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Reports on the feasibility study

WINEUR Deliverable 5.2

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HORISUN

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1 EXECUTIVE SUMMARY

1.1 France

After an identification period of partner cities, feasibility studies have been carried out in 3 French main cities. The difficult environment surrounding urban wind turbines in France has not able to see the construction of one of those projects. However, the willingness is existing. Axenne has been told about the potential study of a urban wind turbine project in Lyon and various possibilities in Lille Agglomeration. Axenne was also asked for information for the needs of a possible project on the municipality of Rillieu-la-Pape. This shows that local authorities are more and more concerned about this issue but probably waiting for financial support.

Lille: The Lille agglomeration was involved in two feasibility studies, in Roubaix and in Templemars. The wind potential of Templemars is more important than in Roubaix. This explains that the choice of the wind turbine model will tend to be for a wind turbine with higher efficiency. It was proposed a Gaia Wind (11 kW) for its annual production or a WES (2,5 kW) for which nominal power corresponds to relative weak wind (8,5 m/s). For the location of Roubaix, the more suitable wind turbine will be a vertical axis. VAWT is more adapted to small wind speed level, turbulences and noise considerations. Furthermore, this new design will fit better with the design of the building. The proposed VAWT is OY Windside. Its annual production is relatively weak but the design of this turbine is seen as an advantage. This two projects are still on the study by the local authorities. Lately, Axenne was told that they are considering it but financial support should be made available.

Lyon: the wind and local conditions of Lyon site offer three technically feasible solutions: Turby 2,5 kW, Ropatec WRE 3 kW and Windwall 2 kW. The cut-in-speed from Turby and Windwall is 4 m/s. According to the average wind speed measured in Lyon, it would be better to choose the Ropatec design which has a cut-in speed of 2 m/s. For the moment, Lyon city has not made concrete express for a future project at the studied location. However, a representative of the local authority was on the study tour and explained us that they are planning a wind feasibility study for an other location.

Grenoble: the results from the wind feasibility study of Grenoble indicate that the site has a weak wind potential. A VAWTs Savonius type, with a cut-in-speed around 2 m/s, was recommended. One of this machine could actually suit to this site location in particularly since there are no big constraints. Up to now, there are no signs of concrete implementation for a urban wind turbine in Grenoble Agglomeration.

1.2 UK

Since the last few years, there is in the UK an increasing amount of interest and support for small wind technologies from politicians, industry, local authorities and the public alike. The large difference is existing in comparison with the French experience. The number of feasibility studies made available in the UK is also a relevant indicator. The cities of Huddersfield, Portfield and Sheffield has contracted IT Power to carry out a wind energy feasibility study. Those feasibility studies were then conducted in the framework of the WINEUR project.

Huddersfield: Kirklees Metropolitan Council have developed a policy which is very favourable to the development of renewable energy technologies. The Council have already installed PV panels on a number of their buildings and on domestic houses in Huddersfield. The Council now wish to install small wind turbines on a Council Building in Huddersfield City Centre. Taking into account results from the wind atlas and general conditions surrounding the project, it was considered that there was sufficient wind resource to justify the installation of wind turbines on the roof. It was decided that due to space limitation and structural strength limitation of the building, two 6 kW wind turbines could be installed. This would provide a maximum generation of electricity while fitting in with the constraints of the construction of the building.

The Huddersfield/Kirklees project proceeded as planned and the installation was completed in July 2006. The wind turbines are the first wind turbines installed on a local authority building in the UK. This project has inspired a new corporate policy of 30% of energy for Council's new buildings to be generated from onsite renewable energy systems, by 2010/11. The project has attracted national attention as a result of a visit from Elliot Morley (former Minister for the Environment and Climate Change) as part of a tour of best practice sustainable development initiatives in West Yorkshire.

Portfield: The Community Primary School which forms part of the St James Education Complex is considering the installation of renewable energy systems at the school. Such installations would demonstrate the technology to students and the local community. This study was commissioned to provide specific technical and economic information to the school. All of the renewable energy options were shown to be more expensive per unit of energy than conventional sources (grid electricity and natural gas) but the renewable energy options show other advantages. These include carbon dioxide emissions savings and other environmental benefits associated with avoiding fossil fuels. There are also benefits to the local economy through the opportunity of using the school as a demonstration of renewable energy technologies that could speed its development toward the low carbon economy of the future.

Having seen the results of the technical and economic assessments, it is recommended that a 6 kW wind turbine, a roof integrated 2 kWp PV system and a 20 m² solar water heating system be installed at the facilities. Unfortunately, the project will not go ahead, as the school does not have enough funding for a wind turbine.

Sheffield: The City Council has contracted IT Power to carry out a wind energy feasibility study for five proposed sites in Sheffield. The first four sites are residential housing redevelopment. The 5th site consists of existing tower blocks and is included in order to explore the potential for siting wind turbines on a 'generic' tower block.

Woodside: the Feasibility study hold in Woodside identifies two possible locations for wind turbine installations:

- Location 1: the park between Woodside Lane and Pitsmoor Road; here the ground installation of either a 2.5 kW, 5 kW or 6 kW turbine was considered.
- Location 2: the rooftop of the planned landmark building; here a roof-mounted installation of either a 1.5 kW or 2.5 kW turbine was considered.

Catherine St. Triangle: the installation of a small wind turbine is not recommended for this site. The location is unsuitable for a number of reasons; the main reason is the small area available and its proximity to trees and houses. Turbulence and safety, noise and shadow flicker are problems that could occur at this location. It was suggested to install PV systems instead of small urban wind turbines.

Skye Edge: Two possible locations for the installation of wind turbines were identified:

- Location 1: on Skye Edge Park, where a 15kW machine was considered; and
- Location 2: on the proposed Landmark building, where smaller 1.5 or 2.5 kW machines were considered.

The installation of the turbines considered for each of these locations was found to be technically feasible. The location with more potential for wind power is the one on Skye Edge Park, as it is an isolated space, far from houses or trees, very exposed and on an area of high ground.

Parson Cross/Falstaff: this study has assessed the technical, economic, planning and health and safety issues associated with installing a small wind turbine at Parson Cross, Sheffield. The installation of a small wind turbine has been shown to be technically feasible at the northeast corner of Parson Cross Park. The proposed wind turbine for this site has a rated power of 2.5 kW which would result in an estimated annual energy generation of 3750 kWh.

Other locations were considered but were found to be unsuitable due to layout and proximity of houses and trees and prevailing wind direction. If the redevelopment plans change significantly, some new opportunities for wind installation could arise. For example, if new open green spaces are planned, then a second wind turbine could be installed.

Netherthorpe Tower Blocks: the installation of one or more small wind turbines is likely to be technically feasible but a structural survey of the building is first required to confirm that the building structure will be able to withstand the additional loads from the wind turbines. This is out of the scope of this study.

Given the cost of installing on the tower blocks, it is recommended that more than one wind turbine is installed on each, to reduce cost per kW installed and gain energy production for investment made. Any of the technologies presented (Swift, Airdolphin, Windsave or Ampair) are technically feasible, although best energy production is likely to be from the Swift or Airdolphin models.

Although this report suggests installation of two wind turbines per block, it may be possible to install more. This depends on a structural survey to ascertain what extra loads and vibrations the tower structure can withstand. The energy from the wind turbines would likely be used to power communal uses such as lighting. Excess generation would be fed into the grid with revenue going to the landlord.

In Sheffield, a seminar was held to present the proposed sites and the results of all the feasibility studies to stakeholders and decision-makers. The city council are considering taking at least two of the sites forward in the near future, probably the Netherthorpe flats and Woodside site. One site was rejected (Catherine Street) and the other two are still in consideration but for the medium to longer term.

1.3 The Netherlands

Horisun had meetings with the city of Hague, three city districts in Amsterdam and other cities and they were expected to lead to a number of feasibility studies. However, due to circumstances out of the control of Horisun, not all feasibility studies happened. The end result is one feasibility study for the city district of Ookmeer in Amsterdam. This combined feasibility study report will present the unique Dutch feasibility study. This feasibility study was made within the revitalization plan including also the rebuilding of a sport centre Ookmeer.

An important aspect of the revitalization process of the City District Osdorp is a visible and tangible environmental friendly image. The City Council requires that the pay-back time of all applied technologies should be less than 10 years. There are already some projects with renewable energy in Osdorp like solar photovoltaic’s and heat and cold storage in aquifers.

Renewable energy option will be inventoried for the the Sport Park Ookmeer. The council would like to deploy urban wind turbines (UT) and that’s why the Dutch partner has presented a feasibility study for this location. This study considers some generalities and conditions for implementation of urban wind turbines and also presents permit requirements.

Considering all the general conditions stated for integration of UT, we can conclude that the MFSC Ookmeer can be made suitable for placing of small wind turbines, providing that the height of the turbines and the distance from trees and other obstacles would fall within the recommended values. More specifically, this implies that the climbing wall (on which the turbines would be placed) should be built half way the east (long) side of the multi-functional building. The turbine would be then exposed to the winds from the west and south-west directions. Additionally, the roof of the climb wall should be higher than the tree tops.

The roof of the existing ALO building is high likely suitable for the placing of urban turbines. These because the building is higher than 20 meters and there are no high trees or other obstacles in the near vicinity.

The feasibility of large wind turbines along the west side of the sport accommodation area should be investigated. The investigation in another part of the city has indicated that the electric yield would probably be significantly impacted and therefore the deployment of the large turbines would probably not be recommended.

COUNTRY PARTNER: FRANCE

2 FRENCH FEASIBILITY STUDIES – INTRODUCTION

Sites identification in partnership with City officers of Lyon, Grenoble and Lille of the potential implementing bodies has been carried out. The French organizations contacted directly depend on the municipalities. They have a mission to develop the social housing at the local level.

They represent in fact an excellent lever to develop wind energy in urban environment. Indeed, given that this technology is completely new in France and that it did not reach its economic maturity yet, this type of public body can consider the wind urban technology setting up in an approach which is not only economic. Following the municipalities policies, these organizations are thus able to consider the interest of a local energy policy which does not fit solely on financial approach.

The Work then consists in selecting a building likely to receive a wind turbine within the partner cities mentioned above. This was done using the following criteria: owner, building height, type of roof, accessibility and surface roof in m².

To choose the more suitable sites, a study of the Wind direction distribution was necessary and possible for the region where data from the French meteorological office were available or where wind measurements have been carried out. The result of this approach was the selection of the sites subjected to the dominant winds.

Finally, the last task of this study was to work on a wind potential assessment and sites constraints. Buildings in Grenoble, Lyon and Lille were equipped with wind measuring apparatus (mast, data logger, shelter box, multimedia card, data kit, anemometer, wind direction vane, cables). These systems have been recording wind data since October on the building of Grenoble, since January on the building of Roubaix and since April in Lyon.

The data are recovered every fifteen days and after that analysed them. Data precision will have an affluence on the accuracy of this analysis. The wind resource assessment is indeed depending on the amount of wind data collected and the exploitable data. This report outlines the results of these three resource assessment and feasibility studies from Lille, Grenoble and Lyon.

This part of the report articulates itself in the following way: first a presentation of the UT designs, then a sum-up of administrative and legal barriers similar for each of the projects, finally it focuses itself on the particular examples of Grenoble, Lille and Lyon. The case studies will describe the resource assessment and the technical characteristics of the proposed wind turbine for each site. To finish this feasibility study, a short economical and financial study is presented.

3 URBAN WIND TECHNOLOGY

3.1 An innovative technology

3.1.1 The concept of urban turbine

Up until recently, the main renewable energy technologies utilised in urban surroundings were solar thermal, solar photovoltaic and heat pumps. In the last few years, small wind turbines have started to become available and are also being installed in urban areas.

The exploitation of the wind resources in urban areas is then a recent idea. Indeed, the roughness of this environment can induce turbulences disturbing the commonly used turbines. However, studies on wind facing obstacles such as buildings have showed that wind accelerates when getting round them. The angle of incidence on a turbine can also increase its electricity production.

Similarly to photovoltaic, urban wind turbines generate electricity on site, preventing transport losses and enabling individuals and organisations to visibly express their commitment to sustainable energy sources.

3.1.2 Two designs

Recently, some manufacturers have developed two new types of wind turbine which could be suitable for urban area conditions. They can be split in two categories depending on the axis orientation which could be horizontal or vertical.

- **Horizontal Axis Wind Turbine (HAWT)**

HAWT models are similar to the classical wind turbine encountered nowadays in wind farms. The blades rotate thanks to the wind kinetic energy who makes the axis, connected to the generator, rotate at the same time. This mechanical energy is then transformed in electrical energy. The characteristics of HAWT are a small size, from 5 to 20 m with a diameter between 2 to 10 m and a power output up to 20 kW.

Figure 1. Proven wind turbine model

- **Vertical Axis Wind Turbine (VAWT)**

There exist two main type of VAWT: Darrieus design and Savonius design.

The **Darrieus** machine is characterised by its C-shaped rotor blades which make it look a bit like an eggbeater. It is normally built with two or three blades. The Wind turbine is using the lift effect. There are different types of machine using this principle which are: tapered, cylindrical, or parabolic where the blades are going up to the head of the rotor. The machine may need guy wires to be hold up.

Figure 2. Tulip wind turbine model

The **Savonius** machine using the drag is composed of two half cylindrical places in opposition. A torque is then produce putting the generator in motion. The cut-in speed of

these machines is quite low, around 2 m/s. The VAWTs are reacting particularly well to turbulences. Moreover this one doesn't make a lot of noise and finally is quite suitable for urban areas.

Figure 3. Windside wind turbine model

The VAWTs have been designed to fit at the best with this turbulence constraints described above. Thanks to this design, they can operate with winds from any direction and are less disturbed by turbulences than the horizontal axis turbines. The VAWTs are relatively quiet and can easily been integrated in building design. The weaknesses of VAWTs are mainly related to the quasi inexistent maturity of its market (investment costs). Due to their small size, their energy production is to a certain extent low but adapted for instance to the consumer needs of one social building. Therefore, they can easily adapt themselves to the urban environment.

In terms of costs, horizontal axis wind turbines (HAWTs) are currently far cheaper than vertical axis wind turbines (VAWTs) and have better energy yield. However, HAWTs present three particular issues: noise, vibration and safety, which arise less frequently with VAWTs.

Urban turbines are generally connected to the low voltage network via an inverter delivering a 230 V sinusoidal mono or three-phase current with a frequency of 50 Hz. The power output of a wind turbine is:

$$P = \frac{1}{2} \times rho \times \pi \times R^2 \times V^3 \times Cp$$

P : power of the wind measured in Watts (W)
rho : density of dry air (1,225 kg/m3 at 15°C and 1013 mbar)
R : radius of the rotor measured in metres (m)
V : velocity of the wind measured in m/s (metres per second)
Cp : Coefficient of performance (no unit : Betz Limit of 59,3 % multiplied by global efficiency 70 %)

The energetic output of a urban wind turbine is depending on two main factors: the nominal power output (with an average value between 5 and 6 kW) and the number of functioning hours at full load within a year (between 1000 and 2000 hours/year).

3.2 Administrative, juridical and legal aspects

In France the needed regulations, procedures and guidelines related to the integration of these small wind turbines in urban areas are not yet in place. This aspect was well developed in the WP3 Report on administrative and legal barriers.

3.2.1 Town planning

According to the Law on Town-Planning and Habitat, July 2nd 2003, the Town-Planning documents ("Plan Local d'Urbanisme") let cities decide whether they authorise wind turbines in their territories or not in urban areas. On one hand, if there is no explicit interdiction, wind energy projects could be authorised. On the other hand, the town-planning document should be revised. However wind turbines, if not used for self consumption, are considered as general interest equipment, therefore they can benefit from a simplified revision procedure.

In some cities, another town-planning document is used: "Plan d'Occupation des Sols". This documents lists every authorised equipment in the different zones. If wind turbines don't figure on that list, a revision of the document will have to be done.

3.2.2 Permit system

When installing a small turbine in an urban environment, the project-carrier has to achieve several administrative procedures.

The implantation of a wind turbine which height is inferior to 12 m doesn't need a construction permit. However, a declaration of work is necessary but this issue is not yet clearly defined. When the energy produced is destined to self consumption, the authority to be consulted concerning the construction permit (or the declaration of work) is the Mayor. When the energy produced is destined to be totally sold, this authority is the Prefect.

The height of an installation is defined as the one between the bottom of the tower and the top of the nacelle, blades are excluded. Concerning turbines on rooftops, this is a critical issue because it doesn't particularly mention if the height of the building is counted.

If the rated power installed is inferior to 2.5MW, no impact study nor public survey is needed. An impact notice is necessary. However, the revision of a town-planning document leads to a public survey also known as the "Bouchardeau survey".

The operator is financially responsible for the disassembly of the installation and the rehabilitation of the site.

All these measures could be summarized in Table 1:

Height \ Power	< 2.5 MW	> 2.5 MW
< 12 m	• Impact notice	• Impact study • Public survey
> 12 m	• Impact notice • Construction permit	• Impact study • Public survey • Construction Permit

Table 1. Sum up of administrative procedures from wind turbine implementation

3.2.3 Grid-connection framework

This has been particularly detailed within the WP3 report on legal and administrative aspects. The "Grid-connection Report" describes particularly well the grid-connection procedures which main points are:

- ✓ Legal framework and feed-in tariff conditions
- ✓ Tariff definition
- ✓ Technical grid connection conditions
- ✓ Installation under 2,5 MW
- ✓ Installation under or equal to 36 kVA
- ✓ Connection process

The general grid-connection framework is described in Figure 1:

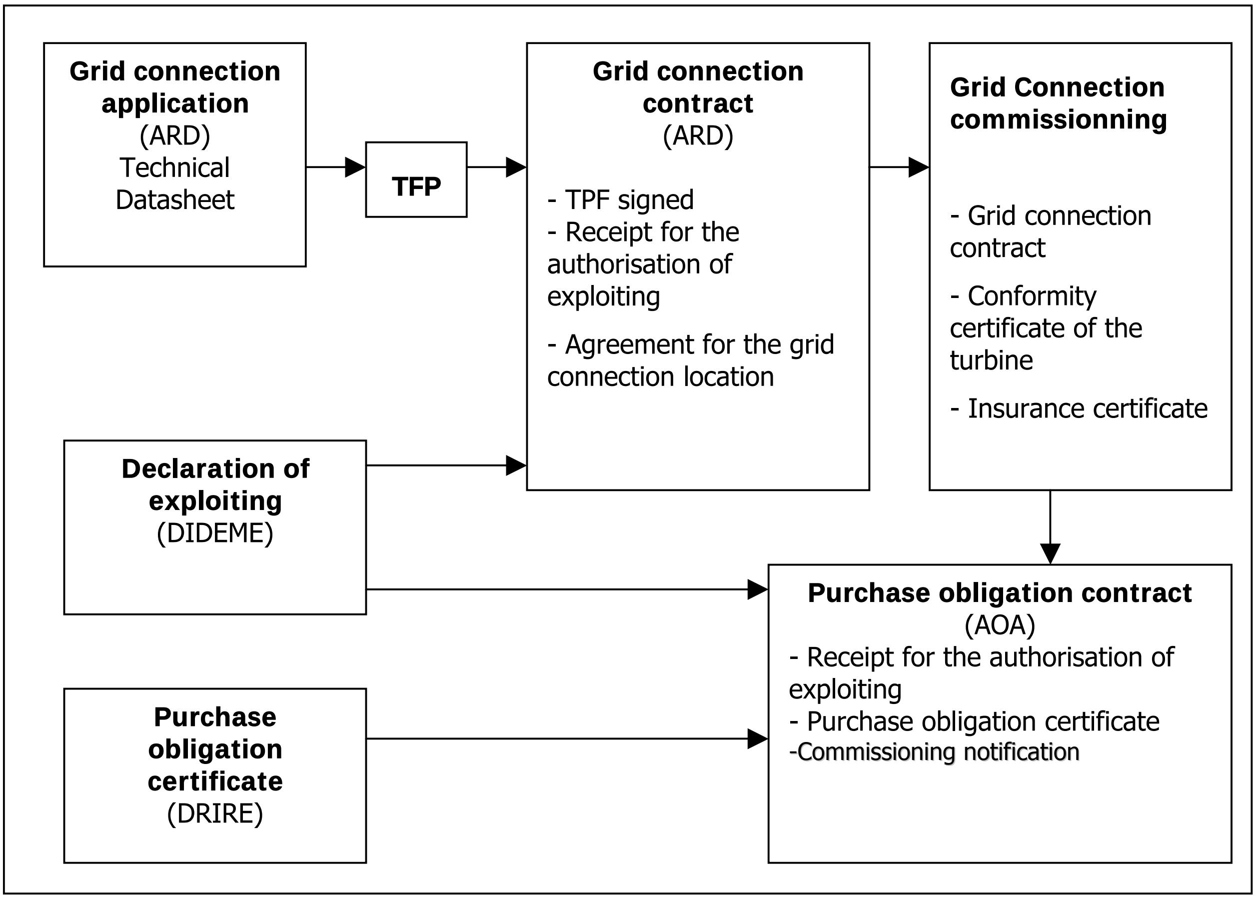


Figure 4.Grid connection procedure for turbines (power inferior to 36 kW).

Within the framework of his public mission of the network maintenance, the historical operator (EDF) set up a particularly demanding procedure for grid connection. These requirements result, with final, in long administrative times to obtain a connection agreement.

However it should be noted that EDF launched consideration process in order to reduce the procedures, considering that the majority of the small wind turbines can be connected directly to the LV distribution network, and that it is thus not necessary to lead important technical studies on the upstream impact of these machines on the MV network.

3.2.4 Noise pollution

In the urban environment, laws are very strict concerning noise pollution. Laws, particularly Decree n° 95-408, April 18th 1995, the on noise pollution state that urban noise is defined through its emergence, which is the sonorous difference between the usual noise of an area, measured in dB(A), and the one created by a specific disturbance.

- Day time (7AM to 10PM): the emergence permitted is +5 dB(A)
- Night time (10PM to 7 AM): the emergence permitted is +3dB(A)

It is important to point that most urban turbines, especially the ones with vertical axis, are almost silent and would therefore satisfy the criteria of the current regulations.

4 CASE STUDY 1: GRENOBLE

4.1 Description of the site

Several meetings between the Grenoble Community and Axenne have lead to the consideration of one particular possible site for the installation of an urban turbine at the following address: 45, rue Anatole France, 38 000 Grenoble.

This building, located in the Mistral area, is run by the public housing office ACTIS. ACTIS is the public body manager of Grenoble social housing and its personal representative is Gilles Billon. The mission of this potential implementing body is to develop the social housing at the local level. This type of organization can thus consider the wind urban technology setting up as an approach which is not only economic. The organization shows a demonstration willingness which is also depending on its role and mission in the society. This issues have been particularly highlighted in the WP4 Report on UT acceptance. From the different meetings and interviews conducted until now, it appears that fears are primarily related to noise which is not a problem here. The question of visibility is of lower importance especially as the site identified has a height higher than 20 meters. Above all, these actors reaffirm the importance to take part locally in the development of renewable energies.

The site is located in the Cité Mistral which is a collective settlement located down town (Figure 5). They are no particular objections to the location of the UT like in an historical district.

Figure 5. Site location in the Grenoble Agglomeration

The wind measurement system was placed on the roof of this social building housing. This building is particularly high so there are no particular obstacles as we could be expecting in an urban area. In Figure 6, we can see clearly that they are no special visual impacts or other constraints that the general ones presented in the paragraph 3.2.

Figure 6. Wind measurement tools on social housing building (Cité Mistral)

4.2 Resource Assessment

Several wind measuring devices have been installed in October 2005 in the Grenoble site such as:

- An NRG 40 anemometer
- A NRG 200P wind vane
- A NRG 9200 logger

The wind resource measuring procedures are the same used for the traditional big scale wind energy. The anemometer measures the wind speed, while the wind vane indicates its direction. All this data will be recorded in two 100-day autonomy memory chips plugged in the logger. This data will then be processed by a specialised engineer in order to determine the energy yield of this site. This measuring equipment must be inspected periodically in order to guarantee its good functioning. Maintenance operations such as replacing the chips will have to be done.

The measured energy yield will the be compared to the data of the region provided by Météo France services over a period up to ten years (Figure 7). This information will allow to identify the matching technology for this specific site.

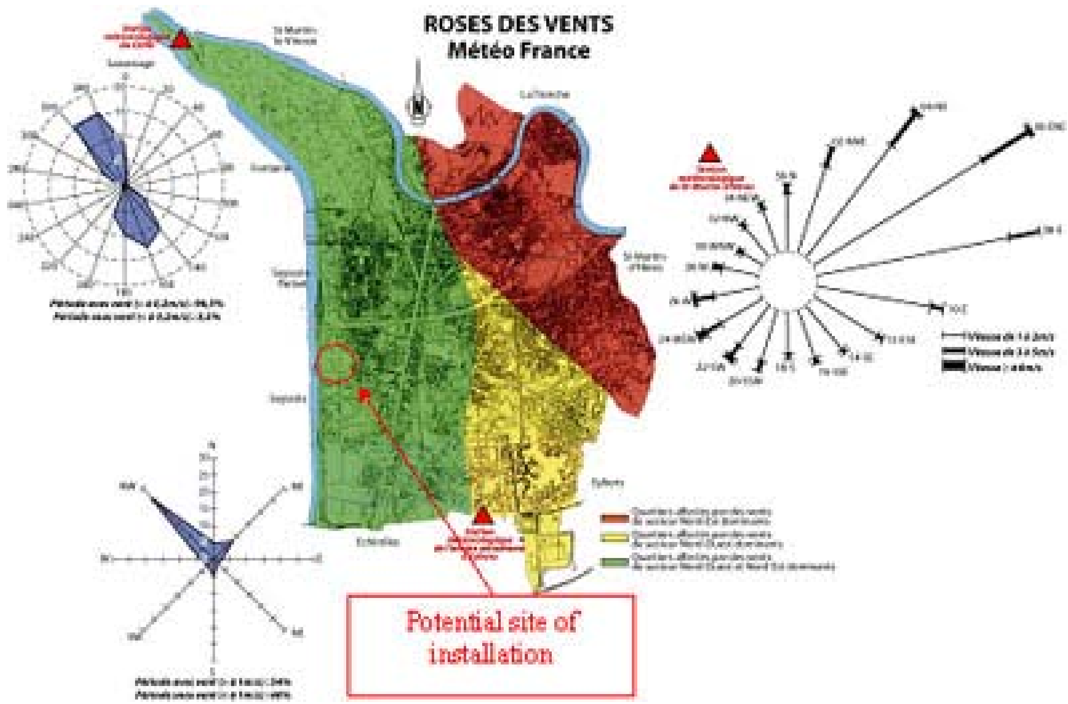
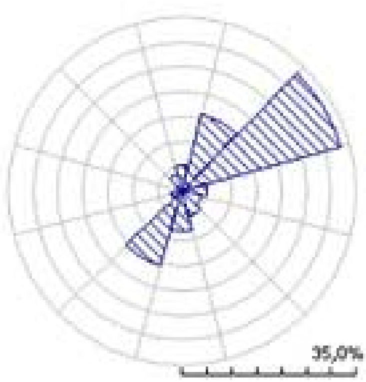
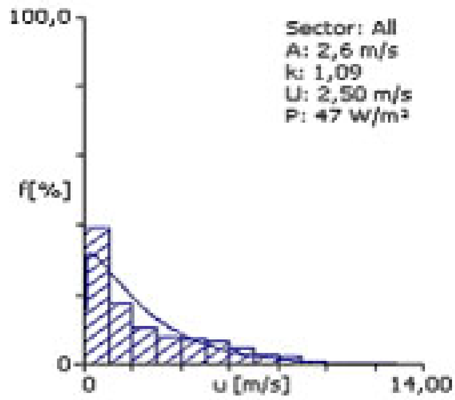


Figure 7. 10 years of meteorological data for the city of Grenoble, Météo France

After a period of four months of measurements, the following results were obtained :

Measuring period	**From October 28th 2005 to February 19th 2006**
Speed availability	68%
Direction availability	52%
Average wind speed (m/s)	**2.36**
% of time when speed>5m/s	15.50%
Average standard deviation	0.82





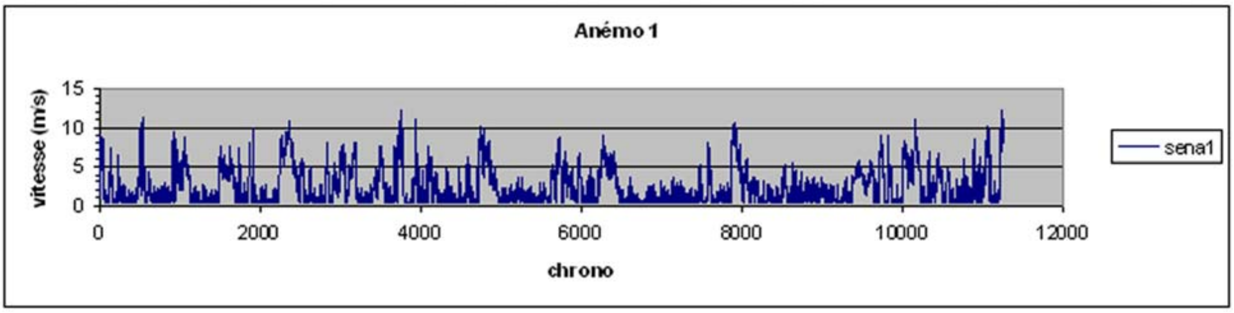


Figure 8. Wind speed variation over the measuring period, Grenoble

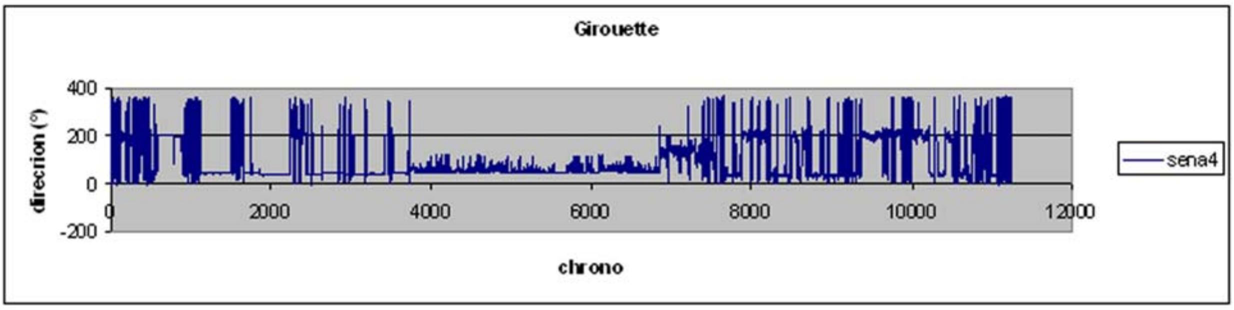


Figure 9. Direction variation over the measuring period, Grenoble

These results indicate that the site has a weak wind potential. The average wind speed is 2.36 m/s. This can be explained by masking noise around the measurement mast. However, we have seen that the VAWTs Savonius type have a cut-in-speed around 2 m/s. One of this machine could actually suit to this site location in particularly since there are no big constraints.

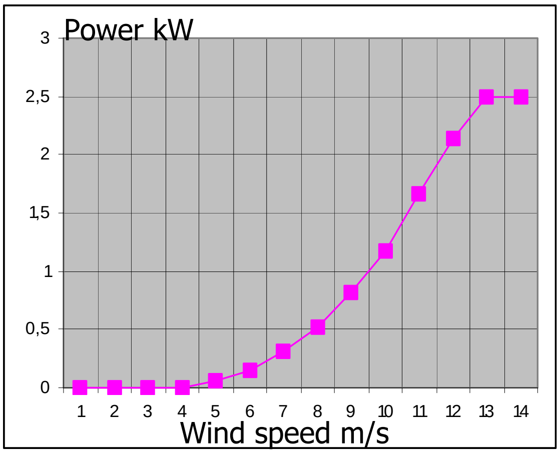
4.3 Description of the proposed wind turbine

Following the energy yield conclusions, we can recommend a VAWT named Turby. This VAWT was studied to be placed on top roof in urban aras. This machine is small, attractive and is working with no noise and no vibrations which facilitate its installation.

It requires no particular maintenance and could be erected with a packed tower (available by the supplier « Eneco energie ») with no needs of a crane.

Turby wind turbine is at the last stage of its development. The first model were installed in 2003 and since that its technical characteristics could have changed a little from the following ones given by the manufacturer (Table 2).

The power curve of the Turby is the one showed on the right.
The Turby UT was installed in different sites in the Netherlands. It was placed for example on roof of public building such as a school or a town hall.



Turby 2,5 kW references

Site	Use	Country
Amsterdam	Proof public building (former school)	Netherlands
Tlburg	Roof flat building	Netherlands
Den Haag	Roof town hall	Netherlands
Delft	Technical University	Netherlands

POWER		Unit
1) Rated power	2,5	kW
2) Rated wind speed	14	m/s
3) Cut-in wind speed	4	m/s
4) Cut-out wind speed	14	m/s
5) Maximum wind speed the turbine can withstand	55	m/s
DIMENSIONS		
6) Rotor weight	135	kg
7) Rotor diameter	1,99	m
8) Rotor height (for VAWT only)	2,88	m
9) Swept area	5,3	m2
10) Height of the mast	6 – 7,5	m
OTHER INFORMATION		
11) Maximum rpm	400	At rated wind speed
12) Gear box type	No gears	
13) Brake system	Electrical brake system	
14) Number of blades	3	
15) Blades material	Carbon epoxy composite	
16) Output voltage	230	V
17) Minimum operation temperature	- 20	°C
18) Maximum operation temperature	+ 40	°C
19) Acoustic levels at a distance of 20 m ? wind = 10 m/s)	45	DB
20) Lifetime	20	Years
21) Is the machine self-starting	No	
22) Use of an asynchronous generator	No	
23) Yaw control system	Independent	
24) Upwind or downwind	Both	
25) Weight (Rotor+mast)	240 kg	

Table 2. Turby 2.5 kW Technical Characteristics

4.4 Economic and financial aspects

The profitability of UT project is calculated in comparing the cost per kWh produced with the purchase tariff from EDF. This cost per kWh is depending mainly on investment costs but also on the equivalent time at full charge (TEFPP).
Investment costs are split in the following way :

- Studies and dimensioning of the installation
- Various permission (building permit, planning permission, grid connection, etc.)
- Generator and mast
- Electrical equipment
- Installation and commissioning of the system

Nowadays, the cost per kWh produced for an urban turbine is around the double of the purchase price fixed to 10,4 ct euro/kWh. The operating time is around 1000 and 2000 hours/year. It clearly sounds that other funding are necessary (Figure 10). However, this feed-in tariff should actually be re-evaluated. The first financial estimations are summarized in Table 3:

Table 3. Economic and financial analysis for Grenoble site

Total investment Cost	18 000 euro
Maintenance Cost	200 euro/year
Feed-in Tariff	10.4 ct euro/kWh
Average production incomes per year	55 euro/year
Project duration	20 years
Subsidies to investment to reach financial equilibrium	**10 865 euro**

Under the current purchase conditions, the level of subsidies necessary to reach profitability, is around 60% of investment costs for a pay back time of 20 years (corresponding to the Turby life span).

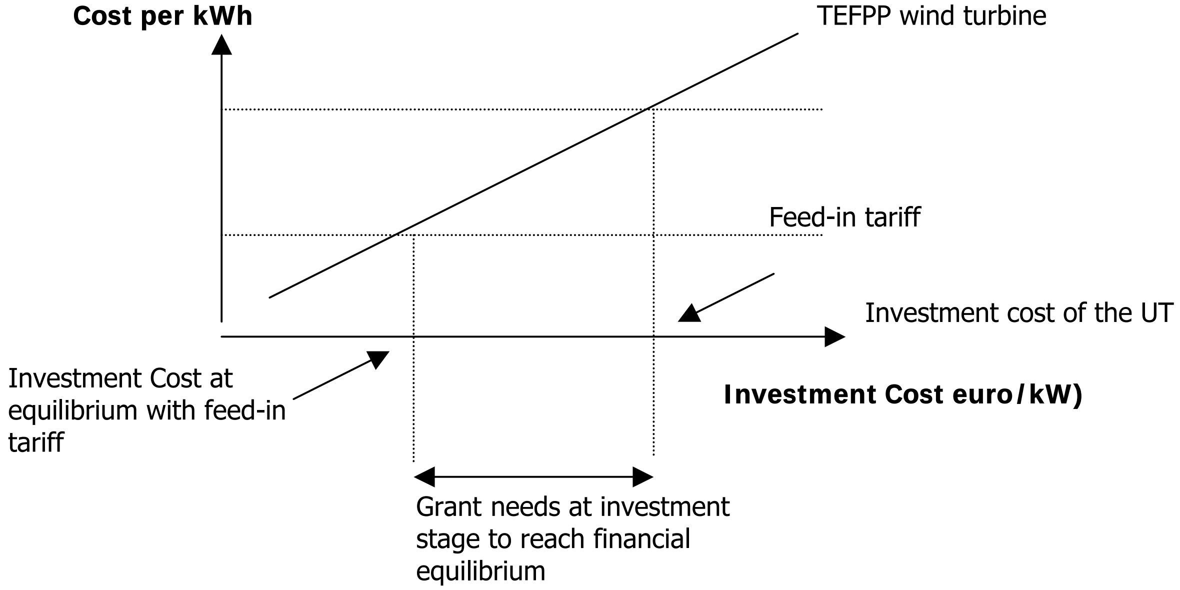


Figure 10. Estimation of subsidies needs

5 CASE STUDY 2: LILLE

5.1 Description of the site

5.1.1 Roubaix

The selected site for the commune of Roubaix is a cultural building named « La condition publique » located, 14 place du Général Faidherbe. This building is situated in an urban area with a relative weak density (mainly small collective). The building is closed to an old industrial area.

Most of the roof is stilted but it is not perfectly horizontal. This has to be considered when placing the UT. To avoid noise effects (even from the building itself), the UT should be installed at the roof edge in the prevailing wind direction.

The "Condition publique" is an old wool and silk fibre factory. This one is registered as an historical building. However, the implementation of a urban wind turbine on the roof could contribute to image of this building which is one side artistic and on the other side pedagogical. Furthermore, this building has already a roof accessible to the public. Figure 11 give a first idea of the neighbourhoods and the potential visual impacts.

East-South East view from the roof

West direction from the roof

South-west view from the roof

Figure 11. Views from the Roubaix Site

5.1.2 Templemars

The second site identified in Lille Agglomeration is the sports complex Colette Besson. It is located in an urban area with a weak density at the periphery of the town (Figure 12).

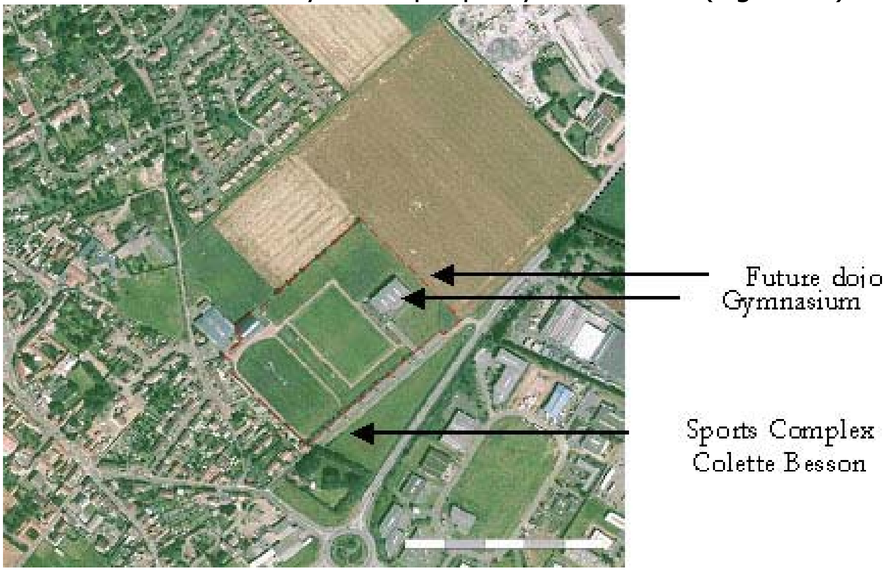


Figure 12. Location of the Sports Complex Colette Besson

Figure 13. Views from the Templemars site

Seeing Figure 13, it's clear that there are not a lot of buildings or construction around the Sports complex. The UT will not be subjected to strong turbulences. At first sight, this site appears to have an interesting wind potential. Two sites could be interesting: on the edge of the existing gymnasium (situated at 200 meters from the first housings) or on the future construction which is a dojo. The wind turbine could not be installed on the gymnasium roof because of its metallic structure.

Furthermore, this site is subjected to two planning constraints: the Lille Metropole PLU and the overhead easement from Lesquin airport. The sports complex is located in the UB area of the PLU. It is then forbidden to install any wind turbine. A revision of this document should necessarily be adopted. Regarding the overheard easement, there are no restriction to the installation of a urban wind turbine which has a height smaller than the 93 meters stipulated.

5.2 Resource Assessment

5.2.1 Roubaix

In the region of Lille, the prevailing wind is in the direction South-west with an average wind speed of 5 m/s. To assess more precisely the wind potential, wind measurement equipment were placed on the roof of the building in February 2006. The same measurement procedure as in Grenoble has been followed.

Figure 14. Wind measurement tools on Roubaix building (La Condition Publique)

The results for the measurement period from 1st of February until 13th of March 2006 are summarized in this table:

Measuring period	**From February the 1st to March the 13th 2006**
Speed availability	94%
Direction availability	93%
Average wind speed (m/s)	**2,54**
% of time when speed>5m/s	**4,48%**
Average standard deviation	**1,00**

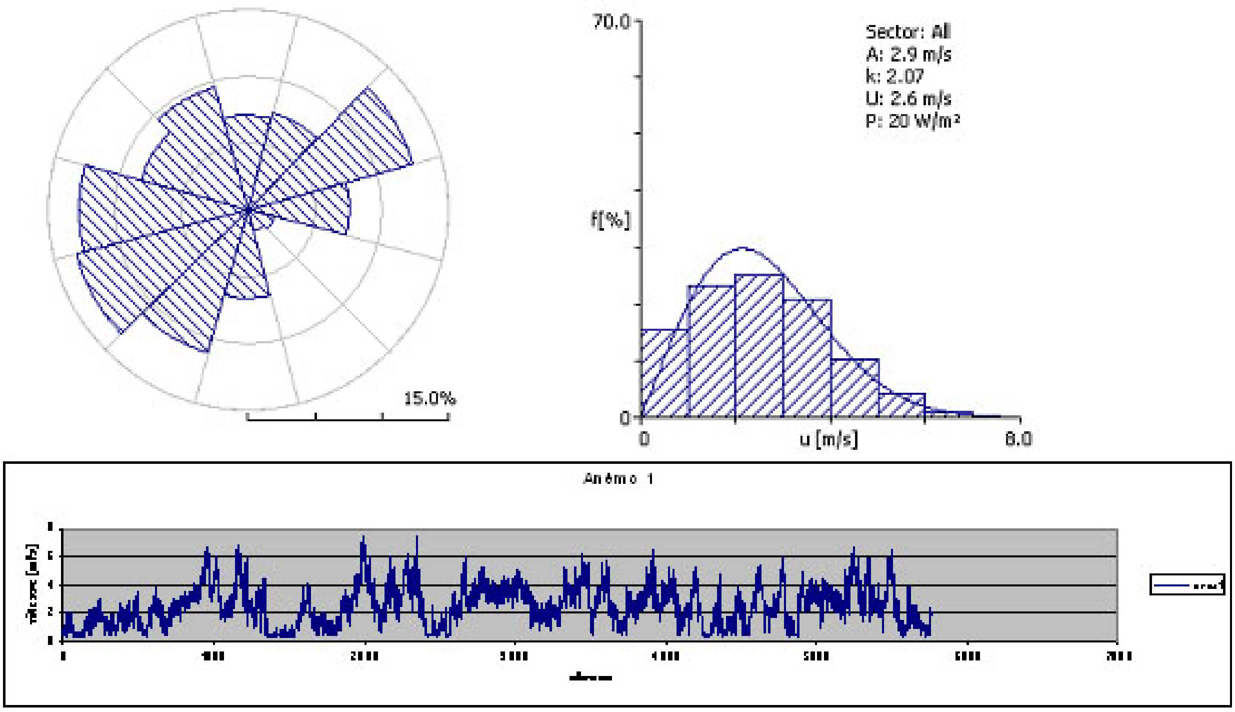


Figure 15. Wind speed variation over the measuring period, Roubaix

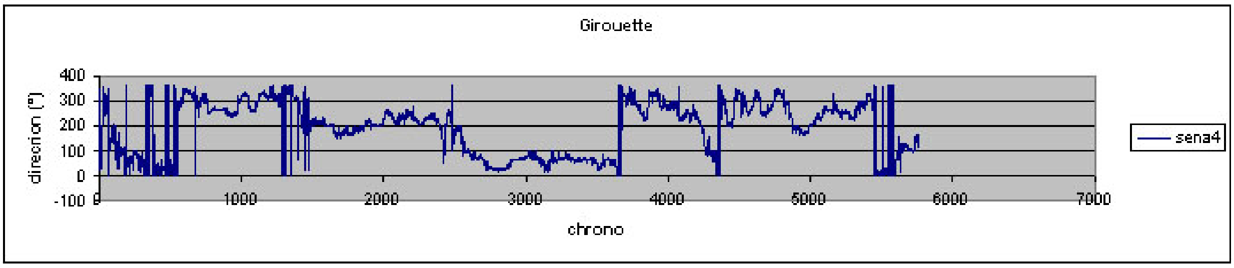


Figure 16. Direction variation over the measuring period, Roubaix

5.2.2 Templemars

As we have seen for Roubaix, the prevailing winds for Lille Metropole are south-west with an average wind speed of 5 m/s. A précised wind measurement was not possible since budget and time were not sufficient. To obtain accurate measurements, the ideal measurement period is one year. That's why the wind potential for Templemars was estimated using the wind rose from Lesquin meteorological station.

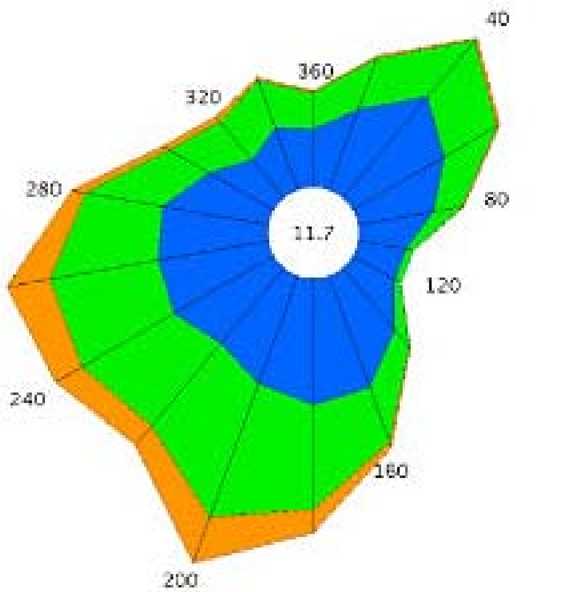


Figure 17. Wind rose from Lesquin.

This wind rose is not enough since between two sites there can have big differences. But this confirms the hypothesis of south-west as the prevailing wind direction.

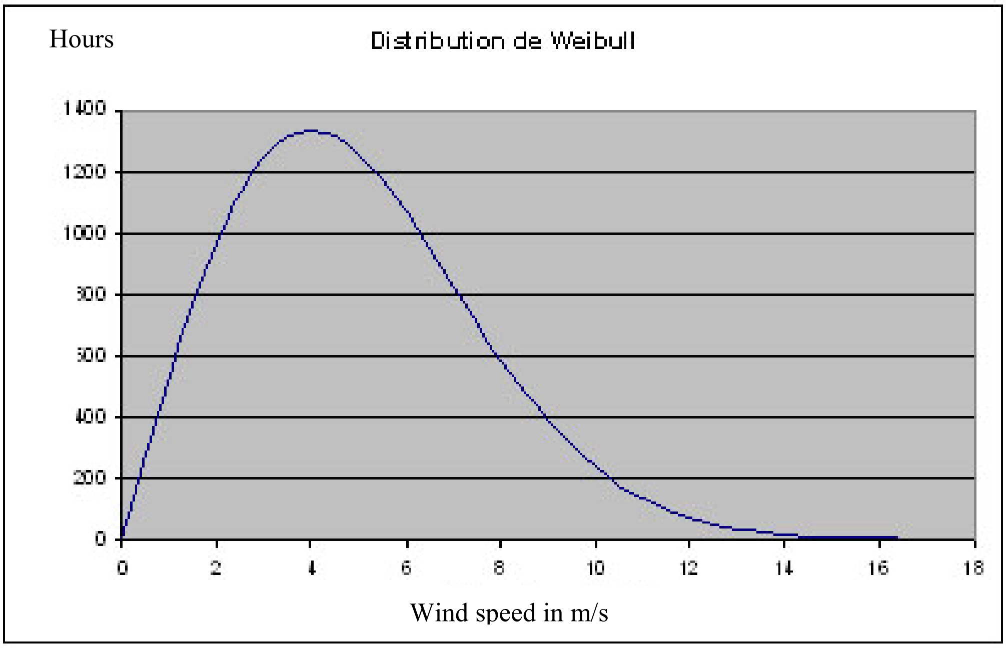
5.3 Annual production output

To estimate the annual production of different wind turbine, the study was made for an average wind speed of 5 m/s (see Lesquin wind data). The wind distribution was simulated by Weibull distribution following the formula:

$$P(V) = \frac{k}{A} * (\frac{V}{A})^{k-1} e^{-(V/A)^k}$$

A : scale parameter (m/s)
k : shape parameter (no unit)

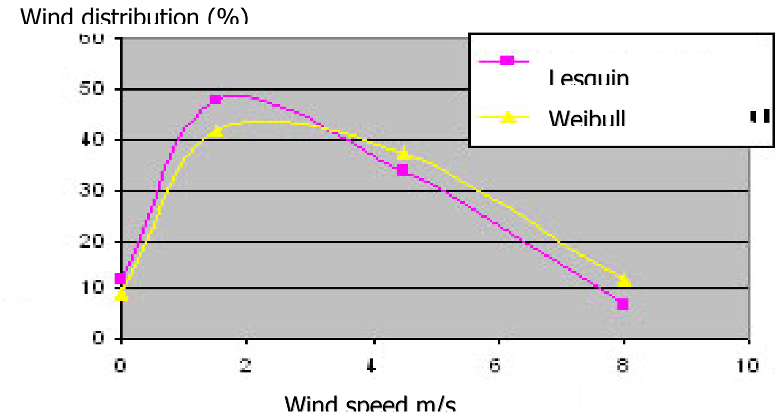
Wind turbine manufacturers usually give a shape parameter of 2. The scale parameter, A, is obtained using the average velocity. We can then have our wind distribution



Weibull Distribution (A=5.64 ; k=2 ; U (average)=5m/s ; U (median)=4.7m/s)

To validate our simulation, we're comparing them with Lesquin data (see graph below). Our simulation seems to be correct if we look at Figure 18.

Figure 18. Comparison between the wind rose of Lesquin and Weibull modelisation



5.4 Description of the proposed turbine

Wind potential is the first factor to select a wind turbine. "La Condition Publique" is an urban area where the wind speed is not quite high where as in Templemars the area doesn't have so much obstacles. The wind turbine should be choose with a nominal power output for a wind under 10 m/s.

In Templemars, the turbine will be seen when entering the city. The UT design should consider this. However, the project will not face noise constraints since the locations are far away for habitations. We easily see the possibility of using a HAWT since the size is not a problem as in Roubaix. The advantage of the HAWT would be its better efficiency.

When choosing the dojo, UT integration will be thought since the beginning of the building conception. There are no problem of establishment conditions (anchoring or staying). However, for the gymnasium site, two options are possible: a mast or guy wires. The first solution needs foundations which are quite expensive. The second one requires a large surface for anchoring.

5.4.1 Roubaix

For the "Condition Publique" site, the more suitable wind turbine is a vertical axis. VAWT is more adapted to small wind speed level, turbulences and noise considerations. Furthermore, the design is new and could be better accepted by the public.

The VAWT chosen is OY Windside. Its annual production is relatively weak but the design of this turbine is seen as an advantage. This project could play a role of dissemination for the urban wind technology. The OY Windside is a quiet machine, doesn't suffer from the turbulences and its rotation speed is slow which can prevent from safety problems. Quite interesting for its design, this UT is resistant and has a life time higher than 30 years.

Rated power (18 m/s)	1000 Watt
Rotor diameter	1 m
Rotor height	4 m
Height of the mast on the roof	8-10m
Rotor weight	700 kg
Swept area	4 m²
Output voltage	0-200 V
Cut-in speed	2 m/s

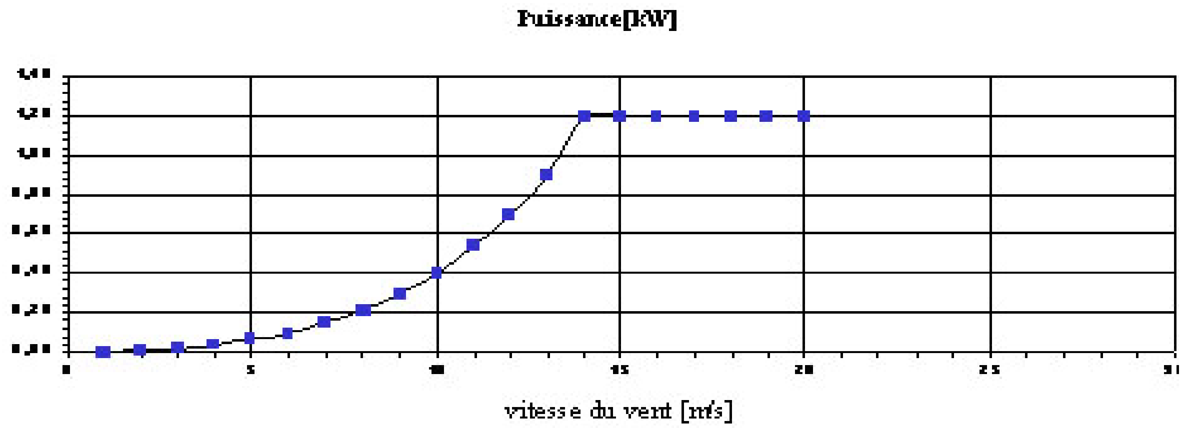
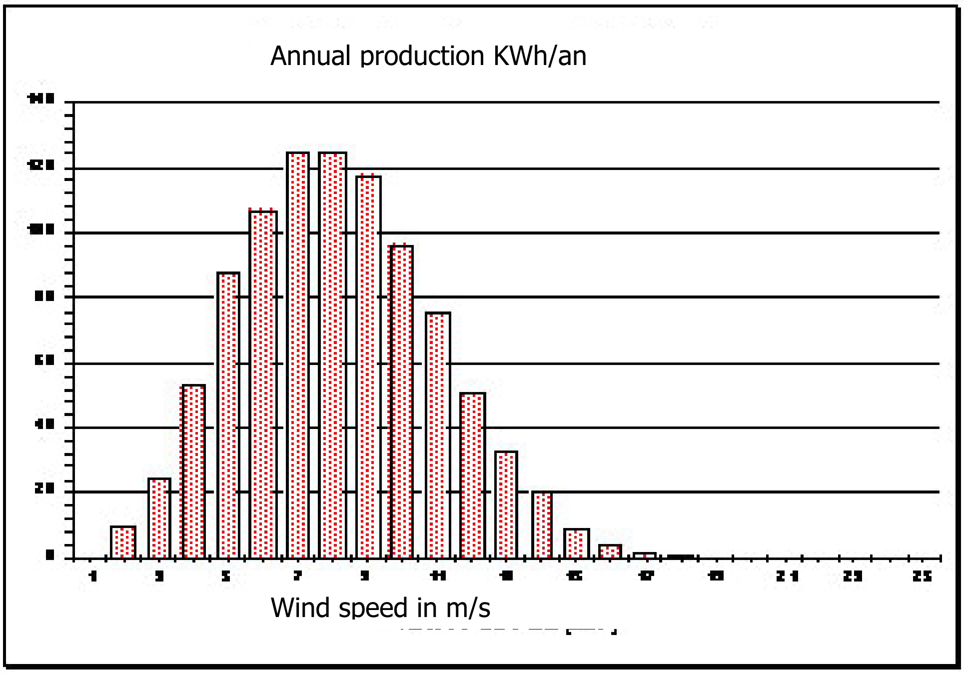


Figure 19. OY Windside Power output versus wind speed

Summing all this wind range, the annual energy output is 934 kWh/year for 8162 of operating hours.



5.4.2 Templemars

The wind potential of Templemars is more important that the one from Roubaix. It 's then possible to choose a wind turbine with a higher efficiency. We select the Gaia Wind (11 kW) for its annual production and the WES (2,5 kW) for which nominal power corresponds to relative weak wind (8,5 m/s).

The Gaia is a two blades horizontal wind turbine with a cut-in speed of 3 m/s particularly suitable for urban areas. The lattice tower recommended by the manufacturer is not a good solution. The UT is not really quiet (45 dB at 60m) but it's not important since the location is 200 m away from any habitations.

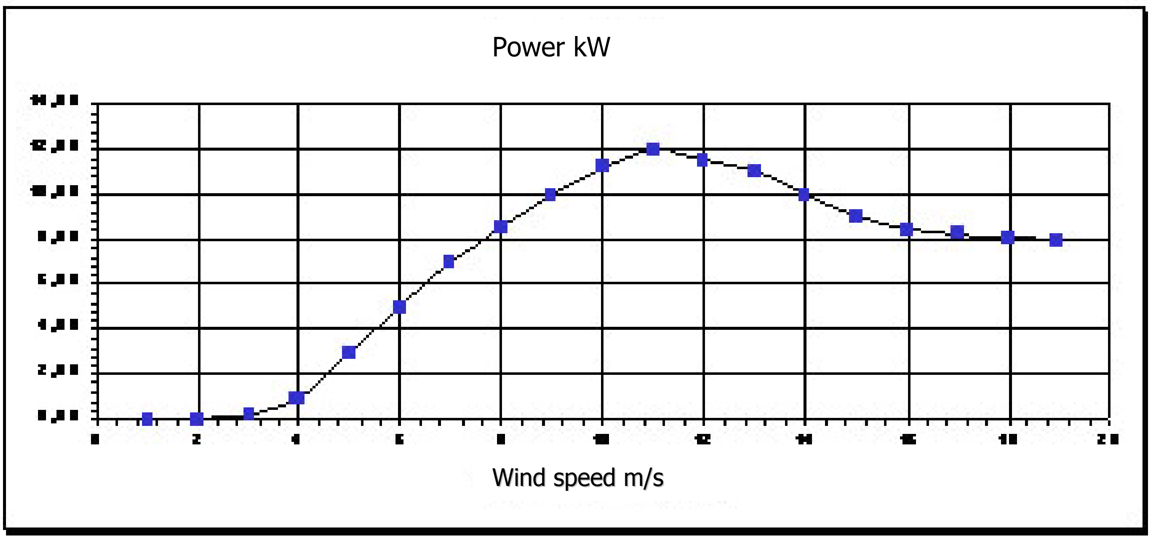
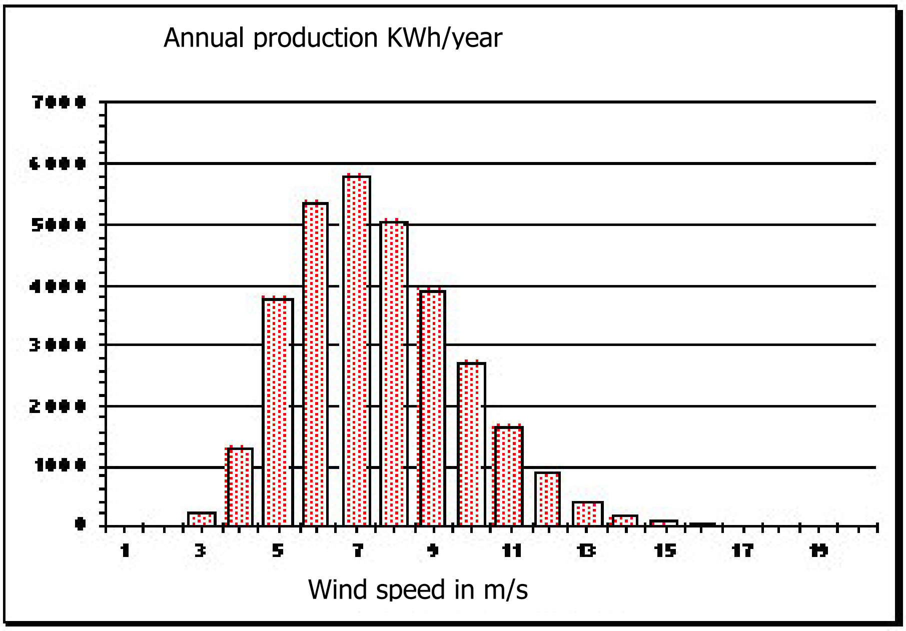


Figure 20. Gaia Power Output versus wind speed



Rated power (10m/s)	11000 Watt
Rotor diameter	13 m
Height of the mast on the roof	15-18m
Rotor weight	208-248 kg
Swept area	132 m²
Output voltage	380-400 V
Cut-in speed	3 m/s

The annual energy output is 31192 kWh/year for 7198 of operating hours.

The second solution for Templemars is the WES5 Tulipo. This turbine has been designed for urban areas and particularly industrial areas. Noise, safety and design have really been considered. This is a three blades turbine with a connection to the grid. The design of the nacelle is quite nice and adapted to urban areas. At 20 meters, the noise reaches around 35 dB (less than a residential street).

Foundations are integrating control system and all electrical wires.

Rated power (8,5m/s)	2500 Watt
Rotor diameter	5 m
Height of the mast on the roof	6-12m
Rotor weight	200 kg
Swept area	19,6 m²
Output voltage	400 V
Cut-in speed	3 m/s

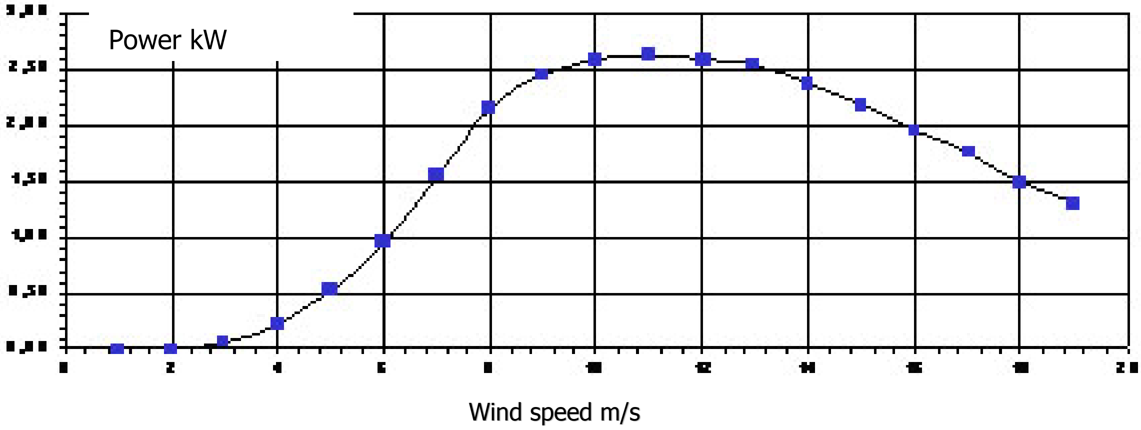
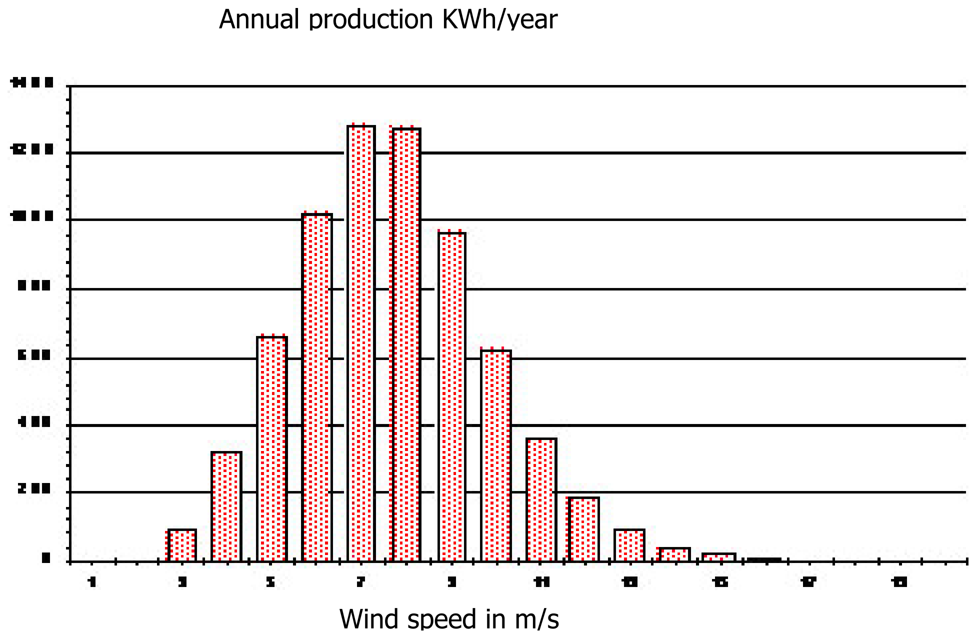


Figure 21. WES Tulipo Power Output versus windspeed

The annual energy output is 6942 kWh/year for 7198 of operating hours.



5.5 Economic and financial aspects

5.5.1 Roubaix

The financial aspects of the project in Roubaix are presented in Table 4:

OY Windside	Wind turbine connected to the grid		
Windside 1,2kW	Control box Nacelle Blades Mast	26 400,00 euros	
Installation and commissioning		3 240,00 euros	
Civil works and assembling		4 000,00 euros	
Grid connection cost		3 000,00 euros	
	TOTAL	**36 640,00 €**	
Annual production		934	kWh/year
Equivalent hours		780	hours
Production incomes		78,27 euros	
EDF equipment rental		45,00 euros	
Annual income		33,27 euros	
Profitability		**11,0132**	**years**
Price of kWh/year	**8,38 ct euro**		

Table 4. Economic and financial analysis for Roubaix site

This project doesn't seem to have a high economic profitability furthermore as we have over estimated the average wind speed. Subsidies are essentials for this project which can serve as pilot project for urban wind technology.

5.5.2 Templemars

The methodology of analysis as for Roubaix has been carried out:

GAIA WIND 11kW		Wind turbine connected to the grid	
Gaia wind	Control box Nacelle Blades		,00 euro
	WPMS	Control pannel Statistic production status list status conde summation	50,00 euro 160,00 euro 60,00 euro 110,00 euro
	Mast	18 m	6 900,00 euro
Civil works			4 000,00 euro
Grid connection cost			3 000,00 euro
		TOTAL	**29 755,00 euro**
Annual production			31192 kWh/year
Functioning hours			2835 h
Production incomes			2 613,89 euro
EDF equipment rental			45,00 euro
Annual incomes			2 568,89 euro
Profitability			**15,68 years**
Price of kWh/year	**8,38 cts euros**		

Table 5. Economic and financial analysis for the site of Templemars, Gaia option

The pay-back period of this wind turbine is really interesting. This is the main advantage of the Gaia. However, it should be considered as an estimation. Installation and commissioning costs could not been evaluated (Table 5). This financial evaluation doesn't consider the maintenance costs which have been estimated to 1000 euros/year. The pay-back period is then around 25 years. It's however the more cost effective urban wind turbine studied.

The second option for Templemars is the WES5 Tulipo which financial balance is the following one:

WES 5 tulipo		Wind turbine connected to the grid		
Wes tulipo	Control box	Grid connection IGBT inverter PLC control Batteries	15 475,00 euro	
	Nacelle Blades Mast	12m D=273mm		
Installation and commissioning		Technical support From an engineer WES trip	1 750,00 euro	
Civil works and assembling			4 000,00 euro	
Grid connection cost			3 000,00 euro	
		TOTAL	**24 225,00 euro**	
Annual production			6942	kWh/year
Operating hours			2835	hours
Production incomes			581,74 euro	
EDF equipment rental			45,00 euro	
Annual incomes			536,74 euro	
Profitability			**45,13**	**years**
Price of kWh/year	**8,38 cts €**			

Table 6. Economic and financial analysis for the site of Templemars, WES Tulipo option

This breakdowns of costs (Table 6) considers all the costs except the engineer accommodation. The grid connection and civil works costs are approximations. The pay-back period seems to be over the wind turbine life time. However, subsidies could help in reducing the investment costs such as the re-evaluation of the feed-in tariff for small wind energy.

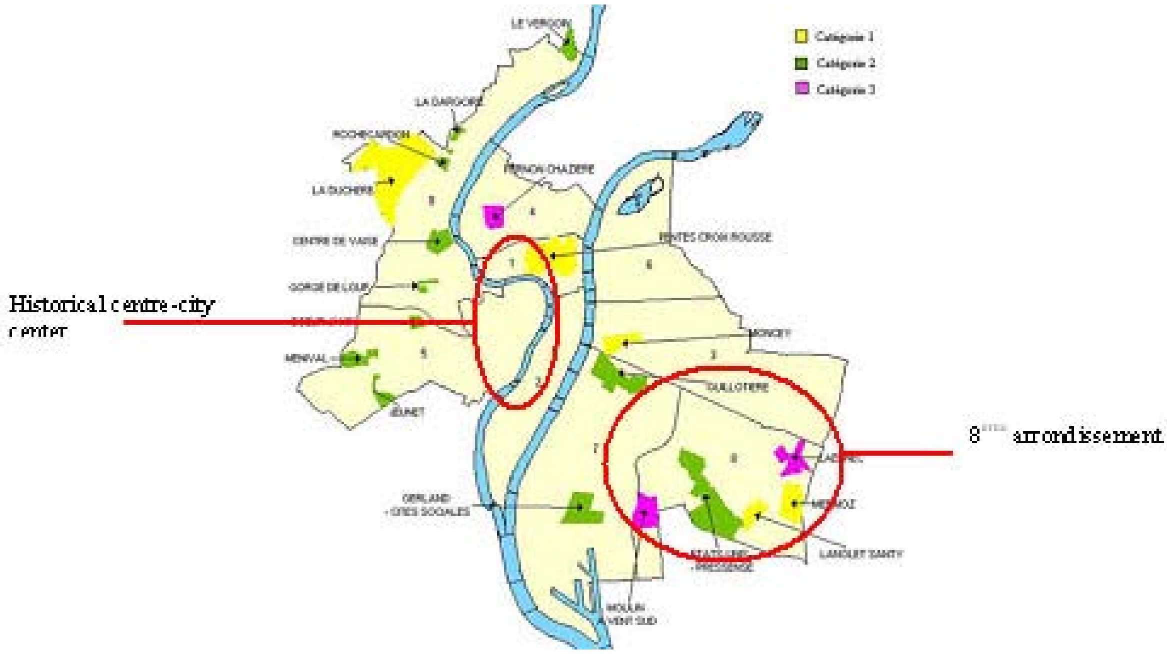
6 CASE STUDY 3: LYON

6.1 Description of the site

The various meetings with OPAC du Grand Lyon, a public body manager of Lyon social housing were successful and a urban turbine site was selected. It's situated at the address: 107 rue Laënnec, 69008 Lyon.

Figure 22. Social building of Laënnec and Wind measurement tools

The "8ème arrondissement" is not an historical district expected Monplaisir. However the location of the UT potential site is situated in a area with other social buildings (approx. 2990 dwellings). The Lyon agglomeration has fixed a new urban politics depending on urban and social criteria (low income household, family with more than 3 children and public housing). From the map below, we can see that the 8ème arrondissement has 5 areas which will be considered by this policy and Laënnec is classified of high priority.



The Laënnec building is far away from the historical centre of Lyon so there are no urban constraints except the ones from the town planning (PLU). We can clearly see on Figure 23 that there are not visual impacts or noise effects from other buildings. On the top roof, we can have a sight with 360° and as the building is particularly high there are not other constraints that the ones from the height of the building itself.

Figure 23. Views and measurement tools at Laënnec building

Views on the top roof reaffirm that the site is quite good with no big obstacles. It should be bared in mind that there are an TV antenna, chimney like in most of the buildings.
As the site is a social building, there are no particular objections for the inhabitants since the management of the building depends on this public housing agency, OPAC. Depending on the municipalities policies these organizations are thus able to consider the interest of a local energy policy which does not fit solely on financial approach. This is a good pilot project and could easily be used to increase awareness of the urban turbine technology.

6.2 Resource Assessment

Up to now, some measures have been collected to compare then to the wind potential obtained from meteorological data from Météo France.

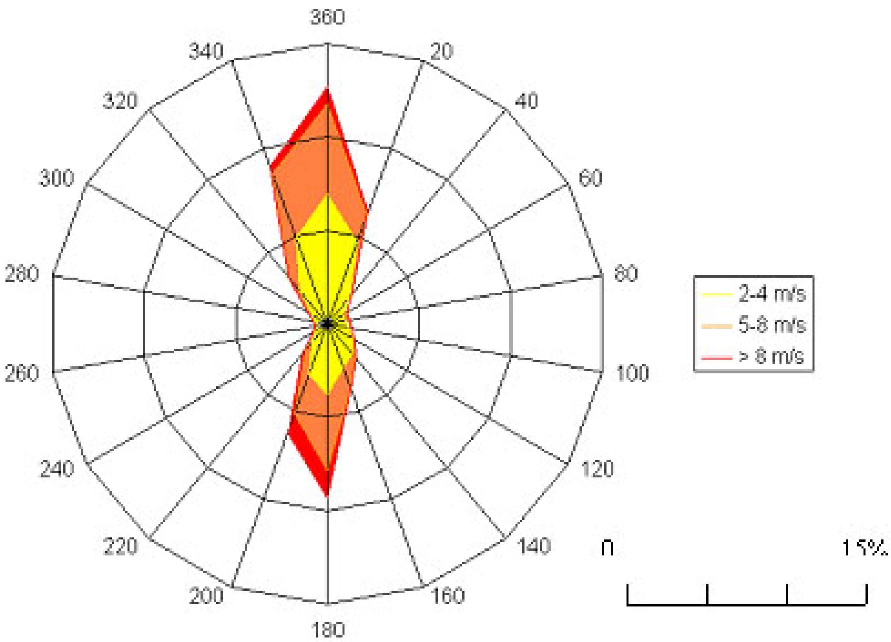


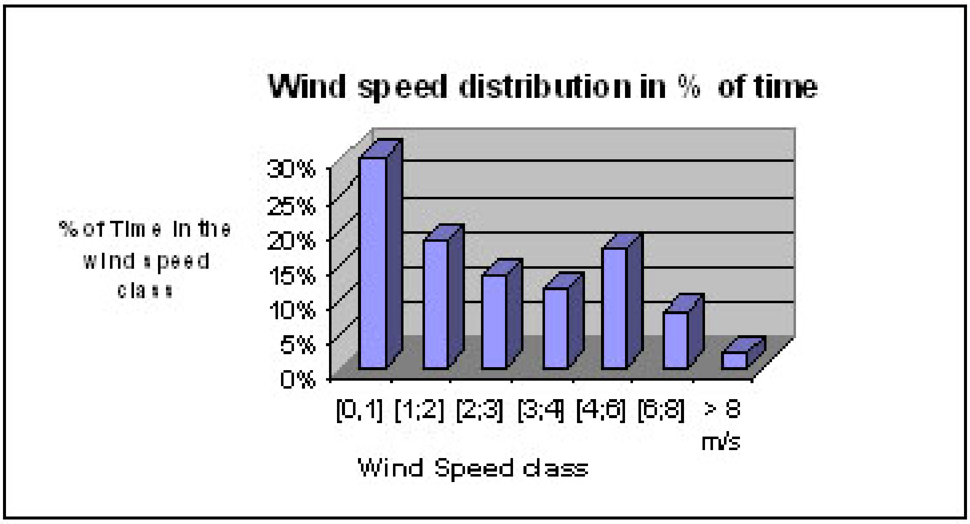
Figure 24. Wind rose from Lyon agglomeration.

The wind rose (Figure 24) clearly outlines the main direction which are north-south. It's also related to the geographical conditions of Lyon, situated in the Rhone-native corridor. The two prevailing class of wind are [2-4 m/s] and [5-8 m/s] relative to urban wind conditions.

The measurement period for the site of Lyon was able from April until June. Due to technical constraints, it was not possible to collect more data. It's important to reaffirm here that to obtain a accurate wind potential, it's a necessity to measure the wind speed during one year and compare it to 10 years data from a meteorological office. The conclusions that we're going to present would not be really precise due to the lack of information.

Measuring period	**From April 12th 2006 to June 10th 2006**
Speed availability	87%
Average wind speed (m/s)	**3.0**

The wind speed availability is considered as the percentage of time we can consider to have wind available. This availability is around 87% which is quite good. The average wind speed is around 3 m/s and the wind speed class with the highest percentage of time is [1;2], [2;4] and [4;6], with respectively 18%, 24% and 17%.

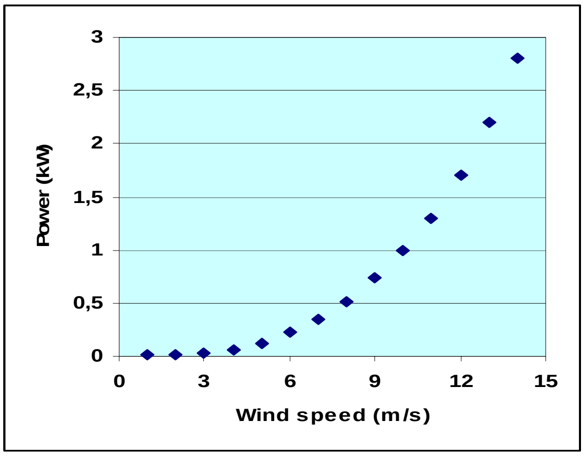


This results are confirming the ones from the Météo France data. These classes of wind are particularly adapted to urban conditions.

6.3 Description of the proposed wind turbine

Nowadays, three urban turbines technically ready to be installed are: Turby 2,5 kW, Ropatec WRE 3 kW and Windwall 2 kW. The cut-in speed from Turby and Windwall is 4 m/s. According to the average wind speed measured in Lyon, it would be better to choose the Ropatec design which has a cut-in speed of 2 m/s.

The Ropatec WindRotor is a vertically driven wind rotor which demonstrates special product characteristics through its unique construction. The systèm could be described as a hybrid solution, building upon the Savonius and Darrieus principles. The UT is independent from the direction of the wind and has a robust construction for extreme wind speeds. Moreover, this turbine is truly noiseless even at high wind velocities and needs low maintenance. The technical characteristics of the Ropatec are the following ones:



Calculated power curve

Wind speed (m/s)	Power* (kW)
1	0,01
2	0,02
3	0,03
4	0,06
5	0,12
6	0,22
7	0,35
8	0,52
9	0,74
10	1

This urban turbine was already been installed in Italy for a water heating system, in Switzerland connected on grid or even in Australia.

6.4 Economic and financial aspects

The costs for a Ropatec WRE 030-3.0 kW is split into the investment cost, the installation costs and a maintenance costs. The average investment costs per kW is 6700 euros and the installation cost per kW is 2500. The total average cost per kW is then 9200euros. The total cost is for this 3kW Ropatec turbine type 27600 euros.

Total investment Cost	27 600 euros
Maintenance Cost	500 euro/year
Feed-in Tariff	10.4 ct euro/kWh

By using the power curves provided by the manufacturers and the wind distribution, we can estimate the annual production of the Ropatec 3kW for an average wind speed of 3 m/s. The energy production is 860 kWh and a load factor of 287 hours/year. It's particularly weak values.

Using the results from the WP2 techno-economic report, we know that for an average wind speed of 5.5 m/s the load factor is 923 hours/year and the energy production 2760 kWh. Then the average cost of produced kWh is 70 euro cents. The financial analysis concludes that the pay-back period in those conditions is 21 years. As we have less energy production in the site of Lyon, the pay-back period will be worse than 21 years. This would not be really reasonable if we compare it to the lifetime of Ropatec turbine (15/20 years).

The manufacturer from Ropatec turbine has emphasised the fact that in regions with wind speeds lower than 5.5-6 m/s annual average, the installation is not really recommended. However, it should be highlighted that the measuring period was also not long enough to gather data representative of a annual wind distribution.

COUNTRY PARTNER: UNITED KINGDOM

7 ENGLISH FEASIBILITY STUDIES – INTRODUCTION

Since the UK Government set the target for 10% of electricity generation to be supplied by renewable sources by 2010, there has been increased interest in using renewable energy technologies in the urban environment. The technologies most commonly considered are solar thermal installations, solar photovoltaics and small wind turbines.

In the last few years in the UK, a number of manufacturers have developed small wind turbines which are specially designed and adapted for operation in built-up areas. These small scale renewable energy technologies generate clean and renewable energy, while reducing CO_2 emissions.

Urban turbines are able to generate electricity close to the point of consumption, so reducing transmission losses. An urban turbine also provides a visual statement and highlights the commitment to sustainable energy and promotion of a 'green' image.

As such, there is an increasing amount of interest and support for small wind technologies from politicians, industry, local authorities and the public alike. The cities of Huddersfield, Porfield and Sheffield therefore therefore contracted IT Power to carry out a wind energy feasibility. Those feasibility studies were conducted in the framework of the WINEUR project.

This study aims to provide general guidance on the installation of small scale wind power systems in urban residential environment, while presenting specific guidance and analysis for Portfield, Huddersfield and five proposed installation sites in Sheffield. The Huddersfield site is the Council building. Portfield site is the example for the installation of a wind turbine in a school. The first four sites in Sheffield are residential housing redevelopment. The 5th site consists of existing tower blocks and is included in order to explore the potential for siting wind turbines on a 'generic' tower block.

This paragraph on UK experiences is structured so that the reader can first look at general guidance and read the results from the specific sites.

8 MICRO-WIND

Building mounted turbines are a fairly recent development. Several manufacturers have launched products in the UK that can be mounted on both pitched and flat roofs provided the building is able to accommodate the additional structural load resulting from the turbine.

However, installing wind turbines on buildings raises several issues that are as yet unresolved. In particular, the issue of health and safety is one being currently examined by BWEA, which has initiated the development of health and safety guidelines. Some other issues are:

- Turbulence affecting performance of the wind turbine in terms of energy production
- Evidence of generally lower wind speeds in built up areas
- Vibration transmission to building
- Flicker affecting neighbouring houses / buildings
- Noise
- Planning issues

Testing and research is underway in many of these areas but results are insufficient to draw any definite conclusions as yet.

Rooftop mounted turbines can generally be mounted on either the side or on top of buildings and as with all wind installations their energy generation is heavily influenced by wind speed[1]. In larger urban environments, the relative heights and orientations of buildings, and the height and orientation of the building of interest are very likely to have a profound effect on the wind flow. Overall, it is very hard to predict wind speed at a specific site in built up areas.

It may be that buildings taller than their surroundings experience less wind speed reduction at their highest floors or rooftops since they are less affected by obstructions, like tall trees or other buildings. When planning the installation of a turbine on a given building or house, it is advised to consider future developments planned for the area which may later obstruct the wind flow.

Another important issue to consider is the vibrations caused by the wind turbine. The rotating motion of the turbine blades and the dynamics of wind applying pressure on the whole turbine installation causes the turbine to vibrate. As building mounted wind turbines are physically linked to the building structure, vibrations are likely to be transmitted through the turbine's supports into the building structure. Turbulent wind conditions acting on both the turbine blades and any mast structures associated with the turbine may further aggravate this effect, which will cause nuisance to the occupants of the building, as well as long term fatigue damage to the building structure.

Ultimately, whatever the type of rooftop mounted wind turbine, the building structure must be able to support the turbine in terms of vibration constraints. Low frequency vibrations require isolation measures in conjunction with heavy weight structures that may not be practical to implement in all cases, particularly in the case if turbines fitted to existing lightweight building structures.

The integration of turbines on new buildings is much more straight forward than the retro-fitting of turbines on existing buildings since new buildings can be designed to incorporate a turbine fixing.

[1] Because wind power is proportional to the cube of the wind velocity if, for example, the wind speed resource is 25 % lower than estimated, then the energy available in the wind may be up to 60 % lower than estimated.

In urban areas, where the wind turbine is likely to be placed fairly close to other houses or buildings, the noise produced by the operating turbine may originate adverse reaction both at external locations and within surrounding buildings (including the building where the turbine is mounted). The total amount of noise produced by a wind turbine is heavily influenced by the wind speed and the characteristics of the flow conditions that the turbine experiences. Although the current technological developments on small wind turbine have allowed for increasingly silent models, this is still an issue that should be taken into account on deciding on installing one of these systems.

It is then advised for the placement of turbines in the least sensitive locations or in areas experiencing high ambient noise levels where the contribution of a turbine noise would be less significant.

8.1 Methodology for calculation of energy output

This section presents mainly technological and cost aspects of four wind turbine models: Windsave, Swift, Airdolphin, Ampair. The turbines examined vary from 0.3 kW to 1.5 kW in size. These were selected for their availability in the UK, suitability for mounting on domestic houses (as well as other buildings) and availability of a minimum of energy performance data for analysis. Designs of building mounted wind systems vary from manufacturer to manufacturer.

The specifications of the wind turbines considered in this report are summarised in Table 7.

Table 7. Selected wind turbines for building mounting

Wind Turbine	Swift	WS1000	Airdolphin	Ampair
Manufacturer	Renewable Devices	Windsave	Zephyr	Ampair
Wind Turbine Type	Horizontal Axis	Horizontal Axis	Horizontal Axis	Horizontal Axis
Rotor diameter, m	2	1.75	1.8	1.2
Number of Blades	5	3	3	3
Rated Power, kW	1.5	1	1	0.3

The average annual energy output for each of the wind turbine models was calculated using the mean wind speed according to the NOABL database and either the corresponding power curve provided from the manufacturer (in the case of Swift and Airdolphin) or manufacturer's figures (in the case of Windsave and Ampair).

The type of landscape of the proposed site was taken into consideration by including the roughness classes of the landscape in the energy production calculation. For example, a high roughness class of 3 to 4 refers to landscapes with many trees and buildings, while a sea surface is in roughness class 0. For the calculations in this section, a roughness class of 3.5 was used, which applies to large cities with tall buildings.

The probability distribution used to estimate the wind probability at the site was based on the Rayleigh distribution. This has been found to be a reasonable distribution to represent the actual wind regime in most countries, including the UK[2].

The electrical conversion efficiency (%) assumed for the wind turbines was 97%, as stated on the BWEA website. According to the same source, "a modern wind turbine produces electricity 70-85% of the time". Therefore, in order to present both pessimistic and optimistic energy

[2] There is anecdotal evidence to suggest that a Rayleigh distribution may not be the most appropriate model for built up urban areas. However, there are no better models available at the moment.

production scenarios, annual energy outputs were calculated for an availability of 70% and 85%.

In addition, the NOABL database does not take into account local topographical features and, consequently, real wind speeds are likely to vary. For example, studies carried by the Reading University proved that the actual mean speed for the Reading area was in fact around 3 m/s, as opposed to the 4m/s stated on the NOABL database. On the other hand, as the NOABL database does not take into account the effect of local thermally driven winds such as sea breezes or mountain/valley breezes, so the wind speed may be higher. In order to try to cope with these uncertainties, three different values for wind speeds were considered: 3 m/s, 4.2 m/s (NOABL database average for Sheffield) and 5 m/s.

8.2 Energy production compared to household consumption

Table 8 to Table 13 show the energy production of the turbines under different scenarios. For the Swift and Airdolphin (where power curves were available, increasing the accuracy of calculations) an analysis at all three wind speeds and two availabilities (70 and 80%) was carried out. For the Ampair and Windsave turbines, only energy output at the manufacturer rated wind speed of 12 m/s is available. As this is a less accurate approach, results for these two turbines are presented only for the optimistic scenario of 5m/s and availability of 85% to try and correspond to conditions used by the manufacturer to estimate the turbine energy output. Results are shown in Table 14.

The grey column shows the energy production as a percentage of consumption for four typical households using the following estimated electricity consumption for each:

1. All occupants retired: electricity consumption 3200 kWh/year
2. Single parent (one adult, one child): electricity consumption 4000 kWh/year
3. Average family (2 adults, 2 children): electricity consumption 4700 kWh/year
4. Large family (2 adults, >2 children): electricity consumption 4800 kWh/year

Table 8. Swift and Airdolphin - Wind speed: 3 m/s; Availability: 70%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	3	389	**12.2%**	191	**6.0%**
Example 2	Single parent (one adult, one child)	3	389	**9.7%**	191	**4.8%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	3	389	**8.3%**	191	**4.1%**
Example 4	Large family (2 adults, > 2 children)	3	389	**8.1%**	191	**4.0%**

Table 9. Swift and Airdolphin - Wind speed: 3 m/s; Availability: 85%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	3	473	**14.8%**	232	**7.3%**
Example 2	Single parent (one adult, one child)	3	473	**11.8%**	232	**5.8%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	3	473	**10.1%**	232	**4.9%**
Example 4	Large family (2 adults, > 2 children)	3	473	**9.9%**	232	**4.8%**

Table 10 Swift and Airdolphin - Wind speed: 4.2 m/s (NOABL database); Availability: 70%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	4.2	936	**29.3%**	541	**16.9%**
Example 2	Single parent (one adult, one child)	4.2	936	**23.4%**	541	**13.5%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	4.2	936	**19.9%**	541	**11.5%**
Example 4	Large family (2 adults, > 2 children)	4.2	936	**19.5%**	541	**11.3%**

Table 11. Swift and Airdolphin - Wind speed: 4.2 m/s (NOABL database); Availability: 85%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	4.2	1136	**35.5%**	657	**20.5%**
Example 2	Single parent (one adult, one child)	4.2	1136	**28.4%**	657	**16.4%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	4.2	1136	**24.2%**	657	**14.0%**
Example 4	Large family (2 adults, > 2 children)	4.2	1136	**23.7%**	657	**13.7%**

Table 12. Swift and Airdolphin - Wind speed: 5.0 m/s; Availability: 70%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	5	1452	**45.4%**	1260	**39.4%**
Example 2	Single parent (one adult, one child)	5	1452	**36.3%**	1260	**31.5%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	5	1452	**30.9%**	1260	**26.8%**
Example 4	Large family (2 adults, > 2 children)	5	1452	**30.3%**	1260	**26.3%**

Table 13. Swift and Airdolphin - Wind speed: 5.0 m/s; Availability: 85%

			SWIFT 1.5 kW		Airdolphin 1.0 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	5	1763	**55.1%**	1531	**47.8%**
Example 2	Single parent (one adult, one child)	5	1763	**44.1%**	1531	**38.3%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	5	1763	**37.5%**	1531	**32.6%**
Example 4	Large family (2 adults, > 2 children)	5	1763	**36.7%**	1531	**31.9%**

Table 14. Windsave and Ampair - Wind speed: 5.0 m/s; Availability: 85%

			Windsave 1.0 kW		Ampair 0.6 kW	
		Wind Speed (m/s)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT
Example 1	All retired household	5	1000	**31.3%**	600	**18.8%**
Example 2	Single parent (one adult, one child)	5	1000	**25.0%**	600	**15.0%**
Example 3	"Average family" (3 bed, 2 adults, 2 children)	5	1000	**21.3%**	600	**12.8%**
Example 4	Large family (2 adults, > 2 children)	5	1000	**20.8%**	600	**12.5%**

From these results, it is clear that the mean wind speed has a very large influence on the turbine performance. An increase of just 1.0 m/s in wind speed results on 2 to 3 times more energy. Therefore, it is essential to ensure that the houses/buildings of interest are adequate in terms of wind conditions.

A review of all the proposed wind turbines is presented in Table 15. This summary assumes the most optimistic scenario with a wind speed of 5 m/s and an availability of 85%, in order to compare all four turbine models. The estimated percentage of energy provided by the wind system is relative to the "average family" (Example 3) scenario, which according to the redevelopment Masterplans is the most likely situation for the new residential units.

The Swift wind turbine will produce the most electricity and contribute most (31%) to an average family's electricity consumption. The Airdolphin, although a smaller machine, can also make a significant contribution with 27%.

Table 15. All four wind turbines reviewed at 5m/s and 85% availability

		SWIFT 1.5 kW			
	Estimated Annual Electricity consumption (kWh)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Annual CO2 savings, Kg	Total Capital Cost including installation, £, ex. VAT
"Average family" (3 bed, 2 adults, 2 children)	4700	1452	**31%**	624	11000

		Airdolphin 1.0 kW			
	Estimated Annual Electricity consumption (kWh)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Annual CO2 savings, Kg	Total Capital Cost including installation, £, ex. VAT
"Average family" (3 bed, 2 adults, 2 children)	4700	1260	**27%**	542	9600

		Windsave 1.0 kW			
	Estimated Annual Electricity consumption (kWh)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Annual CO2 savings, Kg	Total Capital Cost including installation, £, ex. VAT
"Average family" (3 bed, 2 adults, 2 children)	4700	1000	21%	430	Not known

		Ampair 0.6 kW			
	Estimated Annual Electricity consumption (kWh)	Estimated Annual Energy Output (kWh)	% of Annual Energy covered by WT	Annual CO2 savings, Kg	Total Capital Cost including installation, £, ex. VAT
"Average family" (3 bed, 2 adults, 2 children)	4700	600	13%	258	Not known

8.3 Integration of micro wind in new housing in Sheffield

New houses and new multi-occupancy residences could be designed to accommodate any of the roof mounted turbines presented above. Where the Swift turbine has been recommended of landmark buildings at Skye Edge and Woodside, any of the other three technologies (or a combination, if more than one was to be mounted) would again be equally appropriate. Installation of turbines onto buildings requires additional strengthening, fixing points and consideration of vibrations. For the Swift turbine, the turbine itself is fixed to a pole which in turn is fixed to a steel column within the building (see Figure 25 and Figure 26). Such a column could be incorporated into the building design.

Figure 25. Swift turbine mounting pole (fixed internally)

Figure 26. Swift turbine mounting pole (fixed externally)

The advantage of incorporating micro-wind turbines into buildings from the construction phase cannot be underestimated. It presents the opportunity to resolve the issues of structural strength, vibration and optimum siting for wind capture. However, this may add time and cost to the construction phase and hence will need to be negotiated with any potential developer.

It should also not be forgotten that although involving all the appropriate actors from the outset (the Council, architect, developer, small wind specialist installer, residents, etc) will help to resolve many potential problems, there are still some issues that will remain uncertain. Possibly the most important of these is the energy generation from the turbines. There has been very little independent verification of energy production from any of the four models presented above.

Therefore, it is strongly recommended that any installation of these turbines is accompanied by a monitoring programme. This would serve to verify the manufacturer's claims in terms of energy production and provide valuable information to the home occupier and the Council about the performance of micro wind turbines installed on domestic housing.

Finally, although the installation on domestic houses or flats has not been explicitly identified as an option for any of the redevelopment areas of this report, any of the above presented technologies could be appropriate. This would require further investigation with the developer.

9 OWNERSHIP AND MAINTENANCE

9.1 Ownership

Small scale wind power system can either be owned by the local council or by private individuals. Because small wind systems are still expensive and grant funding is generally more generous towards council or community institutions, they are typically installed, owned and maintained by the city council or a community organisation. However, micro-wind installations (<1.5 kW) which are installed on domestic houses could be installed by the Council, with ownership and/or maintenance then transferred to the home owner.

9.1.1 Ownership and management by the Council or a community organisation

It is common practice to connect wind turbines of 2kW capacity or more to community owned facilities, like schools, sport centres and community centres. Besides generating electricity, this has the added advantage of demonstrating how renewable energy systems can be used and encouraging other schools, farms, factories or businesses to benefit from green, clean electricity. The Council taking the lead in installing small wind turbines would encourage more private individuals, community organisations and corporations to use renewable energy technologies.

In the case of the sites examined in this report, it is recommended that the turbines installed in open areas or on community buildings remain under the ownership of the Council. There are a number of reasons for this:

- Considering the scope and size of the proposed installations, it is very unlikely that there will be any economic benefit from their electricity production in the strict financial sense. It is therefore unlikely that private businesses or individuals would want to take on owning and managing them. If the Council were prepared to take on the whole of the capital cost, then it may be possible for a community organisation, NGO, housing association or charity to take over ownership and management of the turbine. They could then possibly organise awareness raising activities and other events, to generate the income required for the maintenance of the turbine.
- As most of the proposed installations are for single turbines, electricity production will not be sufficient to provide electricity to more than one building. It will also be cheaper to connect the turbine into a single building. The easiest management of the electricity produced would be to connect the turbine to a community owned facility (preferably owned by the Council). In this way, the turbine could make a contribution to the energy consumption of that building. In addition, the management of any aspects with regard to operation and maintenance of the turbine, as well as publicity actions could be centrally managed through the same group who manage the community building.
- Although minimal, there are some basic maintenance requirements for wind turbines (see section 9.2 below). These are more easily carried out by the Council, which will also be better placed to cover the annual cost they will incur (between approx. £300 to £500).
- If installations go ahead, they will be some of the first small wind installations in Sheffield and therefore the Council may wish to organise publicity and/ or awareness raising campaigns around these turbines. This will be easier if they are owned and managed by the Council.
- It is also worth noting that particularly in the case of claiming Renewable Obligation Certificates (ROCs) for the renewable energy generated it would be beneficial to group the installations as each individual installation may be to small for it to be worth while

to claim ROCs. By grouping them and submitting an application for ROCs through the Council, some of the cost of the installations could be recouped for future renewable energy projects or the economics will be better for the installed projects.

9.1.2 Ownership and management by the home occupier

Current costs for the installation of small building mounted wind turbines are high. Therefore, it is unlikely many home occupiers will be able to afford to buy them. However, it may be the intention of the Council to pay for the purchase and installation of micro-wind systems for homes and then transfer the ownership and/or maintenance to the home occupier.

The installation of micro-wind on domestic houses is not recommended in this report, as it seems too early in the development of the technologies to implement such installations (unless a monitoring programme is put in place). However, a number of issues concerning this option are listed below for information purposes:

- Manufacturers' claims, on energy generation as well as maintenance issues have yet to be substantiated. This is due to the cost of monitoring but also simply because there are few installations and those that do exist have not been installed for very long. For these reasons, at this moment it is not recommended that individual systems are placed on houses under the responsibility of the house owner. For example, they could be disappointed with its energy production and not understand the limitations of this kind of technology.
- If the turbines are placed on individual houses, it has to be decided whether the occupier will be responsible for maintenance. It is recommended that a home occupier is given ownership of the system with responsibility for maintenance. If they are to own the system, responsibility for maintenance will ensure they take better care of it.
- The installation company will typically provide a user manual to the home owner so that they can manage their wind turbine. The user manual provides basic information such as manufacturer, manufacturer contact details, system power, system dimensions and maintenance requirements. This manual should come as part and package of any installation.
- Private organisations are very unlikely to get involved in the management of energy production of this scale. Also, relying on private companies to carry out maintenance could prove very expensive for the home owner. Perhaps the Council should consider organising / assisting home occupiers with maintenance costs possibly through a fund or list of recommended contractors with whom reasonable prices are pre-agreed by the Council.
- Apart from the benefit to the home occupier of reduced electricity bills from the use of the wind turbine electricity on-site, the occupier might also be advised to arrange to sell back energy produced but not used on-site and injected back into the grid (for example, during the night). There are a number of different deals from electricity suppliers with regard to payment for micro-generation exports into the grid. One such scheme is mentioned here as an example, but there are others and with new products being launched in this sector, it is worth doing some research to get the best deal.
- The Home Generation Scheme from Good Energy will pay a generator for all the energy they generate (whether used on site or exported) for systems under 10kW, which is likely to be case for most domestic installations (and this could also be appropriate for community installations). To join the scheme the home owner needs to first have a renewable energy supply contract with Good Energy. Good Energy then pays the home owners for all the kWh they produce through a quarterly credit on their electricity supply account. ROCs are included in the price paid by Good Energy to the generator.

This means that Good Energy will claim the ROCs, while the homeowner still benefits from the price of ROCs (~4p/kWh) without the considerable trouble of applying for them[3].

9.2 Maintenance

Although small wind turbines typically are sturdy and reliable machines, they do require some annual maintenance, which typically consists of visual and audible checks for blade erosion and signs of component fatigue. There may also be the need for lubricating the bearings once or twice a year.

For a Proven turbine of the type recommended in this report, yearly maintenance including visual check and lubrication of bearings is recommended by the manufacturer. Access for maintenance is made easier by lowering the mast to the ground using a winch.

For the Swift turbines the manufacturer claims that no maintenance is required for at least the first 10 years (this has yet to be substantiated through real installations), however a visual check for blade erosion once or twice a year would seem logical and not overly costly.

Where maintenance is required, it is advisable that local engineers or persons responsible for site maintenance are given training on wind power engineering and turbine maintenance, so that they get the expertise to maintain the system. Alternatively, a maintenance contract can be arranged with the turbine manufacturers or an installer.

In the case of a community installation, it is also recommended that an employee based at the site is selected to undertake occasional simple checks like meter readings, and to report on any problems or issues noted. In the case of a home installation, the home occupier should take on this role and should be provided with some simple guidelines.

10 HEALTH AND SAFETY CONSIDERATIONS

10.1 Safety

For the turbines located in open public spaces, as proposed for Skye Edge, Woodside and Parson Cross in Sheffield, precautions must be taken to ensure that ball games are not played in the proximity to the turbine to remove the risk of a ball being thrown into the moving rotor.

Small wind turbines should adhere to *BS EN 61400: Wind turbine generator systems. Safety of small wind turbines.* Although not necessarily required by the above standard, Proven wind turbines feature an optional automatic brake. This is operated when any abnormal vibration is sensed and can be supplied for added safety. In the event of any mechanical failure or in the event of vandalism, the blades are brought to a halt.

The types of wind turbines considered have previously been installed in public areas where safety has been important, for example at BP garages, on Sainsbury's supermarkets and in schools. The wind turbine manufacturers should be able to put the Sheffield City Council in touch with some of their customers who will be able to explain how any safety issues were resolved.

10.2 Noise

All wind turbines emit a certain amount of noise due to the swoosh of the blades as they move through the air. At average wind speeds of around 5m/s, as is experienced at all of the sites

[3] For more information on Good Energy please see www.good-energy.co.uk

examined in this report, the noise levels would be the same as people talking and during higher winds the noise level would be equivalent to traffic on a moderately busy road. However, during high winds the noise of the wind itself tends to be greater than the noise of the turbine.

The current UK guidance on noise from wind turbines "The Assessment and Rating of Noise from Wind Turbines" was produced by a DTI working group in 1996. The Proven wind turbines considered in this report have had their noise levels measured and noise reports on each turbine (2.5, 6 and 15 kW) are available from the manufacturer. The Proven wind turbines also incorporate a number of features designed to reduce noise. To give an idea of noise levels, the Proven 6kW produces 45 dB at wind speeds of 5 m/s and 65 dB at wind speeds of 20 m/s.

Figure 27 below shows how this compares to other day-to-day activities.

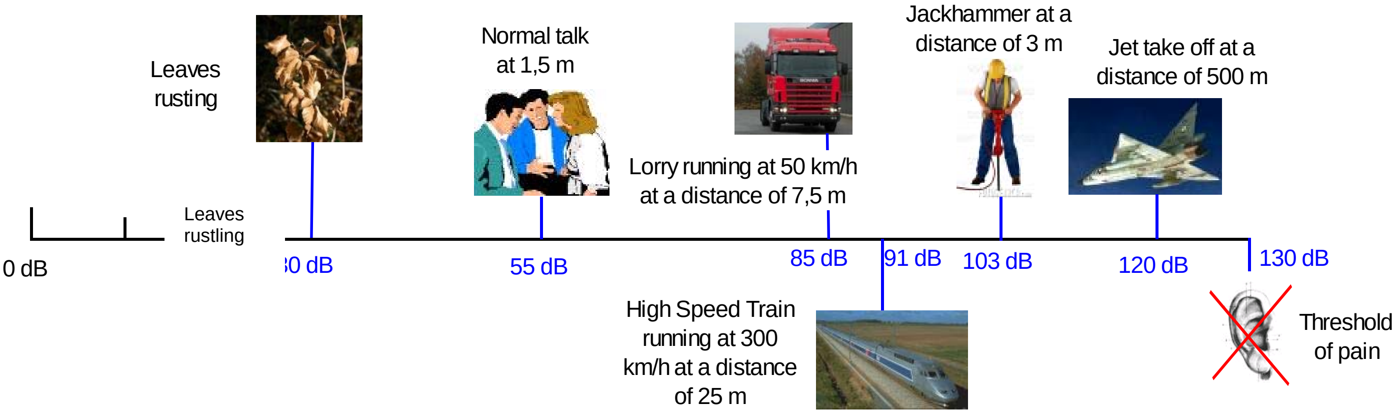


Figure 27. Noise chart of day-to-day activities

10.3 Visual Impact

Some of the wind turbines models reviewed are relatively large which will make a stronger visual statement. In some cases, this may be sought by the local council as a way to create awareness for wider community of alternative forms of energy.

Sometimes there is a lack of awareness of the size of small wind turbines, or a sense of scale compared to their larger 'big brothers'. It may be useful to use a simple visual aid such as the one in Figure 28 below, to show the difference in size between small and large wind turbines and also between small wind turbines and common urban features such as houses and trees.

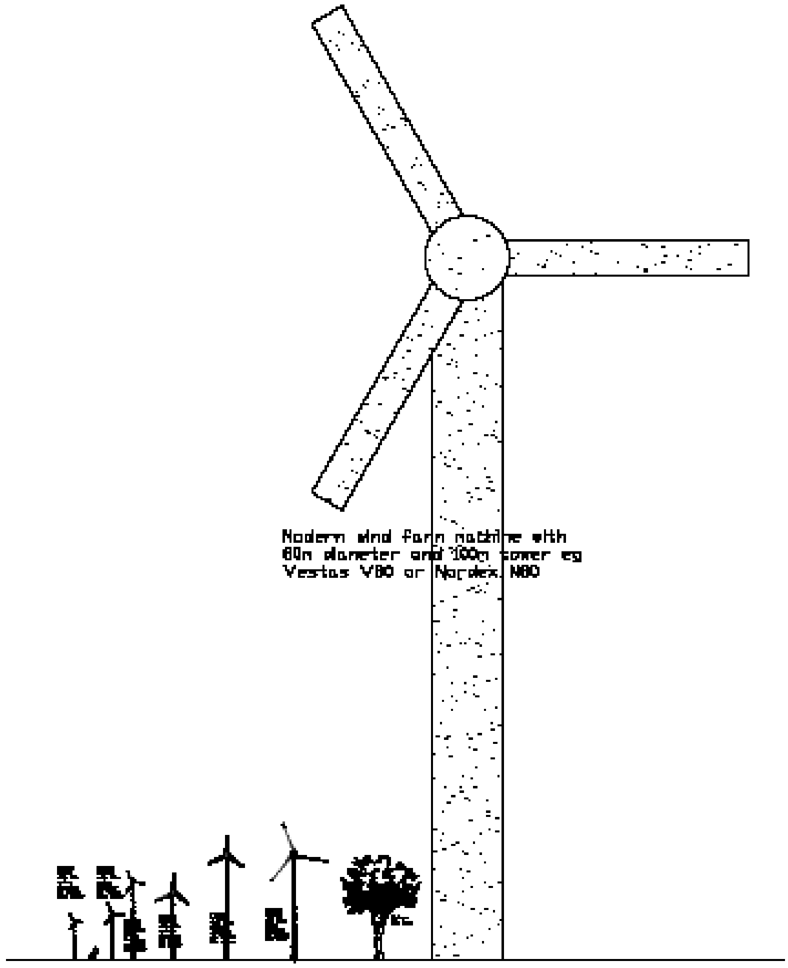


Figure 28. Comparing the size of a typical large wind turbine to small wind turbines (Proven Energy)

In terms of other forms of visual impact, there is a visual effect known as "shadow flicker", which occurs when sunlight passing through moving blades can cause a flickering effect in 'line of sight' directions. The selection of sites for the wind turbines has tried to locate them in places that would minimise the chances of shadow flicker occurring, however the possibility of the shadow from the wind turbine causing flicker on nearby houses should be considered when considering the next steps towards a wind installation.

11 CASE STUDY 4: HUDDERSFIELD CITY CENTRE

Kirklees Metropolitan Council have developed a policy which is very favourable to the development of renewable energy technologies. The Council have already installed PV panels on a number of their buildings and on domestic houses in Huddersfield.

The Council now wish to install small wind turbines on a Council Building in Huddersfield City Centre. This study was undertaken by IT Power to assess the feasibility of an installation of roof-mounted turbines on the Civic Centre 3 Building. The study is part funded by the European Commission through the WINEUR project.

11.1 Description of the Site

The site is the Civic Centre 3 Building situated in the town centre of Huddersfield. A map of the location is shown below. The building is owned by the Council and they wish to make a green statement by installing wind turbines on the roof.

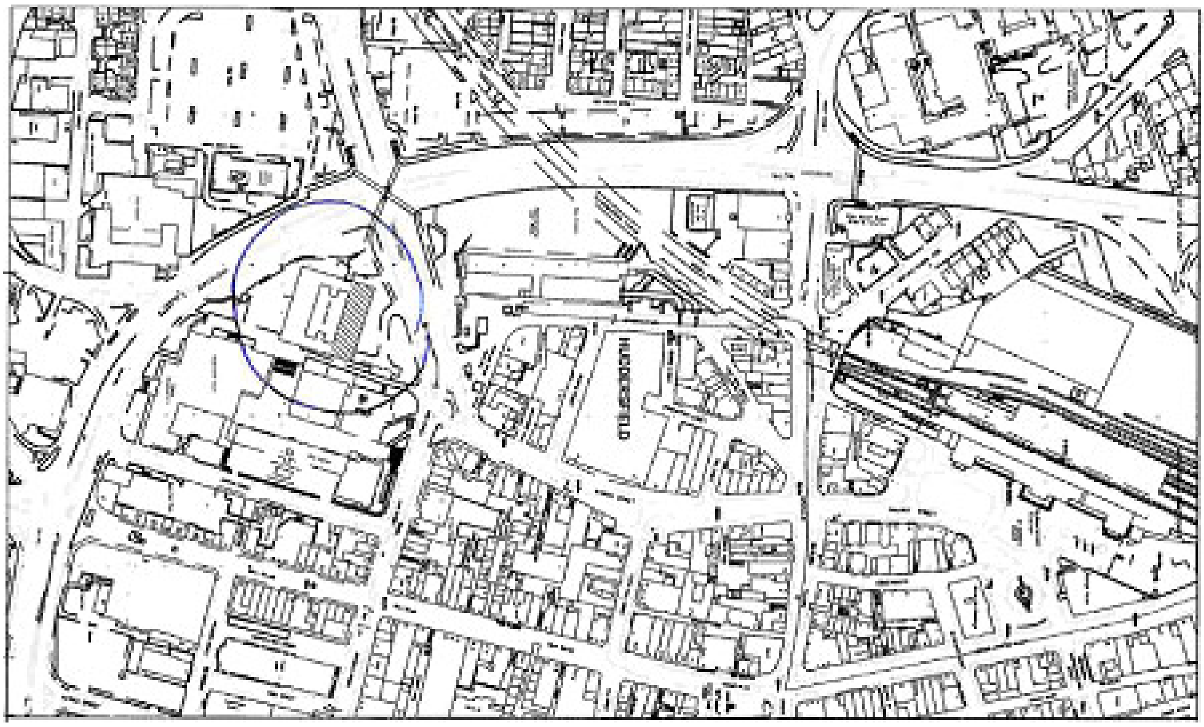


Figure 29. Map of Huddersfield City centre showing the Civic Centre 3 building

As can be seen in Figure 29 above, the site is in a very urban area right in the middle of Huddersfield town. It is also very visible to the public, as it is situated near the high street and main shopping area. The building is in use as offices and many people work there and in adjacent buildings every day.

An installation of wind turbines of the roof would set an example of renewable energy application in an urban area and would raise awareness of renewable energy electricity production.

Figure 30. Civic Centre 3 building in Huddersfield

The building was built in the late 60s early 70s and is a basic concrete structure. It has a flat roof and 3 floors, plus a basement and 2 plant rooms where the buildings service systems (electricity, heat) are housed.

There is one access road to the building and a number of footpaths for pedestrians to use. There is a dual carriage-way road on two sides of the building. A picture of the building is shown in Figure 30 above.

11.2 Identification of the constraints

The main constraints at the site are:

- Space on the building roof;
- Obtaining planning permission;
- Ensuring the building is strong enough to take the additional weight of the wind turbines;
- Vibration issues;
- Access to the building for big equipment, as there is only one small access road; and
- Health and safety issues, as people work in the building everyday and there are a number of footpaths used by the general public in close proximity to the building.

For roof-mounted installations, the biggest concern is arguably the creation of vibrations in the building. Due to the rotating motion of the turbine blades and the dynamics of wind applying pressure on the whole turbine installation, vibration could be generated and transmitted into the building structure. Therefore, when planning a roof-mounted wind turbine, the siting of the turbine within the roof area and its weight and shape should be carefully studied. This is an issue that would have to be investigated fully during the planning stage for the building structure to ensure built-in measures against vibration.

As the site is already in a very urban area, there were no real environmental constraints. There are also no constraints with regard to grid connection.

11.3 Resource Assessment

It was considered too expensive and time consuming to conduct a wind measurement campaign on the roof of the building. Instead the UK Wind Atlas (NOABL database) was used to estimate the wind resource. The results are shown in Table 16. Wind resource estimation for Huddersfield city centre.

Table 16. Wind resource estimation for Huddersfield city centre

Height above the ground (m)	Wind Speed (m/s)
10	3.8
25	4.6
45	5.2

These wind speeds are in the range required to make the installation of a small wind turbine feasible. However, the NOABL database does not take into account local topographical features so real wind speeds are likely to vary from those shown above. Error in urban areas can be as much as ± 3 m/s. Most often the wind speed is overestimated by NOABL.

The height of the mast will depend on the height of the building and the roof layout, as well as the height of the surrounding buildings. However, in order to minimise load stresses on the building a 9m mast for the 6kW turbine is the more likely choice.

It is also worth noting that the building is higher than the surrounding buildings and there are no obstructions in the prevailing wind direction. Taking this and the results from the wind atlas into account, it was considered that there was sufficient wind resource to justify the installation of wind turbines on the roof.

11.3.1 Estimated energy output

The NOABL wind speeds along with turbine manufacturer's published estimated outputs were used to produce estimates of the theoretical available energy from the wind turbine. The results shown in Table 17. Estimated Energy Output for Huddersfield are presented in kWh, which is unit of electrical energy that equals one kilowatt of power applied for one hour.

Table 17. Estimated Energy Output for Huddersfield

Wind Turbine	Proven WT6000
Wind turbine rated power, kW	6
Number of turbines	2
Total capacity, kW	12
Tower Height	9
Annual energy, kWh	12 000 – 15 000

11.3.2 Environmental benefits

Using electricity generated from a wind turbine displaces electricity which would otherwise have been produced from conventional sources. Therefore carbon dioxide (CO_2) emissions are reduced as a result.

According to the Department for Environment, Food and Rural Affairs (DEFRA), each unit of electricity produced by wind energy is equivalent to a saving of 0.43 kg of CO_2. This represents the blend of coal, gas, nuclear and renewable energy used in the UK. The environmental benefits, represented by the estimated annual CO_2 savings are shown in Table 18.

Table 18. Estimated Annual CO2 savings for Huddersfield

Wind Turbine	Proven WT6000
Wind turbine rated power, kW	6
Number of turbines	2
Total capacity, kW	12
Annual CO_2 savings, kg per annum	5160 - 6450

11.4 Description of the proposed wind turbine

The proposed wind turbine for the site is the 6kW model manufactured from Proven. The selection of wind turbine technology focused on one which is reliable and immediately available on the market. The turbine selected has also been approved under the Clear Skies programme. The Proven WT6000 can be installed on a flat roof.

Table 19. Technical description of proposed wind turbine

Model	Supplier	Rating (kW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
WT6000	Proven	6	12	9	3 Blades, 5.5 m diameter, downwind

It was decided that due to space limitation and structural strength limitation of the building, two 6 kW wind turbines could be installed. This would provide a maximum generation of electricity while fitting in with the constraints of the construction of the building. A picture of a 6kW wind turbine is shown in Figure 31.

Figure 31. Proven 6kW wind turbine

The Proven 6kW wind turbine has been installed in many locations in the UK and there have already been building mounted installations of this turbine.

11.5 Installation requirements

The installation of the Proven wind turbines will require a winch and pulley to erect the mast and turbine. A winch anchor should therefore installed for this purpose and also to lower and raise the turbine for maintenance.

The works required for the installation of a wind turbine can be summarised as follows:

- Building of a concrete foundation to which the base plate is fitted. This would be built on top of the existing roof at the location where the turbines are to be fixed to the roof.
- A special steel base frame is required to fix the mast to the roof of the building.
- Making an entry path for cables where electrical connection will take place.
- Strengthening and making secure the stairwell where electrical equipment would be housed.
- The turbine and mast will require craning up to the roof.

Prior to installation a structural survey should be carried out to verify that the building can support the additional forces applied by the wind turbines. This must be carried out by a structural engineer, in collaboration with the wind turbine manufacturer (Proven).

Also prior to installation a Health and Safety plan should be developed as this type of project with fall under the Construction Design management regulations.

11.6 Economic aspects

Capital costs include the costs for the following:

- Wind turbine
- Mast
- Inverter(s) and control equipment
- Electrical items: AC isolators, additional distribution board, MCB, and G59 relay
- Vibration auto brake
- Public display board
- Delivery
- Installation: civil works, erection of wind turbine, electrical integration
- Commissioning
- Scaffolding and edge protection
- Craning
- Works to secure fixing of turbine to the roof structure (Proven turbines)

Total capital costs for the wind turbine are given in Table 20. These include all of the above items but the costs do not include project management costs. Project management of an installation of this type is important but it is an additional cost which can be estimated at between £3000 and £5000.

It is worth noting that if project management can be carried out by the Council, as part of the day-to-day work of a designated department, this would result in significant cost savings. Otherwise a private company can be hired to do project management but of course, this would be a more expensive option.

Costs can only be estimates at this stage of project planning and may eventually be higher.

Table 20. Total Capital Costs for wind turbines at Huddersfield

Wind Turbine Manufacturer	Proven WT6000
Wind turbine rated power, kW	6
Number of turbines	2
Total Capital Cost including installation, £, exc. VAT	69800
Cost per kW installed, £	5820

11.7 Conclusions and Recommendations

The installation of two wind turbines on the roof of Civic Centre 3 in Huddersfield should be feasible. The total capital cost is estimated at £69 800. The next step is to carry out a structural survey and select an installer to carry out the installation. A dedicated project management team is recommended for the installation. They should manager all the subcontractor aspects, planning approval process and health and safety issues.

Overall the installation could have a very positive impact on raising awareness of renewables in Huddersfield, as well as improving the 'green' image of the Council.

The Huddersfield/Kirklees project proceeded as planned and the installation was completed in July 2006.

12 CASE STUDY 5: PORTFIELD COMMUNITY PRIMARY SCHOOL

Portfield Community Primary School which forms part of the St James Education Complex is considering the installation of renewable energy systems at the school. Such installations would demonstrate the technology to students and the local community. This study was commissioned to provide specific technical and economic information to the school.

IT Power has carried out a technical and economic appraisal of wind, solar water heating and PV technologies at the St James Education Complex. This report only focus on the wind feasibility study.

12.1 Methodology

Wind turbines convert energy in the wind into electricity. Small building mounted turbines are becoming available in the UK and can be mounted on buildings including homes with relative ease provided the building is able to accommodate the additional structural load resulting from the turbine.

Wind turbines operate most effectively in a strong, clean flow of wind, free from turbulence. This is achieved by placing the turbine away from obstructions, and as high up as possible. Wind speed increases significantly with height above ground. An annual average wind speed in excess of 5 metres per second is generally required for a project to be economically viable. One should be aware that the power in the wind is proportional to the cube of the wind speed, so a 20% increase in wind speed means a 70% increase in instantaneous power.

Most wind turbine suppliers quote the 'rated' power output (in kW) of their machines at either 10m/s or 12m/s wind speed. Turbine type options to install within the Portfield Community Primary School premises are in the size range 2.5 kW to 6 kW. The physical size of such a turbine would be up to 2m in diameter. Turbines at the larger end of this range could be mounted on large buildings. Small wind turbines can also be installed on the ground, where they should typically be at least 10 m from any nearby obstructions to the path of the wind e.g. buildings, trees. The total length of land required depends on the type of turbine chosen. Many of the 5 to 6 kW turbines are installed via a 'tilt-up' mechanism which means they require just over twice the height of mast for the installation process.

12.2 Wind resources

In the absence of any on site monitoring an estimate can be obtained from the UK national wind database, available on-line at http://www.bwea.com/noabl/nbl-form.html. The database gives an estimate of the average wind speed for each square kilometre of the UK.

The UK Wind Speed Database - NOABL 2000 was used to estimate the wind speed at the site. The results (based on the school location 487175E 105165N) are shown in Table 21.

Height above the ground, m	Wind speed, m/s
10	4.8
25	5.6

Table 21. Wind resources in Portfield

As the height above the ground increases the wind speed and therefore the energy available increases. The chosen height of any wind turbine at the site will be a compromise between maximising available energy and considerations of the tower and visual impact.

12.3 Wind availability

The following options (all approved to be used under the Clear Skies Grant) were reviewed: a 2.5 kW or 6 kW turbine to be installed within the School's premises; or a 20 kW turbine to be installed on the adjacent Parish Council land. The technical details of each option are shown in Table 22.

Wind Turbine Manufacturer	**Proven**	**Proven**	**Gazelle**
Rated size, kW	2.5	6	20
Rotor diameter, m	3.5	5.5	11
Height of tower (hub height), m	11	15	13

Table 22. Wind turbine details

12.4 Wind turbine siting

There are two possible locations for wind turbine(s) at the site:

- Location 1: At the edge of the playing field, to the west of the building;
- Location 2: Across St James Rd, in the open fields.

The Proven wind turbines considered would be suitable for siting at either location 1 or 2. The brushless generator of the Proven WT 6000 has no gearbox. This allows it to operate quietly (<45 dB in 5 m/s wind speed, or <60 dB in 20 m/s wind speed). Other larger and older models of wind turbine produce higher noise levels. The turbine location is at least 250 m from any residential areas, so there is an extremely low likelihood of disturbance.

The 20 kW Gazelle turbine is not suitable for siting on the actual site of the community centre since, due to noise, it should be placed at least 180m from the nearest dwelling. However it may be possible to negotiate with the Parish Council who own the land next to the school.

The NOABL database does not take account of local site specific conditions. The location away from the school site is more open and exposed and is likely to experience higher winds than the location by the school.

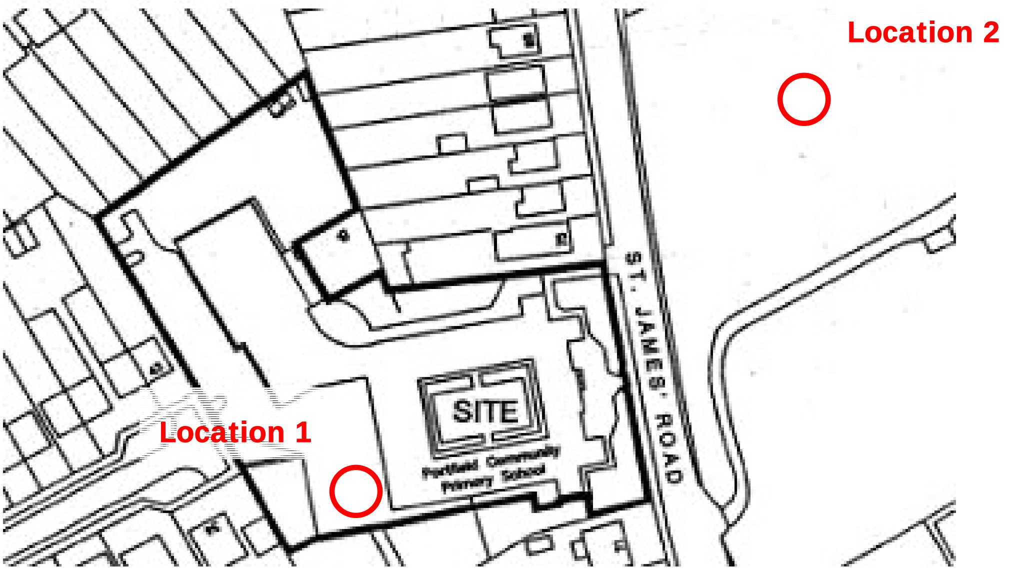


Figure 32. Site locations for wind turbines, Portfield.

12.5 Installation and Maintenance Requirements

12.5.1 Installation

The installation of the Proven wind turbines requires a winch and pulley to erect the mast and turbine. A winch anchor is therefore installed for this purpose and also to lower and raise the turbine for maintenance.

The Gazelle turbine is erected using a crane. The site characteristics mean that a crawler crane would be used.

The civil works required for the installation of a small wind turbine are as follows:

- Building of foundations

  A concrete foundation to which the base plate is fitted and another (in the case of the Proven turbines) for the winch anchor would be installed. These use high strength concrete, approximately $10m^3$ for the base foundation and $2.5m^3$ for the winch anchor.

- Digging of a trench to lay electrical cables (approximately 600mm deep).
- Making an entry path for cables into block F of the school (where electrical connection would take place).
- Strengthening and making secure the stairwell where electrical equipment would be housed.

This work (except for the foundation work in the case of the Gazelle turbine) would be done by a separate contractor to the turbine installer. The turbine installer and supplier would provide the specifications and instructions for the foundation work.

12.5.2 Electrical integration of wind turbines

A small wind turbine normally produces wild AC electricity which is then converted to 230V electricity at 50Hz via a suitable rectifier and inverter. This would then be connected to the mains via the main fuse box or consumer unit. Wind turbines rated at under 16 Amps per phase (so 3.6kW if connected to a single phase) are connected to the electricity network under the Electricity Association Electricity Recommendation G83/1. This sets out requirements for power quality and loss of mains protection. This is achieved by power conditioning equipment installed as part of the wind energy system. Wind power installations also need to adhere to wiring regulations BS 7671.

An agreement with the local Distribution Network Operator (DNO) is required by law before connection of the system to the grid can be made.

12.5.3 Maintenance and requirements

An annual service of the mechanical parts and inspection of the electrical parts of the system is recommended. This will include greasing of bearings and rotor, inspection of the rotor blades and inspection and cleaning of slip rings. This servicing can be carried out either by the installer or by a local engineer. Proven can provide training of a local engineer to enable them to do this. The Proven turbine can be winched down for maintenance.

Annual maintenance to service the mechanical and electrical parts of the system will be required, at a cost of approximately £300 per year, depending on the size of the turbine and whether there is a suitably trained engineer available locally. Some wind turbine installers can provide training of local technicians at an additional cost of £1000. Future maintenance can then be carried out at low cost. After 10 years blades may need to be replaced at a cost of around £1000.

12.6 Economic Analysis

12.6.1 Energy performance and costs

Figure 33 shows estimated annual energy performance of several sizes of wind turbines, along with estimated capital costs, annual carbon dioxide savings and annual cost savings.

The rated power of a wind turbine is the power the turbine would deliver in a wind speed of usually 12m/s (depending on the manufacturer).

Figure 33. Estimated Annual Performance and Capital Costs.

Wind turbine rated power, kW	2.5	6	20
Annual energy, kWh	4 000	12 400	40 000
Total capital cost including installation, £, exc VAT	£15 800	£20 000	£65 000
Annual maintenance costs, £	£220	£300	£645
Annual savings, £	£220	£682	£2 200
Annual CO_2 savings, kg	1 720	5 330	17 200
% Electricity demand provided	7%	22%	70%

*This is the current price of the system however the manufacturer expects this to drop to approximately £1 500 in about 12 months time when they will start to be produced on a larger scale.

Annual cost savings are calculated assuming the electricity generated by the wind turbine replaces electricity imported from the grid at a cost of 5.5p/kWh.

Carbon dioxide (CO_2) emissions reductions are also calculated, assuming an emission factor of 0.43 kg CO_2 / kWh grid electricity. (Taken from the Carbon Trust website www.thecarbontrust.co.uk).

The capital costs given in the above table include all equipment: turbine and generator, tower, inverter, cabling and electrical equipment as required for grid connection and installation.

If the school makes a net metering arrangement with an electricity supplier in order to be credited at retail price for any electricity supplied to the network (since not all electricity generated will be used on site), then generation of 12 400 kWh p.a. would reduce yearly electricity bills by around £680. If such an arrangement was not made, the reduction in electricity bills might be less than half of this.

12.6.2 Lifecycle costs analysis

The following analysis is based on using the 6 kW wind turbine. Assuming an initial capital cost of £10 000 (including a 50% grant from the Clear Skies Community Scheme), and yearly maintenance costs of £150, and a discount rate of 9% over a 20 year period, the lifetime cost is £12 730 and the levelised energy cost is 11 p/kWh.

This analysis neglects future fuel prices above the general level of inflation, and is limited to a 20 year period, and neglects the non-economic benefits of the wind system.

Levelised costs per kWh produced, over a 20 year lifetime for each of the wind turbines considered are as follows:

Wind turbine	£/kWh without capital grant funding	£/kWh with 50% initial capital grant funding
2.5 kW	0.49	0.28
6 kW	0.20	0.11
20 kW	0.20	0.11

12.7 Conclusions and recommendations

Wind, solar photovoltaics and solar water heating technologies have all been considered to provide renewably sourced energy at the Portfield Community Primary School.

All of the renewable energy options analysed were shown to be more expensive per unit of energy than conventional sources (grid electricity and natural gas) but the renewable energy options show other advantages. These include carbon dioxide emissions savings and other environmental benefits associated with avoiding fossil fuels as well as the possibility of demonstrating the use of renewable energy technologies.

Wind energy is able to make the greatest contribution to energy demand at the site. A wind turbine of a rated power of 6 kW would be able to provide over 22% of the centre's annual electricity demand. Wind energy is also able to provide renewable energy at the lowest cost, compared to the other technologies considered. Greater energy contribution could be obtained by locating a wind turbine on the adjacent playing field however this would conflict with the users of the field. Unfortunately, the project will not go ahead, as the school does not have enough funding for a wind turbine.

13 CASE STUDY 6: SHEFFIELD – WOODSIDE

Woodside is a major area of change due to the large scale demolition of the blocks of flats that used to occupy the site. The site, which is about 5 hectares, has some unique aspects, which the redevelopment will aim to enhance; this includes panoramic views of the city and an attractive outlook onto the local park. The redevelopment programme that is currently underway aims to create a distinctive urban form which will exploit the topography of the site, providing it with a distinctive hillside character.

Redevelopment of the Woodside site will promote social well-being, helping to satisfy demand for housing by providing a mixed tenure development of a modern high quality sustainable design. This study was undertaken to assess the technical and economic feasibility of installing a small wind turbine. If wind power is shown to be feasible, it offers a very effective method of generating electricity from renewable sources.

13.1 Project details

Woodside is located near Burngreave, north of Sheffield city centre. Site details are presented in Table 23:

Table 23. Specification of the site location – Woodside

Element	Woodside
Location	North of Sheffield city centre
OS Coordinates	435439, 388612 (SK354886)

13.2 Assessment of Site Characteristics and Wind Turbine Parameters

13.2.1 Location of the wind turbines

Taking into consideration site selection criteria, two possible suitable locations within the Woodside redevelopment area were selected for the installation of a wind turbine.

- Location 1 is at the centre of the open space between Pitsmoor Road and Woodside Lane (marked 1 on the map); and
- Location 2 is on the roof of the planned Landmark Building in Pye Bank Road (marked 2 on the map).

The two different locations are shown in Figure 34.

Figure 34. Plan of Woodside redevelopment area with possible locations for a wind turbine marked.

Location 1 is relatively far from the houses and buildings (approx. 25m as shown in Figure 34), where the electrical connection would take place, and therefore would involve extra costs in cabling. However, as the area is quite large and almost free of nearby obstructions, it would be possible to install a larger wind turbine, which would be capable of generating more energy. On the downside, it would occupy a relatively large area of the public open space. It would also have a considerable visual impact.

At Location 2 the wind turbine would be installed on the roof of the Landmark Building. This means that the wind turbine would have to be smaller compared to the wind turbine of Location 1, which ultimately means less energy generation. However, it would be much less intrusive (both visually and physically) than a larger wind turbine on the ground. There is also the option of installing more than one of the smaller turbines to increase energy generation. A lot would depend on the structure of the planned building and its roof layout, which are at the moment unknown factors.

13.2.2 Location 1 - Public open space

Positioning a wind turbine at Location 1 is the most suitable in terms of energy generation and economics. On this site, it would be possible to install a turbine with rated output within the range of 2.5 to 6 kW.

However, public safety is an issue for this site. This is because the location is a public open space, where ball games are likely to be played, so there is a risk that a ball could be thrown into the turbine rotor. If the rotor were stationary there would be no safety hazard and it would be very unlikely that any damage to either the ball or the wind turbine would be caused. If, however, the wind turbine were operational, then the collision of the ball with the rotating blades could cause the fibre glass blades to break and fly off.

There are two options to reduce this risk:

- Fence off an area around the wind turbine so that it is not possible for a ball to be thrown into the turbine rotor (the rotor would be at a height of 9 - 15m).
- Do not allow for ball games to be played in this space.

Other safety issues are considered in section 11 of this report.

The turbine is likely to have a significant visual impact on the surrounding area due to its position at the centre of the park. Nevertheless, it would also make a statement in supporting and raising public awareness of renewable energy sources. 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.

The dynamic nature of a wind turbine may also cause an effect known as "shadow flicker", which occurs under a special set of conditions when the sun passes behind the hub of a wind turbine and casts a shadow, which rotates with the blades, over neighbouring properties. The houses on Woodside Lane would not be subjected to shadow flicker, as there are trees between them and the wind turbine. However, the houses immediately next to Pitsmoor Road could suffer from this effect, but at this stage of the redevelopment plan it is difficult to assess this eventuality.

The turbine options reviewed along with some details are shown below in the table below. The rated power of a wind turbine is the power output the turbine would deliver in a wind speed of around 12m/s (although the wind speed used for the rating varies slightly according to manufacturer).

The selection of wind turbine technologies focused on those which are reliable and immediately available on the market. The turbines selected have also been approved under the Clear Skies programme.

Three wind turbines were considered. These turbines are installed with self supporting masts rather than masts requiring guy lines. The self-supporting mast, although more expensive than a guyed mast, is necessary due to the site being a public area. The elimination of guy ropes reduces safety risks to the public and also requires less ground area. To increase energy generation potential and reduce safety risk, the higher masts are recommended for each turbine, 11m for the 2.5 kW model and 15m for the 6 kW and 5kW models.

Larger wind turbines, with a higher rated power, were not considered due to the proximity of the nearest dwellings (150m) which would most likely experience noise disturbance from a larger turbine.

Table 24. Wind turbines considered for Woodside – Public open space

Model	Supplier	Rating (kW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
WT2500	Proven	2.5	10	11	3 Blades, 3.5m diameter, downwind
Iskra AT5-1	Iskra Wind Turbine Manufacturers Ltd	5	11	15	3 Blades, 5.4m diameter, upwind
WT6000	Proven	6	12	15	3 Blades, 5.5 m diameter, downwind

Photos of the turbines are shown in Figure 35, Figure 36 and Figure 37.

Figure 35. Proven 2.5 kW

Figure 36. Iskra 5 kW

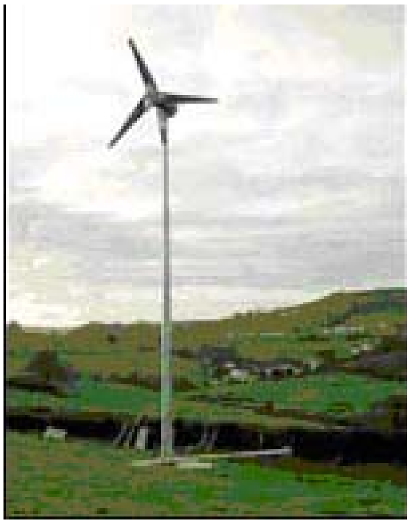


Figure 37. Proven 6 kW

13.2.3 Location 2 - Landmark building

At Location 2, the wind turbine would be installed on the rooftop of the planned Landmark building located between Pye Bank Road and the Pye Bank school building. The advantages are the potential for increased wind speed as it is located at the highest point in the surrounding area. There is also a possibility of creating links to school activities so maximising educational benefits.

This second possible location is only recommended if the Landmark building is expected to be higher than the houses around it. If not, the surrounding houses would block the wind flow, which would significantly reduce the amount of energy generated.

For roof-mounted installations, the biggest concern is arguably the creation of vibrations in the building. Due to the rotating motion of the turbine blades and the dynamics of wind applying pressure on the whole turbine installation, vibration could be generated and transmitted into the building structure. Therefore, when planning a roof-mounted wind turbine, the siting of the turbine within the roof area and its weight and shape should be carefully studied. This is an issue that would have to be investigated fully during the planning stage for the building structure to ensure built-in measures against vibration.

If Location 2 is the preferred option then the fact that the Landmark building is not yet constructed is an advantage, as there is scope to influence its design. It is therefore recommended that the integration of one or more wind turbines on the roof is considered at the outset of the building design, so that changes and adaptations in its design can be made which would render it more suitable for the installation of wind turbines.

The wind turbines considered for installation on the Landmark building are the Renewable Devices SWIFT model (1.5 kW) and the Proven WT2500 (2.5 kW) as shown in Table 25.

Table 25. Wind turbines for Woodside – Landmark building

Model	Supplier	Rating (KW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
SWIFT	Renewable Devices	1.5	12	2	5 Blades, 2 m diameter
WT2500	Proven	2.5	10	6.5	3 Blades, 3,5m diameter, downwind

Photos of the Swift turbine are shown in Figure 38 and the rooftop Proven in Figure 39.

Figure 38. Swift wind turbine (1.5 kW)

Figure 39. Proven WT2500 wind turbine (2.5 kW)

The SWIFT turbine is equipped with two vibration damping systems designed to absorb a wide range of frequencies. This would ensure a minimal transmission of oscillations from the turbine to the building structure. The Proven WT2500 incorporates anti-vibration dampers into the turbine base and has the option of a vibration auto brake, which is an additional safety feature. For a building mounted Proven turbine a 6.5m mast is recommended.

13.3 Installation requirements

The installation of the Proven wind turbines at Location 1 requires a winch and pulley to erect the mast and turbine. A winch anchor is therefore installed for this purpose and also to lower and raise the turbine for maintenance. A similar installation process would be necessary for the Iskra turbine.

The civil works required for the installation of a wind turbine at Location 1 can be summarised as follows:

- Building of foundations: a concrete foundation to which the base plate is fitted and a second small concrete block to which the winch anchor would be installed. High strength concrete would be used, approximately $10m^3$ for the base foundation and $2.5m^3$ for the winch anchor (depending on the wind turbine model used). Detailed instructions are available from Proven Energy and Iskra.
- Digging of a trench to lay electrical cables (approximately 600mm deep).
- Making an entry path for cables where electrical connection will take place.
- Strengthening and making secure the stairwell[4] where electrical equipment would be housed.

At Location 2, the Swift turbine would be mounted on a bespoke aluminium mast with a minimum blade roof clearance of 0.5 metre. The Swift turbine is typically wall-mounted at the gable end of a building using the bespoke brackets supplied. The Swift can also be installed on a flat roof. In this type of installation, the mounting mast described above is replaced with a bespoke mounting stand. As the Landmark building has not yet been built, there is an opportunity here to integrate the installation of one or more Swift turbines into the building roof

[4] In larger buildings there is often an inner staircase (or stairwell); often there is space at the top or bottom of this for electrical equipment. In domestic housing the electrical equipment is usually placed in the loft.

and ensure from the outset the best siting of the wind turbine for energy capture and ensuring structural strength to support the wind turbines.

The Proven WT2500 can be installed on a flat roof. Being a larger, heavier turbine with a 6.5m mast, it will require craning up to the roof. In addition, a special steel base frame is required to fix the mast to the roof of the building. This implies some preparatory work on the roof. These items increase the complexity and cost of the work compared to a ground installation. The additional cost is estimated at £5 000 to £7 000. The additional cost of cranage and other roof work could be minimised if installation takes place at the same time as construction of the building itself.

As mentioned above for the Swift turbine, the Landmark building should be designed with the structural strength to accommodate a wind turbine. Depending on the building design it could be possible to mount two 2.5 kW machines, bring total installed capacity to 5 kW and therefore increasing generation capacity. Appropriate design of the building, including structural issues to accommodate the wind turbine(s) should be decided between a structural engineer, the architect and the client, with information from the wind turbine manufacturer.

13.4 Wind resources and estimated energy output

The UK Wind Speed Database - NOABL 2000 was used to estimate the wind speed at the site, based on the Ordnance Survey grid reference 435388 (SK3588). The results are shown in Table 26.

Height above the ground (m)	Wind Speed (m/s)
10	4.1
25	4.9
45	5.4

Table 26. Estimated wind resource for Woodside

These wind speeds are in the range required to make the installation of a small wind turbine feasible. However, the NOABL database does not take into account local topographical features so real wind speeds are likely to vary from those shown above. Error in urban areas can be as much as ± 3 m/s. Most often the wind speed is overestimated by NOABL.

The prevailing wind at Woodside is most likely to be from the West and South West. The turbines should be located at the highest point which is as far away from trees and houses which would impact on the wind speed and flow.

As the height of the turbine rotor above the ground increases, the wind speed increases and therefore the energy available and electricity generation increases. To increase the energy generation and reduce safety risk at Location 1, the higher masts are recommended for each turbine, 11m for the 2.5 kW model and 15m for the 6 kW model. However, the chosen height of any wind turbine at the site will be a compromise between maximising available energy and considerations of the visual impact. This is ultimately a decision that will have to be made by the Council, following appropriate consultations.

At Location 2, the height will depend on the height of the building and the roof layout, as well as the height of the surrounding buildings. However, in order to minimise load stresses on the building a 6.5m mast for the 2.5 kW is the more likely choice.

The NOABL wind speeds along with turbine manufacturers' published estimated outputs were used to produce estimates of the theoretical available energy from the different types of wind turbine. The results shown in Table 27 are presented in kWh, which is unit of electrical energy that equals one kilowatt of power applied for one hour. An average house uses an estimated 4700 kWh of electricity per year[5].

Table 27. Estimated energy outputs for Woodside

Wind Turbine	SWIFT	Proven WT2500	Iskra AT5-1	Proven WT6000
Wind turbine rated power, kW	1.5	2.5	5	6
Tower Height	2	11	15	15
Annual energy, kWh (average per year)	2500[6]	3750[7]	8000	9000[3]

13.5 Environmental benefits

Using electricity generated from a wind turbine displaces electricity which would otherwise have been produced from conventional sources. Therefore carbon dioxide (CO_2) emissions are reduced as a result.

According to the Department for Environment, Food and Rural Affairs (DEFRA), each unit of electricity produced by wind energy is equivalent to a saving of 0.43 kg of CO_2. This represents the blend of coal, gas, nuclear and renewable energy used in the UK. The environmental benefits, represented by the estimated annual CO_2 savings are shown in Table 28.

Table 28. Estimated Annual Co_2 savings for Woodside

Wind Turbine	SWIFT	Proven WT2500	Iskra AT5-1	Proven WT6000
Wind turbine rated power, kW	1.5	2.5	5	6
Annual CO_2 savings, kg per annum	1100	1600	3400	3900

13.6 Economic Analysis

13.6.1 Capital Costs

Capital costs include the costs for the following:

- Wind turbine
- Mast
- Inverter(s) and control equipment
- Electrical items: AC isolator, additional distribution board, MCB, and G59 relay (where G59 regulations apply).
- Vibration auto brake (Proven wind turbines only)
- Public display board

[5] An average household is defined as 2 adults and 2 children, Household Utilities Prices Indices, DTI, May 2001

[6] Source: Renewable Devices website as of March 2006

[7] Source: Proven Energy website as of March 2006

- Delivery
- Installation: civil works, erection of wind turbine, electrical integration and commissioning

For a roof-mounted turbine the following additional costs can apply:

- Scaffolding and edge protection (depending on site)
- Craning (for larger turbines)
- Additional installation works to secure fixing of turbine to the roof structure (Proven turbines)

Total capital costs for each wind turbine are given in Table 29. These include all of the above items but the costs do not include project management costs. It is worth noting that if project management can be carried out by the Council, as part of the day-to-day work of a designated department, this would result in significant cost savings. Otherwise a private company can be hired to do project management but of course, this would be a more expensive option.

Costs can only be estimates at this stage of project planning and may eventually be higher due to eventual site-specific constraints, type of mast chosen and where the electrical connection takes place.

As the proposed site is undergoing a major redevelopment, installation costs may be minimized if timed to coincide with the construction works and existing on-site equipment is used as far as possible.

Table 29. Total Capital Costs for wind turbines at Woodside

Wind Turbine Manufacturer	**SWIFT**	**Proven (Rooftop)**	**Proven**	**Iskra AT5-1**	**Proven**
Wind turbine rated power, kW	1.5	2.5	2.5	5	6
Total Capital Cost including installation, £, exc. VAT	11000	27400	20400	22000	27900

13.6.2 Life Cycle Cost Analyses

Life cycle cost analyses were carried out for each turbine, assuming a lifetime of 20 years, a discount rate[8] of 5%, taking into account the full capital cost of the turbine and maintenance costs each year. Costs per kWh of electricity were calculated, based on the likely energy output of each turbine. The energy cost was calculated for three scenarios:

1) Using the total capital costs
2) Using 50% capital costs, assuming 50% of the costs are met from grant funding
3) Using 0% capital costs, assuming 100% of the capital costs are met by grant funding.

The results are shown in Table 30. The final row of this table shows the capital grant funding required for the cost per kWh of the energy produced by the wind turbine to equal domestic electricity prices (9p/kWh)[9].

[8] The discount rate is an interest rate used in calculating the present value of expected yearly benefits and costs. It is a way of taking into account the value of goods in the future.

[9] Domestic electricity prices were on average 8.6p/kWh in the first quarter of 2006. This is 9.0 per cent higher in real terms than in the first quarter of 2005 (DTI, June 2006). This price has been rounded up to 9p/kWh for the purposes of this report. It is felt this is a reasonable assumption given the trend of rising electricity prices in the UK over the last few years.

Table 30. Lifecycle Costs for wind turbines at Woodside

Wind Turbine Manufacturer	SWIFT	Proven (Rooftop)	Proven	Iskra AT5-1	Proven
Wind turbine rated power, kW	1.5	2.5	2.5	5	6
Total Life Cycle Cost	12400	30800	22900	24700	31400
Cost of energy, £/kWh	0.40	0.66	0.49	0.25	0.28
Cost of energy with 50% capital grant funding, £/kWh	0.22	0.37	0.27	0.14	0.16
Cost of energy with 100% capital grant funding, £/kWh	0.04	0.07	0.05	0.03	0.031
% Capital Funding Required if cost per kWh is to equal current price of electricity paid	87	97	92	72	76

13.7 Conclusions and recommendations

Overall, the option offering the most economic solution is the installation of an Iskra 5kW wind turbine at location 1, with a capital cost of £22 000 and cost of energy production of £0.25 / kWh. A Proven WT6000 (6 kW) is also a good option. However, all the options presented are technically feasible and if other considerations are deemed more important than the economics, (such as visual impact or educational value), then any of the proposed options could be chosen.

The Iskra and Proven wind turbines recommended for the Woodside area have been installed in many locations around the UK. The expected performance for the Iskra and Proven wind turbine models is reasonably reliable as there is some experience with these turbines. Although the SWIFT turbine has been recommended, it is a recently released model and this should be taken into consideration. There is limited experience from installations and therefore it is recommended that if this option was chosen some kind of follow-up monitoring should be undertaken to check the performance from the turbines.

All the decisions regarding the possible locations for the wind turbines, as well as choosing their size and rated power were based on the proposed redevelopment master plans for the Woodside area. Significant changes to these plans may render some of the recommendations made in this report unsuitable or may open up other options.

Following a seminar hold in Sheffield, Woodside site is considered by the city council as a future site within the 5 sites studied.

14 CASE STUDY 7: SHEFFIELD – CATHERINE STREET TRIANGLE

Catherine Street Triangle is located in the Burngreave & Fir Vale area of Sheffield (Figure 40), which falls within the Transform South Yorkshire Housing Market Renewal Pathfinder. Transform South Yorkshire has 3 strategic objectives, to achieve a radical improvement in the character and diversity of neighbourhoods, to improve housing quality, and to increase the range of housing types and tenures.

This study was undertaken to assess the technical and economic feasibility of installing a small wind turbine. If wind power is shown to be feasible, it offers an effective method of generating electricity from renewable sources and could also contribute to the strategic objectives mentioned above.

Figure 40. Catherine St. redevelopment area

14.1 Project site details

Catherine Street is located on the Burngreave Fir Vale area, north of Sheffield city centre. Site details are presented in Table 31:

Table 31. Specification of the site location – Catherine Street

Element	Catherine Street
Location	North of Sheffield city centre
OS Coordinates	435801, 388700 (SK358887)

14.2 Wind Resource

The UK Wind Speed Database - NOABL 2000 was used to estimate the wind speed at the site, based on the Ordnance Survey grid reference 435388 (SK3588). The results are shown in Table 32. In addition, the information made available by the Council states that there is a ‘good’ wind regime.

Table 32. Estimated wind resource at Catherine Street

Height above the ground (m)	Wind Speed (m/s)
10	4.1
25	4.9
45	5.4

14.3 Assessment of Site Characteristics and Wind Turbine Parameters

Although the wind resource estimation does not preclude a wind installation when taken by alone, when examining the specific site characteristics, a wind installation is not deemed suitable. The site is very small at 0.3 ha and surrounded by obstructions to smooth wind flow on all sides. The proximity to housing and the fact that the turbine would be placed in a playground area raise safety, noise and shadow flicker concerns.

In addition, due to the proximity of houses only the smallest type of turbine could be installed, producing a limited amount of electricity. It would not be economic to sell this electricity straight to the grid, but there is also no ‘community’ or Landmark building to which a turbine could be connected to provide electricity.

14.4 Conclusions and recommendations

This study has investigated the feasibility of wind power generation from small wind turbines in Catherine Street Triangle, Sheffield. The Catherine Street Triangle redevelopment plans include having a green park between Somerset Road and Catherine Street. Although this open space may seem suitable for placing a small wind turbine, a more in-depth analysis reveals the contrary.

The trees surrounding the park would actually act a wall between the wind and the wind turbine, as shown in red in Figure 41. The houses planned also create an obstacle to wind on the South west side.

Figure 41. St. Catherine St. Triangle

Even if the wind turbine was to be placed in the middle of the park, this would only guarantee a distance of about 20-25 m from the trees to the turbine, causing energy production to be significantly impeded. The only way to possibly overcome the lack of open space would to significantly increase the tower height of the wind turbine. However, although this would provide with a slight improvement on the turbine performance, it would also involve substantial extra costs and most certainly planning issues due to the height of the tower.

Even if there are eventually fewer

trees than are shown in the redevelopment proposal, the overall proximity to the houses would pose a problem for the wind flow, noise and visual impact issues. Ultimately, if it is the Sheffield Council's desire to promote and include sustainable energy sources into their redevelopment plans for The Catherine Street Triangle, it is suggested that the most appropriate solution would be solar electricity, through the installation of photovoltaic (PV) systems.

15 CASE STUDY 8: SHEFFIELD – SKY EDGE

Skye Edge is a vast windswept development site, which includes panoramic views of the whole of Sheffield. An ambitious redevelopment programme is underway across the area, aiming to achieve a development that is both environmentally sustainable and architecturally striking. As part of this, it is intended to have renewable energy systems installed on site to provide for a proportion of the area's energy needs.

This study was undertaken to assess the feasibility of installing a small wind turbine. If wind power is shown to be feasible, it offers a very effective method of generating electricity on the site from renewable sources and due to the high visibility of the site from the city, it would project a strong message of support for renewable energy technologies.

15.1 Project site details

Skye Edge is located between Wybourn and City Road, Sheffield. The area, perched on a hillside, has excellent views across the city and is highly visible from city centre and surrounds. Site details are presented in Table 33:

Table 33. Specification of the site location – Skye Edge

Element	Skye Edge
Location	South-East of Sheffield city centre
OS Coordinates	436737, 386927 (SK367869)

15.2 Assessment of Site Characteristics and Wind Turbine Parameters

15.2.1 Location of the wind turbines

Two possible locations within the Skye Edge redevelopment site were considered for the installation of a wind turbine, as shown on Figure 42.

- Location 1 is on Skye Edge Park (marked 1 on the map); and
- Location 2 is on the planned Landmark Building near Skye Edge Avenue (marked 2 on the map).

Location 1 benefits from being on a high ground area and from being relatively far away from the houses and buildings, which will reduce any likelihood of problems from noise, safety or shadow flicker. However, the distance to a connection point has the downside of involving extra costs in cabling. A larger wind turbine could be considered for this site.

At Location 2, which is the Landmark Building, the wind turbine would be installed on the roof of the building. This means that the wind turbine would have to be smaller compared to a wind turbine installed at Location 1, which ultimately means less energy generation. However, it would be less intrusive (both visually and physically) than a larger wind turbine on the ground.

Figure 42. Plan of the Skye Edge redevelopment area with possible locations for a wind turbine

Both proposed turbine locations benefit from an elevated position on top of a hill, 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' (uninterrupted flow) to the south-west is also advantageous, as this is the prevalent wind direction.

15.2.2 Location 1 - Public open space

Positioning a wind turbine at Location 1 is the most suitable in terms of energy generation and economics. On this site, it would be possible to install a relatively large urban turbine with a rated output of 15 kW.

As this proposed area is highly visible from city centre and surrounds, the turbine is likely to have a significant visual impact. Nevertheless, as the plan is to create a "development that is environmentally sustainable and architecturally striking", the wind turbine would most certainly help making a statement regarding the support of renewable energy. Nonetheless, the issue of visual intrusion to local residents is one that should be carefully considered and it is highly advisable to inform residents of the proposals at an early stage.

The dynamic nature of a wind turbine may also cause an effect known as "shadow flicker", which occurs under a special set of conditions when the sun passes behind the hub of a wind turbine and casts a shadow over neighbouring properties. The houses on Fitzwalter Road are the ones which might experience this effect, but further analysis on the ground is needed to ascertain this.

A suitable wind turbine for this site is the Proven WT15000, with a rated power of 15 kW. The rated power of a wind turbine is the power output the turbine would deliver in a wind speed of around 12m/s.

The WT15000 are installed with self supporting masts rather than masts requiring guy lines. This criterion was necessary due to the site being public area; a mast is preferable because it poses no safety risks and also requires less ground area. Larger wind turbines, with more rated power, were not considered due to the proximity of the nearest dwellings, which would most likely experience noise disturbance.

Table 34. The Proven WT15000

Model	Supplier	Rating (kW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
WT15000	Proven	15	12	15	3 Blades, 9 m diameter, downwind

Photos of the Proven WT15000 model are shown in Figure 34.

Figure 43. Proven WT15000 (1.5 kW)

15.2.3 Location 2 - Landmark building

At Location 2, the wind turbine would be installed on the roof of the planned Landmark Building located in the eastern corner of Skye Edge. For this type of installation of the wind turbines (roof-mounted), the biggest concern is arguably the vibrations transferred to the building. Due to the rotating motion of the turbine blades and the dynamics of wind applying pressure on the whole turbine installation, vibration could be generated and transmitted into the building structure.

Therefore, when planning a roof-mounted wind turbine, the siting of the turbine within the roof area and its weight and shape should be carefully studied. If this is indeed the chosen option and as the building is still in planning and not actually built, it is recommended to consider changes in the building design and structure which would render it more adequate for the installation of a wind turbine.

A suitable wind turbine for roof-mounted installation on the Landmark building is the Renewable Devices Swift model. This turbine has a rated output of 1.5 kW. This model is equipped with two vibration damping systems designed to absorb a wide range of frequencies. This would ensure a minimal transmission of oscillations from the turbine to the building structure.

Another possible wind turbine for roof-mounting is the Proven WT2500 (2.5 kW). The Proven WT2500 incorporates anti-vibration dampers into the turbine base and has the option of a vibration auto brake, which is an additional safety feature. For the building mounting of the turbine a 6.5m mast is recommended.

Further details of these two turbines are given in Table 35.

Table 35. The Swift and Proven WT2500 wind turbines

Model	Supplier	Rating (kW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
SWIFT	Renewable Devices	1.5	12	2	5 Blades, 2 m diameter
Proven WT2500	Proven	2.5	10	6.5[10]	3 Blades, 3.5 m diameter, downwind

Photos of the Swift and Proven turbines are shown in Figure 44.

Figure 44. Swift (1.5 kW) and Proven (2.5 kW) wind turbines

15.3 Installation Requirements

At Location 1, the installation of the Proven wind turbines requires a winch and pulley to erect the mast and turbine. A winch anchor is therefore installed for this purpose and also to lower and raise the turbine for maintenance.

The civil works required for the installation of the Proven wind turbine are as follows:

- Building of foundations: a concrete foundation to which the base plate is fitted and another to which the winch anchor would be installed. These use high strength concrete, approximately $16.4m^3$ for the base foundation and $2.7m^3$ for the winch anchor (full details are available from Proven Energy);
- Digging of a trench to lay electrical cables (approximately 600mm deep);
- Making an entry path for cables where electrical connection will take place; and
- Strengthening and making secure the location where electrical equipment would be housed.

At Location 2, the Swift turbine would be mounted on a bespoke aluminium mast the precise clearance from the roof would be dependent on the roof type. The Swift turbine is typically wall-mounted at the gable end of a building using the bespoke brackets supplied. On this type of installation the minimum clearance is 0.5 m from the roof top. The Swift turbine can also be installed on a flat roof. In this type of installation, the mounting mast described above is replaced with a bespoke mounting stand. As the Landmark building has not yet been built, there is an opportunity here to integrate the installation of one or more Swift turbines into the building roof and ensure from the outset the structural strength to support the wind turbines.

[10] For roof-mounting a 6.5 m mast is recommended. For ground installation a mast of 11 to 15m would be recommended.

The Proven WT2500 can also be installed on a flat roof. Being a larger, heavier turbine with a 6.5m mast, it will require craning up to the roof. In addition, a special steel base frame is required to fix the mast to the roof of the building. This implies some preparatory work on the roof. These items increase the complexity and cost of the work compared to a ground installation. The additional cost is estimated at £5000 to £7000. The additional cost of cranage and other roof work could be minimised if installation takes place at the same time as construction of the building itself.

As mentioned above for the Swift turbine, the Landmark building should be designed with the structural strength to accommodate a wind turbine. Depending on the building design it could be possible to mount two 2.5 kW machines, bring total installed capacity to 5 kW and therefore increasing generation capacity. Appropriate design of the building, including structural issues to accommodate the wind turbine(s) should be decided between a structural engineer, the architect and the client, with information from the wind turbine manufacturer.

15.4 Wind Resource and Expected Energy Output

The UK Wind Speed Database - NOABL 2000 was used to estimate the wind speed at the site, based on the Ordnance Survey grid reference 436386 (SK3686). The results are shown in Table 36. Estimated wind resource at Skye Edge.

Table 36. Estimated wind resource at Skye Edge

Height above the ground (m)	Wind Speed (m/s)
10	4.9
25	5.7
45	6.1

The NOABL database does not take into account local topography, such as the fact that the locations selected are at the top of hills, so actual wind speeds may be higher than those shown above. Nevertheless, these wind speeds are in the range required to make the installation of a small wind turbine feasible.

As the height above the ground increases the wind speed and therefore the energy available increases. The chosen height of any wind turbine at the site will be a compromise between maximising available energy and considerations of the tower and visual impact. The tower height available also varies depending on the manufacturer. These wind speeds along with turbine manufacturers' published estimated outputs were used to produce calculations of the theoretical available energy from the different types of wind turbine. The results shown in Table 37 are presented in kWh, which is unit of electrical energy that equals one kilowatt of power applied for one hour. An average house uses an estimated 4700 kWh of electricity per year.

Table 37. Estimated Energy Outputs for Skye Edge

Wind Turbine	Swift	Proven (Rooftop)	Proven WT15000
Wind turbine rated power, kW	1.5	2.5	15
Tower Height, m	2	6.5	15
Annual energy, kWh (average)	2500	3750[11]	23000[12]

15.5 Environmental benefits

Using electricity generated from a wind turbine displaces a unit of electricity which would otherwise been produced from conventional sources and carbon dioxide (CO_2) emissions will be reduced as a result. The environmental benefits, represented by the estimated annual CO_2 savings are shown in Table 38.

Table 38. Estimated Annual Co_2 savings for Woodside

Wind Turbine	Swift	Proven (Rooftop)	Proven WT15000
Wind turbine rated power, kW	1.5	2.5	15
Annual CO2 savings, kg	1100	1600	9900

[11] Source: Proven Energy website - March 2006

[12] Source: Proven Energy website - March 2006

15.6 Economic Analysis

15.6.1 Capital Costs

Capital costs include the costs for the following:

- Wind turbine and mast
- Inverter(s) and control equipment
- Electrical items: AC isolator, additional distribution board, MCB, and G59 relay (where G59 regulations apply).
- Vibration auto brake (Proven wind turbines only)
- Public display board
- Delivery
- Installation: civil works, erection of wind turbine, electrical integration and commissioning

For a roof-mounted turbine the following additional costs may apply:

- Scaffolding and edge protection (depending on site)
- Craning (for turbines typically over 2 kW)
- Additional installation works to secure fixing of turbine to the roof structure (Proven turbines)

Total capital costs for each wind turbine are given in Table 39. These include all of the above but do not include for project management. Costs are only estimates at this stage and may be higher due to the non-standard techniques required in erecting on the top of a mound (Location 1), and type of mast chosen. As the proposed site is undergoing a major redevelopment, installation costs may be minimized if timed to coincide with the construction works and existing on-site equipment is used as far as possible.

Table 39. Total Capital Costs for turbines at Skye Edge

Wind Turbine Manufacturer	SWIFT	Proven (Rooftop)	Proven WT15000
Wind turbine rated power, kW	1.5	2.5	15
Annual energy, kWh	2500	3750	23000
Total Capital Cost including installation, £, ex. VAT	11000	27400	59400

15.6.2 Life Cycle Cost Analyses

Life cycle cost analyses were carried out for each turbine, assuming a lifetime of 20 years, a discount rate of 5% and taking into account the full capital cost of the turbine and maintenance costs each year. Costs per kWh of electricity were calculated, based on the likely energy output of each turbine. Costs were calculated for three scenarios:

1) Using the full total capital costs
2) Using 50% capital costs, assuming 50% of the costs are met from grant funding
3) Using 0% capital costs, assuming 100% of the capital costs are met by grant funding.

The results are shown in Table 40. The final row of this table shows the capital grant funding required for the cost per kWh of the energy produced by the wind turbine to equal the current price paid for electricity.

Table 40. Lifecycle Costs for turbines at Skye Edge

Wind Turbine Manufacturer	SWIFT	Proven (Rooftop)	Proven WT15000
Wind turbine rated power, kW	1.5	2.5	15
Total Life Cycle Cost	12400	30800	66800
Cost of energy, £/kWh	0.40	0.66	0.23
Cost of energy with 50% capital grant funding, £/kWh	0.22	0.37	0.13
Cost of energy with 100% capital grant funding, £/kWh	0.04	0.07	0.03
% Capital Funding Required if cost per kWh is to equal current price of electricity paid	87	97	69

15.7 Medium size wind turbine assessment

It has been requested that the suitability of a medium size wind turbine (around 500kW) on Skye Edge be assessed. Typically separation distances of 300 to 400 metres would be required for turbines of this size. An assessment was made using WindFarm (a specialist software modelling package for the assessment of wind energy projects). The assessment covered two wind turbine sizes; the Enercon 300kW and Enercon 600kW models. The Enercon wind turbines have been preferred for heavily noise constrained sites as the design of the turbines removes the need for a gearbox. The gearbox is usually the noisiest part of a wind turbine.

The assessment of noise can be done in a wide variety of ways. The method used in WindFarm is known as the Danish model. The noise level at a receiver (house) at 1.5m above ground level, is obtained using the following equation:

$$Lp=Lw*a -10*\log_{10}(2*Pi*r^2)$$

Where :
the source (a wind turbine) is producing noise at Lwa dB(A);
Lp is the sound pressure level at the receiver in dB(A);
r is the line of sight distance between source and receiver in metres;
a is the attenuation coefficient in dB/m (if Lwa exists as a single, broadband sound power level, then a = 0.005 dB/m).

The site chosen for the wind turbine was chosen to be on the ridge a reasonable distance from the domestic dwellings to the North and the East and using the industrial area as a buffer zone to the houses to the West.

The noise profile for a 300kW and a 600kW wind turbine are presented below in Figure 45. This shows that for the 300kW wind turbine maximum noise levels of around 43dB will be incurred in residential areas. For the 600kW wind turbine maximum noise levels of 46dB will be incurred in residential areas.

The level of acceptable noise is highly dependent on the background noise level at the dwellings around a site. The noise standard for the assessment of wind turbines is ETSU R97: The assessment and rating of noise from wind farms. This states that the turbine noise level should be kept to within 5dB (A) of the average existing evening or night-time background noise level. A fixed lower value for these limits of between 35 and 40dB (A) is also specified when background noise level is very low, namely less than 35dB (A).

Based on these results the 300kW wind turbine might be ruled out due to noise considerations and the 600kW wind turbine would definitely be ruled out.

Indicative capital costs of a 300kW Enercon wind turbine would be around £300,000 and it would generate (based on a capacity factor of 0.25) around 657MWh. If the Council would like to investigate further the possibility of a medium sized turbine on the Skye edge site, the next step would be to assess the noise levels near to the dwellings and carry out a more complete noise analysis. This should be accompanied by a financial analysis.

Figure 45. Noise profile for a 300kW and a 600kW wind turbine

15.8 Conclusions and recommendations

Skye Edge offers great potential for wind energy system in terms of available space, topography and exposure to wind. From the presented options, installing a larger 15 kW Proven wind turbine in Skye Edge park is the most attractive one, in terms of energy production and economic results. A 15 kW turbine could be installed at a capital cost of £59 400. It would produce on average 23 000 kWh / year and avoid 9900 $kgCO_2$ / year.

The Swift and Proven options presented for the landmark building are also technically feasible but their energy production and economic performance are not as good.

The performance for the Proven wind turbine models is reliable as this turbine model has proved quite popular and there are many installations around the UK. The SWIFT turbine, being a more recent model, and not as widely used, would benefit from follow-up monitoring to check its energy generation.

It may be possible to use a medium sized wind turbine of 300kW at the site but this will be largely dependent on noise levels in and around dwellings. It is suggested that the next step in any assessment would be to do a background noise study and consult with the planning department on the noise policy for Sheffield City.

All the decisions regarding the possible locations for the wind turbines, as well as choosing their size and rated power were based on the proposed master plans for the area. Significant changes to these plans may render some of the recommendations made on this report unsuitable, while opening up new potential options.

In Sheffield, a seminar was held to present the proposed sites and the results of all the feasibility studies to stakeholders and decision-makers. The city council are considering taking at least two of the sites forward in the near future, probably the Netherthorpe flats and Woodside site. Skye Edge site as Parsons Cross site are still in consideration but for the medium to longer term.

16 CASE STUDY 9: SHEFFIELD – PARSON CROSS/FALSTAFF

Parson Cross is one of the areas which will benefit from "The Southey Owlerton Neighbourhood Strategies", which aims to achieve the highest standards of design and environmental performance in all physical changes in order to raise values and establish a new part of Sheffield's housing market.

This study was undertaken to assess technical, economic, planning and health and safety issues associated with installation of a wind turbine. If wind energy is shown to be feasible, it offers an effective method of generating electricity from renewable sources and contributing to an improved environmental performance for the redevelopment.

16.1 Project site details

Parson Cross is one of the six different neighbourhoods that make up the Southey Owlerton area of north Sheffield. Site details are presented in Table 41.

Table 41. Specification of the site location – Parson Cross

Element	Parson Cross
Location	North of Sheffield city centre
OS Coordinates	435439, 388612 (SK354886)

16.2 Assessment of Site Characteristics and Wind Turbine Parameters

16.2.1 Location of the wind turbines

One location was considered adequate for siting a wind turbine within the Parson Cross site. It is located on the northeast corner of Parson Cross Park, as shown on Figure 46 below.

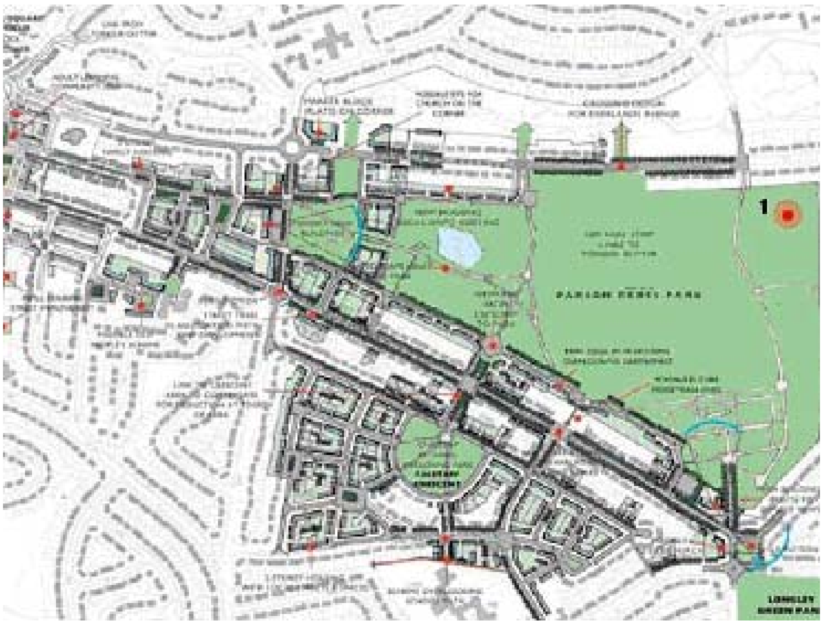


Figure 46. Parson Cross redevelopment area with a possible location for a wind turbine marked.

This location benefits from not having any obstructions to the wind flow, such as trees or houses, from the southwest side which is the prevailing wind direction for this area. The location also means relatively high visibility of the wind turbine as it is near main road and visible from the houses along the park and to people walking through the park.

However, as there are houses fairly close to this location, alongside Lindsay Road, it is recommended not to install a wind turbine of more than 2.5 kW capacity. This is mainly to avoid any issues from noise. If a larger turbine were to be used there could be some noise hindrance to the residents in the close vicinity of the turbine. A second disadvantage of the site is limited options for electrical connection. Suggested options are the nearby school or the houses along Lindsay road. However, the redevelopment plans are unclear on the exact usage of some areas. If any of these areas prove to have suitable buildings for electrical connection than the turbine location could be modified slightly to bring it closer to a suitable connection point.

Other locations were considered, but after careful analysis they were dismissed. One such location was the centre of the Parson Cross Park, which seemed suitable as it offered a large clear area away from houses. However, in order to compensate the extra costs of the cabling from the turbine to any residential area around the park, the wind turbine would have to be quite large. This would obviously mean a more intrusive and noisier structure placed on the park, which does not seem compatible with the current plans for the area, as stated in the master plan documents received from the Council.

The siting of a wind turbine in the Falstaff Crescent area was also considered. The installation of a small wind turbine on this site would not be technically and economically feasible, as it is a rather small and sheltered area. The planned construction of houses of 2 to 3 floors on all three sides of the crescent would block wind flow and create turbulence, making it an unsuitable location for a wind turbine.

16.2.2 Wind turbines

A suitable wind turbine for the Parson Cross Park site is the Proven WT2500 (see Table 42), with a rated power of 2.5 kW. The rated power of a wind turbine is the power output the turbine would deliver in a wind speed of around 12m/s. The WT2500 wind turbine is installed with self supporting masts rather than masts requiring guy lines. This criterion was necessary due to the site being public area; a mast is preferable because it poses fewer safety risks and also requires less ground area. Larger wind turbines, with more rated power, were not considered due to the proximity of the nearest dwellings, which would most likely experience noise disturbance. Photos of the Proven WT2500 are shown in Figure 47.

Table 42. The Proven WT2500

Model	Supplier	Rating (KW)	Rated Wind Speed (m/s)	Height of tower (m)	Rotor Type
WT2500	Proven	2.5	10	11 or 15	3 Blades, 3,5m diameter, downwind

Figure 47. Proven 2.5 kW

16.3 Installation Requirements

The installation of the Proven wind turbine requires a winch and pulley to erect the mast and turbine. A winch anchor is therefore installed for this purpose and also to lower and raise the turbine for maintenance.
The civil works required for the installation of the Proven wind turbine are as follows:

- Building of foundations: a concrete foundation to which the base plate is fitted and a second smaller concrete cube to which the winch anchor would be installed. These use high strength concrete, approximately 6.25m^3 for the base foundation and 1m^3 for the winch anchor (full details are available from Proven Energy).
- Digging of a trench to lay electrical cables (approximately 600mm deep).
- Making an entry path for cables where electrical connection will take place.
- Strengthening and making secure the location where electrical equipment would be housed.

16.4 Wind Resource and Expected Energy Output

The UK Wind Speed Database-NOABL 2000 was used to estimate the wind speed at the site, based on the Ordnance Survey grid reference 434392 (SK3492). The results are shown in Table 43:

Table 43. Estimated wind resource at Parson Cross

Height above the ground (m)	Wind Speed (m/s)
10	5.2
25	5.9
45	6.3

These wind speeds are in the range required to make the installation of a small wind turbine feasible and are better than those found at the other sites considered in this report. Information received from the Council also indicated that prevailing wind direction was from the west. The turbine was sited taking this into account and this should help improve wind resource availability. As the height above the ground increases the wind speed and therefore the energy available increases. It is therefore recommended that the taller mast of 11m available for the 2.5 kW model is used (this will also help reduce safety risks). However, the chosen height of any wind turbine at the site will be a compromise between maximising available energy and considerations of visual impact. This is ultimately a decision for the Council to make.

The NOABL wind speeds along with turbine manufacturers' published estimated outputs were used to produce an estimate of the theoretical available energy from the different types of wind turbine. The results shown in the table below are presented in kWh, which is unit of electrical energy that equals one kilowatt of power applied for one hour. An average house uses an estimated 4700 kWh of electricity per year.

Table 44. Estimated Energy Outputs for Parson Cross

Wind Turbine Manufacturer	Proven WT2500
Wind turbine rated power, kW	2.5
Tower Height	11
Annual energy, kWh (@5m/s)	4200

16.5 Environmental benefits

Using electricity generated from a wind turbine displaces electricity which would otherwise been produced from conventional sources and carbon dioxide (CO_2) emissions will be reduced as a result. The environmental benefits, represented by the estimated annual CO_2 savings are shown in Table 45.

Table 45. Estimated Annual CO_2 savings for Parson Cross

Wind Turbine Manufacturer	Proven WT2500
Wind turbine rated power, kW	2.5
Annual CO2 savings, kg	1800

16.6 Economic Analysis

16.6.1 Capital Costs

Capital costs include the costs for the following:

- Wind turbine
- Mast
- Inverter(s) and control equipment
- Electrical items: AC isolator, additional distribution board, MCB, and G59 relay (where G59 regulations apply).
- Vibration auto brake (Proven wind turbines only)
- Public display board
- Delivery
- Installation: civil works, erection of wind turbine, electrical integration and commissioning

Total capital costs for each wind turbine are given in Table 46. These include all of the above but the costs do not include for project management. It is worth noting that if project management can be carried out by the Council, as part of the day-to-day work of a designated department, this would result in significant cost savings. Otherwise a private company can be hired to do project management but of course, this would be a more expensive option.

Costs are only estimates at this stage and may be higher due to the unknown distance to electrical connection and type of mast chosen. As the proposed site is undergoing a major redevelopment, installation costs may be minimized if timed to coincide with the construction works and existing on-site equipment is used as far as possible.

Table 46. Total Capital Costs for Parson Cross

Wind Turbine	Proven WT2500
Wind turbine rated power, kW	2.5
Total Capital Cost including installation, £, ex. VAT	20400

16.6.2 Life cycle Cost Analysis

Life cycle cost analyses were carried out for each turbine, assuming a lifetime of 20 years, a discount rate of 5% and taking into account the full capital cost of the turbine and maintenance costs each year. Costs per kWh of electricity were calculated, based on the likely energy output of each turbine. Costs were calculated for three scenarios:

1) Using the full total capital costs
2) Using 50% capital costs, assuming 50% of the costs are met from grant funding
3) Using 0% capital costs, assuming 100% of the capital costs are met by grant funding.

The results are shown in Table 47. The final row of this table shows the capital grant funding required for the cost per kWh of the energy produced by the wind turbine to equal the current price paid for electricity.

Table 47. Lifecycle Costs

Wind Turbine Manufacturer	Proven
Wind turbine rated power, kW	2.5
Total Life Cycle Cost	22900
Cost of energy, £/kWh	0.44
Cost of energy with 50% capital grant funding, £/kWh	0.24
Cost of energy with 100% capital grant funding, £/kWh	0.05
% Capital funding required if cost per kWh is to equal current price of electricity paid	89

16.7 Conclusions and recommendations

Parson Cross Park seems to offer great potential for small wind systems. This location has the highest estimated wind speeds according to the NOABL database. However, as the some of the aims of the redevelopment plans for this area are to make this park more attractive and inviting for local residents, it is recommended to adopt a more low profile strategy when choosing the location and size of the turbine. Hence the suggested site for the turbine is in the North-east Corner of the park, instead of in the centre.

If the Council wished to make a bold statement and/or received positive comments after consultations with local residents, the turbine could be located in the middle of the park without significantly altering the economics of the installation. The chosen wind turbine model, the Proven WT2500 has been widely used and proved to be a reliable machine. Thanks to favourable wind conditions, the economics of the installation are better than at other locations studied.

The recommendation regarding a location for the wind turbine, as well as its size and rated power were based on the proposed master plans for the area. Significant changes to these plans may render the recommendations made in this report unsuitable but may open up new options for wind development (for example, a larger 6kW wind turbine in the park).

Following the seminar hold in Sheffield regarding the various feasibility studies, the city council expressed its consideration for two future sites. Parson Cross site is not one of this one but is still in consideration but for the medium to longer term.

17 CASE STUDY 10: NETHERTHORPE TOWER BLOCKS

Netherthorpe is a densely populated and culturally diverse neighbourhood with a mix of residential areas. The Netherthorpe tower blocks consist of three tower blocks near the centre of Sheffield City and as such are prominently visible from a number of points around the city.

This study was undertaken to assess technical, economic, planning and health and safety issues associated with installation of a wind turbine on the rooftop of a tower block. If wind energy is shown to be feasible, it offers an effective method of generating electricity from renewable sources. The study concentrates on installation on one tower block. Results can be replicated to similar tower blocks in Netherthorpe and surrounding areas.

17.1 Project site details

Netherthorpe is a council estate lying North West of the Sheffield city centre. Site details are presented in Table 48.

Table 48. Specification of the site location - Netherthorpe

Element	Netherthorpe Tower Block
Location	North west of Sheffield city centre
OS Coordinates	434338, 387555 (SK 343875)

17.2 Assessment of Site Characteristics and Wind Turbine Parameters

17.2.1 Location of the wind turbines

The wind turbines would be sited on the top of the tower block on the flat roof. However, there is currently no method for selecting the 'best' position for wind capture. Suggested locations (based on experience on the ground thus far and anecdotal evidence from research that has been carried out to date) are:

1. In the centre of the tower block. This may help avoid the turbulence at the edges of the roof and also will be less visible from the ground. The higher the mast the better the wind capture will be. However, if there is an elevator shaft in the centre of the block, it is not recommended that the turbine is installed on top of this.
2. On the edge of the roof (e.g. against a parapet wall) but with sufficient mast height to clear the turbulent zone of wind coming over the top of the roof. This will be more visible and possibly allow more turbines to be installed but the wind turbine may have to deal with more turbulent winds.

17.2.2 Wind turbines

The wind turbines considered for installation on the rooftop of a tower block are the Renewable Devices SWIFT model, the Airdolphin, the Windsave and the Ampair as shown in Table 49. The Proven 2.5 kW model was not considered as cranage costs to lift the turbine and mast to the top of the tower would be excessive in relation to energy production.

Table 49. Wind Turbines reviewed for the Netherthorpe Tower Block

Model	Supplier	Rating (kW)	Rotor Type	Rotor diameter (m)
SWIFT	Renewable Devices	1.5	5 blades	2
Airdolphin	Zephyr	1	3 blades	1.8
Windsave	Windsave	1	3 blades	1.75
Ampair	Ampair (Boost Energy)	0.3	3 blades	1.2

Figure 48. Four wind turbines for the Netherthorpe tower blocks


Swift (1.5 kW)


Airdolphin (1 kW)


Windsave (1kW)


Ampair (0.3 kW)

17.3 Installation Requirements

Any installation would have to be preceded by a structural survey of the tower and if the tower belongs to the Council, then obtaining building control approval will also be necessary. This would be done by submitting a structural survey and detailed calculations of loads on the building, showing the building can withstands the extra loads exerted by the installation of a small wind turbine.

The mechanical and electrical works required for the installation of one of the four models presented above would be similar:

- Preparation of the roof for installation: edge protection, checking lightening protection arrangements, checking waterproofing arrangements, etc.
- Connection of mounting poles at the desired point of installation on the roof. This could be a free-standing mounting stand or a mounting pole installed up against a parapet wall to provide support;
- Installation of the turbines by a specialist installer;
- Running of electrical cables to the distribution board of the building; and
- Strengthening and making secure the stairwell where electrical equipment would be housed.

It has been assumed that cranage work to lift the turbines and mounting poles to the roof will not be required, as they should be able to be lifted up through the building in the elevator. If this is not permitted then a crane or external hoist will be necessary and would add considerably to costs. In addition, craning over a 'live' building is normally not allowed, so the tower block would have to be empty while lifting the turbines to the top of the roof.

17.4 Wind Resource and Expected Energy Output

The UK Wind Speed Database - NOABL 2000 was used to estimate the wind speed at the site, based on the Ordnance Survey grid reference 434387 (SK3487). The results are shown in Table 50.

Table 50. Estimated wind resource at Netherthorpe

Height above the ground (m)	Wind Speed (m/s)
10	3.7
25	4.5
45	5.2

These wind speeds are lower than in other areas of Sheffield. However, given that the installation is to take place at the top of tower blocks, at this height the wind speeds are likely to be in the range required to make the installation of a small wind turbine feasible. Information received from the Council indicated that prevailing wind direction was from the west. The turbines could be sited to take advantage of this.

Because the wind turbines proposed are of relatively small capacity it is proposed to install at least two on each tower block to increase energy generation. The options considered for one Netherthorpe tower block are shown in Table 51.

Table 51. Wind turbine options for Netherthorpe

Wind Turbine Manufacturer	SWIFT	Airdolphin	Windsave	Ampair
Number of turbines	2	2	2	2
Total capacity, kW	3	2	2	0.6
Annual energy, kWh (average)	5000	3000	2000	600

If a block of flats has an annual communal energy consumption of approximately 80 000 kWh[13], the installation of two small wind turbines could contribute between 1% (Ampair) and 6% (Swift) of the block's annual energy consumption.

If a structural survey showed that more wind turbines could be installed then the contribution of small wind systems could potentially increase to 12% (four Swift turbines).

17.5 Environmental benefits

Using electricity generated from a wind turbine displaces electricity which would otherwise have been produced from conventional sources and carbon dioxide (CO_2) emissions will be reduced as a result. The environmental benefits, represented by the estimated annual CO_2 savings are shown in Table 52.

[13] Communication with Neil Piper, Sheffield City Council, regarding energy consumption at the Robertshaw flats, 31/03/06

Table 52. Estimated Annual CO_2 savings for Netherthorpe

Wind Turbine Manufacturer	SWIFT	Airdolphin	Windsave	Ampair
Total capacity, kW	3	2	2	0.6
Annual CO2 savings, kg	2150	1290	860	260

17.6 Economic Analysis

The basic capital costs will be for the purchase of the wind turbine and mounting poles. However, there are a number of other costs, particularly associated with retrofitting wind turbines on an existing structure. A list of the main capital costs is given below:

- Wind turbine and mast;
- Inverter(s) and control equipment;
- Electrical items: AC isolator, additional distribution board, MCB, and G59 relay (where G59 regulations apply);
- Public display board;
- Delivery of equipment;
- Installation: works for mast installation, erection of wind turbine, electrical integration and commissioning;
- Edge protection for working at height; and
- Lightening protection.

Total capital costs for each wind turbine are given in Table 53. These include all of the above but the costs do not include for a structural survey or project management. It is worth noting that if project management can be carried out by the Council, as part of the day-to-day work of a designated department, this would result in significant cost savings. Otherwise a private company (the installer or an independent consultant) can be hired to do project management. The costs given here are only estimates at this stage and may be higher due to the unknown structure of the tower blocks, cabling distances, etc.

Table 53. Total Capital Costs for wind turbines at Netherthorpe

Wind Turbine Manufacturer	SWIFT	Airdolphin	Windsave	Ampair
Number of turbines	2	2	2	2
Total capacity, kW	3	2	2	0.6
Approximate Capital Cost including installation, £, exc. VAT[14]	19700	16600	Unknown[15]	8200

Due to uncertainty over the real costs of installation and maintenance of these wind turbines and differing levels of information from the manufacturers, a comparison of full life-cycle costs would not be accurate. Therefore this analysis has not been carried out here.

[14] Cost for installation of two turbines on the same tower block.

[15] Windsave are quoting a price of £1500 for their wind turbine, including installation, on properties deemed suitable. However, this is not a price that is currently being implemented and further information is not available from the manufacturer.

As more installations of these technologies are carried out, and the price of small building mounted wind turbines stabilises, a more accurate assessment of costs can be made.

17.7 Conclusions and recommendations

It is likely that it is technically feasible to mount at least two wind turbines on each tower block at Netherthorpe. However, this cannot be said with certainty until a structural survey has been carried out. Of the turbines examined, the Swift or the Airdolphin would be the most cost effective (potentially covering up to 6% of communal energy consumption). There is insufficient information to judge the cost of Windsave turbines and Ampair's 0.3kW product is too small to make it cost effective.

The next step is to carry out a structural survey by a structural engineer to ascertain the loads that can be borne by the tower blocks, and possibly where the best positions for the wind turbines would be from the structural point of view.

Depending on the results of the structural survey it is recommended to install the maximum possible number of wind turbines. This would decrease the cost per kW installed and increase the percentage of communal energy consumption covered by renewables.

Monitoring of the wind turbines' performance is recommended to accompany these installations. Monitoring costs have not been included in this study.

Figure 49. Tower blocks at Netherthorpe.

COUNTRY PARTNER: THE NETHERLANDS

18 DUTCH FEASIBILITY STUDIES – INTRODUCTION

Horisun had meetings with the city of Hague, three city districts in Amsterdam and other cities and they were expected to lead to a number of feasibility studies. However, due to circumstances out of the control of Horisun, not all feasibility studies happened. The end result is one feasibility study for the city district of Ookmeer in Amsterdam. This combined feasibility study report will present the unique Dutch feasibility study. However, after several contacts with the municipality of The Hague, the city council has decided for deployment of 30-50 UTs. This deployment will be conducted. The feasibility study for this project will be done in the future and is not part of this report. In Amsterdam, the city districts Zuid-Oost and Westerpark wanted to perform a feasibility study, but could not decide about the location for which the study should be done. Finally, the Dutch partner is able to present the feability study for the City Districit Osdorp.

19 CASE STUDY 11: URBAN WIND TURBINES ON THE ROOF OF THE MULTIFUNCTIONAL SPORT CENTRE OOKMEER, AMSTERDAM OSDORP

19.1 General context of the project

The City District Osdorp in Amsterdam will be revitalized. The revitalization plan also includes the rebuilding of a sport centre Ookmeer. According to the plan, the existing tennis hall will be replaced by a large new Multifunctional Sport Centre including a sport hall, athletic stadium and probably a climbing wall. The Multifunctional Sport Centre (MFSC) will be situated on lot no. 35. The MFSC shall cover the whole lot, 95 m long and 62 m wide (see Figure 50).

An important aspect of the revitalization process of the City District Osdorp is a visible and tangible environmental friendly image. The City Council requires that the pay-back time of all applied technologies should be less than 10 years. There are already some projects with renewable energy in Osdorp like solar photovoltaic's and heat and cold storage in aquifers.

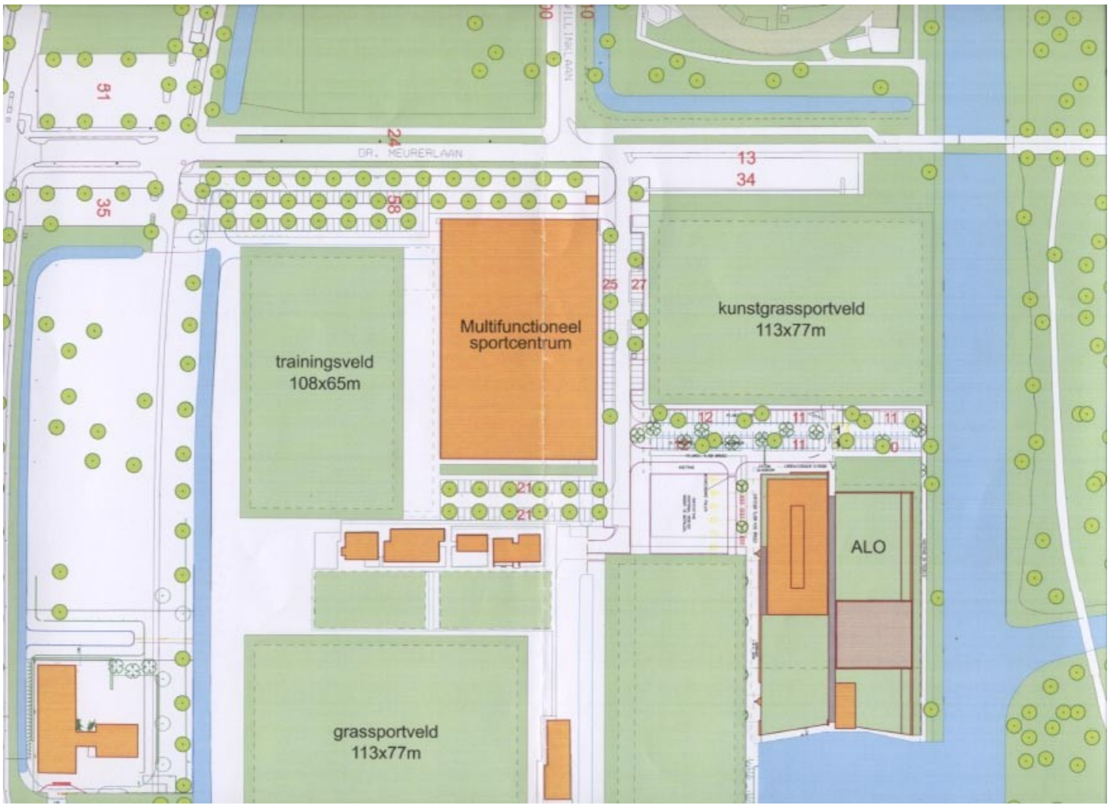


Figure 50: Map of the Sport Park Ookmeer

The Sport Park Ookmeer will be connected to the district heating of the City District Geuzeveld. Also the renewable energy options will be inventoried. For this, a brainstorm session will be organized with a group of external experts. In Ookmeer, the council would like to deploy urban wind turbines (UT).

19.2 Scope of the survey and planning

The first meeting concerning UWTs at MFSC Ookmeer took place on Friday the 10th of June 2005. The meeting was attended by: Mr. Mirko Opdam and Mr. Jurgen Krabbenborg from the City Council Osdorp and Mrs. Jadranka Cace from RenCom. During the meeting the representatives from the City Council explained the future plans regarding the Sport Park Ookmeer. RenCom presented general information regarding UWTs: the available types and the current state of the technology. At the end of the meeting the parties agreed that RenCom would execute a short survey in order to answer to the following question:

Is it possible to deploy urban wind turbines on MFSC Ookmeer and if so, what are the conditions?

Planning issues:

- July 2005 - commission to the architect
- July 2006 - delivery of MFSC

It is important that the requirements regarding UWT are be integrated into the architectural requirements.

19.3 Location

The lot 35 where MFSC will be situated lies in the middle of the Sport Park Ookmeer. The whole area is surrounded by young sequoia trees. This kind of tree can grow very high. The closest building to lot 35 is the Academy for physical Education (Academie voor de Lichamelijke Opvoeding (ALO)). This building is situated about 70 meters to the southeast from the future MFSC. The ALO building is about 23 m high. About 220 m in the south lays the Ookmeerweg. It is a wide, straight street which has high cotton trees on both sides. Along the south side of the Ookmeerweg there is a large residential district Meer en Oever with apartment buildings of up to 25 m high. Figure 51 below shows the location of the Sport Park Ookmeer in the northern part of the city district Osdorp.

Those location characteristics are really important to take into consideration when doing a site feasibility studies for wind turbine implementation. We've seen in the report on resource assessment (deliverable D5.1) that there are some rules of thumb (summarized in the paragraph 19.4.2) to be followed for the site selection. In order to obtain better energy generation on site, we had to respect some conditions and as a consequence to describe the surroundings of the potential urban wind installation site.

Figure 51: Map of the city district Osdorp

19.4 Urban wind turbines, generalities and conditions for implementation

19.4.1 Urban wind turbines in the Netherlands

The first small wind turbine which was especially developed for the built environment in the Netherlands was introduced in 2000. The turbine named Tulipo was developed by the Dutch wind turbine manufacturer Lagerweij. The development of Tulipo was financially supported by the energy company NUON. The turbine was first introduced to the public on the roof of the Dutch pavilion during the Hannover Messe in 2000. A mass interest of the Dutch public for this turbine has inspired a number of other manufacturers to develop new types of wind small turbines for the built environment. This ‘market pull’ has generated a very strong development on the supply side of the market with 11 manufacturers of small wind turbines in 2005. Some of these turbines are specially developed for the urban surrounding. These turbines are often called Urban Wind Turbines (UTs). There are other types of turbine which are more suitable for rural areas.

Most types of UWT are technically not yet mature. In the last few years the number of pilot projects with UTs in the Netherlands has grown strongly. The paragraph 19.6 presents the datasheets of the three types of Uts that could be implemented for this project.

19.4.2 Location requirements

The working conditions for Urban Turbines require wind speeds between 4,5 and 15 m/sec. The nominal yield is achieved at a speed of approximately 10 m/sec. As a consequence, UT should be placed so that it is exposed to these wind speeds for as much time as possible.

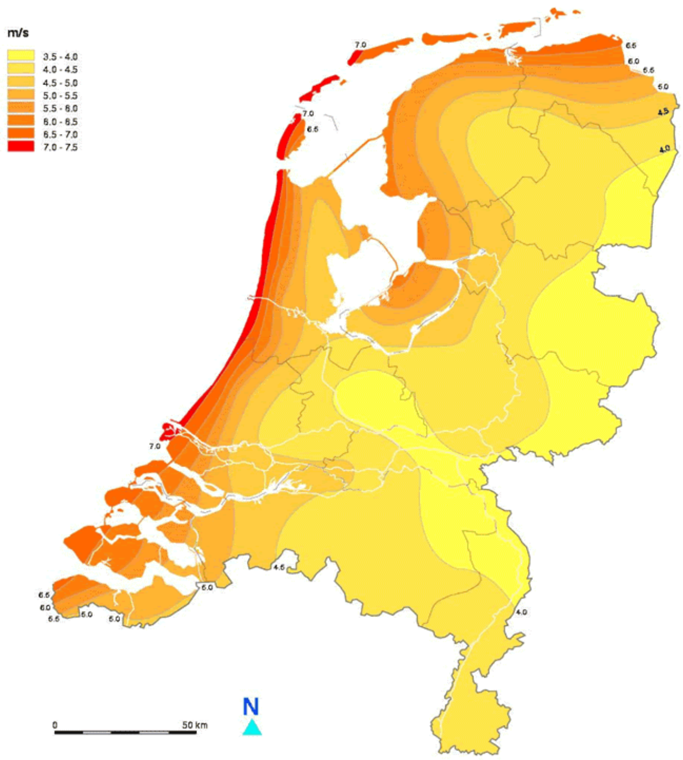


Figure 52: De wind map of the Netherlands

Generally, locations closer to the coast have the most preferable wind conditions. The wind map of the Netherlands in Figure 52, shows that the area around Amsterdam has average wind speeds of 4,5 to 5 m/sec. Manufacturers of wind turbines work with models which include average wind speeds per postal code.

However, local obstructions can lower the wind speed to a great extend. Buildings break the free wind flow, and cause turbulences and wind gusts. With more buildings, trees and other obstacles, an area becomes less suitable for urban turbines. The manufacturers advise some rules of thumb for estimating the suitability of a location for the placement of urban turbines.

Rules of thumb

1. The height of the building which will serve as a base, should be at least 20 metres.
2. The distance between this building and any obstacle should be at least ten times the height of the obstacle.
3. The spot on which the turbine will be placed should be well above the surrounding;
4. The roof of the building should be able to endure static and dynamic stress;
5. Prevent contact noise.

Explanation

Ad 1. The minimum height of the building is based on the empirical figures where the wind regime above that height is generally better.

Ad 2. The appropriate distance between the turbine and an obstacle excludes the possibility that the turbine would be "shadowed". This rule is visualised in the Figure 4. In case the obstacles are trees, one may decide to limit their height.

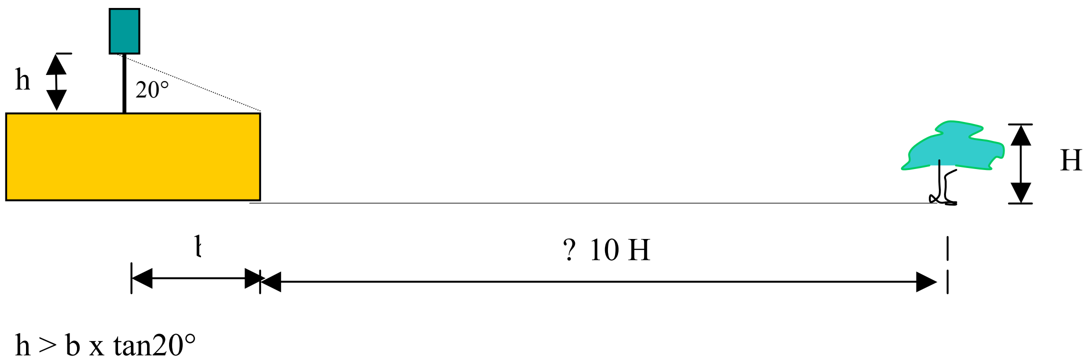


Figure 53: Height related guidance's illustrated

Ad 3. Placing the turbines relatively higher than other structures in the proximity helps avoiding turbulences. For the turbines mounted on a mast a simple formula can be used to calculate the recommended ratio between the height of the mast and the distance from the edge of the (flat) roof: **h= b*tan20°**. The value of 'h' is the height of the mast and 'b' is the distance from the roof edge.

Another advantage of a higher placing the turbine is that it could be kept outside of the "shadow" of the obstacles. In other words, if the distance between the turbine and an obstacle is less than 10 times the height of the obstacle, the negative effects of the obstacle could be avoided by higher placing.

The WindWall turbine is a special case. By its construction it resembles the vertical axis turbines. However, its axis is placed horizontally, which makes it dependent on the wind direction. WindWall can utilize the wind only from the direction vertical to the axis. Therefore is the location choice for this turbine essential.

The manufacturer provides the following guidance's for WindWall (Figure 54):

- Height of the building ≥ 20 m
- Minimum distance between the turbine and an obstacle is at least ten times the height of the obstacle.
- Rounded roof edge on the south-west side of the building.
- The angle of the sloped roof should be in the range 15° - 30°
- Dynamic load of the roof to be calculated conform to NEN 6702, 1 kN/m^2 of the rotor surface.
- The turbine should be placed on a concrete surface that is 2 m wide, 0,3 m thick and long enough to accommodate the turbine.

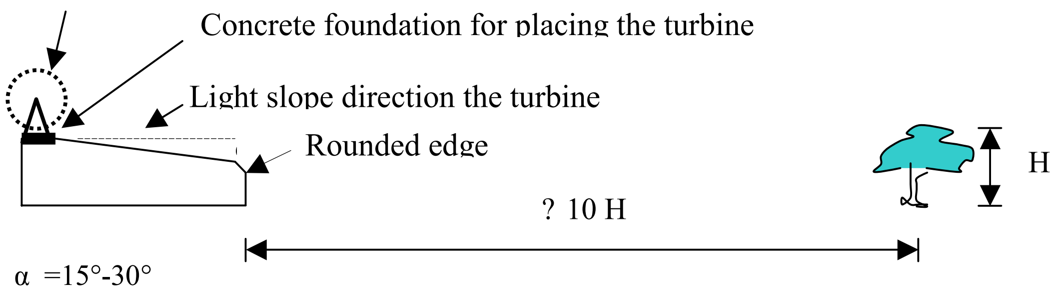


Figure 54: WindWall guidance's illustrated

Ad 4. The turbines impose additional requirements on the construction, due to the weight and due to the wind pressure. This all depend on the turbine type; the manufacturer provided figures of three turbine types are summarized in the paragraph 19.6. The manufacturers also provide mounting instructions and recommendations. All wind turbines in The Netherlands conform to NEN 6702 norm.

Ad 5. Due to changing wind speeds, turbulences or the repositioning of the turbine could cause vibrations and noise. It should be prevented that this noise propagates through the construction of the building. The typical measures are to mount turbines on solid concrete blocks and by using rubber dampers. The problem of contact-noise has not been encountered in practice.

19.4.3 Orientation

The yield of the most urban turbines does not depend on the wind direction. The turbines are either constructed that way (vertical axis turbines), they position towards the wind by the tail or yaw motor or they mostly utilize the upward wind along a side of the building. With the exception of WindWall, the orientation of the turbine is of no significance.

However, in cases when the location is not equally open to all wind direction, the placement is not recommended unless the location is open to the prevailing wind directions.

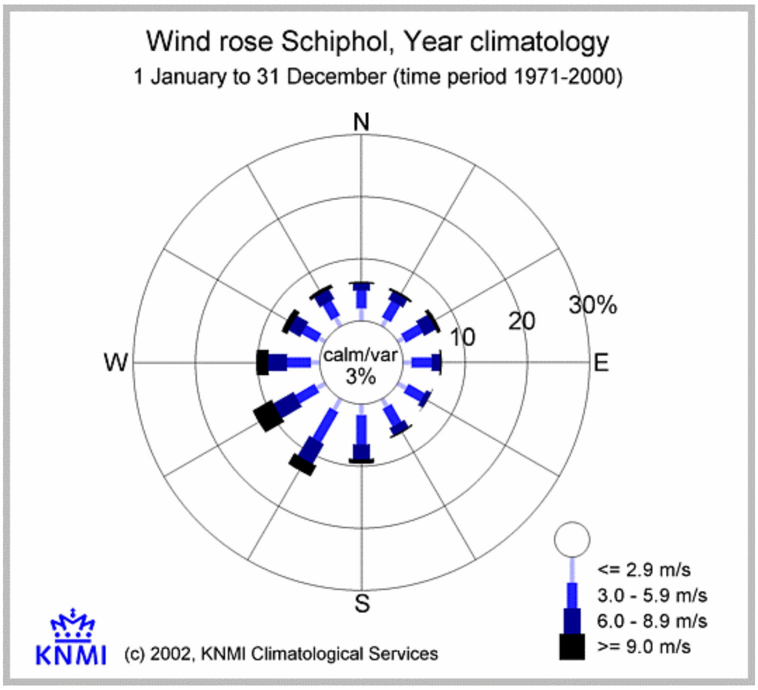


Figure 55: The wind-rose of Schiphol International Airport

According to the data collected by KNMI (Royal Netherlands Meteorological Institute), the wind speeds of above 3 m/s are most often detected from the directions west and south-west. The difference in wind speeds form other directions is of no significance.

WindWall turbine must be orientated towards west or south-west.

19.4.4 Visual integration

The visual integration in the building design is an important aspect of the deployment of urban turbines. Typically, attention should be given to aesthetical issues like: balance between the size of the building and the size of the turbine, the compatibility of the form and the colours, A larger building may accommodate a larger turbine. Another option is to place a group of turbines on a large building. The height of the turbine construction must comply with the destination plan, and, here in Amsterdam, to the regulations regarding the Schiphol airport.

19.4.5 Other issues to consider

Other issues to consider regarding the placement of urban wind turbines are:

- Maintenance access to the turbine should be possible;
- The passage for the cable between the turbine and the main switchboard;
- Space for the additional equipment as inverters and monitoring devices and alike;;
- Connection to the public grid;
- Placing of an MEP- meter (Milieukwaliteit elektriciteitsproductie). This is a special kWh-meter to measure the generated electricity that has to be used if the MEP subsidy would be claimed. Currently, the MEP-tariff for urban turbines is equal to the tariff of large land turbines, 7.7 eurocent/kWh. This subsidy reduces the return on investment period significantly.

19.5 Choice

The definite choice should be made after taking all aspects of the turbine deployment into account: technical and architectural integration, aesthetics, electricity yield, visibility and the budget limitations.

19.5.1 Municipal requirements

Urban wind turbines always require building permit, while the environmental permit may be required in specific situations.

19.5.1.1 Environmental permit

The Environmental law requires no permit if the turbine comply with the ***AmvB*** (Algemene maatregel van het bestuur = Order in Council) for installations. This is the case if:

- Each individual wind turbine has been separately mounted on a mast and,
- Wind turbine has the horizontal axis.
- The distance between a turbine and the closest residence is at least four times the height of the mast.
- The wind turbine or a cluster of turbines have the total power not bigger than 15MW.

19.5.1.2 Building permit

There are very few exceptions that would allow deployment of a wind turbine without the building permit.

The article 43 of the Woningwet (Housing act) determines which construction works require the building permit and which do not.

The exempted construction works are specified in the "Besluit bouwvergunningvrije en licht-bouwvergunningplichtige bouwwerken" (Besluit blb = Act on exemption from building permit for light construction works). The urban wind turbines are not explicitly included there. However, a more general statement allowing for "*constructions of limited size placed on or next to roads, railways or waterways facilitating road, railway, water or air transport or providing electricity for telecommunications*" (article 3, paragraph 3) is in principle applicable to small urban turbines, regardless of the use of the produced electricity. The dispensation has to be requested in the form of the so called "article 19 procedure" which takes approximately three months.

Some municipalities have introduced special regulations for small wind turbines which simplify the administrative process. As an example, as a part of measures stimulating the use of renewable energy, the municipality of Haarlem has regulated the conditions which allow the deployment of urban wind turbines without building permit.

Conditions of the municipality of Haarlem for exemption from building permit
• The rotor diameter of the turbine is smaller than 2 meter; • The turbine cannot be seen from the public roads; • The turbine does not cause vibrations; • The turbine does not cause shadows or reflections • No construction changes of the roof are required; • The power is < 1,5 kW; • The sound pollution of the turbine, measured on the walls of neighbouring buildings remains bellow 25 dB(A). • The turbines which do not comply with these conditions require the building permit, but the turbines with the nominal power smaller than 5 kW are exempted from administrative costs.

19.6 Data Sheets from some urban wind turbines

19.6.1 Tulipo

Turbine type: horizontal axes, 3 blades
Rortor diameter: 5 m
Tower height: 12 m
Rotor weight: 800 kg
Rated Power: 2,5 kW
Electrical yield: 13.500 kWh bij 8,5 m/sec
Noise production: < 35 dB(A) op 20 m distance
Anchoring: the tower is fastened to the foundation by a flange coupling
Price: € 17.700 including the installation
Manufacturer: WES, Zijdewind, North Holland

Figure 56: Tulipo on the roof of the Dutch pavilion at Expo 2000

19.6.2 WindWall

Turbine type: innovative turbine with horizontal axes
Rotor diameter: 2,8 tot 6 m
Length : 5 m/module at 2,8 m diameter
10 m/module at 6 m diameter
Rotor weight: 4.000 kg (2,8 m) up to 30.000 kg (6 modules of 6 m)
Noise production: < 40 dB(A) op 20 m
Rated power: 1,75 kW/module at 2,8 m diameter,
7 kW/module at 6 m diameter.

The expected electricity yield:

- 3.000 kWh for the installation with 2 modules with 2,8 m rotor diameter at an average wind velocity of 5,5 m/sec.
- 52.000 kWh for the installation with 6 modules with 6 m rotor diameter at an average wind velocity of 5,5 m/sec.

Roof load:

- static load: 1 kN/m2 over the static surface when not in operation
- dynamic load: 0,4 kN/m2 over the total aerodynamic surface when in operation

Stability:

- gravity per m length is 9,3 kN/m.
- tilt when stagnant: 11,7 kN/m,
- tilt when operating: 8,7 kN/m.

Anchoring: on a concrete beam 2 m wide, 0,3 m high along the whole length of the roof.

Price for 2 modules of 2,8 m diameter: € 23.500 incl. transport, installation and 10 years yield guarantee. Price for 6 modules (40 kW) of 6 m diameter: € 115.000 incl transport, installation and 10 years yield guarantee.

Tailor made installation size and colour

Manufacturer: WindWall b.v., Delden

Figure 57: WindWall on the rooftop of the municipal building in Oost Watergrafsmeer, Amsterdam

19.6.3 Turby

Turbine type:	vertical axes turbine
Rotor diameter:	1,9 m, rotor height 2,8 m
Tower height:	5 m (variable according to the location)
Rated power:	2,5 kW
Electrical yield:	5.000 kWh at 14 m/sec
Noise production:	< 35 dB(A) op 20 m distance
Rotor weight:	80 kg
Roof load:	tractive power on 25 m height: 1,3 kN; load: 6 kN

Anchoring:	at a tower of 5 m: 4 fastening points on a surface of 4 x 4 m. the surface to carry the load of 10 kN a tractive power of 2 kN. We prefer the roof with the same length and width. Otherwise the tower must be higher.
Price:	€ 16.150 including the installation
Manufacturer:	Turby b.v., Lochem

Figure 58: Turby op the roof of a municipal office building in Bos en Lommer, Amsterdam

Remark: this is an example of a wrong location choice because of the high trees in from of the turbine.

19.7 Large wind turbines implementation

During the meeting of the 10th June, the possibilities of deploying the large wind turbines alongside the western edge of the sport-park and accommodations Ookmeer were discussed. The perception exists that the wind regime is suitable for the large wind turbines. The measurement of the available wind energy is not a costly undertaking and can be completed by a specialized firm. A contact with the utility company Nuon has taught us that Nuon recently investigated a location in Amsterdam South-east. The measurements have shown that the turbines in the built area would have the electricity yield for approximately 20% lower than it would be the case in an open area. An additional concern is the air traffic of the Schiphol airport.

19.8 Conclusions

- The MFSC Ookmeer can be made suitable for placing of small wind turbines, providing that the height of the turbines and the distance from trees and other obstacles would fall within the recommended values. More specifically, this implies that the climbing wall (on which the turbines would be placed) should be built half way the east (long) side of the multi-functional building. The turbine would be then exposed to the winds from the west and south-west directions. Additionally, the roof of the climb wall should be higher than the tree tops.
- The roof of the existing ALO building is high likely suitable for the placing of urban turbines. These because the building is higher than 20 meters and there are no high trees or other obstacles in the near vicinity.
- The feasibility of large wind turbines along the west side of the sport accommodation area should be investigated. The investigation in another part of the city has indicated that the electric yield would probably be significantly impacted and therefore the deployment of the large turbines would probably not be recommended.