WIND ENERGY IN BUILDINGS

Power Generation from Wind in the Urban Environment - Where it is Needed Most

Although the 'roughness' of the terrain in urban environments can mean a reduced and more turbulent wind flow compared to open spaces, urban wind speeds increase the further you are from the ground. Mounting turbines at high points on buildings may provide the perfect opportunity for onsite generation from wind power. Designers are working to harness as much of this power as possible and visionary new designs are starting to become a reality. Emma Dayan, BRE UK reports.

Today wind power is one of the fastest growing industries in the renewable energy sector. The EU wind market grew by 6% in 2005 and the capacity installed has already exceeded the target of 40GW set out by the European Commission White Paper (1997). People are becoming accustomed to the sight of turbines on mountains and stretching into the sea. However, a relatively new sight is that of wind turbines mounted on, or integrated into buildings. This is an area where there is seen to be great potential. A recent UK study part funded by the Carbon Trust estimated the potential annual carbon dioxide savings by 2020 to be in the range 0.75-2.2Mt CO_2[1]. The extent to which this potential is realised obviously depends on manufacture and installation rates in both retrofit and new build buildings.

Wind energy in buildings involves many different challenges to stand-alone wind systems. By definition the turbines will generally be in an area of turbulence due to being in an urban environment, and this can reduce output and increase stress for turbines not designed to operate in these conditions. Society demands that the turbine integrates smoothly to the building, both structurally and visually, and creates minimal noise. The output of a wind turbine is limited by what is known as Betz's limit, which limits the power coefficient to 59.3%. Designers have gone down many different paths to design turbines to approach this efficiency. Small scale stand alone turbines are starting to approach this limit, but the relatively new area of building integrated turbines are often well below this. The power output is proportional to the cube of the wind speed, meaning as the wind speed doubles the output increases by a factor of 8. This explains why it is so important to make sure the wind flow coming into contact with the turbine is the highest possible. In the development of rooftop and building integrated turbines much modelling has been done to simulate how different turbines perform with turbulent wind flows. Computational Fluid Dynamics, traditionally used to model wind speeds around buildings in view of the effect on pedestrians, for example, is now starting to be used to help design and locate turbines in and around buildings.

The recent installation at the CFS tower in Manchester

There are three categories that existing wind energy in buildings can broadly be

Author information

Emma Dayan is a consultant at the Building Research Establishment (BRE) based in Watford, UK. The BRE regularly runs events on the sector covered in this article. Anyone wishing to find out more information should visit the events page of the BRE website at: www.bre.co.uk

divided into. The most common is the horizontal axis wind turbine (HAWT). As its name suggests, the turbine blades rotate around a horizontal axis like traditional windmills. This is the model that people will be most familiar with and is well established in the stand-alone market. An alternative option is the vertical axis wind turbine (VAWT). There has been significant progress in VAWTs over the last few years and there are some that suggest that these turbines are better suited to the built environment than the HAWT due to their better performance in turbulent wind flow[2]. Finally there is seen to be much potential in building augmented wind turbines (BAWT). This approach is quite different from those described above, in that the turbines are designed and installed to make use of the building as a concentrator of the wind.

The Swift turbine developed by Renewable Devices Ltd

Existing technologies

Wind energy in buildings is seen as an exciting challenge for designers and engineers and this is reflected in the range of different approaches that are taken. On-site generation is becoming an increasingly popular alternative for commercial buildings, for example the Cooperative Financial Services building in Manchester has commenced installation of 16 turbines on its roof, being one of the first mini wind farms on a building in the UK. There is seen to be much potential for multiple installations on one building meaning the power output could meet a significant percentage of the energy demands of the building. HAWTs are currently the most common type of turbine seen in buildings. All over the world manufacturers already established in the small scale stand alone market are expanding their models to be mounted on buildings such as the leading Dutch small wind turbine manufacturer Fortis. The Southwest Windpower AIR series offer many of their models with a roof mount option and this is by no means the only small wind company in the US to offer rooftop solutions. In the UK a number of roof mounted HAWTs are now available on the market. One of the most talked about products is the Swift turbine developed specifically to be mounted on rooftops by Edinburgh based company Renewable Devices. This rooftop mounted machine is rated at 1.5kW and its characteristic black rim of 2.1m diameter helps the turbine to make minimal noise. A recent study on domestic roof-mounted wind turbines by the Mid Wales Energy Agency calculated the payback of the Swift turbine to be 8 years, excluding any grants[3].

Already well-established in the marine market, Eclectic Energy has designed the 'D400 StealthGen' which is small and light enough to be attached to most building structures. The company estimates that this will produce an average of 1.8kWh of electricity per day. It is estimated that the average family household uses approximately 10kWh per day[4]. Another product that has recently come to market is the Windsave *Plug 'n' Save* system. The company, based in Edinburgh, was formed in 2002 and has since gone on to widely market the Windsave turbine specifically designed for use on rooftops. The first few installations are now in place and it is claimed that payback for the system is less than 5 years[5]. The Scottish company Proven Energy Ltd is established worldwide for their small turbine manufacturing and installation, with turbines installed in over 30 countries. Recently they have started to install their turbines on buildings with examples in the UK and Japan. Among the smaller scale turbines are companies such as Monodraught, Marlec and Ampair all of whom are rapidly expanding their products to building integrated applications. The UK company FreeGEN is exploring another option and has designed a turbine which itself augments the wind speed. Its Combined Augmented Technology Turbine has a novel concentrator design.

Another generation of wind turbines that are being developed for application in buildings are the VAWTs. The concept of using a vertical axis rather than a horizontal axis has been around for some time, with one of the first examples being the Darreius turbine invented in 1931 by the French engineer George Darreius. Since then a number of manufacturers have designed turbines

The Windsave turbine


Two rooftop mounted Proven turbines

around a vertical axis which has proved to have some advantages for integration into buildings. Some examples of development of VAWTs are present in The Netherlands. For example the WindWall VAWT system has been installed on a number of sites to test its performance with the intention being that a number of these systems are aligned horizontally along a building edge forming a wall. Another Dutch company Ecofys BV has developed a series of Urban Turbines, which it claims are not sensitive to changes in the wind direction or speed. Delft Technical University is also very active in this area and has designed a roof mounted turbine, the Turby which is a Darreius type turbine with twisted axis. The Ropatec wind turbine developed in Italy is a robust VAWT that has been installed in sites all over the world. The turbines can be stand alone or mounted onto the roof of buildings and examples of both are installed in various locations across the world. In the UK two small companies have made exciting developments in this field. Winddam has developed a vertical axis turbine which makes use of the inherent strength of the building to intercept and use the wind energy. The design also uses sustainable wood laminate blades. XCO2 has developed the 6kW *quietrevolution* vertical axis wind turbine. This has been going through pre-production testing and the first installations are planned for early 2006. An option offered by XCO2 is the inclusion of LEDs on the blades which create an interesting visual effect at night.

Building augmented wind turbines is a concept that has been developed over a number of years, and is seen as having great potential for new buildings. The turbines are located so as to make the most of the high wind speeds that occur right next to the building. For retrofit applications the turbine can only make use of any existing augmentation of the wind that is caused by the building. However, for new build the building could be designed to specifically augment the flow through the turbines. The type of turbine used and where it is located is up to the designer. Research in Holland at TU Delft has looked at many different designs including location of the turbine between diffuser shaped buildings, location in a duct through a building and location on or alongside a building. Research by Sanders Mertens concludes that the option of locating between diffuser shaped buildings is not as promising as the other two[2]. One important project has been the design of the WEB Concentrator which was designed by a consortium within the EC funded Wind Energy in the Built Environment project. The project tested two turbines with concentrators and resulting yields were very promising. The WEB prototype successfully demonstrated the technical viability of achieving augmented wind power generation. EU Energy WingPower Limited's patented *Aeolian Roof*^{TM} has been developed from their work on concentrator systems. It consists of a suitably shaped roof with the addition of a wing to enhance the wind speed along the topmost region of the building. This increases the wind energy available at the top of the roof and thus makes it a suitable location for wind turbines. Architects are also starting to consider the possibility of embedded generation in their new build designs. The firm Battle McCarthy has produced a number of inspiring designs incorporating wind turbines into the building.

Challenges ahead

Many argue that this sector's biggest challenge, and one that the large scale wind industry has also had to battle with, is public acceptance and confidence in the technology. This issue is broadly centred on two aspects, which are brought much closer to home with building-integrated systems: the visual effect of installing 2m diameter turbines on a conventional or traditional-build house, and the structural safety of the installation. By definition a wind turbine attached to a building will transmit vibrations to the fabric of the building. Any effect that this will have on the building or building users needs to be tested and certified, in order that such installations do not void the insurance cover for the building and more fundamentally that consumers, both commercial and private, have confidence their building and its occupants are not at risk from the wind turbine. Accreditation and testing of the turbines is an area still under development, hence there is hesitancy in the market compared with other roof-integrated renewable technologies such as solar thermal and PV. Currently there is a lack of standards to assure that a turbine is either meeting the requirements for safe installation and operation or whether once installed it produces its expected output yield. While most systems will perform more or less to their manufacturer's estimates, it is still difficult to compare one system's suitability against another to a particular installation site.

At the Building Research Establishment (BRE) testing facilities are being set-up for structural and performance testing of rooftop and wall-mounted wind turbines,

The Urban Turbine developed by Ecofys UK

particularly in low and variable winds consistent with an urban situation. Using its experience in running the Clear Skies funding programme, including the accreditation scheme for small-scale wind products and installers, BRE aims to assess a number of currently available models, and produce performance data that could ease the concerns of sceptical customers. Safety issues, namely the safe containment of any failed rotor are very important and in some cases the steps taken to deal with this are designed to visually reassure onlookers. For example the WindWall system has an outer metal casing that will contain any parts of the rotor should they become detached. Noise from turbines also needs to be considered and depending on the site that is chosen there will be more or less toleration to noise. The ideal case is always to have minimum noise from the turbine, and many designers are striving to achieve turbines that turn almost silently. This is still a very young industry and consequently money and time need to be invested in research and development of the technology. A recent UK report identified some of the main technical barriers facing the sector as the need to develop understanding of power augmentation and ducting, and the need to design for high turbulence levels[1].

One issue that all microgeneration technologies are now facing is that of metering electricity generated. To an extent feed-in tariffs are proving a successful incentive for the uptake of renewable energy technologies in a number of European countries. In the UK, where there is no set feed-in tariff, some electricity suppliers such as Good Energy will pay a small generator a set price per unit of electricity generated. Since metering requirements can be expensive, the situation can occur where for a fairly small turbine the cost of the meters could exceed any financial gain from the system. Claiming Renewable Obligation Certificates (ROCs) also requires a certain level of metering which can make this process complicated. There is a general consensus that grid connection measures are not adapting as fast as the technology is being installed and developed[6]. Although the most economical situation is to use all the electricity generated in the building all the time, practically this is not always possible, and so a fair and simple method of payment to all embedded generators is essential. As with any expanding industry, cost is always key to its success. Typically, renewable energy technologies have an image of being costly to buy and install. However, with the current trends in energy prices increasing on a global level, and energy security rising up the political agenda, it is becoming more attractive to generate your own electricity. Generally maintenance costs are relatively low and a typical expected lifetime of a turbine is 20 years. There are various grants available and it is likely that as demand increases costs will fall.

Planning permission generally needs to be obtained to install systems on buildings. Although this has traditionally been a frustrating barrier in the past, planners are starting to be supplied with more information about wind turbines on buildings and it is hoped that this will be less and less of an issue.

The future...

The advantages of having embedded generation close to demand have been proven and wind power in buildings is beginning to be seen as an opportunity for supplying this demand. Although the urban environment gives rise to a more turbulent and reduced wind flow, turbines are being designed to operate in these conditions. Location on buildings can make use of the higher wind speeds above street level and the building itself can even be designed to augment the wind speed. Since the highest wind resource will often occur in winter months, wind power can be a very good complement for solar power, and this opportunity is being exploited by a number of companies. There is an exciting future ahead for wind energy in buildings, as many visionary designs are starting to become reality. A crucial issue that this sector must now address before moving into large scale market activity is that performance claims from manufacturers are verified. This is essential for consumer confidence and to establish a high quality of products.

References

1. The Feasibility of Building-Mounted/Integrated Wind Turbines (BUWTs), A G Dutton, J A Halliday, M J Blanch, Energy Research Unit, CCLRC and contribution from partners, May 2005

2. Wind Energy in Urban Areas, Sanders Mertens, Researcher Wind Energy and Wind Technlogy in the Built Environment, Delft University of Technology, March/April 2002 Refocus

3. Domestic Roof-mounted turbines, a publication for the RES-e project, Mid Wales Energy Study

4. Technical specification on Eclectic Energy website: www.eclectic-energy.co.uk

5. Technical specification on Windsave website: www.windsave.com

6. Small scale, building integrated , wind power systems IP 05/12, Emma Dayan, BRE 2005