as the installed capacity increases. The average cost per installed kW for the ClearSkies data was 5440 EUR/kW.

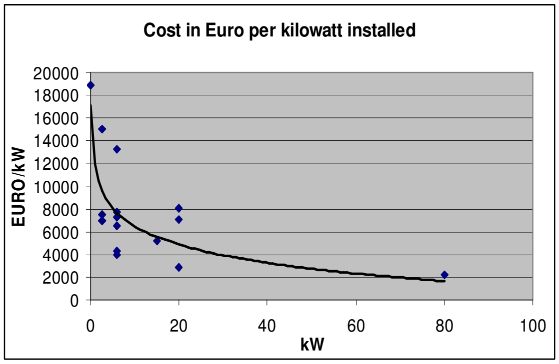

Figure 6. Cost per installed kW – Case study data

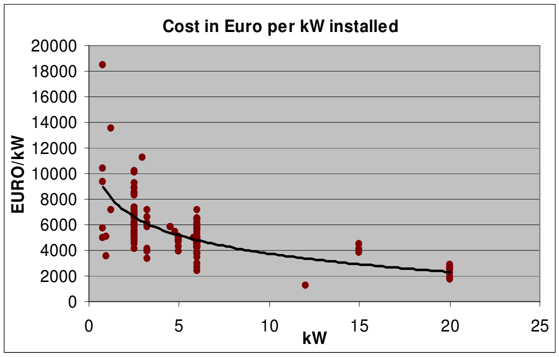

Figure 7. Cost per kW installed - ClearSkies data

8. The economic effects of individual project factors

Two case study projects were examined in detail to assess what factors have the greatest effect on the cost of energy and payback period. The first site is a primary school in Scotland which has a 2.5 kW turbine, and is the most expensive in terms of £/kW installed of all the studied installations. The average annual wind speed is 5.1m/s. The school has a net metering tariff and the value of their electricity is 6.3p/kWh for imports and exports. The cost of their generated electricity based on a 25 year payback period would be 15.6p/kWh, and based on their current electricity tariff; the installation will never pay back financially.

The second site is a country park with a 6 kW turbine, which paid an average price in terms of £/kW installed. Their average annual wind speed is 5.3m/s. The park has a Good Energy tariff where they get paid 4.5p/kWh for energy they produce and pay 7.67p/kWh for imports and a standing charge of 10.1p/day, giving financial payback in 19 years. The cost of their generated electricity based on a 25 year payback period would be 8.5p/kWh. From a sensitivity analysis of differing site factors the effect on the price/kWh of electricity produced from the two sites were analysed, with the influential site factors shown below in Figure 8 . A 25 year payback at a 3% interest rate was used.

The factors which most greatly affected the economics of both installations were applied discount rate, grant funding, wind speed and ground conditions. In an overall analysis of costs, the other main factors effecting economics of installations are maintenance costs, ROCs and electricity consumption on site.

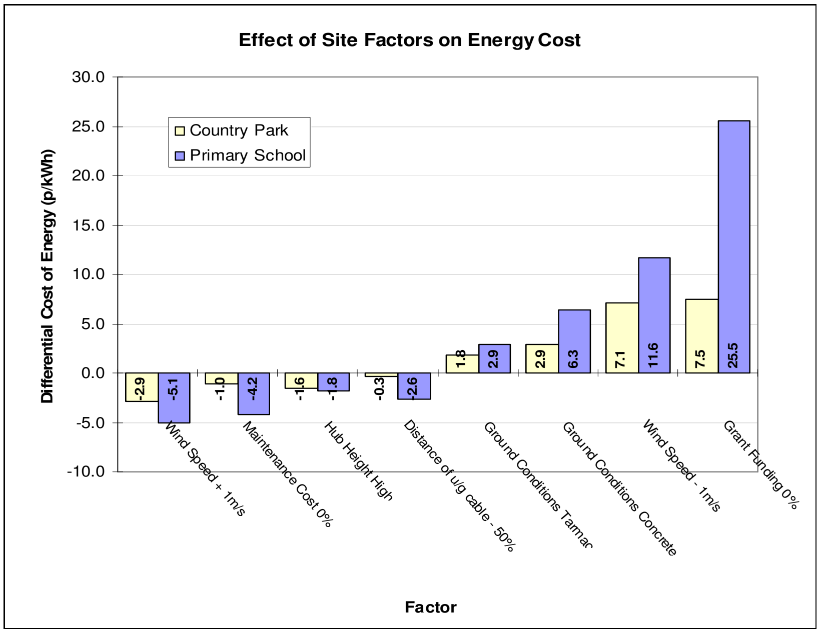

Figure 8. Effect of varying site factors

Applied discount rate: The interest rate at which you choose to discount your investment has an underlying effect on its economics. Large wind farms will discount at around 10%, as they must survive as a business and make a profit; whilst many published payback calculations for smaller turbines are done at a 0% interest rate, and often neglect to take into account running costs. Due to the barriers facing small urban wind turbines none of the studied installations would ever payback at a 10% discount rate. Since only 4% of the installations were for financial reasons it would be incorrect to discount them as a business investment. The economics in this study are therefore calculated using a 3% discount rate to represent inflation.

Grants: At present there are several funding streams available in the UK that project developers can use. The most common grant source is the Clear Skies programme, for England and Wales or the Scottish Community and Household Renewables Initiative (SCHRI) for Scotland. Other grant sources are energy suppliers (e.g. Scottish Power, EDF or Northern Ireland Electricity), local renewable energy agencies (e.g. TV Energy or ALIENERGY) and local authorities. These are the sources of major grant funding available, however this is not an exhaustive list and there may be other sources of small levels of grant funding. For example, funding for small wind projects has also been obtained from the Carbon Trust (for innovative projects) and the Government of Northern Ireland (DETI). However, some project may be ineligible for grants (e.g. businesses are not eligible for ClearSkies) and grant programme come to an end, sometimes without any replacement. The ClearSkies programme is due to end in March 2006, and it is not clear if the replacement funding stream, called the "Low Carbon Buildings Programme" will offer the same kind of capital grants to small wind projects, as ClearSkies did.

Wind speed: The wind speed at an urban site has the greatest influence on its economic viability; therefore it is the most important consideration when siting a turbine. Unfortunately wind speed is an unknown factor at most installation sites since the process of obtaining wind speed measurements prior to installation is time-consuming and expensive. In fact, carrying out wind speed measurements at a specific site could cost as much as a wind turbine installation itself. Therefore measurements are rarely carried out for installations of single turbines. As Figure 4 on the page above shows, a 1 m/s difference in the predicted wind speed can make a very big difference to the economics of an installation. For the school in Figure 4, a decrease in wind speed of 1 m/s would increase the cost of the school's electricity by 11.6p/kWh, whereas 1 m/s high wind speed would decrease the cost by 5.1p/kWh. This is a net swing of 16.7p / kWh. Therefore the extra investment required to increase the hub height of the turbine and place it in a position to receive a higher average wind speed should be considered for most installations. Although it would increase capital expense, it could be worthwhile due to increased wind capture and energy yield.

Ground conditions: It is best practise to distance a wind turbine from habitation to reduce the risk of noise nuisance and increase the distance from tall buildings, which could disrupt airflow. However, this requires cabling over a greater distance, and since the cable is laid underground, the ground conditions can have an effect on costs. For example, cable laying for the school's 2.5 kW turbine through mainly rough ground for a distance of 260 metres accounted for 46% of the total installation cost. The cost of cabling underground increases if the cable has to go under tarmac or concrete, compared to a lawn or a field.

Maintenance costs: yearly maintenance typically involves inspection and re-greasing. The costly aspect of the service is paying for an installer to travel to site and lower the turbine to working level. Due to the relatively less demanding wind regime of an urban area, there may be scope for reducing the maintenance intervals. Another option is to have the service done by on-site staff, therefore avoiding the cost of an installer.

Renewable Obligation Certificates: Claiming Renewable Obligations Certificates (ROCs) on produced electricity adds a value of 4.6p/kWh. Due to complicated registration procedure and a minimum generation requirement, many small generators do not claim ROCs. The analysis showed that claiming ROCs did improve the payback period of an installation, although by itself it did not have a big impact, especially on installations under 5 kW.

Electricity Consumption: The best way to ensure a good price for generated electricity is to offset the need to purchase from the supplier. This is because most often this electricity is charged at a higher rate than electricity bought back (unless net metering is used). For example, in the case of the country park where the turbine electricity supplies a gift shop, visitor centre and café, it has been estimated that for 80% of the time the electricity demanded from the building will exceed the amount of electricity generated from the turbine. Hence the value of their renewable electricity is 12.2p/kW (4.5p + 7.67p), with the remaining 20% of the time being 4.5p/kWh.

Building integrated turbines: Tall buildings and tower blocks seem to offer an opportunity to capture higher wind speeds. Some installations on tower blocks are under way in the UK. Many of the issues facing the economics of today's small scale turbines will not be so significant in the building mounted sector. Building mounted turbines should be closer to the distribution board, will not need underground cabling, will be mounted higher above ground level, and some systems also claim to be maintenance free. However new issues which will affect the economics of the installation will start to emerge, such as planning permission, structural survey costs, noise (both for building users and surrounding environment), flicker from the blades building strengthening costs and possible electromagnetic interference with nearby electrical equipment. With regards to wind data, there is clearly a need for more research on airflows and wind speeds in urban surroundings, particularly looking at airflows around buildings and other obstacles. More data must be collected, and computer models must be developed that can make predictions tailored to urban areas. Project developers should not have to rely on NOABL in the urban environment as it does not take into account local topography, and will very likely overestimate the wind speed. There are currently too few building mounted installations currently in the UK to be able to draw definitive conclusions about costs or success of the installations. However, the building mounted sector is growing and in the future there will be more data to draw upon for conclusions.

9. Planning issues

Planning policy statements (PPS) set out the Government's national policies for different aspects of land use planning in England. These policies need to be taken into account by regional planning bodies in preparation of regional spatial strategies and by local planning authorities in preparation of local development documents. The Government's Planning Policy Statement 22 (PPS22) for renewable energy has some very positive messages to give to policy makers. However, it does not include guidelines on small scale generation, except to state that small scale schemes should be encouraged. This lack of guidance has lead to an overall emission of small scale wind references in regional and local planning documents. A new set of guidelines is needed specifically for small scale generation. This will hopefully be addressed in the micro generation and low carbon buildings strategy currently being developed by the DTI, although there is no mention of amendments to Planning Policy Statements in the consultation document. Regional planning guidelines do set targets for installed capacity of renewable technologies and most specifically for wind, but none for small scale wind. The environmentally positive Lord Mayors' strategy for London renewables briefly mentions urban turbines but states that the potential for urban wind turbines is still unknown.

Stronger and clearer messages are required from all levels of government policies and guidelines if they are to encourage renewable energy installations. Statements often include general get out clauses which can be interpreted to aid or hinder development depending on the readers mindset e.g. "if they deliver significant community benefits and have minimal impact" [5], whereas stating that planning permission should be granted unless significant adverse environmental and negative social impact will occur, switches the ownership of providing evidence onto the proprietors of negative opinions. The overall environmental benefits of an application should be given increased weighting. Small scale installations of urban wind would be further encouraged if planning guidelines were developed specific to small scale generation and if stronger messages were received from government.

A comprehensive (186 page) companion document to PPS22 is available which delivers advice and best practise examples to local and regional authorities. There is no specific guidance on small wind but it does state that a wind turbine development of 50MW or less installed capacity will need planning permission granted by the local planning authority [6]. Many planning authorities contacted also recommended a pre-planning consultation. The constraints experienced by users when applying for planning permission were mainly centred on the local planning departments and individuals' lack of experience with small wind installations. To aid in a successful planning application; the following issues should be addressed [7]:

- Visual appearance – compare to telegraph poles, inc scale drawings comparing to large WT
- Noise – state statuary noise limits and turbine noise levels, and compare to common noise sources e.g. traffic
- Wind speed and predicted power output
- Contribution to national, regional and/or local targets
- Community involvement and consultation e.g. letters of support
- Other issues e.g. safety, electromagnetic interference, reflectivity
- Pre-application consultation

10. Small Wind Turbine Incentives

There are many small schemes with dedicated funds for solar programmes, e.g. Solar for London and the RSPB's Going Solar program. No such schemes exist for small wind, this is due to urban wind only recently being seen as an option for large scale domestic installations. Small generators of electricity (<50kW) have been allowed to claim Renewable Obligation Certificates (ROCs) on a yearly basis, unlike larger generators who have to claim monthly. This makes it infinitely more possible for smaller systems to achieve a generated target of 1MWh, but the administration, paperwork and technical knowledge required in gaining the status of an accredited generator is often too arduous for the small wind turbine owner to justify completing. Due to this fact only 26% of installations from the case studies questionnaire were claiming ROCs. In conclusion, effective incentives for small wind turbines would be to create local initiatives similar to current solar schemes and simplify the ROC collection scheme for small generators.

11. Grid connection

Ofgem is the Office of the Gas and Electricity Markets which regulates the electricity (and gas) industries in Great Britain. Its main activities are to protect and ensure a fair deal for the consumer and generate a competitive market for suppliers. There are four transmission systems in the UK, each separately owned and operated; in England and Wales the transmission system is owned and operated by The National Grid Company (NGC); in the south of Scotland by Scottish Power; in the north of Scotland by Scottish and Southern Energy; and in Northern Ireland by Northern Ireland Electricity. All these companies operate under a transmission license granted by Ofgem. Transmission networks play a central role in the electricity system. Maintaining the balance between supply and demand is a vital task which touches every aspect of electricity supply. The transmission companies are required to develop, maintain and operate an efficient and economical system of electricity and to facilitate competition in generation and supply. In England and Wales there are nine distribution companies operating twelve licensed distribution areas. In Scotland distribution is operated by two vertically integrated energy companies who in addition to operating their respective distribution businesses they are also responsible for generation and transmission throughout the Scotland [8]. Each distribution company holds a separate license for each area they cover and they are strictly governed by the terms of that license. They have a statutory duty to connect any customer requiring electricity within their area and to thereafter maintain the supply to them. They must maintain an efficient cost effective and coordinated system to distribute electricity.

In electricity the transmission and distribution systems are monopoly businesses and are regulated by price controls set by Ofgem. The intention of price control is to protect customers where there is a lack of competition, and to encourage efficiency by determining inflation-limited price caps [9]. The scope of the price control has developed over time in response to changes within the industry and the development of competition. Transmission and distribution price reviews are carried out usually every five years. The average annual electricity bill for a typical domestic customer on standard credit tariff, including VAT, is £250. The breakdown of this bill is: £105 generation; £10 transmission; £60 distribution including metering; and £75 supply

12. Standards and Regulations for Grid connection

Grid connection of small wind power systems fall into two categories, those which supply up to 16 amps per phase and must comply with Engineering Recommendation G83/1 and those which supply over 16 amps per phase and must comply with G59/1. The 16A/ph limit was set because it agrees with European standards for connection. The power quality control elements required once a generator has a current above 16 amps per phase make the equipment necessary for grid connection much more expensive. The G83/1 regulation was introduced in September 2003 to simplify the conditions required for connection of small-scale electricity generators (SSEGs) to the grid. G83/1 enables many small generators to connect to the distribution network by introducing a simplified approach and supporting connection against objections that could be raised from the DNO. It also gives the DNO discretion to "use this engineering recommendation if it is considered more appropriate than G59/1" [10]. Many DNOs do indeed allow turbines such as the 6kW Proven which potentially supply marginally in excess of 16A per phase to connect under the G83/1 regulation. For single installations the recommendation and DNOs recognise that there will be a negligible impact on the network and the installer need only supply the DNO with the necessary installation information within 30 days of the commissioning of the Small Scale Embedded Generator (SSEG). For multiple installations in a close geographical area i.e. as part of a housing development, the DNO will need to be consulted in advance, as the effect on the network may need a more detailed assessment. In this case, there may be an additional cost from the DNO to carry out the assessment. Under the G59/1 regulation micro generators with an output of over 16A/ph must comply with the technical standards of generators up to 5MW in size. This type of connection is significantly more expensive and burdensome than a G83/1 connection as it requires additional work such as network analysis, potential network alterations, additional protection equipment and technical data submission, which can significantly hinder small scale installations. In conclusion, G83/1 has effectively removed all barriers for single connections below 16A/ph and significantly eases multiple connections but a new connection standard for small schemes that are over 16A/ph is needed to reduce complexity and cost of connection

13. Distribution Network Operators Perceptions and Attitudes towards Micro Generation

The changes needed in the electricity transmission and distribution systems to facilitate the increasing levels of generation from renewables are not yet known. The current perceptions of DNOs regarding the effects and issues that surround small scale generation <50kW are discussed below. All information was derived from the DNO questionnaires unless otherwise stated [11].

Incentives: The Distributed Generation (DG) Incentive implemented in April 2005 allows DNOs to recover their generation connection costs by a combination of pass through (80%) and incentive per kW connected (£1.5/kW) plus £1/kW/year for O&M costs. In addition to the DG incentive Ofgem has introduced the Innovation Funding Incentive and Registered Power Zones incentive mechanisms. The information received through the questionnaires indicates that DNOs feel that these incentives are of little significance in terms of assisting the connection of very small systems such as micro wind turbines since it would be a breach of the DNOs licence agreement to refuse any connection under G83/1. DNOs can only give an estimate of costs for the required work to ensure power quality is maintained across the network when a new generator requires connecting. If power quality can be maintained, then the DNO must connect the generator.

Technical Concerns: Voltage rise on networks caused by an increasing number of individual G83/1 connections is the main concern of the DNOs. However, there would have to be significantly more micro generators connecting to the grid for these conditions to occur. The DNOs surveyed felt that it is unlikely that this will occur in the foreseeable future as a consequence of small scale wind connections.

Advantages: Advantages, like disadvantages of distributed generation only really exist when large numbers of small generators are installed. The DNO answers indicated that reduced reinforcement of networks may be argued over a countrywide system, but are not relevant in local systems as networks still have to be specified based on the fact that the embedded generation may not be available.

Financial Implications: Under the current market conditions, significant levels of SSEG would effect the revenue of the DNOs as they charge electricity suppliers a Distribution Use of Service Charge (DUoS) on every kWh sold, and there is also a Generators' DUoS but this does not apply to connections on the low voltage network. However, the market regulator Ofgem is obliged to facilitate an adequate revenue stream for the DNOs and the opinion of the DNOs appeared to be that there are no real financial concerns. Despite user-generators and efficiency improvement initiatives, electricity demand is constantly increasing and networks are constantly being expanded and reinforced to meet new loads; and to facilitate new generation.

Connection Constraints for SSEGs: For connections under G83/1 there are no significant constraints. The generator must install and commission the system according to the regulation but this does not add any significant cost. The DNO has to be notified of the connection but cannot refuse it. For connection under G59/1 the cost of the relevant network analysis and subsequent required work may make the small scale installations uneconomic. The likelihood of a connection charge will be less in urban areas where stronger networks exist compared with those in rural areas. Until April 2005 whether there is a charge and how much it is was entirely dependent on the DNO of the particular region where the generator is being connected, and therefore charges varied from region to region. Since April 2005 a common connection boundary was introduced across generation and demand. New generators pay shallower connection charges and will begin to pay use of system charges. In addition there is a requirement for DNOs to publish their charging methodologies and justify their approach to setting tariffs in accordance with the licence objectives.

Metering Issues: Many meters exist which can run backwards under export conditions. When this happens the DNO is not fulfilling its legal obligation to accurately monitor electricity consumption. Meter readers, electricity suppliers and DNOs will have to be smarter with their information sharing to keep an accurate account off SSEGs. Under current conditions an export meter can be fitted and a consumer can have a supply and buy back contract with an electricity company without the DNO being aware of generation occurring at the property. It is also feared that as the home generation market becomes more developed with off the shelf type systems available a small percentage of installations will occur where the DNO is not informed of the connection. This means electricity consumption may not be accurately recorded and an incorrect load profile may be associated with the property. However, for the time being, these problems remain at a small scale, affecting a very small percentage of the electricity consumption that is monitored by a DNO.

14. Conclusion: what next for urban wind in the UK?

The UK urban wind industry has much potential; its biggest asset is currently the overwhelming interest from both public and private sector actors and the positive attitude these actors have towards the technology. However, it is important at this stage that the industry is realistic about its capabilities. It is evident that wind turbines in urban surroundings receive lower wind speeds and have lower capacity factors. This reduces energy production significantly, thus reducing economic feasibility. The reliability of the systems will improve as the technologies mature. Installers can also improve capacity factors by responding more rapidly to problems and advising customers correctly on the suitability of their location for a turbine. As the available quantity of historical wind data grows energy predictions will become more accurate and experience with siting wind turbines will improve, thus placing them in locations most likely to maximise wind capture. The installations studied in this report showed that at the moment small scale wind can not be justified as a financial investment. However, a turbine owner can improve the financial results by reducing their overheads such as maintenance costs and by achieving a good price for the electricity produced. The best way to do this is to consume a maximum of the electricity produced on site, thus offsetting the need to purchase high cost electricity from a supplier. Another way to improve the financial aspects is to claim the ROCs, although this may only be realistic for larger producers. To this end the system for small generators claiming ROCs need to be simplified by the government and indeed a review process is currently underway that should enable micro-generators easier access to ROCs.

In conclusion, it may be true that small wind turbines are not economic today, but it is also currently true that economic factors are not the primary reason for individuals and organisations installing wind turbines. So although improving the economics of the installations is necessary and feasible, in the meantime the industry can rely on other incentives such as improving environmental and educational awareness to stimulate the market.

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