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Integrating Wind Turbines in Tall Buildings

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Ian Bogle
A founding director of the practice, Ian has led two pioneering projects in recent years - Strata SE1 and Park House – the former now complete and the latter scheduled for completion in 2013. While Strata is the first residential building to integrate wind turbines which generate electricity on site, Park House integrates retail, office and residential space in an innovative building set to revitalize the Western end of Oxford Street.

Ian studied architecture at the Mackintosh School of Architecture, and subsequently worked with the Parr Partnership in Glasgow where he qualified as an architect in 1993. After joining Foster + Partners in 1995, he worked on a wide range of projects, including the Scottish Exhibition and Conference Centre, the Dubai Cultural Centre and Farnborough Business Park. As Project Director, he was responsible for the Bexley Business Academy (short-listed, 2004 Stirling Prize) and had a critical design role on the delivery of London's Swiss Re Headquarters (winner, Stirling Prize 2004). Ian is also an active ambassador for BFLS abroad, in particular overseeing the practice's Prague office where he is responsible for a large landside airport master plan, a mixed-use urban master plan at Žižkov and a number of luxury residential projects. He has a special interest in major education/research projects such as the ELI Laser Research facility near Prague, due on site in 2011, and infrastructure projects such as the consented scheme for the Southern Concourse at Reading Station.

"Should turbines be deployed on every building? Probably not, but I'm sure in time there will be more pioneering examples of project collaborations resulting in highly innovative solutions."

The world is constantly changing. Our energy demands are increasing daily and global population is expected to increase by another 50% to 9 billion people by 2050. Traditional consumption of non-renewable natural resources continues at an alarming pace, with carbon pollution contributing significantly to global warming.

Perched some 3,350 meters (11,000 feet) up a volcano, the Mauna Loa observatory in Hawaii has been measuring CO_2 in the atmosphere since 1958. The Mauna Loa readings, made famous in Al Gore's documentary "An Inconvenient Truth," show an upward trend as emissions pour into the atmosphere and, each spring, the total CO_2 level creeps above the previous year's high to set a new record. Scientists at the observatory claim that CO_2 levels in the atmosphere now stand at 387 parts per million (ppm), up almost 40% since the industrial revolution and the highest for at least the last 650,000 years.

Figure 1. Strata SE1, London © Will Pryce

There is still time to effect a tangible change if we act soon. We do have a choice.

Governments across the world are taking note and as a result building legislation is aligning itself to reduce CO_2 emissions. Investors, developers and occupiers look to designers and engineers for innovative solutions that will meet these requirements through gradual change.

As part of this initiative, in London, there is now a town-planning policy guidance requirement for providing a reasonable percentage of on-site renewable energy within new developments to meet part of the building's energy load requirement.

However, that percentage can be widely different in terms of the actual energy quantum and is directly correlated to the building's use. Traditional energy demands for differing building types drive higher or lower load requirements. In general terms, for example, traditional retail malls have greater loads than residential schemes. Architects and designers across the globe are encouraging developers and occupiers to improve their operational requirements with respect to energy solutions.

We all have a duty to consider how we use energy in our daily lives. Do we share common resources or each use our own? Location dictates a great deal of how we live our lives. As an example, I live in Central London and therefore use public transport to get around – there is little need for a private car.

There is a step change mantra in London policy which looks at energy philosophy as a sequence of three simple steps: Lean, Clean and Green.

- Lean is a question of required consumption – that is, how much energy do we really need to perform the daily duties within our working and living environments.
- Clean is a question of how we can use the most energy efficient equipment to deliver our energy demands.
- Finally, Green looks to utilize a renewable energy source in order to provide a percentage of the energy supply within a given development.

Considerations for each approach varies across every project we undertake depending on site location, constraints and the Client's Brief and Program. In this particular context, no single solution fits all, so the final choice becomes a question of appropriateness.

Wind turbines in buildings are not the only solution for addressing these issues but when project drivers are aligning towards that solution they do offer a green – and visually stimulating – source of energy.

For the Strata SE1 project – Central London's tallest residential development (see Figure 1) – the design team considered the feasibility of a number of options in order to find the most appropriate Lean, Clean and Green solutions.

By virtue of being a residential building the overall energy consumption loads are considerably less than a similar sized retail or commercial office development and therefore the possibility of attaining the desired percentage of on-site renewable energy is an achievable requirement.

Design Solutions

The first point to establish is that we didn't set out to design a building with wind turbines – they arrived through an intensive series of design considerations, evaluating each available renewable option on its own merits and in the context of the site and a tall building (see Figure 2).

Ground source water solutions were considered but the extreme constraints of the site meant that the water pools would not be sufficiently distant from each other to prove practicable. In addition, energy savings would be dissipated when pumped through the height of the entire building.

Photo voltaic solutions were also considered, but the technology available at the time (2005) would have resulted in 80% of the southern elevation being covered with photo voltaic (PV) cells, severely compromising the quantity of glazing necessary to provide adequate day-lighting into and views from the apartments. Commercial issues prevalent in 2005 would also have made this option too expensive, added to which photo voltaic have a limited shelf-life of circa 15 years and need to be kept scrupulously clean. This solution would have had significant implications for service charges. Integrating photo voltaic would also have adversely inflated the cost of the façade per square meter.

Equally, biomass boiler solutions were discussed but the continual energy costs associated with the transport and delivery of the fuel, and the availability issues of such fuel, together with the requirement for a 150-meter (492-foot) flue running the entire height of the building – meant that this solution was discounted.

As such, a number of factors pointed towards a wind-based solution for the building.

Orientation

The building's orientation and concave southern elevation – a direct result of respecting the daylight requirements of the neighboring properties – produced a number of positives. The wind rose for London has a predominantly south-westerly axis in summer-time and the curved elevation was suitably oriented to capture wind from this direction (see Figures 3 and 4).

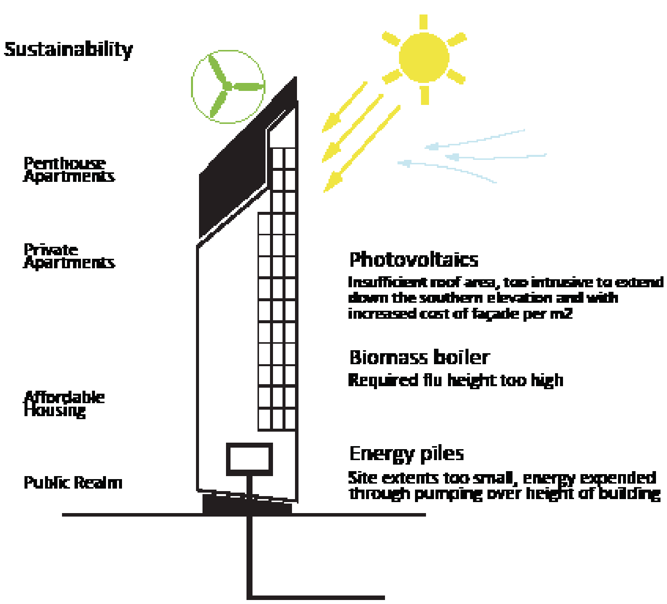

Figure 2. Sustainability options © BFLS

Figure 3. Harnessing wind study © BFLS

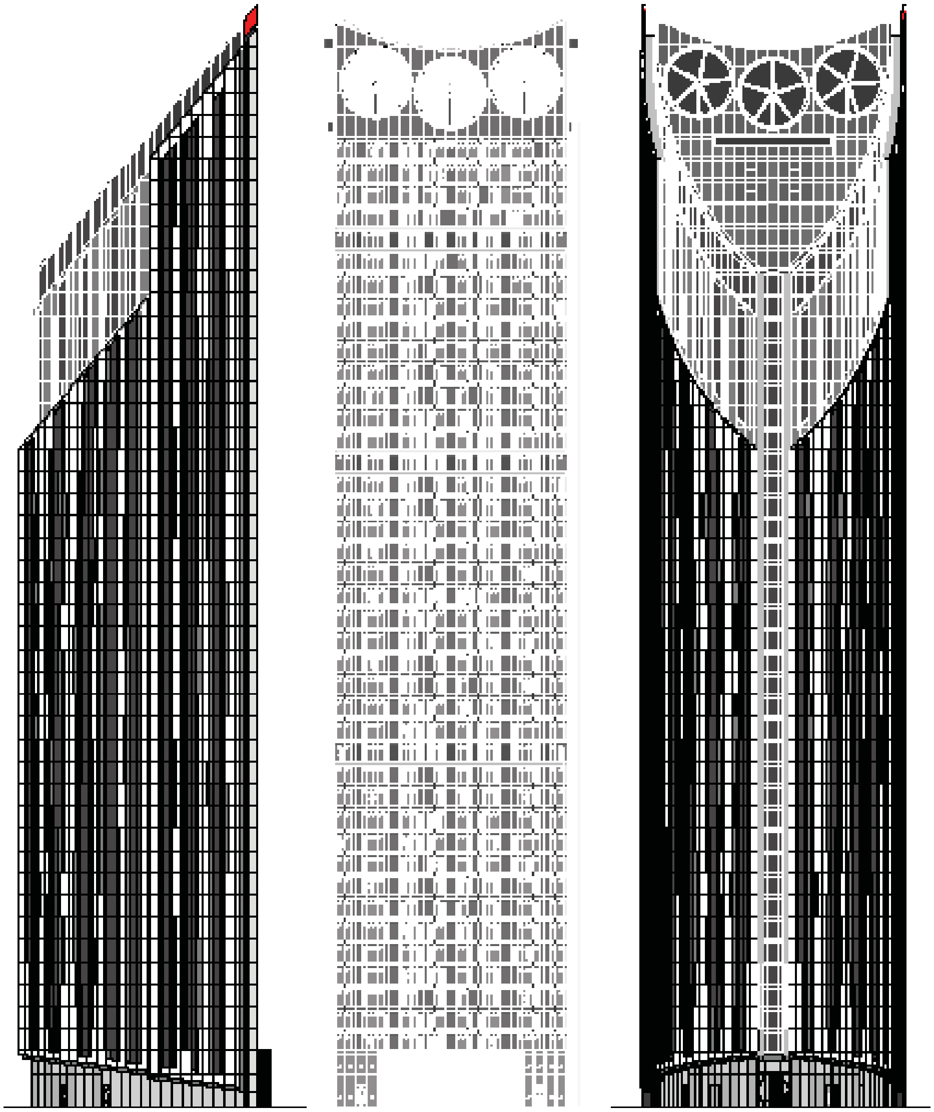

Figure 4. Elevations (from left to right) west, south, and north © BFLS

Wind speed at altitude

Urban wind speeds also vary by altitude and as an example it can be common for wind speeds to increase over a height of 150 meters (492 feet) by up to 5 meters per second (16.5 feet per second) (see Figure 5). This condition is enhanced by the fact that most of South London has few significant high-rise structures to obstruct the accelerated wind patterns at this altitude. Thus, a calm pedestrian-friendly environment at grade can be very different to that encountered 150 meters (492 feet) up in the sky – providing a natural resource that can be converted into energy.

Once the decision was taken to proceed with a wind-based solution at height within the building's envelope, the team embraced this as an opportunity to develop an integrated solution which then became the central motif for the building. A pioneering set of design decisions in turn highlighted a number of issues associated with building-integrated wind turbines.

Harnessing wind

When considering introducing wind turbines as a site-based renewable energy solution, focusing and directing the wind is a key design factor which can significantly enhance

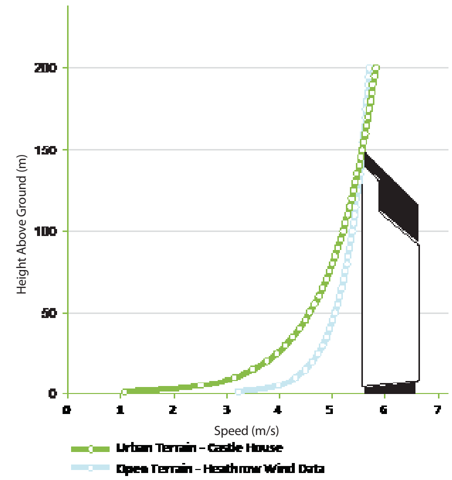

Figure 5. Urban wind speed study © BFLS

the potential operational output of the wind turbines.

The design solution for Strata SE1 is in fact a further iteration of that adopted for the Bahrain World Trade Centre (the first building to explore building-mounted wind turbine technology), also using the principles of a "venturi" to guide wind flow, but in that case between the two towers. There are other important differences too – notably the scale of the project, the fact that the three turbines are externally mounted on link bridges and its desert location, which necessitated full air conditioning which helped combat any adverse acoustic effects.

The Pearl River Tower in Guangzhou also utilizes a controlled path for the direction of the wind. A pair of openings in the façade channel prevailing wind to power the turbines which in turn generate energy for the building.

Performance

The required performance of a wind turbine solution for buildings will vary according to type. In the instance of the design load requirement for Strata SE1, the overall output requirement is 50 megawatt-hours of electricity per year.

This equates to around 8% of the building's total energy consumption and, at the time of writing, represents a microcosm of average global renewable energy production. This doesn't sound significant, but this figure is set to increase over time as more energy suppliers look to renewable methods of production. Germany for example currently produces 16.5% of its energy requirements through renewable technologies.

In the case of Strata SE1, with the inevitable caveat that wind as a source of energy is inherently variable, the anticipated energy produced could be sufficient to satisfy the demands of 32 apartments within the development.

The wind turbines are each rated at 19 kilowatt and the optimal operational wind speed for the turbines is in between 8 and 16 meter per second (26 and 52 feet per second).

The three wind turbines are each mounted with a Venturi-like enclosure. This was to achieve three things: to channel the wind, to control noise and to integrate them within the form of the building. This leads to the adoption of a static solution for the orientation of the wind turbines.

The inevitable disadvantage of opting for a static turbine solution is that there is an automatic reduction in performance, as the set-up can only operate when the wind is blowing from the right direction. In Strata SE1's case this takes advantage of the summertime prevailing winds blowing from the south west.

Size

Wind turbines become more efficient the larger they are – the 160-meter (525-foot) diameter examples seen in off-shore coastal or on-land rural locations are far more productive than their smaller-scale urban counterparts.

In the case of Strata SE1, a single 15-meter (49-foot) diameter turbine would have been just as effective as the three 9-meter (30-foot) units. However the commercial consideration of the loss of two stories of prime residential floor area is a difficult balance for any developer. Similarly, raising the building by an additional two floors would have contravened existing planning regulations: the overall height of the building was defined by working within the London's View Management Framework, a guidance document on protected and significant views across London. Tall building solutions invariably are located in the foreground or backdrop of these views.

Structure

The concept of placing self-supporting pieces of plant equipment on a building is not new and there are a number of parallels between a conventional chiller and a relatively small wind turbine. Load paths need to be controlled and transferred through the building and vibration needs to be isolated.

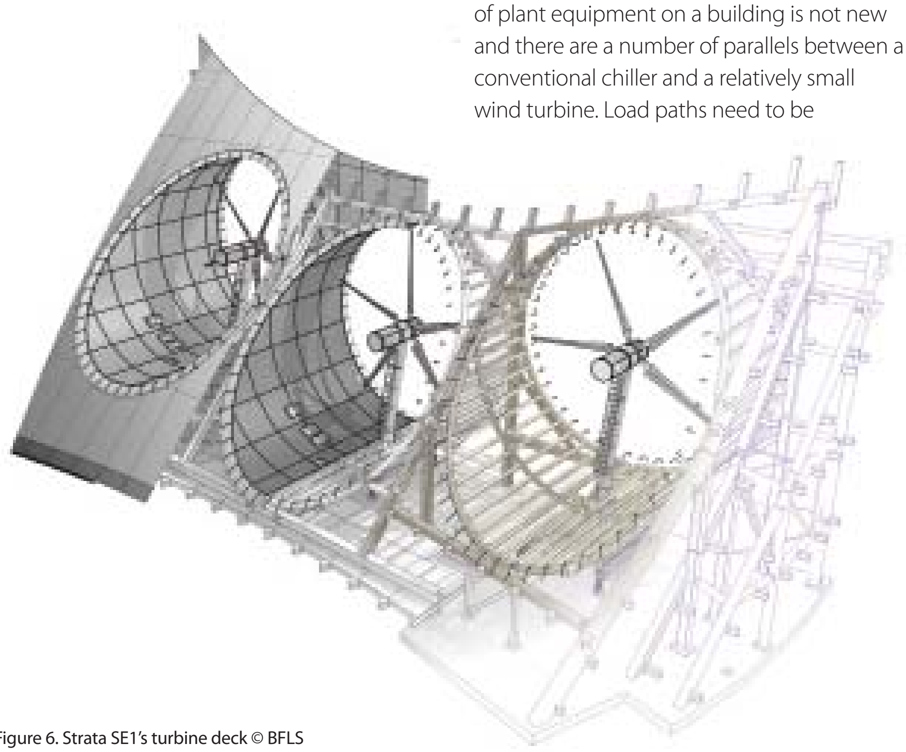

Figure 6. Strata SE1's turbine deck © BFLS

...1 in 1,000

"If this is a 1 in 1,000 year quake, then should we make buildings with a nominal design life of 60 years and bridges with a design life of 120 years?"

Hossein Rezai, Managing Director of Web Structure, Malaysia commenting on the devastation of the earthquake in Christchurch. From "Codes Challenged by Christchurch Quake," NCE, March 3, 2011

On Strata SE1, working alongside structural engineer WSP Cantor Seinuk, a turbine deck was proposed which is very similar to a conventional plant floor (see Figure 6). Each turbine mast is mounted onto a series of inertia damping pads – in essence a larger version of those used in domestic washing machine appliances.

Acoustics

The turbines do generate noise, as would any other typically roof-mounted piece of plant. However, the Venturi-like enclosures actually focus the noise into two sound cones away from the apartments immediately below. All measures to control and minimize sound generation were considered and in some instances these measures actively enhanced performance. Careful positioning of the turbines on plan within the Venturi-like enclosures has a positive effect both in the overall performance and in controlling noise output. In addition, opting for a five-bladed turbine as opposed to the more conventional three-bladed turbine used on larger versions offered further noise reductions (see Figure 7).

Safety

The safe operation and risk-management associated with wind turbine installation

Figure 7. Strata SE1's five-bladed turbines © BFLS

was carefully considered. The global knowledge deployed on the project ensured that numerous checks and devices were deployed to guarantee the safety of the building's occupants and neighbors during and after construction. Brookfield Multiplex Europe led this part of the development of Strata SE1's wind turbine design development.

Installation

As soon as the decision was made to proceed with a wind energy solution we were committed to developing a fully integrated design solution. Coordination of numerous specialist trades was essential across all constituent parts of the design including: the steelwork enclosure, the cladding at the top of the building, the Venturi cladding, the wind turbine Venturi themselves, and finally access requirements throughout the construction period and beyond for routine maintenance.

The final result is a testament to the importance of meticulous coordination, with each component playing its part to enhance the overall solution. It's a tangible demonstration that the whole can be greater than the sum of the parts.

Conclusions and After Thought

Renewable energy production is here to stay whether by solar, wave or wind farms. Thirty years from now the balance of energy production will be providing some interesting results and I'm sure renewables will be approaching 20%. I'd like to think that it will be closer to 50% and hopefully – through some joined-up thinking – this will be the case.

The question of whether buildings should produce the energy is of course a very difficult question. As a hypothetical example, it would be amazing if all domestic solutions 30 years from now were utilizing hydrogen fuel-cells.

A white paper prepared by Southbank University and Brookfield Europe will monitor the performance of Strata SE1's turbines over a two-year period – the results of which should give a more detailed analysis of their performance. We shall have to wait and see what the final verdict is.

Finally, I have always been hugely inspired by Isambard Kingdom Brunel's vision and bravado. He was so convinced of the performance of his pioneering small screw propeller versus the traditional paddle steamer that in 1845 he orchestrated a public tug of war to prove the point, pitting the screw-driven HMS Rattler against the paddle-wheeler HMS Alecto. Indeed the screw propeller duly won the day, which surely proves the point that we should always take on pioneering challenges when they present themselves.

Should turbines be deployed on every building? Probably not, but I'm sure in time there will be more pioneering examples of project collaborations resulting in highly innovative solutions. I would certainly relish the challenge because if we don't ask the difficult questions we'll never find the simple solutions.

"The answer, my friend, is blowing in the wind?" Maybe… ■