Mid-size turbines have big advantage in output relative to visual impact

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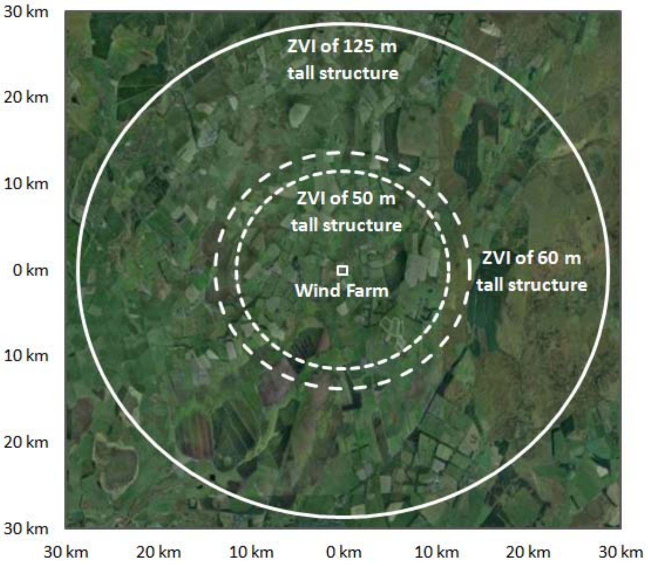
Visual impact of wind farms is a major barrier to their development in many parts of the world, notably England. For example the UK Government is presently erecting commercial and planning impediments to onshore wind power, fuelled largely by political opposition from Conservative Party members who view wind turbines as intruding on “England’s green and pleasant land”.

Given the benefits of onshore wind power (it is the least-cost form of large scale renewable power generation and has virtually zero carbon emissions), this is a lamentable case of conservationism outweighing environmentalism. Indeed the issue comes down to a form of benefit:cost analysis – the critics of wind power’s visual impact frequently cite the magnitude of its impact relative to its environmental benefit, i.e. the MWh of electricity produced with zero carbon emissions.

This raises a very valid question – how does this particular benefit:cost ratio vary with turbine size? Vertical scale is the important determinant of visual impact. We humans, ordinarily less than 2 metres tall, live in a basically horizontal world and only see things in the distance if they obtrude above our local “flat earth” environment. Thus “obtrusiveness” is synonymous with vertical dimension in this context. And the appropriate vertical scale for comparing obtrusiveness is an angular scale, since the eye perceives things to be of equal visual impact if they subtend equal angles (even if they are of different size and at different distances). The comparisons that follow are for a zone of visual impact (ZVI) defined as theoretical visibility within a radius around the wind farm that corresponds to 0.25 degrees of vertical angle.

It can readily be shown that, on flat terrain:

- a wind turbine 50 m high subtends 0.25° at 11.5 km, thus has a circular ZVI of **413 sq.km**
- a wind turbine 60 m high subtends 0.25° at 13.8 km, thus has a circular ZVI of **594 sq.km**
- a wind turbine 125 m high subtends 0.25° at 28.7 km, thus has a circular ZVI of **2,578 sq.km**



The accompanying image clearly shows the large differences in ZVI of mid-size vs. large wind turbines. Note the wind farm in the middle is 1 sq. km (100 hectares) and will produce roughly the same output whether it has mid-size or large turbines.

Herein lies a clue to the degree of opposition that has arisen in England in recent years as turbines 125 m high have become the norm for development. While a wind farm only occupies a few square kilometres of land, its visual impact extends far beyond its own footprint. The above comparison gives a further clue to the effect of turbine size.

Wind farms will produce roughly the same output on the same land area (typically 10-30 MW/sq.km) even when the turbines are of quite different sizes. This is because the spacing between wind turbines varies with rotor diameter in each of two dimensions, and a turbine's output depends on the square of its rotor diameter. So a wind farm covering a few square kilometres will produce roughly the same renewable energy whether it is 50 m high or 125 m high (overall tip-height tends to vary linearly with rotor diameter).

But the larger turbine will have many times the square kilometres of visual impact. For example the following table sets out the comparison for a nominal 1 square kilometre wind farm. It assumes shear follows the "standard" 1/7th power law and 8.0 m/s mean at 50 m above ground. **There is a dramatic difference as regards output per square kilometre of ZVI, being a factor of more than three in favour of the mid-size turbines.**

	Windflow 33-500*	***Windflow 45-500***	***Typical large turbine 90-2000***
Site land area (sq.km)	*1*	*1*	*1*
Wind speed @ 50 m AGL (m/s)	*8*	*8*	*8*
Wind speed @ hub (m/s)	*7.4*	*7.7*	*8.5*
Rotor diameter D (m)	*33*	*45*	*90*
Tip-height (m)	*46*	*60*	*125*
No. of turbines in 3D x 6D array	*64*	*36*	*9*
Wind farm rating (MW)	*32*	*18*	*18*
Annual Energy (MWh/yr)	*47,886*	*51,108*	*66,602*
ZVI at 0.25 degrees (sq.km)	*354*	*594*	*2578*
MWh/yr/sq.km of ZVI	***189***	***86***	***28***

* Following standard practice, the first number refers to rotor diameter (m), the second to rating (kW).

Note that the mid-size turbines enable a similar, or even a higher power rating from a given wind farm site as the large ones. While the energy output is generally better from taller turbines because of wind shear (and wake effects in this model), the cost of energy is not necessarily better. Many elevated sites have lower wind shear. There are economies in the balance of plant required to build mid-size turbines (roading, craneage etc) which (depending of the site and the size of the project) can be more or less significant. Furthermore the access limitations on larger scale turbines limit the number of areas available for development. Visual shielding effects from topography and vegetation are also more effective with mid-size turbines.

If you would like us to provide a site layout, indicative construction cost and assessment of the viability of your project, please contact Colin.Risbridger@windflow.co.nz.