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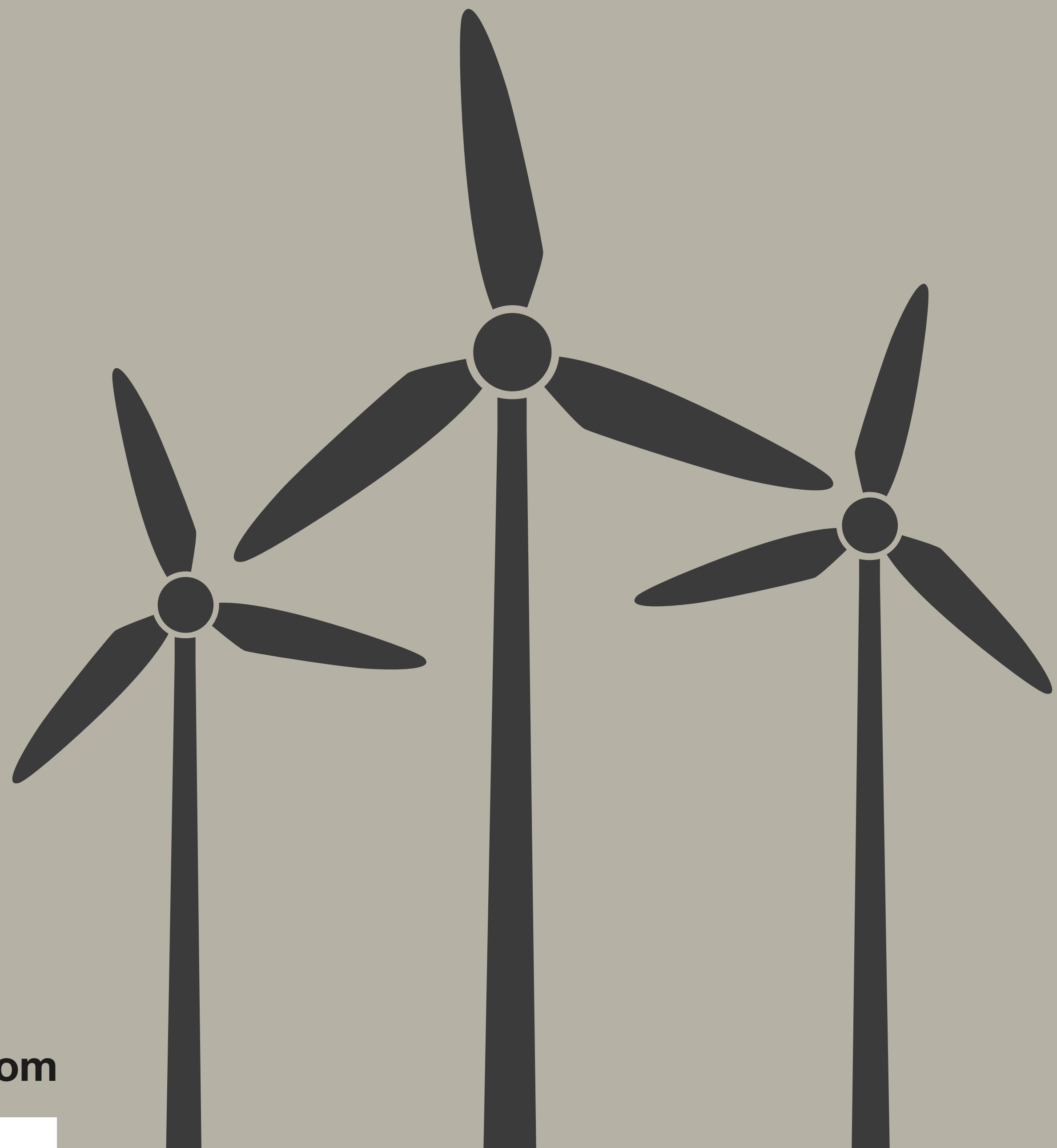
Invest Northern Ireland

Wind Power

A best practice guide for Northern Ireland business



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CONTENTS

The guide is structured to be as easy to use as possible, providing an introductory understanding in Section A. Essential – The Basics, but also satisfying those who wish to understand the more technical detail and develop a feasible project in Section B. Advanced – Feasibility. Where an endnote is added for further explanation it is indicated by roman numerals in superscript.

Table of Contents

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Table of Contents (continued)

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Table of Contents (continued)

List of Figures

A. Essential - The Basics

1 Introduction

Wind is a form of solar energy. Winds are caused by the uneven heating of the atmosphere by the sun, the irregularities of the earth's surface, and rotation of the earth. Wind flow patterns are modified by the earth's terrain, bodies of water, and vegetative cover. This wind flow, or motion energy, when "harvested" by modern wind turbines, can be used to generate electricity.

The terms "wind energy" or "wind power" describe the process by which the wind is used to generate mechanical power or electricity. Wind turbines convert the kinetic energy in the wind into mechanical power. This mechanical power can be used for specific tasks (such as grinding grain or pumping water) or a generator can convert this mechanical power into electricity.

Wind power has been used as long as humans have put sails into the wind. For more than 2,000 years wind-powered machines have ground grain and pumped water[i].

The massive growth in wind power over the last decade continues to accelerate, and, as demand for energy grows across Northern Ireland, wind plays a central role in our energy mix. In 2014 almost a fifth (19.5%) of Northern Ireland's electricity needs came from renewable sources, 18.3% of which was from wind energy.

CLEAN – Wind is an extremely clean form of electricity generation. The lifecycle carbon cost is estimated to be around 37 $kgCO_{2e}$/MWh[ii] comparing well with that of Solar PV at around 58 $kgCO_{2e}$/MWh[iii].

PROVEN – Globally, 51,473 MW of new wind generating capacity was added in 2014 according to the global wind market statistics by the Global Wind Energy Council (GWEC). The record-setting figure represents a 44% increase in the annual market. Total cumulative installations stand at 369,597 MW at the end of 2014.

PREDICTABLE – According to a 2011 analysis by Garrad Hassan, UK average wind speeds are historically consistent to within ≈6% year-on-year with a 1 in 100 year probability of annual mean speeds ≈14% higher or lower. 2010 was such a year. On site measurement aids accurate prediction.

AFFORDABLE – According to British Wind, in 2014, onshore wind energy cost 9.5 pence per kWh (unit), (falling to 9 pence in 2017). Solar costs 12p, offshore wind 15.5p, biomass 10.5 to 12.5p, hydroelectricity 10p and wave and tidal energy 30.5p, while the first new nuclear plant will cost 9.25p in 2023.

When installed in a logical location following a carefully prepared feasibility study, wind power is a secure, strategic investment opportunity for Northern Ireland business.

1.1
What they do
Wind turbines convert kinetic energy (energy of motion) in the wind to electrical power. Typically, the process is as follows. Wind is generated by the weather. As the wind passes the wind turbine blades, it transfers energy to the blades causing them to rotate and turn the central rotor drive shaft. Inside the nacelle, the gear box converts the slow rotation speed to a high speed to drive the electrical generator. The generator converts the mechanical energy into electrical energy. The current flows down a cable inside the turbine tower to a local substation and transformer where it is normalised to grid voltage and frequency before being exported. Smaller wind turbines may be configured differently to this typical example and may be connected to a local load so that generated electricity may be used locally before any excess is exported. This process happens automatically without any user intervention.

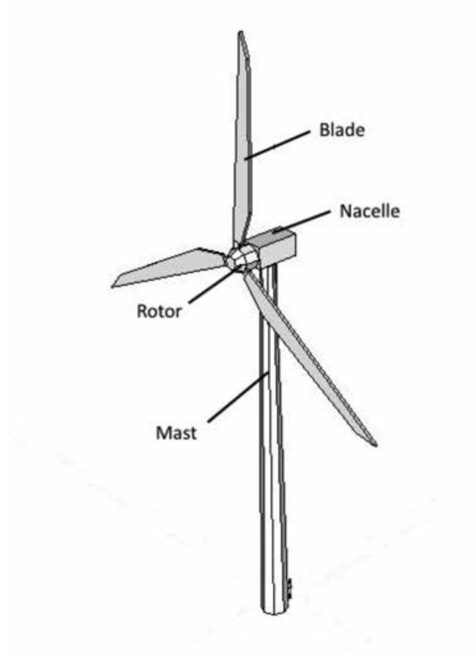

Figure 1: A typical wind turbine
(image courtesy of Element Consultants)

Wind resources are often misunderstood. The wind is a variable source of power that rarely blows with a steady force and direction. It is affected by obstacles in its path and becomes much more powerful with height and speed. An important factor in how much power your wind turbine will produce is the height of its tower. The power available in the wind is proportional to the cube of its speed. This means that if wind speed doubles, the power available from the wind increases by a factor of 8 (2 x 2 x 2 = 8). The power output of a wind turbine at different speeds is described by a power curve.

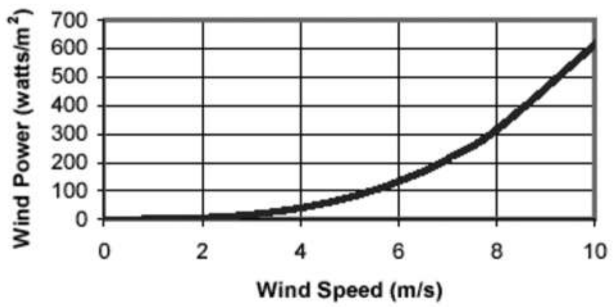

Figure 2: Power Curve
(image courtesy of Element Consultants)

Since wind speed increases with height, increases to the mast height lead to increases in the amount of electricity generated by a wind turbine.

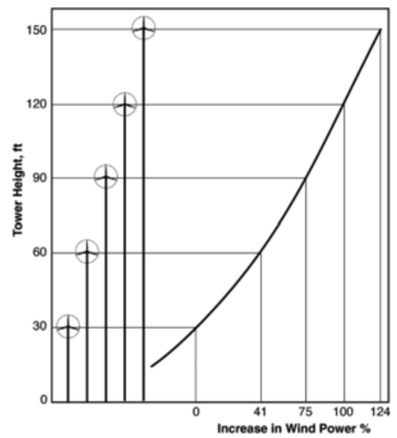

Figure 3: Height .v. Power
(image courtesy of Element Consultants)

Installing a wind turbine on a mast that is too short is like installing a solar panel in a shady area.

1.2
Why we need them
Like most developed economies, Northern Ireland relies on fossil fuel derived electricity; primarily from coal. Global demand for energy is increasing dramatically as populations grow, energy-intensive technology and economic activity flourishes, and immature economies develop. This is happening as fossil fuel reserves diminish, albeit slowly. As a consequence, competition for finite resources is increasing.

In real terms, Northern Ireland's buying power for energy is extremely limited and so we are exposed to price volatility. Furthermore, 80% of the stated fossil fuel reserves will have to remain unburnt if we are to maintain a global temperature increase rate of less than 2ºC this century and negate runaway climate change. As these issues converge, the role of clean energy is enhanced.

Northern Ireland's target is to reduce carbon emissions by 35% from 1990 levels by 2025 and achieve 40% renewable electricity by 2020. Based on current progress it appears unlikely that this will be achieved. Wind power forms an essential part of the reduction strategy.

Wind power is a key technology (although no single renewable energy technology offers a 'silver bullet') because Northern Ireland is regarded as having one of the greatest wind energy resources in Europe. It is important that the potential of this resource is maximised to contribute to an increase in the proportion of our energy that is derived from renewable sources.

1.3
How they make money
The economics of wind power are very simple. Savings and income are derived from three sources:

SAVINGS – by using the clean electricity your wind power system produces, you will buy less electricity from the grid and make savings on your utility bill. As grid-supplied electricity prices increase, the savings you make will also increase.

INCOME – under the NIROCs (Northern Ireland Renewable Obligation Certificates) scheme you are paid for every unit of clean electricity you produce from the wind installation. The payment depends on the size of system you install. Up to 250 kW, you will be paid 4 NIROCs; larger systems up to 5 MW receive

1 NIROC, and above 5 MW, 0.9 NIROC. NIROC values are set annually in October; the price at May 2015 was 4.08 pence per kWh.

NIROC for electricity generation from onshore wind will be cancelled from March 2016.

A LITTLE MORE INCOME – any clean electricity not used is metered and exported to the grid. In May 2015 each exported unit of clean electricity (from a generator < 50 kW exporting for Power NI) earned 5.10p. For generators up to 250 kW an open market price tracking arrangement is available. Generators > 250 kW must arrange a specific contract for selling electricity.

1.4
How they compare to other renewables

In order to achieve a successful outcome for any wind turbine project a variety of factors must be considered. In Northern Ireland all wind turbines require planning permission and this must be achieved before grid connection may be applied for. The optimum size of wind turbine will be determined by the available wind speed, the turbine output, the resulting generation and the amount of that generation that is consumed on site. In order to predict the generation and subsequent earnings, one must understand how wind speed and turbine height affect generation.

Thus, a wind power system is relatively complex to design, develop and install. Considerable resources must be expended before there is any certainty of the outcome. The planning permission process is onerous and takes a considerable period of time to conclude. Even if it is achieved, grid connection may not be available or, if available, may be prohibitively expensive. Once installed, wind turbines require planned maintenance; usually annual or bi-annual. If all operates as planned, the main running cost over time is annual servicing. Typically, wind turbines have a 20 - 25 year lifespan, but can have their life extended by refurbishment[iv].

	Solar PV	Wind	Hydro	CHP
Energy Resource Annual Variation %	3-4	6-10	Site specific	Fuel specific
Technology Maturity (Low, Medium, High)	High	High	High	Med-High
Technology Complexity (Low, Medium, High)	Low	Med	Med	High
Installation Complexity (Low, Medium, High)	Low	Med	High	High
Planning Complexity (Low, Medium, High)	Low	High	High	Med
Carbon Cleanliness (Low, Medium, High)	Med	Med	Med-Low	Fuel specific
Project Scalability	Modular	None	None	None

Figure 4: Renewable energy comparisons

In summary, wind power is one of the simpler renewable energy technologies to install and own but project development is complex and, in Northern Ireland, can be halted by both planning and grid connection issues.

2 What are Wind Turbines?

Wind turbines are relatively complex machines that come in various designs and sizes ranging from the very small (Leading Edge LE300 0.3 kW) to the very large (Vestas V164 8MW). The technology employed varies from one turbine to another but the traditional design for the nacelle for most medium to large wind turbines is shown below; here for a 225kW turbine.

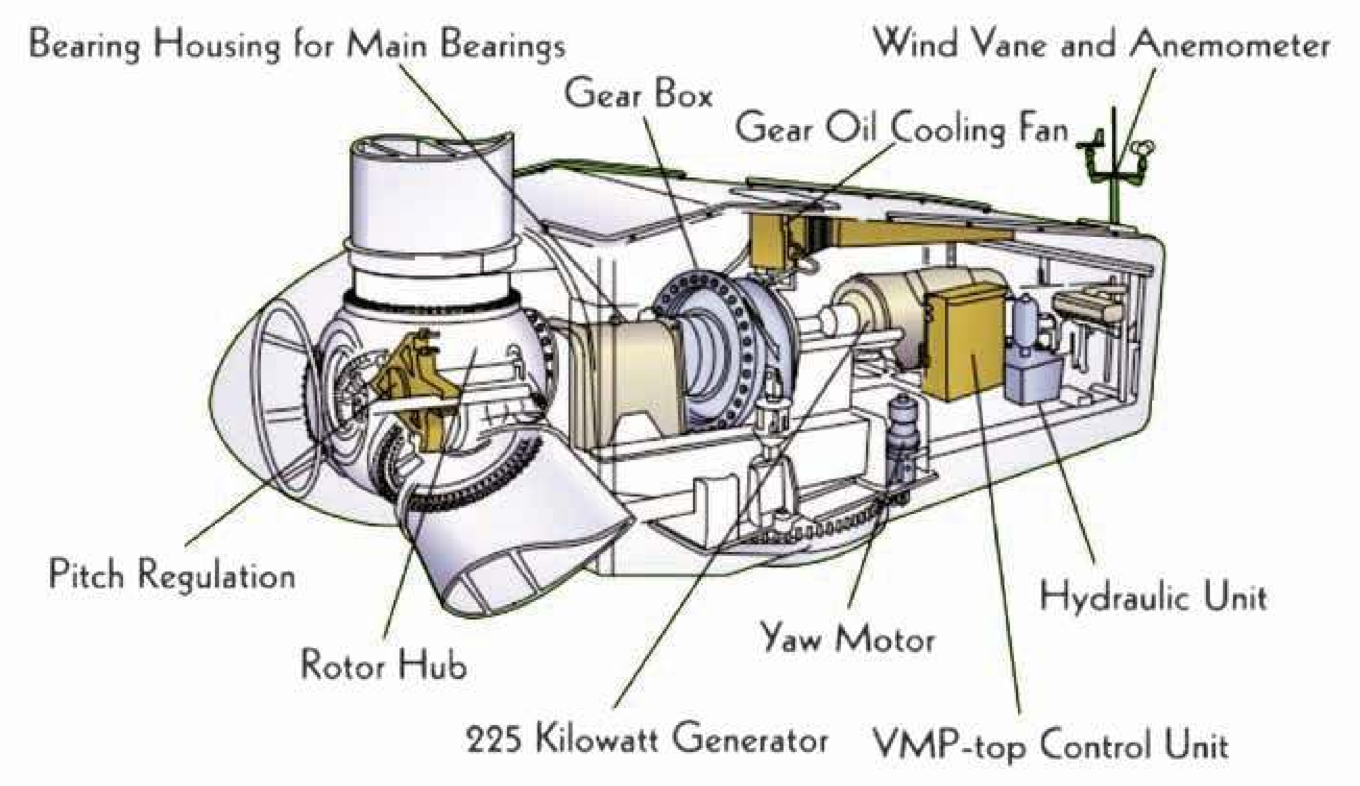

Figure 5: Cell operation
(image courtesy of Virogen.co.uk)

The wind vane monitors the direction of the wind and uses the yaw motor to rotate the nacelle so that the turbine blades are always facing the wind direction. The anemometer measures the wind speed and controls the blade pitch regulation in the rotor hub for optimum generation through the VMP top control unit micro-processor. The hub is mounted onto the drive shaft which passes into the nacelle via a rotor bearing, into a mechanical gearbox. The gearbox is then coupled to a doubly fed induction generator (a special electrical machine that uses two sets of electrically-excited windings to create magnetic fields as part of the mechanical-to-electrical energy conversion process).

Wind turbines operate in a variable wind speed regime from no wind to very high wind speeds so, typically, they have a wind speed at which they start to generate power (the cut in or start up wind speed), a wind speed at which they stop generating power (the shut down or cut out wind speed) and a survival wind speed (above which they can suffer mechanical failure). Therefore, control of the turbine is vital and most turbines are fitted with a brake system. This can include yawing the blades away from the wind direction, using the blade pitch control to fully feather the blades, mechanical and electrical braking.

Turbine towers or masts are normally tubular steel, delivered in section and bolted together. Smaller turbines may use lattice towers or monopole masts; sometimes fitted with rams for simple hydraulic erection.

Blades are often fibre glass, reinforced polyester or carbon or glass fibre reinforced epoxy for durability and flexibility.

Most wind turbines require regular maintenance. Typically, for the standard design turbine above, two annual services will be required; a major service and a minor service. These will include all the mechanical service items associated with a generator and statutory inspections. You should nevertheless check with your installer regarding system specific maintenance requirements before you commit yourself.

2.1
Types of Wind Turbines

Thus far we have discussed what are known as horizontal axis wind turbines (HAWT). Traditionally they are equipped with three blades, however, two bladed versions are available. Two-bladed turbines cost less because they use fewer materials. The removal of one blade makes the rotor lighter, which in turn makes it possible to place the rotor on the downwind side of the tower. Conventional wind turbine rotors face the wind and must resist bending back into the turbine's tower, but downwind rotors can use lighter and even hinged blades that bend away from heavy gusts. Light, flexible rotors translate into further materials savings in the turbine's gearbox, tower, and foundation. The typical two-bladed rotor can use passive blade-angle adjustment. This unique mechanism needs very little maintenance. Its weight and size allow for easy installation in remote locations and installation on a tubular or a lattice tower is possible. Typically, HAWTs need a gearbox and controls at the top of the mast.

Figure 6: Two Bladed HAWT
(image courtesy of WES)

Vertical axis wind turbines (VAWT) allow the main components to be located at the tower base. There are various versions. Earlier versions used a Savonius rotor, a rather crude and inefficient version that resembles an anemometer, some have a helical blade arrangement (Darrieus arrangement) to overcome torque and bending moment. Until recently VAWTs have failed to make inroads against HAWTs in the marketplace. However, a new 55kW version has been launched in 2015[v], designed and manufactured in the UK. Offered with a five year limited warranty as standard and a 20 year extended warranty available, the turbine includes the standard advantages of VAWTs such as ground level servicing of most parts; no need for directional control or blade pitch control; and better performance in gusty and turbulent conditions. It also includes some interesting technology such as regenerative braking and 24 hour remote monitoring.

Shrouded or compact wind acceleration turbines (CWAT) also known as Diffuser-Augmented Wind Turbines (DAWT) use additional structures (normally a shroud or two) to accelerate the wind before it reaches the wind turbine blades. Thus, in theory, a higher generation may be achieved at a lower ambient wind speed leading to increased productivity and/ or lower capital cost as the turbine may be downsized for the same return. According to Ogin[vi], "annual energy output per kW of rated capacity is increased by 50%, while peak energy output from the ultra-compact rotor is increased by up to three times per unit of swept area. The result is a quiet, compact 100 kW turbine that outperforms any other midscale turbine on the market." Note that several attempts have been made to commercialise shrouded wind turbines recently but, to date, none appear to have been successful[vii].

Figure 7: CWAT
(image courtesy of Kingspan Environmental Ltd)

A recent addition to the list is the Vortex Bladeless[viii], a turbine without blades that uses the theory of aero elastic coupling for generation. It is not due to be commercialised until 2017.

3 Sizing

There are several factors affecting the sizing of wind turbines.

1. The available mean wind speed.
2. The available location.
3. Grid connection constraints.
4. Planning permission constraints.
5. To meet energy, or carbon saving targets.
6. To achieve compliance with statutory obligations (Building Regulations, Part F2 Conservation of Fuel & Power, BREEAM, iSBEM).
7. Budget constraints.
8. To optimise income.

The appropriate size for any specific installation will be determined by the examination and resolution of the factors listed above.

4 Planning Permission

Without planning permission no wind turbine scheme can proceed in Northern Ireland. Attaining planning permission for wind turbines has become more complex as the planning authorities have become more familiar with the issues involved. As a result there are now several consultees who are regularly consulted on all turbine applications. Of these, some are objective and some are subjective. Those that demand an objective response can be analysed in advance and will either pass or fail. Where a pass cannot be achieved, the project will not achieve planning permission. For those that require a subjective approach an opinion must be made about the likelihood of achieving planning permission. The factors that need to be considered are covered in detail in the Advanced Section. Note that the planning function has been devolved to the local councils but the relevant planning policies remain in force until superseded by an approved local plan.

5 Grid Connection

NIE distribution controls the grid connection process for generators in Northern Ireland and maintains a dedicated website section for the operation[ix]. It is essential to note that the grid infrastructure in Northern Ireland is poor and, in many areas, both the electricity lines and substations are at capacity for carrying generation. This means that connection may not be possible in many areas and, if possible, may be prohibitively expensive. NIE publish a regularly updated heat map and an interactive line map to assist in assessing the chance of gaining a connection[x].

They currently offer three types of grid connection; G83 applications (microgeneration) cover single phase installations up to 3.68 kW and three phase installations up to 11.04 kW; for 3.69 kW or greater on single phase, or 11.05 kW or greater on three phase you must make a G59 application (small scale generation). Large scale generation greater than 5 MW is dealt with separately.

For a G59 connection you need to apply with full planning permission, and a network study will be carried out to establish if the circuit you are on needs any upgrade to take the extra load. Where network upgrades are required, NIE will provide a quote for the required works. The timescale for G59 applications is 60-90 days to get a quote, 90 days to accept or decline terms offered and, if any construction is needed, it can take between 6 and 12 months to complete. G59 applications cost £668.40 up to 20 kW and £2,002.80 from 21kW to 150kW. There is a fee of £6,676.80 for applications of 151 kW up to 2 MW. All are VAT inclusive.

It is important to note that G59 applications to NIE have increased dramatically and include multiple applications for other generating technologies so the timeframes above are approximate.

6 Predicting Generation

To make an initial, pre-feasibility, calculation of income from a specific system you will need to predict the annual generation (kWh).

Accurately calculating predicted generation is extremely complex. The possible generation of a wind turbine is a function of the mean power (kW) and the operational availability (hours). The mean power is, in turn, a function of mean wind speed, the turbine power curve and the wind speed density distribution for the site. Thus, the calculation is complex and site specific. For a rough pre-feasibility calculation we need to establish a minimum of the mean annual wind speed, the turbine power curve and the wind speed probability distribution.

For an initial estimate of annual mean wind speed, there are two computer generated online resources. The first is the modelled wind speed from the BERR NOABL database online at **http://www.rensmart.com/Weather/BERR**. Enter your postcode and the database returns wind speeds at 10m, 25m and 45m above ground level. The second is the DETI database hosted online at **http://actionrenewables.co.uk/services/wind-monitoring-northern-ireland-wind-speed-monitoring-renewable-energy/windmap/**. Again, enter your postcode, zoom in and click the ‘info’ button to receive 30m, 75m and 100m above ground level wind speed bands. Note that the databases are the result of air flow modelling that estimates the effect of topography on wind speed. There is no allowance for the effect of local thermally driven winds such as sea breezes or mountain/valley breezes. The models take no account of topography on a small scale or local surface roughness (such as tall crops, buildings, stone walls or trees), all of which have a considerable effect on the wind speed. Thus, the results must be treated as a very rough estimate at this stage.

Entering the postcode BT23 6RR will return uncorrected wind speeds of 6.8 m/s at 25m from the NOABL database and 6.5 – 6.75 m/s at 30m from the DETI database. For our purposes we must be conservative in outlook so we will use 6 m/s at 30m to allow for local conditions such as trees, hedges and buildings.

Having established an approximate mean wind speed, we now need to apply this to the site specific wind regime and turbine power curve. As we have briefly discussed, the calculations are complex so it is sensible to take advantage of free online resources. One of the best calculators freely available, in our opinion, is at the Danish Wind Industry Association. There is also a wealth of other information:

http://www.motiva.fi/myllarin_tuulivoima/windpower%20web/en/tour/wres/pow/index.htm

Follow these instructions:

1. Select a site similar to yours from the drop down list. We have used Dunstaffnage in Scotland. (You can change most of the parameters)
2. Change the Weibull shape parameter to 1.66 (unless you know your site data is different)
3. Change the ‘m/s mean’ wind speed to 6 (as determined above)
4. Change the ‘m height,’ to 31.5
5. Select ‘Vestas V27 225/27’ from the Wind Turbine Data drop down list.
6. Read the energy output from the results box as shown below.

So, for a Vestas V27, 225kW turbine on this site, with a hub height of 31.5m, we might expect to generate about 481,820 kWh per annum at full turbine operational availability.

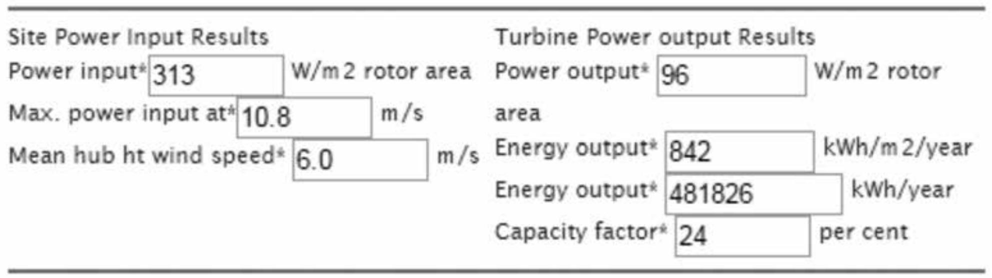

Figure 8: Wind Turbine Power Calculator Output (image courtesy of Danish Wind Energy Association)

7 Financials

7.1
Example system costs
Wind power installed costs will vary widely depending on turbine type, rated output, installation site, installation details and grid connection costs. Below we give example costs for typical sizes using standard, good quality equipment, Microgeneration Certification Scheme (MCS) registered installers, and installed at a site with good access. Grid connection costs have been excluded as they will be site specific. Prices range from 1,800 – 4,200 £/kW.

Generally, the lower the kW rating, the higher the cost per kWh will be. The last comprehensive survey of European costs was undertaken in 2009 but a 2013 report from the US shows that costs have fallen significantly since 2009. The expectation that costs can continue to fall may be unrealistic as costs of transportation and distribution from source will continue to increase. Finally, the cost of designing, supplying and installing wind power as a turnkey package is subject to the same inflationary pressure (especially on fuel, insurance, labour costs etc.) as any other capital project.

Turbine Size (kW)	From (£)	To (£)	Annual Maintenance	£/kW
225	390,000	420,000	6,500	1,800.00
100	270,000	300,000	4,500	2,850.00
50	170,000	190,000	2,500	3,600.00
20	70,000	85,000	2,500	3,875.00
15	55,000	65,000	750	4,000.00
6	20,000	30,000	375	4,166.67

Figure 9: Example system costs

7.2
Replaced power
The income from a wind power system may be made up of a combination of the value of replaced power, including VAT and levies, NIROC payments and export income. If the system is connected directly to the grid no generation will be consumed on site so there will be no income from replaced power. The greatest return on a wind power project will be made by replacing as much grid supplied power as possible. The power that you consume from the grid will always be the most expensive as the cost contains not only generation costs but also transmission costs and losses.

7.3
Export income
As of May 2015, in Northern Ireland, only Power NI can offer export tariffs. For renewable energy generators up to 50 kW, Power NI publishes its prices for export in October each year and this helps you to work out the expected income you can earn for the year ahead. This means that Power NI takes the risk out of fluctuating energy prices for smaller generators and can give certainty when calculating payback periods.

The Power NI export tariff in May 2015 was 5.10 p/kWh.

Export payments are paid annually. Payment for export will be made by Power NI directly into your bank account. A meter reader will continue to read your electricity meter so that a bill can be issued for the amount of electricity you have bought from your supplier. Power NI will contact you to request the export meter reading at the end of each September. As soon as they receive the valid export meter reading, they will arrange payment for you.

For generators above 50kW Power NI offer a payment contract based on open market wholesale prices known as a Power Purchase Agreement (PPA).

From approximately July 2015, Action Renewables Energy Trading (ARET) in conjunction with Budget Energy Ltd will provide a service for small generators. This is expected to be more competitive than the Power NI offering. ARET already offer a service for larger generators arranging the most competitive PPA.

7.4
NIROCs
The Renewables Obligation is the main support scheme for renewable electricity projects in the UK. It places an obligation on UK suppliers of electricity to source an increasing proportion of their electricity from renewable sources. A Renewables Obligation Certificate (ROC) is a green certificate issued to an accredited generator for eligible renewable electricity generated within the United Kingdom and supplied to customers within the United Kingdom by a licensed electricity supplier. One ROC is issued for each megawatt hour (MWh) of eligible renewable output generated. The Renewables Obligation (Northern Ireland) Order came into effect in April 2005 and the

Northern Ireland Renewables Obligation (NIRO) was introduced by DETI.

The NIRO has been subject to regular reviews and the day-to-day functions of administering the NIRO are performed by Ofgem. Ofgem, based in London, is responsible for the process of accrediting renewable energy installations and issuing NIROCs to generators in Northern Ireland.

Until 22 May 2015, Power NI acted as an Ofgem agent for generators up to 50kW so it could help smaller generators to get accredited with Ofgem and to manage the ongoing NIROC administration on their behalf. Since 22 May 2015 Power NI has ceased to act as an Ofgem agent so all generators must either find an alternative agent or apply directly to Ofgem. As far as we are aware, the only alternative agent at the time of writing is ARET. ARET will act as agent for generators <50kW and for larger generators will gain accreditation with Ofgem. The latter service is free where ARET also act as the ROC trader.

NIROCs are subject to banding; different renewable technologies of differing sizes receive a different number of NIROCs. Wind Power receives 4 NIROCs for installations up to 250 kW, 1 NIROC for installations less than 5 MW and 0.9 NIROC for installations greater than 5 MW. The banding levels are subject to regular review.

The Power NI NIROC unit price in May 2015 was 4.08 p/kWh so, for wind up to 250 kW, the payment was 16.32 p/kWh. Larger generators must negotiate their NIROC payments direct with a licensed electricity supplier or through an agent.

Note: NIROC for electricity generation from onshore wind will be cancelled in April 2016.

7.5
Predicting income and simple pay back

In May 2015, a typical average annual unit price for electricity was 13–15 p/kWh, 4 X NIROCs were 16.32 p/kWh, for systems under 50kW, and the export tariff was 5.10 p/kWh for systems under 50 kW. The financial advantage of consuming generation on site as opposed to exporting is clear.

Multiplying the predicted generation by the average unit value (AUV p/kWh) will give you an estimate of predicted income. For the AUV you need to know what size the system will be (to determine the NIROC band), how much of the generation you will export, how much you will use on site and your electricity unit cost. From these figures you can calculate an estimated AUV for the generated electricity as follows.

Assumptions:

1. You pay 15 p/kWh for your grid supplied electricity (including VAT and levies).
2. You expect to export 75% of the electricity you generate.
3. You are installing a 225 kW wind turbine and expect NIROCs of 16.32p/kWh.

75% EXPORT	%	Tariff (p/kWh)	AUV (p/kWh)
Exported electricity	75	5.1	3.83
Consumed on site	25	15	3.75
NIROC	100	16.32	16.32
		TOTAL	**23.90**

Figure 10: AUV for 75% export

This gives you an AUV of 23.90 p/kWh or 0.239 £/kWh. If you were to export only 25%, the AUV would increase to 28.85 p/kWh.

25% EXPORT	%	Tariff (p/kWh)	AUV (p/kWh)
Exported electricity	25	5.1	1.28
Consumed on site	75	15	11.25
NIROC	100	16.32	16.32
		TOTAL	**28.85**

Figure 11: AUV for 25% export

Applying the generation to the AUV renders the annual income at full operational availability. However, experience shows that operational availability over the lifetime of most turbines to date is less than 90% so it will be wise to reduce the income to 85% as shown in Figure 12.

	75% EXPORT	25% EXPORT
Generation	481820	481820
AUV	23.90	28.85
Income @ 8760 hrs	£115,131	£138,981
85% Availability	£97,861	£118,134

Figure 12: AUV for 25% export

Thus, at 85% operational availability, exporting 75% of generation, we might expect an annual income of £97,860 based on current tariffs and rates.

Simple pay back is the length of time that it will take for you to recover your costs. For a wind power system, the costs are the installation costs and the annual costs. Thus in most cases the simple pay back, in years, will be:

$$\textbf{Simple Pay Back} = \frac{\textbf{Capital Cost + Annual Costs}}{\textbf{(Replaced power value + NIROC value + Export value)}}$$

Thus, using the example for a 225 kW system in Section 8.1, simple pay back will be achieved in Year 5 for this system. Note that this is a purely hypothetical example.

	Year 1 (£)	Year 2 (£)	Year 3 (£)	Year 4 (£)	Year 5 (£)
Cost	-405,000	-313,639	-222,277	-130,916	-39,555
Maintenance	-6,500	-6,500	-6,500	-6,500	-6,500
Income	97,861	97,861	97,861	97,861	97,861
Total	-313,639	-222,277	-130,916	-39,555	51,806

Figure 13: Simple Payback

Note that rates and other annual costs have not been included above. Please sees Section 18.2.

7.6
Optimising returns from wind power

Getting the best return from your wind power system will depend on several factors. The main considerations are listed below:

1. Carry out a site survey to understand your project potential and pitfalls.
2. Plan the project carefully.
3. Ensure the system is professionally designed either by an MCS accredited installer or an independent consultant.
4. Ensure you carry out your own calculations for generation and pay back. Do not rely on the installer's illustrations.
5. Ensure you fully understand what you will realistically generate and get paid.
6. Ensure the system is regularly monitored and serviced post installation.

8 Case Studies

8.1
Antrim Area Hospital (660kW)
"Antrim Area Hospital is an acute trust of 350 beds and is part of Antrim United Hospitals Trust. Spurred on by the public sector building energy reduction target, the Hospital investigated installing a wind turbine on site to provide energy. Following a feasibility study, a wind study and an environmental impact assessment (EIA), planning permission for the project was given. From idea conception to installation took three years. The civil work started in autumn 2004 and the turbine was delivered in January 2005. It took only three days to install and has been fully operational since 7 February 2005. The 40 metre high 660 kW Vestas V47 wind turbine is the largest at any hospital in the UK. It will generate an average of 1.2 million units of electricity per annum, which is used as base load replacement. It has the potential to provide enough electricity for the hospital during the night, and two thirds of the power needed during the day, which would otherwise cost £90,000 a year. Even in low wind conditions the turbine is cost effective and the money that would have been spent on power is freed up for improved services for patients. The turbine cost £497,000, of which 80% was a grant from the Government Central Energy Efficiency Fund. Without a grant it would take five years for the initial cost to be repaid (at 2005 energy prices). The wind turbine has been a success and other hospitals across the UK are taking an interest in replicating what has been achieved at Antrim."

More Information: **http://www.tcirenewables.com/default.aspx?lang=en&page=projects-antrim**

Between January 2014 and January 2015 the turbine generated 726,000 kWh of energy, some 60.5% of that originally envisaged. The average capacity factor over the year is 13.7%.

8.2
Brett Martin Wind Turbine (2.3 MW)
"Brett Martin, leading manufacturers of plumbing and drainage systems, plastic roof lighting and glazing materials, has completed the installation of its first wind turbine at the company's headquarters in Mallusk. Representing an investment of over £2 million and standing at a fully extended height of almost 100 metres, the wind turbine is the largest of its kind on an industrial site in Northern Ireland.

Once fully functional the environmental benefits will be significant as the wind turbine is expected to reduce carbon emissions at the Mallusk site by 4,000 tonnes per year. Customers will also benefit from this green initiative which will deliver at least 20% lower energy costs for the company thus enabling more competitively priced products.

Laurence Martin, Brett Martin Managing Director, explains, "The planning and installation of our wind turbine has been sensitively and meticulously managed and planned over the past few years. We are very grateful to all the interested groups and individuals, statutory bodies and government agencies who provided advice and support along the way. At £2m the project represents a significant investment and one which we firmly believe will bring tangible benefits for the company and its stakeholders."

"As a responsible and forward-thinking company, we are strongly committed to reducing our carbon footprint and to maintaining our competitive position, which is in the interests of the business, our employees and the local community. We are confident that this wind turbine will enable us to both minimise our impact on the environment and help reduce our high energy costs. This in turn will enable us to remain a competitive business, securing further orders across our global market and safeguarding local jobs."

Work originally began on the project in 2006 with an initial feasibility study supported by the Carbon Trust. Following wind speed testing at the site and comprehensive research with wind turbine manufacturers the company began the planning application process in 2008 with assistance from planning consultants Turley Associates. Once planning approval was granted in 2010 the order to supply the wind turbine was placed with German based energy organisation Enercon. Preparatory site work began in September 2010 towards a scheduled completed commissioning date of early June 2011.

The Enercon E-70 wind turbine has a blade span of 71 metres and when the blade is fully extended the structure measures 99.5 metres from the ground to the blade tip. With an output of 2.3 MW the wind turbine will contribute 20% of Brett Martin's energy needs. Having supplied and installed the wind turbine Enercon have also been contracted for its ongoing maintenance."

Video: **https://www.youtube.com/watch?v=4BJFsiwG6mw**

Between January 2014 and January 2015 the turbine generated 3,882,000 kWh of energy, some 52.89% of the originally envisaged[xii]. The average capacity factor over the year is 19.38%.

B. Advanced - Feasibility

9 Introduction

The aim of any feasibility study should be to establish whether or not a project is feasible whilst incurring the minimum costs during feasibility as the costs cannot be recovered. One of the main difficulties with undertaking a wind feasibility study is that some of the factors affecting feasibility cannot be determined with certainty at the outset. For example, we have already seen that a grid connection application cannot be submitted until planning approval has been granted. This means that the possibility of getting connected to the grid and the cost of that connection remain unknown until the costs associated with gaining planning permission have been expended. Similarly, the factors affecting planning permission for wind turbines can be categorised as 'objective' and 'subjective'. The objective factors have a relatively simple pass/ fail criteria (although further studies may be possible at a cost) while the subjective criteria are a matter of informed opinion. The logical conclusion is to undertake a pre-feasibility assessment of all the available data to determine initial feasibility and understand likely costs associated with the project. If the project remains feasible, a full feasibility study may be undertaken. Prior to undertaking the pre-feasibility study the potential make and model of the turbine needs to be established. This is because the specific details of the turbine affect planning permission. In order to consider the make and model of the turbine, the turbine must be sized. Turbine sizing will, in turn, be informed by your onsite electricity consumption.

10 Electricity Consumption

10.1
Introduction

As we discussed previously, income from wind comes from three sources; replaced electricity, export and the NIROC scheme. Income from the NIROC scheme is earned on all generated metered electricity regardless of how it is used. Replaced electricity on site will always have a higher value than exported electricity. The difference in value will depend, amongst other factors, on the size of your system. Clearly, the optimum earnings and fastest pay back will be from a system where all of the energy generated is consumed on site.

Generation from wind occurs all year round but varies from season to season and throughout the day and night. Typically highest wind speeds are experienced around mid-day to early afternoon as shown below.

Figure 14: Typical daily wind speed distribution
(image courtesy of Logic Energy)

Thus, unless you operate your business 24/7 and size the system so that you always use all of the electrical output, you will not use all of the electricity generated.

Unless you are only exporting generation, to get a clear understanding of how much the system will earn, you must understand how much of the generated electricity you will consume on site and how much will be exported. To do this, you must thoroughly understand your electrical profile.

10.2
Profiling

10.2.1
Half-Hourly Metering

An electricity load profile describes the pattern of electricity use over time. The time period will vary depending on the amount of metered data available.

If your business has half-hourly metering[xiii], the load profile can be very detailed; some electricity suppliers provide on-line tools that can show you the profile over varying time periods so most of the work will be done for you. Typical tariff banding is divided between weekends, night, summer day, winter day and winter peak. By combining the data on a spread sheet you can produce useful charts. The charts below show an actual case for a factory working weekdays only.

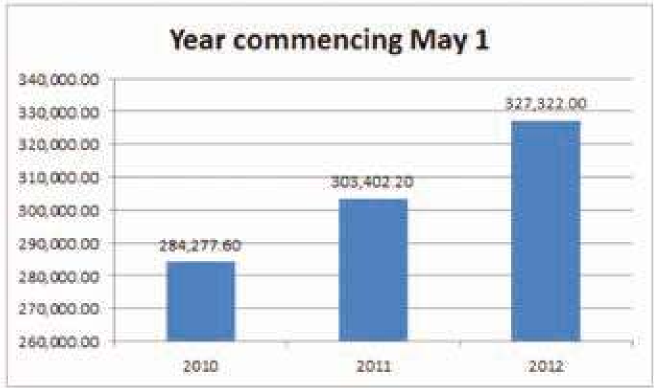

Figure 15: Annual consumption
(image courtesy of Element Consultants Ltd)

In this case we can immediately see that consumption has increased annually by 7–8% so we should allow for that increase in future projections. Profiling by tariff band shows us that the majority of consumption is during summer day tariff.

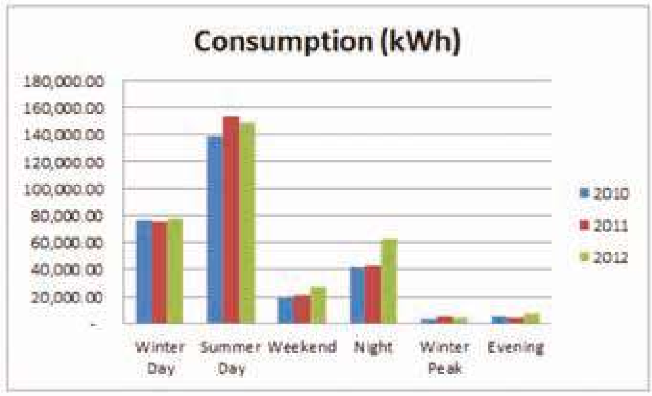

Figure 16: Consumption profile
(image courtesy of Element Consultants Ltd)

Note also the 2012 increase in consumption during the night and weekends. In this case the factory only operates during the weekdays so the chart flags up a change of use outside working hours in 2012 that should be identified and rectified.

The factory has fixed working hours and holidays and this enables us to calculate the mean power loads[xiv]. The mean power loads may be calculated by dividing total consumption (kWh) by working hours and subtracting the idle (weekend and night) load. This gives an annual active load for 2012/13 of 39.53 kW.

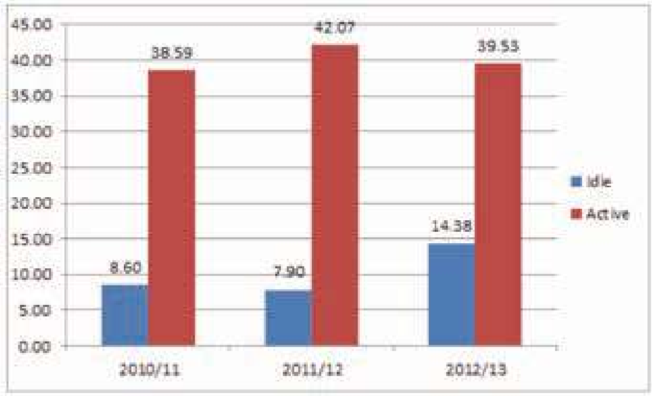

Figure 17: Mean power loads
(image courtesy of Element Consultants Ltd)

Thus, while the power requirement has reduced during working hours, it has doubled during idle hours. As idle hours represent almost 75% of time this is a substantial waste of resources and money.

10.2.2
Standard Metering

Without half-hourly metering, profiling is much less accurate. Billing will normally be monthly and the invoice will show metered consumption. However, it is commonplace for service providers to allow long periods of estimated readings. You must be aware that estimated readings will not assist you in profiling and will be misleading. If you do not have meter readings it will be wise to allow a period of at least a year for you to undertake a thorough meter reading schedule to establish your profile.

If the business has a day and night/weekend tariff, the calculations are simplified slightly. Again, if you have the monthly consumption data and you know the working and idle hours, you can use the method above to calculate the idle and working hours and the subsequent proportions of daytime hours and the relevant loads and consumption.

If the business is on a single tariff, the only way to establish a load profile, apart from very regular meter reading, is as follows:

- Make a complete list of electrical appliances.
- Record the electrical load of each appliance.
- Estimate the hours that they operate for each day of the week.
- Separate the working hours between day and night.
- Multiply the load by the day and night hours for each appliance.
- Sum the day and night hours separately.
- Check that this correlates to your meter readings and adjust as necessary.

10.3
Calculating on-site consumption

If you have standard metering, it is likely that the only useful information that you have will be the monthly average load (kWh / hours). At first sight this is of little use. However, it is possible to use the information to estimate the ratio of local energy usage to total energy. It is possible to plot the fraction of time that a specific wind turbine spends producing between zero and some other level of power as shown below for a Vestas V27.

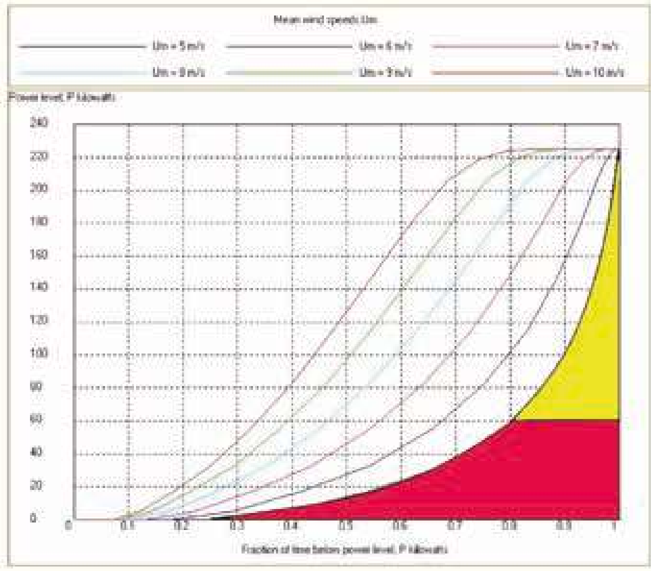

Figure 18: Power Consumed .v. Overall Power
(image courtesy of Pelaflow Consulting)

This plot is, in fact, the cumulative probability function for the power output of the turbine so that the mean power produced by the turbine at different mean wind speeds is simply the area under these curves. The area in red is the power consumed on site for a load of 60 kW at a mean wind speed of 5 m/s. Similarly, the area in yellow is exported. Therefore, the ratio of onsite to total energy generated can be plotted. This useful function is available in the Wind Power programme.

If we apply this to the mean power loads calculated above, for wind speeds of 6 m/s we get ratios of 0.12 and 0.38.

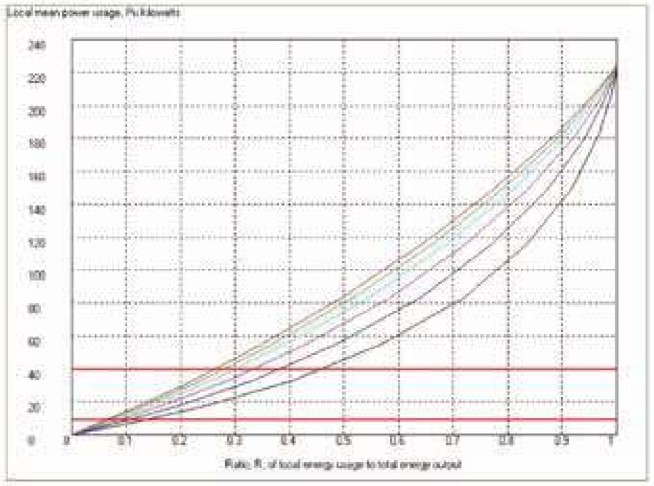

Figure 19: Ratio of Local Energy Use (image courtesy of Pelaflow Consulting)

These can be combined to give the average local use ratio.

kW	Ratio	Hrs	R X T
14.38	0.12	6501	780.12
39.53	0.38	2259	858.42
		Sum	1638.54
		Average Ratio	0.187048

Figure 20: Average Local Use Ratio

As well as being useful where little data is available, it is also useful as a check where data is in plentiful supply.

The simplest calculation using the mean power loads from the half hourly data above is to calculate the number of idle and active hours and multiply them by their respective loads to calculate the kWh consumed on site. However, be aware that this does not necessarily mean that all of the consumed electricity will be replaced by wind energy. If the wind is not blowing, no energy is being produced!

	% hrs	hrs	kW	kWh
Idle	74	6501	14.38	93,484
Active	26	2259	39.53	89,298
			Consumption	182,782

Figure 21: Simple Consumption

Of course, half-hourly metering gives you a huge range of data so it is possible to correlate the metered data directly with the generation data, if available. If an on-site wind survey has been carried out, wind speed data will be available at 10 minute intervals for a year. These can be averaged, three at a time, to form half-hourly wind speeds. From the half-hourly wind speeds we can calculate generation, plot this against half-hourly metered consumption and calculate the export. Note that, as the wind average is per half-hour, the power from the power curve must be halved to give the generation in kWh.

From Wind Survey			From Power Curve		Generation	HH Data	Consumption	Export
Date	Time	Speed m/s	Avg Speed	kW	kWh	kWh	kWh	kWh
10/03/2015	12:40:00	10.0170332						
10/03/2015	12:50:00	9.42873123						
10/03/2015	13:00:00	7.20272386	8.9	95	47.5	40	40	7.5
10/03/2015	13:10:00	8.41112786						
10/03/2015	13:20:00	4.29301422						
10/03/2015	13:30:00	6.18512049	6.3	31.8	15.9	50	15.9	0
10/03/2015	13:40:00	8.10902686						
10/03/2015	13:50:00	9.2379306						
10/03/2015	14:00:00	8.76092902	8.7	95	47.5	42	42	5.5
10/03/2015	14:10:00	7.83872596						
10/03/2015	14:20:00	8.77682907						
10/03/2015	14:30:00	4.89721622	7.2	52.5	26.25	37	26.5	0
					137.15		124.15	13

Figure 22: Correlating Generation and HH Data

This method will deliver a reasonably accurate estimate of on-site consumption and exported electricity.

11 Surveys

11.1 Desktop Surveys

The pre-feasibility studies in the previous sections summarise a typical desktop survey. To complete the desktop survey you will need to determine wind speed.

11.1.1 Wind Speed

As we saw in the basic section, ideally, to get the most accurate prediction of a wind resource, 10 minute average wind data is collected on site at the turbine hub height for a period of at least a year to ensure seasonal variations are fully accounted for. This may then be plotted against the turbine power curve to give a relatively accurate prediction of what a functioning turbine would have generated and subsequently earned. This is covered in the next section.

If actual site wind speed is not going to be measured then you must establish an approximate mean wind speed as accurately as possible. We are fortunate in the UK that the government provide a computer modelled wind speed database (NAOBL) through DECC. Whilst this is no substitute for actual data it provides a valuable resource for a desktop study when correctly interpreted. The original database has recently been upgraded by correlation with the Met Office NCIC data. As we saw earlier, the data is not easily transferable between hub heights for different turbines, nor does it include any methodology for allowing for local topography. Luckily, for a very modest fee, software is available that allows the developer to correlate wind speeds to hub heights and to make allowances for topography and obstacles. The UK Wind Speed Database program[xv] is intended to present the Department of Energy and Climate Change's database in a more user-friendly form and to give users a better feel for the link between wind speed profiles and topography. Clearly, it is of use mainly to those concerned with UK wind power. You need to know your UK Grid Coordinates or your latitude and longitude to input data. You can use the converter at **http://www.howtocreate.co.uk/php/gridref.php** to get these. Now you simply change the hub height to read off the wind speed at that hub height.

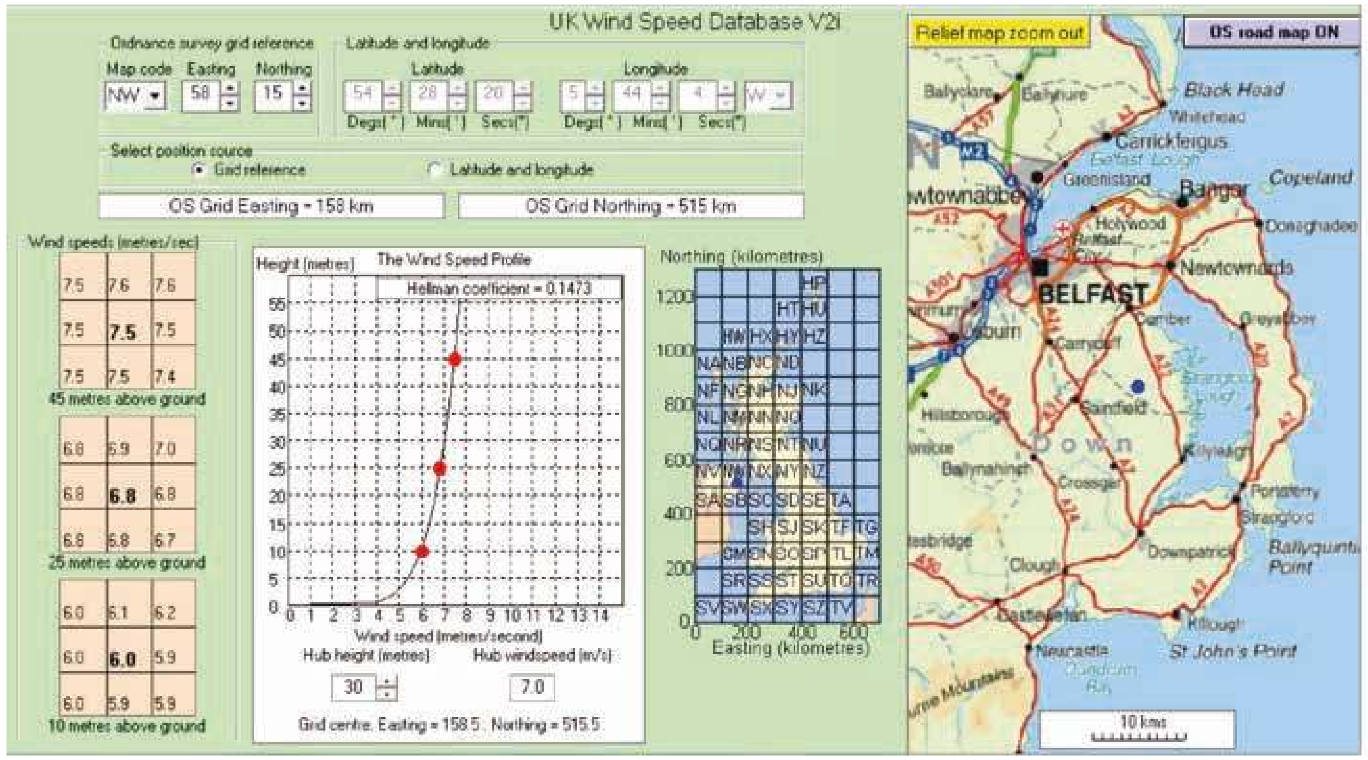

Figure 23: Modelled Wind Speed at 30m Hub height (image courtesy of Pelaflow Consulting)

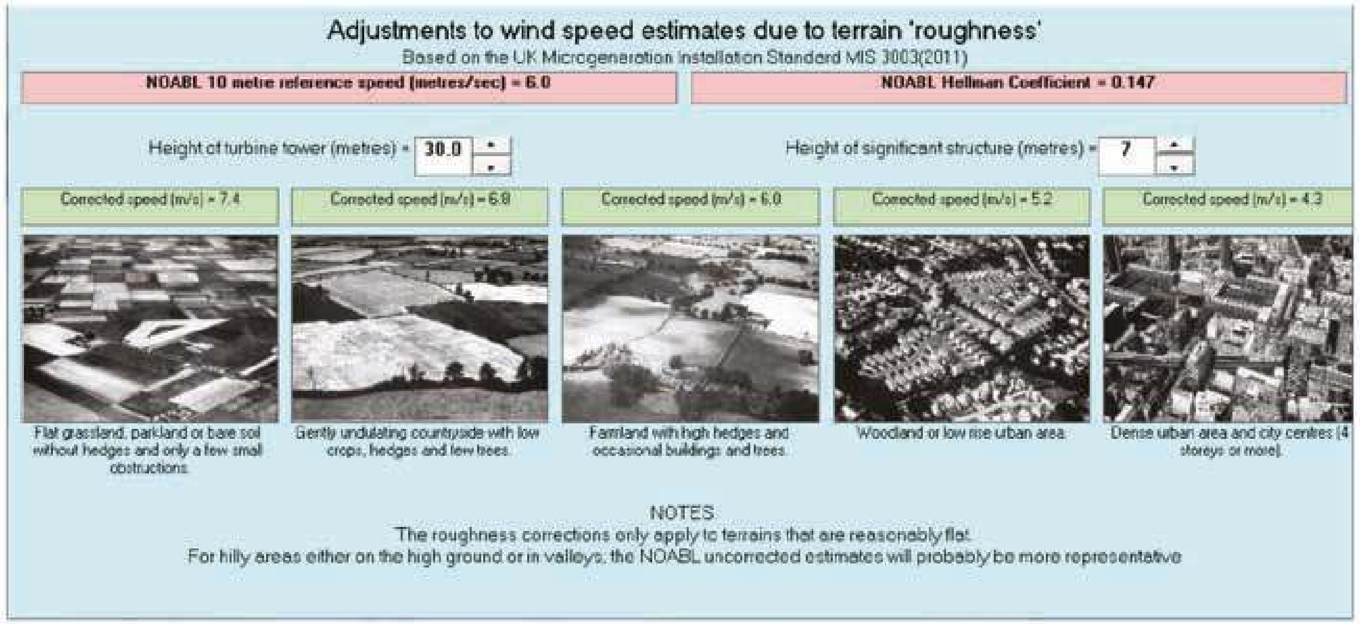

Figure 24: Wind Speed Corrections
(image courtesy of Pelaflow Consulting)

This gives an indication that, at 30m above ground level at BT23 6RR (NW5815), you may expect an average wind speed of 7 m/s in the centre of the grid square. You should note that this is computer modelled and averaged for a 1 km square. It does not take account of local obstacles and conditions.

Roughness is a measure of the obstacles to wind on the earth surface. Thus, the sea has very little roughness, whilst urban areas have high roughness. The greater the roughness the lower will be the wind speed as more turbulence is created. The Micro Generation Certification Scheme (MCS) gives a standard correction formula for roughness and nearby obstacles to be used with the wind speed database. These are available from within the UK Wind Speed Database program allowing you to make corrections to the wind speed based on site vegetation, topography and buildings. The results are shown above.

Clearly, in most cases, a correction must be allowed for roughness. The terrain falls somewhere between 'gently undulating countryside with low crops, hedges and trees' and 'farmland with high hedges and occasional buildings and trees'. Thus we can expect a corrected mean wind speed of between 5.2 and 6.0 metres per second.

In Northern Ireland, in addition to the DECC database we also have the Action Renewables (DETI) database. Again this is a modelled database (from 2003) but based on contours. The database returns a wind speed of 6.5 to 6.75 m/s at 30m above ground level as shown below.

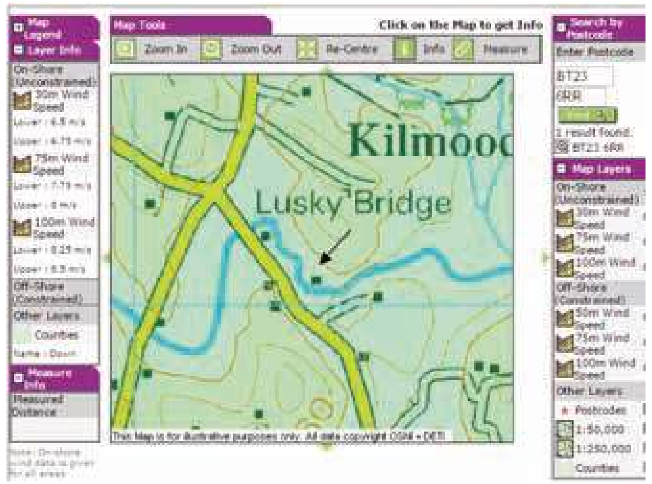

Figure 25: DETI Wind Speed
(image courtesy of DETI)

The DETI wind speed is uncorrected. As the uncorrected wind speeds from the two resources are similar, we may reasonably assume that a corrected speed of about 6.0 m/s at 30m hub height will be as accurate as we are likely to achieve from modelled wind resources.

There are additional sources of information but, most of them come at a considerable cost. The Met Offices "Virtual Met Mast" and "Virtual Met Mast Plus" reports[xvi] are an example of more detailed wind speed reporting.

If the aim is to proceed incurring minimum cost, this level of reporting should not be undertaken until pre-feasibility is complete.

11.1.2
Spatial Surveys

There are many aids to assist you in the completion of this type of survey. Planning Policy is available from the Planning Service NI website[xvii]. All of the NIEA datasets are available as shapefiles and can be downloaded from the NIEA website[xviii] to be used in any Graphical Information Systems (GIS) software such as Google Earth. Similarly, NATS and Civil Aviation shapefiles may be downloaded. If you or your architect has an OSNI license 10m height data files are available for download for a small fee. For applications close to the border with the Republic of Ireland, data may be downloaded from various ROI sites.

11.2
Site Surveys

11.2.1
Wind Speed

We have discussed that the wind speed varies from year to year and between the seasons. Additionally, turbulence levels must be considered. Both of these factors have a direct impact on the project.

- All income is dependent on wind speed and, as a result, the viability of the project depends on it.
- Any bank loan will be dependent on pay back and risk which will be dependent on wind speeds.
- Any other loan available will be dependent on the energy displaced which, in turn is dependent on wind speeds on site.

Only accurate on-site measurement can model this turbulence and the effect it will have on finances.

Financial institutions will demand measured wind speed so that they can achieve some risk assessment certainty. Obviously, the wind must be monitored for a meaningful length of time to ensure that seasonal variations are included and, to this end, it is usual for financial institutions to demand at least a year of wind speed monitoring.

The quality, accuracy and reliability requirements of measuring equipment needed for assessing wind energy generation and profit prognosis are much higher than those used in meteorological, agricultural or general scientific analysis. A small deviation in the results leads to large miscalculations and increases the risk of non-viable operation of the planned investment. For this reason, data has to be recorded for at least 12 months and it is crucial to select the correct choice of sensors and installation of the measuring systems. Mistakes here will add larger tolerances to the end results.

You need to measure the unrestricted horizontal component of the wind stream because this is what is relevant for energy generation. Wind sensors with small cups and a sharp-edged body often have trouble with skew winds and turbulence caused by tower and traverses. Even calibration cannot help much in these cases. Even some high accuracy anemometers do not meet the requirements for accurate energy prognosis. Tolerances specified by the manufacturers can lead to unacceptable deviations in the profit calculations. You only get the necessary reliability if each anemometer is calibrated separately in a wind tunnel. Low cost anemometers tend to suffer from a "drag" effect over time. This means that the economic materials used on its construction will have an effect on their reliability. Accuracy at manufacturing point won't be the same a few months later. Some of the symptoms are that over time it will take more wind to get the anemometer rotating and with light breezes the wind vane may be rotating and the anemometer will generally not be rotating.

Figure 26: A Typical Wind Mast Set Up
(image courtesy of Element Consultants Ltd)

Wrong traverses:
Close to the tower and traverses there is always turbulence and shading, which can have a negative effect on the measurements. The boom itself must have a minimum length. The highest and most important anemometer should be streamed upon from all directions without obstacles. A second anemometer may be installed at a lower height to determine wind roughness/shear.

Wrong measuring heights:
Data from anemometers that are shaded by houses, trees or other obstacles is unsuitable. Anemometers fitted too near to each other give inadequate data for the calculation of the height profile, since the difference between the two results is too small.

Wind Vanes:
For wind direction, potentiometer sensors are being used more widely because of their 1° resolution and low power consumption. It is important to keep in mind that the out-going-signal has to cover a full 360º without gaps. Because they have only a very simple potentiometer, less expensive wind vanes often show a big north-gap. These "low cost" sensors can only have a limited safe-life, because the electro-mechanical material used in their construction is not sufficiently durable. The data logger must also have suitable software for averaging the results, so that the "north jump" can be accounted for: the average of 350º and 10º should result in "North" and not 180º!

Sizes and Heights:
The ideal approach would be to measure the wind speed at the hub height of the wind turbine that is to be installed. Ideally you will measure wind speeds at two heights. So the height profile on this location is determined (Zo – roughness length), which can be used to calculate the wind speed at other heights. Since the calculation with a logarithmic formula represents only idealised wind circumstances and the difference between the average speeds at different heights is small, this implies:

- The use of individual calibrated anemometers which allow sensitivity against skew winds.
- The lower anemometer must be fitted high enough to avoid influences by obstacles (bushes, houses, etc.)
- The wind direction on a location needs to be monitored only once. The wind vane should be fitted about 1.5m below the top of the tower in order not to influence the top-anemometer.

On a simple location with no obstacles, a measuring tower with calibrated anemometers at two different heights is sufficient but in more complex areas the lower anemometer needs to be fitted higher. In order to provide minimum spacing between anemometers, the top anemometer needs to be positioned at the highest point. The wind direction sensor should be fitted about 1.5m below the top anemometer.

Data Recording:
The basis of wind energy prognosis is the relative frequency distribution of wind speed.

- Rayleigh and Weibull Functions are used when only a few wind details are known about the site, like the average wind speed.
- Classifying measurement data, this procedure is used in order to get the measured data into a form which is general and reduced to the necessary facts. Data needs to be recorded at intervals of one minute or ten minutes.
- Data will be recorded over at least one year, so that seasonal fluctuations are taken into consideration. Furthermore, the data of a single year has to be compared with long-term data, because wind speeds over a single year can differ by up to 20% from the long-term average. Estimating energy with just a few months can result in big miscalculations and economic losses.

If the measurement data has been recorded with sufficient resolution and accuracy and corrected as described, very good prognosis results will be obtained. The average frequencies of each single wind speed is multiplied by the corresponding power value of the wind turbine power curve in kWh and then summed. The result is the average output of the station, as shown below.

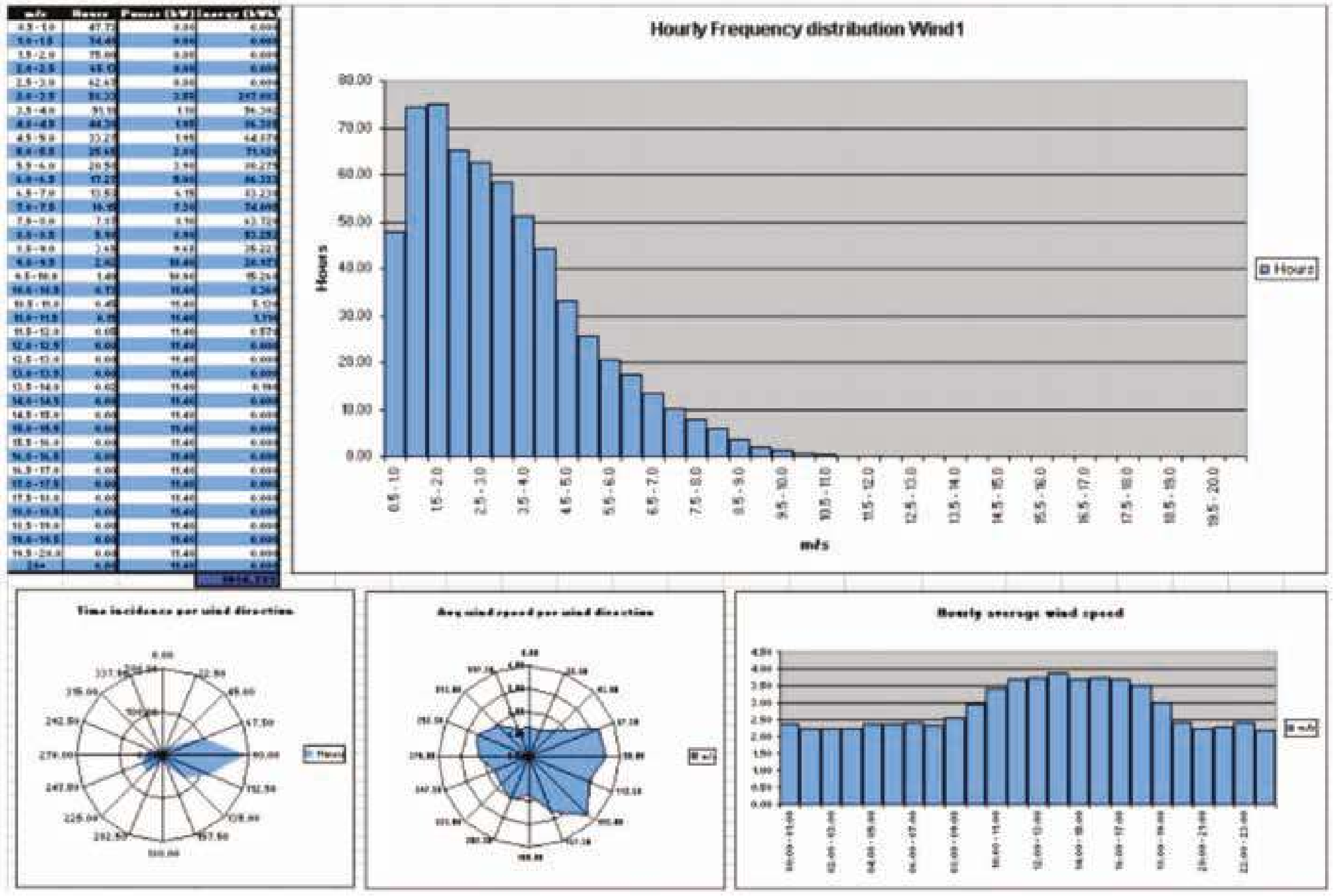

Figure 27: Wind Data Computations
(image courtesy of Logic Energy Ltd)

Typically, it will be necessary to employ a specialist consultant to erect an anemometer mast as close to the hub height as possible on the proposed site. The mast should house at least two calibrated anemometers, a 1% accuracy wind vane and a remote datalogger that records average, maximum and standard deviation for the wind speed at 10 minute intervals over a period of at least a year. Remote data logging is essential to avoid loss of data. Any loss of data will render the data of limited use.

Some financial institutions will insist on MCP (Measure, Correlate, Predict). This method takes the recorded data and correlates it with historic data from a nearby meterological station to predict the future earnings. This is an accepted methodology in wind statistics but, bearing in mind the severe changes in weather patterns in recent years due to climate change we believe that the possible 20% annual swing is more useful as a tool.

11.2.2
Site Survey
If you are to develop a site you must understand it as fully as possible. See Section 12 for more detail. You will need to carry out a physical site survey to establish the following:

1. The details held on spatial mapping and aerial photography systems correspond to those on the ground; i.e. that there have been no changes on the ground.

2. The topography and the local vegetation with reference to peat land, bats, birds and protected species.

3. The location and height of any buildings or proposed buildings that will affect shadow flicker and noise.

4. The location of any obvious fixed links nearby.

5. What roads (including unadopted roads), rights of way, and NIE transmission and distribution lines are nearby so that you can calculate clearance distances.

6. Where the nearest realistic grid connection point might be and whose land it may traverse (i.e. some of those you may need to consult with in future).

7. A good understanding of the ground characteristics so that you can easily pinpoint good locations for visibility photographs.

8. Who the neighbours are that will be affected by the turbine. You should engage with them as soon as possible in the process.

9. How you are going to access the site with the large scale machinery that is usually required and meet the requirements for access and visibility required by Roads Service.

12 Pre–Feasibility Study

If the wind regime on the proposed site is insufficient to generate adequate power, the project will not be feasible. If a project cannot gain planning permission or the costs of achieving planning permission or, indeed, implementing the conditions attached to a permission, are unacceptable to a developer, the project will not proceed. If, for a grid connected scheme, a project cannot gain a grid connection or the cost of grid connection is prohibitive the project will not be feasible. Clearly, the wind regime is dictated by the location of the turbine and the location of the turbine will be dictated by the possibility of gaining planning permission (and grid connection). Thus, the factors are interdependent and must be viewed together.

12.1
Grid Connection
Grid connection is currently the most likely issue to delay or even ensure a project fails. The grid infrastructure has not been upgraded to accommodate the influx of local renewable generators. As a result many parts of the grid, particularly in the north west where wind is prominent, cannot accommodate more generation without upgrading. This structural upgrading must be carried out by the distribution company funded by the electricity levy. Recently, as a result of the Competition Commission determination NIE have issued a statement saying that, where there is no spare capacity, they will no longer be able to issue offers to applicants until a way forward has been determined. This is unlikely to be before late 2015.

In October 2014 NIE published an online tool[xix] showing overhead lines and substations. In February 2015 they published an updated Heat Map to show areas that had no room for generation, areas that still had a little capacity and areas that remained open for connections. Using the previous example (BT23 6RR) the heat map shows that the 11kV lines in the area have capacity so grid connection should be less expensive than areas with more connections. The nearest substations are Ballygowan Central and Killinchy Central. Tracing the 11kV line shows that the area is served by the Ballygowan Central sub – station and this is coloured amber. At first sight, it is therefore unlikely that space will be available for increased generation connection by the time planning permission is achieved, unless the sub-station is upgraded. Note that the situation remains that you cannot be sure of small scale connection status (G59) without making a formal connection application. Thus, even at this early stage, the developer must decide if he wishes to incur further costs by reviewing the likelihood of achieving planning permission in the area.

The size of the wind turbine that you install will be influenced by the electricity supply infrastructure. You should verify the type of supply that you have on site; single phase (two cables) or three phase (three cables) as this will dictate what you can install without incurring connection costs and connection delays. See Sections 5 and 15 for more detail.

You should also examine your existing metering arrangements. Grid connections are allocated according to Meter Point Reference Numbers (MPRN). This can be very useful if you have more than one metered three phase supply as you may be able to install more than one generator.

Note that it may be cost effective to connect to a nearby three phase supply line but this can only become clear once a grid connection offer has been made. Unlike the GB system, there is no real opportunity to assess the grid infrastructure and likely costs of connection prior to applying to NIE.

12.2
Planning Permission

12.2.1
Introduction
Without planning permission no wind turbine scheme can proceed. Attaining planning permission for wind turbines has become more complex as the authorities have become more familiar with the issues involved. As a result there are now several consultees who are regularly consulted on all turbine applications. Of these some are objective and some are subjective. Those that demand an objective response can be analysed in advance and will either be a pass or a fail. Where a pass is not achieved and cannot be achieved, the project will not achieve planning permission. For those that require a subjective approach we must establish an opinion. We consider each relevant issue below.

12.2.2
Planning Policy - Subjective
The relevant planning policies are Planning Policy Statement 18 ‘Renewable Energy’ (PPS18), Supplementary Planning Guidance to PPS18 ‘Wind Energy Development in Northern Ireland’s Landscapes’ (SPG) and the Best Practise Guidance to PPS18 (BPG)[xx]. Whilst PPS18 and BPG set out the government position in supporting renewable energy development and are useful in general, the SPG is the most critical piece of policy legislation in terms of the likelihood of achieving permission in a specific location for a specific size of wind turbine.

The SPG uses the 130 Landscape Character Areas (LCA) of Northern Ireland as a template to provide individual guidance for each LCA for the locations and size of wind turbines that may be available along with the LCA’s capacity for wind development. It should be noted that the final version of the SPG was considerably watered down from the draft SPG (DSPG) and took two years of negotiation with lobby groups to finalise. The DSPG is more specific in its guidance for sizing and location and should be referred to for more specific detail.

ASSESSMENT OF POLICY FOR BT23 6RR.

The site is firmly within LCA 95, Ballygowan Drumlins.

LCA95 is assessed as High to Medium Sensitivity to wind development.

Supplementary Planning Guidance: The main concern in the guidance is the scale and siting of turbines in relation to the drumlin landform. Concern is also expressed regarding the open character of the landscape. Few areas will accept wind turbine development; appropriately scaled and avoiding skylines and settings. It would appear that siting a wind turbine here would be difficult.

Currently there are no local plans in force. However, it is good practice to consult the last local plan for the area and make allowance for any policy or zoning affecting the site or its environs.

The Northern Ireland Assembly’s Environment Committee published its “Report on the Committee’s Inquiry into Wind Energy” in January 2015[xxi]. It made several recommendations that, if implemented, will make a material difference to the current planning procedure. These will affect local saturation point; minimum separation distance; noise; and simultaneous planning applications for both grid connection and the turbine(s). You should be aware that these changes are likely to be introduced and read the report.

12.2.3
Local Planning Applications - Informative
Local planning applications need to be examined for a variety of reasons including the proximity of other turbines or proposed turbines, proposed or granted domestic dwellings and telemetry masts. Nearby turbines that have been granted planning permission may actually help any planning application, as they create a precedent for granting turbines in the area. However, they will contribute to the noise environment and may demand a cumulative noise assessment adding cost and complexity. Similarly, any approved or pending planning application for a domestic building will need to be assessed in the noise assessment.

12.2.4
Environmental Impact Assessment - Objective
All wind turbines over 10m high fall within the scope of the Environmental Impact Assessment Regulations. A determination is undertaken by the planners as to the necessity of an EIA. This is important as the planning fee for any site that is deemed to need an EIA is £10,496 plus the original planning fee. Normally an EIA is only required in close proximity to a protected site.

12.2.5
Environment Agency Factors – Objective / Subjective
The Northern Ireland Environment Agency (NIEA) will be consulted on the application in relation to both natural and built heritage. You should carry out a search of the surrounding area out to 1km, 2.5km and 5 km to determine any significant impact on any of the aspects listed below. It is probably not possible to be exhaustive in your research as NIEA will have more substantial datasets than are publicly available. Where any impact is envisaged you must determine an acceptable mitigation plan or relocate the turbine.

OBJECTIVE
ACTIVE PEAT LAND: Where the site in question is in an area with peat land, you must establish that it is not on ‘active’ peat land as it will not be allowed in most cases.

BATS: Bats are strictly protected. Most bats use significant linear features such as hedgerows, tree lines, woodland edge and watercourses as flight lines for navigation and foraging and are susceptible to impacts caused by turbines. In order to minimise these potential negative effects NIEA advice regarding bats and wind turbines is to maintain a 50m buffer between the tip of the turbine blade and existing habitat features on site. NIEA provide a calculation for this in its guidelines[xxiii]. When confirming the siting of the turbine, it is important to keep this distance in mind as, if the turbine fails this test, a bat survey, lasting from March to October will be required adding a cost in the region of £1,200 with no certainty of the outcome.

SUBJECTIVE
FLORA, FAUNA & HABITATS: RAMSAR, Areas of Special Scientific Interest, Special Areas of Conservation, Area of Outstanding Natural Beauty, Historic Garden,

National Nature Reserves, Special Protection Areas, Priority Species on proposed turbine site. NIEA hold datasets for all of the above sites. These are hosted on both the NIEA website[xxiv] through their Protected Areas Map Viewer and on the Spatial NI website[xxv] as a dataset overlay. To use the NIEA Map Viewer simply click on the link at the bottom left of the home page and follow the instructions. To use the Spatial NI dataset click on 'launch map viewer', then return to the home page and use the 'Browse' facility and select 'Live Map Services' in the tree. Now use the filter box to search for data. Click on 'Add to Map' and accept the license agreement and the data should appear on the map.

WATERWAYS: Protected inland waterways nearby. Waterways may be protected for fish, habitat, shellfish or birds. Again data on protected areas is available through the NIEA River Basin Plan Map Viewer.

BIRDS: Important Bird Areas. These may be analysed on the NBN Gateway[xxvi]. Note that there are areas where protected species (e.g. Whooper Swans) migrate or over winter through non protected areas. In these areas NIEA will ask for a Bird Survey. Like a Bat Survey this will take considerable time and additional cost.

ARCHAEOLOGY & HERITAGE SITES: Area of Significant Archaeological Importance, Defence Heritage, Industrial Heritage, Scheduled Monuments, Site/monument under state care, Listed Buildings Tomb sites. Again data on protected areas is available through the NIEA Built Heritage Map Viewer. Wind turbines can be perceived to impact on the 'setting' of protected sites and this should be considered when developing a scheme.

GEOLOGY: Significant geological sites should be considered through the Earth Science Conservation Review[xxvii]. The simplest way to navigate the ESCR is to use the Grid Reference of your location searching for the northing and easting individually.

12.2.6
Visual Impact – Subjective

Although any turbine will be dominant feature in the landscape, parts of it will be hidden from view from some of the viewpoints and the impact of this visibility should be assessed. A visibility assessment will be an important part of most planning applications. The amount of detail required should be proportional to the size of the turbine. For a small scale turbine a simple written statement should suffice. For a medium to large turbine several viewpoints should be selected from which the turbine has the most visual impact at varying distances from 1 km to 5 km. Photomontages and wireframes should be assembled for each of the viewpoints. In addition a map showing the Zone of Theoretical Visibility (ZTV) should be submitted. Commercial software is available to carry out all of these tasks but free and relatively inexpensive software is also available[xxviii].

12.2.7
Roads Service Clearance & Information - Objective

Roads Service is consulted on transport and access issues. The guidance on the proximity of wind turbines to roads is contained in The Best Practice Guidance to Planning Policy Statement 18 "Renewable Energy". That guidance recommends that wind turbines are set back at least fall over distance plus 10% from the edge of any public road or public right of way. Therefore, in the case of a 45m high 225kW wind turbine, an exclusion zone of 50m exists around all roads and rights of way.

In almost all cases Roads Service will also require a completed transport assessment form available at Annex A of the Transport Assessment booklet available from the Planning Service[xxix]. In addition, the developer will need to submit an existing and proposed plan showing details of the proposed access and sight lines.

12.2.8
NIE Clearance - Objective

NIE stipulate clearance distances for both transmission and distribution cabling; distribution cables require a clearance distance of fall over plus 6m as shown below.

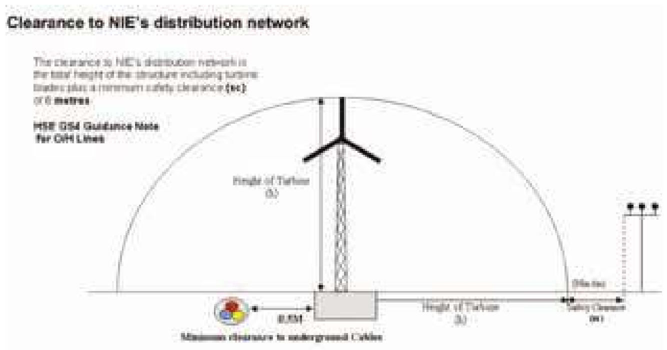

Figure 28: NIE Safety Clearance (image courtesy of NIE)

12.2.9
Aviation - Objective

National Air Traffic Services (NATS), the Defence Infrastructure Organisation (DIO) and local Airports and Aerodromes are consulted on all turbine planning applications. NATS provide a set of self-assessment GIS files to assess impact. NATS issues are rare. The Defence Infrastructure Organisation will not pre-consult.

Both primary and secondary radar at aerodromes are affected by any wind turbine in line of sight of the radar. Wind turbines cause 'clutter' on the radar display effectively blinding the operator. As this is safety equipment, aerodromes can object to any application for a turbine in line of sight of an existing or possible future radar installation within up to 40km, although this is normally limited to a 30km buffer zone as shown below.

Figure 29: NI Aerodrome Buffer Zones (image courtesy of Element Consultants Ltd)

Until recently, there has been no mitigation strategy for wind turbines and radar. However, there are now systems available (at considerable cost) to mitigate interference with radar. Normally, this is controlled by a condition on the planning permission stipulating that the mitigation must be agreed with aerodrome operator prior to commencing works.

12.2.10
Electro-magnetic Interference - Objective

Wind turbines have the ability to cause interference to the signals used by television providers, mobile phone providers and utility services that use radio fixed links. Turbines must normally be located outside a separation zone. Unfortunately fixed link locations are not publicly available. Therefore it is necessary to pre-consult with OFCOM at **Spectrum.Licensing@ofcom.org.uk**. In addition, we consider it good practice to consult **windfarms@jrc.co.uk** for NIE and **Windfarm.Management@magdalene.co.uk** for NI Water. OFCOM will reply with a list of any fixed links within the separation distance and the developer should consult the operators of these fixed links separately. If a fixed link remains within the separation distance, it may be possible to mitigate the issue through a further study, at a cost. Some operators offer this as an additional service. Software is available for assessing the effect on fixed links.

12.2.11
Environmental Health – Shadow Flicker - Objective

Tall structures such as wind turbines cast shadows, which vary in length according to the sun's altitude, and position according to the sun's azimuth (bearing). Rotating turbine blades cast moving shadows, which could, under certain conditions, cause flickering. Planning Guidance on Shadow Flicker is contained within PPS18 and states that, under certain combinations of geographical position and time of day, the sun may pass behind the rotors of a wind turbine and cast a shadow over neighbouring properties. When the blades rotate, the shadow flicks on and off; the effect is known as 'shadow flicker'. It only occurs inside buildings where the flicker appears through a narrow window opening. A single window in a single building is likely to be affected for a few minutes at certain times of the day during short periods of the year. Only properties within 130 degrees either side of north, relative to the turbines can be affected at these latitudes in the UK – turbines do not cast long shadows on their southern side. The further the observer is from the turbine the less pronounced the effect will be.

Shadow flicker can be mitigated by siting wind turbines a sufficient distance from residences likely to be affected. Flicker effects have been proven to occur only within ten rotor diameters of a turbine. Therefore if a turbine has 27m diameter blades, the potential shadow flicker effect could be felt up to 270m from a turbine and within 130 degrees either side of North.

Therefore, the developer should attempt to ensure that there are no occupied buildings within this exclusion zone. If this cannot be avoided, a full shadow flicker survey may be commissioned. Again, this adds cost.

12.2.12
Environmental Health – Noise - Objective
The allowable noise emissions from a wind turbine are governed by ETSU-R-97 'The Assessment and rating of Noise from Wind Turbines'[xxx]. This standard lays down the acceptable noise emissions at the nearest noise sensitive receptors[xxxi] and the methods for establishing those emissions. The full method involves a background noise survey undertaken over the course of a week. The noise data from the turbine is then overlaid onto the measured noise data and, providing the noise from the wind turbine is plus or minus 5dBA, the turbine is acceptable. Full noise assessments are costly (generally over £800) and the guidance allows for a simplified method that mathematically calculates the noise at the receptor. This is obviously a less expensive method and therefore the method of choice.

At project planning stage it allows siting of the turbine to meet the simplified method, if possible. New guidelines were issued in May 2013 for the EHO's to assess noise in relation to wind turbines[xxxii]. In the simplified method the noise emanates from the turbine hub and is received by an imaginary 'receptor' 4m (2nd floor window height) above the ground at the nearest receptors boundary.

In order to carry out the necessary noise calculations to prove that the noise emissions will be acceptable it is necessary to establish the exact model of wind turbine or to use the noise data from a turbine that emits the highest known noise emissions for that power output. This is important as the noise levels from different turbines vary widely.

12.2.13
Planning Results
As discussed above, the aim of the pre-feasibility study is to identify as many of the factors affecting the project as possible, mitigate their effects if possible and arrive at a conclusion that gives the optimum course of action. We have seen that this will be a result of considering all the factors above and how they interact with one another to give the best result. Indeed, it is perfectly possible that no project is feasible. The Objective factors; EIA; bat separation zone; peat land exclusion; roads clearance distances; NIE infrastructure clearance distances; aviation factors; fixed link clearances; shadow flicker clearance; and noise separation distances create a formidable array of conditions that need to be met for a simple application to planning. Even if these can all be addressed, the Subjective factors; planning policy; natural and built environment protected sites and areas; and visual impacts muddy the waters and cause uncertainty. Gaining planning permission is not straightforward.

If the factors above cannot be sufficiently mitigated, there are options available in many cases but these all come at an additional cost, mostly in excess of £1000. The following surveys can be undertaken in the hope that they prove that there is no significant impact that will cause the refusal of planning permission; bat survey; background noise survey; shadow flicker survey; bird (or other ecological) survey; heritage impact assessment; visual impact assessment; and fixed link impact assessment.

12.3
Wind Resource & Turbine
At pre-feasibility stage it may be sufficient to use the modelled wind speeds referred to earlier in this guide to establish if a turbine is feasible from a wind resource perspective. However, in order to establish a specific make and model it will be necessary to examine how a variety of turbines will perform on the preferred site. Only once a specific model has been established can some of the objective planning requirements be addressed.

12.3.1
Hub Height Wind Speeds
The UK Wind Speed Database programme, used in conjunction with the DETI Wind Atlas and the MCS Correction Methodology will give us the best possible estimate of site wind speed without vast expenditure. Indeed, the programme has the added advantage of allowing us to estimate the wind speed at different hub heights for different turbines. If we wished to compare the output of a variety of turbines from 6W to 225kW we would probably be looking at mast heights ranging from 15m to 31.5m and their associated predicted wind speeds as shown below.

Rated Power	Model	Rotor Diameter	Tower Height	Wind Speed @ hub height
(kW)		(m)	(m)	(m/s)
225	Vestas V27	27	31	6.6
100	NP 100	24.4	29	6.6
50	E3120	19.2	25	6.4
20	C & F 20	13.1	25	6.4
10	Bergey 10	7	25	6.4
6	Kingspan KW15	5.6	15	6

Figure 30: Wind Speed at Hub Height

12.3.2
Wind Speed Probability Distribution
It is a matter of common observation that the wind is not steady and in order to calculate the mean power delivered by a wind turbine from its power curve, it is necessary to know the probability density of the wind speed. For those unfamiliar with statistics, this is simply the distribution of the proportion of time spent by the wind within narrow bands of wind speed.

As an example, the figure below shows a histogram of the frequency of different hourly wind speeds at 1 knot intervals (0.52 metres/second) from a weather station in Plymouth, UK. The data consists of three years of observations.

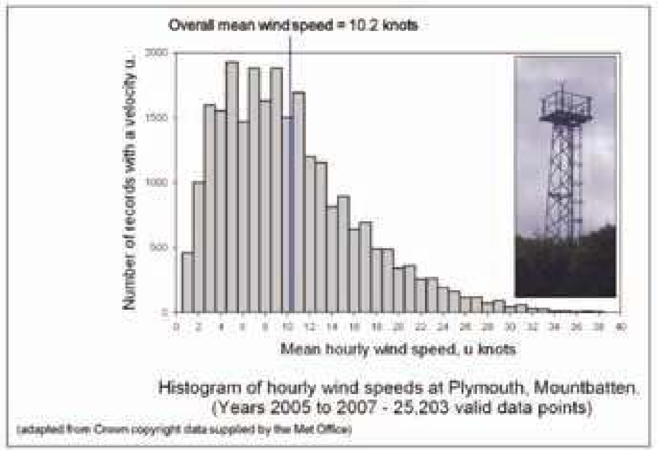

Figure 31: Hourly Wind Speed Frequency
(image courtesy of Pelaflow Consulting)

The basic measure of the unsteadiness of the wind is the standard deviation (or root mean square) of the speed variations. For the above data, the standard deviation is 6.28 knots (3.24 metres/second) so that the ratio of the standard deviation to the mean speed is 0.62 - and this is almost certainly representative of the unsteadiness of the wind everywhere in the UK. However, the value used in the calculation of mean power is normally set at 0.52 which corresponds to a particular form of the wind distribution known as the Rayleigh distribution. The use of these fractions in the Weibull equation results in the Weibull Distribution which describes the probability distribution of the wind.

Therefore, in our calculations we will use the more likely ratio of 0.62 as opposed to the Rayleigh Distribution. Note that the local turbulence will affect the Weibull Distribution.

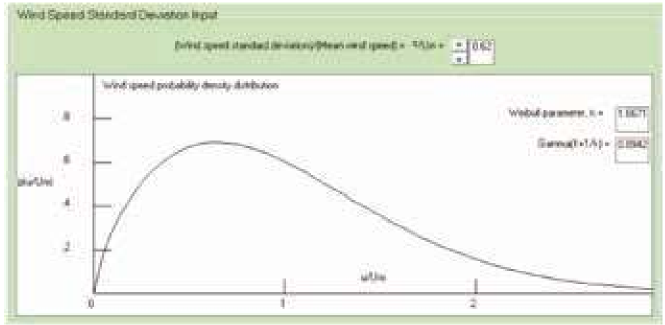

Figure 32: Common Ratio (0.62)
(image courtesy of Pelaflow Consulting)

The Rayleigh distribution gives a higher percentage of wind at higher wind speeds (the hump is higher and further to the right) and thus increases the overall predicted generation at higher wind speeds but reduces generation at lower wind speeds.

12.3.3
Turbine Generation
The theoretical maximum power efficiency of any design of wind turbine is 0.59 (i.e. Betz Law states that no more than 59% of the energy carried by the wind can be extracted by a wind turbine). Once you also factor in the engineering requirements of a wind turbine - strength and durability in particular - the real world limit is well below the Betz Limit with values of 0.35-0.45 common even in the best designed wind turbines. By the time you take into account other inefficiencies in a complete wind turbine system - e.g. the generator, bearings, power transmission and so on - only 10-40% of the power of the wind is ever actually converted into usable electricity. For a second hand wind turbine, even though it has been refurbished, it is difficult to be accurate in estimating these losses.

All wind turbines have a power curve. This curve describes the relationship between wind speed and power generation when the turbine is operating. The curve for a Vestas V27 (225kW) is shown below.

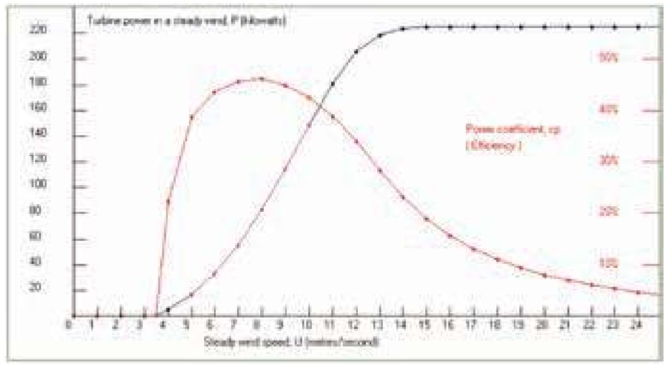

Figure 33: Power Curve
(image courtesy of Pelaflow Consulting)

The power coefficient is a measure of the turbine efficiency. The V27 is almost 45% efficient at 8 m/s. This is a relatively good efficiency. The rated wind speed for the turbine is 15m/s. That is to say that it will reach peak output of 225kW at 15m/s.

Plotting the predicted mean wind speed against the power curve using the probability distribution gives us the mean power output as a function of mean wind speed.

The Wind Power programme[xxxiii], a simple inexpensive programme developed specifically to examine the likely generation of various turbines, may now be used to assess mean power.

Rated Power	Model	Tower Height	Wind Speed @ hub height	Mean Power Generated
(kW)		(m)	(m/s)	(kW)
225	Vestas V27	31	6.6	65.87
100	NP 100	29	6.6	33.34
50	E3120	25	6.4	21.14
20	C & F 20	25	6.4	7.93
10	Bergey 10	25	6.4	3.09
6	Kingspan KW15	15	6	1.615

Figure 34: Mean Power

When mean power (kW) is applied to annual hours, annual generation is computed (kWh) for full operational availability. However, empirical evidence shows that, over their lifetime, wind turbines are rarely operationally available for more than 85% of the time so generation must be derated to a more realistic annual output.

Rated Power	Model	Mean Power Generated	Generation	Availability	Available Energy
(kW)		(kW)	(kWh)	%	(kWh)
225	Vestas V27	65.87	277021	85	490468
100	NP 100	33.34	292058	85	248250
50	E3120	21.14	185186	85	157408
20	C & F 20	7.93	69467	85	59047
10	Bergey 10	3.09	27068	85	23008
6	Kingspan KW15	1.615	14147	85	12025

Figure 35: Comparative Annual Generation

12.3.4
Turbine Income
We have already seen that income comes from replaced energy, export and NIROCs. Where a turbines generation is to be consumed on site, before export takes place, we have emphasised the importance of accuracy in establishing the amount of consumed generation because of the difference in price between imported and exported electricity. If the turbine is simply connected to export to the grid only the calculation is relatively simple; you will receive a payment for export and a payment for the NIROC element.

It is difficult to be sure of the spill (export) rate that will be achieved as the energy companies now negotiate spill rates direct with the client for generators above 50kW. Power NI, Energia, Airtricity and ESB all purchase energy in the Single Energy Market and the developer should expect to receive less than the recently published price for generators <50kW. For illustration purposes we use 4.75 p/kWh here.

All renewable energy generated earns the Northern Ireland Renewable Energy Obligation Certificate (NIROC). Wind turbines up to 250kW earn 4 X NIROC's; currently 16.32 pence per kWh generated. However, the NIROC is a support mechanism and has reduced by nearly 4% each year in 2013 and 2014. We expect that it will continue to reduce by at least 2% per annum.

We have seen the principle of calculating onsite consumption based on mean power consumption. For illustration purposes we will use a mean power consumption of 40kW and an average unit cost of 14 p/kWh.

Rated Power	Model	Mean Power Generated	On site Use Probaility	Available Energy	Onsite use	Export	NIROC
(kW)		(kW)	(kWh)	(kWh)	%	%	(kWh)
225	Vestas V27	65.87	0.55	490468	269757	220711	490468
100	NP 100	33.34	0.64	248250	158880	89370	248250
50	E3120	21.14	0.72	157408	113334	44074	157408
20	C & F 20	7.93	1.00	59047	59047	0	59047
10	Bergey 10	3.09	1.00	23008	23008	0	23008
6	Kingspan KW15	1.615	1.00	12025	12025	0	12025

Figure 36: Consumption and Export

		INCOME					
Rated Power	Model	On Site Use rate	Export Rate	NIROC Rate	Income	Capital Cost	Pay Back
(kW)		(p/kWh)	(p/kWh)	(p/kWh)	(£)	(£)	(Years)
225	Vestas V27	14.000	4.75	16.32	£128,294	£405,000	3.16
100	NP 100	14.000	4.75	16.32	£67,003	£285,000	4.25
50	E3120	14.000	4.75	16.32	£43,649	£180,000	4.12
20	C & F 20	14.000	4.75	16.32	£17,903	£77,500	4.33
10	Bergey 10	14.000	4.75	16.32	£6,976	£60,000	8.60
6	Kingspan KW15	14.000	4.75	16.32	£3,646	£25,000	6.86

Figure 37: Income, Cost & Pay Back

In this theoretical case, it would appear that a Vestas V27 offers the fastest pay back. However, this is theoretical and it takes no account of long term trends.

12.4
Pre-Feasibility Results
At each stage of the pre-feasibility study, any factor that affects the location or size of the turbine will require a reassessment of all of the factors until the optimum location and size are established. This exercise should result in either an abandoned project or a well-informed project aware of the majority of potential pitfalls, possible mitigation and future costs. If the project is to proceed to the next step, the exercise should have defined a location for a turbine of a specific make and model.

13 Technology Detail

13.1
Standards & Turbine Classes
IEC 61400[xxxiv] is a set of design requirements designed to ensure that wind turbines are appropriately engineered against damage from hazards within the planned lifetime. The standard concerns most aspects of the turbine life from site conditions before construction, to turbine components being tested, assembled and operated.

The standards also define the specific methodology to be used in acoustic noise measurement (IEC 61400 – 11) and declaration of apparent sound power level and tonality values (IEC 61400 – 14). IEC 61400 – 22 specifies rules for procedures and management for carrying out conformity evaluation of WT and wind farms, with respect to specific standards and other technical requirements, relating to safety, reliability, performance, testing and interaction with electrical power networks.

Wind turbine "classes" are addressed in part 1 of the standard. Wind turbines are designed for specific conditions. During the construction and design phase assumptions are made about the wind climate that the wind turbines will be exposed to. Turbine wind class is just one of the factors which need to be considered during the complex process of planning a wind power plant. Wind classes determine which turbine is suitable for the normal wind conditions of a particular site. Turbine classes are determined by three parameters - the average wind speed, extreme 50-year gust, and turbulence. Classes range from Ia to IV with IV designed for the lowest annual wind speed and gusts. More detail on the calculation method is available online[xxxv].

13.2
Modelling & Prediction Software
There is a wide array of commercial software available for wind regime modelling, energy yield assessment, noise, shadow flicker and visibility assessment. The majority of the software is prohibitively expensive for a single development and is aimed at wind farm development. Some specialist consultancy companies will have made the investment in wind farm software and it may be possible to use them for relatively inexpensive reports for specific items such as noise or shadow flicker during the project. However, in most cases, it is likely to be more cost effective to carry out feasibility studies using free or inexpensive software until a feasible project is assured. At that stage, the developer may make an informed decision as to what, if any, further analysis is required. A brief description of some of the best known software packages is shown below.

NAME	DESCRIPTION	PRICE	APPLICATION
WAsP II	Wind modelling	From €3,600	Informs Wind Farm Development Software
MeteodynWT RG	Wind modelling	N/K	Informs Wind Farm Development Software
WindSim	Wind modelling	N/K	Informs Wind Farm Development Software
WindPro	Modules for most requirements for a development	From €2,000 to ≈ €20,000	All developments
WindFarmer	Modules for most requirements for a development	From €2,000 to ≈ €20,000	All developments
AWS Openwind	Modules for most requirements for a development	N/K	All developments – Basic & Enterprise editions
RetScreen	Detailed generation and cost software	Free	All (Canadian)
UK Wind Speed Database	Modelled Wind Speed & corrections	£10	All (UK)
WindPower	Detailed generation and cost software	£25	All (UK)
Google Earth Pro	GIS programme	Free	ZTV, visibility wireframes (using Sketchup), all GIS work for protected areas.
Google Sketchup	3D Modelling	Free	Turbine and local environment modelling
Paint.net	Photo editor	Free	Photomontage

14 System Design

In the past, system design was an extremely complex process with significant engineering expertise required to match turbines, electronic gear, cable sizes and foundations. As the market has grown, design software has greatly simplified system design processes; assuming accurate data is used. Turbine manufacturers and installers now dictate foundation and electrical designs. However, experience and expertise remain important to ensure good design standards are achieved. Below are some key design considerations when selecting an installation contractor.

You can expect the installers you invite to bid for your project to explain how their equipment is the best available; the manufacturers and wholesalers they work with are expert at differentiating products in the market. Ask for in-field performance data for Northern Ireland, and ask for a copy of the predicted performance issued with the original contract to see how the two compare. Beware if this data is not forthcoming.

Ensure that the proposed installation will be subject to a structural survey and sign-off by a suitably qualified structural engineer. It is imperative that the foundations can accommodate the mass-loading of the installed system.

Ensure that the electrical system and earthing arrangement are fully signed off and acceptable to NIE distribution.

14.1 Sizing

Initial sizing can be undertaken as described in Section 3 above. Unfortunately, it is a fact of life for wind turbine installations that the cost of grid connection remains an unknown until a grid connection feasibility study has been carried out by NIE Distribution. If you proceed to a grid connection study, you should be ready to engage with NIE to examine the financial effect that different sized generators have on the financial outcome and reassess sizing accordingly.

14.2 Drawings

Drawing sets should be issued for approval pre-installation, and then re-issued ‘as-built’ post installation. Drawing sets are standard practice in the construction industry and serve as evidence of site-specific system design. A typical drawing set will include an electrical schematic for the complete system (as per BS7671; The Wiring Regulations 17th Edition), plans and elevations. An electrical schematic is a minimum requirement of the MCS scheme.

15 Understanding Grid Connection

15.1
Micro-generators
Connection for micro-generators is the simplest option. The installer should apply to NIE on your behalf completing a G83 connection pack and including:

a. G83 SSEG Commissioning Confirmation
b. G83 test results
c. A schematic diagram
d. Technical information on the hardware
e. G83/1 Certification for the inverters used
f. A site layout plan.

There is no charge for this connection. Once the application has been processed an import/ export meter is fitted. Average connection time from application to connection is 1–2 months. Because of the system size (below 3.68 kW single phase and 11.04 kW three phase) connection would be immediate on test and commissioning. The installer would complete a G83 notification for NIE's records but connect without advance approval.

G83 installations are further divided into single properties (G83 Stage 1) and multiple property connections in a close geographical area (G83 Stage 2).

At May 2015 G83/1 applications carried no application fee. However, G83/2 applications carry a fee of £651.60 for each proposed connection if there is no existing line or the line requires upgrading from single to three phase. G83/2 applications will also be subject to network assessment and, if network reinforcement is required, NIE will issue a quotation for the work. This can take up to three months.

15.2
Small-scale generators
The connection process and options for small-scale generators are more complex. There are two options at the outset.

The first is for a feasibility study and is available to anyone at any time. At May 2015, for generators of up to 150 kW the feasibility study costs £668.40, for generators over 150 kW the study is £1335.60. A feasibility study is an optional study providing indicative costs for your generation connection to help you to develop your business plan. This is typically carried out before you make a formal application to the Department of the Environment Planning Service to obtain approval for your generation scheme. The study indicates the current capacity available, details of the work required to provide connection, connection voltage level and the connection point to the NIE network.

The second option is a network connection and capacity study which is a full application process offered to customers who have obtained all permissions, including planning permission at the date of application. This study is a full technical appraisal and requires you to submit a formal application (NIE Generator Questionnaire) and the full electrical technical specification of the generator being connected together with the appropriate non-refundable fee. These fees are: <=20 kW £668.40; <=150 kW £2,002.80; >150 kW <2 MW three phase £6,676.80 (prices correct at May 2015). This is the full connection application and reserves capacity on the grid.

The G59 connection is a nine step process as follows:

1. Online registration at **www.nie.co.uk/genconnect/register.asp**
2. Questionnaire completion and return
3. NIE review application
4. NIE issue formal terms and conditions and quote
5. Applicant formally accepts quote and pays – NIE initiate legalities.
6. NIE provide Generator Connection Agreement
7. Applicant advises NIE of Generators Trading Arrangement
8. Applicant returns signed connection agreement and signed certification
9. NIE countersigns Generator agreement and paralleling commences.

In this case, it is unlikely that NIE will require planning permission in which case timescales are as shown below.

Figure 38: Grid Connection Timescale (No Planning) (image courtesy of NIE)

If planning permission is required the time scale is extended as follows.

Figure 39: Grid Connection Timescale (Planning Required) (image courtesy of NIE)

Average connection time from application to connection is 9 – 12 months but up to 20 months must be allowed for this scale of grid connection, if connection is available. Note that in some areas the grid has reached capacity and NIE will not issue an offer in these cases.

15.3
All generators

The generator must sign a Parallel Generator Agreement. The relevant clauses are that there is no liability for compensation of any loss of profit. Loss due to physical damage is limited to the value of the generator's installation or £100,000; whichever is the lower. NIE may de-energise the facility at any time to inspect or effect alterations, maintenance, repairs or additions to any part of the NIE system and the agreement may be terminated at six months' notice.

You will be required to enter into a Power Purchase Agreement with your power purchaser. The agreement governs the sale of exported electricity. A typical agreement is known as an SEM[xxxvi] Energy and Renewables Benefits Agreement. The key points are as follows:

The seller's obligations are:

- Comply with the Renewable Obligation (Northern Ireland) Order 2009 (RONI)[xxxvii], comply with all regulations, insure all plant, sell all exported electricity and associated benefits to the buyer.
- Contract term is normally five years.
- Any new benefits arising under the agreement to be split 50:50.
- Payment made two months after generation month.
- No VAT.
- Give notice of maintenance events.
- No assignment without agreement.
- Termination: normal clauses – insolvency, non-payment etc.

The buyer's obligations reflect those of the seller. The key points are that there is a minimum two month time lag between generation and payment for generation which will affect cash flow on completion of the installation, and that the agreement cannot be assigned without the buyer's agreement.

Typically, a good PPA will pay the agreed annual NIROC price plus a proportion of the buyout fund; say 80 - 90% at the year end.

You should be aware that the system operated by NIE can cause high connection quotes to be issued for small-scale generators. The system is operated on a first come, first served basis and offers are valid for 90 days. Thus if your neighbour puts in an application before you he will be quoted for the initial line upgrade. Subsequently you will be quoted for the greater upgrade to take the greater load. This will continue until the first quote expires. At that stage the initial upgrade (the least expensive one) becomes available again. This has led to high costs for line upgrades being quoted in the offers being issued. Additionally, the current grid infrastructure, especially in the north-west, is close to capacity. Until NIE receives agreement for a funding mechanism for additional network reinforcement from the Utility Regulator, and that work is undertaken, no connection can be made where there is no capacity. Where there is some capacity the developer should bear in mind that a smaller turbine may well render the project viable (e.g. a 150 kW turbine will require considerably less infrastructure to carry its generation).

Clearly, microgeneration connection will always be the preferable option in terms of cost, time and simplicity.

Size	Phase	NIE Type	Requirements	Process	Costs
<= 3.68 kW	Single	Microgeneration	G83 application	Fit & Connect	No app. fee
<=11.04kW	Three	Microgeneration	G83 application	Fit & Connect	No app. fee
3.68 - 11.04kW	Single	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £668.40 All NIE costs
11.04 – 20kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £668.40 All NIE costs
21 - 150kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £2002.80 All NIE Costs
150 - 2000kW	Three	Small	Generation Capacity G59 application	Apply, receive offer, accept offer, install	App. Fee - £6676.80 All NIE Costs
<=5MW	Three	Small	Bespoke		
>5MW	Three	Large	Bespoke		

Figure 40: Connection Options (Prices Correct at May 2015)

16 Selecting Contractors

16.1 Introduction

When you install a wind turbine you are entering into a long-term arrangement. You expect the turbine to be operational for at least 20 years so it is logical that you will require the companies that both manufacture and install the system to be operating throughout that lifetime to solve any problems that might occur. Whilst you cannot guarantee that the companies will always be there for you, there are some steps that you can take to protect yourself. As a 'rule of thumb', approximately 20 - 25% of the cost of a wind energy development is for work which requires skills typically available from contractors found in most parts of the UK. This includes supplying and pouring concrete, laying cables and basic civil engineering tasks (e.g. tracks and hard-standing, foundations, trench digging for cables, basic construction for sub-station housing etc.). The rest of the cost of a wind farm development consists of more complex and specialist tasks (engineering consultancy, specialist craning, cables and sub-station equipment and most significantly, the manufacture and assembly of the wind turbines themselves). Selecting the contractors with care, using local contractors and well established manufacturers will provide some protection.

16.2 Micro Certification Scheme

The Microgeneration Certification Scheme (MCS)[xxxviii] is an internationally recognised quality assurance scheme, supported by the government. MCS certifies microgeneration technologies used to produce electricity and heat from renewable sources.

MCS itself is an EN 45011 Scheme and was launched in 2008. MCS certifies microgeneration products used to produce electricity and heat from renewable sources. MCS also certifies installation companies to ensure the microgeneration products have been installed and commissioned to the highest standard for the consumer. The certification is based on a set of installer standards and product scheme requirements.

MCS covers electricity generating technologies with a capacity of up to 50 kW. All installations of wind up to 50 kW must be installed by an MCS registered installer using MCS registered equipment to be eligible for government incentives.

The MCS should give the consumer some peace of mind as the scheme places quality standards on both equipment and installation. However, it would be naïve to think that no company operating under the scheme ever failed to meet those standards so it would be wise to put other checks in place.

16.3 Long-term company viability

In today's electronic information age, it is relatively simple to gather information about a company. You will be making a sizeable investment and you should ensure that the company is financially sound and has some organisational depth should they suffer manpower issues in the future. Any company that has traded for a couple of years will have made financial returns which are available from Companies House for a small fee[xxxix]. Ask companies how they are structured and how they will manage if one of their key people drops out. Ask for this information to be included in any tender (see Section 16.6).

16.4 Examples and references

Any company that has a good track record will be more than happy to provide you with references and examples of work they have carried out. Don't be afraid to ask for at least three examples. You need to see work that is similar to the work you are asking to be carried out. Check the references you have been given; go and visit the sites and talk to the site managers. Ask them searching questions to ensure you have a full understanding of any problems that have occurred and how they might affect you. Ask for this information to be included in any tender (see Section 16.6).

16.5 Servicing arrangements

Most wind turbine manufacturers will insist that your wind turbine is regularly serviced to keep your warranty valid. On smaller turbines this is often one service per annum whereas for larger ones it can be every 3-6 months. Regular servicing of your wind turbine is also a good opportunity for a thorough inspection to be carried out to identify and rectify any issues before they become major problems – prevention being better than cure. If possible contract a long-term annual servicing and maintenance package to ensure the availability of the wind turbine is maximised, whilst ensuring the warranty remains valid. Following every site visit, you should receive a detailed Engineer's Report identifying any issues which require attention and photos of any worn, damaged or failed parts. When servicing the wind turbine, the contractor should complete the necessary servicing plan specified by the manufacturer and complete and submit the associated paperwork. In the event you need to make a warranty claim, the contractor should complete the relevant fault and warranty documentation, order replacement parts from the manufacturer and project manage the claim for you.

If you are using external funding to develop your wind project you may find that banks insist you partner with an O&M provider for at least the first five years of the turbines life to minimise technical risk and protect their investment. When choosing an O&M partner, it is essential that you consider their ability to respond quickly when things go wrong (availability of your turbine determines its financial success) and also carry essential spare parts so problems can be fixed on the first visit to site. Wind turbine maintenance is more than just reacting to a breakdown; it is about prevention of maintenance issues in the first place, predicting when a breakdown is likely to occur and being prepared when it does. Wind turbines do break down and the developer requires rapid diagnosis and rectification with the minimum of disruption and downtime.

The income from the system is dependent on it operating correctly so an annual health check including a visual and electrical inspection should be included in the contract. Ask for this information to be included in any tender (see below).

16.6
Tendering
Preparing a tender document and putting the work out to tender allows you to get everything that you require down on paper. The great advantage of this method of getting prices is that all the tenderers will be pricing for the work that you specify and not for what they think you want. This does not mean that you have to specify the nuts and bolts of the system. On the contrary, it is quite common for a tender to ask the tenderer to design and specify a system for a specific site, show his calculations and explain why he has chosen that system for that site. The tender can then require the tenderer to supply other items such as MCS certification, financial information, references, servicing arrangements, payment details etc.

All tenders issued for wind power systems should include a section ensuring that the contractor is responsible for completing all regulatory approval and certification, especially any required for payment of NIROCs. The final payment for the job should be linked to the final certification. Tenders are usually written by Quantity Surveyors or Independent Consultants.

17 Funding and Financial Assistance

17.1
Introduction

In the current environment, with the demise of the banks as we have historically understood their function, funding is a fast moving and changing field. Some banks continue to lend for renewable energy ventures but they are looking for excellent returns and, often, for security.

Therefore, it is all the more important that you thoroughly investigate the financial variations of the scheme and have a well prepared business plan and a thorough understanding of the scheme before approaching a funding source.

17.2
Carbon Trust interest free loans

The Carbon Trust continues to make four year, interest free loans[xl] available to all eligible Northern Ireland businesses excluding some agricultural or fisheries businesses. Incorporated businesses must have been trading for 12 months and non-incorporated businesses for 36 months. The loans are unsecured and government funded. Loans are available from £3,000–£400,000 based on the quantity of carbon emissions saved by the project and the speed of pay back from savings.

The Carbon Trust supplies an online calculator for estimating the carbon savings and subsequent loans that might be made available at **http://www.carbontrust.com/media/47185/calculator-max-loan.xls**. Note that eligibility and loan terms are decided by the Carbon Trust on a case by case basis and cannot be guaranteed.

17.3
Venture capital funding

Venture capital funding should be considered as an alternative to bank lending. Often, if a loan is available, decision making, paper work and issuing of the loan will be considerably simpler than the bank system. However, you must bear in mind that any venture capital financing company will be looking for a good return and an exit strategy. They may be less flexible than banks if things go wrong. Among others, current players in the market are Nationwide Corporate Finance Ltd[xli] and Portman Asset Finance[xlii].

17.4
Leased Land / Joint Venture

Since the introduction of incentives, there have been many organisations offering joint venture turbine or leased land systems.

A company installing a wind turbine that costs you nothing usually undertakes the entire project development at their own risk. In order to minimise the risk the landowner must sign an option over to the developer effectively giving away the ability to develop the site himself; normally for at least 20 years. In turn, if the project succeeds in gaining planning permission and grid connection and is installed, the landowner usually receives an annual rental income. This can often include a share of the turbine generation income. If feasible, the landowner may also get the benefit of reduced energy bills through some of the electricity generated being used on site. However, this is often not feasible and, even if it is, some companies offer the generated electricity at a discounted price, rather than free, so do check. If you are considering an offer of leasing to a wind turbine company, you should work out what the annual benefit to you will be.

The company pays for the installation, connection charges and the maintenance of the system. The landowner may benefit from free or discounted electricity from the turbine. Any electricity that is not used is exported into the local electricity network. Any income associated with this is likely to go to the installation company. As the owner of the turbine, the installing company receives the full NIROC income.

Before committing to a leased land scheme ensure you fully understand the consequences[xliii]. Once the turbine is erected you are committed to at least a 20 year relationship with that company and, should you wish to sell the property, you may find that the contract affects the value or saleability of the property. Remember that companies offering these schemes are making money from your land.

With regard to joint venture schemes, you should ensure that you have the very best legal advice. These schemes are normally offered by companies that supply and/ or install wind turbines. Before you commit, remember that you are entering a legally binding agreement with them for many, many years.

17.5
NIROCs

All renewable energy generated earns the Northern Ireland Renewable Energy Obligation Certificate (NIROC). Wind power installations < 250 kW earn 4 NIROCs; at May 2015 16.32 p/kWh generated. From 250 kW to 5 MW they earn 1 NIROCs. Above this power output they earn 0.9 NIROCs; details are available on the DETI website.

Ofgem issues NIROCs to renewable generators based on the metered output figures. Generators sell their NIROCs either directly to electricity suppliers or to ROC traders who sell on to electricity suppliers. The electricity suppliers present their ROCs to Ofgem to fulfil their Renewable Obligation. As the Obligation is higher than the available ROCs, suppliers must also pay buyout fees to make up the difference in their obligation. The buyout fees make up a buy-out fund that is redistributed to the electricity suppliers according to their proportion of ROCs. In this way, ROCs have a value to electricity suppliers that is at least the buyout price plus the anticipated buyout fund redistribution per ROC.

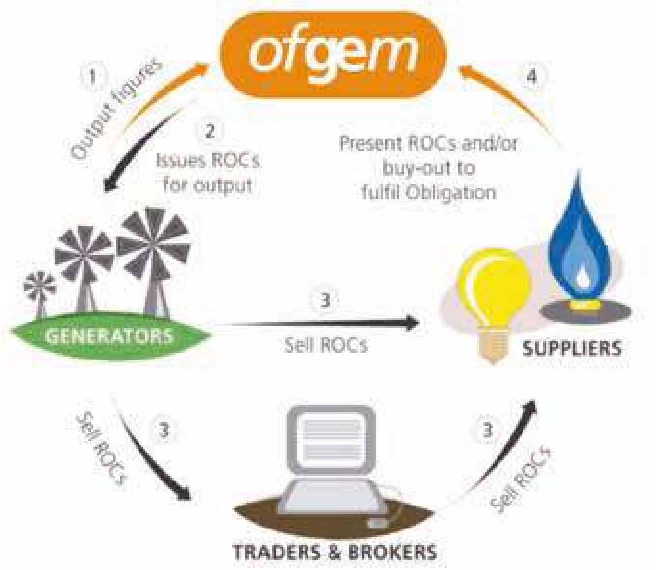

Figure 41: How ROCs work (image courtesy of Ofgem)

The buy out price is calculated by Ofgem annually along with the Obligation. A supplier's obligation, in respect of the electricity that it supplies to customers, increases every year. The price per ROC is increased in line with the Retail Prices Index annually. The trend in increase of the obligation, together with that of the buyout price, are summarised in the following table:

Obligation period (1st April - 31st March	Buy out price (per ROC)	% Increase	Obligation for Northern Ireland (ROCs/ MWh)	% Increase
2009-2010	£37.19		0.035	
2010-2011	£36.99	-0.54	0.0427	22.00
2011-2012	£38.69	4.60	0.055	28.81
2012-2013	£40.71	5.22	0.081	47.27
2013-2014	£42.02	3.22	0.097	19.75

Figure 42: ROC and buy out trend

Thus, the price paid by Power NI to generators <50 kW, for whom it acts as agent, is based on their forecast of ROCs that they will receive during a year and the quantity of electricity they will supply. For generators > 50 kW the developer will enter a PPA that will normally cover both exported power and NIROCs. Typically, the payment received for NIROCs will be the buy out price plus a percentage of the buy out fund. A contract including a floor price might expect to be paid 85% of a combination of the SEM pool price for NIROCs plus LECs[xlv] plus the NIROC buyout. A contract excluding a floor price might receive 90–95%.

The open market price of ROCs may be checked at **http://www.e-roc.co.uk/trackrecord.htm**.

The NIRO will close to new generation in March 2016 but all accredited generators at that date will receive the NIROC for 20 years (to 2037).

17.6
Electricity Market Reform; Feed-in Tariff and Contracts for Difference

As part of the UK wide Electricity Market Reform (EMR) DETI intends to make two specific changes to the current incentive scheme:

a. The introduction of a small-scale (<5MW) feed in tariff (FIT); and

b. The introduction of a Feed-in Tariff with Contracts for Difference (FIT CfD) for large-scale generators.

It is proposed that the enabling powers to introduce a small-scale FIT will be introduced in DETI's forthcoming Energy Bill with an intended implementation date in 2017.

For large-scale generators (>5MW), long-term contracts to encourage investment in new, low-carbon generation will be introduced. These are called Contracts for Difference (CfDs). CfDs work by stabilising the prices received by low-carbon generation, reducing the risks they face, and ensuring that eligible technology receives a price for its power that supports investment. CfDs also reduce costs to consumers by capping the price that consumers pay for low-carbon electricity; requiring generators to pay money back to consumers when electricity prices are high.

This is achieved by paying the generator the difference between a measure of the cost of investing in a particular low-carbon technology (the ‘strike price’) and a measure of the average market price for electricity (the ‘reference price’). The generator participates in the electricity market, including selling its power, in the normal way.

The CfD system will be a competitive system. Renewable energy developers will bid for CfDs, initially on a ‘first come, first served basis’, subsequently in one of two annual allocation rounds. The CfD budget will be fixed. Once the budget is oversubscribed, the CfD allocation will become competitive; the least expensive projects will secure CfDs thereafter.

The CfD system was introduced to Great Britain in 2014 but will not be introduced to Northern Ireland until, at the earliest, 2016.

18 Financials

The following list of financial tools will allow you carry out all of the financial predictions required for analysing the investment. When combined with a short-term and long-term cash flow you will have all you require for approaching a bank for financing.

18.1
Predicting income
In Sections 10 & 12 we established methods for predicting both generation used on site and export quantities. To calculate the predicted income we need to apply those quantities to the relevant earning rates. Wind turbines installed in Northern Ireland earn income in a variety of ways. The turbine may be connected to a distribution board and the energy generated may be used on the premises before any is exported. This allows the owner to replace electrical energy that they would have paid for. This replacement, combined with the maximum NIROC payment is the most cost-effective method of installation and will usually lead to the fastest pay back.

The spill (export) rate that will be achieved will depend on the size of the turbine. For turbines up to 50 kW, Power NI will purchase your electricity (ARET will also purchase from July) and you may avail of their annual published tariff (at May 2015 5.10 p/kWh[xlvi]). For turbines over 50 kW the energy companies now negotiate spill rates directly with the client. Power NI, Energia, Airtricity and ESB all purchase energy in the Single Energy Market (SEM). The purchase price depends on whether a 'floor price' (minimum guaranteed price) is included in the contract but generally reflects the commercial tariff bands.

In March 2015 rates as low as 3.8 p/kWh were experienced in the open market. The following graph describes the historical values. The reduction in open market unit value is clear year on year.

Figure 43: Open Market kWh Values

We can use all of this data to estimate income more accurately. The Met Office publishes historic (1981 – 2010) mean monthly wind speeds for various stations around the UK (A). When converted to percentages (B), those for Aldergrove[xlvii] represent the mean monthly proportion of winds recorded. Having monthly percentages allows us to correlate the monthly generation (C) with specific monthly tariffs. In other words, if we know the predicted annual generation from a wind turbine (478,170 kWh used in this example), the monthly proportion of generation, the monthly average unit value for purchased electricity (F), the monthly open market unit value (G as shown above) and the NIROC rate (H), we can use the on-site consumption ratio (0.55 used here) to determine the on-site consumption (D), the resulting export (E) a more accurate monthly financial income forecast (I to L).

Onsite ratio	0.55											
Met Office 30yr				USE		RATE			INCOME			
Aldergrove			Total	On site Use	Export	On site	Export Tariff	NIROC				
Mean Month m/s	%	Month	kWh	kWh	kWh	p/kWh	p/kWh	p/kWh	On Site £	Export £	ROC £	TOTAL £
A	B		C	D	E	F	G	H	I	J	K	L
10.3	9.763	Jan	46,684	25,676	21,008	13.98	4.359	16.32	3,590	916	7,619	**12,124**
10.2	9.668	Feb	46,231	25,427	20,804	15.44	4.748	16.32	3,926	988	7,545	**12,459**
9.9	9.384	Mar	44,871	24,679	20,192	12.62	3.87	16.32	3,114	781	7,323	**11,219**
8.6	8.152	Apr	38,979	21,438	17,540	10.88	4.23	16.32	2,332	742	6,361	**9,436**
8.3	7.867	May	37,619	20,690	16,929	9.91	4.44	16.32	2,050	752	6,139	**8,941**
7.9	7.488	Jun	35,806	19,693	16,113	9.5	4.179	16.32	1,871	673	5,844	**8,388**
7.7	7.299	Jul	34,900	19,195	15,705	9.44	3.993	16.32	1,812	627	5,696	**8,135**
7.5	7.109	Aug	33,993	18,696	15,297	8.91	4.016	16.32	1,666	614	5,548	**7,828**
8.1	7.678	Sep	36,713	20,192	16,521	9.01	5.117	16.32	1,819	845	5,991	**8,656**
9	8.531	Oct	40,792	22,435	18,356	10.16	4.783	16.32	2,279	878	6,657	**9,815**
9	8.531	Nov	40,792	22,435	18,356	10.49	4.983	16.32	2,353	915	6,657	**9,925**
9	8.531	Dec	40,792	22,435	18,356	12.68	4.768	16.32	2,845	875	6,657	**10,377**
105.5	100	TOTAL	478,170	262,994	215,177				29,659	9,607	78,037	117,302

Figure 44: Predicted income

Having established the income we can define the AUV as the income (£117,302) divided by the generation (478,170 kWh) or 24.53 p/kWh. At more than twice the average price being paid for electricity this is good value. However, the AUV also allows us to compare the value of different systems. Remembering that NIROC rates change over 250 kW, a larger system will have a smaller AUV.

18.2
Capital and annual costs
Capital costs will be specific to the installation. Turbine costs, grid connection and infrastructure costs vary widely and prices vary accordingly. Reconditioned turbines are considerably less expensive than new turbines. In each case, quotations should be received from at least three reputable contractors.

Annual costs will include:

- Specified servicing, lubricants and scheduled replacement parts.
- Insurance and communications costs.
- Rate charges under REVAL 2015 NI[xlviii].
- A sinking fund for one off replacement of failed parts.

You must ensure that you have an agreed cost for scheduled servicing. You should contact Land & Property Services (LPS) to establish the potential rateable value during the pre-feasibility stage. LPS have informed us that from 1 April 2015 wind turbines < 250 kW will be rated on a receipts / expenditure basis. The N value will be calculated from the turbine rated output and a theoretical capacity factor of between 14 and 35%; most will be approximately 20 – 25%. The combination of these factors will dictate an N value from a table of values based on theoretical turbines giving the rateable value.

As a general rule of thumb, assume £60 - £65 per kW for annual O & M costs excluding rates and insurance.

18.3
Pay back

Section 7.5 described how to calculate simple pay back. To calculate pay back allowing for annual costs we need to include the amortised cost of the total annual costs over say a 20 year life span. In this case the equation will be:

$$\text{Pay Back} = \frac{\text{Total Capital Cost}}{\text{(Annual Income) x } (1 - (\text{Annual Cost / Annual Income}))}$$

This equation may be expanded to allow inflation and utility inflation to be added to the variables.

18.4
Carbon savings

DEFRA publishes Carbon Conversion Factors online[xlix]. The document includes an embedded spreadsheet to enable you to calculate carbon emissions from grid generated electricity.

18.5
Total return

The total return on investment is straightforward. It tells the investor the percentage gain or loss on an asset based upon his purchase price. To calculate total return, divide the selling value of the investments plus any income received by its total cost. In essence, this works out to capital gains plus dividends as a percentage of the money you laid out to buy the investment.

$$\text{Total Return} = \frac{\text{Total Income}}{\text{Total Cost}}$$

18.6
Equivalent interest

The equivalent interest rate is the actual annual rate of return that you receive on an investment over the life of an investment when it is compounded. Thus, any competing investment would need to be able to exceed the equivalent interest rate. It may be calculated by the equation:

Equivalent Interest Rate = ((Total Return^(1/Lifetime))-1) X 100

18.7
Cost per kWh

Of the financial indicators, cost per kWh is one of the most useful. If you are trying to compare the relative merits of different schemes or technologies you can compare the cost per kWh of each to see which has the lowest cost per unit of energy generated. This may be useful for comparing, say, solar PV and a wind turbine or for varying turbine sizes. It may be calculated by the equation:

Cost/kWh = (Lifetime Costs / Lifetime Generation) X 100

18.8
Net Present Value

Net Present Value (NPV) is a formula used to determine the present value of an investment by the discounted sum of all cash flows received from and expended during the project. The NPV tells you what the investment is worth to you today. To calculate the NPV you need to know all of the cash outflows and incomes for the project lifetime along with the discount rate. The discount rate is the interest rate that you expect to apply over the lifetime of the project and the amount by which a future receipt or expenditure will be discounted to bring it to present value. The current UK government discount rate is 3.5%. NPV may be calculated by the equation:

$$\text{NPV} = -C_o + \frac{C_1}{(1+r)} + \frac{C_2}{(1+r)^2} + \frac{\quad}{\quad} + \frac{C_2}{(1+r)^2}$$

Where $-C_0$ is the initial investment, C_1 is the cash flow in year one, r is the discount rate and T is time (in years).

We should note that no allowance has been made for utility rate inflation or inflation. Both of these factors will considerably increase the NPV.

18.9
Sensitivity analysis

A sensitivity analysis allows you to adjust certain parameters in your financial calculations to see what effect it will have on the outcome. For instance, you might wish to examine what happens to your pay back if the cost of electricity rises by 10%.

The simplest way to execute sensitivity analyses is to use one of the freely available sensitivity analysis add-in toolkits for Excel available on the internet.

18.10
Cash Flows

It will be well worth while for the developer to undertake two cash flow scenarios.

The first is the short three to five year monthly cash flow during development and initial operation. There are several reasons for undertaking this exercise. In the first place, bearing in mind the seasonal nature of wind turbine generation, greater income will normally be experienced in the winter months. Similarly, if the NIROC accreditation or PPA is delayed, income will also be delayed. A short term cash flow will enable you to examine these factors in detail. It will also be useful tool if you are approaching a lender for funding.

The second cash flow will be a 20 year cash flow. This will enable you to examine different scenarios in the longer term. For example, if the NIROC continues to deflate by 2% per annum what effect will this have on income? Similarly, if the wind speed experienced is, for example 5% less how will that effect income and pay back? What if open market electricity prices continue to reduce?

The cash flows, in conjunction with a sensitivity analysis, will enable you to thoroughly examine all of the financial variables.

19 Project Management

19.1 Introduction

Fortunately, wind is probably one of the easier renewable energy projects to manage. The project management can be further simplified by using the tender process. Tenders should be used to ensure that as much of the responsibility for the job as possible is placed on the contractor. Tenders are normally written by Quantity Surveyors or independent consultants.

19.2 Site safety

Working on turbines is a high risk activity because it involves work at height. 24% of all workers are killed in falls from height. There are several laws relevant to working safely at height and the wind industry have published guidelines for working safely with wind turbines[i].

The Health and Safety at Work Act 1974 is supported by more specific legislation such as the Management of Health and Safety at Work Regulations (MHSWR) 1999. Construction and design specific legislation, e.g. the Construction (Design Management) Regulations 2015[ii] (CDM 2015), ensures the design of safe systems of work. These regulations apply to health and safety management and require the identification and elimination of hazards during all phases of design and construction, during operation, maintenance and eventual decommissioning.

The legal responsibilities of the designer are now extremely onerous; furthermore it is a legal responsibility of the client to ensure that the designer understands and is made aware of their legal duties as a designer. This becomes a particular problem when foreign contractors are employed.

All those who work in the construction industry have their part to play in looking after their own health and safety and in improving the industry's health and safety record.

A CDM client is someone who is having construction or building work carried out, unless they are a domestic client. A domestic client is someone who lives, or will live, in the premises where the work is carried out. The premises must not relate to any trade, business or other undertaking. Although a domestic client does not have duties under CDM, those who work for them on construction projects will.

On all projects clients will need to:

- Check competence and resources of all appointees
- Ensure there are suitable management arrangements for the project welfare facilities
- Allow sufficient time and resources for all stages
- Provide pre-construction information to designers and contractors.

Where projects are notifiable under CDM 2007, clients must also:

- Appoint a CDM co-ordinator
- Appoint a principal contractor
- Make sure that construction work does not start unless a construction phase plan is in place and there are adequate welfare facilities on site
- Provide information relating to the health and safety file to the CDM co-ordinator
- Retain and provide access to the health and safety file.

A notifiable project is one where there is more than 30 days on site or more than 500 man days of resource involved. It is unlikely that projects less than 250 kW will constitute a notifiable project but nonetheless CDM will apply. Before you give the go ahead to start on site you should have complied with the CDM requirement to appoint a competent contractor.

The Management of Health and Safety at Work Regulations 1999 (MHSWR) impose a duty of care on the client to ensure that all systems of work are safe and that employees are safe, insofar as is reasonably practical.

The installations should therefore be subject to:

- Provision and Use of Work Equipment Regulations 1998 (PUWER)
- Electrical Safety
- Control of Substances Hazardous to Health Regulations 2002 (COSSH).

Hazard identification and risk assessments will be required at the very least and thus CE marked for the systems.

Assess the route from the entrance to the site to the place of work for the purpose of carrying equipment and materials to the place of work. Consider areas where access requirements and working patterns may conflict and assess the solution. Once a plan is in place, make a risk assessment of the entire plan and adjust as necessary.

19.3
In-house capabilities
Having read this guide and carried out the site assessment you should have a fairly good understanding of what is required. You should also have an idea of what type and size of system you might install. It may be that your business has the ability, in-house, to carry out the planning and preparation for the work. However, the preparation of a tender by a competent third party is likely to be money well spent. If you choose to use in-house resources, you must also ensure that the capability is available to carry out the project management as a priority. Issues in construction projects normally require instant answers to resolve them.

19.4
Planning the project
Each project will be different so no two project plans will be the same but certain factors will be common to all projects.

- Business work patterns; you will want to arrange the installation so that it has the minimum impact on your daily trading activity. The installation of cable runs and electrical connection internally may be disruptive or create dirt in a clean environment. The installation of the turbine will require access for deliveries and a crane.
- Weather will be a deciding factor when it comes to the installation of the foundation. As we have seen working at height is dangerous. Thunderstorms and heavy rain will prevent work progressing.

When planning the project you should set specific milestones. The milestones will depend on the size of the project.

Once milestones have been identified a full timetable may be drawn up.

Glossary

AC	Alternating current.
AUP	Average unit price.
AUV	Average unit value.
BREEAM	BRE Environmental Assessment Method; a method of assessing, rating and certifying the sustainability of buildings.
BS 7671	Requirements for electrical installations.
Carbon savings	In this case the amount of carbon saved by replacing grid electricity with wind turbine generation.
CAWT / DAWT	Compact wind accelerated wind turbines or diffuser augmented wind turbines (the same technology).
CCL	Climate Change Levy; is a tax on energy delivered to non-domestic users in the United Kingdom. Its aim is to provide an incentive to increase energy efficiency and to reduce carbon emissions.
Cost per kWh	The cost of an investment per unit of energy generated over its lifetime.
Cut in wind speed	The wind speed where generation begins.
Cut out wind speed	The wind speed where generation ceases.
DC	Direct current.
DETI	Department of Enterprise, Trade & Investment.
EMR	Electricity Market Reform; UK wide reform of the market.
EN 45011	Guide for the accreditation of bodies operating certification of products.
Equivalent Interest	The actual annual rate of return that you receive on an investment over the life of an investment when it is compounded.
Export tariff	The rate paid for exported electricity; also known as spill tariff.
FIT	Feed in tariff; incentive system for renewable generation currently used in Great Britain, due for implementation in Northern Ireland after 2015/16.
FIT CfD	Feed in tariff with contract for difference; proposed method of incentives for large -scale projects in Northern Ireland after 2016.
G83 connection	Grid connection for up to 3.68 kW single phase or 11.04 kW three phase.
G59 connection	Grid connection for all connections greater than G83 criteria.
GIS	Geographic Information System.
HAWT	Horizontal axis wind turbine.
HHM	Half-hourly metering; where an electricity meter is automatically read every half hour and the data is recorded.
Inverter	An inverter is an electrical power converter that changes direct current (DC) to alternating current (AC).
Isolator	A disconnector, disconnect switch or isolator switch is used to ensure that an electrical circuit is completely de-energised for service or maintenance.
kWh	Kilowatt hour; the standard unit of measurement for electrical energy consumption (often known as a unit).
kW	Kilowatt; used to rate wind turbines. Normally peak output.
LEC	Levy Exemption Certificate; electricity produced from designated renewable sources is exempt from the Climate Change Levy and is entitled to Levy Exemption Certificates (LECs) which can be bundled with the power when sold to a supplier. The payment received will be dictated by the Power Purchase Agreement. More information here **http://www.tetaproject.co.uk/en/photovoltaics/climate-change-levy.html**.
MW	Megawatt.
MWH	Megawatt hour.
MCS	Microgeneration Certification Scheme.
Mean power load	The average power load over a specific time period.
MPRN	Meter Point Reference Number; the identifying number used by electricity companies for individual electricity meters.
Net present value	tells you what an investment is worth to you today.
NIE	Northern Ireland Electricity Limited owns and manages the electricity transmission and distribution assets in Northern Ireland; it is owned by the Electricity Supply Board in Ireland.
NIRO	Northern Ireland Renewable Obligation also known as RONI (see RO).
NIROC	Northern Ireland Renewable Obligation Certificate (see ROC).
OFGEM	Office of Gas & Electricity Markets is the government regulator for the electricity and downstream natural gas markets in the UK.
Parallel Generator Agreement	Agreement signed with NIE governing the terms of connection of a generator.
Power Curve	A curve describing the relationship between power output and wind speed for a specific wind turbine.
Power Purchase Agreement	Agreement signed with a licensed energy supplier for purchasing generated electricity.
Power NI	One of the electricity supply companies in Northern Ireland, part of the Viridian Group, formerly part of NIE.
PV	Photovoltaic.

REAL Assurance Scheme	Renewable Energy Assurance Ltd carries out a range of certification and consumer protection activities all of which promote sustainable energy.
RO	Renewables Obligation; the main support system for renewable generation in the UK.
ROC	Renewable Obligation Certificate; a green certificate issued to an accredited generator for eligible renewable electricity generated within the UK and supplied to customers by a licensed electricity supplier.
SBEM	Simplified Building Energy Model; to demonstrate compliance with UK Building Regulations.
SEM	Single Electricity Market; the marketplace for electricity in the island of Ireland.
Sensitivity analysis	Allows you to perform ‘what if’ scenarios on your financial predictions.
Simple pay back	The period of time taken to recover your costs on an investment.
Spatial NI	Spatial NI™ is the Northern Ireland Portal for Geographic Information.
Survival wind speed	The wind speed above which damage to the turbine is expected.
Total return	The percentage gain or loss on an investment over the time it is held.
VAWT	Vertical Axis Wind Turbine.

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ii http://www.esru.strath.ac.uk/Documents/MSc_2014/Couttie.pdf

iii http://www.parliament.uk/documents/post/postpn268.pdf

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v http://www.4navitas.com/wind-turbines/

vi http://www.oginenergy.com/our-technology

vii http://www.wind-works.org/cms/index.php?id=117

viii http://www.vortexbladeless.com/

ix http://www.nie.co.uk/Connections/Generation-connections

x http://www.nie.co.uk/Connections/Generation-connections/Small-scale-generation

xi http://www.cesa.org/assets/Uploads/Wiser-2013-RPS-Summit-Presentation.pdf

xii 4000 tonnes CO2 per year @ 0.545 kgCO2/kWh = 7,339,449

xiii A half hourly meter (HHM) registers how much electricity is used in a building for every half hour of every day. They typically have a fixed or mobile phone connection to provide this data to energy suppliers automatically each month, rather than be manually read. This helps energy suppliers issue accurate bills and show building occupiers how they use energy throughout each day. See http://www.edfenergy.com/products-services/large-business/PDF/MBC-FS-HHM-002-1009.pdf .

xiv Power consumption is measured in kWh, power load is measured in kW. Dividing consumption by hours gives power.

xv http://www.wind-power-program.com/UK_wind_speed_database.htm

xvi http://www.metoffice.gov.uk/renewables/vmm

xvii http://www.planningni.gov.uk/index/policy.htm

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xx All available at http://www.planningni.gov.uk/index/news/news_policy.htm

xxi http://www.niassembly.gov.uk/assembly-business/committees/environment/reports/report-on-the-committees-inquiry-into-wind-energy/

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xxviii ZTV's can be produced from Google Earth Pro. Turbines can be modelled in 3D to scale in Google Sketchup and geolocated in Google Earth to create wireframes using ground view. Photomontages can be created in most photographic software including the free Paint.net.

xxix http://www.planningni.gov.uk/downloads/transport-assessment.pdf

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xxxi Noise sensitive receptors include hotels, nurseries and nursing homes. See BS4142:1997

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[xliii] http://www.thorntons-law.co.uk/Wind%20Turbine%20Agreements%20DCD.pdf

[xliv] http://www.detini.gov.uk/existing_and_confirmed_roc_per_mwh_levels_from_1_may_2013.pdf

[xlv] Levy Exemption Certificate (See Glossary)

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[xlviii] http://www.dfpni.gov.uk/lps/reval2015ni

[xlix] http://www.ukconversionfactorscarbonsmart.co.uk/

[l] See http://www.renewableuk.com/en/our-work/health-and-safety/wind-turbine-safety-rules.cfm

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