Introduction to Farm Wind Turbines / Medium-wind Turbines

Although a widely used term, farm wind turbines and medium-wind don't have a strict definition but just covers the ground between 'small' wind turbines up to 50 kW output and large commercial wind farms. For clarity Renewables First has its own definition of farm wind turbines and medium-wind:

A small number, typically one to three, larger wind turbines with power outputs ranging from 330 kW to 2.3 MW. The wind turbines would normally be owned by the land owner where the wind turbines were located, so all of the revenue from electricity generation would go directly to the site owner.

This is distinct from the 'wind farm model' where a wind developer leases land with a high wind speed for their turbines and pays a proportion of the income to the landowner. This is a good model for any landowner who has a large area suitable for wind turbines and/or doesn't want to cover the capital cost of the wind turbines themselves.

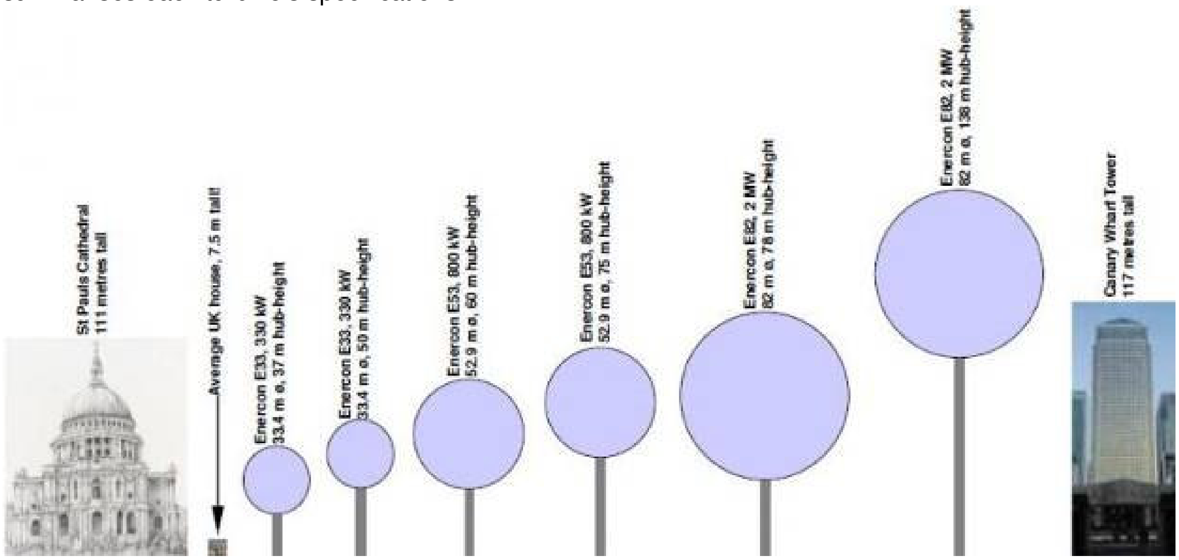
However, if you have a smaller area of land that still benefits from a high wind speed and/or want to own the wind turbine(s) yourself, then Renewables First provides a structured set of services to take your project all of the way from initial feasibility to installation.

You'll notice that our smallest turbine is 330 kW. This is because this is the smallest turbine currently offered by one of the long-established manufacturers – in this case Enercon. There are smaller turbines available but they tend to be manufactured by much smaller companies that don't always have the resources to fully develop their products before launching them on the market, or they are based on older turbine designs which although good, don't benefit from the design advances in areas such as variable-speed operation, direct-drive and low-noise aerodynamics. The unfortunate result of this can be that the turbines don't always operate reliably and efficiently, which is bad for the customer. By sticking with known, quality products from long-established manufacturers you can be assured that your farm wind turbine / medium-wind turbine will operate reliably for many years. If good smaller turbines become available we will start offering them as alternatives.

Contents

How large are farm wind turbines / medium-wind turbines?

When seen in the wider landscape it is often difficult to judge the size of a turbine without something to scale it against. The diagram below shows scale representations of three common Enercon wind turbines, the E33, E53 and E82, in each case on the shortest and tallest towers offered for each model. Alongside are St Pauls cathedral and Canary Wharf, to give you an idea of their scale. The table below summarises each turbine's specifications.



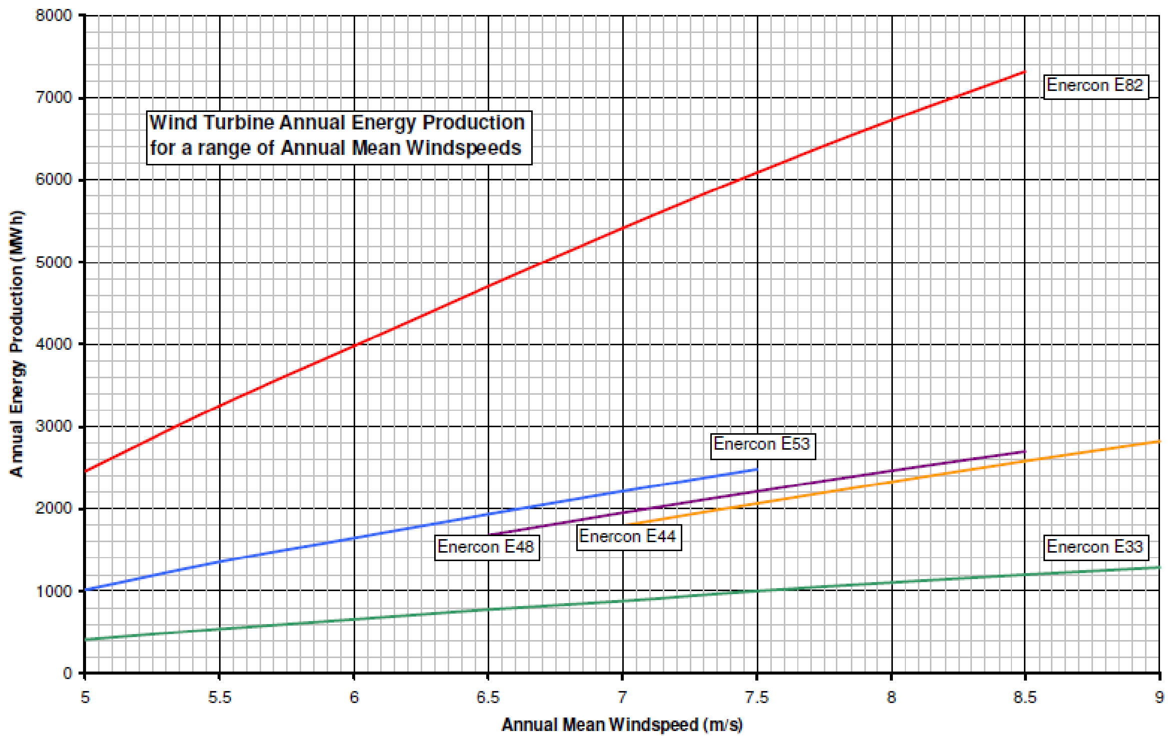
Turbine	Max. Power	Rotor diameter	Tower height(s)
Enercon E33	330 kW	33.4 metres	37, 44, or 50 metres
Enercon E53	800 kW	52.9 metres	60 or 73 metres
Enercon E82	2 MW (2.3 & 3 MW options)	82 metres	78, 85, 98, 108 or 138 metres

Table 1 - Summary of Enercon wind turbine physical sizes.

How much energy could I generate from a farm wind / medium-wind turbine?

The amount of energy that can be generated depends on many factors. The main ones are the average wind speed at the site, the windspeed distribution over a year and the 'power curve' of the particular wind turbine. Other factors which can be significant are the 'roughness' of the surrounding terrain (both in the immediate vicinity and up to 20 km upwind of the site), any hills or other obstacles such as buildings plus several other lesser factors.

Accurate energy production estimates require accurate wind data measured at the site and a lot of modelling on specialist wind software (we use WindPRO), but to answer the original question the following graph and summary table below will give you a good indication, measured in MWh, based on the same three sizes of Enercon wind turbines discussed earlier. Note that the energy estimates shown are based on real data and are slightly conservative, assuming a 95% availability factor for the wind turbine and 10% for other losses (i.e. local electrical transmission and turbulence losses), to be on the safe side.



		Site annual mean windspeed								
Turbine	**Max. Power**	**5.0 m/s**	**5.5 m/s**	**6.0 m/s**	**6.5 m/s**	**7.0 m/s**	**7.5 m/s**	**8.0 m/s**	**8.5 m/s**	**9.0 m/s**
Enercon E33	330 kW	408	541	660	777	880	1,001	1,104	1,200	1,287
Enercon E44	900 kW	n/a	n/a	n/a	n/a	1,795	2,066	2,329	2,583	2,822
Enercon E48	800 kW	n/a	n/a	n/a	1,680	1,952	2,214	2,464	2,698	n/a
Enercon E53	800 kW	1,016	1,357	1,647	1,936	2,216	2,483	n/a	n/a	n/a
Enercon E82	2 MW	2,459	3,256	3,981	4,707	5,413	6,090	6,726	7,318	n/a

Table 2 - Summary of Annual Energy Production (in MWh) for a range of annual mean windspeeds.

Note that the Enercon E44 / E48 / E53 are similar wind turbines, but each is optimised for a different annual mean wind speed.

You'll notice that the annual energy production from the wind turbines increases disproportionately compared to the increase in annual mean windspeed; for example an increase in annual mean windspeed from 6.5 to 7.0 m/s is a 7.7% increase in windspeed, but the corresponding increase in annual energy production is around 15%. This is because the power output of a farm wind turbine is proportional to the cube of the windspeed and demonstrates how fundamentally important it is that wind turbines are located where the local windspeed is at its maximum. Before anyone emails Renewables First to point out that if it was purely a cubic relationship the annual energy production should have gone up by 24.9%, I should mention that there are several other factors to consider, the most important of which is the 'Weibull shape parameter', but this is too complicated for here. Anyone who wants to understand the technicalities should visit the 'energy output' pages on the excellent Danish Wind Industry Association website here http://guidedtour.windpower.org/en/tour/wres/annu.htm.

How windy does it have to be?

Basically the windier the better. The amount of power generated by a farm wind turbine is proportional to the cube of the windspeed. This means that increasing the average windspeed from 6 m/s to 7 m/s results in 59% more power and 35% more energy and annual revenue. The map below shows the average annual windspeeds throughout the UK. Not surprisingly the highest windspeeds correlate with the highest ground, so the mountainous and hilly parts of Scotland, Wales and northern and south-west England have the highest windspeeds.

However, all is not lost if you don't live in one of these areas. There are many localised areas with high windspeeds, typically on tops of hills or in flat open areas. They may be too small to appear on the map above but may still have high annual average windspeeds.

Any site that has an annual average windspeed of 7 m/s or more would be considered excellent for farm wind turbines, and in fact many sites with as little as 5.5 m/s can still be viable when using some of the 'oversized rotor' wind turbines available that are specifically designed for use in lower windspeed countries in continental Europe where it is significantly less windy than the UK. If you have less than 5 m/s it almost certainly wouldn't be economically viable to install a farm wind turbine or medium-wind turbine.

Can the windspeed be increased at a site?

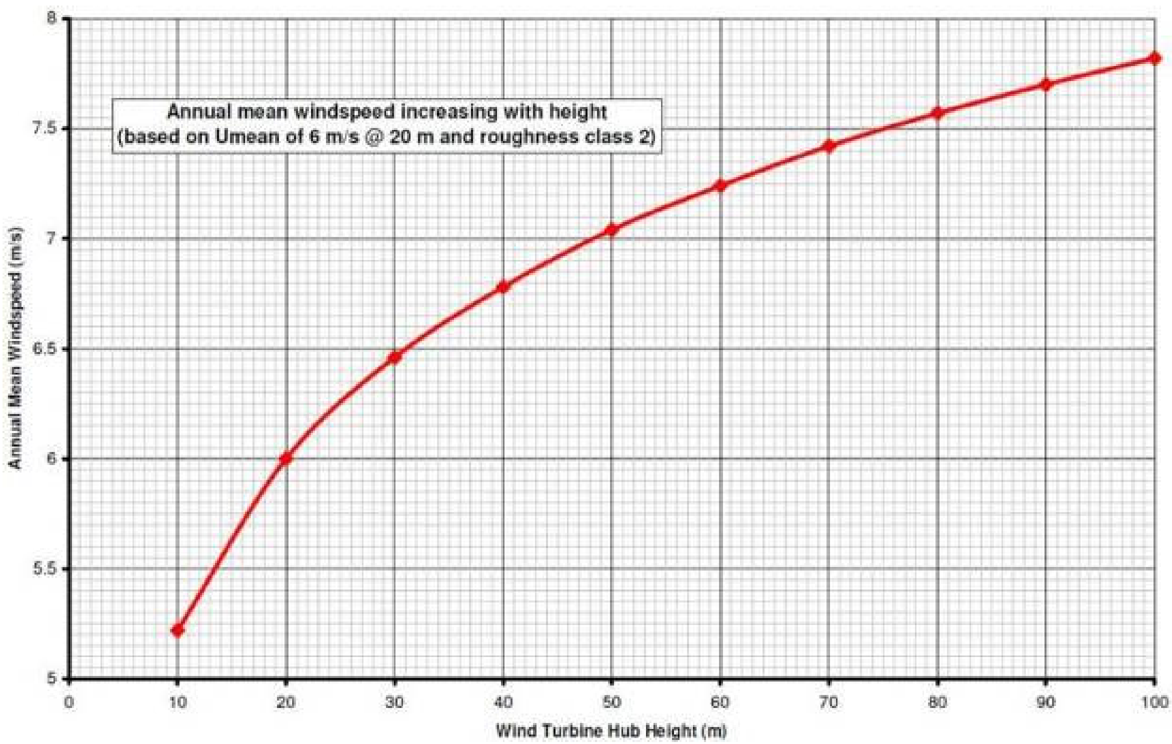
Yes and no. Obviously wind is a naturally occurring phenomenon beyond humankind's manipulation, but there is one thing that can be done to increase the windspeed experienced by a wind turbine at a given location; go upwards by increasing the tower height.

As wind gets closer to the ground it loses some of its speed due to friction as it rubs against any 'surface roughness'. Surface roughness can be low in areas of wide open ploughed fields or short grasslands, or higher over forested areas and more complex terrain with buildings, trees and hedgerows interspersed. A typical UK rural location with a mixture of open areas, some trees and hedgerows and some small buildings would have a 'roughness class' of 2. Compare this to open sea that has a roughness class of 0, and cities or dense forest with a roughness class of 4.

The impact of surface roughness on annual average windspeed reduces disproportionately with height, as shown in the figure below. The figure shows how the windspeed increases with height above the ground, based on a site with an annual mean windspeed of 6 metres/second at 20 meters above the ground. Wind turbines on shorter towers benefit from tower height increase more than wind turbines on higher towers, though all turbines with hub heights less than 150 metres (which is all currently all available wind turbines) will see a significant increase in annual mean windspeed.

Very roughly speaking, for each 1 metre increase in the hub-height of a farm wind turbine the annual energy production increases by 1%. Therefore it is always financially better to opt for the highest tower available.

To use an example, a site that had an annual mean windspeed at 20 metres above the ground of 6 metres/second, which would be quite good for a farm wind turbine or medium wind turbine, would actually have an annual mean windspeed of 6.7 metres/second at 37 metres (the minimum hub height for an Enercon E33) and 7 metres/second at 50 metres (the maximum hub height for an E33). This would mean an increase in annual energy production between the shortest and tallest Enercon E33 of 11%. In summary, an annual mean windspeed at 10 or 20 metres above the ground may not be great for a wind turbine, but when this is extrapolated to the actual operating hub height of commercially available wind turbines it may be much better, and in any case the additional cost of higher towers is always recouped in higher annual energy capture, and therefore income.



How much money could I earn?

This is slightly complicated, but we'll try to explain. There are up to five components that make up the total value of electricity generated, namely:

- Feed-in Tariff (also known as the FiT or Clean Energy Cashback)
- Export value
- Offset value for energy used on-site
- Renewables Levy Exemption Certificates (Renewables LECs)
- Renewable Energy Guarantee of Origin certificates (REGOs)

If you don't want to read about the details of what makes up the total value, move ahead to 'Summary of potential revenue from wind turbines' on page 7

Feed-in Tariff

By far the largest component of the value is the Feed-in Tariff. This is paid for every kilowatt-hour (kWh) of electricity generated regardless of whether it is consumed on-site or exported. The amount paid under the Feed-in Tariff is banded for different sizes of system so that smaller systems which normally cost proportionately more to implement are not penalised. The Feed-in Tariffs applicable for farm wind projects are (from 1st April 2011):

Wind turbine size[1]	Feed-in Tariff
15 kW - 100 kW	25.3 p/kWh[2]
100 kW - 500 kW	19.7 p/kWh
500 kW - 1.5 MW	9.9 p/kWh
1.5 MW - 5 MW	4.7 p/kWh

Notes
1. For turbines that sit on a tariff threshold, the higher (i.e. more money) tariff will apply.
2. This tariff band (only this one) reduces after March 2012 by approximately 1 p/kWh/year.

Once a wind system is registered for the Feed-in Tariff it is locked into that tariff for 20 years. In addition the tariff will be index-linked to RPI, so its value in real terms will not be eroded by inflation.

The export value and the offset value are a slightly more difficult to explain because depending on the site either one may apply or both. For clarity we'll explain each individually first, then what happens when both apply.

Export value
This is payable for every kWh of electricity exported, and the value can vary between the guaranteed minimum amount of 3 p/kWh under the Feed-in Tariff, or the 'market rate' which is currently closer to 4.5 p/kWh. Exported means that it must pass outwards into the local electricity distribution network (what most people call 'the grid') through an export meter. An export meter looks the same as a normal import meter, but records the flow of electricity outwards from a site rather than inwards, which is done by the import meter. Increasingly nowadays the meter is a combined import / export meter.

To export all of the energy produced by a farm wind turbine or medium-wind system it would have to be directly connected to the grid with its own dedicated electrical supply and not first pass through the site distribution board (see more details below under 'offset value'). Under this arrangement every kWh generated by the system would be exported, and the export tariff, typically between 3 – 5 p/kWh would be paid.

Offset value
This is where the farm wind turbine or medium-wind turbine connects into the site owner's main distribution board. It is important to remember that electricity flows like water and will always follow the easiest route to the nearest load. This means that all of the site owner's loads (i.e. lighting, sockets, machinery, air conditioners etc.) that connect to the same distribution board will be supplied firstly by the wind turbine, and only once all of these loads have been satisfied will any surplus energy from the wind turbine flow backwards through the incoming supply cables, either to the next nearest distribution board on the site, or out through the export meter to the grid.

Also, because the electricity produced by the farm wind turbine or medium-wind turbine is fully grid-synchronised, it will mix seamlessly with grid-imported electricity. This means that if the wind turbine cannot meet all of the site owner's loads, then all of the electricity from the wind turbine will go towards the loads and any deficit will be seamlessly imported from the grid. Equally, if the wind turbine was supplying all of the local loads but then a lull in the wind caused the output to drop, then the grid would instantly supply more to make it up. From a consumers point of view the source of the electricity would be unknown; it could be from the farm wind turbine, the grid or a combination of both.

In the situation where the on-site loads far exceed what the farm wind turbine or medium-wind turbine could produce, then all of the electricity generated by the wind turbine would be consumed on site. For example an Enercon E33 has a maximum power output of 330 kW, so if this was connected to a site that had a baseload (i.e. the minimum load 24/7) of 500 kW, then 100% of the energy generated by the farm wind turbine would be consumed on the site. Financially this would be a good arrangement because the price paid for importing electricity from the grid is typically 12 p/kWh (varies between 6 – 16 p/kWh depending on your import tariff), so if the amount of import can be reduced, for every kWh it is reduced by the site owner saves 12 p. If you compare this saving of 12 p/kWh to an export price of 3 – 5 p/kWh, you can see that offsetting on-site loads is worth two to three times more than exporting the electricity.

Combined offsetting and exporting
This is actually the most common arrangement and is basically the arrangement described above under 'offset value' except where the on-site loads are less than the power being produced by the farm wind turbine or medium-wind turbine. Under this arrangement the onsite loads would be supplied first, and then the excess power exported.

The value would be made up of the amount of energy offset at 12 p/kWh (or whatever your import electricity price is) plus the amount of energy exported for between 3 – 5 p/kWh. Obviously the actual value would depend on the relative proportions, but these can be estimated at a feasibility study stage based on existing electricity bills and forecast energy production for the farm wind turbine or medium-wind turbine.

Generally speaking it is best to offset imported electricity first, and then export any remaining surplus to get the highest revenue from a farm wind turbine.

Renewables Levy Exemption Certificates (Renewables LECs)
This is an exemption from paying the Climate Change Levy (CCL) if renewable-sourced electricity is used in place of normal grid-supplied electricity. The CCL is currently set at £4.85 / MWh (or 0.485 p/kWh) of electricity consumed. For renewable generators this means that subject to registration of the renewable generation system with Ofgem, you would be issued with a 'Renewables Levy Exemption Certificate' or 'Renewables LEC' for every MWh of electricity you generated, and this would be worth £4.85 / MWh.

You could use this to offset against your CCL bill if you are a commercial consumer of electricity, or you could simply sell the Renewable LECs to your electricity supplier or one of the established trading companies. The bottom-line is that this adds an additional 0.485 p/kWh to renewable electricity you generate from your farm wind turbine or medium-wind turbine.

Renewable Energy Guarantee of Origin certificates (REGOs)
Confused yet? Well, try this. Now we have Renewable Energy Guarantee of Origin certificates or REGOs. These started appearing in 2003 in response to the EU Renewables Directive. They are basically a guarantee that the electricity has been certified as 'green'. The REGO certificates are issued by Ofgem in a similar way to Renewables LECs, so it is as well to apply for them and keep them in a safe place. Currently there is no established market to sell REGOs on, so they have no value. However, many people advise applying for them and keeping them because they may become essential to show that your electricity is certified as green before you can sell LECs etc. So think of REGOs as important facilitators to realise value, rather than being valuable in themselves.

Renewable Obligation Certificates (ROCs)
This was the old system for incentivising renewable electricity generation. Generators that are larger than 50 kW still have the option of joining the ROC scheme instead of the FiT, but generally speaking for all 'normal' projects the FiT provides a greater financial return, so the ROC system will be ignored here. Projects above 5 MW still have to use the ROC system.

Non-tangible benefits
Also worthy of mention, many farm wind turbine and medium-wind sites generate a great deal of positive publicity and improve a company's image through association with clean renewable energy generation. Sometimes the value of this is greater than the revenue generated by the system, but because of its non-tangible nature it has been ignored here.

Summary of potential revenue from farm wind and medium-wind turbines

Due to the different permutations possible of the different components of the total value for generated electricity, a few assumptions have to be made if a simple table of annual revenues is to be constructed. To keep things simple, in the table below no value for offsetting has been included, and a 'typical' export price of 4 p/kWh has been assumed. This would be the 'worst case' for revenue, and the 'best case' with 100% offsetting could provide 31% more revenue for an Enercon E33 and even more for the larger turbines where the FiT is a less significant proportion of the revenue. Therefore the generated electricity values used are:

Turbine	Max. Power	Feed-in Tariff	Export price	LEC	Total value
Enercon E33	330 kW	19.7 p/kWh	4 p/kWh	0.485 p/kWh	24.2 p/kWh
Enercon E53/E48/E44	800 kW	9.9 p/kWh	4 p/kWh	0.485 p/kWh	14.4 p/kWh
Enercon E82	2 MW	4.7 p/kWh	4 p/kWh	0.485 p/kWh	9.2 p/kWh

Table 3 - Feed-in Tariff, export & LEC value for different sizes of wind turbine.

For each of the 'example' Enercon wind turbines the annual revenue is shown for a range of sites with annual mean windspeeds ranging from a relatively low 5 m/s to an exceptionally high 9 m/s. Remember that a 'good' farm wind turbine or medium-wind turbine site would have an annual mean windspeed of 6 m/s or more, though clearly even with lower mean windspeeds a farm wind turbine or medium-wind turbine can be a very good investment.

	Site annual mean windspeed								
Turbine	**5.0 m/s**	**5.5 m/s**	**6.0 m/s**	**6.5 m/s**	**7.0 m/s**	**7.5 m/s**	**8.0 m/s**	**8.5 m/s**	**9.0 m/s**
Enercon E33	£99k	£131k	£160k	£188k	£213k	£242k	£267k	£290k	£311k
Enercon E44	n/a	n/a	n/a	n/a	£258	£297	£335	£372	£406
Enercon E48	n/a	n/a	n/a	£242	£281	£318	£354	£388	n/a
Enercon E53	£146k	£195k	£237k	£278k	£319k	£357k	n/a	n/a	n/a
Enercon E82	£226k	£299k	£366k	£432k	£497k	£559k	£618k	£672k	n/a

Table 4 - Annual revenue for different sizes of wind turbine for a range of annual mean windspeeds.

Remember that the five 'example' farm wind turbines used throughout this webpage qualify for three different Feed-in Tariff bands, so even though the large Enercon E82 generates by far the most energy, the annual revenue generated doesn't scale in line with the annual energy production because of the lower Feed-in Tariff. This means that in some situations a smaller wind turbine may well give a higher return on investment.

Also remember that the Feed-in Tariff banding applies to the total installed capacity, so if two Enercon E33's were installed the total capacity would be 660 kW and the 9.9 p/kWh Feed-in Tariff would apply, not the higher 19.7 p/kWh that would apply for a single Enercon E33. Note that if a second Enercon E33 was added to a site more than a year after the first E33, then the second would get the lower FiT but the first would continue to receive the higher rate, which is much better than installing two E33's at the same time and them both receiving the lower FiT.

How much do farm wind and medium-wind turbine projects cost?

Also not a straightforward question to answer. The total project cost will depend on many factors, including the cost of the turbine itself and the level of competition in the wind turbine market at the time the turbine is ordered (which varies a lot depending on the current levels of government commitment etc.), the tower height and rotor diameter (taller towers cost more and over-size rotors for low windspeed sites cost more), the cost of any grid upgrades to allow the turbines to export energy, the cost of access roads, foundation and cabling costs.

There are also economies of scale with larger turbines costing less per kW than smaller ones, and single turbines costing more per kW than multiple turbines. Having said all of that, a reasonable conservative budget price for the five Enercon turbines used throughout this webpage would be:

Turbine	Max. Power	Project cost
Enercon E33	330 kW	£730k
Enercon E53/E48/E44	800 kW (E44 900 kW)	£1,228k
Enercon E82	2 MW	£2,968k

This price would be per wind turbine, though additional turbines would cost around 96% of the single turbine price. In each case this would be for the tallest tower height and would include 8% of the project value for grid upgrades and 4% for obtaining planning consent. For reference, typically the actual wind turbine costs around 69% of the total project cost.

What would be my return on investment in a farm wind or medium-wind turbine?

Using all of the various assumptions, revenues and costs discussed above, and also assuming that the annual operation and maintenance (O&M) cost is 9% of annual revenue for an E33 and 5% of annual revenue for an E53/E48/E44 or E82 (typical industry-standard figures), and assuming a design life of 20 years for a good quality modern large wind turbine, the following table of Internal Rates of Return (IRRs) can be constructed for the 'example' range of turbines installed on a range of sites with annual mean windspeeds ranging from 5 to 9 m/s.

	Site annual mean windspeed								
Turbine	**5.0 m/s**	**5.5 m/s**	**6.0 m/s**	**6.5 m/s**	**7.0 m/s**	**7.5 m/s**	**8.0 m/s**	**8.5 m/s**	**9.0 m/s**
Enercon E33	7%	13%	18%	22%	25%	30%	33%	36%	39%
Enercon E44	n/a	n/a	n/a	n/a	17%	20%	23%	26%	29%
Enercon E48	n/a	n/a	n/a	16%	19%	22%	25%	28%	n/a
Enercon E53	6%	11%	15%	19%	22%	25%	n/a	n/a	n/a
Enercon E82	0%	4%	7%	9%	12%	14%	16%	18%	n/a

Table 5 – IRR's for different sizes of farm wind turbines for a range of annual mean windspeeds.

The potential returns on investment are clearly very good, even for sites with relatively low mean windspeeds of 5.5 m/s, and are exceptional for windier sites.

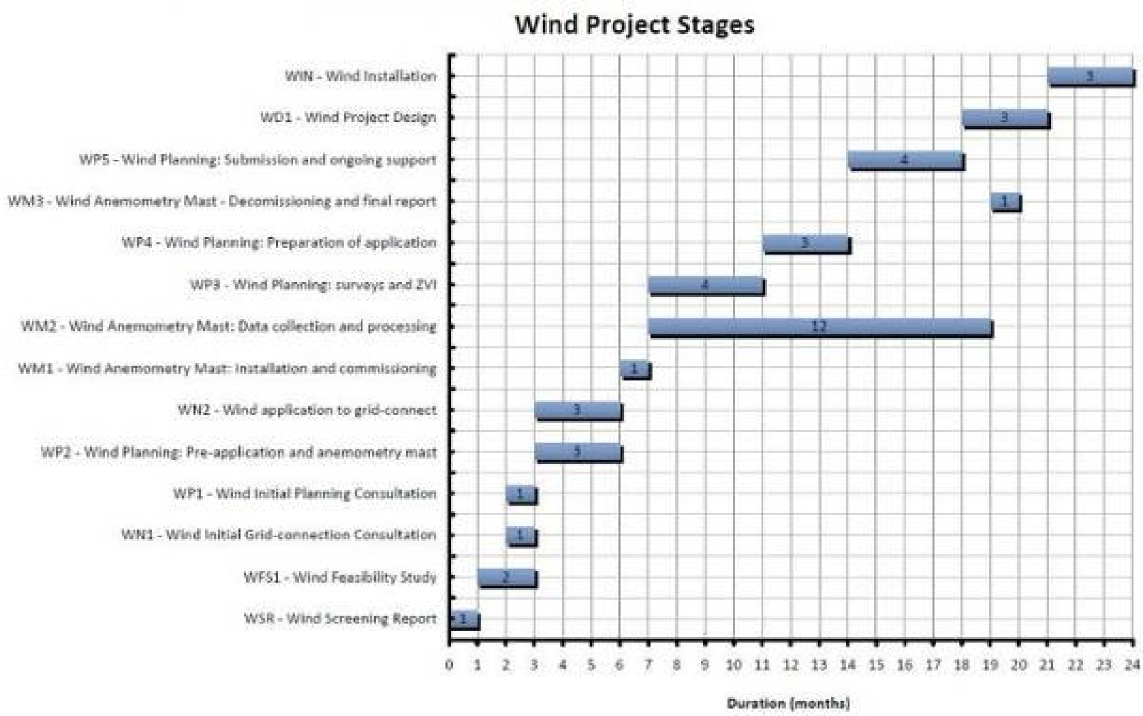
The major project risks are that planning permission may not be granted and that the grid connection of the system may require an expensive upgrade to the electrical supply. However, both of these risks can be mitigated by using a good wind consultancy to conduct the feasibility study and obtain all of the necessary consents.

I want to move ahead - what's the next step?

The normal project stages for a farm wind turbine or medium-wind turbine project are shown in the diagram below, along with the typical durations. At Renewables First we break each stage down into a clearly defined segment and try to minimise risk capital by establishing the key facts at an early stage before significant consultancy fees are incurred.

The project stages are described in more detail under their respective website menu items. The first step for any prospective site is a Wind Feasibility Study (WFS). If you think you have a suitable wind site for development, please log an enquiry through our website, including as much detail as possible. One of our engineers will call you back to discuss the options in more detail.

We also offer external finance for sites with average wind speeds above 6.5 m/s – for more details see the 'Project Finance' page on our website here.



If you've read and understood this whole document well done! Please let us know if there are any glaring errors or gaps that need to be fixed, or if there is anything not clearly explained so we can write the relevant text and update the document.

Please note that by offering all of this detailed information we are trying to be helpful and will accept no liability for errors or omissions!

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