URBAN WIND TURBINES

Technology review

A companion text to the Catalogue of European Urban Wind Turbine Manufacturers

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Contents

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1. GENERAL RESULTS

In order to compile the **Catalogue of European Urban Wind Turbine Manufacturers (July 2005),** over 45 wind turbine manufacturers from 15 European countries were contacted to provide information on their products. Of those, a small percentage (< 12 %) did not respond. A further 17 % of products that were researched were eventually not included in the catalogue because they did not correspond with the definition of "urban" wind turbines or because the product was still at the prototype stage and still several years away from being available on the market.

In total, **32 manufacturers** representing **57 wind turbine models** have been inventoried. Each of the turbines is detailed on a specific technical data sheet and is presented in the Catalogue of European Urban Wind Turbine Manufacturers. Of the inventoried turbines 65% were horizontal axis wind turbines (HAWT) and 35% were vertical axis wind turbines (VAWT).

2. SHORT PRESENTATION OF THE MANUFACTURERS

In terms of experience, the 32 manufacturers identified are not at the same stage of product development. Some manufacturers have been producing wind turbines for several years (such as Oy Windside, Ropatec, Proven, Fürlandër, Travere or WindWall) whereas others are working on close-to-market prototypes (Eurowind, Winddam, Ecofys, VR & Tech or TH Rijswijk).

Concerning the potential applications of the wind turbines in the urban environment some can be used **mounted on buildings** whereas others are only suitable for use as **installed on the ground**. Almost all the Vertical Axis Wind Turbines (Turby, Oy Windside, XCO2, Ecofys, WindWall, Venturi, Winddam, VR & Tech, etc.) can be building mounted as can some of the Horizontal Axis Wind Turbines (such as Atlantis, Proven, Eclectic Energy, Renewable Devices, Travere, Jonica Impianti, Fortis and Marlec). Some of the larger HAWT are only suitable for installation on the ground, such as the Iskra and Gazelle turbines.

It is only quite recently that wind turbine manufacturers have started to target the urban market, which explains why many of them do not yet have significant experience in urban surroundings. Those with the most urban experience are probably Aircon, Atlantis Windkraft, Jonica Impianti, Oy Windside, Proven, Gazelle, Turby and WindWall. Naturally, experience is not automatically synonymous with the most efficient machines.

3. THE URBAN WIND REGIME

Two things particularly characterise the urban wind regime: lower Annual Mean Wind Speeds (AMWS) compared to rural areas, and more turbulent flow. The lower AMWS are caused by the "rough uneven ground" created by buildings, street furniture and other features of an urban landscape, which cause wind speed to increase with height above the ground more slowly. The turbulent flow is a result of the wind interacting with the buildings and other obstacles.

Despite the advantages in bringing local wind generation to cities, the low AMWSs and turbulent flow have discouraged many people who may otherwise have been interested, as wind economics are very dependent on the available wind resource, i.e. the annual mean wind speed.

Turbulent flow presents challenges due to the rapidly changing wind direction, this produces extra stresses on the turbine blades and slows energy production (particularly if the turbine cannot react quickly to turn itself to take advantage of the new wind direction).

The options are to find a machine that copes well with turbulence, or to find the least turbulent areas of the urban environment. Of the latter, building-tops could show a great deal of promise, partly because the wind flow there could be substantially greater as it gets concentrated by passing around and over the building. Other less turbulent areas are open areas on the ground such as school playing fields or parks.

4. PERFORMANCE, STRENGTHS AND WEAKNESSES OF URBAN WIND TURBINES

The energy generated by wind turbines is governed by two "wind laws":

- Power generated is proportional to wind speed cubed. Doubling the wind speed gives eight times the power. Therefore wind speed at the turbine location is very important; and
- Power generated is proportional to the swept area of the blades. Doubling the rotor diameter yields a four-fold increase in swept area with a corresponding increase in power generation.

4.1. HORIZONTAL VERSUS VERTICAL AXIS WIND TURBINES

There is some debate over whether horizontal axis wind turbines (HAWTs) or vertical axis wind turbines (VAWTs) are most suitable for the urban environment and also which would be best for building mounting.

The advantages and disadvantages of the three main designs of small wind turbine are summarised in Table 1 below.

Table 1. Advantages & disadvantages of HAWTs, Lift VAWTs, & Drag VAWTs

	HAWTs	**Lift VAWTs**	**Drag VAWTs**
Advantages	1. Efficient 2. Proven product 3. Widely used 4. Most economic 5. Many products available	1. Quite efficient 2. Wind direction immaterial 3. Less sensitive to turbulence than a HAWT 4. Create fewer vibrations	1. Proven product (globally) 2. Silent 3. Reliable & robust 4. Wind direction immaterial 5. Can benefit from turbulent flows 6. Create fewer vibrations
Disadvantages	1. Does not cope well with frequently changing wind direction 2. Does not cope well with buffeting	1. Not yet proven 2. More sensitive to turbulence than drag VAWT	1. Not efficient 2. Comparatively uneconomic

(Randall 2003, Timmers 2001, and Clear Skies 2003)

Even though the objective of this analysis is not a direct comparison between horizontal and vertical axis wind turbines, it is worth noting that in the built environment where the wind flow is frequently turbulent, the vertical axis machines have the advantage of not needing to be directed into the wind. On the other hand horizontal axis turbines are more efficient in terms of conversion of wind energy to electricity when they are actually running.

An unmodified HAWT will work well where the air flow is less turbulent, on top of high buildings or near open spaces, but in more turbulent areas HAWTs would need to be made robustly in order to cope with blade-buffeting. The disadvantage of increasing the robustness of a turbine is that this will increase the turbine's weight and therefore also the cost. In fact, many of the HAWTs aimed at the urban market are heavy in comparison to surface area, probably for this reason.

4.2. RATED POWER AND RATED WIND SPEED

Wind turbines are most commonly classified by their rated power at a certain wind speed. The rated power is usually defined as the maximum power output and the rated wind speed is the wind speed at which the turbine reaches its rated power output.

The power range of wind turbines analysed was from 100 W to 100 kW with an average rated power of 8,2 kW. The majority of wind turbines were under 10 kW in power.

In the urban environment, where the average wind speed is lower than in open rural areas, it is an advantage for wind turbines to reach their rated power at the lowest wind speed possible. This means they will produce maximum power for longer periods of time. The following table gives the percentage of urban wind turbines achieving a rated power under a certain wind speed.

Rated wind speed	%
Have a rated wind speed < **11 m/s**	26
Have a rated wind speed **≥ 11 < 13 m/s**	46
Have a rated wind speed **≥ 13 < 17 m/s**	21
Have a rated wind speed **≥ 17**	7

4.3. CUT-IN WIND SPEED

The cut-in wind speed is the wind speed at which a turbine starts to operate and produce electricity. Usually, wind turbines are designed to start running at wind speeds of 3 to 5 metres per second but some can cut-in at lower wind speeds and particularly small wind turbines usually have lower cut-in speeds.

Again, in the urban environment where the average wind speed is low, wind turbines capable of starting to produce energy at low wind speeds will have an advantage in terms of total energy production. The following table gives the percentage of urban wind turbines which start producing electricity at certain wind speed.

Cut-in wind speed	%
Have a cut-in wind speed < **3 m/s**	47
Have a cut-in wind speed **≥ 3 < 4 m/s**	38
Have a cut-in wind speed **≥ 4**	14

4.4. CUT-OUT WIND SPEED

The cut-out wind speed is the wind speed at which the turbine shuts down. At a high enough wind speed the turbine shuts down to protect the rotor blades, the generator and other components from failure. No power is generated above the cut-out speed.

To prevent mechanical failure of an operating wind turbine, the system must have safety features that de-power the turbine if the wind speed is too high. Four principles are used to control and minimise rotor speed:

1. Passive stall control: the turbine blades are designed so that at high wind speeds the naturally stall, loosing some power. The higher the wind speed, the more they stall.

2. Active pitch control: the turbine blades are actively pitched by the machine to reduce the energy they capture. This done either by either pitching the blades to feather by reducing its angle of attack with the wind, or by pitching it to stall by increasing its angle of attack.

3. Yaw or Tilt control: the rotor axis is either actively or passively shifted out of the wind. In Yaw Control, the nacelle is rotated to place the turbine's profile to the wind. In Tilt Control, the nacelle cants back until the axis of rotation is perpendicular to the ground.

4. No control: the mechanical and electrical designs are robust enough to withstand all wind conditions.

In the case of the 57 wind turbines in the catalogue, most can withstand extremely high wind speeds and are designed in such a way that they do not shut down at any wind speed. The following table gives the percentage of urban wind turbines that have a cut-out wind speed in certain wind conditions.

Cut-out wind speed	%
Have no cut-out wind speed	54
Have a cut-out wind speed ≥ **20 m/s**	36
Have a cut-out wind speed ≥ **15 < 20 m/s**	7
Have a cut-out wind speed **≥ 10 < 15 m/s**	3

4.5. SELF STARTING TURBINES

Some wind turbines use electricity to bring them up to the required starting speed. In this case, the power from wind turbines is not totally renewable, as the turbines need to consume a small amount of grid electricity in order to start-up. It is much better when the turbine uses wind as the sole source of energy.

Almost all the urban wind turbines inventoried are self-starting turbines. The following table shows the percentage of urban wind turbines that are self-starting or not:

Self-starting turbines	%
Wind turbines that are self-starting	95
Wind turbines that are not self-starting	2
Wind turbines for which no indication was available	3

4.6. NOISE

Any machine with moving parts will make some sound and wind turbines are no exception. However, they are designed to minimise noise and although most do make some noise, it is not enough to be objectionable for most people. Well designed wind turbines are generally quiet in operation and compared to other daily activities, produce very low noise.

With wind turbines, there are two sources of noise: aerodynamic noise may be created by the flow of air over and past the blades of the turbine, and mechanical noise is produced by the gearbox and the generator in the head.

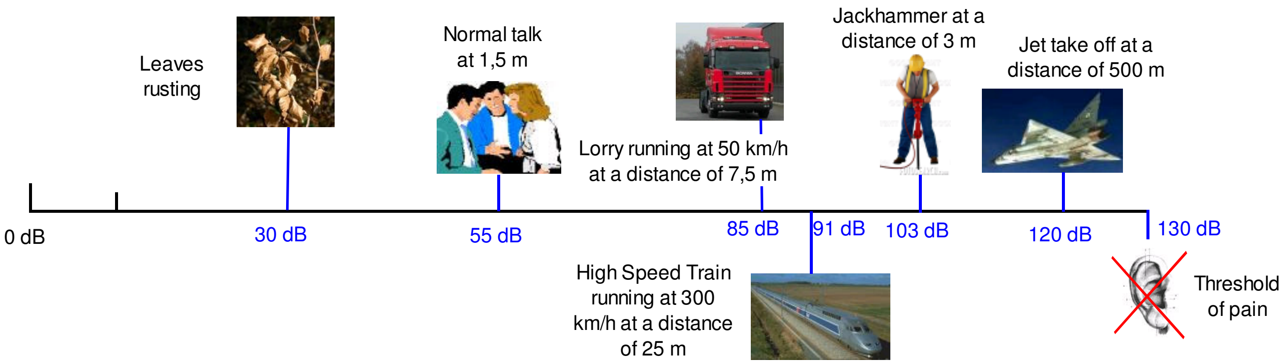
However, noise from the blades and gearbox can be reduced by careful attention to the design and manufacture of the components and the noise from the generator can be minimised with good sound insulation within the turbine head.

There is not a great difference in noise levels between a HAWT and a VAWT, although in general VAWT are regarding as more silent for the two following reasons:

- The blades do not create the usual whooshing noise that occurs with HAWTs when the blades pass close to the mast at each revolution; and
- VAWTs usually operate at lower speeds.

Many small wind turbine manufacturers have not yet carried out any noise testing on their machines. However, the data obtained from those who had is shown in the table below and reveals quite good results.

Noise	%
"Not audible" at the top of the turbine, with a wind speed of 5m/s	26
≤ **to 40 dB** at the top of the turbine, with a wind speed of 5m/s	37
> **40 ≤ 60 dB** at the top of the turbine, with a wind speed of 5m/s	24
> **60 ≤ 80 dB** at the top of the turbine, with a wind speed of 5m/s	13



4.7. LIFE TIME

Modern wind turbines are generally designed to work for around 120 000 hours of operation throughout their design lifetime of 20 years. However, the actual lifetime of a wind turbine depends both on the quality of the turbine and the local climatic conditions, e.g. the amount of turbulence at the site.

The following table gives the percentages of the inventoried turbines with different design lifetimes. An important majority have a designed lifetime between 20 and 25 years. However, because many urban wind turbines are relatively new products not enough time has passed to be able to verify manufacturer claims regarding lifetime of their wind turbines.

Life time	%
Life time of the wind turbine > **25 years**	5
Life time of the wind turbine > **20 ≤ 25 years**	68
Life time of the wind turbine > **15 ≤ 20 years**	20
Life time of the wind turbine > **10 ≤ 15 years**	7

4.8. MAINTENANCE

Generally speaking, there is little maintenance requirement for urban wind turbines. Although more than 40 % of the manufacturers interviewed consider that their wind turbines do not require any maintenance, a majority have mentioned the need for lubricating the bearings twice or once a year and to carry out an annual check in order to keep the turbines in good working order. This should be relatively quick and easy.

In addition to this there are other things one can do to optimise operation:

- Replacement of spy joints every 3 to 5 years (depending on the turbine and on the environment - maritime or continental ;
- Checking brushes and slip rings (according to some of the manufacturers interviewed, brushes may perish over 5 to 6 years) ;
- Checking nuts and bolts ;
- Checking the support connections to the building once a year and after any severe weather conditions (in the case of a building-mounted turbine); and
- Potential replacement of the shaft seals after 5 years (depending on the turbine).

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