The 30% marvel of well-designed wind farms

How can wind farms be just 30% efficient when modern turbines extract 70% to 80% of available wind energy? Both figures are crucial but reflect very different aspects of modern wind farm technology, design, lay-out and operation. They are also testaments to the ultra-reliable machines that harvest low-cost energy continuously from light breezes and gales far out to sea.

sector feature

Offshore wind turbines are amazing machines which meet their design brief extremely efficiently.

They gather natural energy continuously from puffs and light breezes that can turn quickly into gusts and storm force gales. And they do so in remote sea areas for up to 25 years at a time with low maintenance requirements and minimum structural damage.

But they often suffer from a low reputation. Poor information and historic prejudices have created a popular image of costly white elephants with an efficiency of only 30%. Nothing could be further from the truth. A more meaningful statistic can be found in the success of modern turbine technology in extracting between 70% and 80% of available wind energy in the tunnel mapped out by the rotor's swept area.

Why are there two conflicting sets of figures? The answer is that they measure two different things.

The Capacity Factor: One is a useful way of defining how well the superposition of the wind farm on to the natural wind resource, has been done. To this end, it is incredibly effective to collect even 30% of a theoretical 100% capacity (for the particular wind turbines chosen).

To collect anywhere close to 100% would involve spending many millions of pounds in catching every tiny breeze over many square miles of marine catchment area. This has never, so far, been shown to be a good use of capital.

In fact, 30% is already an obsolete figure. Contemporary offshore wind farms are pushing capacity to nearer 50% as a result of modern operational and cost modelling, cable array architecture, routing studies, geotechnical and energy yield assessments, foundation designs and O&M profiling. Some measured capacity factors are presented at www.energynumbers.info/uk-offshore-wind-capacity-factors.

The Efficiency Factor: The other figure is a measure of efficiency. There is a fundamental limit to how much kinetic wind energy can be captured from a given breeze.

Physicist Albert Betz defined this in 1919 in Betz Law, stating that fundamental laws of conservation of mass and energy restrict this to no more than 59.3%. Modern turbines extracting up to 70% or 80% of this maximum figure are impressive, given general mechanical practicalities on the efficiency of machines, and the necessity of converting energy in several ways before the electrical energy output can be compared to the input kinetic energy.

But the story doesn't end here. Using techniques akin to the 'marginal gains' theory that worked so well for British Cycling, the industry continues to hunt down tiny incremental improvements.

As explained later, this philosophy has helped to push wind energy costs down dramatically, particularly for offshore wind, in the last few years.

Shooting the breeze

It's good to restore the good name of wind turbines as one of the cheapest, most reliable, hard-working, low-carbon energy assets we have.

However, it also helps to look more closely at what modern offshore wind farms working in deep water and the wild metocean environment can actually do for us. The short answer is that they are absolutely phenomenal, considering the tasks we set them.

We ask them to harness energy from the diffuse and variable resource called wind. They are designed and constructed to stand up to the wildest storms. Yet, they also generate electricity in faint breezes.

Let's consider our free wind resource's complexity for a moment. A typical turbine can continue to generate electricity not just in steady conditions but at wind speeds as low as 3m/s (6.5mph) rising up to 25m/s (56mph).

Recent turbine developments are raising the bar to almost 80mph. Under these conditions, mere mortals would be blown away. However, the technology is now so sophisticated that turbines can protect themselves from damage when the going gets really tough.

Added complexity

The calculations then become even more demanding. The figures above are only average speeds. The wind is never steady. Severe gust fluctuations can be much higher than mean values.

Fluctuations are larger onshore and smaller offshore. But wind turbines are expected to capture wind energy and generate power reliably despite this stuttering flow of input energy.

Mathematics then has one further trick to play. The amount of energy presented to the rotor varies with the cube of the wind speed. As such, the amount of energy at the rotor increases by a factor of 578 as wind speeds rise from 3m/s to 25m/s. The difference between 3m/s and 35m/s (80mph) is an enormous factor of 1,587. Machines must cope with this huge range of conditions while sustaining no damage, year in and year out, for a design life of at least a quarter of a century.

Wind turbine efficiency – better than expected

A more detailed look at what a 30% or 50% capacity factor means is helpful too. It is also a starting point for much of the added design and engineering value provided by LIC Energy UK.

This approximate estimate of capacity factor is a predicted annual energy yield of a wind farm. It is compared to the maximum possible yield if all wind turbines ran at their full rated capacity for one year. As such, it is a measure used mainly to compare the expected yield of one possible wind turbine type, installed at all positions on a site, against another type.

On a like-for-like basis, it is a very useful metric and one that we use extensively in wind farm planning to help developers make the best, well-informed choices.

It is not an efficiency measure in any scientific sense. To be clear, in the real world it is impossible to reach a factor of 100%.

That would require a turbine with no maintenance downtime. It would also need the wind to blow continuously at, or above, a 'rated wind speed' (typically 12m/s or 27mph).

A 100% availability to export power to the grid would be essential too. The wind farm electrical system would similarly need to be bomb-proof. Finally, peak wind speeds could never be exceeded, or the turbine would shut down to protect itself.

Given all the factors that impact on this theoretical energy yield. it is a major engineering achievement that some wind farms have capacity factors in excess of 50%.

The art of marginal gains

The idea of marginal gains is central to LIC Energy UK's innovative approach to wind farm design and engineering. Company team members understand the site development process intimately.

With experience of projects varying in scale from 500MW to 3GW, we work with sub-consultants and partners to offer a site development and optimisation process that helps clients to move from an initial offshore site red-line boundary to complete capital and operational expenditure estimates.

The service includes energy yield assessments specific to a client's preferred turbines, array cable architecture and routing studies, plus geotechnical assessments that cover the creation and updating of the site's ground model. Foundation designs, cost modelling and construction and O&M expenditure profiles are also a forte. Our drive for greater efficiencies ties in well with offshore industry trends.

For example, larger wind turbines mean that less supporting infrastructure per MW installed is needed. Similarly, electrical cables are now being made to work harder for longer, or 'sweat'.

Improving wind technology on many fronts is becoming more reliable all the time.

A major specialisation area for LIC Energy UK is foundation design and management of fabrication. The increased simplification and automation of foundation manufacture plays to this strength.

The company's understanding and soil-structure analysis capabilities mean that piles can be shorter, cutting costs and steel-use. A lean-steel approach to minimise the attachment of secondary steel to primary steel, so reducing local stress concentrations and wave loads, is intrinsic to our thinking.

The widening academic understanding of wind as a resource also supports our work in developing more efficient wind farm lay outs. Large wind farms also generate opportunities for economics of scale that reduce costs in all areas.

Better paints are available. LIC Energy UK is closely involved, with industrial partners, in the development of an advanced TS(Z) A (Thermally Sprayed (Zinc or) Aluminium process giving long-term steel protection as an alternative to costly sacrificial anodes. Supply chain expansion is creating cost reductions and capacity gains that we are constantly alert to.

Conclusions

Wind turbines are an amazing tool, firstly for harvesting a free and plentiful energy resource and then converting it into pollution-free electricity. Sited well, wind turbines are as far from being 'pointless eyesores' as it is possible to be.

LIC Energy UK believes these powerful attributes are fundamental to the swift, low-carbon economy transition the UK needs urgently to meet climate imperatives.

Always remembering that broad measures of capacity and efficiency are quite different and must never be confused, we should marvel at just how much of our available free wind resource a modern wind farm can capture.

Full article available at
www.licenergyuk.co.uk
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